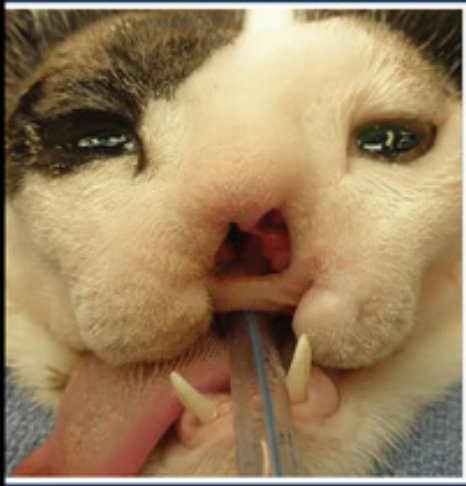
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Atlas of Small Animal Wound Management and Reconstructive Surgery

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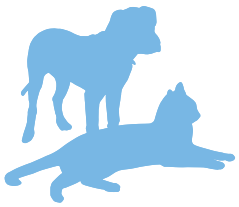
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Dedication

This book is dedicated to my wife Adria; my daughters Afton and Maylin; my son-in-law Patrick; my late parents Merle and Gerry; my late mother-in law Mary and father-in-law Frank; my brothers Frank and Jeff; my sister-in-law Eileen; and my brothers-in-law Mark and Briant for their love, help, encouragement, and support during my career.

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Atlas of Small Animal Wound Management and Reconstructive Surgery

Fifth Edition

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Foreword

I use the techniques described and illustrated in this textbook every day in my practice and I often find myself reaching for the text when presented with a challenging wound or when planning the reconstruction of a wound following resection of a tumor. Often, when presented with traumatic wounds requiring reconstruction or with closure of wound after a major oncologic surgery, I find myself asking, "What would Pav do?" (WWPD?). Novice as well as experienced surgeons will find the *Atlas of Small Animal Wound Management and Reconstructive Surgery* a valuable resource in the management, planning, and execution of surgery for these types of wounds.

I was recently at Purdue University as a locum in small animal surgery and was presented with a patient with a large, full-thickness cutaneous wound over the lateral thigh/hip region secondary to a bite wound. Given the location and size of the wound, a caudal superficial epigastric axial pattern flap was deemed an optimal technique for closure of this defect. While I had performed this surgery many times before, the procedure was new for the resident and students. During the surgery, I found myself "channeling my inner Pav" by mentoring and guiding them in the way that Dr. Pavletic guided me during my training. I was a resident under the tutelage of Dr. Pavletic from 1988 to 1991and was privileged to experience his mentorship first hand with a major focus on plastic and reconstructive surgery. Over the past 50 years, Dr. Pavletic has trained and mentored countless interns and residents, many of whom have continued in their own careers to do the same: I am an example of the teaching ethic that he has instilled in the diaspora of his mentees. His influence on the practice of veterinary plastic and reconstructive surgery has been and will continue to be immense. The techniques described and illustrated in this textbook represent the culmination of a long career in clinical research, teaching, practical problem solving, and the practice of soft tissue surgery.

The fifth edition of *Atlas of Small Animal Wound Management and Reconstructive Surgery* includes over two dozen new plate illustrations and numerous case-based photographs to enhance the reader's understanding of the procedures described in the text. The references have been extensively updated to reflect the current body of knowledge, and there has been an emphasis made on the role that plastic and reconstructive surgery plays in oncologic surgery. In the past, plastic and reconstructive surgery has focused on external traumatic wounds, wound care, and wound closure options and techniques. In this edition, emphasis has been placed on the importance of preoperative planning and wound closure as an integral part of tumor resection so that function is restored or maintained while at the same time considering the cosmetic result. What I found most appealing and informative in the textbook is the inclusion of "Dialogue Boxes"—highlighted text boxes in which Dr. Pavletic provides his own clinical insights, interpretations, and "pearls of wisdom" that can only be obtained through nearly 50 years of surgical experience.

Dr. Pavletic has been recognized for his many accomplishments and contributions to our understanding and management of all types of wounds in small animal patients, whether they be traumatic or the result of oncologic surgery. I believe that perhaps his most distinguished recognition came from the American College of Veterinary Surgeons when he was awarded the 2016 Founders' Award for Career Achievements. This honor is provided only to those individuals who have contributed

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in a major way to the advancement of knowledge and clinical practice in veterinary surgery over their entire career. I can think of no one who has contributed more to our understanding and practice of plastic and reconstructive surgery in small animals than Dr. Pavletic. I am honored to provide you with a brief synopsis on the accomplishments and contributions of my colleague, mentor, and, most importantly, my friend, Dr. Michael Pavletic. I trust that you will find this fifth edition a valuable resource in your everyday practice.

Gary J. Spodnick, DVM, Diplomate ACVS

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Preface

This is the fifth edition of my *Atlas* since the first edition was published over three decades ago in 1993. This updated edition now includes over 200 colored plates and illustrations, with a dramatic expansion in surgical case photographs. Plastic and reconstructive surgery has expanded beyond problematic wound closure; it is now one of the most important areas in surgical oncology. The variety of reconstructive surgical techniques in this new edition will allow the surgical oncologist to resect tumors with the confidence that the large surgical defect can be closed to maintain function to the area. The improved cosmetic results are appreciated by the concerned pet owners.

This fifth edition has introduced over two dozen new techniques since the last edition, using the book's popular instructional color plate format. Numerous case examples have been included from the author's archive of surgical photographs. Chapter 25, "Extras," includes an extensive supplemental series of surgical cases for readers to better understand the use of various closure techniques in different body regions.

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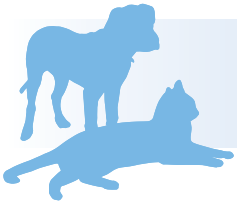


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I would like to thank Sandra Durant, my artist for all five editions of this textbook, for her outstanding work. Her artwork has been a vital component to the understanding of the surgical techniques presented. I would like to also acknowledge the contributions of my friends and colleagues, Dr. Gary Spodnick, Dr. Fred Pike, Dr. Gary Ellison, Dr. Marilyn Kostolich, and Dr. Klaus Loft.

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1

The Skin

Skin Function *2*
Skin Structure *2*
Cutaneous Adnexa *5*
The Hypodermis *8*
Cutaneous Circulation *9*
Pinna: Cutaneous Considerations *12*
Congenital Skin Disorders *13*

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SKIN FUNCTION

The integument is the largest organ of the body and serves as the body's first line of defense against microorganisms. It comprises 24% of the body weight of the puppy but only 12% of that of an adult dog. The outer horny layer, the stratum corneum, provides protection against desiccation and hydration.

The skin is an anatomic barrier while also serving as a sensory receptor of communication between the animal and its environment. Sensory reception includes touch, pressure, vibration, pain, heat, and cold. Its multiple functions include vitamin D production; thermoregulation; and storage of water, fat, electrolytes, carbohydrates, and proteins; a barrier against chemicals and radiation; and, along with the subcutaneous fat, insulation. The skin protects the body from external trauma and infection.

SKIN STRUCTURE

The skin is composed of an outer stratified epithelium (epidermis) and an underlying fibrous dermis (corium). The epidermis is derived from ectoderm, whereas the dermis is of mesenchymal origin. Each of these two layers will be discussed separately.

Epidermis

The epidermis originates as a single layer of cuboidal ectodermal cells that becomes stratified as the fetus matures. In hair-bearing areas, the epidermis of hairy skin consists of three major layers: the *stratum cylindricum* (stratum basale), *the stratum spinosum* (stratum malpighii or prickle cell layer), and the *stratum corneum*. The combined stratum cylindricum and stratum spinosum layers form the *stratum germinativum*. Mitotic activity in the stratum germinativum is responsible for proliferation of epidermal cells. The outer stratum corneum is the superficial dead layer of the skin.

Surgical Relevance

In full-thickness skin wounds, the stratum germinativum along the viable skin margin is the source of epithelial cells to cover the exposed vascularized wound bed. In contrast, partial-thickness skin wounds reepithelialize from surviving epithelial elements, including the external root sheath of hair follicles. Partial-thickness wounds can vary in depth: some viable epidermal cells may survive and contribute to reepithelialization of the open wound.

Melanocytes, which originate from the neural crest of the embryo, are located in the stratum cylindricum and the lower layer of the stratum spinosum. In a few hairy areas, the stratum granulosum and stratum lucidum are found where keratinization is retarded, such as around the hair follicle orifices. These two layers are well developed in the footpads, but are absent in the planum nasale. Epidermal pegging, evident in the footpads, planum nasale, and lip of the dog, is not present in the hairy skin. In contrast, the dermal–epidermal junction of hairy skin is thrown into folds that parallel the skin surface. Small tactile elevations termed *epidermal papillae* are found over hairy skin surfaces of the dog and cat. The epidermis is generally thicker in areas that lack a thick hair coat and thinner in regions with a dense hair growth (Figs 1-1 and 1-2). The nose and digital pads have the thickest epidermis.

Senile Changes to Canine Skin

Senile changes to dog skin include atrophy of the epidermis, dermis, and appendages with a decrease in hair follicles. These changes vary in different body areas.

The Basement Membrane Zone

The basement membrane zone (BMZ) is the dermal–epidermal junction. It comprises two zones, the *lamina lucida* and the *lamina densa*. The basement membrane is primarily composed of fibronectin (an adhesive glycoprotein), laminin, type IV collagen, and heparin sulfate proteoglycan. The BMZ forms a base for connecting the epidermis and dermis.

The Dermis

The dermis (corium) is composed of collagenous, reticular (precollagen), and elastic fibers within a mucopolysaccharide ground substance. This ground substance is composed of hyaluronic acid and chondroitin sulfuric acid; it is the major component of the dermis. Collagen makes up 90% of the dermal fibers. Fibroblasts, macrophages, plasma cells, and mast cells present throughout the dermis are more numerous in the superficial dermal layer. Occasionally chromatophores and fat cells are noted. The dermis contains the cutaneous capillary network, lymphatics, nerve components, arrector pili muscles, a majority of the hair follicles, and glandular structures.

The dermis of the dog and cat is divided into the superficial *stratum papillare* and the deep *stratum reticulare*. The stratum papillare has fine elastic and reticular fibers in

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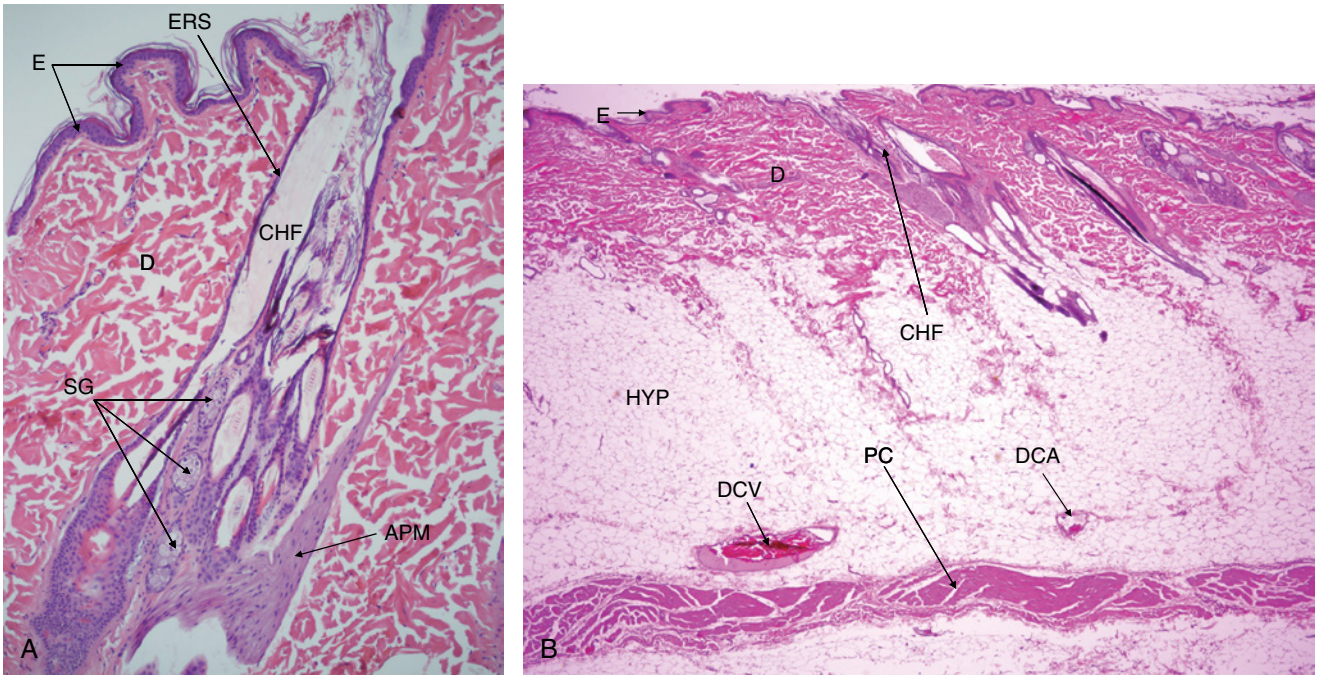


FIG. 1-1 (A, B) Histologic slides of canine skin identifying the following structures: E, epidermis; D, dermis; HYP, hypodermis; CHF, compound hair follicle; ERS, external root sheath; SG, sebaceous glands; DCA, direct cutaneous artery; DCV, direct cutaneous vein; PC, panniculus carnosus muscle; APM, arrector pili muscle. (Courtesy of Melanie A. Buote.)

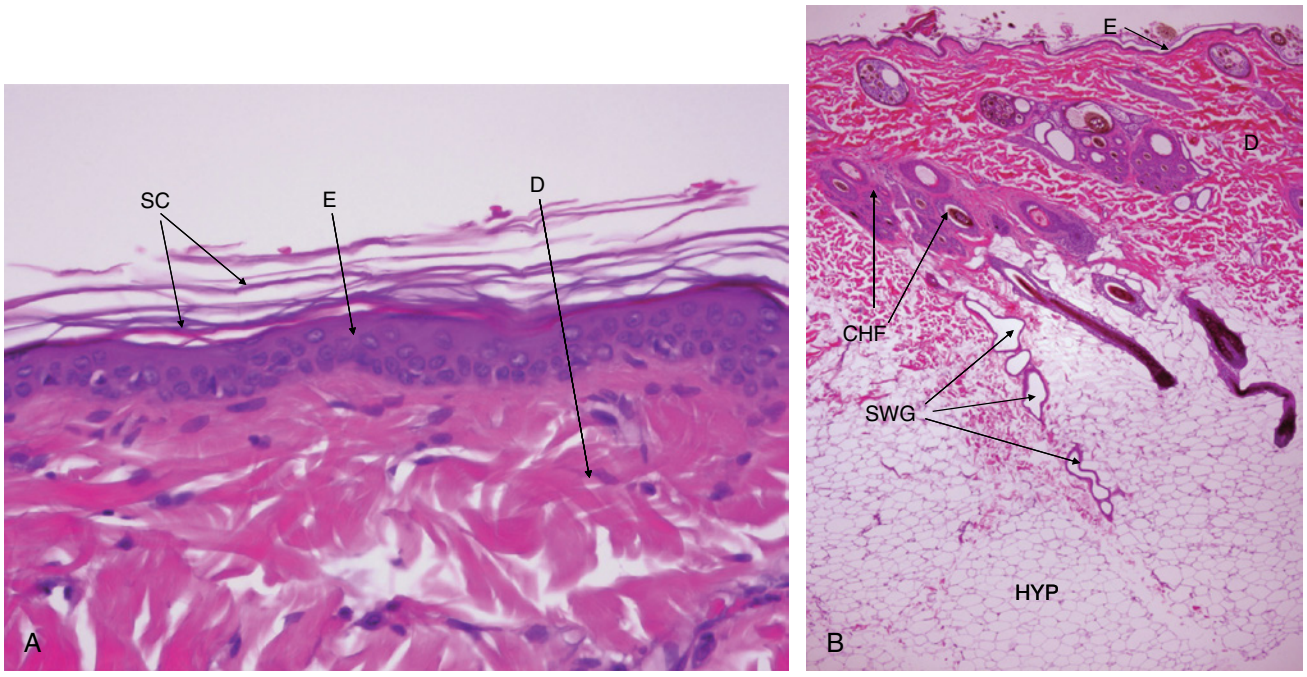


FIG. 1-2 (A, B) Histologic slides of feline skin identifying the following structures: SC, stratum corneum; E, epidermis; D, dermis; HYP, hypodermis; CHF, compound hair follicles; SWG, sweat glands. (Courtesy of Melanie A. Buote.)

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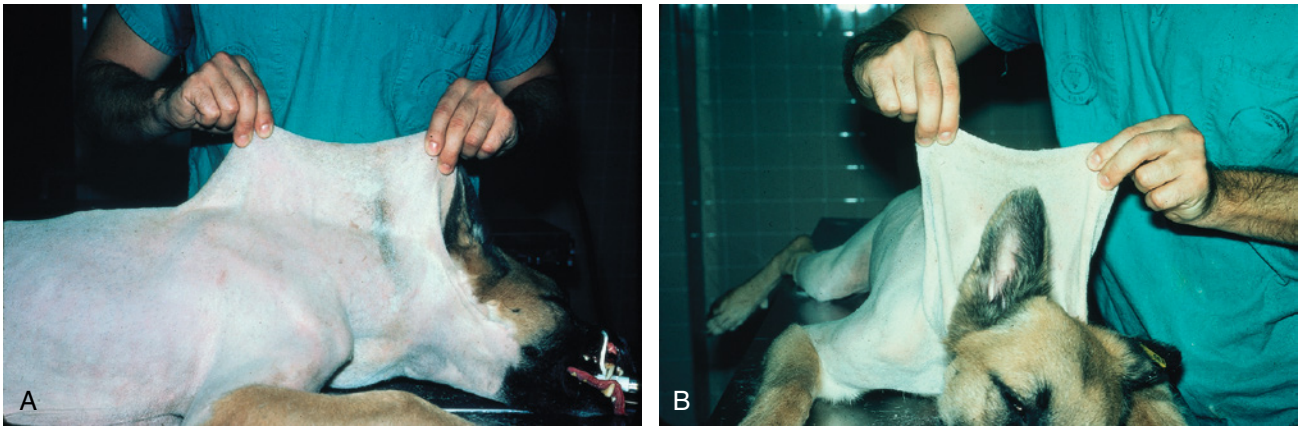


FIG. 1-3 (A) Lateral and (B) anterior view of a German shepherd demonstrating the inherent elasticity of the skin in the cervical region.

densely interwoven collagenous bundles. The basement membrane is formed from reticular fibers and a viscous ground substance, and the stratum cylindricum is attached to the basement membrane via cytoplasmic processes. The stratum reticulare is composed of coarse, densely interwoven collagen bundles.

The most pliable skin (axilla, flank, dorsum of the neck) has small and more loosely woven dermal collagen bundles and greater numbers of elastic fibers in the papillary layer (Fig. 1-3). Less pliable skin (tail, ear, digital pads) has wider, more closely packed collagen bundles with fewer elastic fibers. Collagen fibers in areas of thick skin (head, dorsal body surfaces) are roughly parallel to the cutaneous surface. Pliable skin involving the extremities allows for skin stretch or deformation when the animal is walking and running.

Skin of animals essentially is a nonhomogeneous viscoelastic tissue with the combined characteristics of a viscous fluid and an elastic solid. The inherent elasticity of the skin describes the natural ability of skin to stretch or deform during normal activities.

Surgical Relevance

Surgeons normally assess the *inherent elasticity* of skin by grasping and lifting the skin or by pushing the skin with the index finger toward the direction of the proposed surgical site. Potential lines of tension are assessed, better allowing the surgeon to decide on how to close the surgical defect. (See Plates 14, 15, and 32.)

The skin's extensibility or ability to stretch is dependent on three factors occurring consecutively as a load (stretching force), applied to the skin, is progressively increased: (1) convolutions in dermal collagen progressively straighten; (2) dermal collagen fibers align parallel to each other in the direction of the applied load; and (3) fully aligned collagen fibers extend only on application of great increases in tension. As a result, it is possible to mechanically stretch skin sufficiently to facilitate wound closure by the processes of *mechanical creep* and *stress relaxation* (see Chapter 10).

Surgical Relevance

Skin can be manipulated to stretch beyond the limits of its inherent elasticity by the application of a force that stretches skin progressively over time. This newly recruited skin can be used to close problematic wounds. Examples include presuturing (Plate 35), skin stretchers (Plates 28, 36, and 38), and tissue expanders (Plate 39). Details are discussed in Chapters 9 and 10.

Cat skin contains collagen bundles, which are generally coarser and denser than canine skin. The arrector pili muscles also are larger than those in the dog. The stratum papillare of feline skin contains fine, more uniform collagenous fibers, which usually parallel the epidermis. In the stratum reticulare, the fibers are dense, irregularly arranged, and three times larger than those of the papillary layer. In the most flexible cutaneous areas of the cat—the dorsal neck, scapular region, and lateral upper forelimb—the collagen bundles are smaller and more loosely arranged.

The thickness of the skin is directly related to the thickness of the dermal layer and varies according to body area, sex, breed, and species. In thick skin, the dermis usually is thicker than 1 mm, whereas in thin skin, the dermal thickness is less than 1 mm. The thickest skin of the dog and cat is located over the head and the dorsum of the neck, back, and sacrum. The thinnest skin is located along the ventral body surface, the medial surface of the limbs, and the inner pinna.

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Surgical Relevance

Skin thickness varies with species, breed, and body region in dogs and cats. Dog skin ranges from 0.5 to 5.0 mm whereas cat skin thickness varies from 0.4 to 2.0 mm. The thickest skin is over the neck, back, and sacrum. Skin thickness decreases distally along the trunk, with the thinnest skin located in the inguinal and axillary areas. Similarly, skin thickness decreases from proximal to distal on the extremities. The durability of fur-bearing skin is primarily the result of the dermal thickness. Skin thickness is taken into consideration when closing wounds in body areas more subject to direct trauma, including skin overlying bony prominences. Dense hair growth also affords some degree of protection.

The Extracellular Matrix

The tissue component outside the cellular walls of organs is referred to as the *extracellular matrix* (ECM): the noncellular components of the dermis are the ECM of the skin. Tissue cells and the ECM are considered in a state of "dynamic reciprocity." In embryonic development, their interaction plays an essential role in cellular differentiation and function. Cells in turn secrete macromolecules into their immediate environment, forming a matrix between the developing cells. The regional embryonic mesenchymal tissue induces epithelial cell differentiation; epithelial cells, in turn, influence the development and structure of the mesodermal tissues. The ECM includes the fibrillar proteins and glycosaminoglycans (GAGS) that attach to core proteins, forming proteoglycans. The dermal ECM can be described as a network of fibrillar proteins organized within a hydrated gel of proteoglycans. The two principal types of the skin's ECM are the *basement membrane* (or *basal lamina*) in contact with the basal epithelial cells and the underlying *stromal* or *connective tissue*. The stromal tissue provides structural integrity and support to the cellular components of the skin. Collagens are the major proteins of the ECM. However, the ECM comprises a variety of extracellular proteins that may be classified on a functional basis: structural (basal lamina and connective tissue) or adhesive (fibrin and fibronectin); remodeling or counter-adhesive (thrombospondin, tenascin, SPARC—*secreted protein acidic and rich in cysteine*); proteolytic (serine proteases, matrix metalloproteases [MMPS]) and anti-proteolytic (serpins, plasminogen activator inhibitor-1, tissue inhibitors of metalloproteases [TIMPs]). These proteins have a complex interrelationship during wound healing that will be discussed in Chapter 2.

The ECM is a complex protein framework that tissue cells attach to, migrate, and build on during the processes of wound healing. See Chapter 2.

CUTANEOUS ADNEXA

The cutaneous appendages (adnexa) of hairy skin include the hair follicles, sweat glands, and sebaceous glands. Other cutaneous glandular structures include the mammary glands, supracaudal (tail) glands, anal sacs, superficial circumanal glands, and perianal (deep circumanal) glands. All these structures are ectodermal in origin.

Hair

The hair follicles are the units of hair production. They are located in the lower portions of the dermis but also extend into the subcutaneous tissue (subcutis, hypodermis). The wall of the hair follicle is continuous with the epidermis and is divided into inner and outer root sheaths. During fetal development, hair follicles originate from clusters of germinative cells in the epidermis. These ectodermal cells sink into the dermis and form a cylindrical epidermal peg, the base of which develops into the hair bulb. The hair bulb molds around a mesenchymal papilla. These germinative cells give rise to the inner epithelial root sheath and the hair shaft. The outer epithelial root sheath, which encircles the hair shaft, is a continuation of the stratum cylindricum.

Surgical Relevance

In partial-thickness skin losses, both the epidermis and variable portions of the dermis have been destroyed. The epithelial cells comprising the external root sheath of the compound hair follicles are the primary source of epithelial cells required for reepithelialization of partial-thickness skin defects (see Fig. 1-4). Even with full-thickness skin loss, hair follicles in the underlying subcutaneous fat may survive; elements of the external root sheath can be a source of epithelial cells in the reparative healing process.

Sebaceous glands develop as extensions of the outer root sheath at the upper part of the follicle. In dogs and cats, an apocrine sweat gland develops with each hair follicle and extends into the hypodermis. The duct empties into the common portion of the follicle complex between the skin surface and sebaceous gland orifice.

The arrector pili muscles originate in the dermal papillary layer and insert in the connective tissue of the hair follicle. They are anchored by elastic fibers at their attachments and are innervated by the autonomic nervous system. The arrector muscles are especially well developed along the back of the dog and cat, causing the hair to bristle on their contraction when the animal is alarmed or under stress.

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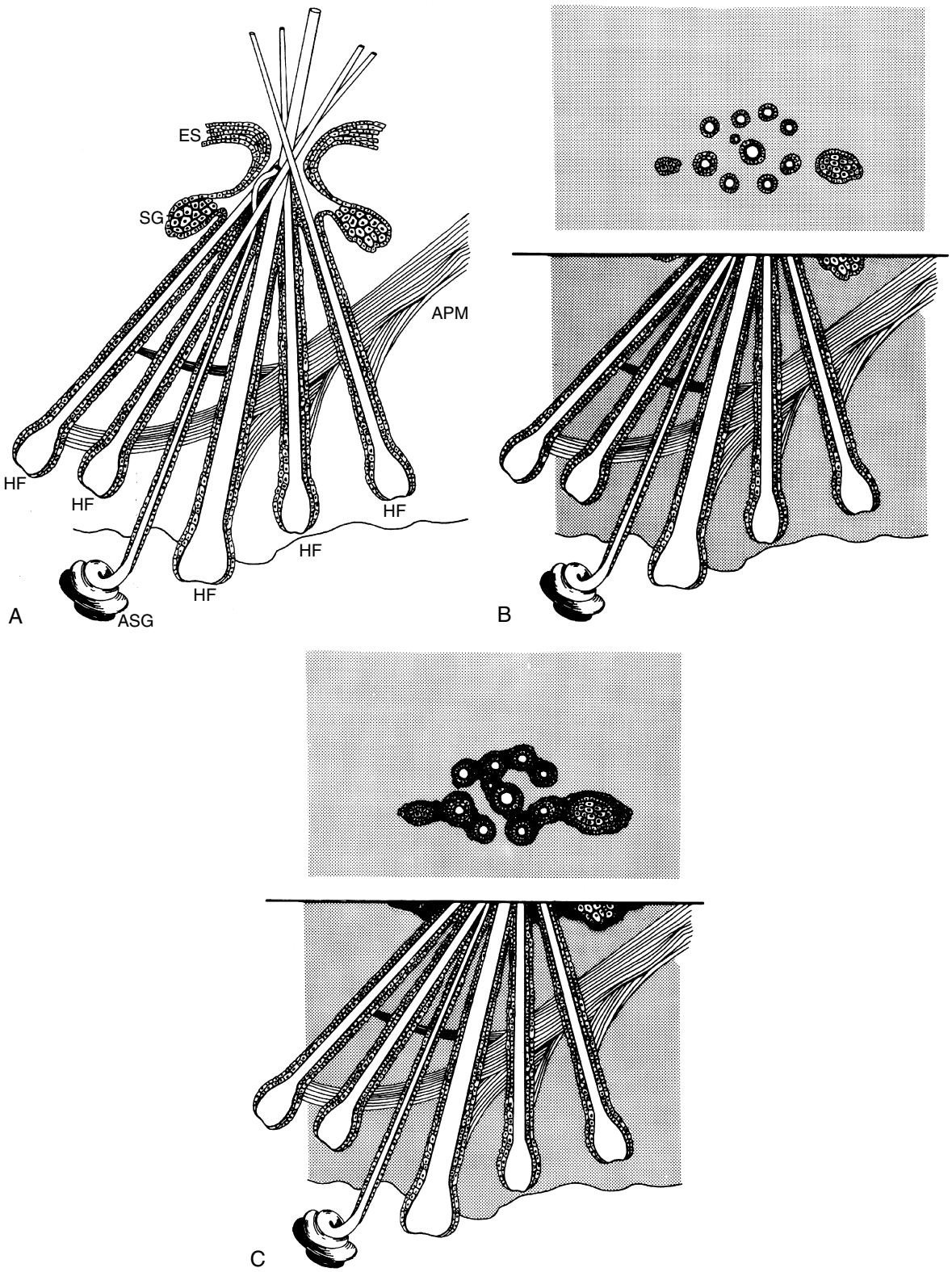


FIG. 1-4 (A) A compound hair follicle (HF) with its associated sebaceous gland (SG), apocrine sweat gland (ASG), and arrector pili muscle (APM). Note the epidermal cellular components of these cutaneous adnexa, which are continuous with the epidermal surface (ES). (Source: Pavletic MM. 1993. The integument. In: Slatter DH, ed. *Textbook of Small Animal Surgery*, 2nd ed. Philadelphia: WB Saunders. Reproduced with the permission of WB Saunders.) (B) Loss of the epidermis and superficial dermal surface. (C) Note epithelial cell migration primarily originating from the external root sheath of each hair follicle.

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In the newborn animal, hair follicles develop from a simple follicle containing a single hair to a compound follicle containing seven to ten hairs emerging from a common follicle orifice. This occurs at 28 weeks of age as a result of accessory buds arising from the original follicle. Sebaceous glands also become compound, emptying where the hairs are contained as a single tubular follicle. The compound follicle contains a main or guard hair surrounded by a number of finer, woolly lanugo, or underhairs. Although the hair shafts share the same external follicular orifice, they branch into their own respective hair follicles below the level of the sebaceous glands. The guard hair follicle is larger and penetrates into the subcutaneous tissue.

Feline hairs are arranged in clusters of two, three, four, and five, grouped around a central guard hair. Clusters of two and three are more common on the dorsal aspect of the feline body; clusters of four and five usually occur on the ventral body and lower extremities. Each lateral group contains three primary hairs surrounded by 6–12 lanugo hairs. In adult dogs, 3–15 hairs are noted in each compound follicle, whereas in cats, the compound follicles contain 12–20 hairs. Hair is partially or completely absent in Devon rex cats and Chinese crested dogs.

Surgical Relevance

Siamese cats have a temperature-dependent coat color, owing to an enzyme that converts melanin precursors to melanin at lower temperatures. As a result hair coats can grow back darker after clipping, a fact best explained to the owner prior to a surgical procedure.

Vibrissae are larger, more prominent tactile or sinus hairs involving the muzzle and facial area. They allow dogs and cats to locate and assess the proximity of adjacent objects.

Hair growth rates vary seasonally among breeds. Hair growth in male beagles has been noted to be 0.4 mm/day in the winter and 0.34 mm/day in the summer, whereas greyhound hair has a growth rate of 0.18 mm/day in the fall and 0.04 mm/day in the summer. Hair growth is more rapid in the winter. As a rule, short canine hair coats take approximately 130 days to regrow completely. However, as long as 18 months is required for regrowth of the hair coat in long-haired breeds such as the Afghan. These facts must be taken into account prior to clipping a patient, particularly when dealing with show dogs.

The characteristics of the hair coat in dogs and cats vary with the location on the body. The hair coat is usually thicker over the back and sides of the body, whereas the hair inside the ears and on the flanks, ventral abdomen, and underside of the tail is thinner. Cosmetic wound closure should account for variations in growth patterns and direction of growth of the coat.

In one study in cats, primary and secondary hair bulbs decrease in activity after December. Total inactivity was noted in January. Hair growth commenced in April followed by maximum activity over the next 2–4 months. This increase in growth activity was considered to be the result of the increasing photoperiod with hair loss and subsequent replacement in the spring.

Surgical Relevance

When attempting to close major wounds, hair growth pattern usually plays a secondary role in selecting the method of closure. The surgeon and owner must consider the safest, simplest, and most economical method to effectively restore function to the affected area. It is the author's experience that changes in regional hair growth, color, and pattern following wound closures are not a serious concern of pet owners. It is possible, for example, to better utilize the lateral skin of the proximal pelvic limb for a more cosmetic closure in limb amputation, compared to using the thinner medial thigh skin that has a more sparse hair coat when closing the surgical wound.

Cutaneous Glands

The glandular structures of the skin include the sebaceous glands, sweat glands, supracaudal (tail) glands, anal sacs, circumanal glands, and mammary glands. These ectodermally derived structures form by the down-growth of epidermal cells into the dermis during embryonic development.

Sebaceous Glands

Sebaceous glands commonly originate from the external root sheath. They produce an oily secretion that exits through the pilosebaceous canal to keep the skin and hair soft and pliable and to protect them from excessive moisture and drying. Sebaceous glands are well developed over the neck, back, and tail of the dog, particularly in the tail gland area.

The sebaceous gland complex in the cat is smaller and simpler in structure than that of the dog. Larger sebaceous glands are found in association with the hair follicles of the upper jaw, prepuce, and dorsal tail surface. Sebaceous glands not associated with hair follicles include the meibomian, or tarsal, glands of the eyelids and glands of the labia, vulva, anus, prepuce, glans penis, and external ear canal. These holocrine glands empty directly onto the epithelial surface.

Circumanal glands (superficial sebaceous glands) and perianal glands (deep sebaceous glands) are modified sebaceous glands located at the mucocutaneous junction of the anus. Perianal glandular tissue also can be found in

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the skin of the prepuce and groin. Circumanal glands have well-defined ducts and contain fat. Perianal glands have solid ducts and show no secretory activity. Circumanal glands contain fat, unlike the deeper perianal glands. Perianal gland cells are filled with proteinaceous cytoplasmic granules.

At the level of the 7th to 9th coccygeal vertebrae in dogs, the dorsal skin of the tail has a concentration of large sebaceous glands and apocrine glands. This is referred to as the *tail gland* or *supracaudal gland*. The individual hair follicles in this region (2.5–5 cm long) contain a single coarse hair in comparison to the complex follicles containing 6–11 hairs in the adjacent skin. Cats also have a supracaudal gland. The sebum produced is stimulated by androgen release in intact males. Seasonal dimorphism of this order has been reported in both sexes and is associated with estrus. This glandular structure also is susceptible to dermatitis and infection (referred to as "stud tail") and may require medical management.

Sweat Glands

Sweat (sudoriferous) glands are apocrine and merocrine (eccrine) in nature. Cutaneous apocrine sweat glands are large, simple, saccular or tubular structures with a coiled secretory portion and a straight duct. The glands may be tortuous or serpentine. The apocrine sweat gland duct opens at the external root sheath between the skin surface and the pilosebaceous canal. Merocrine glands are coiled, simple, tubular glands found mainly in the footpads of the dog and empty directly onto the epidermal surface. Sweat glands are better developed in dog breeds with long, fine hair.

Sweat glands in the hairy skin of dogs and cats do not participate actively in the central thermoregulatory mechanism but protect the skin from an excessive rise in temperature. This is in contrast to human beings, in whom the cutaneous sweat glands are vital for vaporizational heat loss to cool the body at high temperatures.

Other Glandular Structures

A number of apocrine glands have specialized structures and functions. These include Moll's glands of the eyelids, the ceruminous glands of the external ear canal, the anal sac, and the glands of the prepuce, vulva, and circumanal region.

The mammary glands of the skin are compound tubuloalveolar apocrine glands resembling sweat glands in their mode of development. They undergo conspicuous changes during pregnancy and during and after lactation in the female. They remain rudimentary in the male dog and cat.

Anal sacs have a thin, stratified squamous epithelial lining that includes sebaceous and apocrine sweat glands. Sebaceous glands tend to line the neck of the sac, whereas the apocrine glands are concentrated in the fundus.

Surgical Relevance

Increased secretory function of the sebaceous and apocrine sweat glands is noted with inflammatory processes involving the skin, especially where a large number of these glandular structures are assembled. During these inflammatory processes, more frequent bandage changes may be expected. Wound care is important to the prevention of tissue maceration and infection secondary to moisture accumulation.

THE HYPODERMIS

The hypodermis (subcutis) or superficial fascia is associated with the overlying dermis. This subcutaneous tissue is composed primarily of fat with loose collagenous trabeculae and elastic fibers. It varies in thickness regionally but is poorly developed beneath the eyelids, ears, and scrotum, and other areas where the skin is closely attached to underlying structures.

The inherent elasticity of the skin; its lack of firm attachments to bone, muscle, and fascia; and the length and extensibility of the direct cutaneous vessels account for the high degree of mobility of skin over the head, neck, and trunk of the dog and cat. In one histologic study, two distinct layers of the hypodermis were reported: the *stratum adiposum subcutis* (containing fat) and a deeper *stratum fibrosum subcutis*, which includes the panniculus muscle layer. This fatty layer provides insulation to the body, serves as a cushion to external impact, and is a storage source of energy.

The hypodermis is closely associated with normal skin function. The subdermal plexus capillary circulation is associated with the hypodermis and dermal surface. Direct cutaneous vessels must traverse this layer to supply the overlying skin. In this respect, the panniculus muscles play an important role during the surgical elevation of the skin (see Figs 1-1 and 1-2).

Panniculus Muscles

The *panniculus muscle* (panniculus carnosus) is a collection of thin muscles beneath some cutaneous areas in the dog and cat (see Figs 1-1 and 1-2). The panniculus muscles in the head and neck regions are the platysma, sphincter colli superficialis, and sphincter colli profundus. The cutaneous

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trunci is the major cutaneous muscle of the body, extending from the gluteal region cranial and ventral to the pectoral region. It is not present beneath the skin over the middle and lower portions of the limbs. Fibers from this muscle make up the preputialis muscle in the male dog and the supramammarius muscle in the female dog.

The cat has a similar cutaneous muscle distribution. The cutaneous trunci (cutaneous maximus) of the cat extends over the thoracic and abdominal regions of the body. The platysma in the cat covers the head and neck. In the cervical region, the platysma can be subdivided into the supercervicocutaneous muscle and cervicofacial muscle along a line of attachment to the skin. The associated sphincter colli superficialis muscle is smaller and of irregular occurrence. The feline panniculus muscle is a component of the stratum fibrosum subcutis, the deep connective tissue layer of the hypodermis.

Panniculus muscle fibers are very irregular and tend to run transversely. Fibers penetrate the dermis and allow voluntary movement of the skin. The cutaneous trunci is used to shake the skin in response to irritating or noxious stimuli. Repeated contraction (shivering) of this muscle can increase heat production in cold animals. The platysma muscle moves the vibrissae and gives expression to the face. The preputial muscle in dogs helps to draw the prepuce over the glans penis after erection. The supramammary muscle aids in the support of the mammary glands and perhaps in milk ejection in the bitch.

Surgical Relevance

The direct cutaneous vascular supply and associated subdermal plexus of the skin are closely associated with the panniculus muscle layer, where present. Preservation of this thin muscle layer with the overlying skin helps preserve cutaneous circulation during the surgical manipulation of the skin (e.g., skin flaps, tissue undermining). See Figs 1-5 and 1-6.

CUTANEOUS CIRCULATION

The cardiovascular system is the first major system to function during embryonic development. The hemangioblast is believed to be the precursor to blood vessels and blood cells during embryonic development. Blood vessels are constructed by two processes: *vasculogenesis* and *angiogenesis*. In vasculogenesis, blood vessels are created *de novo* from the lateral plate mesoderm. Hemangioblasts formed from these splanchnic mesodermal cells condense into "blood islands." The inner cells of these blood islands become hematopoietic stem cells, the precursors of blood cells. The outer cells become angioblasts, the precursors of blood vessels. Angioblasts differentiate into endothelial cells. Endothelial tubes form and interconnect to form the *primary capillary plexus*. Angiogenesis is the process in which this primary capillary network is remodeled and pruned into distinct arteries, veins, and capillary beds. The developing vascular network is essential to supplying the tissues with the necessary oxygen and nutrients important for fetal development. *Cytokines*, or growth factors, play a central role in the initiation of vasculogenesis.

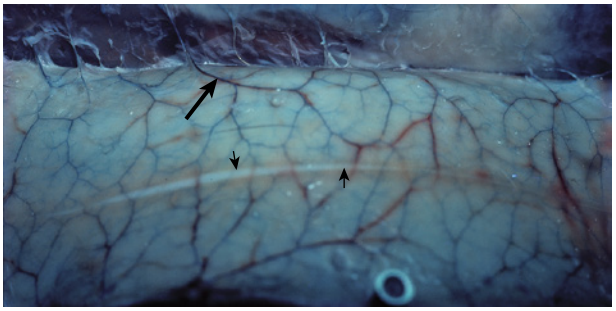


FIG. 1-5 Skin reflected from the back of a cat cadaver. Blue latex has been injected into the arterial system to highlight the direct cutaneous arteries. The thin cutaneous trunci (panniculus) muscles on each side of the cat join over the dorsal midline (small arrows). A direct cutaneous artery can be seen approaching the panniculus muscle and overlying skin in parallel fashion (large arrow). As it arborizes, terminal branches "form" and supply the subdermal plexus. Note the "mirror" image formed by the direct cutaneous vasculature on each side of the midline. (Source: Pavletic MM. 2003. The integument. In: Slatter DH, ed. *Textbook of Small Animal Surgery*, 3rd ed., 250–9. Philadelphia: WB Saunders. Reproduced with the permission of WB Saunders.)

The cutaneous vascular system is divided into three interconnected levels:

- The deep, subdermal, or subcutaneous plexus
- The middle or cutaneous plexus
- The superficial or subpapillary plexus

This general vascular arrangement is present in the hairy skin. Variations in the arrangement are noted in the canine external ear, footpad, nipple, and the mucocutaneous junctions of the nostril, lip, eyelid, prepuce, vulva, and anus.

The Subdermal Plexus

The subdermal plexus is the major vascular network to the overlying skin. The vessels of this plexus generally run in the subcutaneous fatty and areolar tissue on the deep face of the dermis of the middle to distal portions of the limbs where no panniculus muscle is present. Where there is a layer of cutaneous muscle, the subdermal plexus lies both superficial and deep to it (Fig. 1-5). An experimental

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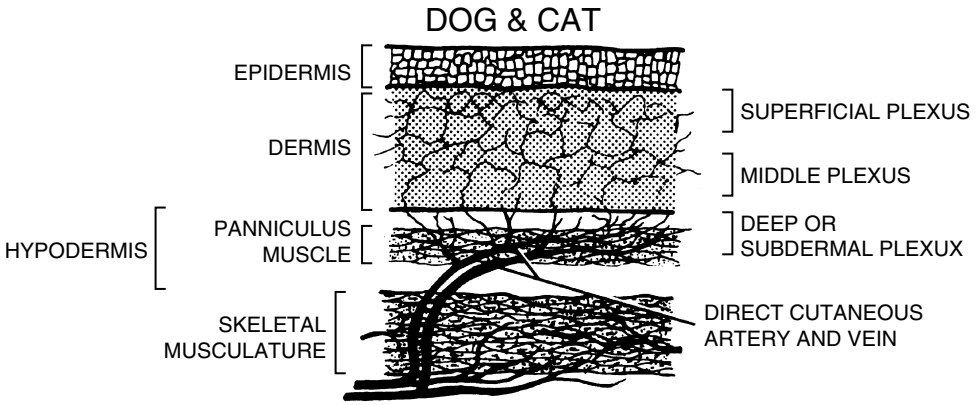


FIG. 1-6 Cutaneous circulation in the dog and cat. The subdermal plexus is supplied by terminal branches of direct cutaneous vessels at the level of the panniculus muscle in the dog and cat. Note the parallel relationship between the direct cutaneous vessels and the overlying skin. This is unlike the perpendicular orientation of musculocutaneous vessels in the human. (Source: Pavletic MM. 2003. The integument. In Slatter DH, ed. *Textbook of Small Animal Surgery*, 3rd ed., 250–9. Philadelphia: WB Saunders. Reproduced with the permission of WB Saunders.)

study (Pavletic 1982) on the misapplication of subcutaneous pedicle flaps in the dog demonstrated the vital relationship between the panniculus muscle and the overlying skin. Complete severance of the panniculus muscle results in necrosis of the island flap, whereas preservation of the muscular layer assures its survival by preserving the subdermal plexus. The skin should always be undermined in the fascial plane beneath the cutaneous musculature to preserve the integrity of the subdermal plexus. In areas devoid of this muscle layer, one should undermine in the fascial plane well below the dermal surface to preserve it (Fig. 1-6).

Cutaneous (Middle) and Superficial Plexuses

The subdermal plexus supplies the hair bulb and follicle, tubular glands, and deeper portions of the ducts as well as the arrector pili muscle. Branches of the subdermal plexus ascend into the dermis to form the middle, or cutaneous, plexus located at the sebaceous glands. Branches from the cutaneous plexus ascend and descend into the dermis to supply the sebaceous glands and reinforce the capillary networks around the hair follicles, tubular gland ducts, and arrector pili muscle. The middle plexus shows developmental and positional variations according to the distribution of the hair follicles in the skin. Radicals from the middle plexus ascend to supply the superficial plexus. The superficial plexus lies in the outer layer of the dermis. Capillary loops from this plexus project into the dermal papillary bodies to supply the epidermal papillae and adjacent epidermis. However, the capillary loop system and papillary bodies are poorly developed in the dog and cat, unlike the human, anthropoid ape, and pig, all of which have well-developed capillary loops. This anatomic difference explains why canine skin normally does not blister with superficial burns.

Surgical Relevance

Split-thickness skin grafts are normally harvested with the use of a dermatome. The depth of the dermal incision will expose different levels of the dermal vascular network. For example, thinner grafts expose the finer, numerous vascular channels of the superficial plexus. Exposure of the graft's vascular channels increases the probability of successful revascularization. For this reason, thin split-thickness skin grafts reportedly have a higher probability of revascularization when compared to thicker skin grafts. The bleeding pattern on the cut dermal surface will reflect the depth of the graft harvested.

Cutaneous Arteries

Segmental vessels arising from the aorta, well beneath the body muscle mass, give off perforator branches that traverse the skeletal muscle to supply the subdermal plexus. Two types of arteries supply the cutaneous circulation in the human: musculocutaneous arteries and direct cutaneous arteries. Musculocutaneous arteries are the primary vascular supply to the skin of humans, apes, and swine. Perforator arteries send several branches to the overlying muscle mass before terminating as musculocutaneous arteries perpendicular to the skin. Direct cutaneous arteries arise from perforator arteries that send few branches to the overlying muscle mass before ascending to the subdermal plexus. Direct cutaneous arteries run parallel to the skin and

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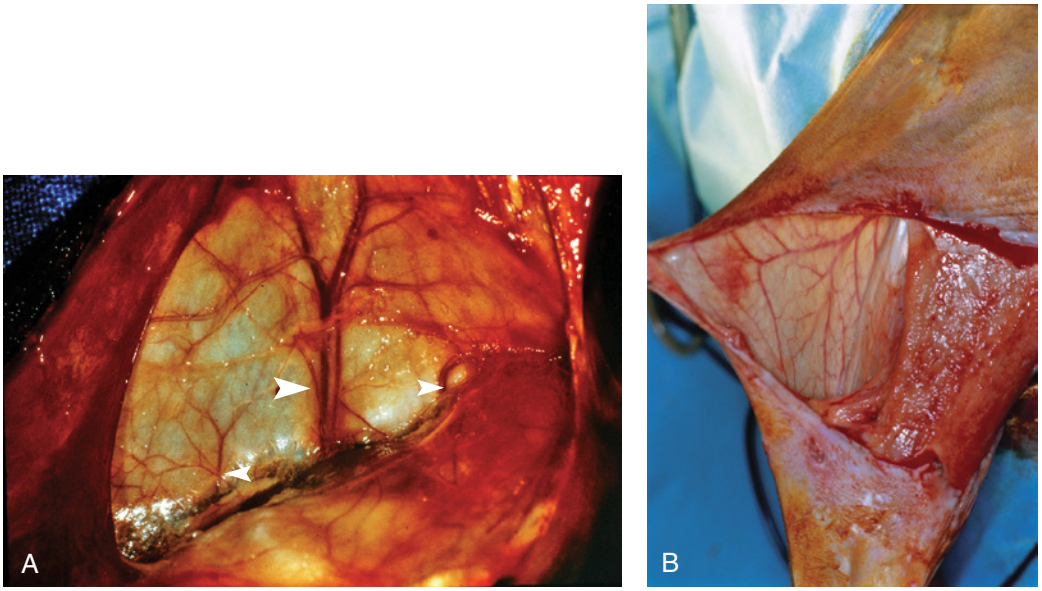


FIG. 1-7 (A) Elevation of a skin flap illustrating a large direct cutaneous artery and vein (large arrow). Small direct cutaneous vessels (small arrows) also are noted. (B) Intraoperative view of the ventral branch of the deep circumflex iliac artery and vein in a cat. The skin is being elevated to close a skin defect involving the left mid-thigh region.

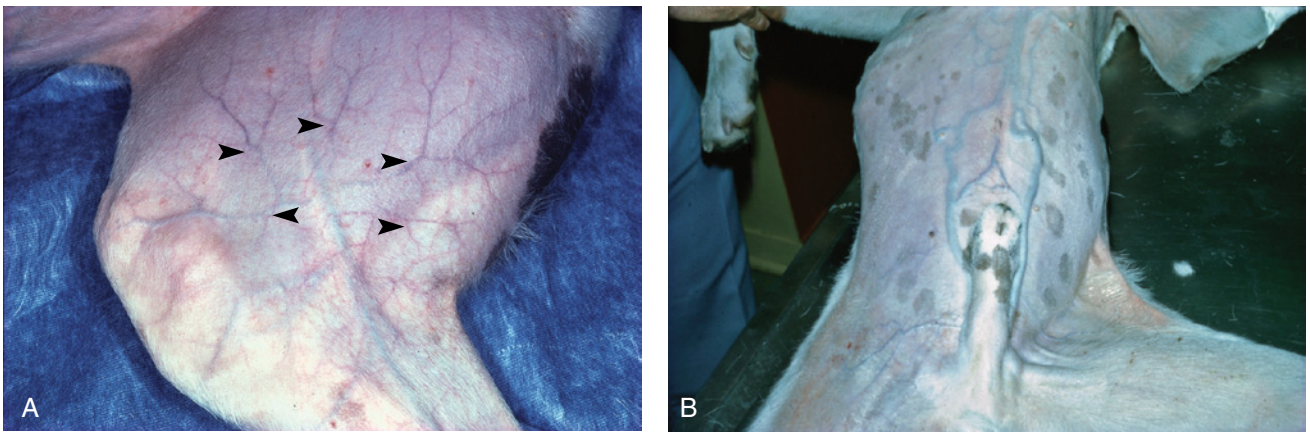


FIG. 1-8 (A) Inner thigh of a greyhound illustrating several direct cutaneous vessels traveling parallel to the overlying skin surface (arrows). (B) Ventral abdomen in a thin-skinned retriever, demonstrating prominent caudal and cranial superficial epigastric vessels.

supply a greater area of the skin compared with a single musculocutaneous artery, but play a secondary role in the total cutaneous circulatory pattern in the human (Figs 1-5 and 1-6).

Hughes and Dransfield (1959) divided arteries supplying the canine skin into two groups: mixed cutaneous arteries and simple cutaneous arteries. Mixed cutaneous arteries run through a muscle mass and supply a significant number of branches to it before emerging and supplying the skin. Simple cutaneous arteries give few branches to the muscles between which they run before supplying the skin. Despite the descriptive similarities to the perforator–musculocutaneous and perforator–direct cutaneous systems of humans, all vessels in the skin of dogs and cats approach and travel parallel to the skin and are direct cutaneous arteries (Fig. 1-7). Two of the most visible direct cutaneous arteries include the caudal and cranial superficial epigastric arteries covered by the thin ventral abdominal skin (Figs 1-8, 1-9, and 1-10). Standard anatomy texts illustrate the superficial arteries of the canine trunk (Fig. 1-11).

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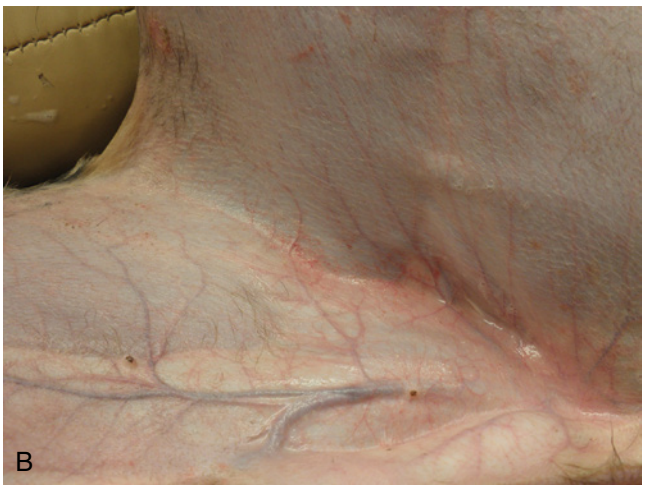




FIG. 1-9 (A) Note the caudal and cranial superficial epigastric vessels in this greyhound. (B) Close-up view of the caudal superficial epigastric artery and vein; note the small branches supplying the adjacent skin. (C) Close-up view of the left cranial superficial epigastric artery and vein.

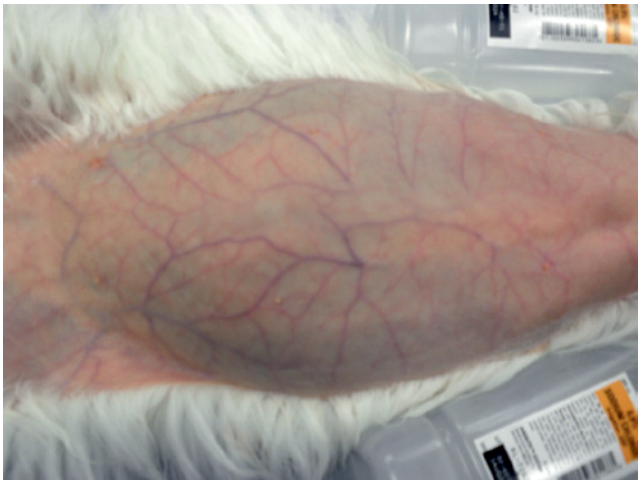


FIG. 1-10 Complete view of the lower thorax/abdomen in a thin cat, demonstrating the epigastric vasculature and collateral branches.

Clinical Relevance

By far, the single most important consideration in reconstructive surgery is preservation of the circulation. Because of differences in skin circulation, care must be taken when attempting to adapt human reconstructive surgical techniques to the dog and cat.

PINNA: CUTANEOUS CONSIDERATIONS

Chapter 23 discusses the anatomy of the pinna as well as reconstructive surgery of this unique anatomic structure. The terminal third of the pinna is composed of skin affixed firmly to the underlying perichondrium. The inner or medial surface of the pinna is covered with skin that is sparsely covered with hair, whereas the

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FIG. 1-11 Superficial arteries of the canine trunk. 1, Superficial cervical branch of omocervical; 2, cranial circumflex humeral; 3, caudal circumflex humeral; 4, proximal collateral radial; 5, lateral thoracic; 6, cutaneous branch of thoracodorsal; 7, cutaneous branch of subscapular; 8, distal lateral cutaneous branches of intercostals; 9, proximal lateral cutaneous branches of intercostals; 10, ventral cutaneous branches of internal thoracic; 11, cranial superficial epigastric; 12, caudal superficial epigastric; 13, medial genicular; 14, cutaneous branch of caudal femoral; 15, perineal; 16, deep circumflex iliac; 17, tubera coxae; 18, cutaneous branches of superficial lateral coccygeal. (Source: Evans HE. 1993. *Miller's Anatomy of the Dog*, 3rd ed. Philadelphia: WB Saunders. Reproduced with the permission of WB Saunders.)

lateral surface of the pinna is primarily covered by looser fur-bearing skin that is not attached to the perichondrium. This is a potential donor source for pinnal reconstructive surgery, along with the skin surrounding the base of the ear.

CONGENITAL SKIN DISORDERS

Cutaneous Asthenia

Cutaneous asthenia is a congenital hereditary collagen defect in humans and animals that is highlighted by fragile, hyperextensible skin. The condition is analogous to *Ehlers-Danlos syndrome* (EDS), an eponym for eight variations (EDS I–VIII) of this disorder in humans. Other names include *dermatosparaxis* and *collagenous tissue dysplasia* in cats, sheep, and cattle, a condition similar to EDS I in humans. The disease is generally considered autosomal dominant with incomplete penetrance in dogs, cats, and mink. Dermatosparaxis in some cats, cattle, and sheep may be a recessive trait. (In humans, EDS I, II, III, and VIII are considered autosomal dominant; EDS V, X-linked recessive; EDS VI and VII, autosomal recessive.)

Canine breeds affected with cutaneous asthenia include springer spaniels, beagles, Manchester terriers, Welsh corgis, German shepherds, dachshunds, boxers, St. Bernards, Cavalier King Charles spaniels, and mixed breeds (Fig. 1-12). It has been reported in Persian, Himalayan, and domestic short-haired cats (Figs 1-13 and 1-14).

Documented biochemical disorders in humans have included type III collagen synthesis (EDS IV), lysyl oxidase deficiency (EDS V), lysyl hydroxylase deficiency (EDS VI), a type I collagen defect (EDS I, II, III), and a procollagen peptidase deficiency (EDSVII).

In humans, EDS can result in joint hypermobility, congenital vascular fragility, bowel ruptures, ocular lesions, and hernias. Hernia repairs in human patients normally require the use of reinforcement mesh. However, increased skin fragility with hyperelasticity and laxity is the primary clinical feature of EDS in humans. Extracutaneous collagen fragility has been noted in the mesentery, intestinal wall, aorta, and muscle attachments in dogs.

Hyperlaxity may increase with age in dogs: the skin may appear excessive, hanging in folds, especially around the limbs. Affected animals usually have a history of lacerations and abscesses. The skin tears easily with comparatively minor trauma. Scars appear tissue-paper thin (onion-skin scars). "Pseudo-tumor" formation secondary to vascular fragility may be noted.

Histologically, the dermis and epidermis may have variable thickness. The most notable alteration is the size, shape, and orientation of the collagen bundles. Many collagen fibers appear smaller in diameter than normal, and larger collagen fibers may be fragmented. Collagen bundles may be dissociated and haphazardly arranged and lack the characteristic interwoven appearance seen in

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FIG. 1-12 (A) King Charles Cavalier with Ehlers-Danlos syndrome. (B) Note the hyperextensible facial skin. (C) Hyperextensible skin of the trunk. (Courtesy of Dr. Klaus Loft.)

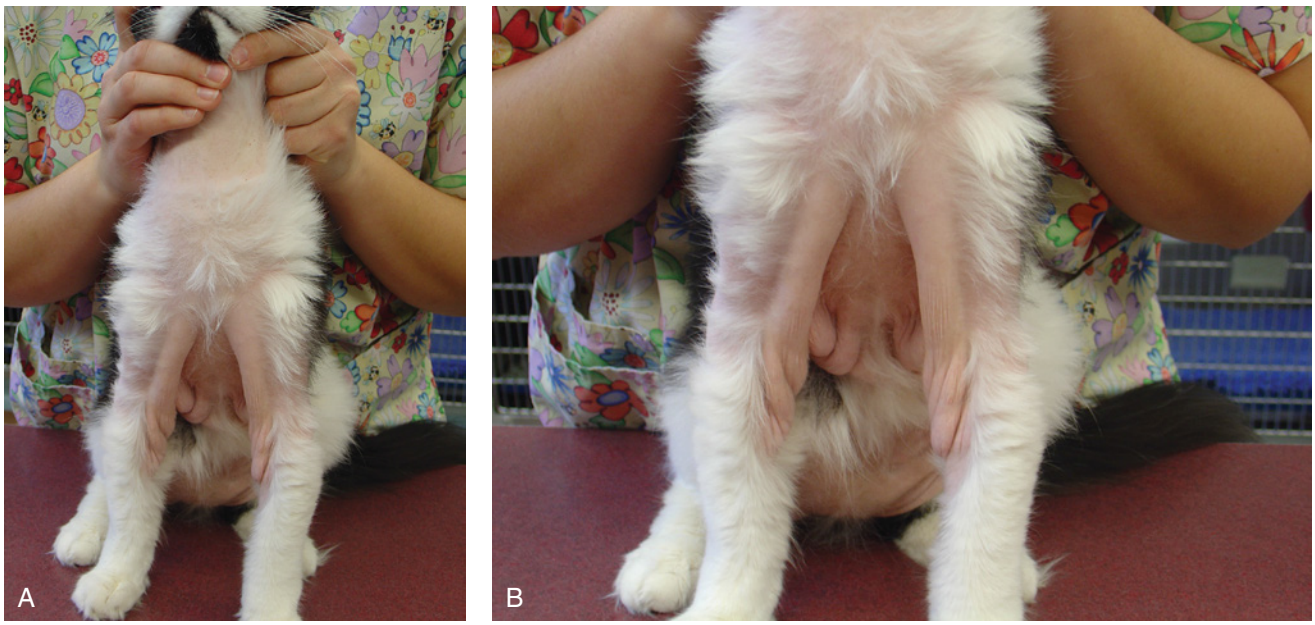


FIG. 1-13 (A) Ehlers-Danlos syndrome in a feline patient. (B) Close-up view demonstrating the thin elastic skin of the forelimbs and trunk. (Courtesy of Dr. Klaus Loft.)

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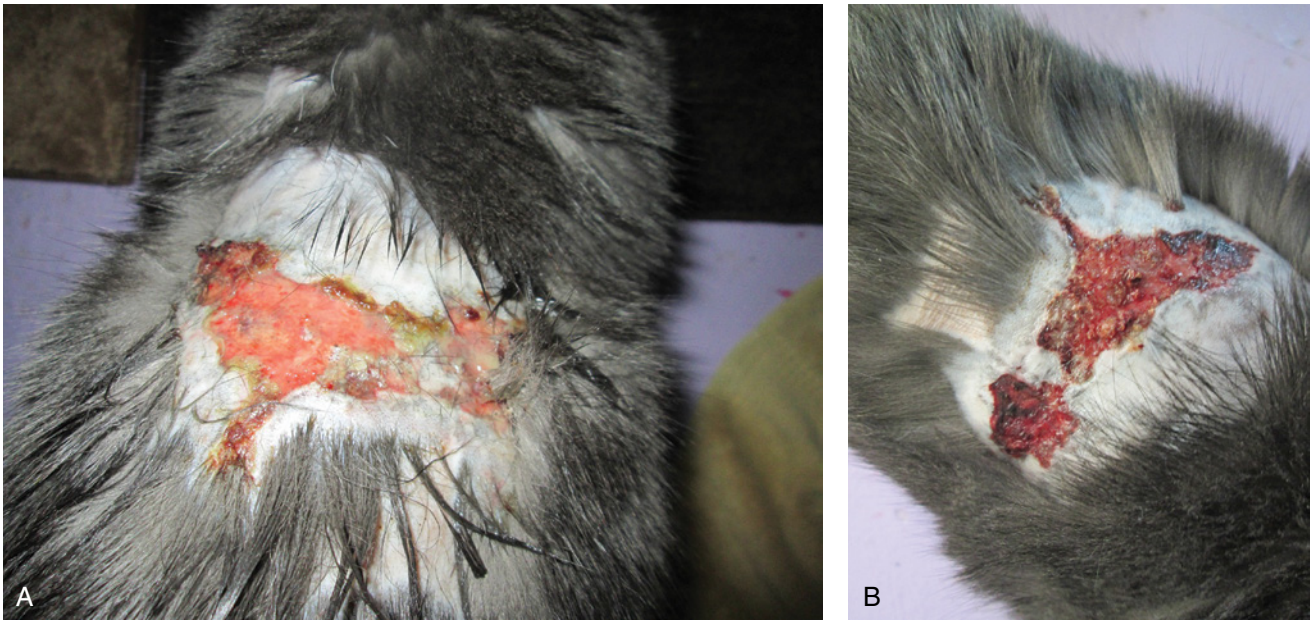


FIG. 1-14 (A) Skin tear of the dorsal trunk area in a cat. (B) Note the dorsal skin overlying the thoracic area of this feline patient. Second-intention healing is one option for promoting closure in both patients. However, debridement followed by careful undermining and closure is another option, as noted in the text.

normal skin. Abnormalities in dermal collagen packing into fibrils and fibers have been noted in mixed-breed dogs. A decrease in acid glycosaminoglycan also has been reported without histological evidence of collagen fiber disorders. The collagen may lack normal staining uniformity. A skin extensibility index greater than 17% correlates consistently with collagen packing defects.

The prevention and management of skin injuries are of primary concern in dogs and cats. Care is required to prevent trauma to the skin from clippers. Atraumatic or reverse-cutting needles are used to help prevent suture pull-out. Combining an intradermal pattern with a vertical mattress suture pattern may be advisable to reduce the risk of dehiscence. In cats, declawing the patient can reduce self-inflicted trauma from scratching. An Elizabethan collar also should be considered to prevent licking and chewing at any surgical area. Interestingly, wounds can heal readily by second intention and the stages of healing appear similar to those in unaffected skin. Tensile strength of healed wounds appears comparable to that of the surrounding skin (Fig. 1-14).

Surgical Relevance

A study compared sutured skin incisions in dogs and cats with Ehlers-Danlos to normal dogs and cats. It was noted that wound healing in dogs and cats in both groups was similar. One cat with cutaneous asthenia had a diaphragmatic hernia and bilateral perineal hernias repaired successfully.

Epitheliogenesis Imperfecta

Epitheliogenesis imperfecta is a heritable condition highlighted by areas of skin and mucosa lacking an epidermis. It has been reported in cats, lambs, and horses. Skin ulcerations are susceptible to infection. If the condition is limited to a few areas, wound-closure techniques may be considered. Breeding of affected animals is inadvisable.

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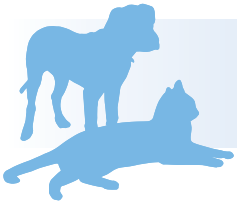
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2

Basic Principles of Wound Healing

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Processes of Wound Healing *18*
Acute versus Chronic Open Wounds *31*
Species Variations in Wound Healing *31*
Artificial Skin and Skin Substitutes *31*

Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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INTRODUCTION

By definition, a wound is a break or loss of cellular and anatomic continuity, with impairment of the tissue's protective or physiologic functions. Trauma, by definition, is a physical injury or wound caused by external force or violence. In common usage, *trauma* is used to indicate the general aspects of a physical injury, whereas *wound* is used to describe a more specific lesion.

Wounds to the skin, subcutis, and underlying muscle are among the most common injuries treated by veterinarians. The causes are many, including bites; automobile accidents; lacerations from sharp objects; penetration by bullets, sticks, or metal objects; and thermal injuries. Surgical wounds are created in the process of resecting diseased or damaged skin regions.

All wounds are the result of the absorption of energy transferred to the body, whether it is from a projectile, an electrical current, or a surgeon's scalpel blade. The severity of the insult depends on the strength of the energy source, how it is dispersed to the body, and the specific tissue(s) absorbing it. Understanding the processes of wound repair is essential to a thoughtful approach to wound care.

PROCESSES OF WOUND HEALING

Significant advances in cellular and molecular biology over the past several years have improved our understanding of the processes of wound healing and tissue regeneration. Wound healing is a complex dynamic process that integrates the functions of formed blood elements, the extracellular matrix (ECM; see Chapter 1), parenchymal cells, and soluble mediators. In uncomplicated wounds, the repair process follows a fairly consistent time sequence. There are a number of factors that are capable of delaying healing, and these will be discussed in detail in Chapter 6.

For the sake of simplicity, healing can be divided into three phases: the *inflammatory phase*, the *proliferative phase*, and the *maturation/remodeling phase*. However, these phases are not mutually exclusive but overlap in time.

Each phase of wound healing is regulated in large part by mediators termed *cytokines*. Cytokines include a number of substances (such as interferon, interleukins, chemokines, and growth factors) that are secreted by cells involved in the wound-healing process, which in turn affect the function of other cells. Cytokines can act on the cells responsible for their release (autocrine), adjacent cells (paracrine), or distant cells (endocrine). *Intracrine* refers to intracellular cytokines that exert their effect within the cell. Cytokines can direct cells to produce proteins, enzymes, proteoglycans, attachment glycoproteins, and other components required in the repair of the extracellular tissues.

> The term "cytokines" is used to collectively describe growth factors, interleukins, tissue necrosis factors, and interferons. As will be discussed, cytokines exert their effects on a variety of cells and proteins by specific receptors on their molecular surface. Platelets, monocytes, macrophages, fibroblasts, and endothelial cells are the major sources of cytokine release.

Prostaglandins and leukotrienes also appear to play a role in the healing processes. Prostaglandins of the E series may be involved in the inflammatory phase of healing, while the later anti-inflammatory effects may be due to prostaglandins of the F and possibly A series.

Cytokine, Chemokines, and Wound Healing

As noted, cytokines play a major role in regulating the processes of wound repair. Chemokines are a family of small cytokines or *signaling proteins* that induce chemotaxis. Cytokine proteins are classified as chemokines according to their function. *Growth factors* are cytokines that bind to cell surface receptors and serve as important regulators of cell function and growth. These extracellular proteins originate from a variety of tissues and often exist as several isoforms. The most notable growth factors include the following:

- Connective tissue growth factor (CTGF) (endothelial, fibroblasts)
- Epidermal growth factor (EGF) (platelets, macrophages)
- Fibroblast growth factor (FGF) (macrophages, mast cells, T-lymphocytes, endothelial cells, fibroblasts, etc.)
- Granulocyte/macrophage colony-stimulating factor (GM-CSF) (multiple cells)
- Heparin-binding epidermal growth factor (macrophages)
- Insulin-like growth factor-1 (IGF-1) (macrophages, fibroblasts, epidermal cells, lymphocytes, etc.)
- Keratinocyte growth factor (KGF) (fibroblasts)
- Nerve growth factor (NGF) (neural cells, glial cells)
- Platelet-derived growth factor (PDGF) (platelets, macrophages, endothelial cells, epidermal cells, smooth muscle cells)
- Transforming growth factor-alpha (TGF-α) (T-lymphocytes, macrophages, epidermal cells, endothelial cells, fibroblasts, smooth muscle cells)
- Vascular endothelial growth factor (VEGF) (epidermal cells)

Other mediators and regulators include tumor necrosis factor (TNF) (macrophages, mast cells, T-lymphocytes), interleukins (ILs) (macrophages, mast cells, epidermal cells, lymphocytes, etc.), interferons

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(IFNs) (lymphocytes, fibroblasts), macrophage inflammatory protein (MIP) (macrophage), macrophage chemoattractant protein (MCP) (epidermal cells), matrix metalloproteinases (MMPs) (macrophages, epidermal cells, endothelial cells, fibroblasts), and nitric oxide (NO) (leukocytes, endothelial cells, etc.). These growth factors and mediators/regulators generally have more than one effect on the healing processes. Their cellular effects include chemotaxis, promoting mitosis (mitogenic properties), cellular stimulation and activation, and regulatory properties on different components of the wound-healing process.

Growth factors hold promise in the management of nonhealing wounds (see Chapter 4). In experimental rabbit and rat studies, PDGF significantly accelerated the healing response: there was an increased rate of granulation tissue formation and the formation of procollagen-laden fibroblasts in a dose-dependent manner. Challenges in their clinical use include the manufacturing of specific growth factors while providing a stable and effective vehicle for their application to problematic wounds. Selection and application of exogenous growth factors may be an oversimplistic approach to problematic wounds due to the complex interrelationship between the cytokines. Becaplermin (Regranex®, Ortho-McNeil Pharmaceutical, Inc., Raitan, NJ) has had variable results in the management of diabetic ulcers in humans. PDGF-BB has been used successfully in human clinical trials. Regranex is a human recombinant PDGF in a gel vehicle for application. The author has been encouraged by its use in problematic extremity wounds in a few small exotic animals, both in its stimulation of a healthy granulation tissue and subsequent epithelialization of the slow-healing cutaneous defects. Controlled studies are still needed to determine its efficacy compared to other modalities of wound management. Instead of exogenous sources of growth factors, a great deal of research has focused on topical agents that are capable of stimulating cytokine production by the patient or retaining their presence in the natural wound environment with specific dressings.

PDGF, for example, is strongly chemotactic for monocytes, neutrophils, fibroblasts, and smooth muscle cells. It has mitogenic properties, promoting the mitosis of fibroblasts, endothelial cells, and smooth muscle cells. It stimulates angiogenesis, wound contraction, granulation tissue formation, and wound remodeling. PDGF also stimulates the production of fibronectin, hyaluronic acid, and matrix metalloproteinases (MMPs). It also inhibits platelet aggregation and regulates integrin expression. It was originally isolated from platelets, but other cells produce PDGF, including tissue macrophages, endothelial cells, keratinocytes, and smooth muscle cells, as noted earlier (see Chapter 4).

Transforming growth factor-beta (TGF-β), and its three isoforms, are derived from platelets, T-lymphocytes, macrophages, endothelial cells, keratinocytes, smooth muscle cells, hepatocytes, eosinophils, and fibroblasts. TGF-β has similar chemotactic properties to PDGF, including lymphocytes. It has a powerful mitogenic effect on macrophages, smooth muscle cells, and osteoblasts. Like PDGF, it stimulates angiogenesis and fibroplasia as well as keratinocyte migration. It also stimulates TIMP (tissue inhibitor of matrix metalloproteinase) synthesis and regulates integrin (see Proliferative Phase later in this chapter) expression and other cytokines. TGF-β has an inhibitory effect on the production of MMP, keratinocyte proliferation, endothelial cell growth, lymphocytes, and epithelial cells.

Epidermal, keratinocyte, connective tissue, endothelial cell, and fibroblast growth factors have mitogenic properties for their named cell lines, but they also have stimulatory properties for other aspects of wound healing. EGF (derived from platelets and macrophages), for example, stimulates keratinocyte migration and granulation tissue formation. KGF (derived from fibroblasts) stimulates keratinocyte migration, proliferation, and differentiation. KGF may stimulate progenitor cells within the hair follicles and sebaceous glands. Thus, it may play an important role in adnexal reepithelialization of partial-thickness skin wounds. FGF (derived from macrophages, mast cells, T-lymphocytes, endothelial cells, fibroblasts, and other tissues) also stimulates keratinocyte migration as well as angiogenesis, wound contraction, and matrix deposition. FGF appears to be mitogenic for cells of mesenchymal and neuroectodermal origin. CTGF (derived from endothelial cells and fibroblasts) has chemotactic and mitogenic properties for various connective tissue cells. Insulin-like growth factors IGF-1 and IGF-2 (derived from macrophages, fibroblasts, liver, pancreas, and other tissues) stimulate the synthesis of collagen, sulfated proteoglycans, fibroblast proliferation, and keratinocyte migration. Tumor necrosis factors TNF-α and TNF-β (derived from macrophages, monocytes, mast cells, and T-lymphocytes) activate macrophages and stimulate angiogenesis and fibroblast mitosis, but also have a regulatory effect on other cytokines. TNF appears to play a role in collagen remodeling by stimulating collagenase production. Colony-stimulating factor (CSF) (derived from a variety of cells) modulates monocyte and macrophage function and promotes differentiation and proliferation of granulocytes. NGF (derived from neural and glial cells) is a neurotrophic factor that modulates neuronal cell survival.

Interleukins (IL-1) (derived from macrophages, mast cells, keratinocytes, lymphocytes, etc.) are chemotactic for fibroblasts and polymorphonuclear cells. They also stimulate angiogenesis, MMP-1, and TIMP synthesis.

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They play a regulatory role with other cytokines. Interferons (IFN) (derived from lymphocytes and fibroblasts) activate macrophages; they play an inhibitory role in fibroblast proliferation and the synthesis of MMPs. Like interleukins, they also regulate other cytokines.

The exact mechanisms that lead to cessation of healing in problematic wounds occasionally remain elusive and are likely different for various wounds. There are a number of recognizable factors (poor nutritional support, improper wound care, protracted inflammatory conditions, etc.) that negatively impact wound healing. When all identifiable causes are eliminated, concern is directed at the possibility of healing deficiencies at the cellular level. A lack, or imbalance, of cytokines may be a factor in these challenging cases.

Wound healing is a complex process in large part regulated by cytokines. More simply put, the wound-healing process is a complex interrelationship of proteins that influence cell function. Research on problematic, nonhealing wounds currently focuses on the stimulation or supplementation of growth factors. From a clinical perspective, most problematic wounds have a number of common causes that demand our attention before we consider inherent healing issues. Promoting the healing processes and eliminating factors known to impair wound healing remain a primary focus for wound management (see Chapter 6). There is a wide variety of medical/surgical options to consider before resorting to the application of supplemental growth factors.

Phases of Wound Healing

Inflammatory Phase

The inflammatory phase is occasionally referred to as the *lag phase* or *preparatory phase* of healing and normally lasts for 3–5 days. The inflammatory process is an essential phase in the initiation of the wound-healing process. As previously noted, during all three phases of healing (inflammatory, proliferative, maturation) a series of events occurs at the cellular and molecular level, resulting in the mobilization of cells and the release of cytokines and chemokines. Proper wound management at the beginning of the traumatic event can facilitate healing through all three phases.

The initial inflammatory phase (6–12 hours) is followed by a second stage or debridement phase with the advancement of neutrophils and macrophages entering the trauma site. As noted earlier, severe tissue trauma causes the disruption of blood vessels with the extravasation of blood constituents. Vasoconstriction is the immediate response to injury, lasting for 5–10 minutes, followed by vasodilation. Blood clotting within the vessel lumen reestablishes hemostasis, whereas the extravascular clot will later provide a provisional matrix or scaffold for cellular migration. The extravascular clot is an important component of the inflammatory response. Platelets facilitate the formation of this hemostatic plug while secreting vasoactive mediators and chemotactic factors to recruit leukocytes. Fibrin in concert with fibronectin will later serve as a provisional matrix for the migration of monocytes, fibroblasts, and endothelial cells.

Hemorrhage, following major tissue disruption, fills the wound space. Platelets "degranulate" and initiate clot formation. This clot limits further blood loss while acting as an early extracellular matrix or scaffold for cell migration into the wound space. Fibrinolysis is activated, breaking down the fibrin, which facilitates cell migration.

During this phase, danger/damage-associated molecular patterns (DAMPs) generated by necrotic cells as well as pathogen-associated molecules (PAMPs) or microbe-associated molecular patterns (MAMPs) signal innate receptors on local cells to trigger an acute inflammatory reaction. The body in turn responds by the release of inflammatory mediators to initiate the inflammatory response. Damaged cells also release hydrogen peroxide, chemokines, and other lipid mediators. Hydrogen peroxide release promotes neutrophil migration. Pattern recognition receptors (PRRs) on resident cells trigger the inflammatory process.

Cell migration is dependent on the formation of integrin receptors on the surface of each cell. Integrin receptors recognize and attach to the molecular structure of fibrin, fibronectin, and vitronectin. Proteolytic enzymes (proteases) later assist in removing these proteins in preparation for the proliferative phase of wound healing. Two major classes of proteases of the ECM include serine proteases and MMPs. MMPs include collagenases, gelatinases, stromelysins, membrane-type MMPs, and novel MMPs. MMPs require calcium or zinc for activation. Some proteases (certain collagenases) can be highly specific in their lytic activity, whereas others (including stromelysins) are more general. Protease inhibitors (anti-proteases), including serine protease inhibitors (serpins) and TIMPs, bind directly to the proteolytic enzyme to block its activity. Thus, normal wound healing involves the proper balance between proteolytic enzymes and their inhibitors.

Matrix metalloproteinases (MMPs) play a vital role in all phases of healing. In the inflammatory phase, MMPs (collagenases) help cleave the damaged extracellular matrix collagen molecules, allowing gelatinases to further degrade the collagen into smaller molecules. Neutrophils and macrophages then engulf these fragments.

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Within 30–60 minutes after injury, leukocytes adhere to the endothelium (termed *margination*) of the vessels at the injury site; this especially is evident along the venules. Gaps between endothelial cells allow for the escape of tissue fluid and macromolecules including plasma proteins, complement, antibodies, water, electrolytes, and circulating humoral substances. Histamines, serotonin, and kinins released primarily from mast cells act on the venous side of capillary loops of 20–30 μm in size, resulting in a separation of contacts between endothelial cells; this in turn allows blood components to escape from the vascular lumen. Transudation increases in magnitude for approximately 72 hours. Damaged endothelial cells release phospholipids from the cell membrane and are subsequently converted into arachidonic acid. Arachidonic acid is an important mediator in platelet aggregation and vascular tone.

Leukocytes pass through the basement membrane of the vessel wall by diapedesis. Endothelial cell surface receptors (selectins) assist neutrophil adherence to the endothelium, whereas integrin receptors on the neutrophil cell surfaces assist in their binding to the ECM. Activated neutrophils release elastase and collagenase molecules, which facilitate their penetration through the blood vessel basement membranes. Both neutrophils and monocytes emigrate to the injured tissues, but neutrophils arrive in greater numbers due to their abundance in the circulation. Chemotactic substances (complement factors, IL-1, TNF-α, PDGF, TGF-β, platelet factor-4, fibrinopeptides, fibrin degradation products, and bacterial products) stimulate neutrophil migration. PDGF, collagen fragments, elastin, fibronectin, enzymatically active thrombin, and TGF-β serve as chemoattractants for monocytes. Monocytes entering the wound progressively become activated, transforming into tissue macrophages.

Complement is found in serum and extracellular fluid. It induces lysis of target cells and assists in the binding (opsonization) of neutrophils to bacteria, facilitating phagocytosis.

Neutrophils release proteinases to degrade necrotic tissue, which in turn serves as a chemoattractant for additional neutrophil migration. Neutrophils at the wound site destroy contaminating bacteria via phagocytosis and enzymatic and oxygen radical mechanisms. Neutrophils also remove damaged cells and denatured ECM. Interestingly, provided that infection is not present, neutrophils are not essential to the healing process.

Neutrophils arrive into the wound tissue shortly after injury and peak in number within 24–48 hours; they undergo programmed cell death (apoptosis) within a few days. In the absence of infection, their numbers decrease dramatically in 72 hours. These effete neutrophils are subsequently phagocytosed by tissue macrophages. However, substantial contamination (bacteria, foreign debris, necrotic tissue) can propagate a neutrophil-rich wound environment until particle clearance has been completed. Macrophages continue to survive and begin to dominate numerically by the fifth day in uncomplicated wounds.

Pus is the liquid product of inflammation and is composed of tissue fluid, dead and degenerated neutrophils, and albuminous substances. An abscess is the localized collection of pus in any part of the body. Although most abscesses are associated with bacterial infection, they can form under sterile conditions in the presence of a foreign irritant. Prompt medical and surgical intervention in acute injuries can reduce the likelihood of infection.

The macrophage was once described as the "digestive tract" of the wound. It also has been referred to as the "grand maestro" of the wound-healing process. Derived from monocytes, macrophages begin to show up in the wound 2–3 days later, followed by lymphocytes. Macrophages are capable of surviving in an oxygen-depleted environment, removing bacteria, contaminants, and tissue debris by phagocytosis. They also release proteases (including collagenase, elastase, and plasminogen activator), facilitating wound debridement: excessive release of these enzymes is also capable of damaging healthy tissues. In uncomplicated wounds, the macrophage population will decline as the inflammatory phase subsides. In the face of extensive foreign debris, contaminants, and necrotic tissue, macrophage numbers will persist in the wound, a "cellular indicator" associated with chronic inflammatory conditions.

Wound debridement and lavage can significantly reduce the volume of necrotic tissue and contaminants, thereby facilitating the healing processes. The removal of dead tissue and debris also plays an important role in preventing and controlling infection.

Macrophages may coalesce to form multinucleated giant cells designed for the phagocytosis of foreign debris. Macrophages also have the capacity to differentiate into epithelioid cells and histiocytes. Some macrophages appear to be primarily involved with host defense and cell-mediated immunity, whereas other cells are involved in tissue growth and repair. Thus, activated macrophages serve in a "director capacity" and play a pivotal role in the transition between inflammation and repair. Macrophages release proteinases and enzymes that break down clots and tissue debris, forming small pockets or channels for fibroblasts and endothelial cells to advance

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into the wound. Macrophage-derived growth factors are essential to the initiation and propagation of new tissue formation, including fibroplasia and angiogenesis. The macrophages also release lactate into the wound environment, which stimulates fibroplasia and subsequent collagen production.

The inflammatory or lag phase lasts for approximately 5 days in experimental wounds. The classic signs of inflammation (redness, swelling, heat, pain) are the result of vasodilation, fluid escape, and obstruction of the local lymphatic channels. Lymphatics are fragile and easily injured; fibrin formed at the wound site can plug these channels and enhance local fluid retention. Pressure, chemical stimulation, and stretching of nerve endings result in pain. Circulatory compromise will lower wound pH due to accumulation of lactic acid. This wound environment is ideal for bacterial infection. *Rough handling of compromised tissues may be the factor that "tips the scale" in favor of tissue necrosis and subsequent infection*. As discussed in Chapter 6, the inflammatory phase in acute wounds normally occurs in a timely fashion. One characteristic in chronic wounds is the abnormal prolongation of the inflammatory phase.

Surgical debridement remains a mainstay in removing significant areas of necrotic tissue; the short-term use of mechanical debridement (employing wet-to-dry dressings) can be used to quickly supplement the removal of smaller areas of adherent necrotic tissue remaining. Dressings that support the process of autolytic debridement are useful to remove any remaining areas of residual necrotic tissue. (See Chapters 4 and 5.)

Proliferative Phase

The proliferative phase is usually considered to be 5–20 days after injury, although some papers indicate it begins as early as 3 days after injury.

The term *granulation tissue* is derived from the granular (fine pebble-grain) appearance of newly forming tissue when incised and its edge is visually examined. The surface of a well-developed granulation bed often assumes a fine pebble-grain or granular appearance. Granulation tissue is a matrix of fibrin, fibronectin, collagen, proteoglycans, and glycoproteins. Cells include new capillary buds (capillary loops), fibroblasts, platelets, macrophages, and leukocytes. Granulation tissue can be considered "living body putty," filling in body defects while providing a vascular scaffold for epithelial cell migration. Granulation tissue forms a barrier to invasive bacteria. Fibroblasts extrude collagen, essential to increasing the tensile strength of the wound. The connective tissue deposited forms the provisional ECM.

In a simple wound, the acute inflammatory reaction subsides and early repair commences 3–5 days after the initial insult. Approximately 4 days after an uncomplicated injury, early granulation tissue begins to form (depending on the species of the patient and local wound environment).

Surgical Relevance

In one study investigating granulation bed formation in cats, experimental fasciotomy or excision of the dense epaxial muscle fascia expedited granulation tissue formation (~9 days) versus retaining the muscle fascia (~18 days) or abrading the fascial surface (~17 days). The advantage of fascial excision in cats must be weighed against the additional trauma inflicted to the patient. To facilitate wound closure, fascial resection may be useful for those cases where closure with a free graft is required for a problematic wound.

Supportive cells (macrophages, platelets, leukocytes), fibroblasts, and capillary buds can be considered as a "wound module," underscoring their interdependence during tissue repair. As noted, cytokines play a key role in stimulating fibroplasia and angiogenesis. The blood clot (specifically the fibrin and fibronectin network) serves as a provisional ECM. The fibrin and fibronectin form a scaffold to support and guide low-impedance cell migration (macrophages, fibroblasts) and collagen deposition. Integrins are cell membrane receptors necessary for cell binding or adherence to specific glycoproteins of the ECM. The fibronectin receptor complex binds the cell wall to fibronectin as well as cytoskeletal proteins on the inside of the cell. As a result, contraction of intracellular actin microfilaments can move the cell through anchorage to the fibronectin and other ECM proteins. Thus, integrins are receptor proteins that integrate the extracellular and intracellular scaffolds, allowing them to work in concert. Once fibroblasts and endothelial cells express the proper integrin receptors under stimulation of cytokines and provisional matrix proteins, these are capable of moving into the wound environment. Over time granulation tissue is replaced by a framework of collagen and elastin fibers. Tissue remodeling follows, with new collagen synthesis mediated by TGF-β and old collagen degradation by PDGF.

The four key processes associated with the proliferative phase of wound healing will be discuss as subsets, including (1) neovascularization/angiogenesis; (2) fibroplasia and collagen deposition; (3) epithelialization; and (4) wound contraction (Figs 2-1 and 2-2).

NEOVASCULARIZATION: NEOANGIOGENESIS

A key event in the healing process is new blood vessel formation, termed *neoangiogenesis*. Without adequate circulation, fibroblasts cannot survive in the wound

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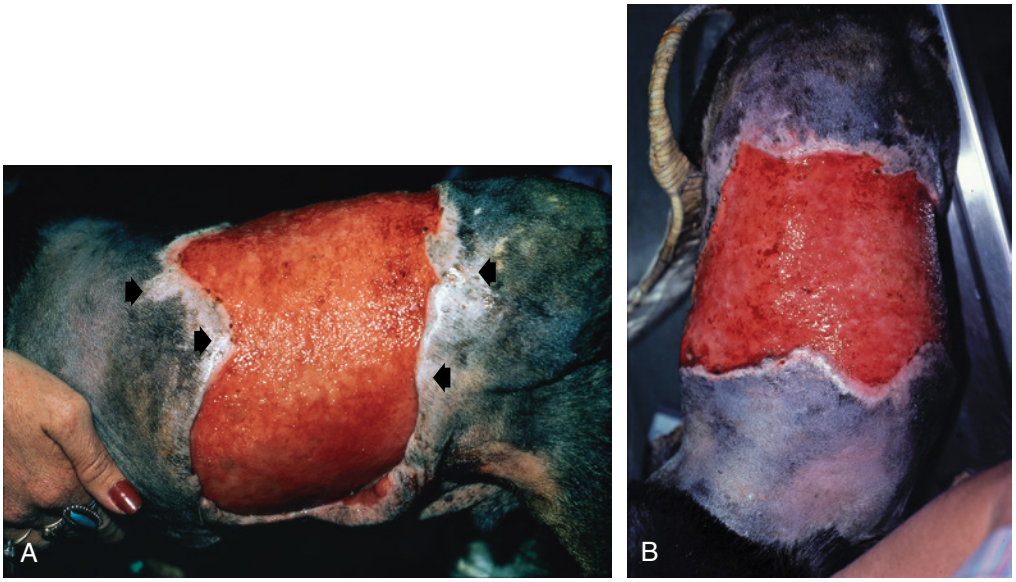


FIG. 2-1 (A, B) Granulation bed involving the canine trunk. Early wound epithelialization (arrows) is noted along the wound margins. Note the distinct "pebble-grain" or granular surface composed of outgrowths of capillaries by budding from existing capillaries. Fibroblasts surround these capillary loops, forming individual granules that coalesce to form granulation tissue.



FIG. 2-2 (A) Lower paw with a healthy, vascular granulation bed secondary to extensive loss of skin. An external fixator was applied to stabilize a compound comminuted fracture. (B) Successful full-thickness graft "take." The external fixator provided a surface for securing the bandage required following graft application.

environment: in short, no fibroblasts, no collagen. Epithelialization also is dependent on the presence of a vascularized ECM.

Neoangiogenesis is a complex process and depends on four interrelated phenomena: cell phenotype alteration; chemoattractant-driven migration; mitogenic stimulation; and the local development of a supportive ECM.

Vascular endothelial cells arise from the damaged end of vessels and local capillaries will form from these vessels along the base and edges of the wound. Under the

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influence of growth factors, endothelial cells detach from the vessel wall (vascular buds) that penetrate the provisional matrix in the wound. These endothelial "sprouts" extend in length; when they contact another bud, they connect to establish a circulatory loop. Growth and chemotactic factors within the wound prompt local endothelial enzyme release. The local wound environment also potentiates angiogenesis, including the presence of low oxygen tension, biogenic amines, and lactic acid. The low oxygen tension likely stimulates macrophages to produce and secrete angiogenic factors.

Plasminogen activator and collagenase released from endothelial cells (located at the venule side closest to the angiogenic stimulus) transit through the degraded basement membrane. Endothelial cells project pseudopodia through the weakened basement membrane and migrate into the perivascular space. Endothelial cells from the parent vessels proliferate by the second or third day after injury and serve as a cell source during angiogenesis. Capillary buds extend into the matrix, where their tips eventually branch and connect, forming capillary loops. New branches extend from the loops to form a capillary plexus.

The ECM has a strong influence on endothelial cell morphology and function. A rich fibronectin matrix around the endothelial buds helps support and guide endothelial cell movement. This emerging capillary system deposits its own matrix of proteoglycans and fibronectin, ultimately forming its own basement membrane. Angiopoietin, FGF, VEGF, and TGF-β stimulate endothelial cell migration. Integrins on the endothelial cells link them to the ECM. MMPs degrade the basement membrane and the ECM, thereby creating openings for the migration and formation of endothelial tubes, forming new capillaries. Unlike the individual migration of fibroblasts, endothelial cells migrate in sheets. These immature capillary buds are porous with loss of fluid into the wound; this is noted in immature granulation tissues. Over time, the capillaries mature with a commensurate decline in leakage. As granulation matures, portions of the capillary population eventually degenerate secondary to apoptosis. The ECM molecules influence this process by the release of antiangiogenic factors (endostatin, angiostatin, angiopoietin 2, and angiotensinogen) and thrombospondin (1 and 2). This decline in vascularity explains the pale appearance of chronic granulation tissue.

FIBROPLASIA AND COLLAGEN DEPOSITION

Fibroblasts are noted in the wound 72 hours after injury and rapidly proliferate over the first week. Fibroplasia is the component of granulation tissue that includes the fibroblasts and the associated ECM. Fibroblasts originate from the viable "periwound" tissues, although other viable mesenchymal cells are capable of differentiating into fibroblasts. In dogs there are subtle regional differences in the healing process.

In one study (Winstanley 1976), healing of experimental skin wounds of the thoracic and metatarsal areas in dogs was compared. In thoracic wounds, the adipose tissue and areolar tissues were the source of fibroblasts, whereas fibroblasts developed from the region of blood vessels in metatarsal wounds. Little free exudate was noted in thoracic wounds while greater exudate accumulated in the cavity of metatarsal wounds. The resultant exudate supported the formation of granulation tissue.

Cytokines and the provisional matrix stimulate the proliferation of fibroblasts, express the formation of integrin receptors, and ultimately migrate into the wound space. Fibroblasts adhere to fibrin and fibronectin cell receptors allow fibroblasts to move through the filamentous scaffold. Fibroblasts also have integrin receptors, allowing them to attach directly to fibrin and other protein strands. Fibroblasts will advance toward the chemotactic gradient by extending lamellipodia toward the stimulus. The integrin bonds will release and reform as the fibroblast creeps forward. Fibroblasts release proteolytic enzymes—plasminogen activator, interstitial collagenase (MMP-1), gelatinase (MMP-2), and stromelysin (MMP-3)—to facilitate their migration through this filamentous fibrin-linked jungle. After migration into the wound, fibroblasts gradually shift to protein synthesis. Initially, fibroblasts secrete large quantities of fibronectin, forming a loose ECM; a collagenous matrix follows.

Collagen is a glycoprotein arranged in three alpha chains forming a spiral or helix. The collagen molecule is composed of 33% glycine, 33% proline, and the remaining 33% is a variety of other amino acids. The amino acids proline and lysine must be hydroxylated when they are incorporated into the alpha chains by the fibroblast. The enzymes propyl hydroxylase and lysyl hydroxylase are necessary for this essential step in collagen formation. Oxygen, ferrous iron, alpha ketoglutarate, and a reducing agent such as ascorbate (vitamin C) or light-activated riboflavin are necessary for the enzymatic hydroxylation process. Vitamin C is essential for optimum collagen production. If the hydroxylation process is not completed, the collagen molecule cannot be excreted from the fibroblast. Although the dog and cat generally possess adequate levels of vitamin C, it is worth considering its supplementation in severely stressed patients that have a poor nutritional status.

On hydroxylation, a galactose molecule is attached to the assembled intracellular collagen molecule, which is then excreted. This extracellular molecule is termed *procollagen*. Terminal or registration peptides are cleared from this molecule by procollagen C-proteinases and procollagen

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N-proteinases. When this occurs, the procollagen molecule aggregates to form tropocollagen fibers. The tropocollagen molecules in turn assemble to form fibrils. This assembly or aggregation, due to lysine–lysine amino acid cross-linkage, is responsible for a major portion of the strength in the collagen fibril. A variety of diseases and drugs can alter this orderly process, resulting in potentially serious wound-healing and functional complications.

During the wound-remodeling process previously discussed, a primitive collagen gel (collagen III) or matrix is deposited initially, only to be resorbed by collagenase enzymes as a stronger collagen (collagen I) is laid down over a period of weeks to months following an injury (see the Maturation and Remodeling Phase discussion later in this chapter). Sources of collagenase in the wound are inflammatory cells, endothelial cells, fibroblasts, and keratinocytes. Collagenase activity is closely controlled by cytokines. As noted, the net result of the process is less collagen compared to the original closely packed collagen, but a collagen network of greater tensile strength due to its structurally superior basket-weave design. Collagen generally realigns to form sheets parallel to physiologic tension lines using increasingly firm cross-linkage of collagen strands or bundles. This is readily evident in the normal controlled healing process during tendon repair.

Day 4–5 after surgery is a critical juncture in surgical wound repair. Prior to this, sutures primarily maintain alignment of the tissues. Day 4–5 (species variations) is the general time frame at which fibroplasia and early collagen deposition are more prominently noted. Tensile strength increases rapidly after this point.

Although wound dehiscence can occur at any point of the healing process, it is the author's clinical experience that most (not all) cases of wound dehiscence occur 3–5 days postoperatively. For problematic wound closures, the first 5 days of healing (inflammatory phase) require the surgeon's close attention.

Collagen is directly responsible for the tensile strength of a healing wound. A lack of collagen or its improper formation can lead to wound dehiscence. As collagen is deposited by fibroblasts, fibrin strands are removed. Net collagen synthesis is increased for at least 4–5 weeks after wounding, spanning the proliferative and maturation phases of healing. Increased collagen deposition is due to increased fibroblast numbers and increased collagen deposition from each cell. Collagenase activity in advancing epithelial cells and in adjacent fibroblasts is important in controlling collagen deposition. This fibroblastic phase lasts for 2–4 weeks, depending on the wound size. The termination of this phase is noted by a decline in the number of capillaries and fibroblasts and by a greater deposition of collagen.

Collagen levels peak 2–3 weeks after injury, but the tensile strength of the scar progressively increases over the next 12+ months as collagen remodeling progresses. Collagen fibrils realign in the direction of maximum stress, with cross-linkage between fibers.

Over time, chronic granulation tissue will form in a nonhealing open wound. Older scar beds are laden with collagen, while the fibroblast and capillary populations have declined. As a result, chronic granulation tissue does not support epithelialization or wound contraction without surgical intervention. If the underlying tissues that supported the original granulation bed remain healthy, excision of the chronic wound bed will result in the formation of a new healthy granulation bed within days after its debridement.

During open wound management, granulation tissue formation is an important guideline of the healing process for the veterinary clinician. (1) Granulation tissue formation indicates that the wound bed is now composed of viable vascular tissue capable of supporting its growth. (2) Formation of a healthy granulation bed, in turn, opens up the possibility of wound closure by second-intention healing, delayed primary closure, or surgical closure (undermining and closure, skin grafting, skin flap, etc.). Combining closure techniques is an option for many of the more challenging defects.

EPITHELIALIZATION

Wound healing is incomplete without restoration of the epithelial surface. One or two days after injury, epithelial cells begin to proliferate in the basal zone and overlying prickle cell layer along the viable border of the skin defect. The epithelial cells dissect clot and damaged stroma by secreting proteolytic enzymes (collagenase, plasminogen activator) as they attempt to repave the viable tissue surface. Mitotic figures can be noted as early as the first 24 hours; mitotic figures can be seen in the migrating epithelium on the second day.

Epithelial cells undergo a marked phenotypic alteration. They lose their tenacious binding with the dermis and lose their apical–basal polarity. They advance over the viable tissue surface by extending pseudopods along the basolateral sides of the wound. Epithelial cells will enlarge and flatten during migration over the vascular wound bed as they lose their attachments to the basement membrane and adjacent epithelial cells. Chalone (water-soluble glycoproteins) found in the epidermis normally inhibits mitosis; it is diminished in wounds, allowing epithelial cells at the perimeter of the wound to undergo mitosis and migrate onto the adjacent granulation tissue

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(or viable vascular tissue). As the cells slide forward, collagenase is released to facilitate their migration beneath any scab present on the wound surface. Integrin receptors facilitate their movement over the wound surface and the bed of fibrinogen, fibronectin, and type 1 collagen. Epithelial migration is guided by collagen fibers.

Marginal basal cells loosen from the underlying dermis and begin to migrate across the provisional vascularized matrix. The epithelial cells progressively extend outward in a horizontal direction over the flat wound surface. When epithelial cells contact epithelial cells (from another locus of epithelial cells), movement halts in what is termed "contact inhibition." A key to open wound management is providing an environment that nurtures epithelial cell migration. This includes ensuring a vascular wound surface that supports the process of epithelization.

In sutured wounds with a minimal dermal gap, epithelial cells can bridge the minor gap by 48 hours. In moderate to large wounds, epithelial migration may take weeks or may never completely cover the open wound. Thus, the process of epithelialization can extend from the proliferative phase well into the maturation phase of healing in problematic wounds.

The surface of epithelialized wounds (scar epithelium) is normally characterized by thinness and fragility. The initial epithelial layer is only one cell layer thick, but gradually thickens to a variable degree as additional cell layers form. On "protected" areas of the animal, the durability of scar epithelium may be satisfactory. In body areas subject to periodic trauma, abrasive surfaces, or solar exposure, the same scar surface may ulcerate. Hair growth is minimal within the epithelialized scar. Given these considerations, coverage with full-thickness skin (flaps, grafts, skin advancement) may be advisable, depending on the location and magnitude of the cutaneous defect, the durability required to withstand wound breakdown, and the cosmetic results desired.

The source of epithelial cells varies according to the thickness of the skin defect (see Chapter 1). The viable skin perimeter is the source of epithelial cells in full-thickness skin defects. Partial-thickness wounds (loss of the epidermis and portions of the dermis) can predominantly reepithelialize from viable dermal adnexa, especially the external root sheaths of the compound hair follicles (see Chapter 3) (Fig. 2-3).

Partial-thickness loss of skin is commonly seen with deep dermal abrasions and second-degree burns (both thermal and chemical). Despite the loss of the epidermis, adnexal reepithelialization is considerably faster than in comparable full-thickness skin defects. In the more superficial injuries, healing may occur with little scarring and surprisingly good cosmetic results.

PSEUDO-HEALING

Sutured wounds can appear healed after epithelialization has occurred at the junctional gap of apposed skin margins. However, without appropriate collagen deposition below the epidermal surface, the wound has a low tensile strength and is subject to dehiscence with premature suture removal.

This has been noted in dogs on high levels of corticosteroids over a prolonged period of time. Pseudo-healing also has been reported in cats as a result of the comparatively slower healing processes. When a delay in wound healing is suspected, sutures should be retained for a longer period of time (3 weeks is suggested) to reduce this risk. Additionally, intradermal sutures can be used to support incisional healing, followed by skin sutures. The intradermal pattern can reduce incisional tension and provide additional support after skin suture removal. Another cautionary measure can be used in problematic healing cases: alternate skin sutures can be removed, followed by the remaining ones 2–3 days later.

WOUND CONTRACTION

By definition, wound contraction is the process in which the skin peripheral to a full-thickness defect advances in a centripetal fashion toward the center of the wound. Wound contraction spans both the proliferative and maturation phases of healing (Fig. 2-3). The cells responsible for this phenomenon are called myofibroblasts. While wound contraction normally is reported to start 5 days after open wound formation, its effect may not be visually evident until several days later.

Both fibroblasts and myofibroblasts are thought to derive from inactive mesenchymal cells, called fibrocytes. These progenitor cells are also believed to be capable of differentiating into osteoblasts, chondrocytes, and adipocytes. Blood-borne fibrocytes, derived from the bone marrow, are capable of traveling to wound sites. After migration into the ECM, the cells transform into fibroblasts, changing to a profibrotic phenotype during which collagen (types I and III) is deposited. During the second and third weeks of repair, fibroblasts, induced by TGF-β1, develop smooth muscle properties as contractile proteins (F-actin microfilaments) along the cytoplasmic face of the basement membrane. These contractile fibroblasts are called *myofibroblasts*.

Myofibroblast integrins link the cells to the fibronectin network and the collagenous fibrils in the ECM. Collagen bundles in turn interlink within the granulation tissue and the dermal layer of the bordering skin margins. These cell–cell, cell–matrix, and matrix–matrix interconnections result in the ability of myofibroblasts to apply a traction force to this pericellular matrix. This force is exerted as

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FIG. 2-3 (A) Extensive thermal wound in a dog, maliciously set on fire using a flammable agent. (B) Large granulation bed formed after aggressive debridement of an extensive full-thickness burn to the trunk, 1 week later. Islands of epithelium are forming in the central area of the wound bed (arrows). (C) Close-up view of these epithelial islands demonstrates that hair follicles (arrow) surviving in deep dermal and hypodermal tissue after debridement are the source of these epithelial cells. Combined cutaneous closure techniques were necessary to cover this massive defect. (D) Intraoperative view of deep circumflex iliac island arterial flap (ventral branch). The flap was rotated 180 degrees to cover the dorsal pelvic portion of this sizable skin defect. (E) Combined closure employing a thoracodorsal axial pattern flap (open arrow), deep circumflex iliac island arterial flap (ventral branch) (solid arrow), and advancement of the lateral thoracic skin using "walking sutures" (Plate 27). Islands of epithelium (noted in C) were harvested and reimplanted as punch grafts in the remaining granulation bed. (F) The patient, 6 weeks after surgery. The remaining open wounds primarily closed by wound contraction, with epithelialization playing a secondary role in this instance. (Source: Pavletic MM. 1990. Massive trunk wound secondary to thermal trauma. *Vet Med Report* 2:59. Reproduced with permission from Veterinary Medicine Report.)

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myofibroblasts align with the wound contraction lines. As the myofibroblasts extend and contract their pseudopods, the collagen bundles align and condense in concert. Cytokines (especially PDGF from macrophages) likely are involved in activation of these processes. Earlier reports suggest that fibroblasts also are capable of contributing to the process of wound contraction in the appropriate ECM components, and cytokine signals are present.

When actin microfibril bundles contract within the myofibrobasts, the force is in turn exerted on the attached collagen network with the assistance of integrins and other adhesive molecules. The cross-linkage of collagen and fibronectin with myofibrolastic attachments is analogous to a net used in commercial fishing. Traction on the net draws or drags anything trapped or attached to the fishnet. In wound contraction, the skin margins interlinked with the collagen network are literally dragged toward the center of the granulation bed.

The timing of wound contraction has been reported to be between the 3rd and 42nd days in experimental rabbits. By contrast, the initial contraction phase in dogs begins 5–9 days after injury. As the skin is stretched in a centripetal fashion, both the epidermis and dermis narrow in response to the tension. The term *intussusceptive* growth describes the process of epithelial proliferation and collagen deposition that occurs within the stretched skin to bolster and restore cutaneous areas that are under significant tension. As will be discussed in Chapter 10, skin also is capable of stretching beyond its inherent or natural elasticity by application of external forces, including the use of skin stretchers and tissue expanders.

WOUND CONTRACTION: CLINICAL CONSIDERATIONS

Experimentally, wound contraction proceeds at a rate of 0.6–0.75 mm per day. Wound contraction appears to decline after 42 days in experimental rabbits; it also decreases in other animals over time. Therefore, 6 weeks is a general guideline on what to expect for problematic wounds in which wound contraction is considered the best option for closure. After 6 weeks, any remaining skin defect will need to close by epithelial cell migration (without surgical intervention). In some cases, the surgeon may elect to manage a problematic wound by promoting the process of wound contraction. If the wound closes significantly during this time, any remaining defect will be smaller and more amenable to a simpler closure technique.

The term *contracture* refers to the loss or inhibition of motion or function as a result of excessive scar tissue or muscle atrophy or fibrosis. Wound contraction also can contribute to contracture formation when skin tension secondary to this healing process limits function (especially involving the extremities). This will be discussed in greater detail in Chapter 6.

Puppies and kittens have the remarkable ability to close wounds primarily by the process of wound contraction (Figs 2-4 and 2-5). Provided with a healthy diet and proper wound care, surprisingly large skin wounds can close within weeks after injury. During this process it is important to assess the patient periodically for signs of wound contracture.

Wound contraction is remarkably effective in loose-skinned, fur-bearing animals compared to the human. As a result, surgical intervention using skin grafts and flaps is more common for larger wounds in humans, whereas wound contraction may be considered a useful closure option in many veterinary patients. Interestingly, square and rectangular wounds contract more effectively than circular skin defects, based on animal studies. The linear edges favor the linear traction forces of the myofibroblasts. By contrast, circular wound margins are pulled simultaneously, with the skin margin binding from the offset or angular contractile forces applied to its edge. From a wound-management standpoint, any remaining skin defect remaining after contraction ceases would need to heal by epithelial cell migration. (For this reason, a circular skin wound is used to accommodate a colostomy stoma in humans. A linear incision or square skin defect created at the stoma is more likely to contract and form a constriction.)

The independent healing processes of wound contraction and epithelialization will affect the cosmetic outcome in wound closure. Skin wounds that close primarily by contraction will have a relatively small, hairless epithelialized scar. Adjacent hair growth may cover over this hairless area. In contrast, wounds that heal to a significant degree by epithelialization will have a comparatively large, thin, hairless surface. From a cosmetic and functional standpoint, this is less favorable (Fig. 2-6).

Wound contraction is not important in small wounds, but it can be critical to the management of larger open wounds (barring surgical intervention). In large skin wounds, which have adjacent loose, elastic skin, successful second-intention healing is *predominantly by wound contraction* (Figs 2-4 and 2-5). Epithelialization occurs independent of wound contraction. When wound contraction ceases naturally or is impaired, epithelization must complete the closure process without surgical intervention. In some cases, epithelialization simply is not up to the task of closing the remaining large wound when contraction ceases; that is when flaps or skin grafts often become the best option for successful closure. Alternatively, other options to stimulate closure may be considered for the chronic wound (see Chapter 4).

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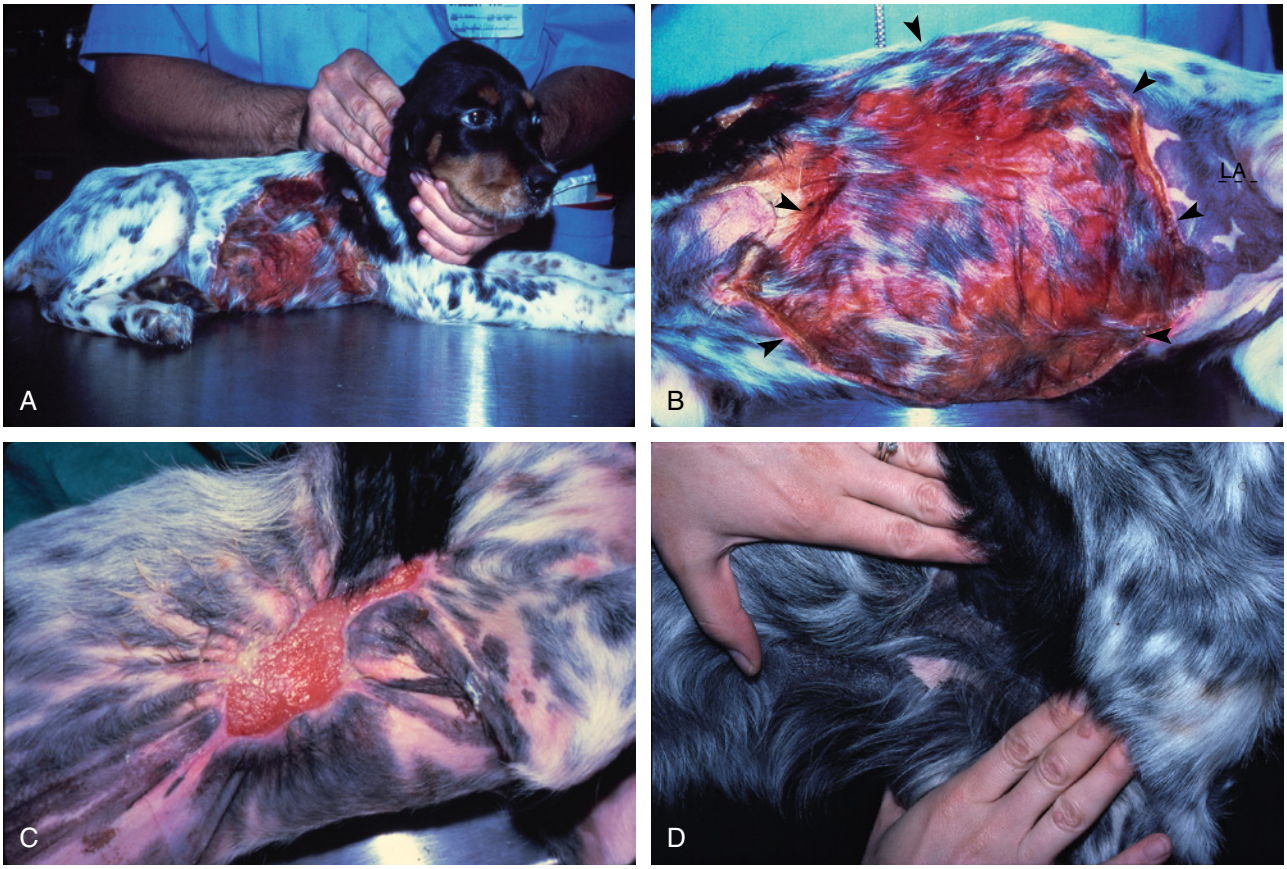


FIG. 2-4 (A) Extensive thermal burn as a result of an electrical heating pad in this retriever puppy. (B) Close-up view of the lower thorax and abdomen. Wound contraction progressed during the next 6 weeks by centipedal advancement of peripheral loose skin. Serial debridement was performed; silver sulfadiazine was used on the burn. (C) The thermal wound closed predominately by contraction. (D) A small epithelialized scar eventually can be seen after parting the hair. (Source: Parritz DL, Pavletic M. 1992. Physical and chemical injuries: heatstroke, hypothermia, burns and frost bite. In: Murtaugh R, Kaplan P, eds. *Veterinary Emergency and Critical Care Medicine*. St. Louis: Mosby-Yearbook. Reproduced with permission from Mosby-Yearbook.)

Maturation and Remodeling Phase

During the transition from granulation tissue to scar maturation, collagen remodeling occurs, with a balance between collagen deposition and collagen catabolism. Type III collagen gradually decreases as type I collagen increases. Specific collagenase enzymes (metalloproteinases) from macrophages, fibroblasts, and epidermal cells cleave type I, II, III, X, and XIII collagens. Balancing the degradation of collagen are TIMPs. Cytokines and the ECM play an important role in this process. Nonfunctional collagen fibers are broken down by these proteolytic enzymes within the ECM.

Collagen deposition is directly related to the tensile strength of a wound. The scar has 20% of its final strength 3 weeks after injury. Thereafter, gains of tensile strength occur at a much slower rate. Over the next several weeks, a scar will achieve only 70–80% of the tensile strength of normal skin. Tensile strength is primarily associated with collagen remodeling, resulting in larger collagen bundles and intermolecular cross-links with adjacent collagen fibers. In the end, there is less collagen than initially noted in the early healing process but with a structurally superior configuration. As maturation progresses, the dense capillary network of healthy granulation tissue progressively declines.

The maturation and remodeling phase is generally considered to take place from day 20 to approximately 1 year after injury, although Baranoski and Ayello (2016) suggest that the maturation phase starts as early as 7 days. In general, I prefer to remember the phases of healing in simple five-day sequences. This is easier to remember and assists us in assessing the progression of the healing processes.

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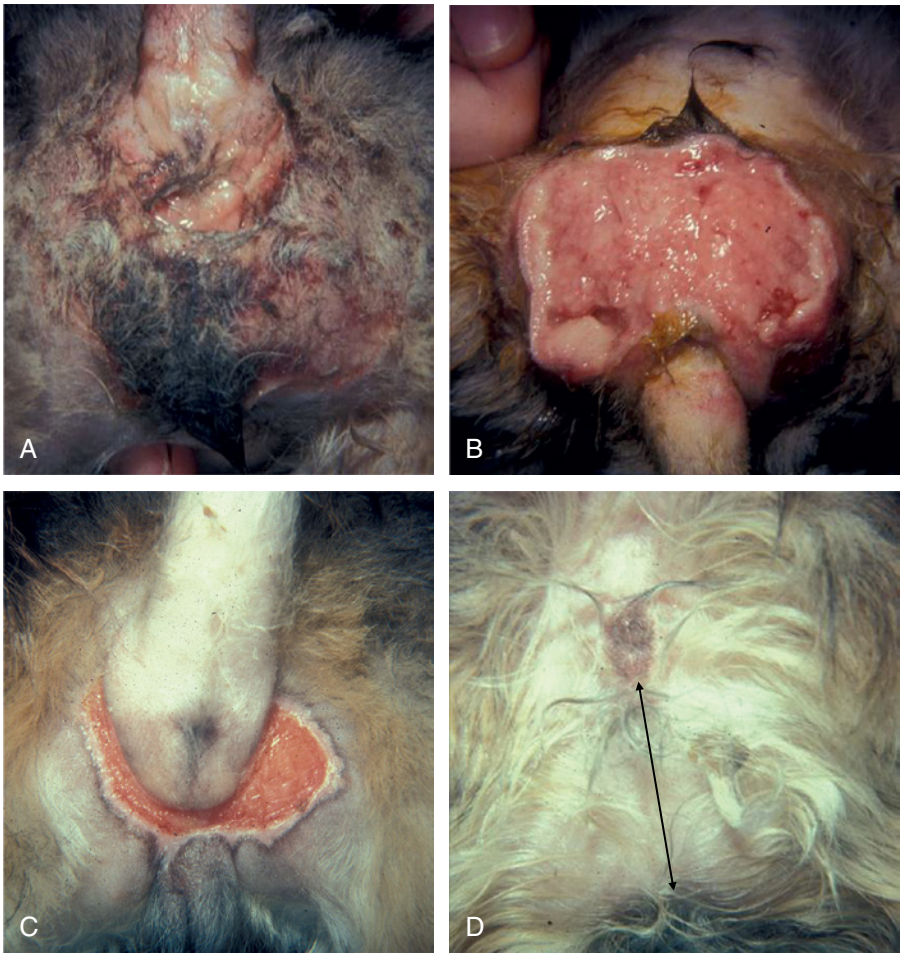


FIG. 2-5 (A) Perineal slough in a 9-week-old shih tzu following its first vaccination. The exact cause of the slough was unknown. (B) The necrotic skin was resected (patient in dorsal recumbency). (C) The wound rapidly contracted in a 3-week period. Note that epithelialization is minimal. (D) Female litter mate. The arrow denotes the relative distance between the anus and vulva. The process of wound contraction resulted in the upward displacement of the vulva. This finding was of no clinical consequence and the shih tzu completely recovered.

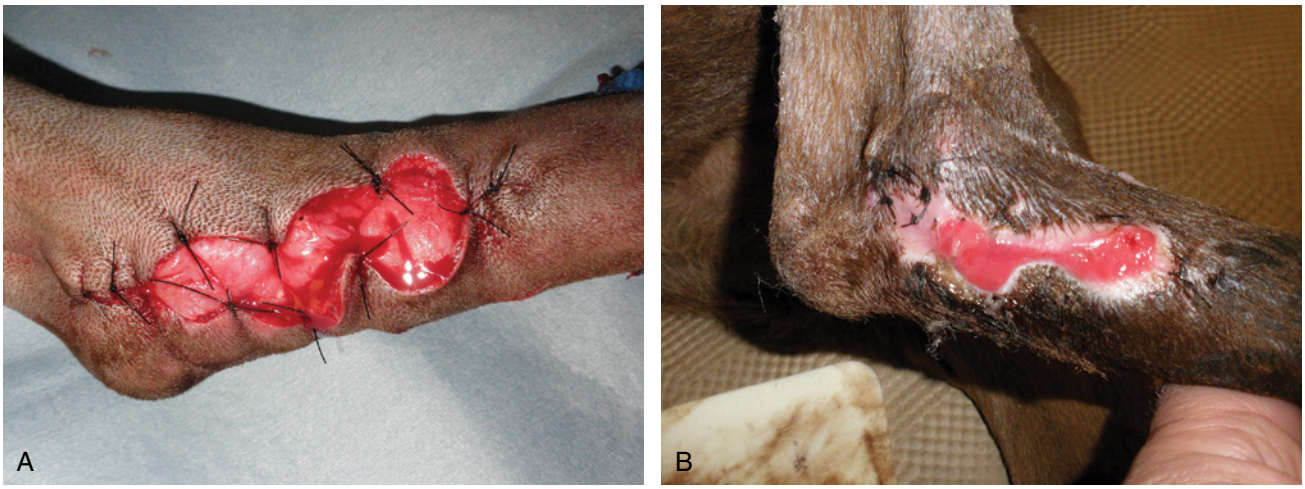


FIG. 2-6 (A) Resection of a granulomatous lesion involving the lateral right tarsal–metatarsal area. Neither primary closure nor the use of a transposition flap was feasible. The cutaneous margins were sutured to the fascia to reduce the gap (magnitude) of the defect. This reduces the surface area of the wound to facilitate healing by second intention. (B) Approximately 3 weeks later. Note the wound has contracted significantly. Epithelial cell migration is further reducing the defect along the perimeter of the granulation tissue.

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Five-Day Sequencing

It is simple to remember the "relative" time frames of wound healing by considering the phases as sequences: inflammatory phase, 5 days; proliferative phase, 5–20 days; maturation phase, 20–365 days. (In reality, phases of healing are a continuum.)

As noted, chronic, nonhealing wounds develop a fibrotic matrix highlighted by collagen deposition and a decline in the capillary population. Chronic wound beds usually lack the vascularity to support epithelialization or the application of a skin graft. Tangential excision of the chronic granulation bed down to the otherwise healthy underlying tissue plane can induce formation of a healthy vascular granulation bed. In less than 1 week, the reconstituted granulation bed usually is able to support free graft application.

A common misconception of veterinarians is that healing is largely complete at the time of suture removal. In fact, the maturation phase of healing takes months (12 months estimated) as both the collagen and the capillary circulation remodel. Tensile strength increases as collagen forms a structurally superior weave; collagen bundles thicken with increasing cross-linkage.

Problematic wounds including skin ulcers overlying the olecranon (see Chapter 7) are best protected into the maturation phase, where vascular and collagen remodeling are better able to sustain the daily stresses to this susceptible cutaneous area.

It also must be noted that, over time, the capillary population declines as vascular channels mature. The fibroblast population also declines as a result of apoptosis. This presents a problem in chronic wounds that have failed to heal in a timely fashion. Chronic wounds are discussed in Chapter 6.

ACUTE VERSUS CHRONIC OPEN WOUNDS

The term "chronic wound" suggests a wound that fails to heal in a normal, orderly, and timely fashion as expected of similar wounds. These are the *open wounds* that veterinarians find the most vexing to manage. In chronic wounds the proteolytic environment can degrade the growth factors required to promote wound healing. The increase in MMP activity degrades the ECM, inhibiting cell migration and collagen deposition. The application of human recombinant variants of PDGF-BB has been noted to promote healing in some chronic diabetic wounds in humans.

Veterinarians are often confused as to why certain wounds, expected to heal by second intention, fail to do so. Conditions influencing healing are discussed in greater detail in Chapter 6.

Chapter 6 discusses chronic wounds, causes, and closure options in greater detail. In general, there are a number of micro-environmental factors that may impair the healing processes in open wounds.

SPECIES VARIATIONS IN WOUND HEALING

Differences in anatomy and the circulation to the skin have been well recognized both in mammals and in other species. Variations in wound healing also can be expected. One study in cats indicated that formation of granulation tissue is slower compared with dogs (7.5 days in dogs versus 19 days in cats). Granulation tissue appeared to originate from the entire wound bed in dogs, whereas granulation tissue appeared to develop along the wound border and progressively advance over the wound in a centripetal fashion in cats. Overall, the development of granulation tissue, wound contraction, and epithelial cell migration in cats lagged behind dogs. Wound epithelialization and total healing were greater for the dog than the cat over a 21-day period. Wound contraction was greater in dogs than cats at day 7, but not at days 14–21. As a result, the tensile strength of feline incisions was substantially less (approximately 50%) than canine subjects in this study. Furthermore, removal of the subcutaneous tissues at wound closure may slow the processes of healing, especially in cats. Due to the limitations of this study, additional research is required to explain these physiologic differences in healing.

As discussed, when there is a concern regarding completeness in wound healing, skin sutures can be retained well beyond the time at which sutures are normally removed. Prolonged retention of skin sutures can result in more prominent suture scars, which is not a major concern in fur-bearing animals. Intradermal skin sutures can provide supplemental support to skin closures and significantly reduce the risk of wound dehiscence after external skin sutures are removed.

ARTIFICIAL SKIN AND SKIN SUBSTITUTES

Replacement of significant skin loss in clinical veterinary practice largely revolves around the use of free grafts, skin flaps, and skin stretchers. In extensive burns, *in vitro* cultivation of autogenous epidermal keratinocytes has been performed successfully in humans, with one report in a dog. Although research continues to try to develop an effective skin substitute, there is no currently available *complete skin substitute*.

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Research in skin replacement basically focuses on developing (1) a temporary wound dressing to cover major wounds (usually thermal wounds) and (2) a viable dermal substitute that can be incorporated into the healing process. Various materials are used to create the semblance of a dermal scaffold; with capillary ingrowth, the dermal replacement may provide a superior surface for accepting an epidermal cover compared to a granulation bed alone.

Clinically, the only epithelial cells that can survive are autologous epidermal cells. Autologous grafts can be in the form of a thin split-thickness skin graft or by applying a layer of harvested epidermal cells. In veterinary medicine, applying an epidermal cover to a healthy granulation bed remains a practical option in most cases.

Skin substitutes may be biologic, synthetic, or biosynthetic materials. They are currently utilized as a temporary or permanent solution to problematic skin loss in humans, especially for extensive burns. The elements of skin substitutes may help prevent infection and reduce further trauma to the wound. Ideally, there will be a reasonable cosmetic and functional outcome.

Composite skin substitutes, in the form of allografts (same species) or xenografts (from one species to another dissimilar species), can be applied as a temporary cover to problematic open wounds. They may be used as a dressing to promote healing by second intention or as a means of protecting a wound in the preparation for permanent wound closure using autologous skin grafts or flaps. Other temporary biologic dressings include the use of placental substitutes, including human chorionic or amniotic membranes for wound coverage, especially for partial-thickness burns in humans.

Skin substitutes may be permanent, semi-permanent, or temporary. Based on anatomic structure they can be classified as epidermal, dermal, or dermoepidermal (composite) skin replacements. Further classification includes the biomaterial used: autologous, allogenic, xenogenic, or synthetic (biodegradable or nonbiodegradable).

Commercially available skin substitutes include xenografts, synthetic bilayers, acellular allografts, allogeneic living epidermal substitutes, allogeneic dermal substitutes, composite allografts, and autologous cultured skin grafts. Commonly used acellular synthetic skin substitutes in humans include Biobrane® (UDL Laboratories, Inc., Rockford, IL), Dermagraft® (Organogenesis, Inc., Canton, MA), Integra® (Integra LifeSciences Corp., Plainsboro, NJ), AlloDerm® (Biohorizons Implant Systems, Inc., Birmingham, AL), and TransCyte (Shire Regenerative Medicine, Inc., San Diego, CA). They include a nylon mesh or collagen dermal substitute and an outer silicone membrane.

Natural cellular skin substitutes are primarily cultured allogenic or autologous cell suspensions or sheets of cultured keratinocytes. Commonly used natural skin substitutes with allogenic cells include Dermagraft and Apligraf® (Organogenesis, Inc.). Cellular allogenic skin substitutes are normally produced using living neonatal foreskin fibroblasts incorporated in a mesh or matrix.

In contrast, Epicel® (Vericel Corp., Cambridge, MA) utilizes the inclusion of autologous cells. Allogenic substitutes provide temporary coverage whereas autologous skin substitutes are capable of providing permanent coverage. There are two types of autologous skin substitutes available: cultured epidermal autograft (CEA) and cultured skin substitute (CSS). CSS has both epidermal and dermal components. The use of CEA and CSS is costly. It was estimated that coverage of 1% of the body surface area in humans with Epicel would cost more than $13,000.

A novel method of covering large surface areas with autologous epithelial cells is the RECELL® System (Avita Medical, Inc., Valencia, CA), in which a harvested segment of skin is processed into an autologous skin cell suspension that is sprayed onto a vascularized wound surface. Although not a skin substitute per se, it could be combined with a vascularized dermal substitute. There is one case in the veterinary literature employing RECELL in a dog with large full-thickness skin defects to epithelialize the dorsal cutaneous defect.

The xenograft skin substitutes commercially available comprise porcine dermal or bovine type I collagen with elastin for temporary wound coverage. The exogenous collagen may be chemotactic for macrophages and fibroblasts, while providing a matrix for the ingrowth of the surrounding tissue margins. This ECM may reduce the metalloproteinases known to inhibit wound repair in chronic nonhealing wounds. Xenografts are absorbed as the wound heals, making them potentially useful for wound healing by second intention, and can be used as a temporary wound cover in preparation for free graft application.

The use of an autologous skin substitute for deep wounds in dogs was reported to be feasible in one study. However, the routine clinical use of commercially available skin substitutes in veterinary surgery, exclusive of their overall high cost, would be considered infrequent at this time. Importantly, dogs and cats have a considerable surface area of skin, allowing the veterinarian to close most of the more daunting wounds with the use of local skin flaps, axial pattern flaps, skin grafts, and wound closure facilitated by skin stretchers.

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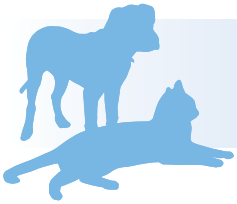
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3

Basic Principles of Wound Management

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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INTRODUCTION

The most basic principles of wound management have not significantly wavered from those advocated by Esmarch and Halsted decades ago (Tables 3-1 and 3-2). Although many of the wounds seen by the clinician are not life-threatening, proper assessment and management of the wounds will have a significant impact on their outcome. Many smaller wounds can heal despite the misguided efforts of uninterested clinicians. Careless wound management of more serious injuries can promote multiple wound complications, including tissue necrosis, infection, and wound dehiscence. More importantly, further trauma by the veterinarian may be the "death blow" to a body region already suffering from circulatory compromise secondary to disease or injury. The tissue death that follows may result in the need to amputate an affected limb, precipitate the need for costly treatments, or result in the death of the animal (Fig. 3-1).

Consistently successful results in wound management require practice, attention to small details, and adherence to the basic principles of wound care.

PATIENT PRESENTATION

When a traumatized patient is first presented to the surgeon-practitioner, a complete medical history must be obtained, including specific details pertaining to the cause of the injuries. A detailed physical examination is performed on all patients. Patients with minor trauma require no emergency treatment on presentation.

TABLE 3-1 Halsted's principles of surgery.

A. Minimal surgical trauma (gentle tissue handling)
B. Accurate hemostasis
C. Preservation of an adequate blood supply
D. Aseptic surgical technique
E. No tension on tissues
F. Careful tissue approximation
G. Obliteration of dead space

TABLE 3-2 Esmarch's principles of wound management.

A. No introduction of anything harmful
B. Tissue rest
C. Wound drainage
D. Avoidance of venous stasis
E. Cleanliness



FIG. 3-1 Shar-pei with massive facial injury secondary to vehicular trauma. Despite the shearing wound to the face, the excellent blood supply to the head maintained tissue viability. Atraumatic surgical technique is important to minimize further circulatory compromise to these traumatized tissues.

Patients that present with severe trauma are best managed with a simultaneous team approach employing the critical care, surgical, and radiology staff. Assessment of the critical care patient's airway, breathing, and circulatory status is performed as supportive care is instituted, including the insertion of one or more intravenous catheters. Collection of samples to determine the baseline complete blood count, serum chemistry profile, and urinalysis should be considered for each patient. Subsequent or serial reassessments are predicated on a patient's intraoperative and postoperative status.

Some injuries may require immediate emergency surgery following initial efforts to stabilize the patient. For unstable patients with nonthreatening open wounds, basic wound care and bandage application can suffice until definitive wound exploration and closure can be attempted. Analgesics and sedation should be considered, provided that medication does not impair the ability to fully assess the critical patient. In general, analgesics and/or sedation should be initiated as soon as patient assessment is complete. Specific details on wound care are discussed later in this chapter.

MECHANISMS OF INJURY AND WOUND TERMINOLOGY

In humans, three basic forces have been described that result in injury to the skin: *shearing*, *tension*, and *compression*. Shearing injuries are the result of sharp objects, including knives, glass, and other cutting surfaces.

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Because energy is dispersed along a more finite area, minimal tissue destruction may be noted. Tension injuries arise from the tangential or angular impact from a blunt or semi-blunt object or surface. The skin is under tension at the point of impact and the skin splits. Partial avulsion of skin or traumatic flap formation may be noted. Large avulsion wounds often result in the tearing of regional circulation; a variable degree of tissue necrosis should be anticipated. Compression injuries occur when an object or surface strikes the skin at a right angle, resulting in a ragged edge to the skin. The effects of tissue compression or crushing may result in significant circulatory compromise to the area, with an increased risk of necrosis and infection. Bite wounds, for example, may have compression and tension forces applied to regional tissues. Circulatory compromise and tissue necrosis, combined with the introduction of oral bacterial flora, are an invitation to infection.

There are several terms generally used to describe specific wounds (Table 3-3). They are useful for accurately describing this subset of injuries commonly seen in small animal practice.

TABLE 3-3 Descriptive terminology in wound management.

Abrasion Skin wounds caused by tangential trauma to the epidermis and dermis Skin is rubbed against a resistant surface in a rubbing or scraping fashion *Note:* minor abrasions to the skin also may be noted with removal of an adhesive agent (adherent bandage, surgical adhesive, etc.)
Avulsion *Complete avulsion*: complete displacement or tearing of a tissue segment or portion of the body *Partial avulsion*: partial detachment of a tissue segment or portion of the body (for example, traumatic skin flap) *Degloving injury*: traumatic partial avulsion of skin from an extremity in a circumferential fashion, resembling the peeling off or removal of a glove
Incision A cut of orderly depth with a sharp instrument
Laceration An irregular cut of nonorderly depth; a jagged wound or cut
Puncture wound A hole or wound created by a sharp-pointed object *Penetrating wound*: a puncture wound in which the object enters a given tissue plane or structure but does not emerge beyond it *Perforating wound*: a puncture wound in which the object enters and exits a given tissue plane or structure (a "through-and-through" wound to the involved tissue plane or structure)
Contusion (bruise) An injury in which the skin is not broken, usually exemplified by swelling, pain, and discoloration (capillary rupture with escape of blood)

WOUND CLASSIFICATION

Four Basic Wound Classifications

The surgeon is faced with a variety of issues when managing an open wound. Clearly, the severity of tissue trauma, degree of contamination, and presence of or potential for infection are factors in determining the most appropriate wound care. The intraoperative assessment of the wound after exploration, debridement, and lavage is the best time to determine whether wound closure should be attempted now or at a later time.

Thorough debridement of necrotic tissue and cleansing—lavage to remove contaminants—may convert a contaminated wound to a surgically clean wound that is suitable for primary closure.

From the information gathered from the history and physical examination, a wound can be classified into one of four basic categories according to its condition. These four categories or classes, in increasing order of severity, are the following:

- Class I: Clean
- Class II: Clean–contaminated
- Class III: Contaminated
- Class IV: Dirty and infected

It is occasionally difficult to accurately select the exact category based on gross assessment of the degree of contamination and the time that transpired after injury. When in doubt, it is best to downgrade the wound's classification and treat it accordingly. Clean, clean–contaminated, and contaminated wounds would generally be considered to have fewer than 100,000 bacteria per gram of tissue. Because bacterial counts increase for every hour of neglect, early intervention can reduce the likelihood of infection. (See the section Age of the Wound: Clinical Significance.)

Research has indicated that bacteria can proliferate from 100 organisms per gram of tissue to over 100,000 organisms per gram within 6 hours. The virulence and population of the bacteria present will have a major impact on the development of infection. (See Infection and Biofilm Formation in Chapter 6.)

The basic question on the mind of the doctor is the following: Can I close the wound primarily or should the wound be managed as an open wound for a variable period of time? Wound classifications are a useful guideline for determining how a given wound is best managed. Selection of the most appropriate method of closure is best determined after definitive wound exploration and initial management of the wound.

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Clean Wounds

A clean wound is a nontraumatic, uninfected operative wound in which neither the oropharyngeal cavities nor the respiratory, alimentary, or genitourinary tracts are entered. Clean wounds are made under aseptic conditions. They are usually primarily closed (Fig. 3-2).

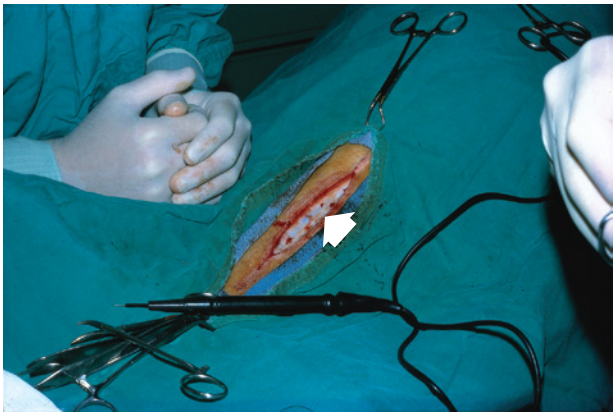


FIG. 3-2 A clean wound (arrow) is one created under sterile surgical conditions.

Clean–Contaminated Wounds

Clean–contaminated wounds are operative wounds in which the respiratory, alimentary, or genitourinary tract is entered without unusual contamination. Wounds with minor contamination or a clean wound with a "minor" break in sterile surgical technique may be classified in this category (Fig. 3-3). Properly managed, these are usually closed primarily.

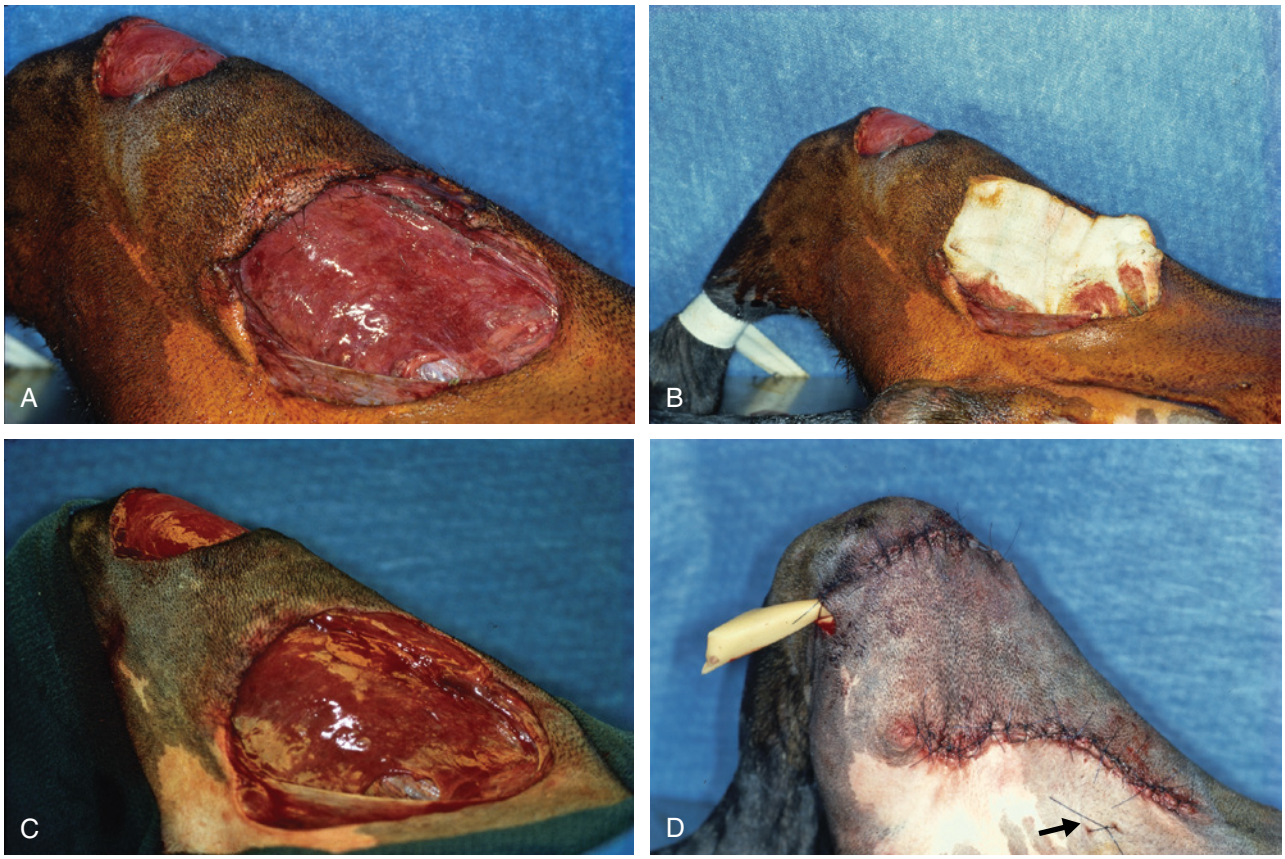


FIG. 3-3 (A) Example of a clean–contaminated wound. This pit bull presented shortly after lacerating the skin of his inner thigh and knee while leaping over a cyclone fence. Minimal contamination was evident in this fresh wound. (B) The wound was protected with a sterile, moistened saline gauze pack prior to the liberal removal of fur and surgical preparation. (C) Damaged and devitalized tissue was excised on removal of the gauze sponges. The wounds were lavaged under pressure with sterile saline. (D) The wound was closed primarily; a Penrose drain was used to control dead space and prevent serum accumulation. Note that only the distal portion of the drain is exposed. The proximal end is secured with a single suture placed through the skin (arrow).

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Clean–contaminated wounds generally are considered a wound less than 6 hours old and can be subclassified as Class 1 wounds. Some articles subdivide contaminated wounds into wounds 6–12 hours old (Class 2) and greater than 12 hours old (Class 3). However, time itself is not an accurate guideline in determining the classification of a given wound and the appropriate method of closure. In many cases, the veterinarian may have no knowledge of the exact age of the wound.

Contaminated Wounds

Contaminated wounds include open traumatic wounds, wounds made in operations during which there was a major break in sterile technique, and incision wounds made in areas of acute, nonpurulent inflammation or made in or near contaminated or inflamed skin. Unless the procedure is performed without a breach in sterile surgical technique, wounds made for access to the lumen of the colon may belong in this category (Fig. 3-4).Unless properly prepared intraoperatively, a variable degree of open wound management is normally indicated.

Dirty and Infected Wounds

Dirty and infected wounds include old traumatic wounds and those involving clinical infection or perforated viscera. The definition of this classification suggests that greater than 100,000 organisms per gram of tissue are present in the wound before the operation, or that pus has contaminated the wound (Fig. 3-5). A variable degree of open wound management is normally indicated.

Age of the Wound: Clinical Significance

Many pet owners have no exact knowledge of the time a given injury occurred, especially in those unsupervised animals allowed to roam outdoors for extended periods of time. In those cases, the clinician must rely on his/her clinical assessment of the patient to determine the best method to manage the open wound.

Historically, the time frame of less than 6 hours has been referred to as the "golden period" of wound healing in the literature: the bacterial inoculum is likely to be below the threshold of infection ($<10^6$ per gram of tissue). Intervention within this grace period can reduce the risk of establishing infection.

There are a variety of factors that influence the risk of infection. Surgeons experienced in wound management know that the severity of wound contamination, body region involved, presence of necrotic tissue, and circulatory compromise are greater considerations than time, both in classifying a wound and in selecting the appropriate method of closure.

To reduce the likelihood of wound infection, early medical and surgical intervention is preferable to unnecessary delays in open wound management, especially in potentially life-threatening wounds.

The body region involved in the injury also impacts whether primary closure or delayed closure options should be considered. For example, the head has a superior blood supply compared with the distal extremities. Primary closure may be a suitable option for many older head wounds, whereas a similar wound involving the lower extremities may be better suited to open wound management for a variable period of time before wound closure is contemplated.

Any wound (regardless of the time of injury) after aggressive cleansing, irrigation, and debridement can be considered for primary closure if:

- All devitalized tissue is removed
- All contaminants and debris are removed
- The tissues appear healthy with a viable circulation
- There is no evidence of infection

When assessing a wound, it can be difficult to differentiate which category it belongs in for purposes of treatment. Under these circumstances downgrade the wound and treat it as the worst of the two categories.

OPTIONS FOR WOUND CLOSURE

Classification of a wound will enable the clinician to logically decide on the proper method of management. For a given wound, there may be more than one option to achieve closure. The four basic options for closure of an open wound are:

- Primary closure
- Delayed primary closure
- Secondary closure
- Healing by second intention

A variation of second-intention healing is adnexal reepithelialization of partial-thickness skin losses. The choice among these four basic methods of closure depends on the wound size, location, and condition. Two key factors stand out as major reasons to avoid primary closure in favor of open wound management: (1) the presence of dying or devitalized tissue or extensive contamination, and (2) the presence or high probability of infection.

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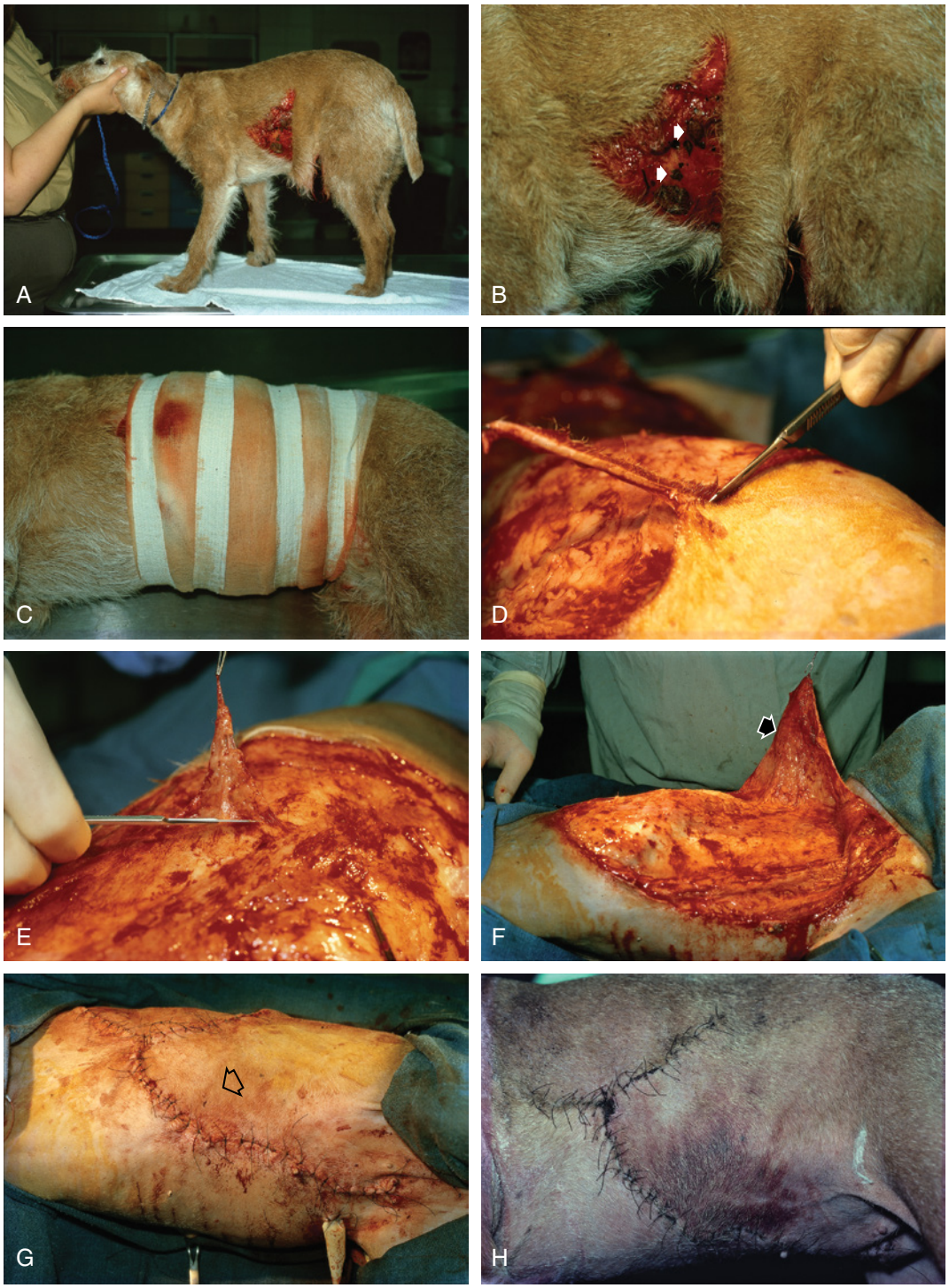


FIG. 3-4 (A) Example of a contaminated wound involving the lateral thorax and abdomen. The skin was avulsed when it was hooked on a metallic object as the dog was running. (B) The avulsion wound involving this dog's lateral thorax and abdomen was contaminated with bark and dried leaves adhered to the exposed subcutaneous tissues (arrows). (C) A sterile wet (saline–chlorhexidine) dressing was temporarily applied to the wound prior to anesthetic induction. (D) Irregular skin edges were excised to facilitate closure. Although it is desirable to note vigorous bleeding to the cut skin edge, the presence or lack of bleeding is not consistently accurate in determining skin viability at the time of surgery. More aggressive skin excision can be performed when ample loose skin is present to facilitate closure. (E) Contaminated subcutaneous fat overlying the skeletal muscle was excised tangentially. (F) Debridement was followed by copious pressure lavage. Contaminants that adhered to the partially avulsed skin segment (arrow) were carefully removed with forceps in order to avoid further circulatory compromise. The avulsed skin flap was partially debrided back to a bleeding skin margin, providing sufficient skin for surgical closure. (G) Primary closure of this contaminated wound was successfully accomplished after prompt surgical intervention and attention to thorough removal of contaminants and necrotic tissue. A Penrose drain was used in this case; a closed suction unit would have been more appropriate to control this wide area of dead space. (H) Healed wound. The thin skin of the lower abdomen readily shows subcutaneous hemorrhage.

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FIG. 3-5 (A) Example of an infected wound. A bacterial infection with necrotic skin was the result of bite wounds improperly managed 4 days prior to presentation. (B) Wound debridement of the necrotic skin and subcutis. (C) Wet-to-dry dressings, changed twice daily, were used to mechanically debride residual necrotic tissue for 3 days. This was followed by the topical application of an enzymatic debriding agent (trypsin). (D) Six days following surgical debridement, a healthy granulation bed has formed. (E) Because the owner had no desire to manage the wound at home, secondary closure was performed. Portions of the granulation bed and fibrotic skin borders were excised to facilitate accurate skin apposition with sutures. A Penrose drain exits ventral to the wound. Healing proceeded without incident.

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Primary Closure

Primary closure or healing by first intention is the direct closure of a recently created wound. Surgical wounds and recent traumatic injuries usually fall into this category. Wounds considered for primary closure include the following:

- Wounds with little or no contamination and minimal tissue trauma
- Contaminated wounds converted to "clean" wounds with judicious debridement and copious lavage with sterile isotonic solutions (Fig. 3-4)
- Skin defects after complete excision of smaller, localized areas of contamination and infection
- Adjacent skin available to close the wound without undue tension (see Chapter 9, Tension-Relieving Techniques; Chapter 11, Local Flaps)

Delayed Primary Closure

As the term implies, wound closure is delayed for a 3–5-day period in order to manage and reassess the wound during daily bandage changes. This option is selected when the surgeon feels that a wound, after initial surgical/medical management, appears to contain tissue of questionable viability and vascular compromise, residual contaminants, or possible infection. Under these circumstances, it is best to manage the wound and inspect its condition on a day-to-day basis. Sterile dressings/topical agents are inserted into the wound cavity and are normally changed once a day, depending on the condition of the wound. Delayed closure provides optimal drainage to the area and time for inflammation to subside and circulation to improve before closure. Consequently, tissue resistance to infection improves dramatically, thereby reducing the likelihood of infection after closure. In summary, common wounds considered for delayed primary closure include the following:

- Wounds with borderline contamination despite initial wound exploration, debridement, and lavage
- Wounds with moderate tissue trauma or considered at risk of infection after wound exploration, debridement, and lavage
- Wounds in which there is a question as to the tissue viability at the wound site
- Wounds that require additional (serial) debridement beyond initial wound cleansing and debridement
- Wounds in which significant tissue swelling precludes primary closure

By day 4–5 after injury, capillary buds, fibroplasia, tissue macrophages, and associated cytokines are present within the wound. As a result, tissues are more resistant to infection at this time. If the tissues are viable, and swelling has declined without evidence of infection, successful closure is likely (Fig. 3-6).

Secondary Closure

On occasion a wound is not suitable for delayed primary closure and open wound care is extended until a healthy granulation bed covers the surface of the wound. As noted in Chapter 2, granulation tissue is a positive indicator that the exposed tissues are viable; as a result, the damaged tissues are able to form vascular granulation tissue. Secondary closure is attempted between the fifth and tenth days after injury. By this point, a healthy granulation bed normally is developing over the open wound surface.

Secondary closure is reserved for problematic wounds in which:

- Delayed primary closure is not possible, usually as a result of persistent infection
- Persistence of necrotic tissue requires additional serial debridement and wound care beyond 5 days
- There is persistence of a moderate to severe inflammatory response

Secondary closure can be attempted by one of two methods: (1) direct suture apposition of the two granulation surfaces (healing by third intention) or (2) granulation tissue excision and primary closure. The latter technique is preferred by many surgeons for humans because of the relative ease in mobilization of the wound edges for closure, the better cosmetic results, and the lower incidence of infection after excision of the granulation tissue (Fig. 3-5). The author uses a combination of both variations by removing sufficient scar tissue to facilitate closure of the defect. Complete excision of a healthy granulation bed generally is unnecessary.

"Healing by second intention" is sometimes called "healing by secondary intention." This is easy to confuse with the term "secondary closure" because of the inclusion of "secondary," but these two methods of managing wounds are different.

Second(ary)-Intention Healing: Contraction and Epithelialization

Healing by second intention (healing by contraction and epithelialization) is a commonly employed method to close problematic wounds in veterinary medicine. With appropriate management, the processes of myofibroblastic

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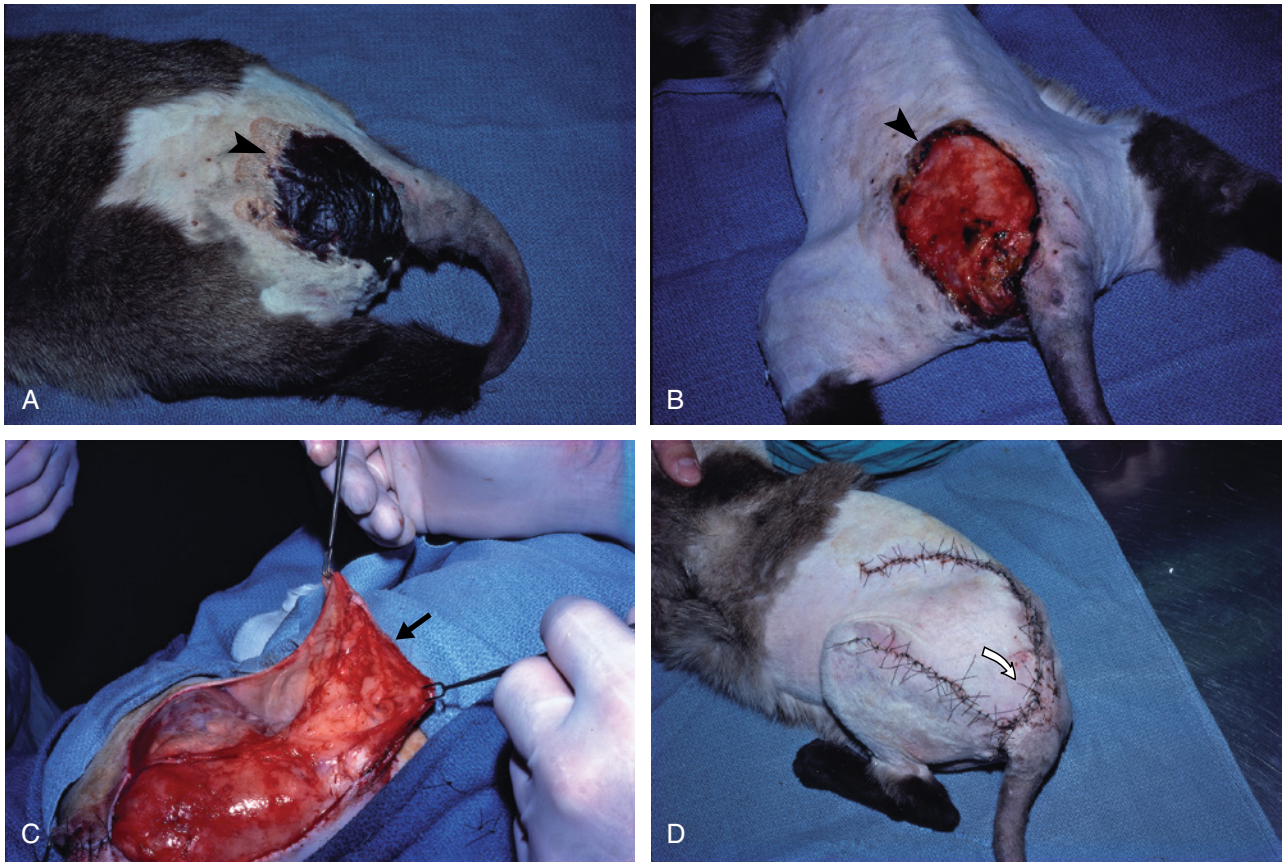


FIG. 3-6 (A) Delayed primary closure of a burn. This thermal wound was sustained when the cat contacted an automobile muffler. (B) The burn eschar was excised and the wound treated with topical medicated wet dressings to facilitate debridement. (C) A transposition flap was elevated on day 4 from the lateral abdominal wall prior to its placement (arrow) on the recipient bed. (D) The flap was rotated (arrow) and sutured into the wound bed. (Source: Pavletic MM. 1993. Surgery of skin and management of wounds. In Sherding RG, ed. *The Cat: Disease and Clinical Management*, 2nd ed. New York: Churchill Livingstone. Reproduced with permission from Churchill Livingstone.)

wound contraction and epithelial cell migration over the external surface of granulation tissue are promoted (see Chapter 2). Second-intention healing is generally reserved for the following wounds:

- Dirty and infected wounds in which closure by the previous three techniques is inadvisable
- Cutaneous defects that cannot be closed adequately using conventional surgical techniques. This is particularly true for skin defects located in areas lacking a source of loose elastic skin to facilitate primary closure (mid to lower extremities, tail wounds, large trunk wounds, etc.)
- Defects whose closure under tension likely will result in dehiscence
- Defects where closure may create a "biologic tourniquet effect," compromising circulation distal to the closure
- Wounds that would benefit from surgical closure but could heal by second intention. In many cases, financial constraints preclude surgery in favor of open wound management until contraction and epithelialization are complete.

Many moderate to large trunk wounds in puppies and kittens have a remarkable ability to heal by second intention.

Wound contraction can be used initially to reduce the size of a problematic wound that has the possibility of closing in part by this process. Any portion of the wound remaining after contraction peaks can be closed with a smaller skin graft or flap. As a result, a simpler and more economical surgical closure can be implemented.

Skin tension around a wound (inherent elasticity of the skin) can be assessed by manually pushing the wound border to determine the degree of laxity required for wound contraction to occur unimpeded. If sufficient peripheral skin laxity is present, unimpeded wound contraction can be expected in many cases. Otherwise, epithelialization must cover the remaining deficit once

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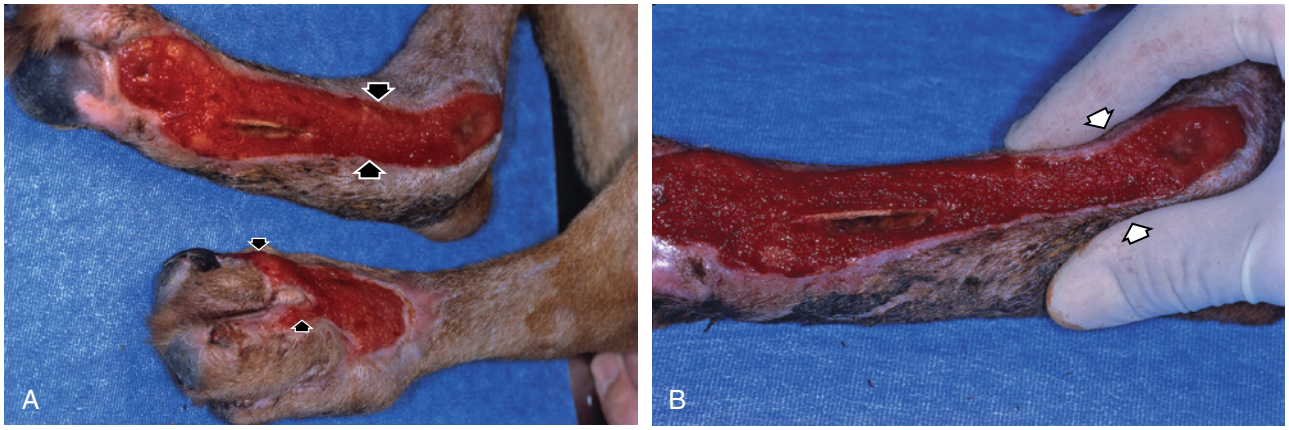


FIG. 3-7 (A) Full-thickness skin loss sustained in an automobile accident. A healthy granulation bed has formed. Edema has subsided, allowing for assessment of peripheral skin tension. Narrow areas of the wound bed (arrows) are expected to epithelialize and contract rapidly; the widest area of the wound will be the last to heal. (B) Gently grasping the wound borders and displacing skin toward the central defect indicates that sufficient skin laxity is present to promote wound contraction. Epithelialization will cover the remaining portions of the wound.

contraction ceases (Fig. 3-7). This may be an impossible task in large defects.

The clinical question "Can this wound heal by second intention?" can be partially answered by assessing the skin tension (inherent skin elasticity) bordering the defect. As will be discussed in Chapter 6, Common Complications in Wound Healing, a lack of mobile skin can effectively neutralize the centripetal force exerted on the skin by myofibroblastic contraction. This is particularly evident when assessing moderate-sized defects involving the lower extremities. As previously noted, skin tension is best assessed only after tissue swelling subsides. (Edema separates the dermal collagen and elastin fibers. The collagen and elastin fibers also retract away from the wound, exaggerating the magnitude of the skin defect in the early days of injury.)

Distal extremity defects with loss of 25% of the circumference of the skin are likely to heal by second intention. As the skin loss approaches half the circumference (or beyond), contraction and epithelialization are unlikely to succeed. Skin grafting usually is the best closure option under these circumstances.

Skin tension around the wound can be determined by lifting or pushing the local skin toward the center of the defect. If the opposing skin edges can be compressed into the defect, a variable degree of wound contraction is likely to occur. In irregularly shaped wounds, narrower areas are likely to heal by second intention before the widest part of the wound defect.

Experimentally, wound contraction normally slows 42 days (6 weeks) after injury. Contraction takes place at a rate of 0.6–0.7 mm/day, unrelated to the size of the wound in one study. Epithelial cell migration must cover the remaining open wound at this point, unless surgical intervention is considered (see Chapter 2).

In fur-bearing animals, wound contraction is more important in healing by second intention than the process of epithelialization in moderate to large wounds. The centripetal advancement of full-thickness skin provides a superior cosmetic result compared to a wide, hairless epithelialized scar.

In many cases, second-intention healing is a practical and economical method of effecting closure, provided that adequate wound care is administered. There are cases, however, where healing is prolonged and the attendant costs of hospital visits, bandage materials, and topical medications meet or exceed the cost of surgical closure.

Not all wounds expected to heal by second intention will close in optimal fashion. Wounds that heal primarily by epithelialization will have a larger hairless scar compared to those defects that close primarily by myofibroblastic contraction. Fragile epithelialized scars exposed to mild external trauma may abrade or split. As noted in Chapter 2, excessive scarring or contraction resulting in restricted motion to a limb or other body region is called wound contracture (see also Chapter 6). Cosmetic and functional results may be unsatisfactory.

Studies by Bohling et al. (2004, 2006) suggests that cutaneous wound healing proceeds more slowly in cats than in dogs. Slower gains in tensile strength and healing by second intention are also noted in cats when compared to dogs. The authors speculated that loss of

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subcutaneous tissues appears to retard healing in cats more than in dogs (see Chapter 2).

Surgical Relevance

Bohling et al. (2006) noted that the tensile strength of healing incisions in cats was approximately 50% less compared to dogs at 7 days. Granulation tissue appeared in dogs at 4.5 days versus 6.3 days in cats. Complete granulation tissue coverage of experimental wounds was 7.5 days in dogs compared to 19 days in cats. Removal of subcutaneous tissue reduced the rate of granulation tissue formation in both dogs and cats, but was most notable in cats. Epithelialization of the wounds was 44% coverage in dogs at 2 weeks versus 13% in cats.

It is important to note that second-intention healing can be used as a means of reducing the size of some problematic wounds that may not necessarily heal to completion. Wound contraction can direct regional elastic skin centripetally to reduce the size of a wound substantially. When contraction slows or stops, and epithelialization is not likely to close the remaining defect, surgical closure may be attempted. By delaying surgery, a smaller skin flap or skin graft may now be used, thereby reducing the cost associated with final closure. This technique is not used for closing large regional wounds that have little or no likelihood of partial closure by second-intention healing. In these more problematic cases, definitive surgical closure becomes the first choice for managing the wound.

Surgical Relevance

On occasion, the surgeon may elect to manage a problematic wound conservatively in order to determine whether the wound can substantially close by wound contraction. The majority of contraction occurs within the first 6 weeks following injury. Although healing may be incomplete and require surgical closure at this time, the surgeon is better able to deal with a smaller wound that may be closed more easily by a smaller skin graft or simpler flap technique.

Post-traumatic swelling is especially evident in distal extremity wounds. Swelling and elastic retraction of the cutaneous margins can exaggerate the width of the defect by approximately 25–30%. As edema subsides, the true magnitude of the wound can be determined.

Healing by Adnexal Reepithelialization

Not all wounds involve the entire thickness of the skin. Tangential loss of a portion of the skin layers may result in the partial loss of the epidermis or complete loss of the epidermis and a variable degree of dermal destruction. Examples of partial-thickness skin losses include the following:

- Superficial burns (first-degree burns)
- Partial-thickness burns (second-degree burns)
- Abrasions or scrapes of varying depth
- Chemical burns (including turpentine and other chemical irritants)
- Split-thickness skin graft donor site

Cutaneous burns and abrasions of the skin may be categorized as superficial, partial-thickness, or full-thickness according to the depth of injury (see Chapter 7). Superficial cutaneous loss includes loss of the epithelium but sparing of the germinal layer. Reepithelialization originates from this surviving epithelial layer. A partial-thickness loss results in the loss of the entire epithelial surface and a variable portion of the dermis. In this case, surviving adnexal structures (hair follicles, sebaceous glands, sweat glands) located in the remaining dermis and subcutaneous tissue are the source of epithelial cells for healing (see Chapter 2). The donor site from which a split-thickness graft is harvested will heal as a partial-thickness wound. Similarly, the donor site has the advantage of minimal tissue injury because the wound is made under aseptic conditions with minimal trauma. One must remember that any partial-thickness injury may be converted to a full-thickness loss by infection or improper wound management (Fig. 3-8).

POINTERS IN SELECTING THE PROPER CLOSURE TECHNIQUE

Clean wounds and wounds with minimal surface contamination are natural candidates for primary closure, provided that sufficient skin is available. Most lightly contaminated wounds with minor tissue necrosis can be closed primarily after single-stage debridement and wound lavage.

Local skin flaps or tension-relieving techniques may be used to close wounds where incisional tension may be problematic. If edema and contusions are evident, delayed primary closure may be advisable, allowing time for the circulation and lymphatic drainage to improve in this 4–5-day period.

Small contaminated or infected wounds can be completely excised and the area closed primarily. This is a useful technique for wounds located in body regions with sufficient skin laxity to facilitate "en bloc" resection of the area.

The most important factor in determining the best method of closure is the final assessment of the wound after proper exploration, debridement, and copious pressure lavage of

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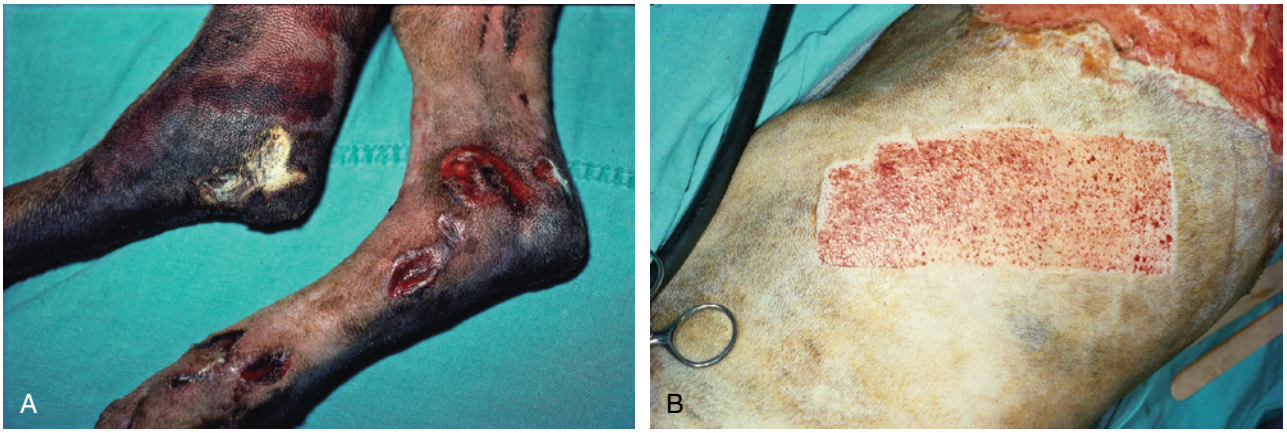


FIG. 3-8 (A) Partial-thickness abrasions to the lower extremities of a Doberman secondary to being struck by an automobile. Partial- and full-thickness skin wounds are evident. (B) Donor site after harvesting a split-thickness skin graft. This partial-thickness wound will heal readily by adnexal reepithelialization.

the wound. Many of the larger grossly contaminated and infected wounds are not difficult to assess: the poor state of the regional tissues clearly precludes primary closure. Whether the wound can be handled by delayed primary closure, secondary closure, or healing by second intention is determined as wound management progresses.

Those wounds that require closer assessment are grossly contaminated wounds. Infection may not be evident, but contamination with grit, dirt, and organic matter has been present in the wound for a variable period of time. Close postoperative assessment for infection is necessary. If there are any reasonable doubts, the wound should be managed as an open wound (delayed primary closure, secondary closure, second-intention healing).

The surgeon must determine the probable viability of the tissues in the wound. If tissue survivability cannot be accurately assessed at this time, open wound management is advisable. Otherwise, aggressive debridement can be considered for those traumatized tissues considered expendable.

If small areas of necrotic tissue cannot be excised without causing unnecessary tissue injury, open wound management is again advisable. Serial (scalpel, scissors) or mechanical debridement (wet-to-dry dressings) techniques are used to remove necrotic tissue remnants, provided that significant collateral tissue trauma can be avoided. More selective forms of debridement (autolytic, enzymatic) are very useful once the bulk of necrotic tissue is removed. Selective debridement should be considered in wounds where delicate tissue structures may be otherwise damaged by surgical/mechanical debridement techniques. The presence of necrotic tissue is particularly problematic since the risk of infection increases. Timely removal of dead tissue can dramatically reduce the bacterial population in a wound. Moreover, necrotic tissue can significantly delay the healing process.

It is important to note that *secondary closure* (not *second(ary)-intention healing*) is the next step if delayed primary closure is not advisable. In turn, second-intention healing is the next option if secondary closure is not feasible. Surgical closure is considered for those cases in which contraction and epithelialization cannot close a wound effectively. Surgical intervention can be performed at the point at which there is an absence of infection and tissue viability is assured.

Granulation tissue is a natural barrier to invasive infection. Once granulation tissue covers the wound, systemic antibiotics normally can be eliminated in favor of topical antimicrobial agents. Exceptions to this general rule would include those patients with other underlying infections or health issues that require continued systemic antibiotic therapy.

> As noted, granulation tissue is a key indicator of tissue viability. Granulation tissue forms only from the viable vascularized tissues comprising the base and the margins of the wound. Its presence over the surface of the wound is the "surgeon's indicator" that necrotic tissue has been eliminated.

With partial-thickness skin wounds, gentle cleansing of the wounds with sterile saline/lactated Ringer's or a commercial wound cleansing agent (Chapter 4), followed by an appropriate topical dressing and topical agent, can support the epithelial remnants necessary for reepithelialization of the area. Depending on the depth of injury, this process usually occurs within 2–3 weeks after injury.

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However, the veterinarian may elect for excision and primary closure of small partial-thickness wounds when sufficient skin is present.

Most wound contaminants can be eliminated with debridement and pressure lavage (see Chapter 4). Complete tissue viability, the elimination of necrotic tissue, and the absence of infection are key points in determining whether early wound closure can be attempted. Wounds closed with the presence of necrotic tissue are candidates for infection, dehiscence, and drainage. Removal of dead tissue dramatically reduces the primary source of nutrition and shelter of bacteria. However, with the presence of infection at the time of intervention, open wound management for a variable period of time is the safest method to reduce or eliminate the risk of perpetuating an infection once final closure is attempted. Open wound management provides optimal drainage and allows the surgeon to inspect the wound daily.

BASIC WOUND MANAGEMENT IN SIX SIMPLE STEPS

Establishment of a healthy vascular wound bed, free of necrotic tissue and infection, allows the surgeon to consider all options for final wound closure. Initial management of open wounds can be summarized in six simple steps (see Fig. 3-4):

1. Prevent further wound contamination
2. Debride dead and dying tissue
3. Remove foreign debris and contaminants
4. Provide adequate wound drainage
5. Establish a viable vascular bed
6. Select the appropriate method of closure

Preventing Further Wound Contamination

On admission, the patient's wounds should be temporarily protected from further trauma and hospital-borne bacteria with a topical antimicrobial, sterile dressing and protective wrap (Figs 3-3 and 3-4; see also Chapters 4 and 5). Sterile gauze moistened with saline that contains an antibiotic or a nonirritating antimicrobial agent is useful, especially to maintain tissue hydration and control infection until definitive wound repair can be performed later in the day. Stock povidone–iodine solution can be diluted to 1 part solution to 9 parts saline. This 0.1% solution has antimicrobial properties and will not cause tissue injury. Stock chlorhexidine diacetate solution can be diluted to a 0.05% solution by adding 1 part solution to 40 parts sterile saline. This solution also has antimicrobial properties and will not cause tissue injury.

In preparation for definitive wound cleansing and surgical management, the exposed wound is covered with sterile gauze pads impregnated with sterile K-Y® Jelly (Johnson & Johnson, Langhorne, PA), sterile saline, or an antimicrobial solution prior to liberally clipping the skin and preparing the defect for surgery. Sterile K-Y Jelly can be applied to the fur along the wound borders before clipping (No. 40 clipper blades). The gel facilitates clumping of the fur and reduces airborne hair fragments being deposited onto the adjacent wound surface. The temporary wound cover minimizes further open wound contamination from clipped hair fragments and topical debris when preparing the area for surgery.

Fur should be liberally removed around the wound area. A circumferential clip is recommended when managing extremity wounds. Fur adjacent to wounds has a tendency to retain discharge from the wound surface, potentiating tissue maceration and bacterial proliferation: its removal also facilitates periodic wound cleansing and bandage reapplications. Water-impermeable drapes are ideally used to drape off the surgery site; the temporary protective dressing is then removed.

Debridement: Selective versus Nonselective

There are two broad categories of wound debridement: selective and nonselective. Selective forms of wound debridement more specifically target the presence of necrotic tissue. Nonselective debridement is considered less precise, since it inadvertently damages viable tissue to a variable degree within the wound. Forms of selective debridement include the use of gels and dressings that create an ideal medium for autolytic debridement. Enzymatic debridement is a second form of selective debridement, using exogenous proteolytic enzymes to separate nonviable tissues. Biotherapy, using maggots, is a third form of selective debridement. (See Chapters 4 and 5 for details pertaining to selective debridement techniques and products.)

Nonselective debridement is a more aggressive and faster method of removing necrotic tissue. The downside is that nonselective debridement may traumatize viable tissues in the wound to a variable degree. The two basic forms of nonselective debridement are:

- Surgical (scalpel, tissue excision) debridement
- Mechanical (wet-to-dry dressings) debridement

Selective debridement is a less aggressive and slower method for removing necrotic tissue. The upside is that necrotic tissue is targeted and viable tissue trauma is minimized. This is worth serious consideration if important delicate tissue structures may be damaged

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by nonselective debridement. The three basic forms of selective debridement are:

- Autolytic (use of topical gels, dressings)
- Enzymatic (use of topical enzymes)
- Biotherapeutic (maggot debridement therapy)

Surgical debridement normally employs scalpel blades, surgical scissors, and forceps to lift and excise the tissue. The most common form of mechanical debridement is the use of wet-to-dry dressings; serial dressing changes pull or lift attached necrotic tissue that is adhered to the gauze. If overused, this technique also irritates and damages local tissue (see Chapter 5). However, both methods are able to quickly and effectively remove necrotic tissue. The judicious use of nonselective debridement in the *first 72 hours* of wound management causes minimal collateral damage. The rapid removal of necrotic tissue facilitates granulation tissue formation and opens the possibility of early wound closure. Small areas of necrotic tissue may be effectively managed with many of the topical agents promoting autolytic debridement. Indeed, surgeons may disagree on which method to use on a given wound containing necrotic tissue. It is the author's contention that large areas of necrotic tissue are best excised; short-term use of wet-to-dry dressings will remove residual areas of necrotic tissue. Alternatively, topical autolytic debridement agents and dressings can be substituted for wet-to-dry dressings when minimal amounts of necrotic tissue are present, according to the preference of the clinician. In general, selective debridement techniques alone are not ideally suited for the removal of large areas of dead tissue.

Surgical Debridement

The surgeon's ability to remove necrotic and severely compromised tissues is a major determinant for whether *primary* or *delayed primary* closure should be considered. Areas of questionable viability may be excised if the tissue is not essential to healing or function (see Fig. 3-4). Areas of the body with loose, elastic skin permit a more aggressive approach to debridement, whereas extremity wounds warrant a more cautious approach when tissue viability cannot be determined on presentation.

The cost of veterinary wound management and closure is influenced by the speed of successful wound debridement. The early removal of necrotic tissue and formation of a healthy wound bed enable the surgeon to close the wound earlier, eliminating the need for additional/prolonged open wound management.

It is not always possible, however, to accurately assess tissue viability at the time of initial wound exploration, and it may take 24 hours or longer to clearly delineate devitalized tissues. It would be appropriate to consider delayed primary closure until tissue survival is assured, especially when important structures are involved. Daily wound assessment and serial surgical debridement can be used to remove devitalized tissue as it becomes identifiable.

Is this skin viable? Assessment of skin viability, in the early stages of trauma, can be difficult. Black to an ashen gray are the characteristic colors of necrotic skin, although pale (pearl) white is noted in skin devoid of circulation. Skin pigmentation can obscure color assessment. Deeply contused (bruised) skin may precede skin necrosis, although circulation may recover in some cases. Keep in mind that hemorrhage beneath thin skin (especially the lower abdominal skin) is easily visualized and may not reflect skin viability. It can take several days to visually determine skin viability, especially in extensive burns.

When large amounts of devitalized tissue are present, removal of the tissue is facilitated by locating a definable underlying fascial plane. Debridement of full-thickness skin necrosis is facilitated by undermining at the level of the hypodermis. In turn, necrotic hypodermal tissues are resected; the underlying muscle fascia (epimysium) and muscle tissues are assessed for viability and managed accordingly. This stepwise, downward excisional technique is occasionally referred to as "layered debridement" (Fig. 3-9).

Exposed contaminated and compromised subcutaneous fat overlying skeletal muscle can be safely excised, thus removing the devitalized tissue and the embedded debris. However, excision of subcutaneous fat and portions of panniculus muscle attached to the dermal surface of traumatized skin is best avoided if possible; debridement under these circumstances may further compromise the traumatized skin's blood supply (subdermal plexus and associated direct cutaneous vessels). Wound lavage and careful removal of topical debris (with forceps) from partially avulsed skin are preferable. The area can be reassessed with subsequent bandage changes.

Surgical Tip

In areas where there is adequate loose skin, such as the trunk, more aggressive debridement can be performed for cutaneous tissue of questionable viability. However, the skin of the extremities is limited. When the viability of skin is in question, conservative debridement is advisable and the area should be reassessed over the ensuing days.

Although bleeding along the skin margins is considered a desirable intraoperative clinical sign of adequate

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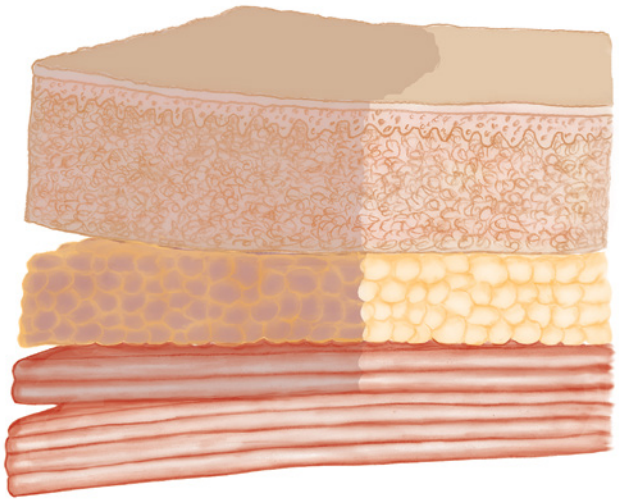


FIG. 3-9 The concept of layered debridement. When the depth of severely damaged or necrotic tissue is uncertain, tissue can be removed through a defined layer of tissue or between the natural tissue planes in a given body region. For example, when full-thickness skin necrosis is present, the surgeon will naturally attempt to debride the skin in the underlying hypodermis. If the hypodermal layer is noted to be necrotic, this layer of tissue will be tangentially debrided to the underlying muscle fascia. If tissue necrosis is involving the underlying muscle layer, the outer muscle fascia can be excised and the underlying muscle fibers assessed for viability.

cutaneous arterial circulation, it provides no information as to venous return when dealing with traumatized skin (Fig. 3-4). It is also no guarantee that blood is not being shunted away from the nutrient circulation of the skin. Vasospasm and pronounced hypotension may cause a temporary drop in local cutaneous circulation with a misleading decline in bleeding from the wound edge. Furthermore, the presence of circulation within a skin area at the time of initial examination also is no assurance that trauma, edema, infection, venous compromise, or progressive thrombosis will not subsequently obstruct the circulation. Feline skin generally bleeds less than canine skin when incised.

Early visual indicators play a role in assessing skin viability after initial injury. For example, large avulsion wounds in which significant loss of segmental direct cutaneous vessels is noted would suggest that a variable portion of the terminal "traumatic flap" will undergo necrosis. Additionally, stripping of the underlying subcutaneous tissues is an indicator of vascular compromise via loss of the subdermal plexus and supporting direct cutaneous vasculature. The options are to wait and reassess the skin over the next 4–5 days or to consider partial resection of the compromised tissue. Restrained debridement is initiated by excising the terminal edge of the traumatized skin, looking for indications of edge bleeding. The excision is performed in a stepwise fashion. Excision is stopped at the point at which primary closure can still be accomplished with minimal tension. Excision obviously can be stopped before this point, if bleeding is noted at the incised edge of the traumatic flap. The wound may then be closed or left open and reassessed over the next 4–5 days for final debridement and wound closure. During the next few days, the remaining skin is assessed for viability before final closure. (See Chapter 1 regarding circulation to the skin.)

Mummified Necrotic Skin: Nonsurgical Considerations

There have been a few occasions in which a dog or cat presented with a small area of necrotic, mummified skin with the absence of infection. Owners, concerned about cost, elected for conservative medical care with periodic rechecks to assess healing progress. Followed over time, second-intention healing occurred, albeit at a slower pace. In these cases, there was progressive epithelialization around the perimeter, separating the necrotic margins as healing progressed toward the center of the cutaneous defect. Loose necrotic skin and subcutaneous tissues along the margins were periodically resected with scissors until healing was complete.

Wound Lavage and the Removal of Foreign Debris and Contaminants

Dirt, clay particles, and organic debris promote infection and delay wound healing. Removal of specific infection-potentiating factors in soil can impair tissue defenses and promote infection. Radiographs can be used to locate radiopaque materials including glass fragments, grit and gravel, and metallic objects. Ultrasonography is useful in detecting radiolucent objects and abscesses.

Gross contaminants adhered to adipose tissue overlying muscle surfaces may be removed more easily by excising this tissue tangentially (Fig. 3-4). As previously noted, debris adhered to the subcutis of skin should be manually removed to better preserve cutaneous circulation. Manual removal of gross debris followed by pressure lavage with isotonic solutions will remove additional microscopic contaminants remaining after the initial debridement. Small to moderate-sized wounds are generally lavaged with 500–1000 ml normal saline or lactated Ringer's solutions. (See Chapter 4

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regarding antiseptic lavage solutions.) Additional lavage solution is employed for large wounds. The author has had excellent clinical results with the use of isotonic solutions in contaminated wounds under pressure, using an 18-gauge needle attached to a 35 ml syringe. The full force of the plunger will effectively deliver 8 pounds per square inch (psi) to the wound surface when the needle is placed immediately perpendicular to the wound surface. (Effective pressures for irrigation are reported at between 4 and 15 psi.) The addition of a three-way stopcock attached to a sterilized intravenous fluid line will enable the surgeon to refill the syringe more quickly during lavage. Funnel-tip syringes also can be adapted to pressure lavage with a catheter adaptor (Fig. 3-10). The surgeon should cup a hand around the area to minimize overspray. Commercial lavage units also are available for clinical use for those practices that have a caseload capable of supporting their cost. Stryker Instruments (Kalamazoo, MI) sells a disposable pressure lavage unit (SurgiLav®) that connects to intravenous fluid bags (Fig. 3-11).

One veterinary study (Gall and Monnet 2010) noted variable psi with the use of syringe lavage, depending on the gauge of the needle. The full force of the plunger generated pressures of 18.40 (+/– 9.80) psi with a 16-gauge needle; pressures of 16.70 (+/– 6.50) were noted with an 18-gauge needle. This suggested that higher than acceptable pressures generated with syringe lavage could injure tissues. Use of a 1-liter fluid bag with a pressure cuff (pressurized to and maintained at 300 mmHg) was able to deliver 7–8 psi more consistently. However, pressure will vary with the manual force exerted on the syringe plunger. Considering the acceptable range of 4–15 psi in humans, the simple syringe technique (using a 35 ml syringe and 18-gauge needle) is within the acceptable 4–15 psi range reported for lavage of ulcers in humans (Fig. 3-12). Moreover, one study in humans noted that a saline solution delivered at 15 psi removed 84.8% of the soil infection-potentiation factors from the wound. A second report advocated an irrigation pressure of 13 psi for cleansing wounds without causing tissue trauma.



FIG. 3-10 Funnel-tip syringe, with catheter tip adaptor, for pressure lavage. A gunshot wound over the left scapula is being lavaged with a chlorhexidine–saline solution after debridement.

Lavage

Wound lavage is an important means of removing open wound contaminants following debridement and manual removal of gross contaminants adhering to the wound surface. The effective volume required and the pressure applied remain unclear. One paper suggested 50–100 ml per cm of the wound surface. Following any initial lavage attempt, the surgeon makes a visual assessment of whether additional lavage is indicated. SurgiLav lavage units include a cupped end to limit overspray or fluid splatter contamination to the neighboring surgical area. If using a hypodermic needle and fluid application under pressure, the surgeon can cup one hand around the area to reduce this problem.

It is important for the surgeon to separate and elevate the wound edges gently to examine adjacent fascial planes that are likely to be harboring debris. However, indiscriminate dissection is to be avoided in the interest of preventing additional tissue trauma and contamination to uninvolved areas.

It is best to avoid or minimize the use of deep dermal or subcutaneous sutures in those wounds in which residual contamination may precipitate infection with their use.

Provision of Adequate Wound Drainage

As a general rule, leaving a wound open provides optimal drainage for problematic wounds with the presence of contaminants/infection. As discussed in Chapter 5, various dressing options can be employed depending on the volume/type of wound exudation. At the time of wound closure, drains may be used to control dead space and provide an outlet for the removal of tissue fluids that may accumulate in the area. In the face of infection without devitalized tissue and foreign debris, drains can provide an outlet for purulent discharges that otherwise may accumulate or spread into adjacent tissues.

Drains can be divided into two basic types: passive drain systems and active drain systems. Each system has specific advantages and disadvantages. (See the discussion in Chapter 4 regarding wound drainage systems.)

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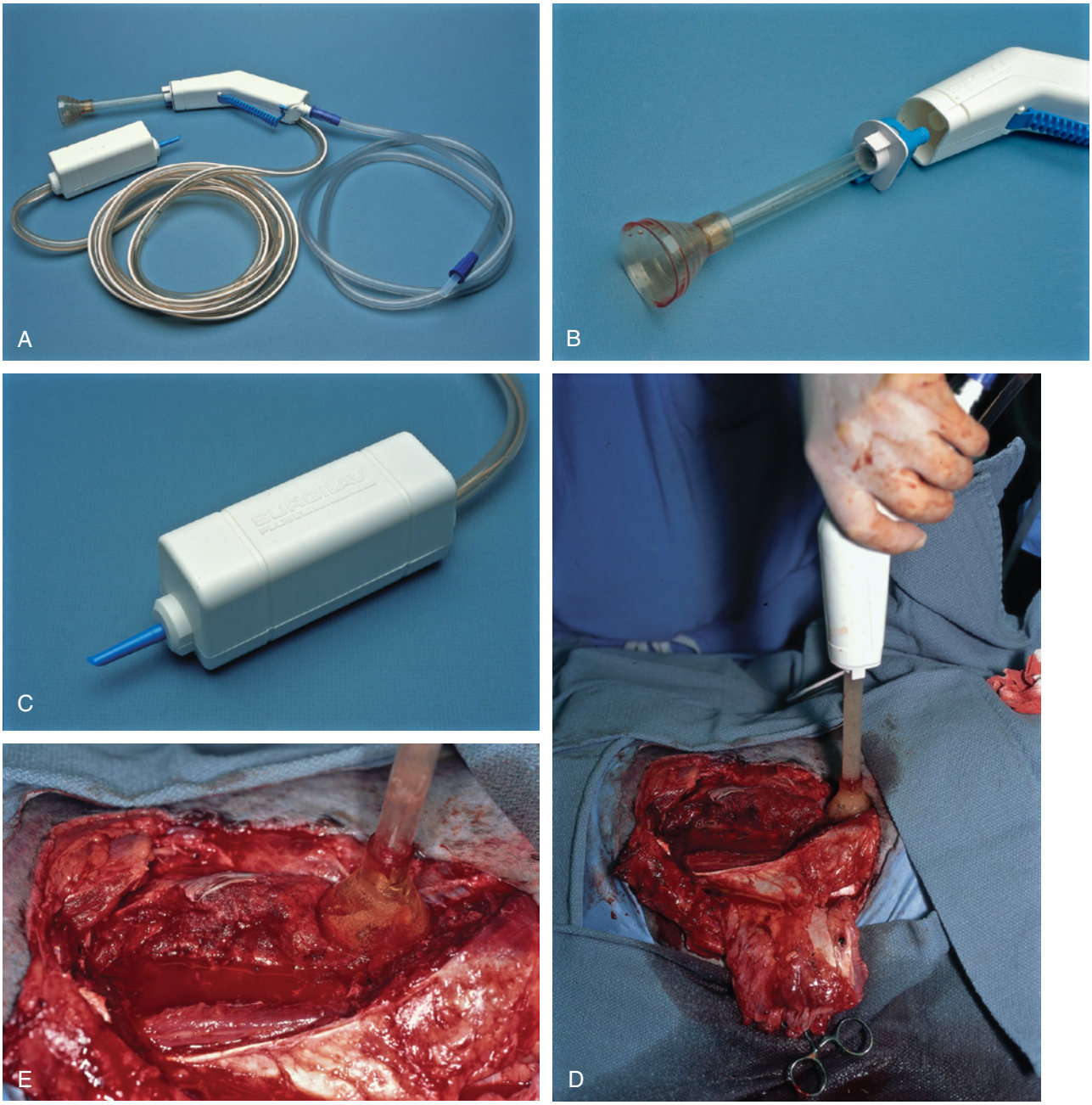


FIG. 3-11 (A) SurgiLav debridement unit (Stryker Instruments, Kalamazoo, MI). Note the hand piece connected to the battery-powered motor unit. The blue-tipped tubing is connected to a vacuum canister. (B) Detachable funnel tip with spray jets. (C) The motor unit is inserted into an intravenous fluid bag. (D) SurgiLav unit being used to clean a contaminated avulsion wound involving the left lateral lumbar region. (E) Close-up view of the funnel tip in contact with the tissue surface. The cone prevents overspray from the fluid nozzle; a vacuum port in the attachment simultaneously sucks fluid away from the wound and into the vacuum canister.

Promotion of a Viable Vascular Bed

Removal of necrotic tissue, debris, and contaminants minimizes the risk of infection and delayed healing. Similarly, adequate postoperative wound drainage provides a route for the escape of debris and tissue fluid, and this can further reduce the likelihood of abscessation. Dressings and bandages help protect the wound from additional contaminants and trauma. Under these circumstances, circulation to the remaining viable tissues

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FIG. 3-12 Pressure cuff with the placement of a 1-liter bag of lactated Ringer's solution. The cuff is pressurized and maintained at 300 mmHg to generate 7–8 psi through the intravenous tubing connected to an 18-gauge needle. This is one alternative to the use of a 35 ml syringe and 18-gauge needle for pressure lavaging open wounds.

can improve and support the development of a granulation bed. Thus, the veterinarian's major effort in the management of most dirty and infected wounds is to promote a healthy vascular (granulation) bed. At this point, the appropriate method for closing the wound can be chosen.

Selection of Appropriate Method of Closure

The true magnitude of the defect is best determined once tissue swelling subsides and the wound is devoid of necrotic tissue. This is particularly evident when managing open wounds of the lower extremities. At this stage (generally 7–10 days after the initial injury), the surgeon may note that the wound is considerably smaller than originally ascertained and it may heal by contraction and epithelialization without further surgical intervention (see later Fig. 3-14). Secondary closure may be attempted if there is adequate skin adjacent to the wound. Skin flaps or free grafts should be considered for larger defects, for which healing by second intention may be prolonged or expensive. These reconstructive techniques also are advisable when wound contracture or a fragile epithelialized scar may occur. As discussed, surgeons will occasionally manage some open wounds for a few weeks to determine whether healing by second intention will reduce the magnitude of the wound before final surgical closure is attempted. This option often is considered for some small to moderate-sized skin wounds (not located in a critical area) in which sufficient peripheral skin is present to help promote contraction and epithelialization.

EXPOSED BONE: OSTEOSTIXIS

When feasible, healthy exposed bone can be covered with adjacent skin or muscle. Although exposed bone stripped of the periosteum cannot easily support a granulation bed, the adjacent viable soft tissue will often form healthy granulation tissue that creeps over the bone surface (Fig. 3-13). Small holes may be drilled into the cancellous layer of the bone to promote granulation tissue coverage of the exposed cortical surface. This technique, termed *osteostixis*, is usually reserved for large exposed bone surfaces or smaller areas in which healing is delayed. Care must be taken to avoid fracturing narrow, compromised bone segments such as the metacarpal or metatarsal bones (Fig. 3-14). In some areas, muscle flaps can be rotated over an exposed bone to improve circulation to the wound area and provide a vascular surface, if needed. (See Chapter 6 for additional details on managing exposed bone.)

ACUTE VERSUS CHRONIC WOUNDS

This chapter is largely devoted to *acute wounds*; that is, wounds that heal in an orderly, uncomplicated fashion using the wound management and closure options discussed. By contrast, *chronic wounds* are wounds that have

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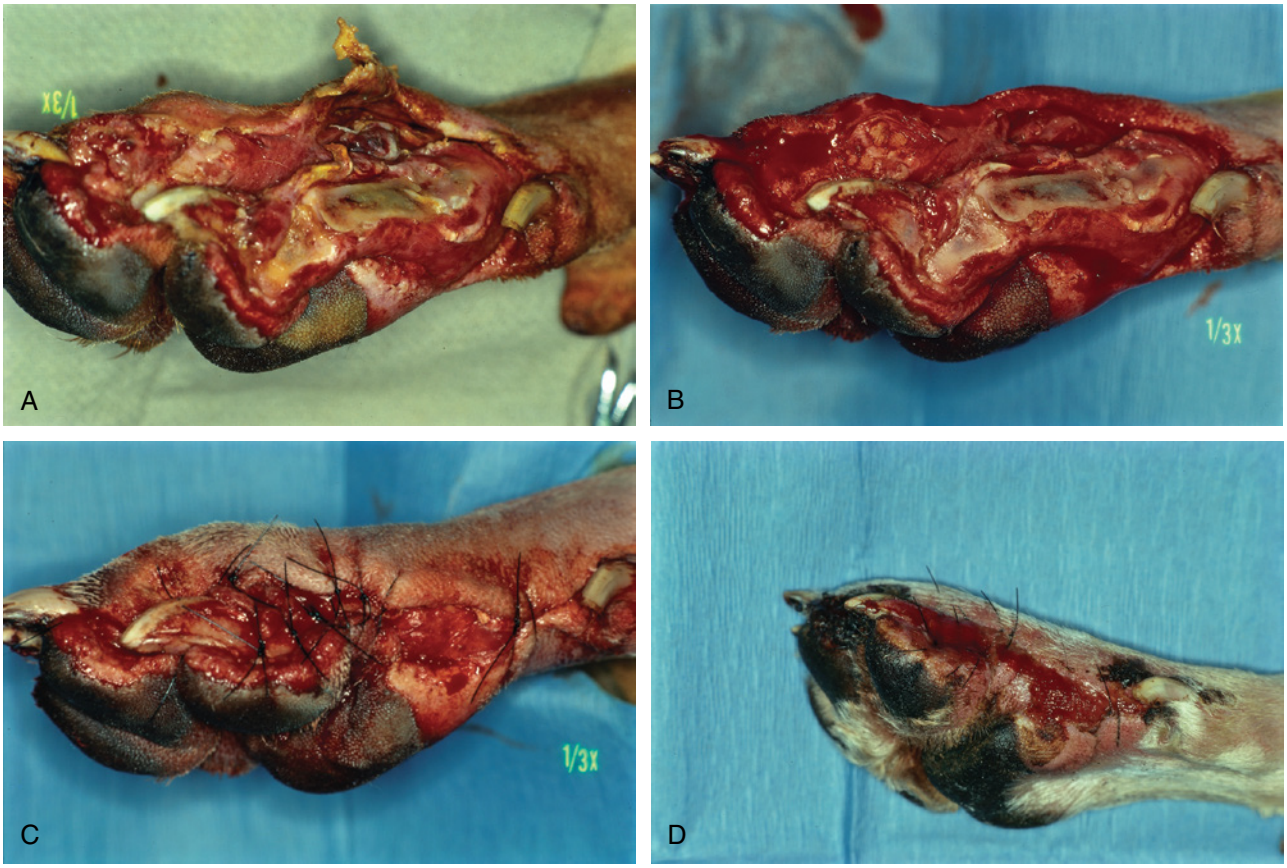


FIG. 3-13 (A) Shearing wound to the left rear paw secondary to vehicular trauma. The size of the wound is exaggerated by edema and elastic retraction of the cutaneous borders. (B) Debridement and copious lavage were used to remove necrotic tissue and contaminants. (C) Skin borders were tacked to adjacent fascia. (D) After 2 weeks, the edema has subsided and the small remaining wound will heal by second intention.

a lengthy, prolonged healing process. The Wound Healing Society (Lazarus et al. 1994) defined chronic wounds as wounds that "fail to progress through a normal, orderly, and timely sequence of repair or wounds that pass through the repair process without restoring anatomic and functional results."

Chronic open wounds fail to heal for a variety of causes (see Chapter 6). Over time, the wound microenvironment of the wound impairs the healing process. Prolonged inflammation is a major factor in delaying the healing processes. The prolonged presence of destructive proteinases in chronic wounds, an important component of normal healing, damages those tissues necessary for eventual closure of the wound. *Bacterial biofilms* can form, further impairing the healing processes. Bacterial biofilms, composed of colonies of bacteria embedded in a self-made protective, slimy barrier of sugars and proteins, attach to the wound surface. Biofilms, in turn, contribute to the chronic inflammatory response. To combat the biofilm, neutrophils and macrophages secrete proteases; unfortunately, the proteases also damage normal tissues in an attempt to dislodge this adherent bacterial film covering the wound surface. There are surgical and medical options to manage chronic, nonhealing wounds. Chronic wound management is discussed in greater detail in Chapter 6.

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FIG. 3-14 (A, B) Loss of the plantar surface of the left metatarsal area secondary to tumor resection and overlying compression bandage. Despite tendon loss, the patient can bear weight on the paw, although the digital pads will rotate dorsally. Future care included wearing a protective boot when the dog walked on hard surfaces in order to prevent abrasion of the dorsally displaced digital pads. (C) Osteostixis, using a fine-tipped drill to penetrate the medullary canal of the exposed metatarsal bone. Note the granulation tissue creeping around the perimeter of the bone. (D) The burr tip was used to gently feather over the compromised outer cortical surface. (E) Mesh graft application. (F) Two weeks postoperatively. The small open granulation areas eventually closed by epithelialization.

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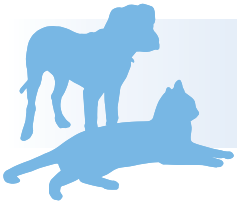
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Topical Wound-Care Products and Their Use

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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WOUND EXUDATE

Wound exudate (wound fluid) is a general term to describe the discharge from the surface of various wounds once hemorrhage is controlled. The fluid provides essential nutrients, growth factors, and a moist environment for cell viability and migration in the complex process of wound healing. Exudate is plasma, essentially leaking from the capillary system. This increased permeability (discussed in Chapters 2 and 3) enables chemical mediators, cytokines, and white cells to escape into the wound. In uncomplicated acute wounds, tissue fluid decreases over time; there is a progressive decrease noted in dogs after subsidence of the inflammatory phase. Various forms of trauma and the surface area involved will influence the volume of exudate generated. As granulation tissue forms and contraction and epithelialization progress in a normal fashion, the volume of exudate progressively decreases in uncomplicated wounds.

Fluid samples can be submitted for cytology and aerobic/anaerobic culture when infection is suspected. Uninfected exudate normally is clear: tinged with red blood cells, it assumes a clear-pink color. Infected exudate usually appears cloudy with variable color: cytologic examination reveals large numbers of neutrophils and bacteria also may be observed.

In acute wounds that are healing in an orderly fashion, the volume of exudate decreases over time. In contrast, chronic wounds (see Chapter 3), with a sustained inflammatory phase, have continuous production of exudate. The microenvironment of chronic wounds differs considerably from that of acute wounds. Neutrophils and macrophages continue to release proteases (including metalloproteinases) in this sustained inflammatory phase, causing collateral damage to viable cells, inhibiting the proliferation of fibroblasts, endothelial cells, and keratinocytes. Excessive production of chronic wound exudate, spilling onto the adjacent skin, can result in tissue maceration and increase its susceptibility to infection. Management of chronic wounds is discussed in Chapters 5 and 6.

During the inflammatory phase after trauma (surgical trauma included) production of exudate can be considerable. Fluid accumulating in dead-space areas after wound closure can result in significant seroma formation; large seromas in particular will separate tissue planes and impair the normal healing process. Excessive accumulation of subcutaneous fluids may drain through the surgical incision, delaying normal healing and serving as a route for bacterial contamination to the underlying tissues. Surgical drains are commonly used to remove tissue fluid in the surgical wound after closure of the skin incision, but are occasionally used for draining deep infected pockets. Drainage can be life-saving by providing an escape route for exudate from contaminated and infected wounds.

When a wound is managed as an open wound, topical medications and dressing selection will vary with the changing condition of the wound. In closed wounds, drain selection is, in part, determined by the surface area of the surgical wound, its location, and the anticipated volume of exudate.

WOUND DRAINAGE SYSTEMS

Passive Drains

The simplest and most economical of the passive drains employed in small animal surgery is the Penrose drain (various manufacturers), a soft tubular strip of radiopaque latex or silicone that is sold in various widths. In small animal practice, only the ¼-inch Penrose drain is considered useful; larger drains are rarely needed (Fig. 4-1). Penrose drains allow for the passage of fluids by capillary action over the outer surface of the drain. Fluid then gravitates downward and out of the dependently placed exit incision. *Cutting holes in a Penrose drain does not improve drainage and has the added disadvantage of increasing the drain's susceptibility to tearing if traction is applied to the exposed end*. The dorsal/proximal end of the buried drain is secured with a single skin suture; a second suture is used to secure the drain to the skin as it exits ventrally/distally (Fig. 4-2).

In general, placement of a Penrose drain beneath the incision or suture line is ideally avoided. The drain may irritate the tissues in contact with the drain and possibly interfere with healing of the closed incision. Healing of the skin incision to the underlying tissue plane also

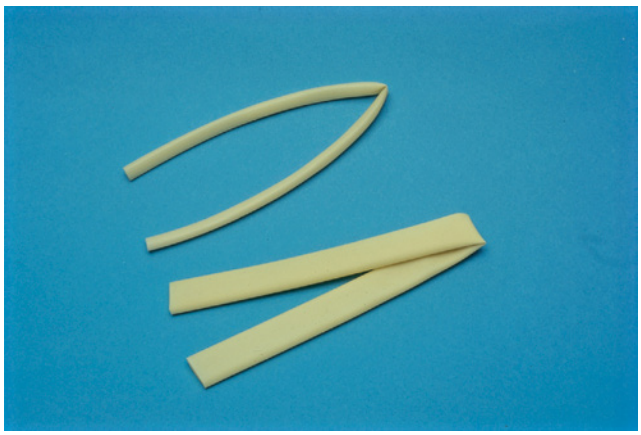


FIG. 4-1 Penrose drains are composed of radiopaque latex or occasionally silicone. They come in a variety of sizes. Examples include the ¼-inch and ⅜-inch Penrose drain. In small animal surgery, the ¼-inch Penrose drain is the preferred size.

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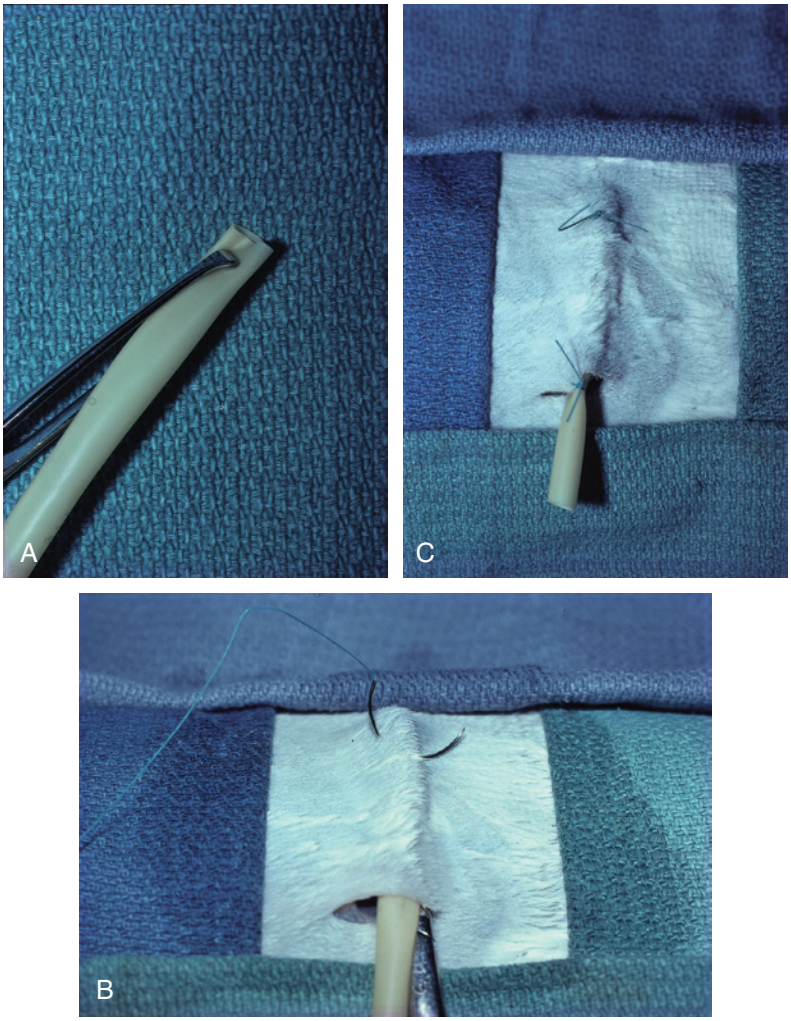


FIG. 4-2 (A) Method for inserting Penrose drains into dead-space pockets and seromas using Allis tissue forceps. The Penrose drain is grasped at its end with the forceps. A portion of the drain is tucked into the space between the jaws of this instrument. (B) The Allis forceps and drain are inserted through a stab incision created in the dependent area of the surgical site. The forceps are inserted into the cavity. The forceps are palpable beneath the skin. As a suture needle is inserted through the skin, the Allis forceps are rotated slightly, allowing the needle to pass through the instrument gap where the drain has been tucked. The end of the needle is then pushed partially through the skin. Leaving the needle in position, the Allis tissue forceps are removed. The drain is gently tugged to confirm that the suture needle has captured or secured the drain. (C) The drain is sutured into position, including a suture placed at the exit wound. This technique is both simple and effective in blind placement of Penrose drains.

There are veterinarians who prefer to secure the dorsal/proximal drain in the deeper tissues, using a fine absorbable suture (usually 4-0 chromic catgut). When the drain is no longer required, a firm tug is used to break the retention suture and remove the drain. The author does not advise using this technique for one simple reason: there is a risk of tearing the drain, with retention of a fragment in the wound. Because Penrose drains are radiopaque, a radiograph can be taken to determine whether a portion of a drain is retained. Retrieval of retained drain fragments can be surprisingly difficult. Blind retrieval can be attempted by inserting forceps to grasp a drain fragment through the exit wound; fluoroscopy also has been used to locate problematic drain fragments. Partially reopening the original surgical incision or using a smaller access incision over the location of the drain fragment is a last resort.

may be impaired. More commonly, careless suturing of the skin may inadvertently snag the underlying drain, making subsequent drain removal difficult. (*Note*: tugging on the drain usually will "wiggle" the offending suture(s).) In practice, the location of the incision or wound in relation to the necessary dependent exit site of a drain can make the suggested rule of thumb impossible to follow. Despite the potential problems noted, the author has *not* found that having a drain cross an incision line poses a significant problem to wound healing.

Penrose drains are adequate for the drainage of smaller dead-space areas but are less than ideal for larger areas, especially when prolonged drainage is

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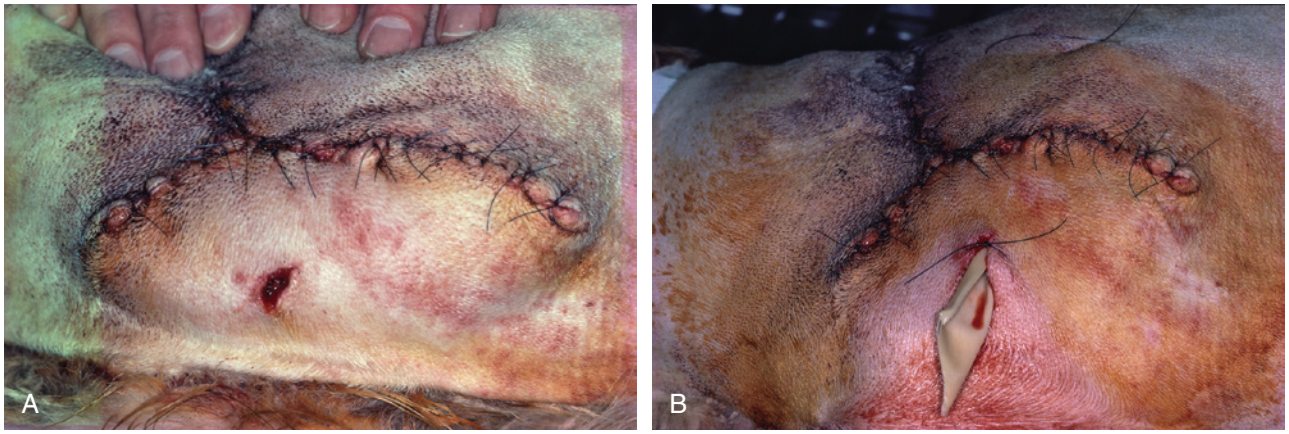


FIG. 4-3 (A) Forelimb amputation; premature removal of a surgical drain resulted in seroma formation. (B) Allis tissue forceps were used to replace a Penrose drain, followed by an external bandage to help control dead space.

anticipated. Penrose drains are normally retained for 3–5 days, depending on the volume of fluid exiting the area. They can be removed by the second day if drainage is minimal. In general, the longer the drain is retained, the greater the likelihood of ascending infection from contamination at the drain exit (Fig. 4-3). When possible, the exposed end of a Penrose drain should be covered with a sterile dressing and a topical antimicrobial agent, although this is not easily accomplished in some body regions (e.g., inguinal and axillary areas). If left exposed, it is advisable to gently cleanse the exit area with sterile saline (with the addition of povidone–iodine or chlorhexidine) followed by a topical antimicrobial agent three times daily (Fig. 4-4). Using an Elizabethan collar is advisable to prevent the patient from chewing or removing the drain. As previously noted, should a patient tear a portion of the drain, radiographs may be necessary to confirm retention of the radiopaque fragment.

Penrose drains function suboptimally in body areas where gravitational drainage cannot be provided. Moreover, they permit the entry of air into a wound area and cannot be used in thoracic wounds in which pneumothorax may occur. In flank wounds cranial to the hindlimbs, the exit site of the drain occasionally can create a sucking wound, with subsequent development of subcutaneous emphysema to a variable degree. Closed-suction drainage systems are best employed in these situations.

There are two common errors noted with the use of Penrose drains: (1) improper placement (a "mental disorientation" error) of the *exit* site associated with the position of the surgical patient and (2) having both the proximal/dorsal and distal/ventral ends of the Penrose drain exit the skin. In the former, a patient is in dorsal recumbency and the surgeon accidentally directs the *exit* wound into the inappropriate (dorsal/proximal) location. This placement error usually is discovered only after the patient is placed in lateral recumbency during anesthetic recovery. Lastly, having the drain exiting dorsally provides no drainage and is a potential area for contamination to the surgical area.



FIG. 4-4 For smaller dead-space areas Penrose drains can be used very effectively. In this example, a ¼-inch drain is used to control the dead space below the transposed flap and the donor area.

Active Drains

Closed-suction drainage devices are active drain systems that operate on the principle of creating a vacuum in a chamber that draws fluid from the body area through a rigid fenestrated drain placed beneath

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the skin. Most chambers are collapsible plastic canisters that rely on an internal spring mechanism or the inherent tendency of the chamber wall to expand outward in order to create a vacuum. A one-way (antireflux) valve prevents reflux of fluid from the chamber back to the wound. Milliliter (cc) markings on the canister allow the surgeon to determine the relative amount of fluid accumulated. A spout permits emptying of fluid or any air accumulated in the vacuum chamber; the reservoir is collapsed and the stopper provided is inserted to reinstitute this active drainage system (Figs 4-5 and 4-6). The Jackson-Pratt® Active Drain System (Cardinal Health, McGaw Park, IL) is one of the more common systems currently used in veterinary surgery (Fig. 4-5), although there are various companies that produce Jackson-Pratt–style drain systems. Reservoirs can be purchased in various volume capacities (100 cc, 150 cc, 200 cc, 400 cc). In most cases, the 100 cc reservoir is ideal for small animal patients.

The best wound drains are silastic (silicone) materials with multiple holes and/or recessed grooves to minimize obstruction. The fenestrated portion of the drain is placed in the wound; the nonfenestrated portion exits the area through a small stab wound in the skin. The fenestrated tubing can be shortened to accommodate to the wound space. A purse-string skin suture provides an airtight seal at the skin–tube interface and the suture strands are then looped around the drain and tied to prevent tube displacement (sometimes called the "Roman sandal" knot or "Chinese finger-trap" knot). Redundant external tubing is cut off with scissors before attaching this nonfenestrated segment to the vacuum canister. The canister or reservoir is secured to a bandage or an adhesive band placed around the trunk or cervical area. Closed-suction units can be used for several days with minimal risk of ascending infection. In general, they are used for 3–5 days.

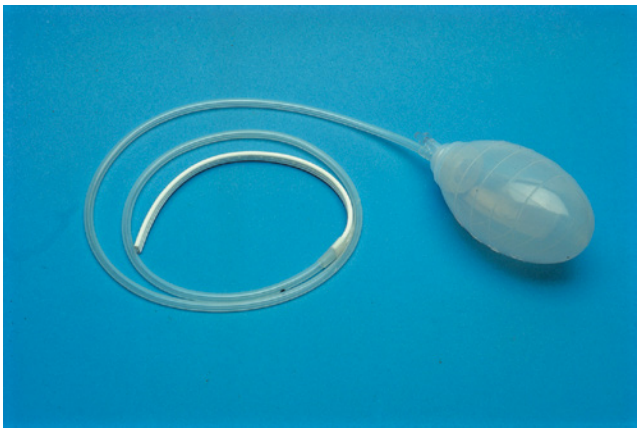


FIG. 4-5 Example of the Jackson-Pratt 100 ml vacuum reservoir and attached drain tubing. Composed of silicone, the reservoir and tubing can be cleaned and autoclaved. Several companies supply this economical vacuum drain system.



FIG. 4-6 Examples of the J-VAC™ closed drainage system (450 ml and 150 ml reservoir capacity) (Johnson & Johnson, Cincinnati, OH). J-VACs cannot be resterilized in the autoclave. The larger reservoir is too large for routine small animal usage.

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Vacuum drains have several advantages over Penrose drains:

- They function independent of gravity
- They allow the surgeon to quantify fluid volume
- They eliminate the need for bandages and nursing care typical of the external drainage associated with Penrose drains
- With basic instructions, they are easy for most owners to manage at home
- The risk of ascending infection is low
- They are very useful for draining deep wound pockets and abscess cavities devoid of necrotic tissue and contaminants
- The vacuum draws tissue planes together, thereby eliminating the need for internal "tacking" sutures to eliminate subcutaneous dead space
- If so desired, silicone drains and reservoirs can be cleaned and autoclaved for additional usage

Vacuum drainage systems are remarkably effective in removing fluid from large surface areas (Fig. 4-7). Most owners are capable of managing vacuum drains at home (see Table 4-1 for instructions). The author also has used vacuum drain systems extensively for managing mild cases of peritonitis and various abdominal abscesses and has found them quite effective.

In the presence of active bleeding, clotted blood can obstruct the drain holes. Tissue debris occasionally obstructs the drain. In many cases this problem can be remedied by removing the drain from the reservoir using sterile technique and flushing it with several milliliters of sterile saline to clear tube fenestrations. The vacuum is reactivated and watched closely for any future obstructions.

The milliliters (cc) of fluid removed, as well as its color and clarity, are recorded along with the time the reservoir is emptied by the owner. The reservoir scale provided is a general guideline for the volume of fluid. For the most accurate reading, the reservoir is emptied into a disposable cup; the fluid is aspirated with a syringe and the total volume is then recorded. The drain can be removed when the volume declines to several milliliters over a 24-hour period.

On occasion, obstruction of the fenestrated drain can be misread as a decline in fluid volume; fluid volume rarely drops to an abrupt "zero." One indication of tube obstruction is any visible/palpable accumulation of fluid at the surgical area. As noted, "retro-flushing" of the drain, using sterile technique, can be used to clear obstructed channels and reinvigorate the vacuum system. If this maneuver fails, drain replacement may be necessary.

A common complication noted in the immediate postoperative period is air entering the wound through one or more areas of the closed skin incision, inactivating the reservoir vacuum required to remove fluid. The chamber expands with air when there is an incisional leak, loose connection, or hole in the external drain tubing/reservoir. The skin incision, the exit site of the drain, the external tubing, and the reservoir must be examined to locate the source of the air leak. On occasion, a few drops of surgical soap can be applied to confirm the suspected site of the air leak in the external tube segment. When the vacuum chamber is activated, the area is assessed for visible bubbles, signifying a source of air entry.

Although uncommon from my experience, prolonged placement of the drain can lead to infection. In those few cases, an unexpected increase in fluid production was noted with a variable degree of incisional swelling. A sample of fluid obtained from the sterile nonfenestrated tubing demonstrated multiple neutrophils and the presence of bacteria on the stained slide created. The fluid sample was submitted for aerobic and anaerobic cultures followed by broad-spectrum antibiotic therapy. The infection resolved and the drain was subsequently removed a few days later.

Long incisions are more prone to cumulative air entry between individual skin sutures or staples, until a fibrin seal forms along the incision line hours after surgery. Air entry negates the vacuum within the reservoir, necessitating its evacuation and vacuum reactivation. To prevent this, the author has used a few techniques that can be effective in sealing air entry along an incision line (Fig. 4-8):

- Apply a line or "caulking bead" of ointment over the incision line and repeat as necessary. (Usually a fibrin seal will be noted by the following day)
- Depending on the length of the incision, a surgical cyanoacrylate glue may be applied over the suture/staple line
- If an exact area of air leakage is seen between sutures, additional reinforcing sutures or skin staples may be applied.

Vacuum drain systems are economical to use: silicone models are capable of being cleaned and resterilized if necessary. Although more expensive than Penrose drains, they are considered indispensable for the proper treatment of larger wounds and deeper pockets unamenable to Penrose drains.

The Case of the Very Aggressive German Shepherd

This patient presented with two large pressure sores overlying each olecranon. Previous attempts at closure had failed prior to referral. Instead of using Penrose drains after closure, a Jackson-Pratt drain was used to drain each wound with a 15-Fr Hemaduct drain (see following section). PIPE (see Plate 10) was used to protect the elbows from further trauma.

1. The Jackson-Pratt drain eliminated the need for the daily dressing changes required with the use of Penrose drains
2. The vacuum drains also served as a sentinel to dehiscence: breakdown of the wounds would result in loss of the vacuum
3. The vacuum drain system allowed us to quantitate the volume of exudate to determine the best time to remove each drain. Prolonged protection (>6 weeks) with PIPE resulted in a successful outcome (Fig. 4-9)

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FIG. 4-7 (A) Massive abscess of the left femoral area. The exact cause of this infection was unknown, although a penetrating wound was suspected in this farm dog. Note the pitting edema of the lower extremity. Ultrasonography outlined a deep U-shaped abscess cavity, curving from the hip down the femoral shaft area. (B) The depth and location of the abscess were determined with a syringe needle. When the abscess cavity was located, pus was seen exiting the needle hub. A scalpel blade was used to incise down to the cavity, using the intact needle as a depth guide. Blunt dissection with Metzenbaum scissors was performed to approach this long abscess cavity from two sites. (C) A finger was inserted into the depth of the abscess; aerobic and anaerobic cultures were obtained from the deep abscess cavity. (D) All pus was aspirated and flushed from the abscess pocket. The interconnecting access incisions facilitated drainage and visual inspection of the cavity. (E) The drain tubes exited through two small, separate stab incisions and were secured to the skin with a purse-string suture and Roman sandal suture. (F) Close-up view of the surgical area. Access incisions were closed and the reservoirs were attached to the drain tubes. The drains were left in the area for 6 days after insertion.

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TABLE 4-1 Vacuum drain instructions for pet owners.

1. The oval reservoir holds 100 ml (about 3 oz) of fluid. A milliliter (cc) scale is marked on the side of the reservoir.
2. To open the reservoir, remove the attached stopper from the spout. Next, look at the scale and note the volume of fluid in the chamber.
3. Record in a notebook the fluid volume (including color, clarity) and the date and time of removal.
4. To empty the reservoir canister, pour the liquid into a disposable container (e.g., a Dixie cup). If needed, a more exact measurement may be recommended by your veterinarian by using a syringe to withdraw the fluid from the disposable container. This fluid can then be flushed down the toilet and the paper cup can be discarded.
5. To reactivate the vacuum inside the reservoir chamber, squeeze the air out of the chamber and insert the stopper back into the spout. The reservoir will appear to be collapsed.
6. The entire drain system (reservoir and tube) can be removed when the amount of drainage decreases significantly. Contact your doctor to determine when to remove the drain.
7. The surgeon can remove the drain on an outpatient basis: in most cases drain removal will take less than 5 minutes.



Fenestrated Drains for Active Drain Systems

There are a variety of shapes and designs for the drains attaching to the vacuum reservoir. The author commonly uses the flat, 10 mm drain, which is a combination of a linear groove design supplemented by multiple circular holes; this is ideal for large dead-space areas. The author also has found that circular Hemaduct® drains (10-Fr, 15-Fr) (Cardinal Health) are highly effective for drainage: four drain channels are superior to simple fenestrated drains that rely on multiple individual circular holes. (Other drain sizes are available.) They are ideal for small to medium dead-space pockets (Fig. 4-10). Although more expensive, they also can be purchased with a trocar to facilitate placement. Use of the Hemaduct drains is also discussed for hygroma (Chapter 7) and aural hematoma management (Chapter 23).

Noncommercial Active Drain Systems

A small vacuum collection system can be made from a 35 to 60 ml syringe to manage small wounds or when a vacuum drain system is unavailable. A vacuum chamber can be created from the syringe by drawing and securing the inner syringe plunger to the outer cylinder, thereby creating a static vacuum chamber. Commercial tubing can be partially fenestrated with scissors and inserted into the wound (Fig. 4-11). It is important to adjust the vacuum force by including air in the chamber, otherwise the vacuum force is excessive. This device can be used effectively for small wounds when a comparatively small volume of fluid is anticipated. A three-way stopcock can be used to facilitate emptying the exudate accumulated in the syringe and resetting the vacuum chamber. This set-up lacks the anti-reflux valve present in commercial systems, increasing the potential risk of bacterial contamination, especially when emptying the syringe and reactivating the vacuum.

Originally reported for use in human pediatric surgery, Vacutainer® tubes (Becton, Dickinson and Co., Franklin Lakes, NJ) can be adapted for draining smaller dead-space pockets. A partially fenestrated drain is created with a butterfly catheter, removing the syringe hub and partially fenestrating a portion of the tube with scissors. The tubing is secured to the surgical area and the needle is inserted into the Vacutainer. As fluid accumulates, the Vacutainer suctions the fluid into its chamber. There is the danger of the glass tube shattering and it must be secured in a bandage to protect it from external impact. Unfortunately, the reservoir capacity is quite small and the small-diameter tubing is susceptible to plugging. As a result, its routine use is inadvisable.

Discharging Dogs and Cats with Active Drains

Canine patients are routinely discharged from Angell Animal Medical Center with Jackson-Pratt drain systems use to control subcutaneous dead space following surgery that is not associated with a body cavity. Owners are instructed on the proper use of the drain system and sent home with a standard instruction sheet (see Table 4-1). One paper (Lu and Wright 2023) reported minor complications associated with discharging dogs and cats with active drains that did not preclude their use in a home environment. From the author's experience, owners cope well with the use of active drains and monitoring fluid output.

NEGATIVE-PRESSURE WOUND THERAPY

Negative-pressure wound therapy (NPWT) or vacuum-assisted closure (VAC) is a wound drainage system in which a subatmospheric vacuum source is applied to a

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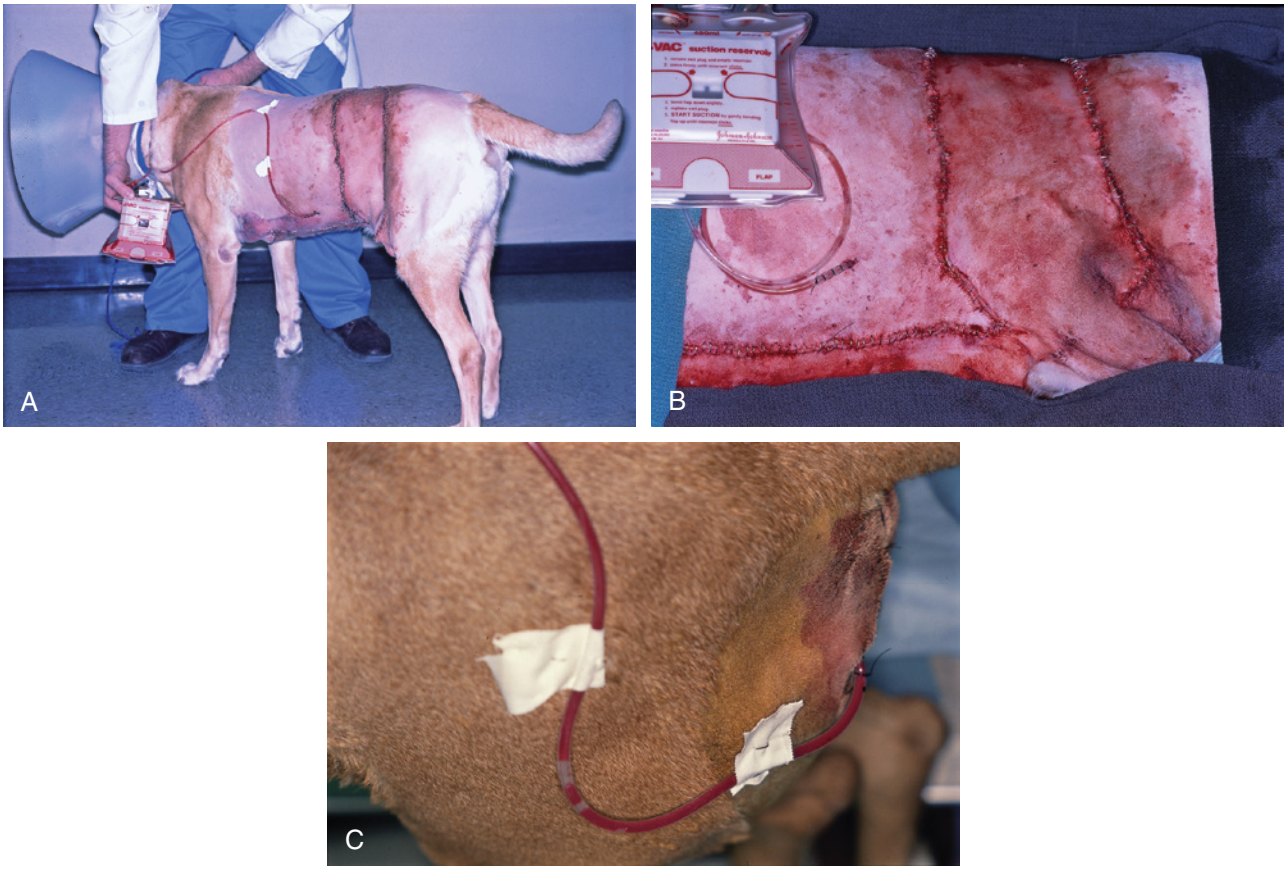


FIG. 4-8 (A) J-VAC used to control dead space beneath a caudal superficial epigastric axial pattern flap used to reconstruct the flank area after wide tumor resection. (B) The combined closure of the long donor and recipient areas increases the probability of air seepage between skin sutures/staples. Until a fibrin seal forms, application of an incisional sealant may be needed to prevent inactivation of the reservoir vacuum. Topical ointment or the application of a surgical glue over the closed incisions can be effective for this purpose. Adhesive plastic drapes can be used, although the cost of maintaining them may be greater. (C) Close-up view of a drain tube leading to a reservoir. To maintain the position of the tubing, tape strips can be applied to the tube and sutured or stapled to the skin.

wound encased in an outer plastic sheet. Activation of the vacuum through a tube connected to this sealed "wound tent" draws exudate from the wound into the applied absorbent layer; excessive fluid is retained in a collection chamber. The mode of action has been a subject of considerable research and the following have been noted: (1) increased blood flow as far as 3 cm from the foam base; (2) increased rate of granulation tissue formation; (3) enhanced epithelialization; (4) removal of exudate, cellular debris, and interstitial edema in the wound; (5) reduction in bacteria levels; (6) stimulation of cell proliferation; and (7) elastic skin deformation with reduction in the wound perimeter from the application of mechanical strain. NPWT is generally used during the inflammatory phase and early proliferative phase of wound healing when exudation is normally the greatest.

There are numerous articles in the human literature alone regarding the use of NPWT for a variety of acute and chronic wounds. Reports on its efficacy for full-thickness and split-thickness graft "take" have been noted in both humans and small animals. Its ability to enhance circulation to free grafts is equivocal based on variable research results in the literature. However, NPWT can be very useful to secure grafts in problematic areas. It has been effectively used to secure free grafts to burns in children, where patient compliance can be challenging (similar to many of our veterinary patients).

The earliest report on the application of subatmospheric pressure on open wounds was noted by Fleischmann in 1993. By 1995, Kinetic Concepts, Inc. (KCI, San Antonio, TX) had introduced a viable commercially available system for wound care known as V.A.C.® for vacuum-assisted closure. (V.A.C. and NPWT are frequently used

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FIG. 4-9 (A) A German shepherd patient being treated for bilateral ulcers overlying the olecranon. PIPE (see Plate 10) was applied after closure of these chronic wounds. Bilateral Jackson-Pratt drains were used to manage postoperative surgical dead space. Besides preventing the patient from disturbing the surgical sites, Elizabethan collars also provide a degree of protection from being bitten during daily treatments. (B) The patient required sedation for PIPE replacement. The vacuum drains served as a "sentinel" for wound dehiscence: loss of the vacuum would suggest breakdown of the closure site (which fortunately did not occur). (C) The reservoirs are secured to a loop of Elastikon® (Johnson & Johnson) placed around the thorax. A surgical shoe cover was stapled to the adhesive Elastikon loop; this provides a convenient pouch for holding Jackson-Pratt reservoirs.

as synonyms.) Success was quickly followed by competitors; after numerous lawsuits, other companies eventually won the right to develop alternative NPWT systems. Today, a wide variety of vacuum-assisted wound drainage systems have been developed to manage problematic wounds in humans, including ActiV.A.C.®, InfoV.A.C.®, and V.A.C. Freedom® (KCI); Venturi® Avanti (Talley Medical, Romsey, Hampshire, UK); Avelle™ (Convatec, Skillman, NJ); Prospera Pro II® (DeRoyal Industries, Powell, TN); EZCare™, VISTA™, and RENASYS™ (Smith & Nephew, Inc., Memphis, TN); and Avance® Solo (Mölnlycke Health Care AB, Göteborg, Sweden). They vary in the hardware and the disposable systems employed. The commonly used KCI V.A.C. includes (1) polyurethane open-cell foam sheets (packing) that can be trimmed with sterile scissors to conform to the wound surface; (2) a plastic sheet with a topical adhesive that overlaps the foam, forming an airtight seal over the entire wound area; (3) a firm plastic tube that attaches to the plastic

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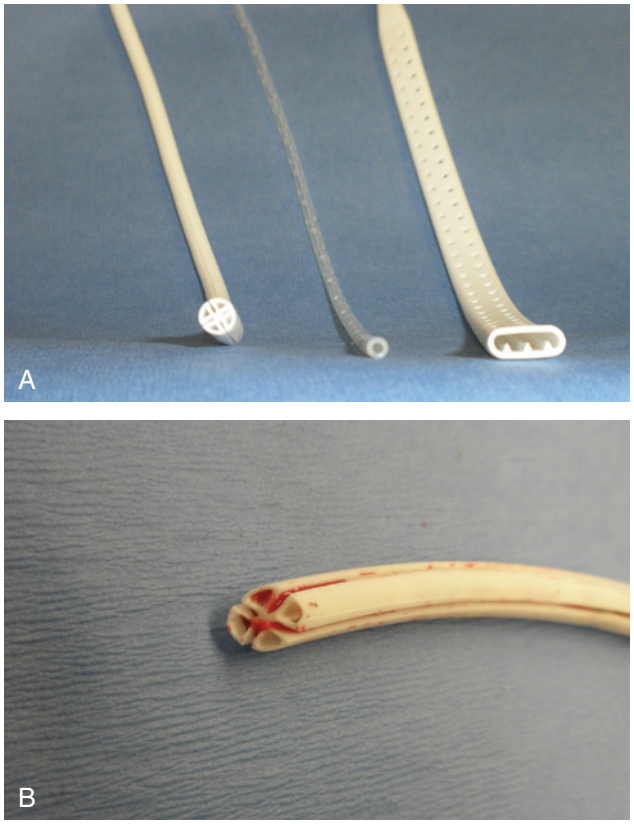


FIG. 4-10 (A) There are a variety of vacuum drains available. Examples include the Hemaduct drain with four grooved channels, a circular fenestrated clear silicone drain, and a 10 mm flat perforated and channeled drain for larger dead-space areas. (B) Close-up view of a Hemaduct drain removed from a patient. Note the blood drawn into the grooved channels. Hemaduct drains are excellent for draining a wide variety of wounds and are easily extracted on completion of their use.

sheet/foam pad with an adherent disc; and (4) a vacuum pump with a fluid reservoir to which the distant end of the tube is attached. Activation of the vacuum pump applies subatmospheric pressure to the foam chamber created (Fig. 4-12). By contrast, the Talley Medical Venturi system utilizes an open-cell foam or gauze matrix placed under negative pressure. Gauze coated with the antimicrobial polyhexamethylene biguanide (PHMB) is considered an ideal material. The foam sheet is cut to conform to the prepared wound and can be stapled to the skin margin of the defect (Fig. 4-13).

Studies with *chronic ulcer management* in humans have demonstrated significant financial savings with NPWT compared to the costs of multiple conventional dressing changes. However, the costs associated with VAC systems are not insignificant when you consider the price of the disposable items, vacuum unit, and hospitalization normally required to assure it is functioning properly during its application.

Improvised (noncommercial) systems have been used effectively, in both human and veterinary patients, by employing commercially available materials, including plastic surgical adhesive drapes, sterile gauze or sterilized "stereo speaker" foam (or other open-cell hydrophobic plastic foam materials), firm plastic tubing, and a standard vacuum pump used in surgical procedures. The outer borders of the adhesive plastic drape can be further supplemented by standard surgical drape spray adhesive used to secure the plastic drape that encases the wound. A line or "caulking bead" of colostomy paste can be applied to the outer border of the plastic drape to further prevent air seeping into the encased wound site. The partially fenestrated end of the semi-rigid tube is inserted into the foam or gauze packing material, followed by application of the outer plastic sheet. The distant end of the drain tubing is attached to the vacuum pump/reservoir (Figs 4-14 and 4-15). In human controlled studies, home-made VAC results were generally comparable to the commercial systems.

Polyurethane foam or gauze can serve as a platform for distributing the vacuum force uniformly to the surface of the wound and allowing the fluid to be transferred to the collection reservoir (including wound discharge, tissue fluid–edema). The original KCI V.A.C. system utilized a gray, hydrophobic polyurethane foam (pore size 400–600 μm). The pore size allowed granulation tissue to adhere to the foam. A white hydrophilic polyvinyl alcohol foam was introduced to reduce the risk of adherence (pore size 200–1000 μm). Pressures can be adjusted (−50 to −200 mmHg) and *applied continuously or intermittently*. Intermittent application of the vacuum (3 minutes on, 5 minutes off) was demonstrated to have beneficial effects on blood flow, granulation tissue formation, and skin flap survival in experimental animals. Removal of the extracellular fluid, in particular, can significantly improve microcirculation to edematous tissues.

Adjunctive studies have included the addition of silver-impregnated foam to reduce bacterial counts. Intermittent instillation of saline and antimicrobial solutions in conjunction with NPWT has been used to facilitate wound cleansing. Results in one study were comparable to the efficacy of pressure lavage, without the potential risk of contamination associated with overspray to the immediate hospital area. NPWT has also been applied to evacuate subcutaneous fluid and protect incisions following closure, thereby reducing the risk of seroma and hematoma formation that may contribute to wound dehiscence.

During the "off period" of the pump (intermittent suction), the foam gradually reexpands and this motion does

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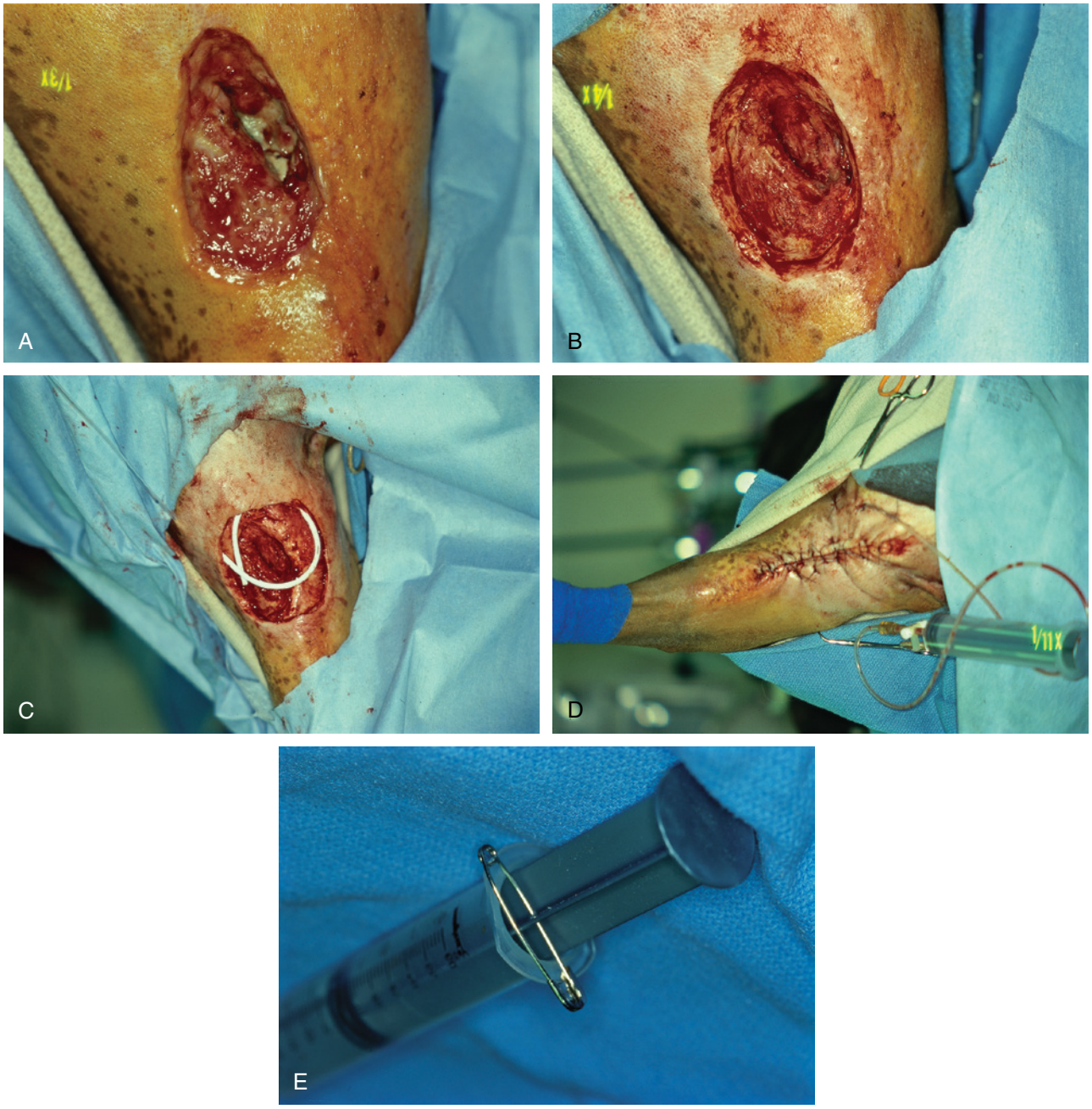


FIG. 4-11 (A) Chronic radiation ulcer in the popliteal area of a dog, secondary to orthovoltage therapy for mast cell tumor. (B) Surgical debridement and lavage. The skin borders were partially undermined to facilitate wound closure. (C) Insertion of 5 mm round fenestrated tube; the tube was shortened to fit into the small dead-space pocket prior to skin closure. (D) A purse-string suture and Roman sandal knot were used to secure the drain tube exiting the small stab incision. Skin closure with intradermal sutures followed by a vertical mattress tension suture pattern. A syringe vacuum was used to collapse the wound pocket and prevent seroma formation in this clean–contaminated wound. A three-way stopcock facilitates use of this simple drainage system. (E) Safety pins are useful to maintain the vacuum chamber. This "lock" pin can be shifted eccentrically to empty the syringe without its removal.

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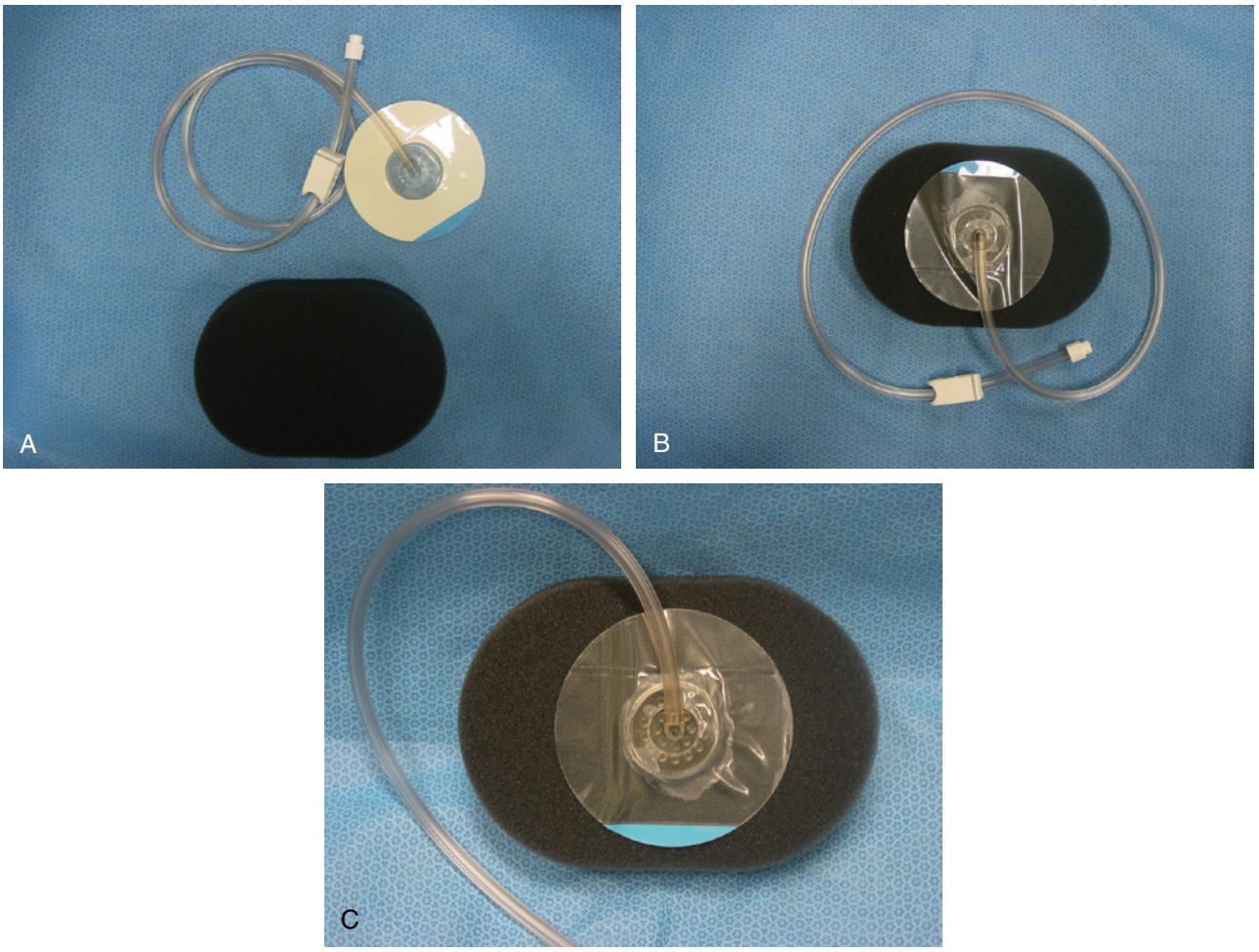


FIG. 4-12 (A, B) The V.A.C. or vacuum-assisted closure system. The system comprises a sterile polyurethane (open-cell) foam, an attachable vacuum tube with an adhesive medallion, and an adherent plastic drape designed to envelop the foam and adjacent wound margins. Foam pads come in different sizes and can be trimmed to fit a specific wound bed. (C) Close-up view of the perforated adhesive disc that attaches (sticks) to the opening provided in the plastic sheet placed over the foam surface. The opposite end of the tube is attached to the V.A.C. pump, which provides continuous or intermittent subatmospheric pressure to the foam. The plastic adhesive drape overlaps the peripheral skin and forms an airtight canopy over the foam, tubing, and wound. Activation of the vacuum pump removes air beneath the plastic cover, collapsing the foam. Fluid accumulating on the wound surface (wound discharge, serum, edema–tissue fluid accumulation) is drawn into the foam. Excess fluid is collected in the pump reservoir. As discussed, gauze-based systems appear to have comparable clinical results.

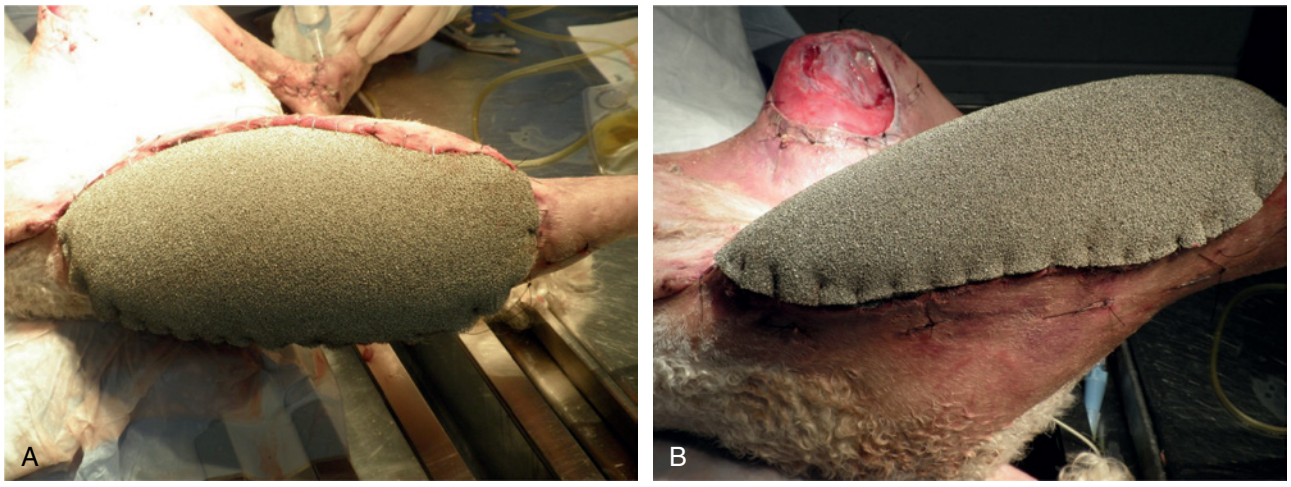


FIG. 4-13 (A) Open wound management of a traumatic skin wound overlying the right knee and upper thigh. Note that the polyurethane foam is secured to the skin margins with staples prior to placement of the plastic cover. (B) Lateral view of the foam secured to the skin margins.

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FIG. 4-14 (A) Forelimb degloving injury in a 6-month-old domestic short-haired cat. The digits were lost although the metacarpal pad was retained. (B) The right lateral thoracic area was prepared for harvesting a full-thickness skin graft. (C) The prepared mesh graft was secured over the cutaneous defect. (D) Application of the VAC system to secure the full-thickness mesh graft: −70 mmHg vacuum pressure was applied to the area for 72 hours. This was followed by a protective bandage. (E) Mesh graft at 10 days. (F) Note that the metacarpal pad provided a functional weight-bearing surface for this feline patient. (Courtesy of Gary Ellison DVM, DACVS and Kelley Thieman Mankin DVM, DACVS.)

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cause pain in human patients. In most cases, continuous suction is used without adverse results. A negative pressure of −125 mmHg is most commonly used in human and veterinary patients. A lower negative pressure of −50 mmHg is selected for wounds with excessive serous drainage and the postoperative prevention of fluid accumulation (seroma, edema). The polyurethane foam or gauze variation usually is replaced every 2–3 days with the patient under heavy sedation.

Increased bacterial clearance from the wound bed is an advantage to vacuum-assisted closure. However, these systems are not a replacement for surgical debridement of devitalized tissues. It is very important to remove necrotic tissue prior to using these negative-pressure systems (Figs 4-14, 4-15, and 4-16). Highly contaminated and infected wounds may require daily changes. Malodorous changes would indicate that more frequent bandage changes are needed. In many cases the NPWT bandage is changed every 2–3 days for a total of two to three times before the wound is ready for surgical closure or open wound management.

As noted, vacuum systems also can be used as a dressing to secure free grafts (Fig. 4-14). However, care is required when changing the foam or gauze in order to avoid displacement of the graft. To reduce this risk, low-adherent dressings (Adaptic™, Johnson & Johnson) can be applied to the graft surface prior to placement of the plastic foam or gauze matrix. Figure 4-17 demonstrates the step-by-step use of the V.A.C. in a cat.

Complications associated with vacuum systems include the ingrowth of granulation tissue into the plastic foam or gauze matrix. Its forceful removal can traumatize the granulation tissue, rupturing capillaries and resulting in hemorrhage. This is more commonly noted if the bandage is left in place for more than 3 days. This risk can be reduced by covering the granulation bed with a low-adherent dressing. Large air leaks can negate the vacuum; small air leaks may cause the adjacent skin to dry from the continuous passage of air over the area. The skin overlapped by the plastic barrier is also subject to skin irritation. These systems must be used with caution if thoracic or abdominal viscera risk contact with the foam. Thin and compromised skin can be traumatized with negative-pressure therapy. Lastly, vacuum systems should not be used on wound surfaces containing cancerous tissue (see Plate 1).

The general economics of wound management are multifactorial. Costs include bandage and dressing materials; hospitalization fees (intensive care vs. routine boarding); recheck examination fees associated with wound care, including bandage changes; medical costs, surgery, and anesthesia fees. In the case of NPWT systems, there are costs associated with the purchase/lease of each system. Each company supplies the disposable components of its respective system, an added cost with each application. NPWT patients normally require continuous supervision during their hospitalization to assure proper function. In many veterinary hospitals, this would require placing the patient in an intensive care unit, adding to the expense of their use.

Costs are partially offset by the less frequent changes staged every 2–3 days versus the associated costs of conventional bandage changes. One option to simplify changes of NPWT systems is to change the foam or gauze through a small central access incision in the overlying plastic seal, thereby eliminating the need to redo the entire replacement process; after its replacement, a second adhesive sheet can be used to patch over the area.

As noted, NPWT systems are not a substitute for the proper surgical debridement and lavage of contaminated and infected open wounds. The author has found them most useful for large, deep-pocketed, contaminated and infected wounds. In general, they may be best reserved for more complex, advanced, or difficult wounds as well as grafting problematic areas (Figs 4-14, 4-15, and 4-16). While VAC systems are useful in the wound management of many problematic wounds, there are other methods to manage wounds efficiently and economically (see Chapters 5 and 6).

CONCEPT OF MOIST WOUND HEALING

Preserving and maintaining a moist wound environment in open wounds support the processes of wound healing. In contrast, a dry wound environment results in cellular trauma and slows healing. The body's natural exudate contains the cytokines and nutritional environment to support healing. Topical therapy is used to supplement and support the moist wound environment. Epithelial cell migration is facilitated by a moist environment: damage from desiccation is prevented and the hydrated wound surface helps prevent dry scab formation that impedes epithelial cell advancement. The moist wound environment supports granulation tissue formation and the associated myofibroblast population essential to healing by second intention.

There are a number of topical agents supplied in jars or dispensing tubes. They are applied directly to an open wound surface; in many cases a low-adherent dressing and bandage are required to help maintain their continuous contact with the injured tissues. In select cases, such as a superficial burn on an area difficult to cover with a bandage, the topical agent may be simply painted on the surface to prevent desiccation of the traumatized tissues. Many of the topical agents discussed in this chapter are incorporated in commercial wound dressings, many of which contain an outer synthetic membrane (see Chapter 5).

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FIG. 4-15 (A) Traumatic bite wound to the lateral thorax of a 4-year-old female dachshund with skin loss and a secondary open pneumothorax. (B) The wound was debrided and a VAC was applied; stoma paste was applied under the Ioban™ dressing (3M Co., St. Paul, MN) to ensure an airtight seal. (C) The appearance of the wound 72 hours after initiating VAC. Note that the ribs were approximated with monofilament polypropylene to close the rent in the thoracic wall. (D) The wound was closed and the patient made an uneventful recovery. (Case photographs courtesy of Gary Ellison DVM, DACVS.)

TOPICAL WOUND-CARE PRODUCTS

Overview

Historically, a variety of topical agents have been used in managing open wounds and the list of these products is rather long. Some of the more unusual remedies noted by Rudolph and Noe in their book *Chronic Problem Wounds* (1983; see Suggested Reading) have included carrots, turnips, bread, egg white, gold leaf, aluminum foil, linseed oil, pectin paste, silicone spray, chlorophyll, tannic acid, yeast extract, wine and vinegar, frankincense and myrrh, mud, oil and grease, beer, dung, fresh meat, heavy metals, saliva, sesame oil, willow leaves, rust, soot, onion, garlic, cinnamon and other aromatic spices, licorice root, and rose water. Both potato peelings and banana leaf have been used as effective burn dressings and are an economical alternative used in developing countries. There is a continuing interest in the use of honey and sugar for topical wound care. Honey, in particular, has a number of desirable features in wound care. Unfortunately, the true efficacy of all topical products cannot be accurately assessed without

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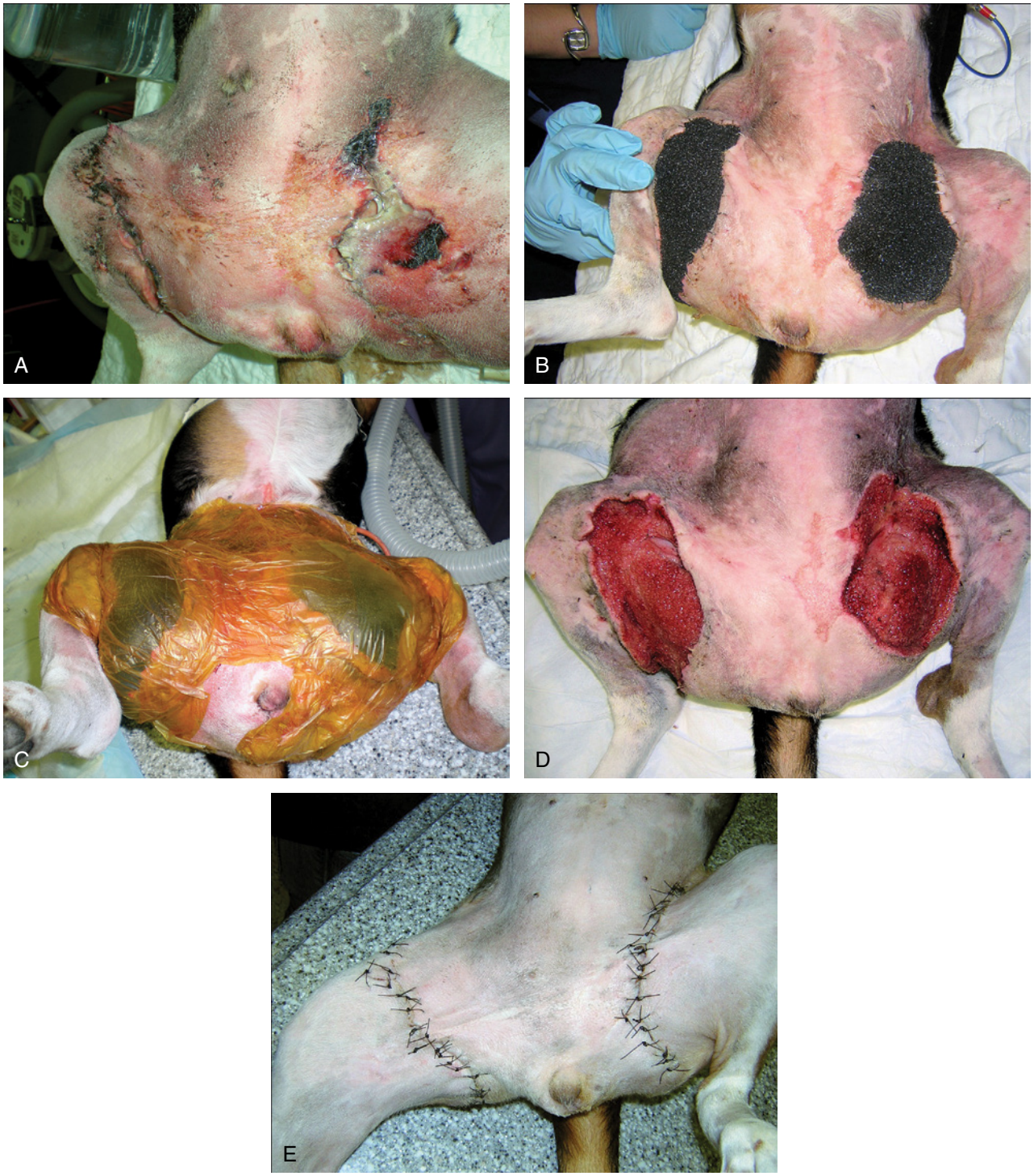


FIG. 4-16 (A) Photograph of a 5-year-old female beagle with bilateral inguinal wounds secondary to vehicular trauma. The wound was surgically closed 72 hours prior to presentation. Wound dehiscence was noted secondary to tissue necrosis and infection. (B) Following wound debridement, VAC foam was secured to the wound borders with surgical staples. (C) An Ioban dressing was applied over the wounds. Once secured to the skin bordering the wounds, −120 mmHg vacuum pressure was applied. (D) Five days postoperatively, 72 hours after initiation of VAC, the sterile foam and Ioban dressing were replaced. (E) Following formation of a healthy granulation bed, the wound was successfully closed. (Courtesy of Gary Ellison DACVS.)

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well-designed comparative studies. An excellent reference regarding wound-care products is Thomas's *Surgical Dressings and Wound Management* (2010; see Suggested Reading).

Wound-care products are a multibillion-dollar industry in human health care; the veterinary market is a mere fraction of this burgeoning market. In veterinary medicine, most information pertaining to wound-care products is largely based on professional experience. The lack of well-designed comparative studies of wound-healing products in dogs and cats is in large part due to a lack of research funding. Most pharmaceutical research uses rats, rabbits, and pigs. Variations in research protocols also make accurate comparisons of products difficult. Although clinical applicability of studies between species is open to debate, research results can serve as general guidelines regarding the use of wound-care products in veterinary patients. *In vitro* study results may not correlate with the *in vivo* efficacy of a given product. The frustration in the lack of comparative studies of the multitude



Fig 4-17 (A) Traumatic skin loss involving the right hindlimb in a cat. Following debridement and open wound management, a healthy granulation bed formed. (B) A full-thickness hand mesh graft was secured to the recipient bed followed by placement of a nonadherent dressing (Adaptic™, 3M.). Triple antibiotic ointment was applied to the dressing; skin staples were used to secure the dressing. (C) The polyurethane foam being folded over the grafted area using skin staples. (D) Progressive encapsulation of the grafted area with polyurethane foam using skin staples. (E) The foot is placed over the adherent plastic sheet cover. The left half of the sheet is folded over the polyurethane and adheres to the right side of the sheet. (F) Coloplast stoma paste is applied to the circumference of the upper sheet to help prevent any air leak. (G) An opening in the plastic membrane is created with a no. 15 scalpel blade prior to placement of the vacuum disc and tube. (H) The adherent disc is fixed over the opening. Activation of the vacuum pump removes the air, collapsing the polyurethane film and plastic membrane around the embedded grafted area. The excess overlapped plastic sheet is trimmed off. (I) The long vacuum tube was secured under a cotton tubular stockinette vest. (J) Front view of the Freedom V.A.C. control panel. (K) Back view of the V.A.C. displaying the disposable canister that retains any fluid accumulated from the surgical area. (L) The graft approximately 1 week later. The V.A.C. was removed after 72 hours and replaced by a conventional graft bandage.

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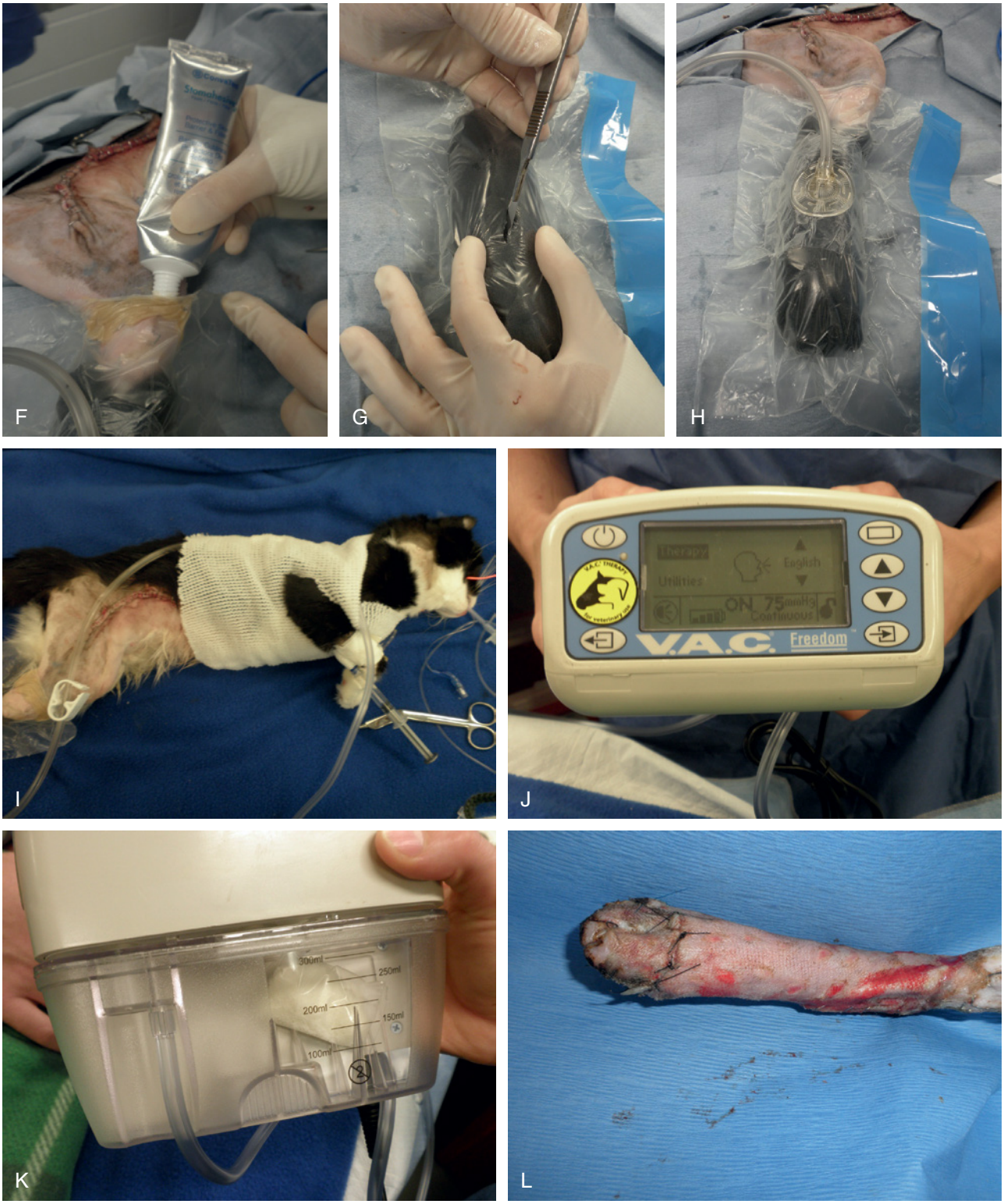


Fig 4-17 (Continued)

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of dressings offered has also been noted in the human literature.

Problems with Veterinary Medicine and Current Research on Wound Healing

- Species differences
- Variations in wound depth, size, and body location
- *In vivo* vs. *in vitro*
- Experimental vs. clinical wounds
- Clinical case variables
- Research design flaws
- Limited number of subjects

There is a true need for evidence-based medicine, allowing us to incorporate new information and technology and enabling veterinarians to integrate the best research evidence with our clinical expertise. The high cost of research often prohibits larger controlled studies.

Wound-healing models for assessment of epithelialization normally are based on the creation of partial-thickness skin wounds in research animals using a dermatome. (Most wound closure in humans relies more heavily on epithelialization than on wound contraction.) Partial-thickness skin defects epithelialize in a fashion different from full-thickness wounds (see Chapter 2).

In fur-bearing animals, second-intention healing is often dominated by myofibroblastic contraction. Because epithelialization occurs independent of wound contraction (and vice versa), research pertaining to rates of epithelialization often fails to address rates of wound contraction. Providing an optimal environment for epithelialization may not necessarily be ideal for wound contraction. For example, rigid adherent dressings may impair the centripetal movement of skin (splinting the skin margins) but provide a moist environment for epithelialization.

Most wound-healing studies for humans focus on epithelialization. Except for a few body areas, epithelialization is generally considered a more important part of second-intention healing for humans. By contrast, wound contraction in veterinary medicine is more important for closing most wounds in fur-bearing animals.

As discussed in Chapter 3, initial wound management is directed at removing devitalized tissue and contaminants, thereby improving the likelihood that earliest possible wound closure can be achieved. In turn, veterinary clinicians seek out the simplest effective means of closing the wound and restoring function to the injured area. Most open wounds in small animals in fact heal using the basic wound-care principles outlined in Chapter 3. Confusion often arises when attempting to select the best wound-care product for more problematic wounds from an array of topical agents currently available in the health-care market. This is especially evident in chronic wound care. The wide variety of topical products available adds to the confusion regarding which products to select. Many veterinary brochures demonstrating the superior "before and after" benefits on clinical cases do not always hold up to closer clinical scrutiny. With a lack of accurate comparative research, veterinarians are naturally inclined to use products they have had success with in the past, but look for other options only when results are suboptimal for a given patient.

In determining the most appropriate topical wound product, there are a few basic questions to consider:

- Is there devitalized tissue or tissue of questionable viability?
- Is the skin wound partial or full thickness?
- Is infection present or is it a significant concern?
- What is the volume of exudate?
- What stage of wound healing is present?
- Is wound healing progressing normally?

These questions will help direct the clinician to select the most appropriate topical agents to consider for managing an open wound. Devitalized tissue will require removal surgically or by the use of topical debridement agents (discussed later in this section). Infection must be managed or prevented, often with topical/systemic antibacterial medications. Otherwise healthy wounds normally require a protective moist environment to support the normal healing processes leading to wound contraction and epithelialization of the defect. The volume of exudate produced will impact the type of dressing or bandage used to cover the wound as well as the frequency of bandage changes. Delayed healing dictates elimination of potential causes and the possible use of topical agents to "jump start," enhance, or supplement the processes of wound healing. In a number of cases, surgical closure of the wound can preclude the cumulative expense of topical agents, dressings, bandage materials, appointments, and transportation costs in more problematic wounds.

General Definitions to Remember

Aerosols: Medicinal agents incorporated in a suitable solvent and packaged under pressure with a propellant. Wide, uniform dispersion and ease of application are advantages to the use of aerosol compounds.

Cleansing agents: A broad class of agents used to facilitate the removal of debris and contaminants from the surface of the skin or open wounds. Agents may contain surfactants, antibacterial agents, or particulate materials to facilitate wound cleansing prior to open wound management or surgical closure.

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Cream: A water–oil emulsion containing a drug or chemical. Evaporation of the water leaves an oily film. Creams often are easier to apply than ointments.

Collodion: A drug in an ethereal solution of cellulose acetate. After application the ether evaporates, leaving a flexible coating on the skin surface.

Gel: A clear, jelly-like topical agent, usually with a greaseless water-soluble base. Medicinal agents may be dispersed in the base.

Liniments (braces): Liquid or semi-solid preparations to be applied to the skin with rubbing (inunction). Most contain counter-irritants to relieve muscle or tendon pain. Liniments are more commonly employed in horses.

Lotion: A solution or suspension of soothing substances applied to the skin without friction.

Ointment (salve, unguent): A semi-solid greasy preparation in which the drug is dispersed in a suitable base; the base may be an oleaginous substance (petroleum, lard, or lanolin) to which the medication is added. Ointments also may have a water-soluble base, such as polyethylene glycol. Ointments normally are denser and less easily spread over the skin or wound surface than are creams and gels.

Topical Enzymatic Debridement Agents

Enzymatic debridement usually refers to the topical application of proteolytic enzymes to degrade nonviable proteins within the wound (see Table 4-2). Collagen fibers form attachments between the viable wound bed and overlying necrotic tissue; degradation of these collagen bonds facilitates separation of the necrotic tissue. Enzymatic debridement agents are usually applied to remove residual necrotic tissue in conjunction with surgical debridement. In humans, they may be considered for patients too ill for surgical debridement. It must be noted that the use of papain is not approved by the US Food and Drug Administration (FDA) for use in wound care, due to adverse reactions reported in humans. Outside the United States papain products may be available; it is important to review the literature on their safe use.

More current research in the European literature has noted that a proteolytic enzyme (anacaulase bcdb) enriched in bromelain (NexoBrid) is effective in the rapid and selective debridement of necrotic tissue in thermal wounds, without injury to the adjacent viable tissues. The proteolytic enzymes in NexoBrid are a mixture of enzymes from the stem of *Ananas comosus* (pineapple plant). It is approved for use as a topical gel in adults with partial- and full-thickness burns; it has also been used safely in children 6 months to 18 years of age. It has been approved for use in the United States.

Enzymatic debridement is considered a *selective method of debridement* since it specifically targets devitalized tissue only, sparing the adjacent viable tissues. (As a comparison, wet-to-dry dressings are considered nonselective, since this technique can remove viable tissues adjacent to the necrotic tissues.)

Advantages of selective debridement include little or no hemorrhage or pain, and the avoidance of any trauma to important tissue structures during surgical debridement. They may be useful in patients with bleeding disorders or those at risk with surgery/anesthesia. However, careful surgical debridement can rapidly eliminate major amounts of devitalized tissue; this may enhance the efficacy of enzymatic agents or eliminate their need.

Some enzymatic debriding agents are quite expensive, which may preclude their routine use in veterinary practice.

In the natural healing process (autolytic debridement), collagenase and other proteolytic enzymes within the wound break the peptide bonds in collagen to facilitate its detachment from the wound surface. Some topical agents are designed to facilitate autolytic debridement by providing an optimal wound environment for this to occur.

Enzymatic debridement is most commonly reserved for use in human patients that are not suitable candidates for surgical debridement. Because these enzymatic agents do not damage viable tissues, they can be used in areas where the bleeding, pain, and collateral damage associated with surgical debridement are best avoided. Removal of a necrotic eschar can be facilitated with the use of collagenase, papain, or anacaulase. Fibrinolysin is useful for the removal of fibrin or blood. Incising or cross-hatching the surface of necrotic eschars can facilitate topical enzyme penetration.

Surgical debridement is more effective than enzymatic debridement for the rapid removal of large areas of necrotic tissue, especially in septic patients. The more potent enzymatic debriding agents can be expensive to use and normally require a dressing or bandage wrap to assure their prolonged contact with the exposed wound surface. As noted, papain-based products are not approved by the FDA for use in the United States. Pharmaceutical websites are available for readers interested in these products.

Topical Products Promoting Autolytic Debridement

Autolytic debridement (necrotic tissue autolysis) refers to the body's natural process of debridement at the cellular level using the endogenous enzymes released in the wound. In

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TABLE 4-2 Enzymatic debridement agents.

Anacaulase	NexoBrid® gel (Barda–MediWound Ltd., Yavne, Israel; previously called Debrase Gel Dressing, DGD). *Application:* Anacaulase bcdb enriched in bromelain. Derived from the pineapple plant (*Ananas comosus*). Applied as a topical gel with rapid action within hours of application.
Papain–urea	Accuzyme® ointment (Healthpoint Ltd., Fort Worth, TX); Ethezyme® (Ethex Corp., St. Louis, MO); Kovia™ ointment (Stratus Pharmaceuticals, Inc., Miami, FL). *Application*: Papain is derived from the papaya (pawpaw), *Carica papaya*. The proteolytic enzymes papain and chymopapain are present in this fruit. The activity level is over a pH range of 3–12. Urea molecules disrupt cross-linking bonds in collagen, allowing the proteins to unfold. Unfolding of the collagen fibrils allows the enzyme papain to digest the exposed proteins. Cross-hatching of a thick eschar is necessary to facilitate penetration into the deeper tissues. A layer of ointment is applied to the wound and covered with a dressing. Debris is flushed from the wound and the ointment reapplied once or twice daily. Papain may be inactivated by salts of heavy metals (lead, mercury, silver). Hydrogen peroxide also inactivates this enzyme. *Not approved for use in the United States*.
Papain–urea, chlorophyllin copper complex sodium	Panafil® and Panafil SE (Healthpoint); Ziox™ ointment (Stratus Pharmaceuticals). *Application*: In addition to papain–urea, chlorophyllin copper complex (CCC) reduces fibrin formation, reportedly facilitating macrophage migration and fibroblast activation for collagen deposition. Copper reportedly enhances the structural integrity of the deposited collagen matrix. CCC is also reported to promote healthy granulation tissue, control local inflammation, and reduce wound odors. CCC inhibits the hemagglutination and inflammatory properties of protein degradation products in the wound, including the products of enzyme digestion. Wound cleansing precedes application of the ointment, once or twice daily. Longer intervals between redressings (2–3 days) also may prove to be satisfactory, depending on the condition of the wound. *Not approved for use in the United States*.
Trypsin, balsam of Peru, castor oil	Granulex® V (Pfizer Animal Health, Exton, PA) and Xenaderm™ (Healthpoint) (Fig. 4-18) are no longer manufactured, but BCP Wound-V® (BCP Veterinary Pharmacy, Houston, TX) contains the same basic agents. *Application*: Balsam of Peru is a capillary bed "stimulant" and has mild antibacterial properties. Castor oil forms an oily barrier, providing a moist environment for promoting epithelialization. Providing a moist environment also reduces local wound pain. Trypsin has limited efficacy as an enzymatic debriding agent.
Collagenase	Santyl® (Smith & Nephew). *Application*: Enzyme is derived from the fermentation of *Clostridium hemolyticum*. Optimal pH range is 6–8. Avoid use with heavy metal ions or detergents. Compatible with Dakin's solution and hydrogen peroxide. Apply once per day. Thick eschars should be incised (cross-hatched) with a scalpel blade to facilitate penetration. Remove as much loosened necrotic tissue as possible to facilitate enzymatic debridement. Wounds are cleansed prior to application of ointment. Topical antibiotic powder may be applied to the wound prior to ointment application. The medicated wound is covered with a dressing. The bandage is changed on a daily basis. (Note that there are other collagenase compounds that vary in source and concentration. Collagenase from *Vibrio alginolyticus* also has been used in clinical studies for wound debridement.)
Desoxyribonuclease with fibrinolysin	Elase® (Pfizer Animal Health). *Application*: Fibrinolysin is derived from bovine plasma; desoxyribonuclease is derived from bovine pancreas. Their combined actions include breakdown of fibrinous material and nucleoprotein (DNA). Fibrinolytic activity is primarily directed at denatured protein. The wound is cleansed prior to application once or twice daily. Elase would appear to be less commonly employed than the other enzymatic debriding agents mentioned.

a moist wound, proteolytic enzymes and phagocytic cells liquefy necrotic tissue, allowing macrophages to engulf and digest this tissue debris. Autolytic debridement is best employed for wounds retaining residual amounts of necrotic tissue, including wounds after surgical debridement of the bulk of the necrotic tissue present. However, it is not advisable for deep and surrounding wound infections as it may lead to a more severe infection.

Autolytic debridement is considered a selective or gentler method of debridement since it specifically targets nonviable tissues only, sparing adjacent viable tissues. Advantages include less hemorrhage, pain, and collateral trauma that may be associated with surgical debridement. However, there is a risk of promoting infection with autolytic debridement, particularly with the presence of significant amounts of devitalized tissue.

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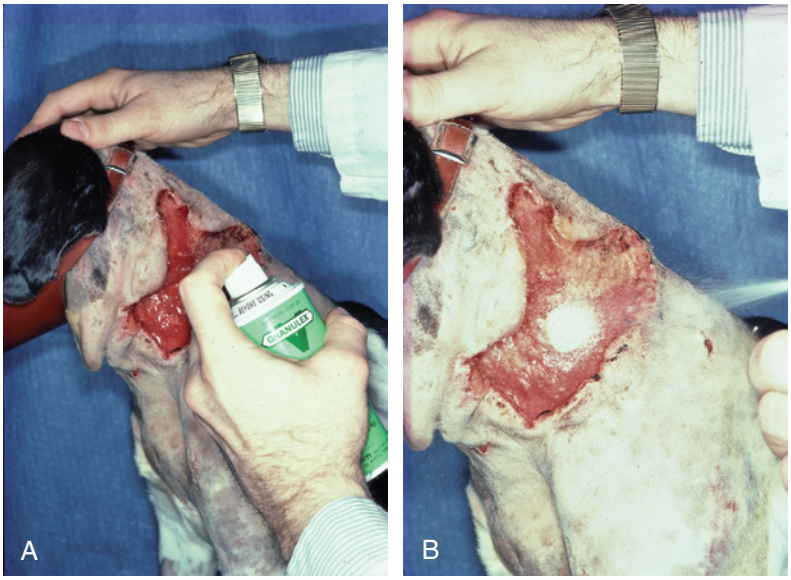


FIG. 4-18 (A) Application of Granulex enzymatic spray, containing trypsin, balsam of Peru, and castor oil. Granulex is no longer manufactured, but a similar product, BCP Wound-V, contains the same basic agents. (B) Topical sprays are easy to apply without contaminating the nozzle for future use. A nonadherent dressing and light bandage were used to help keep the medication in continuous contact with the wound surface.

There are a variety of topical hydrophilic wound gel products available for use in humans, most of which are applicable to animals (see Wound Gels). Moisture-retaining gels and dressings can be used to promote this form of selective debridement. When using topical gels and ointments, a low-adherent dressing is normally applied followed by a bandage. Many of these topical gel-like compounds also have been laminated to synthetic membranes, forming a dressing platform for easier application to flat wound surfaces. Semi-occlusive and occlusive moisture-retaining barrier dressings may include hydrocolloids, hydrogels, and alginates (see Dressings, Chapter 5).

Hydrogels and Hydrocolloids

A *gel* is a jelly-like colloid in which water is dispersed; a *hydrogel* therefore is a gel where water is its liquid constituent. A hydrogel is a specific form of *colloid* in which the particles trap the aqueous medium. The term *xerogels* refers to compounds applied in a dry state that subsequently form a gel by absorbing tissue exudate. Chemically, hydrogels are basically hydrophilic three-dimensional molecules. They are composed of various products, including carboxymethylcellulose (CMC), alginates, pectin, and polyvinylpyrrolidone (PVP). Other compounds added to hydrogels include carrageenan, chondroitin sulfate, dextran sulfate, chitosan, polylysine, collagen (gelatin), chitin, fibrin, agrarose, and pullulan. (The absorptive properties of hydrogels mean they also have been used as thickening agents in food and medicines, as well as incontinence and feminine hygiene products. They are used too as a topical lubricant for urinary catheters.) Hydrogels can be used to distribute medications to the wound. They often contain 80–90% water and provide moisture to the wound surface; however, they have limited ability to absorb wound exudate.

The term *hydrocolloid* was coined in the 1960s for gel-forming absorbent polymeric materials designed to adhere to mucosal surfaces (mucoadhesives). *Hydro-* refers to the hydrophilic nature of the colloid substrate rather than the presence of water in the hydrocolloid gel. In the 1980s, hydrocolloid was used to describe a class of materials that contain a gel-forming agent, usually including carboxymethylcellulose that is dispersed in a substrate of adhesives and tackifiers. Pectin and gelatin are frequently added to CMC. Hydrocolloids are commonly incorporated into dressings and have been used in a paste form (see Chapter 5). The term *colloid* refers to a mixture of two substances: the dispersed phase (colloid) is distributed into a dispersion medium. *Hydrosol* refers to water-insoluble particles or insoluble liquid colloidally dispersed in water. Besides CMC, hydrocolloids can include alginates, chitan, chitosan, and hyaluronidase (glycosaminoglycan). Hydrocolloids are designed to absorb and contain wound exudate, thereby retaining moisture to promote healing. Confusion arises with these terminologies, since a variety of gel-forming fibers are used both in hydrogel and

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hydrocolloid dressings. There are multiple formulations of these products on the market, making comparison of their clinical efficacy difficult or impossible.

Wound Gels

Gel application is restricted to the wound surface since prolonged exposure to the adjacent skin can cause skin softening secondary to overhydration. A topical dressing and light bandage usually are required to help maintain gel contact with the wound bed. Gels will soften and may drain from beneath the overlying wrap, depending on the location of the wound. According to the condition of the wound, gels normally are applied once or twice daily.

Gels can be used to support autolytic debridement as described earlier, or as a topical agent on healthy granulation beds or partial-thickness skin wounds (Fig. 4-19). The following is a partial list of gels available on the market:

- Curafil® Wound Gel (Kendall Healthcare Products Co., Mansfield, MA)
- Intrasite™ Gel hydrogel (Smith & Nephew)
- Nu-Gel™ Hydrogel with alginate (3M Science)



FIG. 4-19 (A) Curafil hydrogel. Hydrogels are applied liberally to the wound and usually are covered with a nonadherent dressing and bandage wrap. Hydrogels will have a greater tendency to drain into the secondary bandage layer and may require more frequent application, especially during early wound management. (B, C) Example of a hydrogel (CarraVet®, Carrington Labs, Palmetto, GA) with a tube of generic triple antibiotic ointment. Hydrogels will hydrate tissues but have limited ability to absorb significant amounts of discharge. Triple antibiotic ointment has a white petrolatum base, combined with the antibiotics bacitracin zinc, neomycin sulfate, and polymyxin B sulfate. The oily film helps provide moisture retention (semi-occlusive effect). The ointment and wound discharge will be wicked into the secondary bandage layer over time.

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Other agents can be added to a gel base to enhance its healing properties, including maltodextrin, acemannan (aloe vera), collagen, tripeptide copper complex, chitosan, and alginates. A number of companies now sell a variety of hydrogels that include these compounds. Hydrocolloids are commonly used in the form of wound dressings (Chapter 5).

Confused? You should be, since companies mix a variety of products in their topical gels, colloids, and dressings, blurring the selection process for human and veterinary doctors. A relative lack of comparative studies in the dozens of products available renders it difficult to select the best product. Similarity in design does not mean that all products are equal.

Hydrophilic Pastes and Powders

Hydrophilic pastes and powders are available to fill *exudative* wound cavities or pockets. Many of the powders and pastes contain components of hydrocolloid dressings. (Sugar paste formulations are discussed later.) As they absorb discharge from the wound surface they form a gel. Like the hydrogels noted earlier, they facilitate autolytic debridement. Examples include DuoDERM® Sterile Hydroactive® Paste (Convatec); Granuflex® sterile paste and powder (Convatec); and Comfeel® sterile powder and paste (Coloplast Corp., Holtedam, Denmark). As noted earlier, a topical dressing and bandage are normally used to contain or "corral" the product to the wound surface.

Wound-Care Products: Do They Enhance, Accelerate, or Promote Wound Healing?

By definition, the word *enhance* means to increase, make greater, or augment. *Accelerate* means to increase the speed of, to cause to occur sooner than expected, or to cause to develop or progress more quickly. *Promote* means to contribute to the progress or growth of something. These terms are often used in describing the benefits of many wound-healing products, not always accurately. Most wounds managed in practice heal uneventfully using basic wound-care techniques. Delays in healing may be the result of a variety of factors that are discussed in greater detail in Chapter 6.

Maltodextrin is a D-glucose polysaccharide derived from the hydrolysis of corn or potato starch. It absorbs moisture, forming a protective cover on wound surfaces. It is reported to have chemoattractant properties, attracting neutrophils, macrophages, and lymphocytes into the wound; this in turn increases cytokine levels. Maltodextrin also has been reported to have antibacterial and bacteriostatic properties. Hydrolysis of this polysaccharide may provide a source of glucose to the cells. Maltodextrin powder with 1% ascorbic acid (Multidex®, DeRoyal Industries) can be used for enhancing autolytic debridement and as a topical agent in the latter phases of wound healing. It can reduce odor, swelling, and infection and may enhance epithelialization. It also can be used as a hydrophilic powder in exudative wounds. The gel form of this product is used for dry wounds. A 5–10 mm layer of powder is secured with a nonadherent, nonocclusive dressing. A topical dressing and supportive bandage are necessary to maintain contact of a 5–10 mm layer of maltodextrin compounds with the wound surface. Saline is used to flush residual gel from the wound prior to reapplication on a daily basis.

Acemannan (acetylated mannan or mannose) is derived from the aloe vera plant. It reportedly serves as a growth factor and increases levels of the cytokines (interleukin-1, tumor necrosis factor-α). These factors in turn are known to stimulate fibroblast proliferation, epidermal growth and motility, neovascularization, and collagen deposition. Acemannan may also bind growth factors, prolonging their stimulating effect on granulation tissue. In gel or dry (free-dried powder wafer) form (CarraVet or CarraSorb® M, Carrington Labs) it can be used for autolytic debridement and throughout the management of open wounds (Fig. 4-19). The hydrophilic powder is commonly used for exudative wounds in a manner similar to that of the other products in this section. Its greatest effect may be during the first 7 days of application.

Bovine collagen (type I) gels, powders, sheets, wafers, and sponges have been employed in open wound management, including Medifil® II (BioCore Medical Technologies, Inc., Elkridge, MD); Collasate™ (PRN Pharmacal, Pensacola, FL); and hyCURE® (Hymed Group, Bethlehem, PA). The hydrophilic property of topical collagen products helps maintain a moist wound environment for autolytic debridement while possibly providing a protective environment for epithelialization in the latter phases of healing (Figs 4-20 and 4-21). It may initiate an inflammatory response, stimulating fibroplasia and providing a scaffold for fibroblast migration. Hydrolyzed collagen may provide a substrate for fibroblasts and subsequent collagen deposition. Like other topical agents, a dressing and outer bandage are required to help maintain product contact with the wound; bandages are changed daily. Collagen powders are highly absorptive: CollaMend is reported to absorb up to 60 times its weight in fluid. The wound surface is cleansed and slightly dabbed of excess moisture before applying the collagen powder. A layer up to ¼ inch (6 mm) thick may be used, depending on the amount of exudate. Highly exudative wounds may be covered with gauze to help retain the fluid. A retention dressing is used to maintain collagen contact with the wound bed. The collagen

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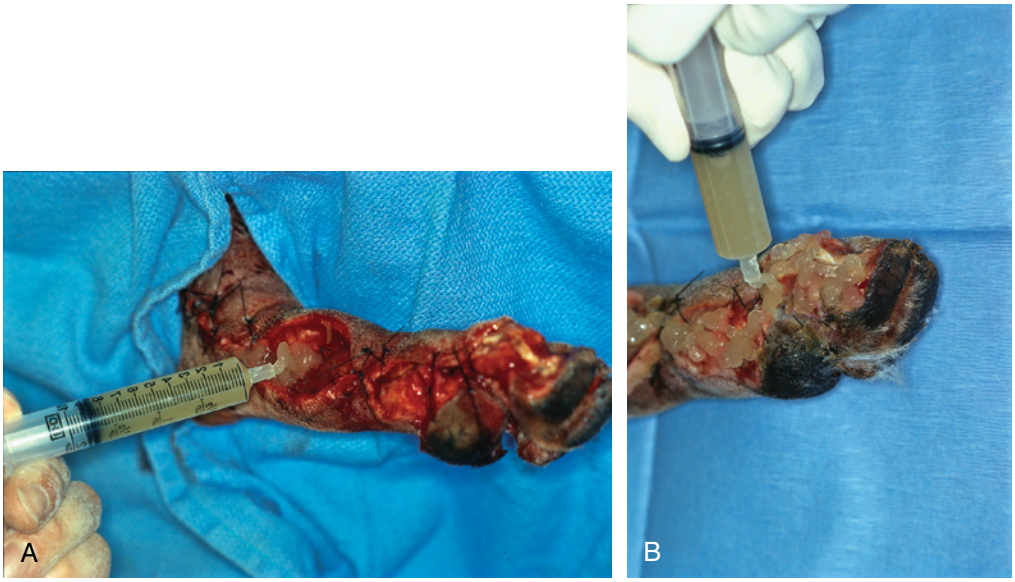


FIG. 4-20 (A, B) Application of collagen gel to shearing wounds using a dispensing syringe. Following application, a nonadherent dressing and light bandage were used to keep the gel in continuous contact with the wound surface.

powder may be flushed with saline and the wound dabbed of excess moisture before reapplication on a daily basis. Less frequent changes are required as the condition of the wound improves.

Tripeptide copper complex (glycyl-L-histidyl-L-lysine-copper) has been reported to stimulate several mechanisms essential to wound healing, including stimulating neovascularization, collagen deposition, wound contraction, and epithelialization. It is a chemoattractant for mast cells, monocytes, and macrophages. Copper is needed by enzymes involved in collagen cross-linking. Only one study in dogs demonstrated greater granulation tissue formation with its use at day 7 compared to the vehicle/base and control. However, by days 14 and 21 there was no notable difference in the contraction and epithelialization of the four groups. (Despite early granulation tissue formation, another interpretation of the results would suggest that tripeptide copper complex did not improve the final outcome of wound healing in this report.)

Chitosan (glucosamine, polysaccharide) is primarily derived from the chitin exoskeleton of shellfish. It is a linear copolymer of linked beta-glucosamine and *n*-acetyl-d-glucosamine that is usually derived from the chitin-rich crab shell. Topically, it is reported to enhance the function of inflammatory cells (neutrophils, macrophages), fibroblasts, and cytokines (transforming growth factor, platelet-derived growth factor). There is one small study using three research dogs that claims beneficial healing results. Chitosan is commonly added to a variety of wound dressings. A chitosan dressing currently available for wound care is HemCon® (Tricol Biomedical, Inc., Portland, OR).

Natural Products

A natural product, by definition, is any compound or substance found in nature; in a broader sense, natural products include any substance produced by life. Many of the topical products discussed in this chapter can be considered "natural," including chitosan, collagen, alginates, and so on. This section focuses on a few of the basic natural products used in wound care, including honey, sugar, yeast extract, and aloe vera. Chapter 6 discusses the use of potato peel and banana leaf dressings.

Honey and Sugar

Honey has a broad history in its use in wounds. There are numerous historical references to its use in early Sumerian clay tablets (4000 years ago) and ancient Egypt (1700 BCE), in ancient Chinese medicine, and among Native Americans, ancient Greeks, and east African tribes. Today there are a variety of honey products marketed for wound care.

Honey is a supersaturated solution comprising sugars (38.2% fructose, 31% glucose, 7.35% maltose, 1.3% sucrose, on average) with small amounts of amino acids (50% being proline), minerals, organic acids, vitamins, and enzymes. The composition of honey does vary according to the geographical source. Of interest are the enzymes contained in honey, including *invertase* – converts sucrose to glucose and fructose; *amylase* – breaks down starch; *glucose oxidase* – converts glucose to hydrogen peroxide and gluconolactone, which in turn forms gluconic acid; *catalase* – converts peroxide to glucose oxidase, oxygen, and water; and *acid phosphatase* – separates

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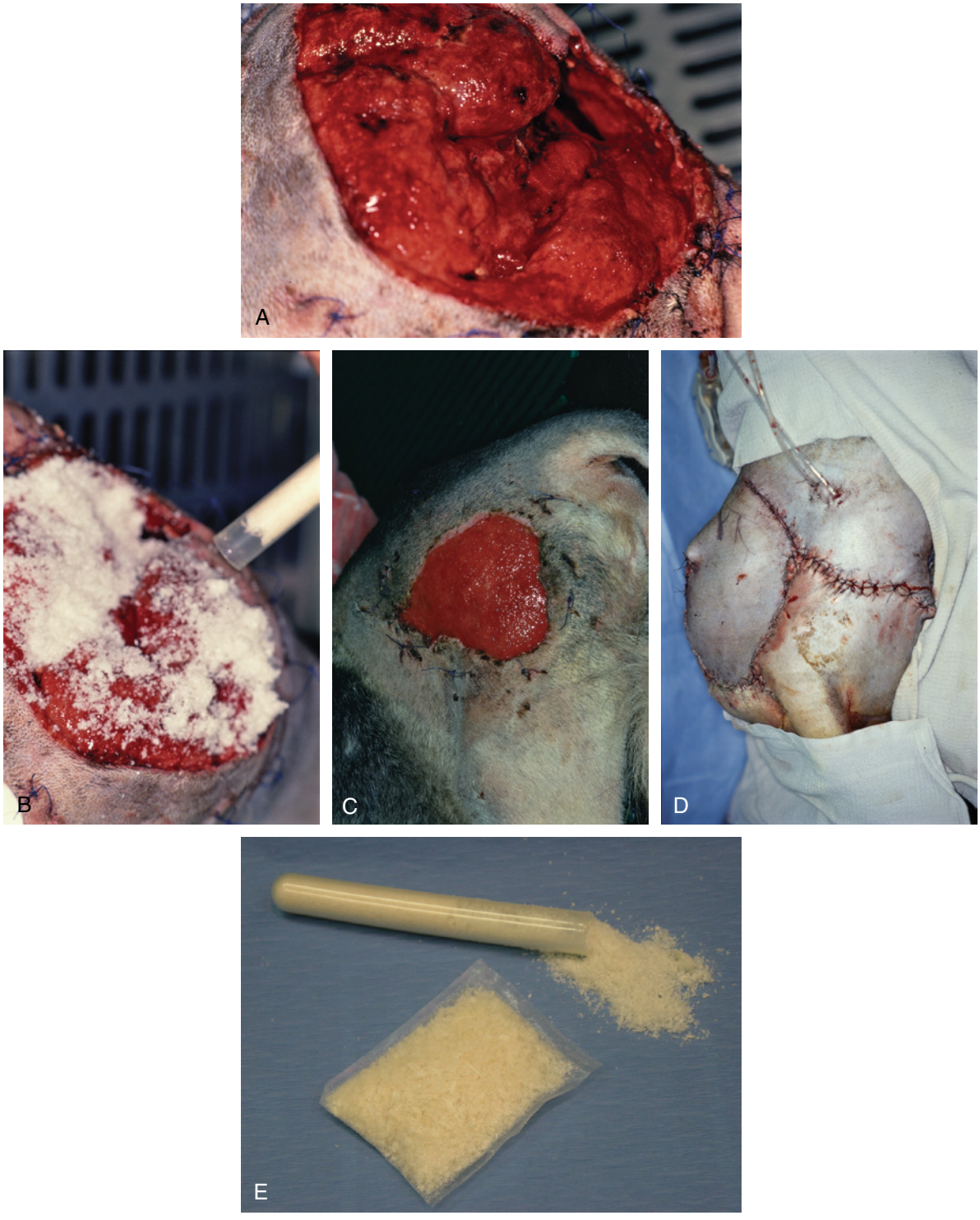


FIG. 4-21 (A) Skin loss secondary to vehicular trauma. The large skin wound was overlying the left trochanteric area in this dog. (B) Following surgical debridement of the necrotic skin, collagen powder was applied to this moist wound surface, followed by a nonadherent dressing secured with a padded tie-over dressing. (C) Development of a healthy granulation bed. (D) Closure with a left deep circumflex iliac axial pattern flap (dorsal branch). (E) Collagen powder also can be applied to cavitated wounds in a packet form ("tea bag"); a clear, perforated Telfa membrane contains the collagen medication.

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inorganic phosphates from organic phosphate. The low pH (3.5–6.0) of honey is the result of the multiple organic acids present.

The antibacterial activity of honey is the result of several factors (*inhibins*). Hydrogen peroxide is produced by glucose oxidase when diluted with water. Content varies with various honeys. A second antibacterial component found in honey is produced from the flowers of the New Zealand manuka bush (*Leptospermum scoparium*) or the jelly bush (*Leptospermum polygalifolium*) in Australia. The antibacterial properties of this "unique manuka factor" or UMF vary in different batches of honey. The antibacterial properties of the UMF can be rated by measuring its equivalency to dilutions of phenol (carbolic acid). In other words, the relative UMF antibacterial activity of a given source of manuka honey is rated by its relative equivalency to the comparable antibacterial activity of a corresponding concentration of a given phenol dilution. A classification of relative UMF concentration has been developed. For medical applications a basic rating of 10 has been proposed, although some batches of manuka honey can rise to a rating of 25. Unfortunately, this rating system can be misrepresented. It has been proposed that medical-grade manuka honey should have a "nonperoxide" equivalency of a 12% phenolic concentration. New Zealand manuka honey can have a wide range of potency from <2% to 58% phenolic antibacterial activity.

The UMF may be in part due to the compound *methylglyoxal* (MGO); an MGO concentration of 100 mg/kg is required in honeys used for medical applications. Unfortunately the MGO rating system is not considered accurate; MGO concentration and antibacterial activity are not linear. For example, doubling the MGO concentration does not result in a similar rise in the UMF value. Flavonoids and plant-derived phenolics also may be responsible for the honey's antibacterial properties.

Besides the antibacterial properties of honeys containing peroxide, and the nonperoxide UMF factor, the high acidity of honey has antibacterial properties. Honey has been demonstrated to be useful in treating the biofilm of infected wounds, neutralizing destructive free radicals in chronic wounds, and promoting healing processes. Wound-healing attributes reported for honey include stimulation of macrophage migration, angiogenesis, fibroplasia, and epithelialization.

Results in one study in humans noted that honey appeared to improve healing times in mild to moderate superficial and partial-thickness burns; however, it did not improve healing in chronic leg ulcers. In a canine study (Repellin et al. 2021) on acute full-thickness wounds, there was no evidence to support its efficacy to promote healing by second intention.

Raw honey may also contain bacterial and fungal contaminants, including anaerobic spore-forming organisms. It is for this reason that medical honey in all its forms must be sterilized for human use, despite the fact that the relative risk of infection is considered low. Based on the considerable research that demonstrates the benefits of this natural product, veterinarians should take a more serious look at the use of medicinal honey in wound management. The use of honey dressings is further discussed in Chapter 5.

Both honey and sugar are hygroscopic agents with a high osmolarity that have been used to reduce local tissue edema. This hyperosmolarity can inhibit or kill bacteria while promoting granulation tissue.

The high sugar content may provide an alternate source of energy both to the viable tissues and to bacteria. Bacteria may utilize glucose over the amino acids present in the wound and may in turn produce lactic acid rather than malodorous discharge from putrefaction of the nonviable tissue proteins.

Unlike the beneficial antibacterial properties noted in honey, sugar primarily reduces bacterial proliferation due to its high osmolarity, thereby lowering the moisture content in the wound. Sugar also is reported to enhance macrophage migration, granulation tissue formation, and epithelialization. Various sugar products are not sterile; powdered sugars contain calcium phosphate or sodium aluminum silicate to prevent caking during storage. Powdered sugars can be used to form a topical paste to apply to open wounds.

APPLICATION OF HONEY AND SUGAR

In human wound care, honey dressings (sterilized by ionizing radiation) are the most common method of applying honey to a wound. Large areas of necrotic tissue are best surgically debrided prior to application of honey or sugar. Both should be applied liberally to the wound, followed by the application of a dressing and a thick outer absorptive layer to help retain discharge from the wound surface. Bandage changes may be initially performed daily and altered according to the clinician's assessment of the wound. Wounds are lavaged and inspected prior to dressing reapplication. Gauze also can be soaked in honey to simplify its application to the wound, keeping in mind that the gauze may adhere to viable tissues and cause pain and irritation during its removal.

Sugar can be poured into the wound with a 1 cm plus layer over the wound surface, followed by a topical dressing and bandage wrap. Bandage changes also may be performed daily and modified according to the wound's condition. Granulated sugar has a tendency to spill and isolating it to the wound surface can be problematic. A sugar paste is easier to apply. Gordon reported in 1985 sugar paste formulations (thin or thick paste variations) with antibacterial properties even when diluted by 50% from wound serum. One sugar paste formula is made by mixing two commercially available sugars found in grocery stores. Previously reported for use in humans, the

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following sugar paste was advocated: 400 g powdered (caster) sugar, 600 g icing (confectioner's) sugar, 480 ml glycerin BP, and 7.5 ml 3% hydrogen peroxide. (There are a number of sources of glycerin on the internet.) A commercial sugar paste (U-PASTA™, Kowa Co. Ltd, Nagoya, Japan) containing 70% sugar and 3% povidone–iodine was demonstrated to inhibit bacterial growth and promote reepithelialization in one study. The sugar paste is applied liberally and a topical dressing and bandage are used to maintain it in contact with the wound. The numerous documented advantages of (manuka) honey suggest it is a better choice than sugar. Nonetheless, sugar is an economical option that is readily available in the grocery store.

When a healthy granulation bed forms, surgical closure can be considered or open wound management continued with other topical products. Caution is required when using honey and sugar on large surface areas. Loss of fluid, protein, and electrolytes can be considerable, necessitating close assessment of the patient.

Live Yeast Cell Derivative

Live yeast cell extract (brewer's yeast, *Saccharomyces cerevisiae*) and shark oil were used in early formulations of Preparation H (Whitehall Laboratories, New York, NY). The yeast extract was reported to stimulate oxygen consumption, epithelialization, and collagen production in wounds. However, the current formulation of Preparation H no longer contains yeast extract or shark oil. Preparation H cream containing the live yeast extract Bio-Dyne (also referred to as LYCD or live yeast cell derivative) can be purchased from Canada over the internet. (Some individuals have used this LYCD formulation to effectively reduce the appearance of facial wrinkles in humans.)

Aloe Vera

Aloe vera extract has anti-thromboxane and anti-prostaglandin properties. It is useful to reduce inflammation (superficial burns), but may negatively alter the inflammatory phase when managing an open wound. Aloe vera is commonly added to a variety of commercial products. One randomized study in dogs and cats suggested that aloe, in a liquid (juice) or gel, improved wound closure in open wounds compared to the use of silver sulfadiazine as a control.

Exudative Wounds: Polysaccharide Beads, Glass Nanofibers

These products are generally used for managing exudative wounds; they are contraindicated in wounds with minimal discharge, since they would have a drying effect on the wound. The wounds normally have been debrided of most devitalized tissues and cleansed prior to their application. These products are used primarily in the early phase of healing to facilitate debridement of small areas of retained necrotic tissue and infected tissue debris.

Debrisan™ (Pharmacia & Upjohn Ltd., Milton Keynes, UK) comprises small nonbiodegradable polysaccharide beads that are 0.1–0.3 mm in diameter. The dextranomer beads will absorb four times their weight in tissue fluid and exudates. A minimum 3 mm thick layer is applied to the wound and covered with a retention dressing. At the time of dressing change, the beads are flushed from the wound surface prior to application of an additional layer of beads. As a result, Debrisan is used on moist, exudative wounds to draw tissue fluid and debris from the wound surface: a form of "internal flushing." Dressings are changed once or twice per day. As the wound improves, changes can be extended to alternate-day treatments.

Iodosorb™ (Smith & Nephew) is a variation of Debrisan made of 0.1–0.3 mm biodegradable cadexomer microspheres containing 0.9% w/w elemental iodine. The iodine is firmly held within the microsphere structure. Iodosorb ointment and Iodoflex™ dressings are also available. As with many iodine-containing preparations, care must be taken to avoid iodine absorption, especially when using these products on a large surface area or during prolonged periods of contact with the patient.

Borate glass nanofibers, resembling the appearance of fine cotton candy, have been introduced as a wound-healing product. They reportedly form a scaffold for trapping platelets, allowing the formation of a wound cover. The glass fibers are later absorbed by the body. The product is not used as a debriding agent *per se*. In the veterinary market it is sold under the trade name RediHeal™ (Avalon Medical, Stillwater, MN) to promote healing.

As mentioned, other pastes and powders also can be used in exudative wounds (see Hydrophilic Pastes and Powders earlier in this chapter).

THE MAGGOT AND THE LEECH IN WOUND CARE

Maggot Therapy

Maggot therapy, also called larval therapy, takes advantage of the natural process of certain fly larvae to ingest necrotic tissue. Infestation of wounds with maggots is called myiasis. The relationship between fly and host is divided into two categories: obligatory and facultative myiasis. Obligate parasites develop only on live hosts. Facultative parasites develop on hosts or carrion. *Cuterebra* sp. is one example of obligatory myiasis (Fig. 4-22).

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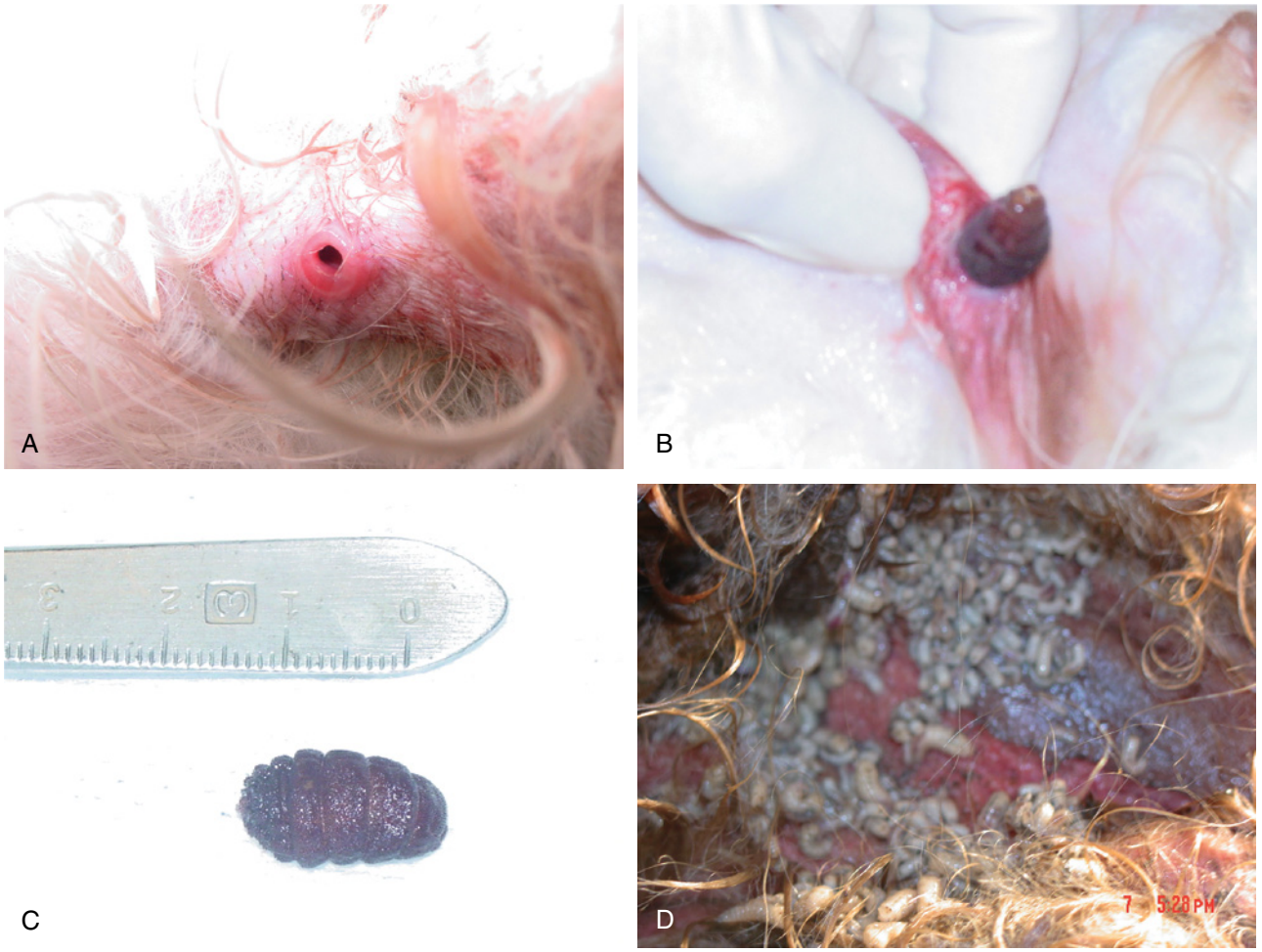


FIG. 4-22 (A) *Cuterebra* sp. in a young dog, located beneath the cervical skin. Note the small sinus opening. (B, C) The stout larva can be gently expressed from its cavity facilitated by the use of surgical forceps. The small subcutaneous pocket created by this larva is flushed with an antiseptic solution; the wound normally heals uneventfully. However, maggots can cause severe systemic illness in Yorkshire terriers and other small-breed dogs. (D) Infected skin wound containing maggots. Tissue necrosis, infection, and invasive fly larvae can result in life-threatening sepsis in small animal patients. Maggots can wander or migrate into other body regions; on rare occasions they also may invade adjacent body orifices, including the anus and vulva.

Ironically, myiasis or the infestation of the organs and/or tissues of animals in untreated wounds or due to medical neglect can lead to bacterial contamination and infection of the patient. Maggot therapy, however, employs the use of larvae raised in a controlled environment for medical use and employed under medical supervision.

Maggots ingest only dead cells, exudates, secretions, and debris. The release of proteolytic enzymes facilitates the liquefaction and subsequent consumption of necrotic tissue. The bacteria engulfed by maggots are destroyed in their digestive tracts.

Maggots are also useful in managing the biofilm that forms in chronic infected wounds. Second- and third-stage larvae of myiasis-producing flies have mouthparts capable of rasping the skin and inflicting considerable damage. Tissue trauma and secondary infection can result in extensive tissue destruction.

Not all larvae have an adverse effect on the processes of wound healing. As early as 600 BCE in India, maggots were reportedly used as a form of *biotherapy* to remove gangrenous tissue, thereby facilitating the process of wound healing. This technique may be particularly useful for chronic, problematic wounds in which effective debridement is difficult. Each maggot may consume up to 75 mg of necrotic tissue per day. Monarch Labs (Irvine, CA) is the exclusive supplier of disinfected, medical-grade maggots (*Lucilia* (*Phaenicia*) *sericata* or green blowfly) in the United States.

Maggot debridement therapy (MDT) has been used in veterinary medicine to a very limited degree. Many

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veterinarians have managed sick or debilitated pets infested by maggots; many of us have a negative visceral reaction to their use in wound care. With the advent of penicillin in the mid-1940s, the use of maggot therapy dramatically declined for managing infected wounds. In recent years there has been renewed interest in this rather unique form of wound care in humans. Maggots function optimally in a wound pH of 8.5; they do not survive and function well in an acidic wound environment. Their survival and activity can be affected by harmful transport and storage conditions. The motility of maggots (Maggot Motility Index) has been used to predict their viability and efficacy.

MDT is not performed simply by dropping maggots into a wound and covering the area with a light dressing. Dressings are designed to contain the maggots while protecting them from external trauma and providing oxygen for their survival.

Considering the costs involved with procuring and utilizing maggots, the variety of debridement options available, and the general visceral repulsion around their use, it is unlikely that maggot therapy will gain any following in veterinary practice.

Application

FREE-RANGE MAGGOTS

Medical maggots arrive in a sterile container. If they have not hatched, they can be placed in a warming incubator (37 °C). Normally, maggots should be used within 24 hours of receipt. A specialized dressing is needed to confine the maggots to the wound. The shape of the wound or ulcer is cut out of the center of a hydroactive dressing (DuoDERM). This is applied over the wound, leaving the ulcer exposed. Maggots are applied by removing (with a moistened sponge) 5–10 larvae per cm^2 of wound surface area and applying them to the wound surface. A patch of Dacron chiffon mesh (or nylon stocking) is applied over the hole, followed by a semi-permeable transparent adhesive dressing (Tegaderm™ Tegapore™, 3M Health Care). A central hole is provided in this last dressing layer to provide aeration for the maggots. A light layer of gauze sponges is applied over this containment dressing with tape. The outer gauze pads absorb discharge from the wound via the central opening in this specialized dressing; they are changed as needed. The maggots are removed every 48 hours (maximum 72 hours) as a general rule. They are removed with moistened sponges and cotton swabs; the maggots and bandage material are secured in a plastic bag prior to disposal. The wound is gently cleansed and inspected before reapplication of additional maggots. Normally three to five replacement cycles are used to manage the average problematic wound.

Medical maggots currently cost $295 for 250–500, although prices usually increase over time. Monarch Labs sells "Creature Comforts" sterile Dacron chiffon dressings and sterile nylon stocking dressings. Shipping costs vary, depending on the method used. Current costs can be determined at the company's website (www.monarchlabs.com). The purchase of the maggots and the dressings, combined with the cost of shipment, should be compared to other alternative forms of debridement.

BAGGED MAGGOT THERAPY

Other bandage configurations to "corral" free-range maggots are discussed in Thomas (2010). A simple method of utilizing maggots (in a more palatable form) is their containment in fine nylon mesh pouches. Biofoam fragments can be added to facilitate absorption of the liquefied debris formed from the release of the maggots' proteolytic enzymes.

Leech Therapy

Leeches have been used for thousands of years to treat a wide range of ailments. Today they are used to help salvage compromised skin (flaps, grafts). Leeches have been used in an attempt to manage hemodynamic imbalance or venous insufficiency in compromised skin. Medicinal leeches (*Hirudo medicinalis*) have been used to advantage in some cases. Anemia and infection are potential complications associated with leech therapy, with the incidence of infection ranging from 2.4 to 20%. One paper reported problematic infections of *Aeromonas hydrophilia* directly associated with their use. Improved superficial skin perfusion has been noted within 16 mm of their biting zone; the various leech enzymes (hirudin–thrombin inhibitor, apyrase, collagenase, hyaluronidase, Factor X inhibitor, fibrinase I and II) instilled have an anticoagulant effect over the following 5–6 hours.

Leeches are commercially available from Leeches USA Ltd. (Westbury, NY), whose website provides guidelines for their application and disposal (http://leechesusa.com). The costs of leeches, supply costs, and shipping fees are listed. Expedited shipping is available. The costs and risks associated with leech therapy should be weighed against the potential benefits of their use (Fig. 4-23).

COMMON TOPICAL ANTISEPTIC AND CLEANSING AGENTS

Topical antiseptics are antimicrobial agents that kill, inhibit, or reduce the number of microorganisms in a wound. Unlike antibiotics, antiseptics have a broader

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FIG. 4-23 (A) Following tumor resection at the tail base of this canine patient, inflammation and swelling of the tail were noted. In an attempt to reduce venous stasis, leeches were applied to the tail wound daily over a 4-day period. Forceps were used to gently grasp and direct the leeches to the skin surface. The head end of a leech is recognized by its searching movements; the tail end is primarily used as a sucker for attachment to the skin. A gauze pad with a hole cut in the center can be used as a barrier to corral the leech to the area of desired attachment. Leeches may attach and engorge for up to 45 minutes and then detach themselves. (B) One method used to direct the leeches to the skin surface was by using a syringe casing. Forceps application appears to be easier for this task. (C) Close-up view of *Hirudo medicinalis* leeches. A challenge for veterinarians is restraint of the patient. Sedation of some patients may be necessary to attach leeches and maintain their attachment. (D) Engorged leeches were humanely euthanized. (E) The tail at day 10. Swelling resolved and the skin survived. The degree of contribution of the leeches in resolving this postoperative swelling is not certain. However, the use of leech therapy was simple (and fascinating) to perform. (F) Leeches can be rapidly shipped to any hospital and are packed in a sealed fluid pouch. They are purchased in prepacked units of 20 for emergency or overnight deliveries. Simple-to-follow instructions are included.

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spectrum of activity including bacteria, fungi, viruses, and protozoa. There are concerns that antiseptics can have an adverse effect on healing; this warrants caution to ensure that the proper concentration is applied to the wound.

Chlorhexidine Diacetate

Chlorhexidine diacetate is an effective Gram-positive and Gram-negative antibacterial agent used both as a surgical scrub and as a topical solution (Fig. 4-24). It maintains bactericidal activity in the presence of blood or pus. A 0.05% solution was compared to a 0.1% povidone–iodine solution in one study. The *in vivo* study indicated that chlorhexidine diacetate had greater bacterial activity over a longer time frame (6 hours) compared with povidone–iodine. The addition of tris-EDTA (see later) reportedly enhances bacterial susceptibility to destruction by 1000-fold compared to 0.05% chlorhexidine alone. It reportedly lyses *Pseudomonas aeruginosa*, *Escherichia coli*, and *Proteus vulgaris* on contact. Like chlorhexidine alone, it will precipitate in electrolyte solutions and this will not affect its potency.



FIG. 4-24 Chlorhexidine solution, in a 1 : 40 dilution with sterile saline, is an effective and economical cleansing agent for open wounds. It also can be used in wet-to-wet and wet-to-dry dressings.

Application

Stock chlorhexidine solution can be diluted (1 part chlorhexidine to 40 parts sterile water or saline) for use as a wound lavage solution, wet-to-wet dressings, and wet-to-dry dressings. The resultant 0.05% concentration is effective against bacteria without causing damage to viable tissue.

Povidone–Iodine Solution

Povidone–iodine is a commonly used surgical scrub and prep solution that has the bactericidal activity of iodine. Iodine is slowly released from this polymer: a 7.5% povidone–iodine solution releases 0.75% iodine. It is effective against Gram-positive and Gram-negative bacteria, fungi, viruses, yeasts, and protozoa. The presence of organic material does not affect the efficacy of povidone–iodine. Povidone–iodine has less bacterial activity and a shorter duration of efficacy compared to chlorhexidine diacetate in one study.

Application

A dilution of 1 part povidone–iodine solution to 9 parts sterile saline can be used as a lavage solution without causing significant harm to viable tissues. In one report, a 1% povidone–iodine solution was advocated for contaminated wounds in humans. This solution can be used in wet-to-wet and wet-to-dry dressings.

Tris(Hydroxymethyl)Aminomethane-EDTA

A tris(hydroxymethyl)aminomethane or tris buffer enhances the antimicrobial properties of EDTA (disodium-calcium salt of ethylenediaminetetraacetic acid). Tris-EDTA in sterile water readily lyses *Pseudomonas aeruginosa*, *Escherichia coli*, and *Proteus vulgaris*. Tris-EDTA synergism against *E. coli* is noted with penicillin, oxytetracycline, and chloramphenicol. Similarly, it has synergistic properties against *P. vulgaris* when combined with gentamycin, oxytetracycline, polymyxin B, nalidixic acid, and trimethoprim–sulfonamide.

Application

This broad-spectrum lavage solution is inexpensive and easily prepared (1.2 g of EDTA with 6.05 g of tris added to 1 liter of sterile water for injection). The pH is adjusted to 8.0 with a dilute solution of sodium hydroxide. The solution is autoclaved for 15 minutes after mixing.

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Dakin's Solution

Dakin's solution (Dakin fluid or Carrel-Dakin fluid) is a dilute sodium hypochlorite (NaClO) solution that is commonly known as bleach (a combination of sodium peroxide and hydrochloric acid). This sodium hypochlorite antiseptic solution is buffered with boric acid and sodium bicarbonate. Chlorine in the solution reacts with water to form hypochlorous acid, which has a potent antibacterial effect on aerobic and anaerobic microorganisms including methicillin-resistant *Staphylococcus aureus* (MRSA). It is also effective against viruses, fungi, and spores.

Dakin's solution (concentration of 0.025%) is used to irrigate and cleanse wounds in humans; it can be used in wet-to-dry dressings to treat or prevent infection. At these concentrations, it does not damage tissue cells and maintains its potency in the presence of blood serum. It has a solvent action on necrotic tissue and facilitates its separation from viable tissue. It is cheap and can be purchased commercially for immediate use. It can be irritating to skin and viable tissues, especially at higher concentrations.

Dakin's solution comes in various concentrations, which can be confusing when selecting the best solution for wound care. Concentrations include "full" strength = 0.5%, "half" strength = 0.25%, and "quarter" strength = 0.125%. However, these concentrations are too strong to use in wounds and should be diluted to 0.025%. Solutions greater than 0.025% may be potentially harmful to wound healing. In one study, a 0.057% sodium hypochlorite solution was compared to normal saline. Results indicated that the hypochlorite solution was more effective in microbial bioburden reduction with a better reduction in wound size compared to saline.

Application

As noted, only a 0.025% concentration of Dakin solution is recommended for wound care in humans and can be initiated after surgical debridement of the wound. Stronger solutions can be cytotoxic. Because Dakin's solution loses its antiseptic properties rapidly after application, gauze sponges used to pack the wound need to be changed frequently. Typically a minimum daily change is recommended for light to moderate exudative wounds; twice daily is recommended for exudative or contaminated wounds. The placement of an irrigation tube into the gauze dressing can enable the doctor to infuse a small amount of Dakin's solution every 6–8 hours, thereby maintaining its efficacy and an effective moist environment. The skin should be assessed daily for irritation, redness, and swelling during dressing changes. Topical ointment can be used to protect the skin around the perimeter of the wound to reduce cutaneous irritation.

Dakin's solution is not recommended for use in pregnant human patients. Oral consumption can cause gastric irritation and is toxic in large quantities. While the safe use of sodium hypochlorite is currently limited to its use in veterinary dental procedures, the veterinary literature lacks any documented use in wound care. Clinical use of Dakin's solution in small animals is likely to be effective based on the current recommendations for human application in wound care. A clinical study on its use in veterinary wound management is indicated to assess its advantages in problematic wound care.

Wound-Cleansing Solutions

A variety of solutions have been advocated for cleansing wounds. Tap water, although hypotonic and potentially harmful to exposed tissues, has been advocated by some for the removal of gross contaminants adhering to open wounds. A comparison of tap water versus sterile saline in irrigating experimental wounds in rats indicated both were similar in their ability to reduce bacterial counts. However, an *in vivo* study demonstrated that tap water (hypotonic, alkaline pH) is notably cytotoxic to fibroblasts. Sterile saline (0.9% NaCl, unbuffered, acidic pH) also displayed cytotoxic effects on fibroblasts; no negative effects were associated with phosphate-buffered saline and Ringer's lactate.

Water as a Lavage Solution?

Various studies have been published regarding the use of tap water in cleansing wounds. One report indicated there was no difference in the infection and healing rates in acute and chronic wounds when comparing potable tap water and normal saline in humans. Tap water could be considered initially to remove gross contaminants involving open wounds exposing subcutaneous tissues prior to more definitive debridement and sterile saline lavage. However, a major concern would be the use of (hypotonic) tap water for sensitive or compromised tissues. It is best to consider the use of sterile saline and similar solutions to minimize trauma at the cellular level.

Sterile saline is most commonly used to swab or flush wounds in veterinary medicine; under pressure (8–15 psi) it can be effective in displacing microscopic contaminants (see Chapter 3). Antiseptic solutions (listed in the previous section) are frequently used to cleanse wounds. Although uncommonly used in veterinary medicine, hydrotherapy facilitates the removal of devitalized tissue, primarily in human burn patients with large surface thermal injuries.

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Avoid Use of Hydrogen Peroxide

Hydrogen peroxide has been used in bleaching, cleansing, and disinfecting surfaces in homes and industry, with concentrations varying from 3% to 70%. Over-the-counter hydrogen peroxide (3%) has been used in mouth washes, for cerumen removal, and in hair bleaching. It has been used medically in the past as a disinfectant and irrigation fluid. Unfortunately it rapidly oxidizes, releasing free radicals that damage proteins, DNA, and cell membrane lipids in viruses, bacteria, and open wounds. While the foaming action does impart a degree of "psychological gratification" to the user, when poured into an open wound hydrogen peroxide does cause additional trauma that may be significant in tissues already badly compromised. As a result, it cannot be recommended as a topical solution for wound management.

There are a number of commercially available wound-cleansing agents used to facilitate the removal of surface contaminants and wound exudate. They are most commonly used to clean a wound prior to the reapplication of a topical agent and dressing. Wound cleansers basically contain water, surfactants (sodium lauryl sulfate, etc.), salt, and a preservative. Some cleansers include antimicrobial agents (triclosan, chlorhexidine gluconate, chloxylenol, etc.). Humectants may be added for their moisturizing property (glycerin, methyl glucose esters, lactates, lanolin derivatives, mineral oil, etc.). Various alcohols may be added for their antibacterial properties and to serve as an emollient or thickening agent. Common wound-cleansing products include Curaklense™ and Constant-Clens™ (Kendall Healthcare Products), Allclenz® (Healthpoint.), SAF-Clens® (Convatec), CarraKlenz® (Carrington Labs), and Dermagran® (Derma Sciences, Inc., Princeton, NJ). In one study Constant-Clens was considered the most biocompatible. Most wound-cleansing products come in a convenient pump-spray or squeeze bottle for application to the wound surface (Fig. 4-25).



FIG. 4-25 One example of a wound-cleansing agent. Many come in a convenient pump-spray bottle. Wound cleansers commonly contain water, a surfactant, humectants, and an antimicrobial agent.

Topical Antimicrobial Agents

Topical antimicrobial agents are used both to prevent and to manage infections in open wounds. The ointment or cream base can provide a moisture-retaining barrier to prevent tissue desiccation, promoting epithelialization. It is capable of delivering concentrated amounts of the antibacterial agent directly to the wound surface.

Removal of debris and necrotic tissue will enhance such agents' efficacy in both preventing and treating wound infections.

There are a variety of economical topical antimicrobial agents on the market, with a variety of manufacturers for most of these products:

- Chlorhexidine ointment
- Gentamycin ointment
- Nitrofurazone cream/ointment
- Povidone–iodine ointment
- Silver sulfadiazine (see Fig. 4-26)
- Triple antibiotic ointment



FIG. 4-26 Application of water-miscible silver sulfadiazine ointment to a burn. Silver sulfadiazine is most commonly used in the management of burn wounds.

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One chlorhexidine ointment is Nolvasan® 1% (Fort Dodge Laboratories, Inc., Fort Dodge, IA), although other companies sell similar products. Chlorhexidine, silver sulfadiazine, and povidone–iodine ointment are hydrophilic (water-miscible) ointments that are easily flushed from the wound surface to facilitate inspection. Oil-based (hydrophobic) topical antimicrobials, including gentamycin ointment and triple antibiotic ointment, form a greasy film that may repel lavage solutions. The author finds water-miscible agents useful in cases of delayed primary closure: they are easily flushed from the wound surface, allowing for easier assessment of the tissues during subsequent bandage changes. In turn, oil-based products are preferred on healthy granulation beds for their better ability to maintain a protective film on the wound surface. In most routine cases, triple antibiotic ointment is both effective and economical to use.

In practice, the use of "community jars" of ointment is best discouraged due to the potential for introducing contaminants. The author has witnessed a number of occasions when busy veterinarians use an index finger to dispense a dollop of the medication directly onto a wound or dressing. Jars are best used exclusively for a single patient. Autoclaved tongue depressors can be used for removing the ointment, especially when dealing with large open wounds (burns). Individual tubes of topical antimicrobials reduce the risk of contamination and can be devoted to individual patients with smaller wounds.

Chlorhexidine has a broad spectrum of activity against microorganisms. Gentamycin has efficacy against Gram-negative microorganisms, including *Pseudomonas* spp. and *Staphylococcus* spp. Nitrofurazone has both Gram-positive and Gram-negative activity. It has broad-spectrum antibacterial properties but has little effect against *Pseudomonas* spp. Its hydrophilic polyethylene base enables it to draw and retain body fluid and discharge from the wound surface. Topical povidone–iodine ointment also has a broad spectrum of activity against a variety of microorganisms.

Triple antibiotic ointment (neomycin sulfate, bacitracin zinc, polymyxin B sulfate) is both economical and readily available at pharmacies (over the counter) and veterinary supply houses. The combination of these three antibiotics has a synergistic effect against a variety of bacteria, although less so against *Pseudomonas* spp. Triple antibiotic ointment can enhance reepithelialization but may have a slight retardant effect on contraction.

Triple antibiotic ointment is economical, easily accessible, and economical. The author commonly uses it for smaller wounds and for the protection of free grafts. The sticky petroleum base provides protection against tissue desiccation. Combined with a nonadherent dressing and protective bandage, it has a semi-occlusive effect on the grafted area.

Prior to the closure of a granulation bed, the liberal application of a topical broad-spectrum antibiotic 24–48 hours before surgery can substantially reduce the residential bacterial population prior to the final surgical preparation of the area.

Silver sulfadiazine is effective against a variety of microorganisms including *Pseudomonas* spp. The author normally reserves its use for burns (Chapter 7). *In vitro* studies indicate it has toxicity to human keratinocytes and fibroblasts and an inhibitory effect on neutrophils and lymphocytes that can be reversed with aloe vera. Clinically, it remains one of the most effective topical agents in the management of thermal injuries (Fig. 4-26).

Topical antimicrobial agents can have variable effects on the processes of wound contraction and epithelialization. In general, comparative studies are lacking to determine which ointment or cream has the greatest wound-healing benefits; it is unlikely there is a dramatic difference between these products.

ALTERNATIVE FORMS OF WOUND THERAPY

Commercial Topical Growth Factors

Becaplermin (Regranex; see Chapter 2) is a recombinant human platelet-derived growth factor for topical management of lower-extremity diabetic neuropathic ulcers in humans that extend into the subcutaneous tissues or the viable tissues beyond. It is an adjunct to ulcer management. Clinical studies have demonstrated increased neovascularization, epithelialization, and wound contraction in humans when applied on a daily basis, although its overall efficacy in humans is variable. The author and exotic medicine clinicians at Angell Animal Medical Center have used it in a long-standing, nonhealing lower-extremity ulcer in a chinchilla and a wing wound in a cockatoo (secondary to feather picking). Healing was complete within 6 weeks of initiation of therapy in both patients. There is one small study in two dogs that indicated beneficial results in promoting epithelialization. There is a risk of malignancy in humans with the use of more than three tubes of becaplermin and caution is required in its use. Although expensive, becaplermin may be worth considering for use in small problematic wounds in which surgical alternatives are not feasible or ideal.

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Platelet-Rich Plasma (Contribution by Fred Pike DVM, DACVS)

Background

The use of platelet-rich plasma (PRP)—defined as defined as an autologous platelet-rich product harvested from whole blood—was initially described in peer-reviewed literature in 1990 with the clinical application of platelet gel (PG) as an alternative to fibrin as a sealant during cardiovascular surgery. Since then, PRP has been described for medical uses not limited to orthopedics, sports medicine, dentistry, otolaryngology, neurosurgery, ophthalmology, urogenital surgery, burns and wound healing, cardiothoracic surgery, and maxillofacial surgery.

The primary clinical application of PRP in wound therapy is to promote wound healing by increasing the local concentration of growth factors involved in migration, proliferation, and maturation at the site of injury. Additionally, PRP has been shown to exert anti-infective properties, the etiology of which remains theoretical. A recent peer-reviewed publication has documented that PRP had an antimicrobial effect and accelerated healing when applied to wounds colonized by MRSA in a canine model. Autologous PRP consists of cytokines, growth factors, chemokines, and a fibrin scaffold. The mechanism of action for PRP is thought to be via the amplification of molecular and cellular events occurring during the inflammatory, proliferative, and remodeling phases of wound healing.

Accelerated healing is thought to be through the local release of growth factors contained within platelets. Platelet granules contain bioactive molecules (growth factors) that on activation promote wound healing via the mechanisms already referenced. These growth factors include (and are not limited to) platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-β), vascular endothelial growth factor (VEGF), fibroblast growth factor (FGF), epithelial growth factor (EFG), interleukin (IL), insulin-like growth factor (IFG), and fibronectin.

Platelet gel should be differentiated from fibrin glue. Fibrin glue is commonly called platelet-poor plasma (PPP) and lacks significant platelet concentration. Fibrin glue contains elevated fibrinogen concentrations, resulting in a fibrin-rich clot facilitating cell migration and adhesion following activation. The theoretical value of fibrin glue as a wound dressing (with or without adjuvant PRP application) warrants prospective investigation. Fibrin glue has been employed in human surgery as a hemostatic agent, to seal suture needle track holes, to reduce bleeding from solid organs (liver and spleen), and to help augment sealing of anastomoses sites (intestinal, esophageal, and ureteral).

PG has been documented to decrease the incidence of deep sternal infections in humans following median sternotomy and the Society for Thoracic Surgeons endorsed its use to reduce sternal wound infections. A 2022 meta-analysis evaluating autologous PRP use during sternotomy closure found that PRP significantly reduced the incidence of both superficial and deep sternal infection. A 2023 meta-analysis published in the *Journal of Orthopaedic Surgery and Research* identified accelerated healing of diabetic foot ulcers treated with PRP compared to conventional therapy. A 2023 study published in the *International Wound Journal* concluded that PRP has a positive effect on repairing burn wounds and reducing patient pain associated with burns. Clinical use on animals was documented in 2001 when the effect of a PRP on bone formation of calvaria defects in rabbits was evaluated. Recent years have seen a significant increase in veterinary publications regarding the clinical use of PRP, primarily for orthopedic and sports medicine applications. At the time of writing, literature regarding the use of PRP/PG for wound therapy in veterinary medicine is limited.

The author has used PRP/PG for problematic wounds including (1) patients with extensive shearing wounds prior to definitive wound closure; (2) burn victims to augment traditional wound care; and (3) complications following radiotherapy of distal limb extremities. The author has also used PRP/PG to augment primary repair during tracheal and ureteral surgery. In these clinical cases, subjectively, PRP/PG has decreased the time to definitive wound closure and decreased the extensiveness of the planned surgical intervention. Personal experience suggests that PRP/PG can augment traditional wound management and reconstruction techniques.

Platelet-Rich Plasma Preparation

Several validated commercial PRP collection systems are available for veterinary use, including the Angel® System (Arthrex, Naples, FL), Companion Regenerative Therapies (CRT; Companion Animal Health, Dallas, TX), Harvest® Platelet Concentrate System (Harvest Terumo BCT, Inc., Lakewood, CO), and Magellan® PRP (Arteriocyte Medical Systems, Inc., Hopkinton, MA). Regardless of the collection system utilized, fractionation of whole blood via centrifugation is the mainstay of PRP preparation (Fig. 4-27). For human procedures, the harvested product can be held at room temperature until ready for use. It is generally accepted that harvested PRP should not be held longer than the duration of the surgical procedure. When ready for application to the tissue bed, PRP is activated with a mixture of bovine thrombin and 10% calcium chloride ($CaCl_2$). The gel-stage product is formed within 5–30 seconds as the citrate component of the anticoagulant is neutralized and the thrombin causes

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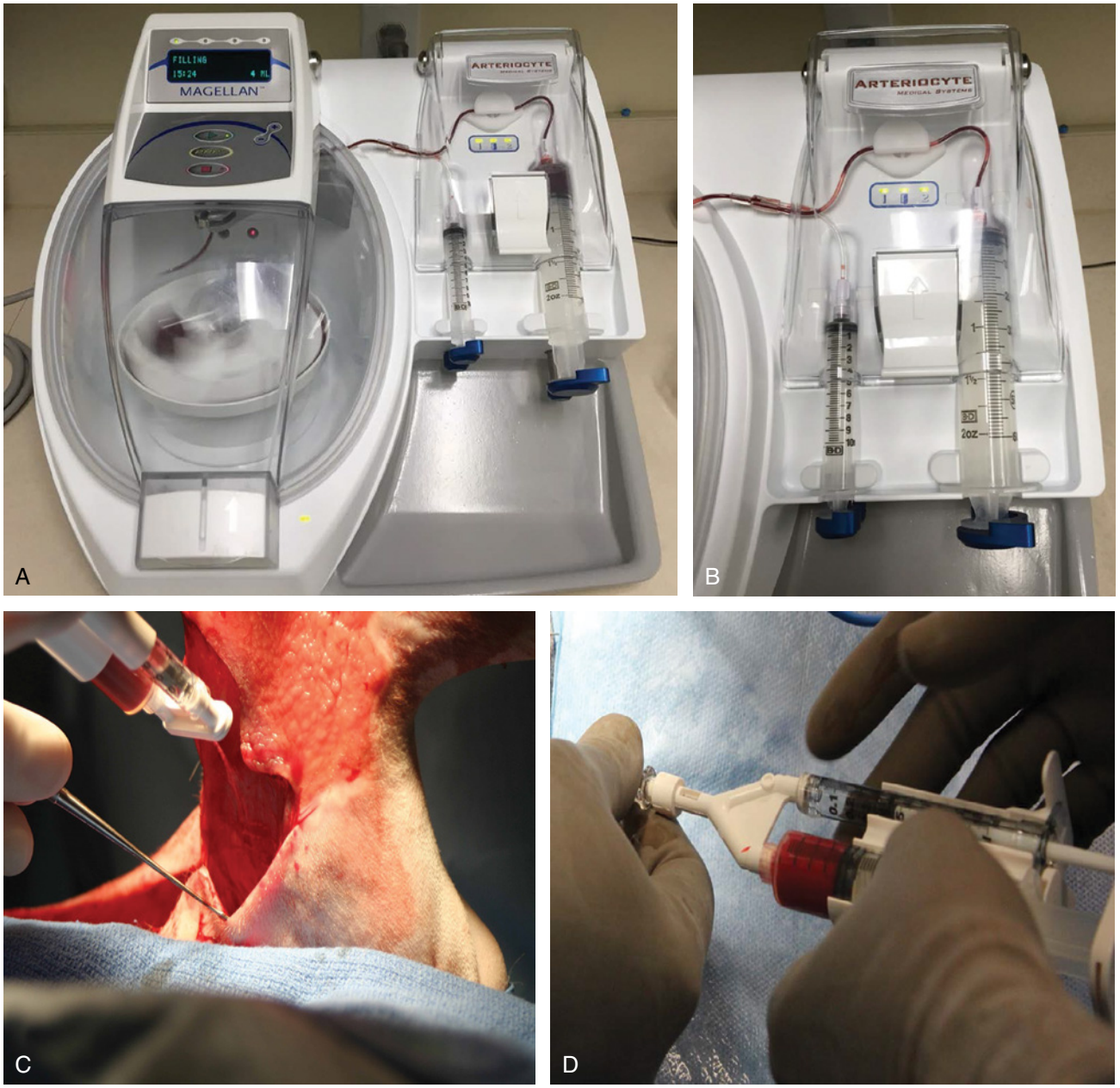


FIG. 4-27 (A) Magellan PRP autospin centrifuge. The centrifuge (large chamber on the left) is programmable for a final platelet-rich plasma (PRP) volume of 3–10 ml. (B) Close-up of the Magellan PRP. The larger syringe on the right will collect the post-PRP blood (waste product), which can be administered to the patient via a blood filter. The smaller syringe on the left will collect the final PRP product. (C) The viscous delivery system (Arthrex) enables mixing of bovine thrombin and calcium chloride (thrombin diluent) with the PRP, with resultant platelet activation and gel formation. The applicator facilitates delivery of the final product as a spray to the site of application. Gel formation occurs within 5–30 seconds. (D) The viscous delivery system can be used for intralesional injection of PRP or topical spray of platelet gel to a wound.

fibrin polymerization and degranulation of the platelets. PRP collection systems can be classified as low yield (2.5–3 times baseline concentration) or high yield (5–9 times baseline concentration). The ideal leukocyte concentration of the final PRP preparation is unknown and is likely dependent on the clinical application.

Clinical Application

In contrast to other clinical applications of PRP, PG generally requires exogenous activation when used for wound therapy. Bovine thrombin and 10% $CaCl_2$ are typically used for activation. Once activated, a fibrin network begins to form

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within the PRP, rapidly resulting in a gel-like membrane after contact with a wound, ulcer, or surgical site. The PG provides a gradual release of growth factors to the site of application. The gel also provided regional containment of the growth factors to the site of application. The application of unactivated PRP (in a nongel form) may represent a more physiologic state; however, containment to the site of injury becomes challenging.

Once the PRP product has solidified to a gel-like state, an occlusive dressing is placed over the wound (primary wound dressing without absorptive properties) (Fig. 4-28). Secondary and tertiary bandage layers are applied as needed for immobilization dependent on the location of the wound. The bandage remains unchanged for approximately 5 days. Following the initial bandage change, additional wound management is continued as dictated by the local wound environment and biology. Given that PG is an autogenous product, repeat applications are applicable as needed without concern for local or systemic reaction.

Mesenchymal Stem Cells

Mesenchymal stem cells (MSCs) have been actively investigated for their potential benefits in wound repair by differentiating and proliferating into various cell lines. There has been a focus on their use in damage to bone, joints, tendons, and ligament repair. They have anti-inflammatory properties and the ability to modulate pain. Well-designed control studies are generally lacking in small animals, although one study reported improved epithelialization of MSC-treated wounds and less inflammation compared to the control group. Topical MSC transplantation in experimental canine wounds noted more rapid wound closure as a result of increasing collagen synthesis, cellular proliferation, and angiogenesis. MSC wounds showed a decreased expression of pro-inflammatory cytokines (IL-2 and interferon-γ) as well as wound-healing factors (basic FGF and matrix metalloproteinase-2).

Oxygen Therapy

Hyperbaric Oxygen

Chronic wounds may lack the circulation required to deliver oxygen to the ischemic tissues. Hypoxic tissues cannot heal optimally and are more susceptible to infection. Oxygen tension above 40 mmHg promotes healing; chronic wounds may have oxygen tension values below 20 mmHg. Traumatic and infected wounds typically have oxygen tension values less than 30 mmHg. Considering that active cell division requires a minimum of 30 mmHg, the normal processes of healing are jeopardized in chronic nonhealing wounds.

Hyperbaric oxygen therapy (HBOT) is defined as the administration of 100% oxygen delivered to the patient in a pressurized chamber exceeding 1.4 atmospheres absolute (ATA). For routine conditions, HBOT is normally administered between 2.0–2.5 ATA, for 90 minutes of oxygen breathing. During this time, a 5–10 minute "break" is established for breathing room air. The effect of HBOT is instantaneous, with a plateau in soft tissues noted in 1 hour, and progressively declines 2–4 hours after administration.

Hyperbaric oxygen increases dissolved oxygen in plasma, an 18–20-fold increase in dissolved oxygen compared to normal room air (FiO_2 21%). Benefits noted include an upregulation of growth factors or cytokines including PDGF and VEGF. HBOT stimulates angiogenesis, fibroplasia, collagen formation, and epithelialization. HBOT can enhance the leukocyte's bactericidal effect. Vasoconstriction takes place in both arterial and venous vessels, reducing edema and congestion; the increase in oxygen diffusion compensates for any reduction in circulation. HBOT also has antioxidant properties to reduce the harmful effects of ischemia and reperfusion injury.

Hyperbaric oxygen may be most suitable in combating ischemia that is threatening tissue survival. Clinical examples for its use in wound management (in humans) include crushing injuries, severe anemia, necrotizing soft tissue infections, refractory osteomyelitis, and acute thermal injuries. HBOT has been used to salvage skin compromised by external trauma, disease, or surgery (e.g., skin flaps, skin grafts, muscle flaps). Although generally considered safe, one study (Montalbano et al. 2021) noted pulmonary edema in one dog and central nervous system oxygen toxicity manifesting as focal or generalized seizures. The beneficial effects may vary among patients. In three animal studies, however, HBOT failed to improve flap and graft survival. No differences were noted between control and HBOT groups pertaining to epithelialization, wound contraction, histopathologic assessments, and wound cultures.

Hyperbaric oxygen chambers have been developed for several people (multiplace) or as units for one person (monoplace). Smaller units are available for small animal patients. Although detailed information pertaining to its true clinical efficacy in veterinary medicine is lacking, there may be occasions where HBOT may benefit those patients with the most challenging problematic wounds.

Transdermal (Topical) Oxygen Therapy

Adequate oxygen distribution into wounds is essential to the normal healing processes. Various oxygen-delivery systems have been used to improve delivery of oxygen to

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FIG. 4-28 A 5-year-old, MN mixed-breed dog that survived a wildfire. First-, second-, and third-degree burns were present over 50% of the body. Fourth-degree burns were present over the common calcanean tendon. (A) The patient, day 5 post presentation. Close-up of the fourth-degree burns over the common calcaneal tendon. (B) Application of platelet gel (PG) over the wounds. Note the closure of the lateral thigh burns with a caudal superficial epigastric axial pattern flap (lower right corner). (C) The PG was covered with an occlusive dressing and modified Robert-Jones bandage. (D) Left pelvic limb day 10 post presentation, day 5 post PG application. (E) Right pelvic limb day 10 post presentation, day 5 post PG application. (F) Caudal view of the pelvic limbs 10 weeks post presentation. The skin at the burn site remains thin and fragile and was protected with a custom support wrap.

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the wound environment, with an emphasis on the management of diabetic ulcers in humans. Topical oxygen therapy (TOT) may have merit in other problematic wounds and skin graft/flap survival. The concentration, frequency, and duration of TOT are still under investigation. Granulox® (Mölnlycke Health Care) is a topical hemoglobin spray used to diffuse hemoglobin into the wound exudate and bind oxygen to the wound. From a veterinary perspective, this may have practical economic application for problematic wounds in animals, although research is lacking on its efficacy for veterinary use.

Placement of an open wound in a container or tent infused with oxygen has been used to improve wound healing. A novel device, OxyBand Wound Dressing™ (OxyBand Technologies, Inc., St. Louis, MO) can deliver oxygen to the wound surface for up to 5 days. Oxygen is held in a reservoir and slowly diffuses at a constant rate through a semi-permeable membrane. In a recent controlled study by Lairet et al., OxyBand wounds healed faster compared to the control wounds. EpiFLO® (Ogenix Corp., Beachwood, OH) is yet another device approved by the FDA for use in humans and animals. As with the other products in the wound market, additional research is needed to determine the efficacy of these oxygen-delivery systems.

Laser Therapy and Electromagnetic Fields

Low-intensity laser light (phototherapy) and pulse electromagnetic fields (0.5–18 Hz) have been used experimentally to stimulate the normal healing processes. Low-level laser therapy reportedly induces the proliferation of fibroblasts, shortens the inflammatory phase of healing, and enhances the release of factors that stimulate the proliferative phase of healing. There was a synergistic effect reported when laser therapy was combined with photosensitizer drugs in experimental rats.

Electrical stimulation, including the use of pulsed electromagnetic fields, has been demonstrated to improve microvascular flow while activating fibroblasts. *In vitro* and *in vivo* studies have noted the migration of cells essential to wound repair toward the anode or cathode. Fibroplasia was noted to increase with enhancement of circulation associated with negative polarity. One study indicated that pico-Tesla electromagnetic field treatment improved wound strength and speeded up contraction of open wounds in rats. Another study reported enhancement of wound epithelialization in dogs. Similarly, microwave irradiation has been used to induce hyperthermia, thereby improving epithelialization in wounds in rabbits and humans. The FDA does not currently approve electrical stimulation for wound healing in humans, although it is approved for other uses including the management of edema and pain. It is contraindicated in the presence of basal and squamous cell carcinoma in humans, as well as osteomyelitis.

Bioelectric dressings have been used for diabetic ulcers, pressure sores, and thermal wounds in humans, as well as acute and chronic wounds in dogs. Wound exudate forms a conduction medium for microcurrents (2–10 μA); these dressings reportedly simulate these microcurrents over the underlying surface area, beyond the 1–2 mm wound margin to which the current is normally limited in an open wound. Reported benefits include their antibacterial properties, prevention of biofilm formation, promotion of a moist environment, and promotion of epithelialization (keratinocyte migration from galvanotaxis). Procellera™ (Vomaris Wound Care, Inc., Tempe, AZ) is one such commercially available dressing, which consists of a polyester substrate containing zinc microcell batteries and elemental silver. However, other bioelectric dressings are also commercially available for purchase. Better controlled studies are needed to prove their efficacy in small animals, although early reports suggest they may improve the rate of epithelialization.

Evidence of the true clinical efficacy of using laser, photodynamic, electromagnetic, and microwave irradiation is currently lacking. Two studies employing low-level laser therapy have failed to demonstrate its efficacy in stimulating healing. The reader is reminded that the vast majority of wounds seen in veterinary practice can be managed successfully without the use of these devices. Additional research is needed to prove their clinical worth.

High-Frequency Ultrasound

High-frequency ultrasound (1.0–3.3 MHz) has been used primarily for orthopedic conditions and, more recently, for wound healing. Continuous or pulsed waves are used to elicit thermal and nonthermal effects. Experimentally high-frequency ultrasound was noted to stimulate inflammation, fibroblast proliferation, macrophage phagocyte function, leukocyte adhesion, fibrinolysis, production of growth factors and nitric acid, collagen deposition/tensile strength, and angiogenesis. It may be useful to reinitiate the acute inflammatory response in stalled wounds. Low-frequency (noncontact) ultrasound (40 kHz) has been used for wound size and bioburden reduction. Experimentally, increased granulation tissue formation, decreased wound exudate formation, and increased collagen deposition with increased vascularity were seen. Ultrasonic low-frequency debridement (22.5, 25, 35 kHz) has been reportedly effective in promoting fibrinolysis of the wound surface without damaging the underlying granulation tissue. At 35 kHz, it may be effective in

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damaging the cell walls of bacteria, reducing the bioburden in the wound. With saline as the transfer medium, the shockwave formed can be effective in breaking down necrotic tissue. This form of debridement takes longer than sharp debridement. Additional clinical studies are required to assess its clinical efficacy.

CONCLUDING REMARKS

Wound drainage is an important component of managing wounds. Penrose drains, vacuum drains, and more recently vacuum-assisted closure are options to consider, depending on the size, location, and condition of the wound.

Sterile saline is commonly used initially to flush wounds. There are a variety of topical cleansing and antimicrobial agents available to facilitate wound care. The early removal of necrotic tissue is a vital step in reducing the presence or risk of infection; its removal also promotes the formation of a healthy granulation bed. Both selective and nonselective debridement techniques may be used in veterinary patients. Surgical debridement remains the quickest means of removing major areas of devitalized tissue. Topical agents may be used to facilitate the removal of smaller areas of necrotic tissue (topical enzymatic debridement, autolytic debridement). Infection can be managed with a variety of topical antibacterial agents, depending on the condition of the wound. Topical agents that reportedly enhance or accelerate healing are worth closer scrutiny by the veterinary clinician. The bottom line is the final point of wound closure: early benefits seen in a comparative study mean little if the projected final outcomes are basically the same. Without well-designed research models and clinical data, the selection of topical wound products is largely based on the information provided by the company and the experience of the clinicians who use a given product. Fortunately, most wounds heal with basic surgical and medical care.

As veterinarians, our goal is to close the wound safely and as efficiently as possible to restore function. Removal of contaminants and necrotic tissue is essential to the prevention and control of infection. Surgical debridement and topical wound care play a joint role in this endeavor. The formation of a healthy granulation bed is visual proof that the underlying tissues remaining are viable. In many cases early surgical closure can preclude the need for the time and costs associated with second-intention healing. Cost plays a role in wound management and the projected costs of prolonged wound care must be compared to the advantages of surgical closure.

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Plate 1

Vacuum-Assisted Closure

DESCRIPTION

Vacuum-assisted closure (V.A.C., KCI) refers to a simple drainage system comprising open-cell polyurethane foam that is connected to a vacuum pump with rigid plastic tubing. Discharge from the wound surface is partially retained in the foam, whereas excess tissue fluids are retained in the vacuum pump reservoir. The V.A.C. is best considered for large, deep, or cavitated wounds; it may also be used to secure skin grafts to a recipient bed. It is capable of reducing edema during open wound management. A similar alternative, a gauze-based system (Venturi, Talley Medical), was introduced into the veterinary market. There are several other systems currently available for negative-pressure wound therapy (NPWT). It is possible to improvise a vacuum-assisted closure system using gauze or polyurethane foam, red rubber tubing, a vacuum source, adherent plastic drape, and colostomy paste.

TECHNIQUE

(A_1) Example of a large cavitated wound involving the left flank and lateral abdominal area. The skin has been widely clipped of fur and cleaned with a surgical scrub and isopropyl alcohol swabs; the skin must be completely dry.

(A_2) After initial surgical management of the wound (removal of necrotic tissue and debris), the V.A.C. foam pad is trimmed to the size of the wound. Alternatively, gauze can be used in place of the plastic foam sheet. Gauze sponges impregnated with polyhexamethylene biguanide (PHMB) may be most useful. Other antimicrobial dressings may be applied to the wound prior to placement of the plastic foam or gauze. The tubing unit will be applied to the plastic sheet cover. Skin staples can be used to secure the foam to the skin margins of the wound. Skin staples also can be used to secure foam pads that are folded around the lower extremity. (See Figs 4-13 and 4-17.)

(B) Prior to application of the adherent plastic drape over the entire wound site, a thick bead of stoma adhesive sealant paste used for securing colostomy bags (Stomahesive™, Convatec; or similar products) can be applied to better secure the perimeter against an air leak.

(C) The adherent plastic drape is applied to seal the entire area. A spray adhesive may be used on the skin to improve adherence of the plastic drape to the skin (Vi-Drape®, Medical Concepts Development, St. Paul, MN; EZ Drape®, AD Surgical, Sunnyvale, CA). On the lower extremities, the plastic membrane can be folded over the foam (see Fig. 4-17). A small hole or cross-split is created in the center of the sheet; the adherent medallion is applied over this opening. The exit tube is attached to the vacuum pump/reservoir. A continuous vacuum pressure of −125 mmHg is most commonly used. (See text for additional details on the use of negative-pressure systems.) The foam or gauze is changed and the wound is inspected every 2–3 days. Normally two to three changes are required to manage problematic wounds. (See the details in the chapter text.) Note that some clinicians will incise the center of the plastic drape to remove the foam or gauze and inspect the wound. Following reapplication of a new foam or gauze dressing, a second plastic drape is applied over the hole created in the first plastic cover and an adhesive medallion is reattached; the vacuum is then reactivated. Patients are normally kept in an intensive care ward for continuous monitoring of the NPWT.

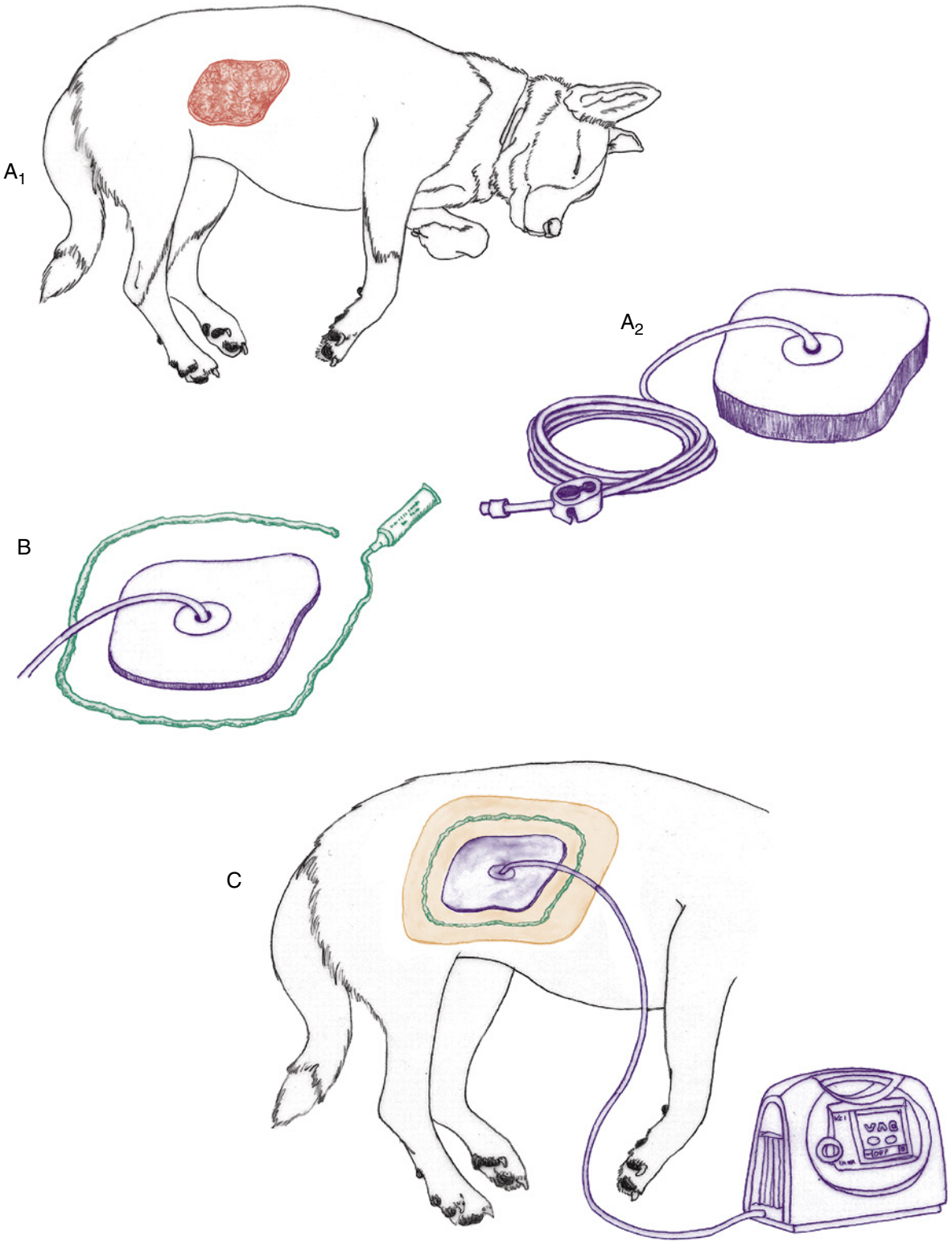
COMMENTS

The merits of NPWT have been demonstrated in the veterinary and human surgical literature. Most of the wounds noted in lectures and journal articles also can be managed by other dressing/bandaging techniques. *Necrotic tissue and debris still must be removed from the wound prior to the use of these systems*. It is the author's impression that the system is most effective in deep, cavitated wounds (e.g., large flank wounds extending into the medial thigh region) where drainage and wound care are especially problematic. NPWT can be effective in immobilizing free grafts in a problematic body region; when it is used for this purpose, a nonadherent dressing is applied over the graft to prevent the foam or gauze from adhering to the surgical area. It also would be useful for reducing edema in open wounds with extensive soft tissue swelling. The surgeon must assess the advantages of NPWT versus other methods of wound care based on (1) wound size, location, and classification and (2) all costs (including time and labor) associated with the use of these systems versus alternative methods. (See Figs 4-13 and 4-17.)

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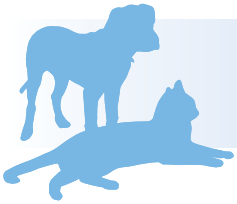
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Plate 1



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5

Dressings, Bandages, External Support, and Protective Devices

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INTRODUCTION

Bandages and dressings are an integral part of wound management. A bandage is a wrap primarily used to hold plain and medicated dressings in place, support or immobilize a body part, apply pressure to control hemorrhage, obliterate dead space or cavities, and protect a wound from external trauma and contamination (Fig. 5-1).

A dressing refers to a material that is applied directly to the surface of the wound. Some dressings are designed for direct application to a wound without the need for an outer supportive wrap. Most dressings require the added support of a bandage to prevent their displacement, optimize their contact with the wound bed, and potentially serve as an outer absorptive layer for retention of any discharge. As a result, the dressing is part of the anatomy of a bandage.

Bandages have three defined layers: the primary (contact dressing) layer, the secondary (intermediate) layer, and the tertiary (outer) layer.

DRESSINGS: THE PRIMARY BANDAGE LAYER

The primary layer lies in direct contact with the wound. Most commonly, this involves the application of a topical wound dressing. The term *dressing* has changed somewhat in its usage over the past several years. Wound dressings are normally considered topical synthetic membranes, gauze materials, or pads designed for direct application to a wound. Some companies refer to their topical agents (pastes, gels, etc.) as *wound dressings*.

No single dressing is suitable for all types of wounds. Different dressings may be needed during the various phases of wound management. In general, dressings perform one or more of the following functions: absorb and retain discharge from the wound, provide a moist environment to promote healing, provide a product that promotes the healing process, provide protection from bacteria and other contaminants, absorb wound odor, provide insulation and mechanical protection, and facilitate autolytic debridement.

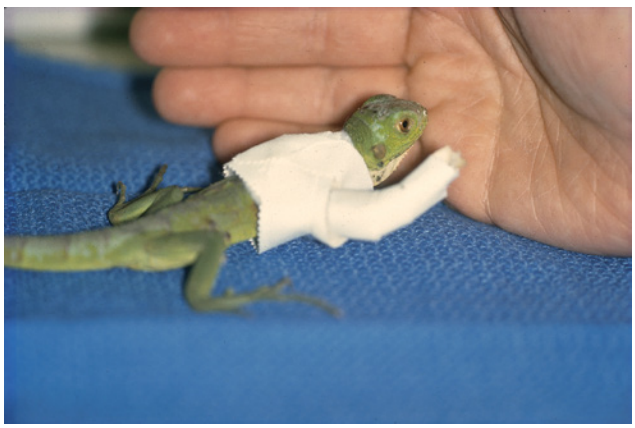


FIG. 5-1 Spica bandage for a lizard. Bandages can be a critically important component to wound management in small animals.

The term *primary dressing* refers to the dressing in direct contact with the wound. On occasion *a secondary dressing* is used to secure the primary dressing.

Is there a perfect wound dressing? The answer is no: different dressings may be useful for different phases of the wound healing process.

If the ideal dressing existed, it would have all of the following properties:

Is safe (nontoxic, nonirritating)
Maintains a moist environment
Has low or nonadherence*
Is capable of retaining and releasing medication
Provides thermal insulation
Provides protection from external contaminants
Is vapor and oxygen permeable
Provides mechanical protection
Has good absorptive properties (exudative wounds)
Provides comfort to the patient
Is easy to use and change
Conforms easily to the wound surface
Requires infrequent changes
Is affordable and cost-effective to use

*Adherent dressings are used as a form of mechanical debridement.

Dressings will be discussed in the following categories:

- Adherent dressings
- Nonadherent dressings
- Absorptive dressings
- Semi-occlusive dressings
- Occlusive dressings
- Moisture-retaining dressings

These broad categories overlap to a variable degree: a given dressing can have more than one property and function. Moreover, as discussed in Chapter 4, various topical agents can have an effect on wound healing similar to the dressings discussed in this section. For example, a topical hydrogel applied to a wound may have the same basic properties as a hydrogel dressing. The primary difference is the external membrane of the dressing with its adherent gel compared to the use of a gel covered by a retention layer (membrane or dressing) placed over it. In deeper wounds, a gel may be preferable to a hydrogel dressing, whereas shallower wounds may be managed more easily by using a hydrogel dressing. Watery gels will

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tend to gravitate from beneath a topical dressing or bandage, thus requiring more frequent application. Other dressings have been developed as a form of wound "packing."

The proliferation of a variety of "designer dressings" by multiple manufacturers has added an element of confusion to the process of selecting the best dressing for a given set of circumstances. As noted in Chapter 4, a variety of topical agents are used in hydrocolloid gels and hydrogels. Alginates, collagen, and starch copolymers alone or in combination have been added to moisture-retentive dressings. Which hydrogel or hydrocolloid dressing is best? It is impossible to say. How one dressing compares to another dressing cannot be ascertained without comparative studies.

Dressings either play a relatively passive protective function (passive products, such as plastic membranes, nonadherent dressings) vis-a-vis the wound, or play an interactive role in promoting wound healing (interactive products, such as hydrogels, foam dressings, etc.). Such "interactive dressings" can provide a substrate or microenvironment supportive of the wound-healing process (e.g., bioactive products, such as hydrocolloids, alginates, collagens, chitosan, etc.).

As noted in Chapter 4, open wounds produce a variable amount of exudate. High-exudative wounds require dressings (and a secondary bandage layer) to absorb the appropriate volume of discharge. By contrast, low-exudative wounds will require dressings that provide moisture for optimal wound healing. As healing progresses, the requirements for wound support change, including the dressings selected. The presence of necrotic tissue and infection also are considerations in the selection of topical medications (Chapter 4) and dressings.

Adherent Dressings

Adherent dressings are used for the mechanical debridement of necrotic tissue and the absorption of discharge from the wound surface. Wet-to-dry and dry-to-dry bandages fall into this category. Both bandages use coarse or wide-mesh cotton gauze as the contact layer with the wound surface.

Mechanical debridement refers to the removal of necrotic tissue and foreign material from a wound by physical force. This includes the use of wet-to-dry dressings; removal of the adherent gauze can strip off necrotic tissue and topical debris adhering to its surface. Hydrotherapy and wound irrigation also are forms of mechanical debridement. These modes of debridement are considered "nonselective" since their use can indiscriminately damage local healthy tissues at the same time as they remove devitalized tissues.

Wet-to-dry dressings are gauze pads moistened with Ringer's lactate or sterile saline and applied directly to the wound surface. (A 0.05% chlorhexidine diacetate or 0.1% povidone–iodine solution may be used; see Chapter 4.) The moist sponges initially hydrate the wound environment and dilute the purulent discharge, facilitating its absorption into the gauze.

Composed of readily available surgical gauze and sterile isotonic fluids, wet-to-dry dressings are economical to use. Cost is primarily determined by the frequency of dressing changes.

Wet-to-dry dressings can be used effectively in wounds with low to high amounts of exudates: they hydrate, dilute tenacious exudates, and have a high capacity to wick and retain the discharge.

Over several hours, moisture partially evaporates through the outer surface of the dressing. As it (partially) dries, the gauze has a tendency to adhere to the wound surface and necrotic tissue in contact with its surface. As the gauze is lifted from the wound, adherent necrotic tissue is stripped from the viable tissues. The process is repeated daily, usually once per day (Fig. 5-2).

Sponges impregnated with the antimicrobial agent polyhexamethylene biguanide (PHMB, Covidien Kendall, Minneapolis, MN) can be moistened with Ringer's lactate or sterile saline for immediate application to the open wound. These sponges also have been used in conjunction with negative-pressure wound therapy (see Chapter 4).

To reduce the risk of wicking bacteria into the wound (termed *strike-through*), an outer wrap should be applied to a wet dressing. The author commonly uses surgical paper drapes secured with gauze and tape to cover the wet-to-dry dressing.

Wet-to-dry dressings have been criticized primarily for causing a variable degree of trauma to the adjacent viable tissues. Removal can be transiently painful to the patient. Retaining cytokine-laden exudate is diluted and removed with their use; in multiple comparative studies, gauze dressings underperform compared to hydrogel and hydrocolloid dressings.

The truth is that the "dry" in wet-to-dry is not completely accurate: in veterinary use, these dressings normally retain a variable degree of moisture, especially when several layers of moistened gauze are applied. It is not uncommon to remove wet-to-dry gauze without significant adherence to the wound. Under these circumstances, they are not completely serving the goal of mechanical debridement as much as contributing moisture to the wound and diluting/wicking thick exudate away from the wound.

It is the author's contention that *surgical* debridement should be used to reduce the bulk of devitalized tissue in

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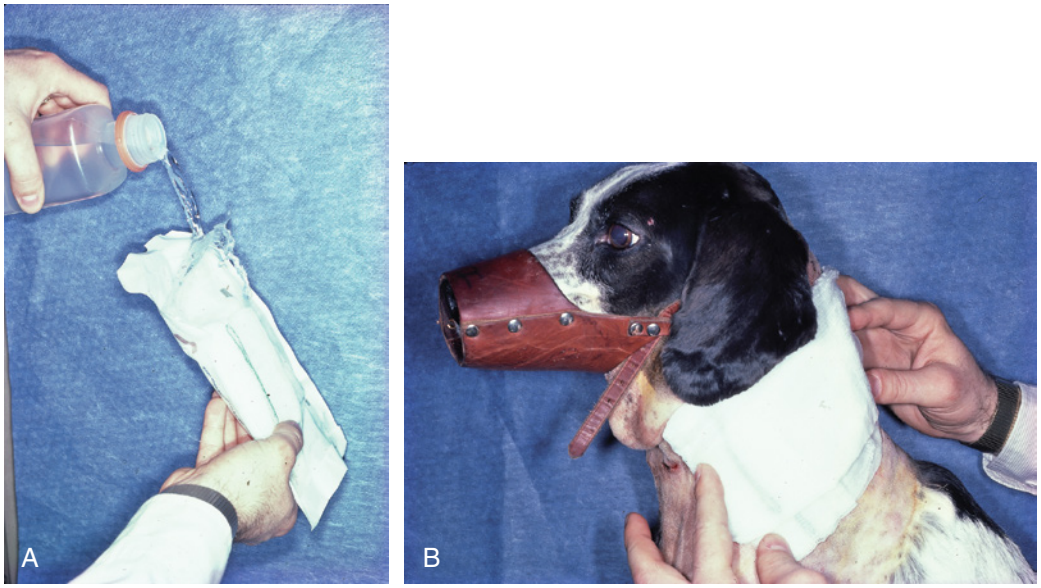


FIG. 5-2 (A) Applying saline to a package of sterile gauze pads prior to dressing an open wound. An antimicrobial agent can be added to the solution to treat a bacterial infection (see Chapter 4). (B) Application to a cervical bite wound.

problematic wounds; wet-to-dry dressing use should be limited to the inflammatory phase of healing. The author normally limits its use to 72 hours (corresponding to the inflammatory phase of wound healing). Short-term use, as described, does not significantly interfere with the emerging granulation tissue and has minimal effect on epithelialization. In the absence of necrotic tissue, adherent dressings serve no practical purpose in open wound care over other dressings discussed later in this chapter. Moisture-retaining dressings can be used to facilitate autolytic debridement once most of the necrotic tissue has been removed surgically or mechanically. They should not be applied in the presence of moderate amounts of devitalized tissue

Judicious surgical debridement, combined with wet-to-dry dressings, is one of the faster methods of preparing wounds for eventual closure. There is no indication for their use on healthy wound beds.

Wet-to-dry dressings are often used for unreasonably long periods of time by many veterinarians. Short-term use (normally 3 days) is strongly recommended to avoid prolonged trauma to the emerging granulation tissue and epithelialization noted during the proliferative phase of wound healing.

Dry-to-dry dressings are not commonly used in open wound management. Technically a dry-to-dry dressing would describe simple gauze application to a closed wound. In practice, dry-to-dry describes the application of dry sponges to a low-viscosity, highly exudative wound; this is not recommended.

Warm sterile saline or lactated Ringer's solution can be used to reduce gauze adherence to the wound. Keep in mind, however, that adherence is necessary to optimize mechanical debridement. Oversoaking should be avoided.

Alternatively, 2% lidocaine can be applied topically to the gauze. Lidocaine also can be diluted with sodium bicarbonate (9 : 1 mixture ratio) to reduce the stinging sensation occasionally noted with the subcutaneous injection of 2% lidocaine as a local block.

Nonadherent or Low-Adherent Dressings

Nonadherent (or, more properly, low-adherent) dressings are most commonly applied over a healthy wound or skin graft to facilitate dressing removal with minimal disturbance to the underlying tissue. They are often used to cover a skin incision to prevent an overlying cotton bandage from sticking to the area. These dressings usually comprise a treated fabric mesh impregnated with paraffin or petrolatum. Examples include cotton "leno-weave" fabric impregnated with paraffin, such as tulle gras dressings, including Jelonet® and Bactigras® dressings (Smith & Nephew) and Sofra-Tulle® (Hoechst Marion Roussel Ltd., Uxbridge, UK); knitted acetate fabric impregnated with a petrolatum emulsion (Adaptic™, Johnson & Johnson); and a fine mesh gauze impregnated with petrolatum and 3% bismuth tribromophenate (Xeroform™, Kendall Healthcare Products). Telfa™ (Kendall Healthcare Products) consists of a thin layer of absorbent cotton fibers enclosed in polyethylene terephthalate. This perforated plastic film has reduced adherence to the

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FIG. 5-3 Application of a nonadherent Telfa pad over a wound. A collagen gel has been applied to the wound surface before its application. An outer bandage wrap is required to maintain the position of the dressing.

wound surface while allowing the passage of exudates into the cotton backing of the dressing (Fig. 5-3). The author finds Telfa nonadherent strips and Adaptic nonadherent dressings the most flexible and useful of the nonadherent dressings for veterinary use.

Nonadherent dressings are commonly used in conjunction with topical wound-healing ointments, creams, and gels to help maintain their contact with the wound surface (see Chapter 4). This combined effect can create a partially or semi-occlusive dressing that helps provide moisture retention while protecting the area from desiccation. The porous or perforated surface of the nonadherent dressing allows for the passage of tissue fluids and exudates into the overlying secondary (absorptive) layer of the protective bandage. Over time, as the topical medication and discharge pass into the overlying absorptive layer, its occlusive properties diminish.

Despite their name, nonadherent dressings do occasionally adhere to portions of the wound surface. Fibrin and dried exudate can "glue" the dressing matrix to the wound surface. Granulation tissue can imbed in the open channels, forming "keys" that make removal difficult without causing a small amount of bleeding. Warm saline can be applied to soften the fibrin and dried discharge to facilitate their removal. More frequent dressing changes can reduce this complication. Dressings such as Telfa have smaller pores than Adaptic and may reduce granulation tissue embedment. However, the large openings in Adaptic provide superior drainage. The clinician must judge which dressing is most useful for a particular wound.

Other dressings, including occlusive dressings, may have nonadherent or low-adherent properties, but they are more appropriately discussed separately.

Absorptive Dressings

In the first week of wound management, wounds tend to be more transudative or exudative as a result of inflammation, infection, venous congestion, and local lymphatic compromise. The volume of fluid released can be retained and controlled by the use of an absorptive dressing and/or the overlying secondary (absorptive) layer of a bandage.

Both wet-to-dry and dry-to-dry cotton dressings are highly absorptive; as noted, wet-to-dry dressings can hydrate and dilute thick exudates and facilitate their absorption into the gauze matrix. In the presence of necrotic tissue, they provide mechanical debridement. However, there are other dressings that may be used to withdraw and retain discharge from the wound and that are better suited to promote the natural process of (selective) autolytic debridement of residual devitalized tissue.

Polyurethane Foams

Polyurethane foam is highly absorbent and able to retain several times its weight in fluid. It can be very useful in managing wounds releasing large volumes of tissue fluid. Foam can be used in conjunction with an overlying absorptive layer of bandage material.

Because of its fine porous surface, foam is basically nonadherent. Foams are less effective in debridement compared to alginate and hydrocolloid dressings (e.g., promoting autolytic debridement). Polyurethane and silicone foams can be moistened and applied to hydrate dry wounds. Because of their partial retention of moisture, they can be considered *semi-occlusive* in nature. Commonly used in veterinary practices, Hydrosorb® (Covidien Kendall) has a smooth, soft, nonirritating surface. It can be useful in protecting the skin over flexion surfaces from the abrasive effects of bandage material during ambulation. Because of their elastic nature, foams do not readily contour to irregular surface wounds without the application of an outer wrap to maintain their position. They can be used to cover a healthy granulation bed, although other products may be more useful for this purpose. Based on the physical properties of the material, polyurethane is a nonadherent dressing, absorptive dressing, semi-occlusive dressing, or moisture-retentive dressing, depending on the wound environment (Fig. 5-4). Other examples of this product include Allevyn® (Smith & Nephew) and Mepilex® (Mölnlycke Health Care) (Fig. 5-5).

Polyurethane foam is most useful for highly exudative wounds. In low-exudative wounds it also may be premoistened before application.

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Frequency of dressing changes will depend on the volume of discharge absorbed by the dressing. As a healthy granulation bed forms, the frequency of dressing changes normally declines.

Alginate Dressings

Alginate dressings are composed of alginic acid derived from various varieties of seaweed (Phaeophyceae). Alginic acid consists of a polymer containing mannuronic and guluronic residues. Alginates rich in mannuronic acid form soft flexible gels, whereas those rich in guluronic acid form firmer gels. Zinc, sodium, and calcium salts are added to the alginic acid polymer. Silver ions also have been added to alginate dressings to enhance their antibacterial property (see Antimicrobial Dressings). Alginate–foam dressings also are available (Askina® Caligtrol®, B. Braun Medical Inc., Bethlehem, PA).

Retained alginate is broken down by the cells into sugars without eliciting a foreign-body reaction. Alginate dressings (especially those containing zinc) have a topical hemostatic effect by activating prothrombin. Alginate dressings are commonly used in flat sheets, although a rope form is available for packing deeper wounds. Alternatively, the flattened sheet can be rolled and inserted into narrow cavities.

It is common to cover alginate dressings with an outer absorptive bandage to maintain the position of the dressing and assist in the absorption of excessive discharge from a wound surface. Alginates and collagen are commonly added to various moisture-retentive dressings and topical gels (see Chapter 4). On absorption of moisture, the dressings tend to soften into a gel-like compound that has the capacity to trap and store bacteria to a variable degree. With loss of moisture, alginate dressings can dry, forming a sticky plaque that requires traction with forceps

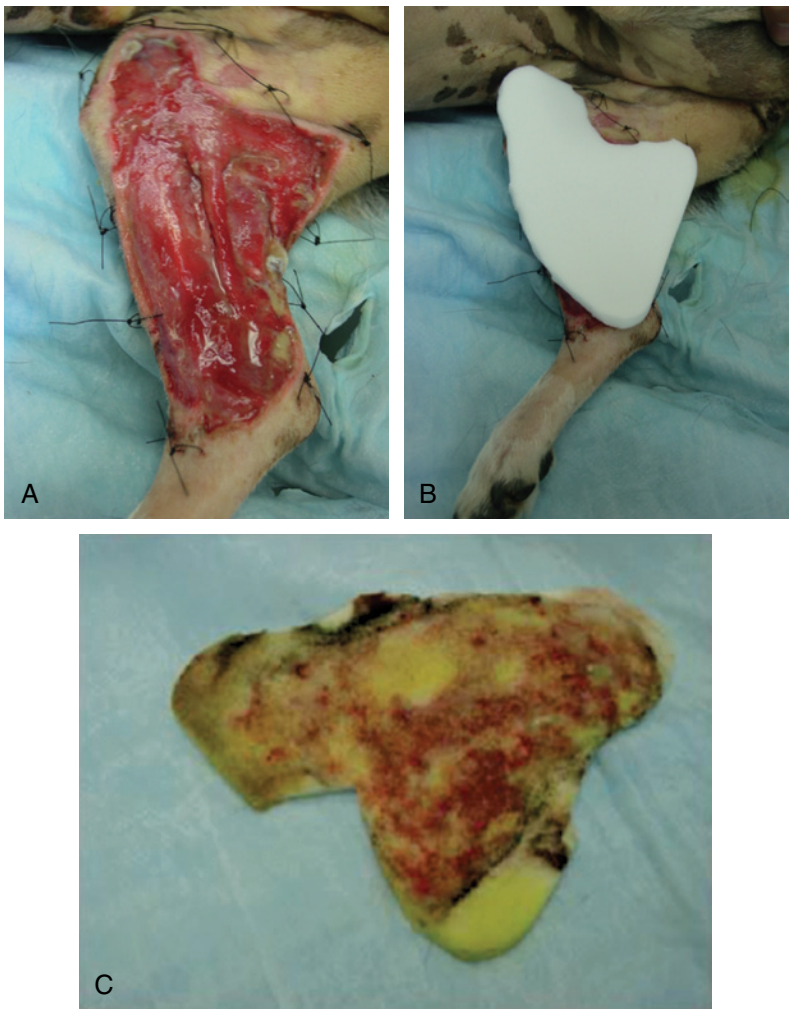


FIG. 5-4 (A) Use of polyurethane foam on a highly exudative wound. (B) The foam was cut to the shape of the wound and secured with a tie-over dressing. (C) Dressing change 24 hours later: note the high absorptive capacity of this dressing.

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during removal. Saline can be used to facilitate separation. Because of their absorptive properties, the dressings can dehydrate the surface of low-exudative wounds. The author has also used lightly moistened alginate dressings to cover healthy granulation beds. Contrary to one report, the author has seen no adverse effects to the skin peripheral to a wound if an alginate dressing overlaps the area. However, the flat dressings can be trimmed to better conform to the surface of a wound.

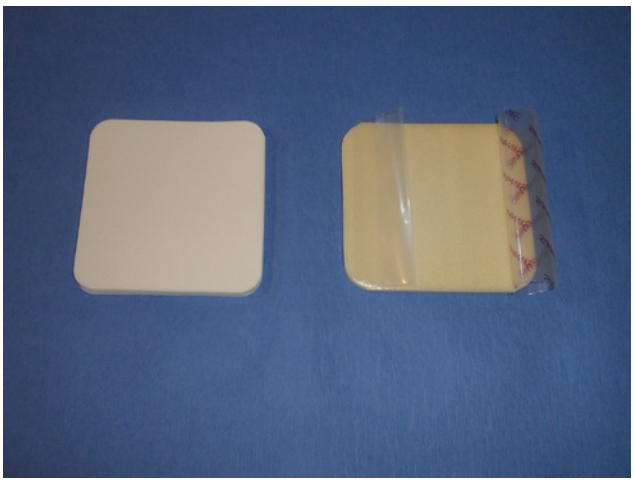


FIG. 5-5 Absorbent hydrophilic foam dressings: Kendall™ hydrophilic foam dressing (Covidien Kendall) and Mepilex silicone foam dressing with Safetac® technology (Mölnlycke Health Care). Both foam dressings are nonadherent and capable of absorbing moderate amounts of exudate. They also can be used to provide supplemental padding to wounds susceptible to external pressure or abrasion.

Dressings normally are changed every 3–4 days. In heavily exudative wounds, daily changes are advisable. It is the author's opinion that alginate dressings are best used in wounds after early formation of a granulation bed (Fig. 5-6). (See later Fig. 5-12 for a comparison with methylcellulose dressings.)

Examples of alginate dressings include Curasorb™ ZN (Covidien Kendall), Nu-Derm™ (3M), Sorbsan® (Pharmaplast Ltd., Alexandria, Egypt), Tegaderm™ Alginate (3M), and Kaltostat® (Convatec). Alginate dressings that include an absorbent backing also are available for heavily exudative wounds (Sorbsan Plus, Pharmaplast). Alternatively, an absorbent layer of gauze or absorbent pads can be applied over the alginate dressing to help retain the anticipated wound drainage. Apinate dressings, made by Comvita Medical (distributed by Derma Sciences), have a combination of a calcium alginate dressing and manuka honey. This product is sold as Medihoney™ calcium alginate dressing (see later Fig. 5-16). Manuka honey is discussed in Chapter 4.

Hypertonic Saline Dressings

Hypertonic saline dressings are cotton gauze sponges saturated with 20% sodium chloride. The hypertonic saline has an absorptive osmotic effect on the wound and can be useful in reducing edema secondary to trauma. In drawing water from the wound, it can facilitate the hydration of devitalized tissue and its subsequent mechanical debridement during bandage changes. The hypertonic saline also blunts the ability of bacteria to proliferate. Unfortunately, these dressings have the potential to dehydrate viable tissue in the wound. As moisture is drawn into the dressing, the salt concentration will progressively decline, necessitating periodic bandage

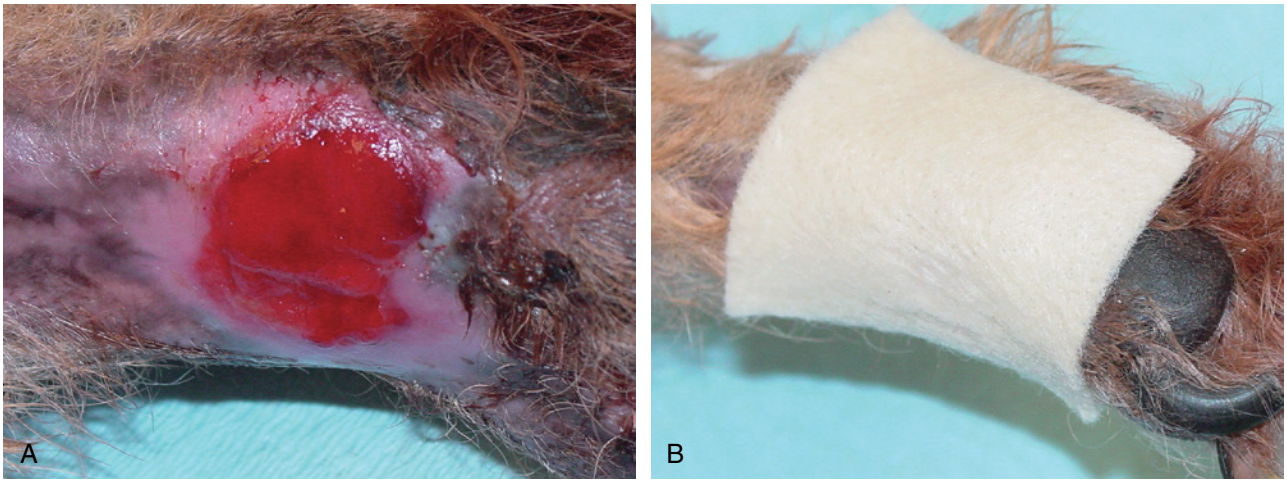


FIG. 5-6 (A) Feline paw wound managed with an alginate dressing. Note the excellent granulation bed and peripheral epithelialization. (B) A single alginate pad can be divided into smaller pads as second-intention healing progresses.

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changes every 3 days or less, depending on the volume of fluid. Curasalt™ (Covidien Kendall) is marketed to veterinarians. (In essence, hypertonic saline-impregnated gauze dressings are a variation of the wet-to-dry dressing previously discussed.) Hypertonic dressings are normally abandoned with the early formation of granulation tissue.

Moisture-Retentive Dressings and Occlusive Dressings

Providing a protected, moist wound environment can optimize the processes of wound healing. Moisture-retentive dressings are soothing to sensitive wound surfaces and reduce patient discomfort. These properties also may be accomplished with topical medications (see Chapter 4) or by using more specialized moisture-retentive dressings.

There is a broad range of dressings that fall into the category of "moist dressings." As noted, some absorptive dressings also may have variable moisture-retentive properties.

Many moisture-retaining dressings are occlusive or semi-occlusive by nature. The outer synthetic membranes of occlusive dressings prevent or minimize penetration of contaminants. They are capable of retaining the exudate's cytokines essential to wound healing. Low oxygen tension beneath an occlusive dressing stimulates macrophage activity, fibroblast proliferation, and neovascularization. The rate of epithelialization is reportedly twice as fast as for wounds left exposed to the air. Partially occlusive dressings may be gas permeable or moisture vapor permeable—allowing moisture beneath the dressing to escape from the membrane. Because they retain and hydrate tissues, these dressings facilitate natural autolytic debridement of residual necrotic tissue adhered to the underlying viable wound surface. Hair should be clipped liberally from around the wound to improve their adherence to the adjacent skin to facilitate wound care.

Dressings with a low moisture vapor transmission have a higher retention of water and are better able to maintain a moist wound environment. Moisture is typically lost through normal skin and this can be quantified as trans-epidermal water loss. Intact human skin has a trans-epidermal water loss of 4–9 $g/m^2/h$, whereas water loss increases dramatically in partial- and full-thickness skin wounds (80–90 $g/m^2/h$). Dressings that have a low moisture vapor transmission value, less than 35 $g/m^2/h$, are considered moisture retentive. Dressings that retain the tissue fluids also help contain both the cellular and extracellular components (cytokines, etc.) of wound healing (see Chapter 3) that naturally support the healing process.

Moisture Transmission Values of Common Dressings ($g/m^2/h$)

Normal skin: 4.0–9.0
Hydrocolloid dressing: <12.5
Polyurethane film: 12.5–33
Polyurethane foam: 33.4–208
Cotton gauze: 67

Wet-to-Wet Dressings

Wet-to-wet dressings are particularly useful to hydrate dry or mummified necrotic tissue, thereby facilitating its removal. This normally can be accomplished in 24 hours. A wet-to-wet dressing includes the application of moistened gauze sponges secured to the wound with an outer wrap or "tie-over" dressing (see later in this chapter). Sponges are periodically moistened with Ringer's lactate or saline during this time. An antimicrobial solution (chlorhexidine or povidone–iodine) may be used, or antimicrobial polyhexamethylene biguanide (PHMB)–impregnated gauze sponges can be substituted for standard cotton sponges (see Antimicrobial Dressings). The author prefers to insert sterile fenestrated tubing between gauze layers to facilitate injecting additional fluid into the bandage every 6 hours in order to maintain a high moisture level (Figs 5-7 and 5-8). Alternatively, fluid can be injected or trickled into the bandage with a syringe. Use of this wetting technique is also discussed in Chapter 4 under Dakin's solution.

When the wet-to-wet dressing is removed, the necrotic skin and underlying tissues are invariably softened from the absorption of water, facilitating their surgical removal. Heavy sedation or general anesthesia facilitates the bulk removal of devitalized tissue. If residual necrotic tissue remains, wet-to-dry dressings, hydrating topical agents (see Chapter 4), or a moisture-retaining dressing can be used to facilitate its removal.

Hydrogel Dressings

Chapter 4 discusses topical hydrogels in detail. Hydrogel dressings are primarily composed of water (70–95%) that is retained in a fiber network of humectants and various superabsorbent hydrophilic polymers (carboxymethylcellulose, polyethylene oxide, starch-grafted copolymer, polyvinyl alcohol copolymers, etc.) that absorb aqueous solutions by hydrogen bonding with water. In general, hydrogel dressings essentially are sheets of cross-linked polymer gels. (*Note*: superabsorbent polymers are also used in many personal hygiene products, including baby diapers.) Many of these dressings are semi-transparent, which facilitates initial wound inspection (Figs 5-9 and 5-10). Some

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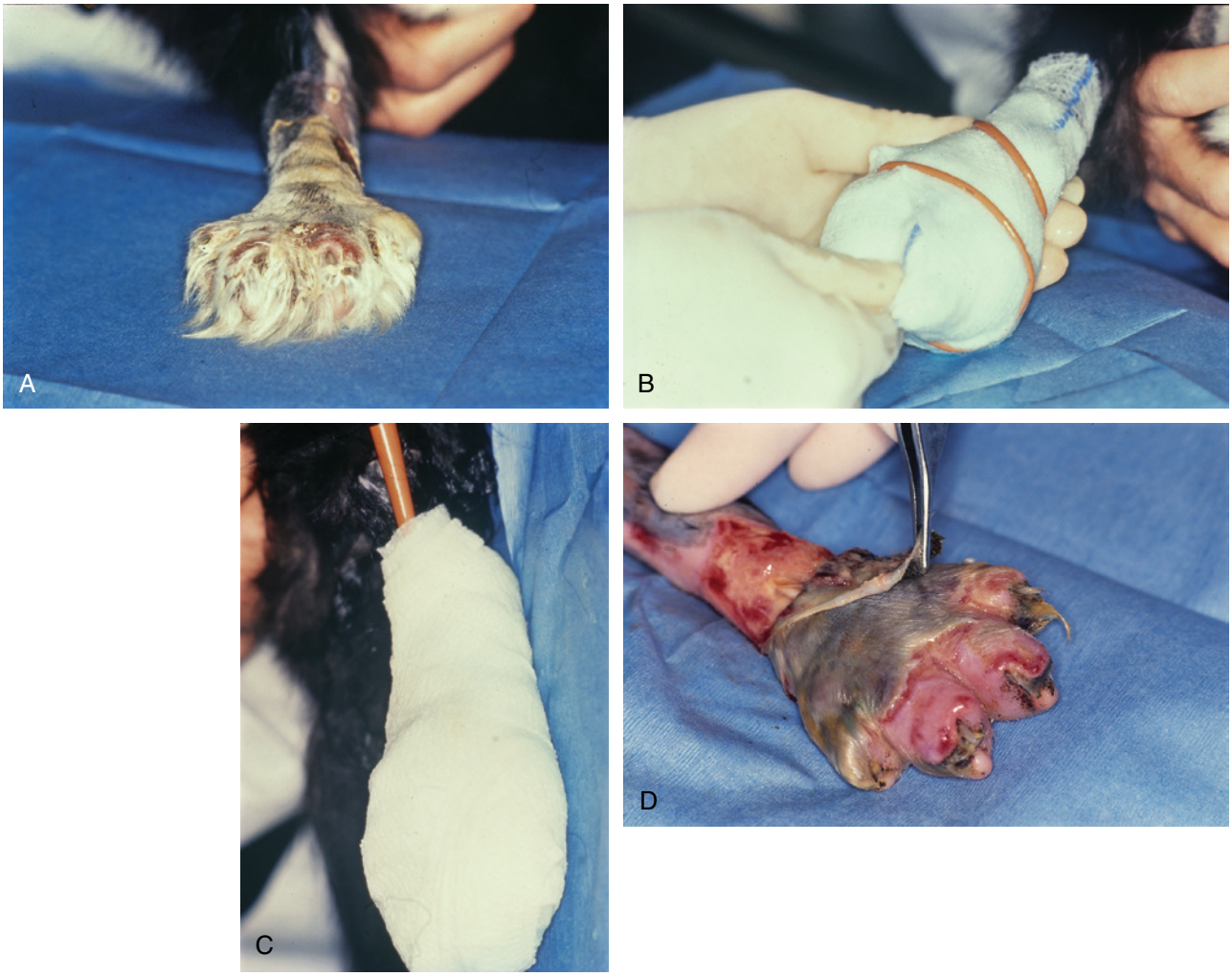


FIG. 5-7 (A) Extensive skin loss involving the hind paw of a cat. A wet-to-wet dressing was applied to hydrate the mummified necrotic skin overlying the metatarsal area. (B) Saline-moistened cotton gauze sponges were wrapped over the entire paw, followed by the spiral application of a fenestrated rubber catheter. An additional layer of sponges was wrapped over the tubing, followed by a layer of self-adherent roll gauze and autoclaved Vetrap™ (3M). (C) Approximately 10 ml of saline was injected into the funnel-tipped catheter end exiting the bandage. This was repeated every 6 hours. (D) After 24 hours, the patient was sedated and the bandage removed. The hydrated necrotic tissue easily peeled off the paw with forceps. The foot was closed with a mesh graft a few days later.

hydrogel dressings contain other products: Nu-Gel™ (Systagenix Wound Management Ltd., Gatwick, UK) and Purilon® (Coloplast), for example, contain alginate in their hydrogel matrix. Nu-Gel also comes in a dressing containing collagen in order to enhance the otherwise modest absorptive capacity of the dressing. Antimicrobial agents, such as silver, metronidazole, and silver sulfadiazine, have been added to hydrogel dressings to prevent or manage low-grade infections (see Antimicrobial Dressings).

Most hydrogel dressings require an outer bandage or wrap to secure them to the wound surface. Hydrogels are relatively easy to apply to flat wound surfaces. Overlapping the adjacent skin margins of a wound should be minimized, since the dressing may contribute to maceration.

> Unstable dressings can be secured to a wound surface with surgical staples or sutures. This is particularly useful in ensuring the dressing will not slip off the wound surface when infrequent dressing changes are necessary.

Hydrogel dressings form a protective gel covering with a somewhat limited capacity to absorb exudates. They can be considered an "interactive dressing." Their ability to hydrate a wound facilitates autolytic debridement of

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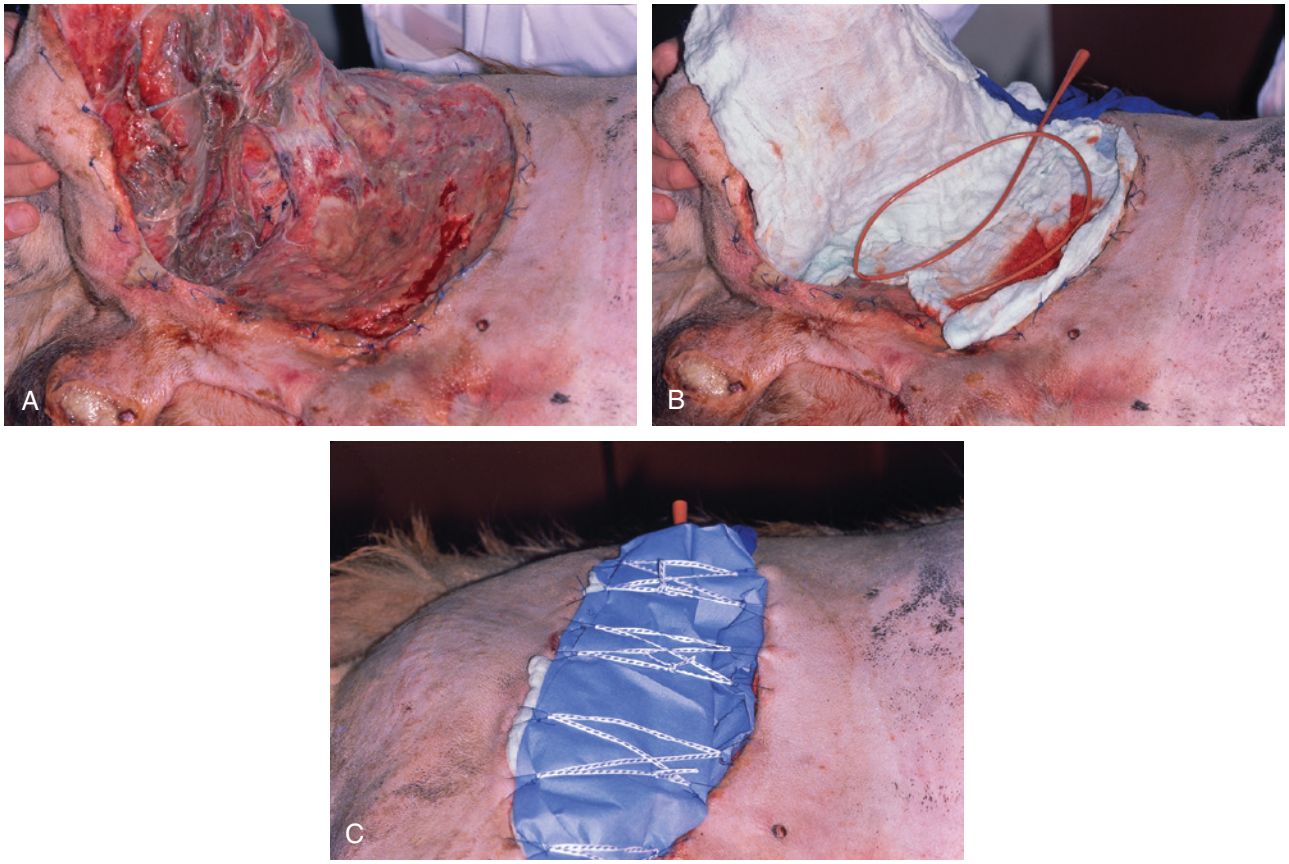


FIG. 5-8 (A) Large right flank and thigh wound extending to the knee due to secondary vehicular trauma. (B) After initial surgical debridement, a wet-to-wet dressing was used to facilitate subsequent removal of residual necrotic tissue. Saline-moistened laparotomy pads were applied to the wound, followed by a fenestrated red rubber tube. A second moistened pad was applied over the coiled tubing. (C) The wet-to-wet dressing was secured to the area with a tie-over. A caudal superficial epigastric flap was later used to close this large skin defect.

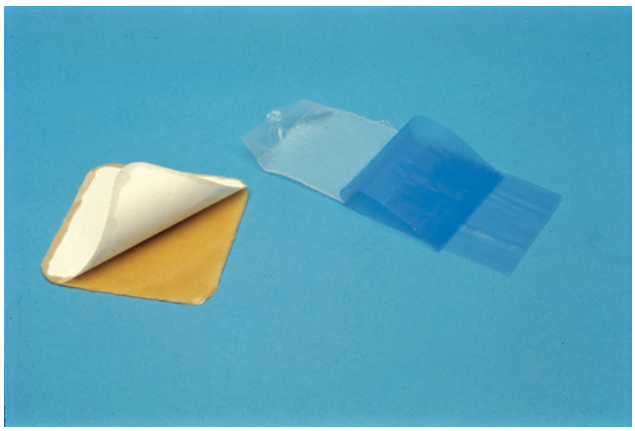


FIG. 5-9 Examples of a hydrocolloid (left) and hydrogel (right) dressing. A protective cover is peeled off the dressing, exposing the sticky contact surface of the dressing for placement over an open wound.

residual necrotic tissue. They support healing by second intention and reduce patient discomfort. In one experimental study (Ramsey et al.1995), they appeared to promote wound contraction on extremity wounds, but less so for trunk wounds in dogs. They are best employed for wounds free of infection and excessive necrotic tissue. Dressings are normally changed every 3 or 4 days for most noninfected wounds. Saline or a wound-cleansing agent (see Chapter 4) can be used to prepare the wound for the replacement dressing. Because of their occlusive properties, the use of hydrogel dressings in infected wounds is not advisable. In one study, wounds covered with hydrogel dressings displayed greater wound contraction compared to hydrocolloid and polyethylene dressings.

A few examples of hydrogel dressings include Biodress (DVM Pharmaceuticals, Miami, FL), Vigilon™ (Bard Medical Division, Covington, GA), Tielle® and Nu-Gel dressings (Systagenix Wound Management), Aquasorb®

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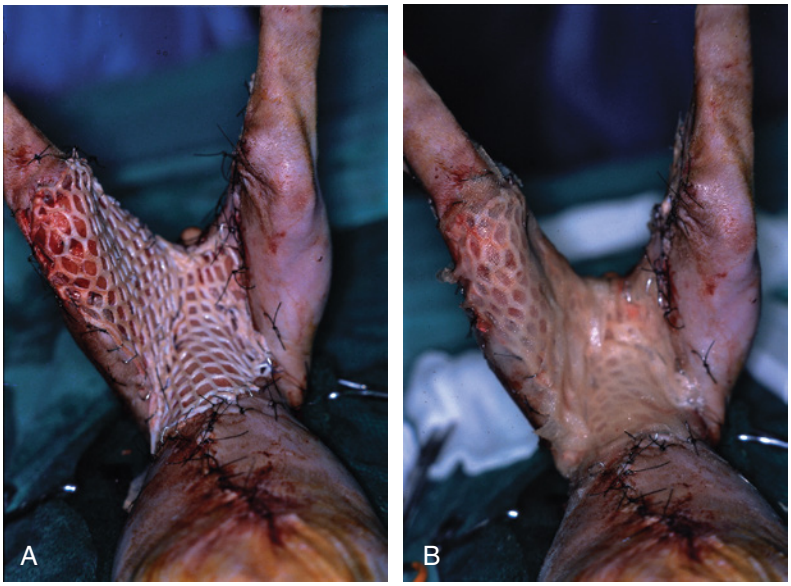


FIG. 5-10 (A) Mesh graft application to a problematic inner thigh defect. (B) In this case a hydrogel dressing was stapled over the grafted area to maintain hydration of the area and promote epithelialization. The hydrogel was successfully used, but was not considered any better than the customary use of a nonadherent dressing (Adaptic) combined with triple antibiotic ointment.

(DeRoyal Industries), and Curagel® (Covidien Kendall). Control studies between the various hydrogel products are lacking.

Hydrocolloid and hydrogel dressings have a moisture-retaining matrix applied to an outer synthetic membrane. In effect, they are similar to comparable topical agents designed to provide a moist environment for optimal healing. This group of dressings may be easier to apply and change compared to the reapplication of a comparable topical gel for shallow wounds. Topical gels may be more useful for more cavitated defects, with a dressing and bandage applied to help maintain their prolonged contact with the wound surface. Hydrocolloids can better retain exudate than the water-based hydrogel dressings.

Hydrocolloid Dressings

Chapter 4 discusses the use of topical hydrocolloids in detail. Hydrocolloid dressings contain a variety of constituents, including sodium carboxymethylcellulose, gelatin, pectin, and polyisobutylene. Gelatin, pectin, elastomers, alginates, silver, and other materials can be added to these substrates. The tacky matrix is affixed to a polyurethane film or foam backing for easy application to flat wound beds. The outer cover forms a protective barrier against external moisture and contaminants (Fig. 5-11). Hydrocolloid dressings tend to be stiffer than most hydrogel dressings; they will soften to some degree when warmed by simply compressing the dressing between the hands for a couple minutes before application. Hydrofiber pads or ribbons can be formed from sodium carboxymethylcellulose fibers (Fig. 5-12).

Hydrocolloid dressings have some capacity to absorb exudates from the wound surface, forming a gel over time. For this reason, they are also considered to be an interactive dressing. Hydrocolloid dressings may vary in their performance as it pertains to their individual absorbency, fluid-handling characteristics, and physical properties. The moist environment facilitates autolytic debridement. However, they are best used for wounds with minimal necrotic tissue; they should be avoided in the presence of wound infection. Hydrocolloid dressings are normally applied to a wound by slightly overlapping the skin that makes up the perimeter of the wound. Excessive overlapping may overhydrate the adjacent skin. Most dressings are changed every 3–4 days. Saline or wound-cleansing agents (see Chapter 4) may be used to remove the somewhat tenacious gel–exudative debris that forms on the wound surface during their use. Hydrocolloid dressings may adhere to the wound without a secondary wrap. When used on the lower extremity, tape strips can be used for added security. The relative stiffness of these dressings may "splint" the wound, thereby impeding myofibroblastic contraction of the skin bordering the wound (Figs 5-13 and 5-14).

There is a wide variety of hydrocolloid dressings available. A few examples include DuoDERM or Granuflex (Convatec), Restore® hydrocolloid dressing (Hollister Inc., Libertyville, IL), Nu-Derm (3M), Tegaderm hydrocolloid dressing (3M Health), Replicare® hydrocolloid dressing (Smith & Nephew), and Invacare® hydrocolloid dressing (Invacare Corp., Cleveland, OH).

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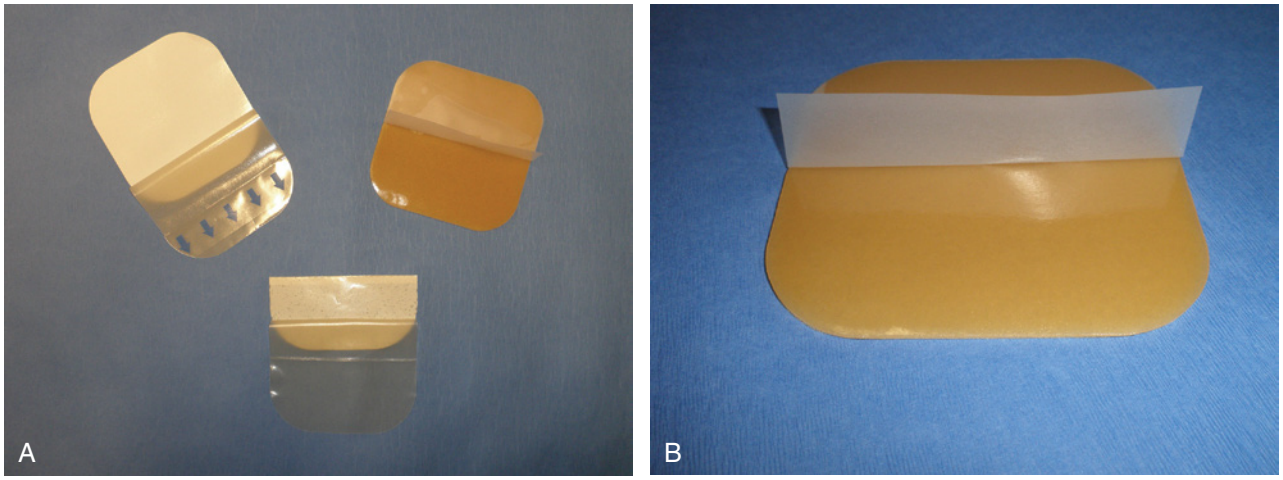


FIG. 5-11 (A) Examples of three hydrocolloid dressings: Primacol® (Derma Sciences) (left); DuoDERM CGF (Convatec) (right); and Exuderm® LP (Medline Industries LP, Northfield, IL) (bottom). Note the backing sheet is partially peeled back to expose the stick hydrocolloid matrix. The DuoDERM CGF is a thicker matrix compared to the Primacol and Exuderm hydrocolloid dressings and can hold a greater amount of exudate. (B) Close-up view of the DuoDERM CGF. The backing is held to facilitate dressing placement prior to its removal. This thick hydrocolloid is placed over the wound, overlapping the adjacent skin edges. The tacky substrate adheres to the wound and skin surface.

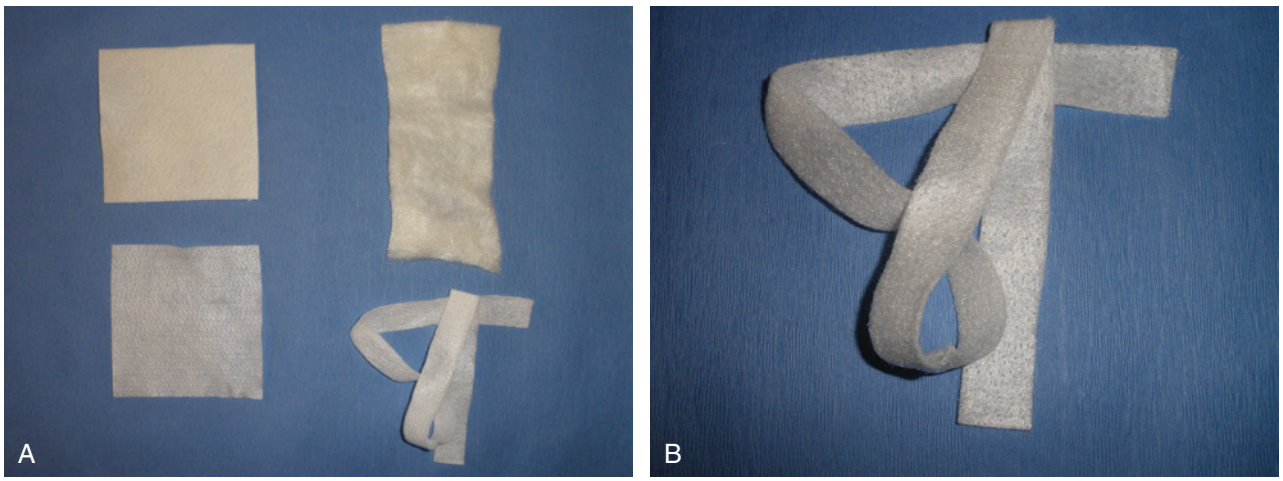


FIG. 5-12 (A) Examples of hydrofiber absorbent dressings: Kendall zinc sodium alginate dressing (Kendall Healthcare Products) (upper left); Kaltostat® CE calcium sodium alginate dressing (Convatec) (lower left); Aquacel® hydrofiber wound dressings (Convatec) pad form (upper left) and ribbon form (lower left), composed of sodium carboxymethylcellulose. These absorbent dressings, when in contact with exudate, form a soft gel to promote autolytic debridement. Each is capable of absorbing and retaining mild amounts of exudate. Despite the similar appearance of these dressings, the comparative performance of the various dressings is unknown without comparative research. (B) The uacel ribbon is designed for packing into small pocket wounds: the end can be grasped and retracted from the wound cavity followed by simple reapplication.

In early wound care, highly exudative wounds will overwhelm the fluid-retaining capacity of hydrogel and hydrocolloid dressings. More absorptive dressings would be advisable until capillary stability and fluid reduction are noted. This is usually associated with the development of a healthy granulation bed. This general rule of thumb also would be applicable to highly exudative wounds. As a result, the use of these dressings may be more suitable for granulation beds free of excess necrotic tissue and contaminants.

In veterinary medicine, wound contraction is heavily relied on for closing most skin wounds. Wound contraction is particularly important for the closure of larger full-thickness skin defects; epithelialization plays a lesser role. Any stiff dressing that "splints" the wound margins can impair wound contraction, despite its reported promotion of epithelialization.

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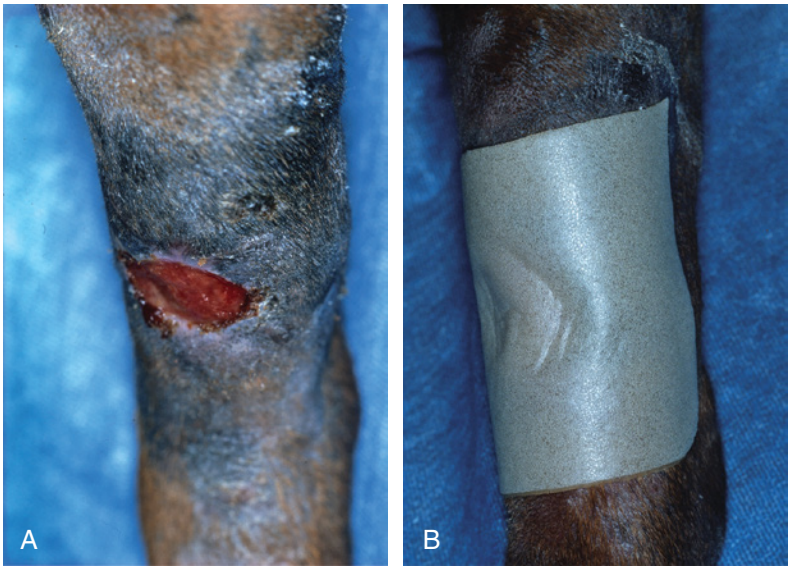


FIG. 5-13 (A) Application of a hydrocolloid dressing (DuoDERM) to a lower-extremity wound. (B) The dressing overlaps the skin and adheres fairly well to the area. Tape strips or a light wrap can be used to ensure the dressing does not shift. The rigidity of this type of dressing may impede wound contraction.

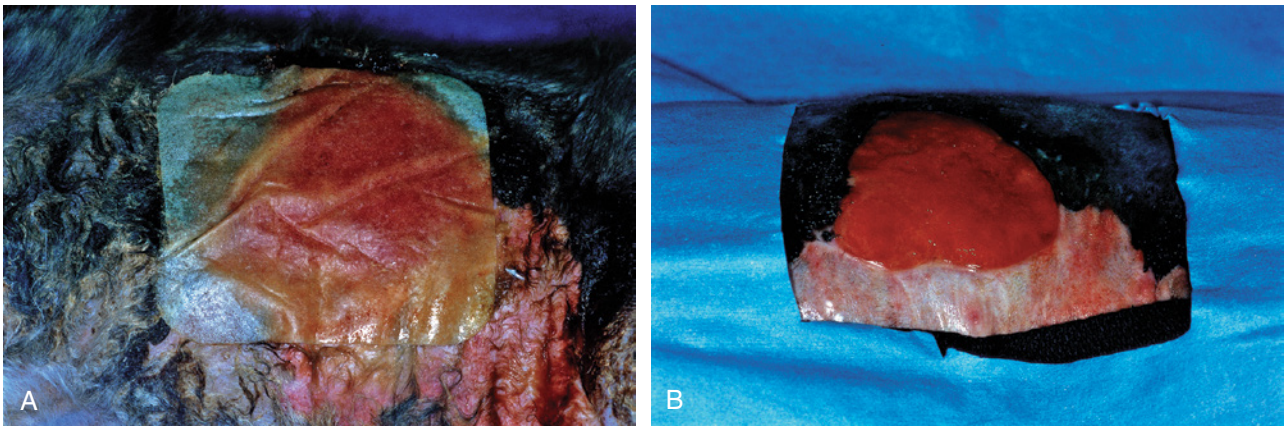


FIG. 5-14 (A) Application of a hydrocolloid dressing (DuoDERM) to a problematic skin defect in a cat. Note the hydrocolloid discharge onto the lower adjacent skin surface. (B) The wound remained unchanged after 4 weeks. A transposition flap was later used to successfully close this defect. This example underscores the fact that many wounds will remain challenging despite the development of multiple wound dressings and topical agents designed to promote healing.

Vapor-Permeable Films

Vapor-permeable films generally allow for the passage of water vapor and oxygen. However, vapor permeability, adhesiveness, and conformability vary with each product. The term *film dressing* refers to a thin, transparent polyurethane membrane coated with a layer of adhesive to secure it to the bordering skin surface. The film can be used as a protective membrane over minimal exuding wounds or as a protective barrier (e.g., closed incisions).

Polyurethane is the most commonly used transparent plastic film barrier to protect wounds. Polyurethane is permeable to gas but protects the wound from external contaminants (water, bacteria). Polyurethane films are considered semi-occlusive, allowing water vapor to escape from their surface. They have no absorptive capacity and moisture can accumulate beneath polyurethane, potentially promoting the proliferation of skin organisms.

The film may be applied to superficial wounds with minimal exudates and it has an adhesive to secure the dressing to the skin surrounding the wound borders (minimum 1 inch [25 mm] overlap). Removal of fur, followed by cleansing and drying the skin, will facilitate its

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adherence. In general, film does not adhere and conform well to mobile body regions and skin folds. The use of film alone should be avoided in the presence of infection, necrotic tissue, or highly exudative wounds. Some polyurethane films contain a light gauze dressing and can be used as protective barriers over a sutured incision (Tegaderm; OpSite® Post-Op, Smith & Nephew) (Fig. 5-15). Polyurethane dressings also are used as protective containment barriers to secure other dressings (e.g., alginates, gauze, etc.) and topical medications. These film dressings are frequently used to protect a skin incision from moisture and topical contaminants postoperatively, rather than as a dressing for open wounds.

Plastic drapes primarily used in orthopedic procedures can be adapted for maintaining dressings and bandages in problematic body areas. Ioban (3M), Vi-Drape (Medical Concepts Development), and OpSite Incise Drapes (Smith & Nephew) are examples of plastic drapes used in surgery. Surgical drape adhesives can be used sparingly to enhance the adherence of these plastic films to the skin (Hollister Medical Adhesive 3.20). They may be useful for securing dressings and bandages to the lateral surfaces of small animals. Subsequent dressing changes may be facilitated simply by splitting the plastic drape to gain access to the wound. The drape opening is retaped after changing the dressing.



FIG. 5-15 The Tegaderm transparent dressing is a waterproof thin plastic film designed to protect wounds from external contaminants. A thin adhesive film sticks to the skin surface. In this example, the protective backing was removed from the adhesive surface and applied to the blue surgical drape. The outer tabs assist in positioning the Tegaderm: following application of the dressing, the ends of the tabs are grasped and removed. It does help to have an assistant when removing the backing and applying Tegaderm: the dressing readily adheres to itself, producing folds or wrinkles prior to placement. Although they are effective in protecting incisions from contaminants, Tegaderm dressings do not always adhere well to canine skin and are prone to displacement. Supplemental tape strips or skin staples can be used to reduce inadvertent removal.

Miscellaneous Dressings

Antimicrobial Dressings

Silver was first recorded in Mesopotamia in the Ubaid period, between 5000 and 3500 BCE. It was recognized that silver-lined containers or the addition of silver to vessels made water potable. It has long been recognized that silver ions possess broad-spectrum antimicrobial properties, including efficacy against *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus*, and vancomycin-resistant *Enterococcus* and *Candida* sp. Silver ions also may mitigate inflammation by inhibiting matrix metalloproteinase activity. Nanocrystalline silver (particle size <20 nm) is commonly added to a variety of dressings. It has been postulated that complex metastable silver hydroxide compounds form on the surface of nanocrystalline silver particles that provide antibacterial properties. Silver ions, absorbed into the bacterial cells, inhibit respiratory enzyme(s) and form reactive oxygen species that cause cell damage. It is also believed that silver cations bind to cell walls and intracellular/nuclear membranes, disrupting them. The oxidizing properties of silver ions may inactivate enzymes and impede DNA synthesis.

Silver-impregnated dressings are available in a wide variety of forms. Some examples include:

- Antimicrobial alginate dressings: Silvercel™ (Johnson & Johnson), Algicell® (Derma Sciences), Seasorb®-Ag (Coloplast), Sorbsan® Silver (Creed Health, Mansfield, UK), Silverlon® CA (Argentum Medical LLC, Geneva, IL), and Maxorb® Extra Ag (Medline Industries)
- A 90% collagen–10% alginate wound dressing: Fibracol® (Johnson & Johnson)
- A collagen-oxidized regenerated cellulose dressing containing 1% silver: Promogran Prisma® (Johnson & Johnson)
- Actisorb® silver antimicrobial binding dressing using an activated charcoal woven fabric containing 0.15% silver by weight (Johnson & Johnson)
- A hydrogel dressing containing silver: SilvaSorb™ (Medline Industries)
- Nylon-impregnated dressing: Silverlon® negative-pressure dressing (Argentum Medical)

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- Foam products: Algidex Ag® (DeRoyal Industries) and PolyMem® Silver (Ferris Manufacturing Co., Burr Ridge, IL)
- A highly absorbent sodium carboxymethylcellulose hydrofiber dressing: Aquacel

Silver application to open wounds, managed by vacuum-assisted closure (VAC), also has been reported (see Chapter 4).

As noted previously, gauze impregnated with the antimicrobial agent PHMB can be used to manage or help prevent infection. PHMB is a cationic surface-active agent (related to chlorhexidine) that irreversibly destabilizes cytoplasmic membranes of bacteria. Chlorhexidine acetate has been formulated into topical dressings to protect minor wounds from infection (Bactigras). Polytracin dressings (polymyxin B, bacitracin zinc, neomycin sulfate) are also available from Galaxy Medicare Ltd. (Orissa, India).

Cadexomer iodine also has been used in wound dressings (Iodosorb™ sheet dressing, Smith & Nephew, Inc.) and as an ointment or powder (Iodosorb ointment/Iodosorb powder). Cadexomer iodine is a biodegradable mixture of cadexomer polysaccharide beads as a carrier for 0.9% iodine. Cadexomer iodine-based products slowly release iodine, unlike povidone–iodine dressings, which deposit their iodine immediately on application to the wound. They have a high rate of fluid absorption for exudative wounds. Dressings with cadexomer iodine should be used cautiously over large surface areas due to the risk of iodine toxicity.

Bioactive Dressings

Dressings composed of materials that originate from living tissue are called *bioactive dressings*. The following are examples of this family of dressings. They may have properties similar to other dressings discussed. Occasionally, companies will combine bioactive products with hydrocolloid or hydrogel dressings and topical agents. See Chapter 4 for more details on these products.

Acellular Fish Graft Dressings

Fish skin has been prepared for use as a cover graft for a variety of wounds in humans; cases studies have been noted in the veterinary literature. The acellular dermal matrix (ADM) of tilapia and other fish species including the North Atlantic cod is reportedly similar to the dermal matrix of mammals. Gentle processing of the skin maintains omega-3 fatty acids, lipids, collagen, laminin, elastin, and laminin as well as proteoglycans and glycosaminoglycans. The microporous structure of fish skin grafts (FSGs) serves as a scaffold, allowing them to be incorporated into the wound bed within 7–10 days. They reportedly can speed up the healing processes while serving as an antimicrobial barrier. Other ADMs include intestinal submucosal or amniotic tissue from pigs, cattle, and horses. In one study, FSGs were noted to promote healing significantly faster than these ADMs. FSGs were also reported to improve revascularization and epithelialization compared to fetal bovine dermis in a swine study for deep partial-thickness thermal wounds. It has been suggested that epidermal growth factor and fibroblast growth factor induction may occur in the presence of FSG, contributing to the proliferation and differentiation of fibroblasts and epithelial cells. Peptides found in tilapia skin may have antimicrobial activity.

While medical-grade cod FSG is commercially available (Kerecis® VET, Kerecis, Arlington, VA) for partial- and full-thickness burns in humans, it is also available for purchase in animals. Sizes include 3 cm × 7 cm, 7 cm × 7 cm, 7 cm × 10 cm, and 8 cm × 20 cm sheets. A 3 cm × 7 cm sheet reportedly costs $118; this would practically limit the use of this product for smaller problematic wounds. It is likely that other treatment modalities would be considered before resorting to this product. (See Fig. 25-20.)

Medical-grade tilapia skin, used as a xenograft, does not appear to be commercially available as of this writing. In humans, tilapia skin is sterilized with irradiation or glycerolization. The lyophilized version of tilapia skin also shows promise. One veterinary case report noted that they purchased tilapia and harvested the skin; the skin was then copiously cleansed using 2% chlorhexidine for 90 minutes, then 100% glycerol and 2% chlorhexidine at a 3 : 1 ratio for 60 minutes; after that the grafts were manually massaged with 100% glycerol for 5 minutes, followed by 100% glycerol for 60 minutes. Sterile saline washes were used between each treatment. Grafts were then cultured (aerobic, anaerobic) prior to placement in a sterile plastic sleeve before storing them at 4 °C.

FSGs are placed on healthy wound beds devoid of necrotic tissue and the presence of infection. Prior to placement, a thin layer of sterile hydrogel can be spread on the wound surface to improve adherence of the FSG. An additional layer of hydrogel is placed on the FSG followed by placement of gauze or a hydrophilic foam and then a soft bandage. Removal of the FSG can be facilitated by applying sterile saline. In humans, FSGs are replaced on a weekly basis, usually over a 5–6-week time span. One veterinary reference suggested FSG replacement in animals every 2–3 days, although changing the FSG every 10 days, protected by a bandage, is also an approach that has been used in small animals. Based on this elaborate process, it is unlikely that

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tilapia will be the first choice in veterinary wound care over other products that are commercially available and economical to use. Moreover, the use of autogenous skin grafts, skin flaps, and skin-stretching techniques could be considered once a healthy wound bed is established. Alternatively, wounds that are contracting effectively can be supported with a variety of wound dressings until the point at which this healing process slows; then surgical closure can be attempted on the resultant smaller full-thickness skin defect.

It is important to note that FSGs have an appetizing odor to carnivores. Dogs and cats are inclined to eat the graft, given the opportunity. The FSG should be covered with a bandage followed by placement of an Elizabethan collar to prevent this occurring.

COLLAGEN (EXTRACELLULAR MATRIX BIOSCAFFOLD) DRESSINGS

Bovine collagen can be used as a topical agent: it may be applied as a powder, gel, pad, or in packet form for a variety of applications (see Chapter 4). However, collagen can be applied as a biologic dressing that may serve as a scaffold to facilitate wound healing. The organized collagen fibrils act as a substrate or filamentous network for fibroblast, endothelial, and epithelial cell migration. Research into skin substitutes has focused on the use of artificial dermal scaffolds that better mimic the natural properties of the dermis, in contrast to organized scar tissue secondary to granulation tissue maturation. These products are reported to promote angiogenesis and the chemotactic recruitment of white cells and fibroblasts (see Chapter 2).

Promogran Prisma, for example, is a *composite* dressing with 55% collagen, 44% oxidized regenerated cellulose, and 1% silver. Prisma is used in the management of chronic ulcers and other open wounds. Biobrane® (Smith & Nephew) is a biosynthetic wound dressing constructed of a silicone film and a nylon complex three-dimensional trifilament network to which collagen is chemically bound. Blood and sera will clot in this matrix, firmly adhering the dressing to the wound surface; the moist environment created promotes epithelialization.

Porcine small intestinal submucosa (SIS) has been integrated into an extracellular wound matrix dressing (e.g., Oasis®, Cook Biotech, Inc., West Lafayette, IN; CollaMend®, C. R. Bard, Inc., Covington, GA; Vet BioSIST®, Smiths Medical PM, Waukesha, WI) that provides a three-dimensional collagen scaffold to help "direct" collagen deposition and facilitate the ingrowth of cells and capillaries into this matrix for partial- or full-thickness wounds. (SIS comprises type I, III, IV, V, VI, and VIII collagen, fibronectin, hyaluronic acid, chondroitin sulfate, and heparin.) It has been used to assist in the repair of hernia and chest wall defects in humans. Acellular urinary bladder matrix or submucosa (UBM or UBS) also has been used as an inductive scaffold for tissue replacement. ACell Vet™ (ACell Inc., Columbia, MD) has been advocated for a variety of soft tissue and orthopedic procedures. Both SIS and UBM/UBS reportedly also contain growth factors to promote wound healing.

These bioscaffold dressings can be integrated into the healing process; as healing progresses, an additional layer of these materials can be placed over the original dressing without its removal. Loose dressings or hydrolyzed fragments can be removed prior to replacement with a fresh dressing at the time of bandage change.

A study using porcine-derived SIS on exposed bone in dogs failed to demonstrate its effectiveness in promoting wound contraction and epithelialization. A study in horses also failed to demonstrate efficacy. A third study noted that porcine SIS applied to wounds in research dogs contracted more slowly, epithelialized less, and had more acute inflammation compared to control wounds. Based on these reports, there would appear to be no advantages in the use of SIS in open wound management in dogs at this time.

Equine amnion dressings have been used experimentally as occlusive dressings. They were noted to be effective in promoting contraction and epithelialization in experimental dogs.

> With the presence of other economical dressing alternatives, the routine clinical use of these products remains unclear.

CHITOSAN DRESSINGS

As previously noted (Chapter 4, Topical Agents), chitosan is derived from chitin, a natural polysaccharide biopolymer originating from crustacean shells. Partial deacetylation of chitin gives rise to a linear polysaccharide with interspersed D-glucosamine and acetyl-D-glucosamine units. Chitosan has antimicrobial properties and is biodegradable. It may improve the strength of newly formed collagen in granulating wounds and enhance the function of inflammatory cells, cytokines, and fibroblasts. It has been used in a variety of biomedical, nutritional, and cosmetic products. Chito-Seal™ topical hemostasis pads (Abbott Laboratories, Abbott Park, IL) and ChitoSAM® hemostatic dressings (Emergo Europe, The Hague, Netherlands) have been designed to manage actively bleeding wounds: positively charged chitosan molecules attract negatively charged red blood cells and platelets. The HemCon dressing is another commercially available chitosan dressing in the United States.

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HONEY DRESSINGS

The advantages of honey for topical wound management are discussed extensively in Chapter 4. Sterile dressings that include manuka honey are available for use both for humans and for small animal patients. Several companies provide topical honey and dressing products, including Advantis Medical (Dallas, TX), Aspen Medical (Deakin, ACT, Australia), Comvita Ltd. (Te Puke, New Zealand), Dermagenics BV (Santa Barbara, CA), Eras Natural Sciences (Ventura, CA), Manuka Honey USA (Orlando, FL), Mediprof Ltd. (Lancaster, UK), Sanomed GmbH (Vöhringen, Germany), and Triticum Exploitatie BV (Maastricht, Netherlands). Comvita's Medihoney® Apinate dressing is a commonly used product (Fig. 5-16). It is unknown whether pets would have an "appetite" for honey dressings; it may be advisable to cover them with a protective wrap and use an Elizabethan collar.

SPRAY-ON AND LIQUID DRESSINGS

Spray-on and topical dressings are available for providing a protective film on minor abrasive wounds, small nicks or cuts, and sutured incisions. OpSite spray (Smith & Nephew) is a fast-drying transparent film that is permeable to vapor and air. A variety of over-the-counter liquid bandages are available. Examples include Band-Aid® (Johnson & Johnson), New-Skin® (Advantice Health LLC, Bridgewater, NJ), Skin Shield® (Insight Pharmaceuticals LLC, Tarrytown, NY), Pet Care and Nexcare™ (3M). They reportedly form a breathable and flexible seal. Commercially available veterinary products include KeriCure® (KeriCure, Inc., Land O Lakes, FL) and Miracle Care (Miracle Care Pet Products, Dayton, OH) spray-on dressings.



FIG. 5-16 Medihoney dressings are a combination of an alginate dressing saturated with manuka honey.

Most liquid bandages are cyanoacrylate formulations that polymerize, usually with an activator. They may be useful in protecting incisions or minor nicks and scrapes in areas where contact contamination would be a concern. Alternatively, surgical cyanoacrylate glues can be used to seal skin incisions closed with skin sutures, staples, or an intradermal suture pattern.

SILICONE DRESSINGS

Silicone dressings are used primarily to reduce the formation of hypertrophic and keloid scarring in humans. Silicone dressings have been used to reduce exuberant granulation tissue formation in horses. Silicone may promote hydration of scar tissue. It is postulated that the silicone dressing occludes microvessels, gradually decreasing oxygen tension in the tissues, reaching a point of anoxia in which fibroblasts cannot function and undergo apoptosis. There is no information regarding the clinical use of silicone dressings in small animals.

CELLULOSE DRESSINGS

As noted earlier, many hydrogel and hydrocolloid dressings contain carboxymethylcellulose. A woven microfiber cellulose dressing has also been developed with both absorbent and hydrating properties: XCell® (Xylos Corp., Langhorne, PA). Another example is the Aquacel hydrofiber wound dressing already discussed. These can be used to promote autolytic debridement and absorb discharge from the wound surface. The fine microfiber reduces wound adherence (see Fig. 5-12).

Plant-Based Dressings: Potato Skins and Banana Leaves

In developing countries there is a need for effective, economical wound dressings for humans. Potato skins have been examined for use as a temporary dressing for partial- and full-thickness wounds, as well as other skin conditions. Boiled potato skins, secured to the wound with an outer wrap, have been reported to be effective in some cases, primarily by maintaining a moist wound environment. This was compared to the use of a banana leaf dressing for partial-thickness burns in humans. Both dressings were comparable in maintaining a moist wound environment without promoting infection. The larger surface area of the banana leaf was useful for covering larger surface burns. While there are a variety of medical dressings to select from for wound care, it is interesting to note that even basic plant-based dressings are capable of promoting the natural processes of healing.

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Cost Factors

Is special wound preparation required?
Is it cost-effective?
Is it easy to apply and remove?
How frequently must it be changed?
Is a supportive bandage required to maintain dressing?
What is the length of use in relation to the changing wound environment?
Is it readily available?
Is it the best product for the task?
Is this a problematic wound that requires a more innovative approach to facilitate closure?
Is surgical excision/closure of a problematic wound a better alternative at a given stage of open wound management?

Some Practical Considerations

Is a small amount of necrotic tissue present?

- Consider moisture-retentive dressings and topical products, including hydrogels, hydrogel dressings, and hydrocolloid dressings
- Use wet-to-dry dressings on a limited basis to facilitate removal of necrotic tissue

Is infection present?

- Consider dressings and topical agents with antimicrobial properties
- Early removal of necrotic tissue dramatically reduces bacterial numbers

Are these moderately exudative and effusive wounds?

- Consider dressings and topical products that facilitate absorption and retention, including alginates and polyurethane foams

Is there a healthy granulation bed?

- Consider moisture-retentive dressings and topical products, including semi-occlusive and occlusive dressings

Are these low-moisture or dry wounds?

- Consider moisture-retentive dressings

Note: as wounds respond in a positive fashion to appropriate therapies, dressings can be changed to support the current status of a given wound.

THE SECONDARY BANDAGE LAYER

The secondary layer of a bandage is the bulk or absorptive layer. Roll cotton, cast padding, absorptive combination pads, gauze pads, and roll gauze usually comprise this layer of the bandage. The bulk or thickness of this layer will depend on the function of the bandage.

Factors Influencing the Application of the Secondary Bandage Layer

- Must it secure the primary dressing layer?
- To what extent does it need to protect or shelter traumatized tissues?
- How great is the volume of wound discharge?
- Is there dead space to be controlled?
- Is it intended to immobilize a given body region?
- Is it necessary to control local bleeding?
- Are there drains or exposed surgical devices that need protection from contamination or patient tampering?

In a wound with a copious discharge, the secondary layer can facilitate the wicking and retention of tissue fluids from the wound surface. Moisture retention in this intermediate layer depends on the volume released from the wound surface, the absorptive or retentive properties of the dressing, and the rate of moisture loss by evaporation through the outer tertiary wrap. For this reason, larger wounds in the early stages of healing (first week) generally require more frequent bandage changes.

Practice Tip

When a large bandage is used to immobilize an area while also managing a wound, the area overlying the wound can be cut out, creating an access window to the wound. The soiled bandage area can be removed and redressed without necessarily removing the entire supportive bandage. The access window is more easily created at the time of bandage application. See Chapter 12, Plate 53, as an example of this technique.

As a healthy granulation bed forms during the second week after injury, the volume of discharge decreases as the capillary bed matures and the surface area of the wound begins to decrease by wound contraction and epithelialization. Unless a thicker bandage is required for immobilization, the volume of the secondary bandage layer can be reduced as the amount of discharge progressively declines. As the discharge decreases, moisture-retaining or absorptive dressings are better able to contain the fluid for a greater period of time with less spill-over into the secondary bandage layer. Both dressing and bandage changes may be reduced to every 2–4 days in many cases, depending on the products used.

Frequency of Bandage/Dressing Changes in Open Wound Care

- During the first week of open wound management, bandage changes are normally required on a daily basis (usually once per day)

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- During the second week, granulation tissue has formed and the volume of discharge normally declines. Bandage changes may be extended to every second day in many cases, depending on the severity of the wound and the types of dressings used
- By the third week, wound contraction and epithelialization usually assume prominent roles in wound closure. As they occur, the surface area of the open wound progressively declines. In many cases, the bandage/dressing change interval may be extended to every third or fourth day
- As noted, a variety of dressings and topical products are available for use as a healthy granulation bed is forming (see Chapter 4). The frequency of bandage changes also is dependent on how often a given wound product requires reapplication based on the manufacturer's suggestions
- When using moisture-retaining dressings on healthy granulation beds, changes normally are scheduled every 3–5 days. This is a relatively safe time to reassess an otherwise uncomplicated open wound

Application of the Secondary Layer

As noted in Plate 2, cotton padding is overlapped by 50% to provide an orderly, more uniformly thick supportive layer. On the extremities, materials are applied from a distal to proximal direction. Tape stirrups and padding around pressure points are commonly applied prior to application of the secondary layer (see Plate 3). Additional absorbent pads may be imbedded in the secondary layer or applied over the wound area before application of the roll cotton (usually in the form of cast padding). Following one or two revolutions of cotton padding, self-adherent gauze helps stabilize the cotton layer before additional cotton/gauze layers are applied; this layering can be repeated until the appropriate thickness is achieved. The final outer cover of gauze provides a suitable substrate for application of the tertiary layer of the bandage. This layered application also provides more uniform compression, improving stability and reducing the risk of applying a bandage too tightly. Thicker secondary layers reduce the risk of circulatory compromise that otherwise may occur if the outer elastic cover is applied with moderate tension.

Baby Diapers?

For large exudative wounds involving the trunk (including the management of peritonitis with the open abdomen technique), diapers may be used as an economical outer absorbent and protective layer. A sterile primary and secondary bandage layer may be followed by integrating the diaper into the outer nonsterile secondary layer of the bandage.

THE TERTIARY BANDAGE LAYER

The outer or tertiary layer serves as a binding or security layer for the contact and absorptive layers of the bandage. There is a wide variety of elastic products on the market, many of which come in an array of colors. Most tertiary wraps are self-adherent as a result of their texture and slightly tacky surface properties (e.g., Vetrap) (Fig. 5-17). For pets that chew at their bandages, PetFlex® No Chew (Andover Healthcare, Salisbury, MA) is flexible, cohesive bandaging impregnated with a bitter chemical to discourage this behavior. Other products adhere to the contact layer of the secondary bandage layer (usually gauze) with a tenacious adhesive (e.g., Elastikon from Johnson & Johnson) (Fig. 5-18).

Standard (porous or nonporous) surgical tape also may be used as a tertiary wrap. Elastic wraps have the advantage

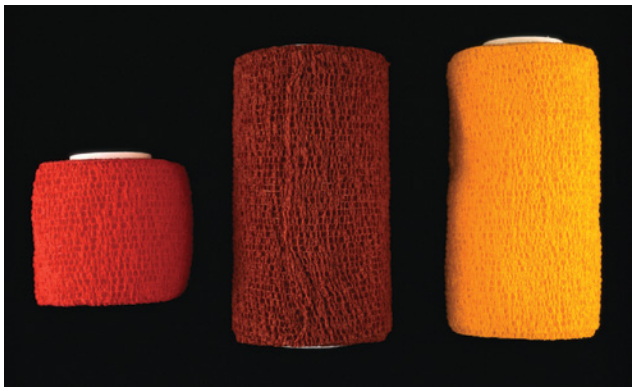


FIG. 5-17 Vetrap adheres to itself but does not adhere to the skin. Vetrap can be autoclaved and used as a temporary sterile tourniquet for lower-extremity surgeries.

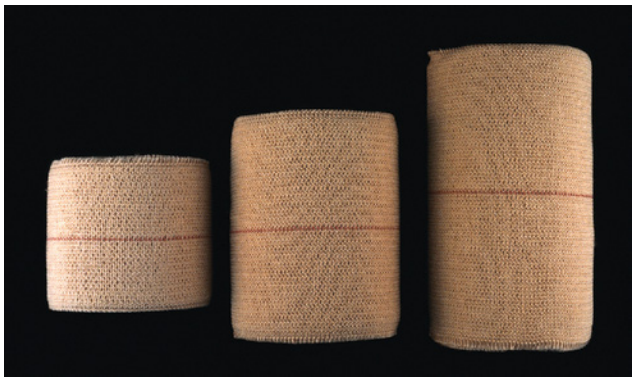


FIG. 5-18 Elastikon 2-inch, 3-inch, and 4-inch widths. Elastikon is a durable, elastic adhesive wrap that is effective for a variety of uses, including as a durable outer bandage wrap, for a variety of sling applications, and as a supplemental adhesive layer to prevent bandage slippage.

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of compressing the underlying secondary bandage layer and have better conformation to the contour of the body region. They also provide a pleasing "tailored" appearance to the completed bandage compared to surgical tape alone.

Some cats may not tolerate bandages encircling the trunk, resulting in a reluctance to stand and walk.

Caution

Elastic wraps present a risk to the patient. Excessive use of elastic tension during application can compromise circulation, especially for bandages involving the extremities. This is more commonly seen in bandages with a relatively thin secondary bandage layer.

Most outer wraps are porous or breathable, allowing a variable amount of moisture to evaporate from the secondary bandage layer. Unfortunately, they also permit wicking to occur, thereby promoting contamination from absorption of fluid into the bandage unless precautionary measures are taken. Occlusive (nonporous) tapes may be advisable for areas in contact with moisture only if the veterinarian remembers that excessive use of this tape will also restrict evaporation from the secondary layer, necessitating more frequent bandage changes from moisture retention. The author generally limits the use of occlusive (nonporous) tape to that portion of a bandage susceptible to fluid contamination (e.g., the paw); a breathable outer wrap is used for the remaining bandage area.

Elastikon and similar materials can be expensive, but they are quite durable. They are most useful for bandages and slings that do not require frequent changes. Because of their sticky backing, they will adhere to the skin (see Fig. 5-18).

Vetrap and similar products are thinner and more elastic than Elastikon. They do not adhere to the skin. They are more economical to use in those cases requiring more frequent bandage changes.

Standard surgical tape (1 or 2 inch) is economical, but lacks the physical advantages of Elastikon and Vetrap. It is useful for those cases that require frequent (daily) bandage changes.

Vetrap and Elastikon can be effectively used in combination. Vetrap can be used for the bulk of the tertiary wrap; strips of Elastikon can be used to secure the Vetrap to the adjacent skin to prevent bandage slippage. Elastikon also can be used on the bottom of the bandage, providing a durable and more abrasive walking surface.

PREVENTING BANDAGE DISPLACEMENT

Bandages can shift or slip as a result of a number of factors, including the contour of the body region bandaged, the lack of a frictional body surface to resist slippage, the normal effects of gravity and body motion, subsequent stretching and loosening of the bandage layers, or forcible removal or partial destruction by the patient. (Cats, for example, are notorious for "flicking" bandages off their extremities using a short, rapid snapping motion of the involved limb.) Resolution of edema, and variable degrees of disuse muscle atrophy also contribute to bandage laxity and displacement over time. Periodic bandage inspection is required by the owner and veterinarian to ensure bandages are properly maintained. However, there are techniques that can be used to reduce the likelihood of bandage slippage, including *tape stirrups* for extremity bandages (see Plate 3); elastic adhesive tape (Elastikon) to join bandage borders to the adjacent skin (Fig. 5-19); adhesive tape "friction saddles" (trunk) and anchor bands (trunk, tail, limbs) (see Plate 4); spica bandage extensions (limbs) (see Plate 5); and "figure 8" or "bandolero" adhesive straps for thoracic bandages. Long fur may be clipped shorter, thereby improving the adherence of adhesive tape materials.

The Double-Edged Sword of Aggressive Tape Adhesive

Adhesive bandage materials (Elastikon being one of the best) are very effective in securing bandage borders to the skin. Removal of the tape, especially if it is in contact with bare skin, occasionally can be difficult and painful to the patient. Adhesive tape solvents (e.g., Mueller Tape & Tuffner® Remover, Mueller Sports Medicine, Inc., Prairie du Sac, WI) can facilitate its removal. If the tape is adhered to the fur, gently pulling the tape off in the direction of hair growth also facilitates its removal. The underlying fur may be judiciously trimmed with scissors in problematic areas to facilitate removal as slight traction is applied to the adhesive tape.



FIG. 5-19 Elastikon can be used to secure the Vetrap-encased bandage to the proximal skin. Elastikon has excellent adherent properties and is one of the most durable tertiary wraps available for bandages, splints, and slings.

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Skin staples may be used to secure dressings and link gauze layers together; they are especially useful for skin graft bandages. Casts and splinting materials can be used to further immobilize body regions, thereby reducing motion and subsequent stretching of bandage layers.

Bandage displacement from chewing can be restricted or eliminated by the judicious use of Elizabethan collars, neck braces, body braces, slings, and tape stirrups (see Miscellaneous Protective Devices). Foul-tasting topical agents can be used to discourage licking or chewing of exposed bandages (bitter apple, etc.). Fiberglass casting material also can be applied to the tertiary layer, forming a barrier to chewing. PetFlex No Chew wrap can be used to discourage pets from chewing their bandages.

TIE-OVER DRESSING/BANDAGE TECHNIQUE

The tie-over dressing/bandage technique is a method of securing bandages to dependent areas of the body and areas of the trunk, head, or neck where conventional bandage wraps have limited effective use. In humans, the tie-over dressing uses sutures to secure the perimeter of the graft. The sutures are left long and are gathered (twisted) together over the top of a small, preformed dressing or bandage. A removable metallic clip is applied to the twist to secure the dressing. Unfortunately, this technique is tedious to execute (Fig. 5-20).

A variation of the conventional tie-over technique, developed by the author, uses a series of 2-0 monofilament suture loops placed in the skin surrounding the wound (or graft area), approximately 2–3 cm from the wound border. A loop (with a 10–15 mm profile above the skin surface) is created to facilitate insertion of a strand suture or umbilical tape using forceps or mosquito hemostats. The dressing or light bandage is applied to the wound surface prior to lacing the suture or umbilical tape between opposing loops in a crisscross or zigzag fashion. A piece of water-resistant paper surgical drape also can be placed over the gauze or bandage to limit bandage topical contamination or "strike-through." As a result, a tie-over dressing immobilizes the immediate wound without restricting regional motion. Bandages are removed and easily replaced in identical fashion using this technique (Fig. 5-21). Practitioners will find this dressing technique to be simple, economical, and very effective for areas that are otherwise difficult to bandage. Motivated owners can be instructed to change bandages (in cooperative pets) with minimal difficulty.

PRESSURE POINTS: BANDAGE OPTIONS

See the discussion of pressure sores in Chapter 7. See also see Plate 10: Pipe Insulation Protective Device: Elbow.

BANDAGE "ACCESS WINDOWS"

When a large bandage is used to immobilize a body region and also protect an open wound, constructing an access window at the time of its initial application can facilitate wound inspection without removal of the entire bandage. With this technique, the bulk of the bandage is applied, leaving an area (access window)

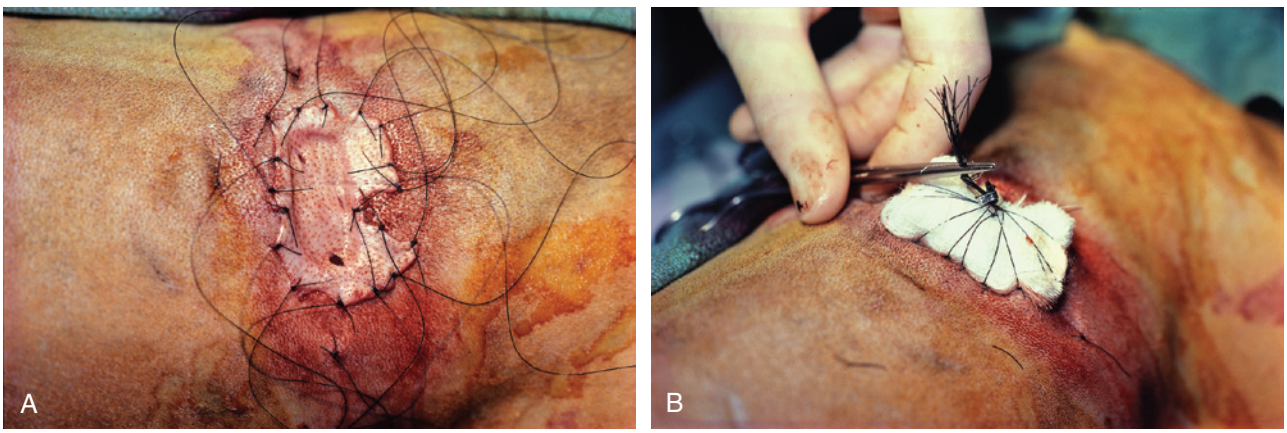


FIG. 5-20 (A) Conventional tie-over dressing. Suture strands that secure the graft are used to secure the dressing in place. (B) Ointment, a nonadherent dressing, and a layer of gauze cut to the dimensions of the wound bed are applied. Suture strands are twisted and tied. Alternatively, a removal clip can be used if replacement of the bandage is required. A sterilized coin or metallic disc can be inserted into the middle layer for added rigidity.

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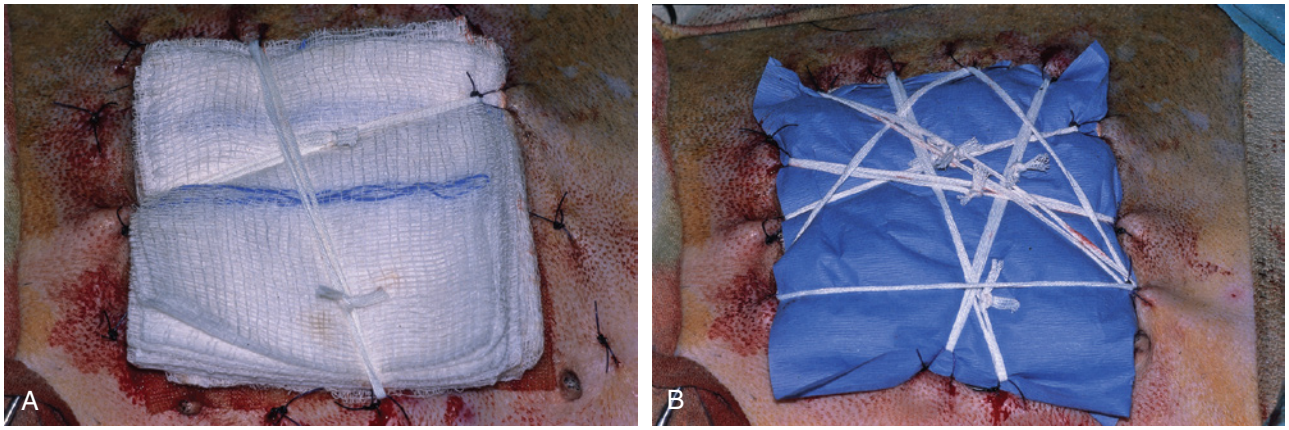


FIG. 5-21 (A) Author's tie-over dressing technique. Suture loops (eyelets) placed around the graft site secure the dressing by lacing suture material or umbilical tape between opposing loops. Loops are created approximately 2–3 cm from the wound borders; loops are 10–15 mm in diameter to permit passage of suture strands or umbilical tape. (*Note*: some clinicians tie their loops over a 3 ml syringe cylinder to facilitate creating the tie-over loops.) (B) A piece of sterile paper surgical drape is applied prior to final application of the umbilical tape to minimize contamination to the gauze layer.

over the open wound. With completion of this bandage, a local dressing, secondary padding, and outer cover can be placed in the access window and secured with adhesive tape. Subsequent bandage removals require removal of the local wound bandage only, saving both time and money during open wound care. Alternatively, the surgeon may cut a window in the bandage segment overlying the wound and replace the local dressing and bandage as described at the time of the first change (see Plate 53).

BANDAGING TECHNIQUES FOR SKIN GRAFTS

See Chapter 14 for specific details on bandaging skin grafts.

BANDAGING TECHNIQUES FOR SKIN FLAPS

As a general rule, the author avoids applying bandages over most skin flaps. When properly developed, skin flaps have an inherent blood supply. Bandages and splints, unless carefully applied, could compromise vital circulation to the flap.

Unlike free grafts, flaps do not require a bandage for their early revascularization and survival. On occasion, a protective bandage and splint are used to protect a flap over a flexion surface (e.g., carpus, tarsus) (Fig. 5-22). The author also has carefully constructed bandages reinforced with splints to protect local flaps and axial pattern flaps placed in areas where excessive motion or trauma could compromise postoperative healing.

Bandages are used in distant direct flaps in which the involved limb is secured beneath a skin flap elevated on the side of the dog and cat. These bandages are important to support the elevated extremity and prevent the patient from displacing the flap from the wound site (see Plates 53 and 55 on distant flap techniques).

SPLINTS, CASTS, REINFORCED BANDAGES

The bandage is the most common method of protecting and supporting the injured area. As previously noted, inappropriately applied bandages can be detrimental to wound healing. Tight bandages can restrict circulation. Loosely fitting bandages, however, may permit regional motion, resulting in rubbing and abrasion of the wound surface, especially wounds involving the joints and mobile areas (flank, axilla, neck, etc.). Additional immobilization or rigidity of the bandaged area may be advisable under these circumstances. Half-shell or clamshell fiberglass casts (Scotchcast™ Plus, 3M), plastic or aluminum "Mason" meta-splints (Penn Veterinary Supply, Inc., Lancaster, PA), tongue depressor splints, commercially available aluminum rods (6 foot lengths, Patterson Veterinary Supply, Loveland, CO), and heat-malleable plastic (Orthoplast®, Johnson & Johnson) are effective for immobilizing lower-limb wounds when applied just inside or outside of the tertiary bandage layer.

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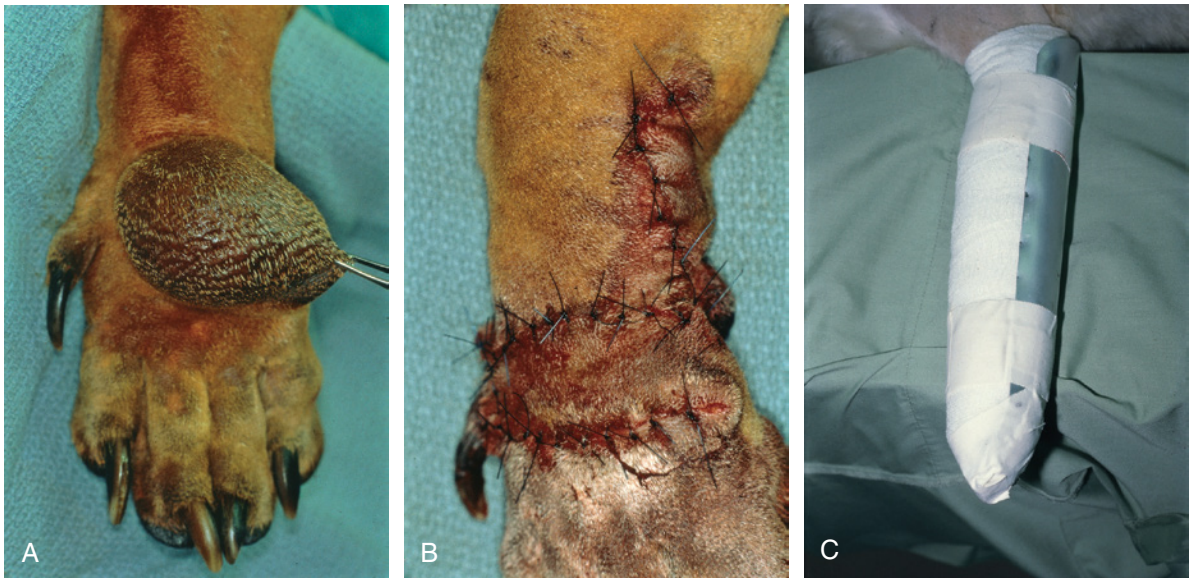


FIG. 5-22 (A) Benign adenoma overlying left carpal area. (B) Excision and closure with a transposition flap. (C) Because the closure was directly over the carpal surface, an aluminum splint was applied over a protective bandage to minimize motion until suture removal. Fiberglass is often preferred over premade "meta-splints" composed of aluminum or solid plastic. Fiberglass is lightweight, provides aeration, and better conforms to the underlying bandage.

Splinting in Soft Tissue Wound Care

When external fixation is used for fracture immobilization, excessive padding between the bone and splint reduces its efficacy in immobilizing the fracture site.

In contrast to fracture stabilization, supplemental splinting of soft tissue bandages is primarily used to minimize joint movement and motion of the bandage in relation to the wound surface. As a result, splints can be applied over thicker soft tissue bandages safely and effectively.

External splints can compress the underlying tissues, depending on the thickness of the secondary bandage layer. To reduce the risk of pressure necrosis over bony prominences (olecranon, tarsus, accessory carpal pad), supplemental padding should be placed around the base of bony depressions; this padding reduces the pressure cone effect that otherwise can occur between the bony prominence and overlying splint. See Plates 2 and 3.

Schroeder-Thomas splints provide excellent immobilization to the limbs, using aluminum rods or sturdy coat hangers for smaller dogs and cats. They are excellent for immobilizing the elbow, carpus, knee, and tibiotarsal joint and allow the veterinarian to change small bandages without removing the splint (Figs 5-23 and 5-24). The bars provide protection to these body regions from direct impact (see Plates 6 and 7). It must be noted that it does take practice to properly design and place the splint.

Spica bandages or splints also are effective in immobilizing the upper extremities. The spica bandage envelops the limb and trunk, restricting motion to the shoulder or hip joint. It can be reinforced with an aluminum bar, fiberglass casting material, or a thin plywood silhouette of the affected limb to increase spica rigidity (Figs 5-25 and 5-26). In the more difficult wound closure areas, including the flank, inguinal, and axillary areas, combined bandaging techniques may be required for achieving optimal healing results (see Plate 5).

MISCELLANEOUS PROTECTIVE DEVICES

Protective Covers for Bandaged Paws

To avoid contamination of bandages when dogs are taken outdoors, owners can secure a plastic bag or use food wrap to cover the bandage. Some veterinarians, in a pinch, have used empty plastic intravenous fluid bags. However, there are manufacturers of canine "bandage booties." One of the better bandage covers is made by MediPaw (Benkelman, NE). These are waterproof and easy to apply and remove from the bandaged foot. It is important to inform the owner to remove the plastic cover when the dog returns to the house in order for the bandage to breathe and to prevent moisture accumulation (Fig. 5-27).

A concern following bandage placement on a paw postoperatively is the risk of the dog standing in water, urine, or feces following recovery from anesthesia.

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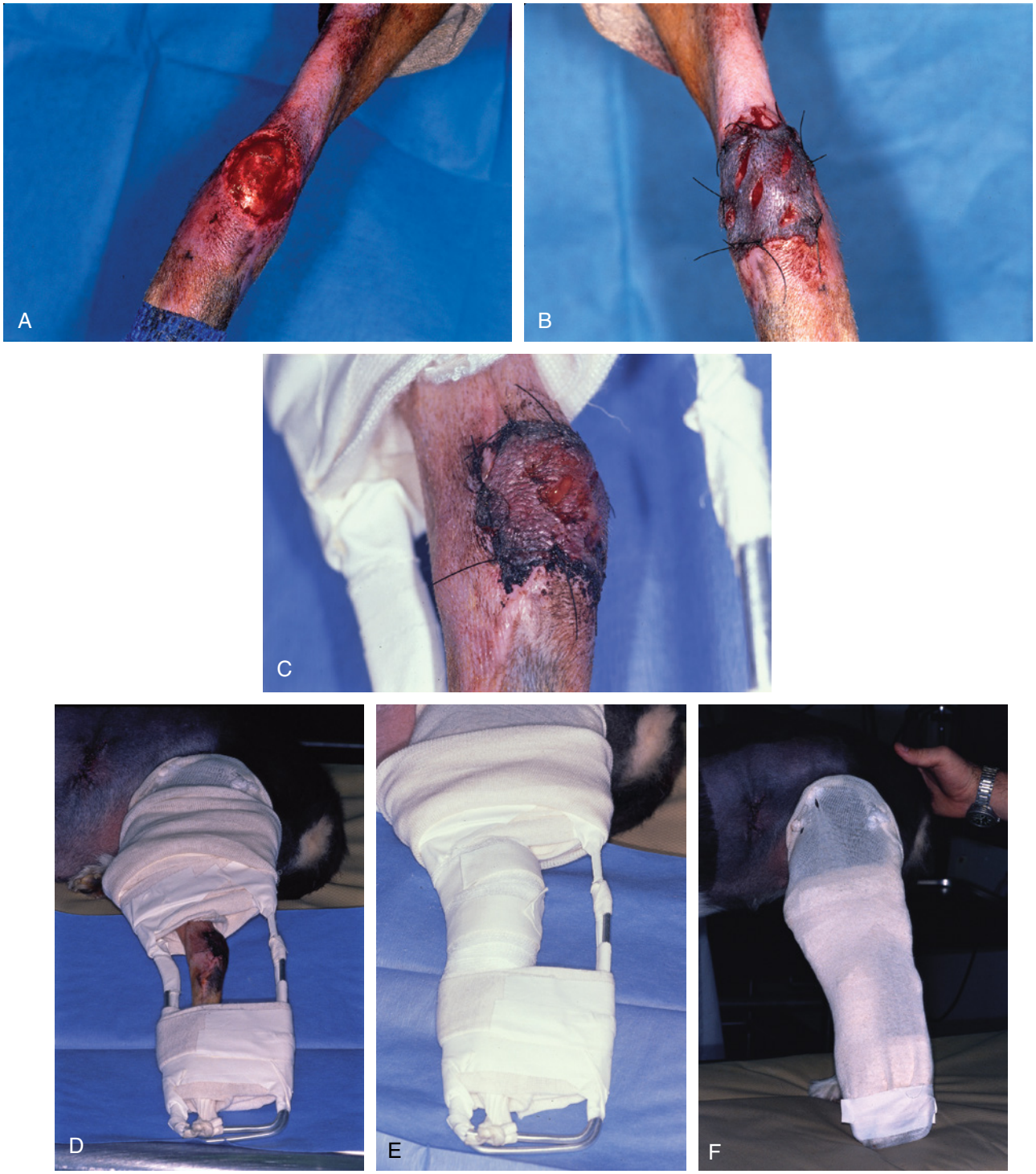


FIG. 5-23 (A) Nonhealing wound overlying the fibular tarsal bone in a sheltie. No loose skin was available for closure with a pedicle graft. (B) A mesh graft was applied over the granulation bed. A Schroeder-Thomas splint was used to protect the surgical site from motion and trauma. (C) The graft on day 5 with 100% viability. (D) Note that the local bandage overlying the graft can be replaced without removing the splint. Stockinette strips and tape were used to secure the limb to the splint. (E) Reapplication of the bandage. (F) A piece of stockinette is secured to the outer ring of the Schroeder-Thomas splint and pulled over the bandaged area for added protection.

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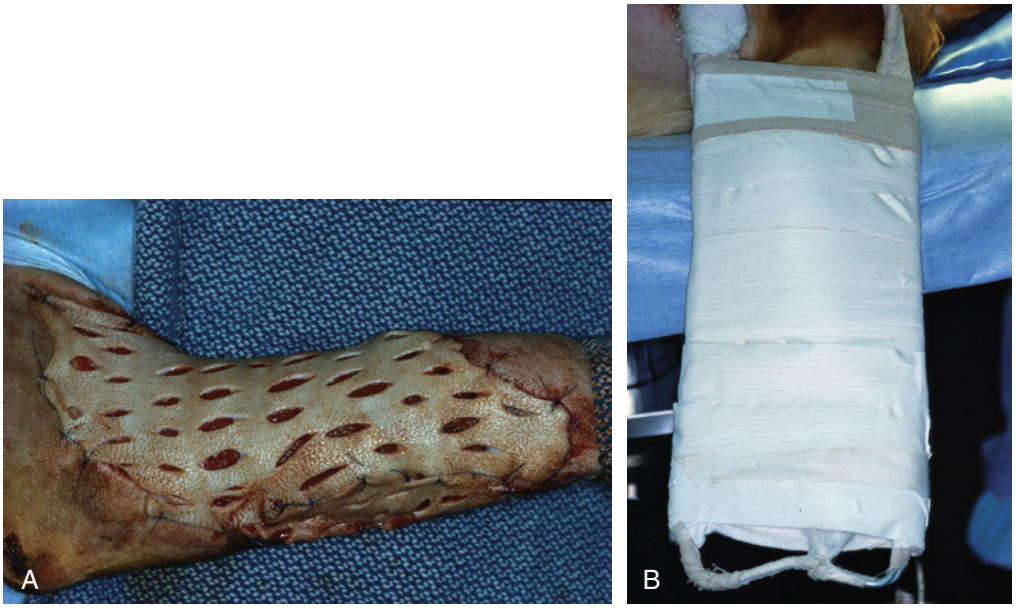


FIG. 5-24 (A) Mesh graft application to the forelimb. Immobilization of the carpus and elbow were considered essential to graft survival in this active golden retriever. (B) A Schroeder-Thomas splint was applied to provide rigid immobilization to the graft.

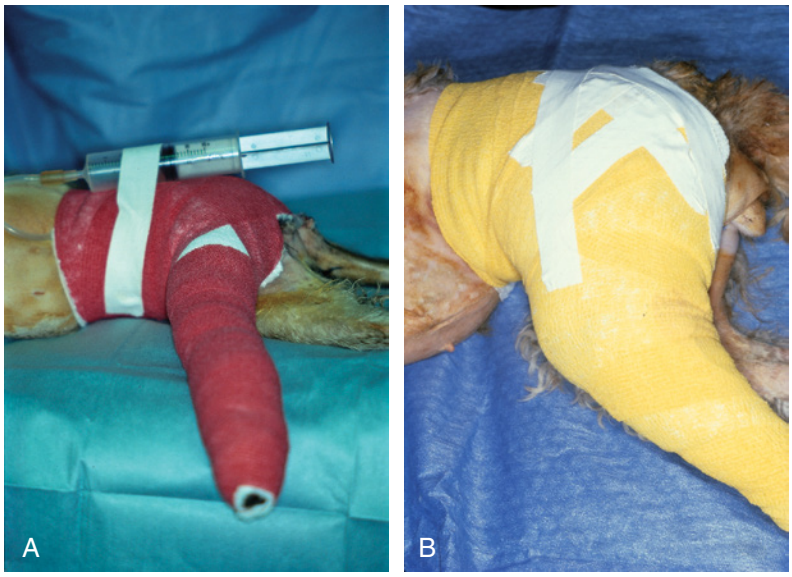


FIG. 5-25 (A) A spica bandage of the hindlimb, encircling the trunk of a cat. This bandage was used to immobilize a difficult wound closure. Note the vacuum drain, using a syringe. Spica bandages are commonly used for grafts that extend into the proximal area of the limbs. This is especially true for cats who have a propensity to remove bandages. (B) A large flank wound was temporarily covered with a spica bandage. Note that the bandage encircles the trunk for added security to prevent the bandage from slipping. Reinforcement material can be incorporated into the bandage if rigid immobilization is required. In this example, a tie-over dressing could have been more effectively used.

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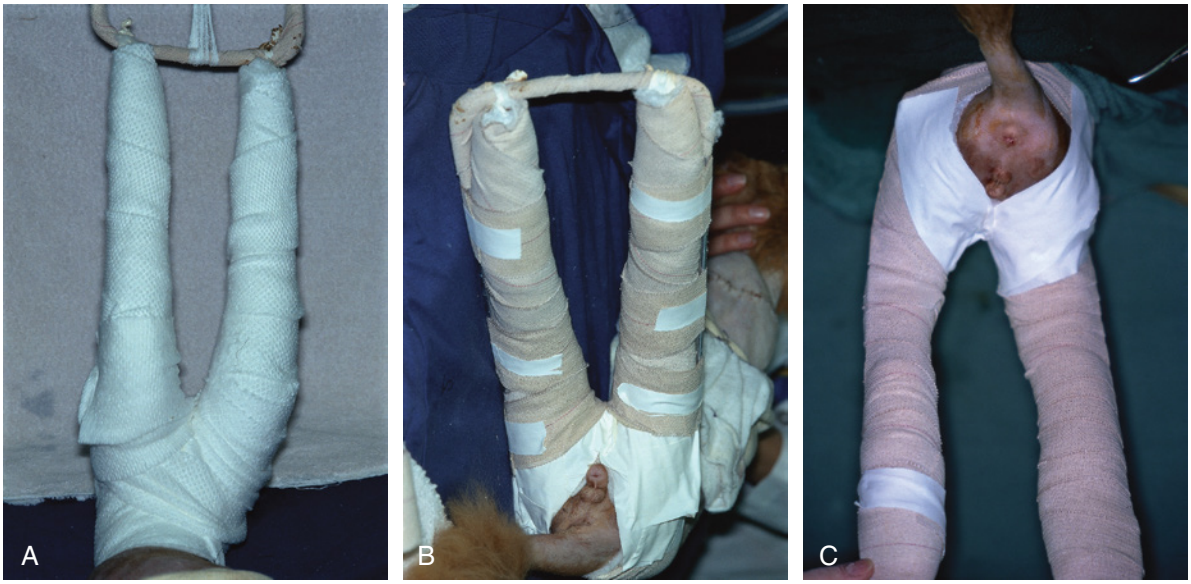


FIG. 5-26 (A) Cat, inner thigh, and inguinal wound. A full-thickness mesh graft was applied to the large defect. Skin staples were used to secure nonadherent dressings. A tie-over dressing was applied over the nonadherent dressing before application of the spica. The legs were suspended by an aluminum U bar secured to the rear paws with tape stirrups. This set-up was used for subsequent bandage changes, by suspending the bar base to which the paws were taped. (B) The spica bandage was completed, followed by the application of each arm of the aluminum bar with Elastikon tape. (C) Caudal view of the spica splint. Note that this spica bandage kept the limbs apart, approximating the width of the pelvis. Waterproof white tape was applied to the bandage around the perineal area to facilitate cleaning around the area. The cat was placed on baby diapers to collect urine and feces. The patient was turned every 2 hours. This device was removed 2 weeks after surgery.

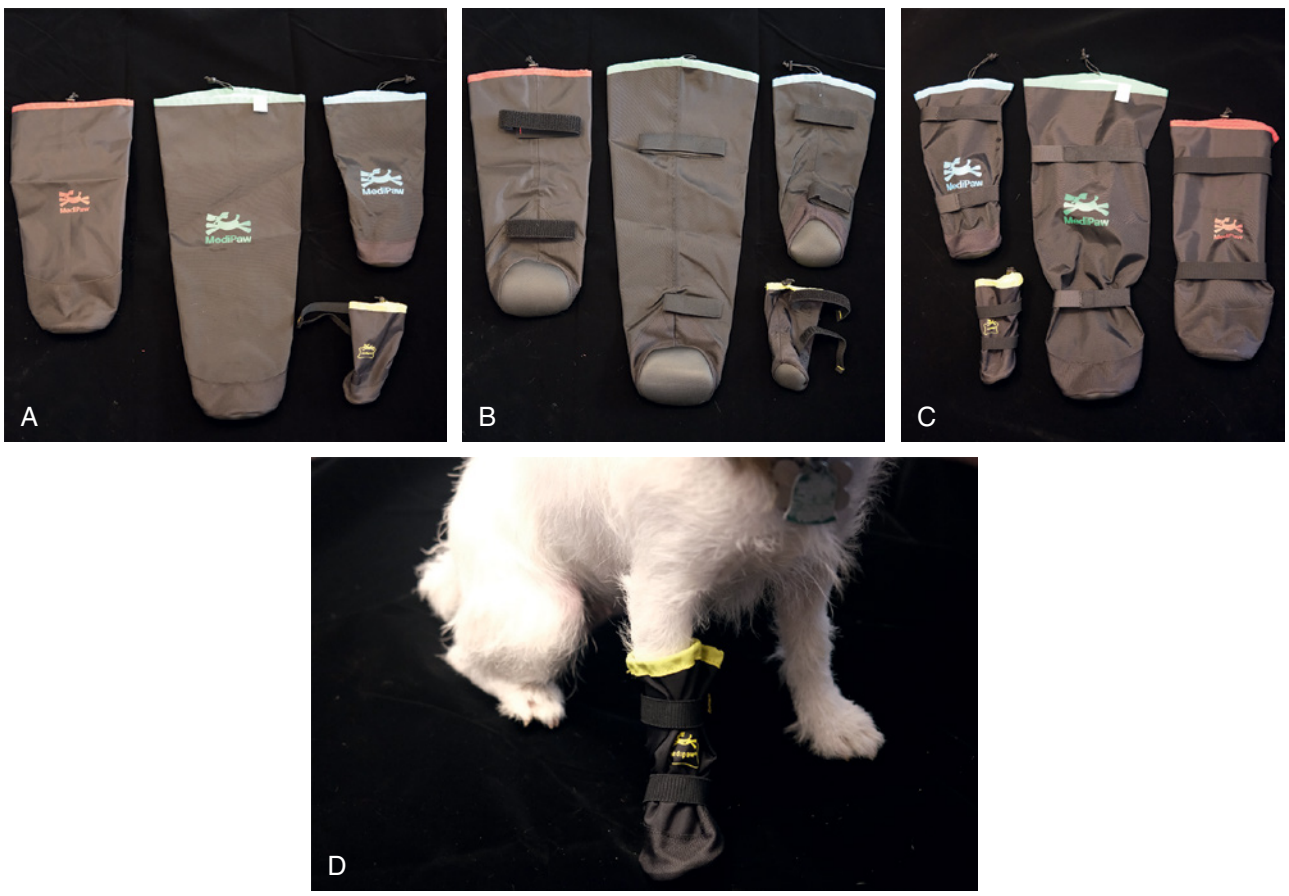


FIG. 5-27 (A) MediPaw bandage bootie covers. Elastic Velcro straps secure the MediPaw to the limb. There is an elastic purse-string closure at the top of the sleeve. (B) Elastic Velcro bands are unfolded from the back and encircle the MediPaw cover. (C) Example of the Velcro straps secured around the MediPaw cover. (D) Extra-small MediPaw modeled on the paw of the author's Jack Russell, Stella.

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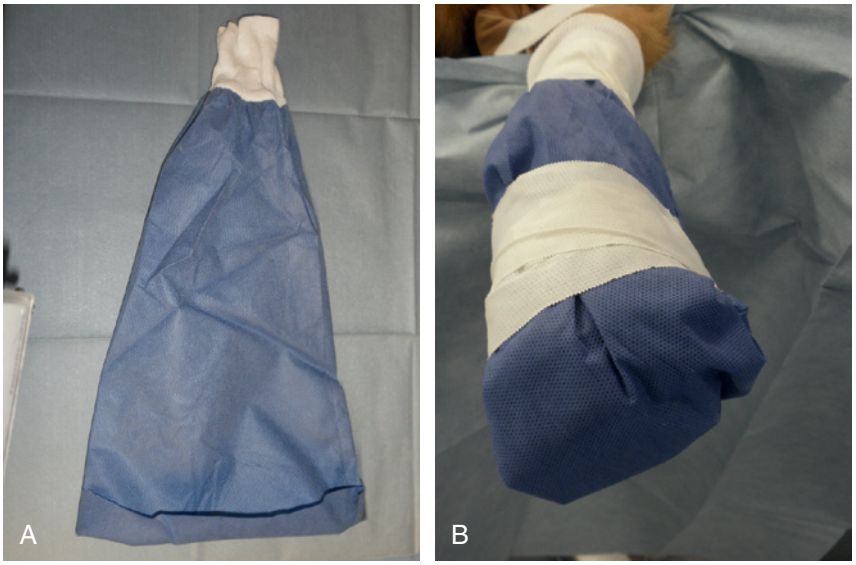


FIG. 5-28 (A) The author has used a sleeve from a surgical gown as a water-resistant cover for paw bandages during hospitalization. (B) The sleeve is secured with surgical tape and the end of the sleeve is folded upward to give a water-resistant seal. A logical alternative is to place a commercially available "bandage bootie" to protect the bandage postoperatively; the dog can be sent home with the bootie, to be placed on the bandaged paw when the dog is taken outdoors.

Applying a commercially available bandage bootie is one option to protect the bandage from hospital contamination. Another alternative developed by the author is cutting a sleeve off a clean surgery gown. The sleeve can be slipped over the paw bandage and secured with surgical tape. The owner can remove the sleeve when the dog returns to their home (Fig. 5-28).

Body (Side) Brace

On occasion, a body or side brace fashioned with aluminum rods is useful to prevent dogs from licking or chewing at wounds involving their caudal trunk and hindquarters. An aluminum rod is fashioned into a circular central loop to fit over the head and around the neck of the dog. Padding is applied to the cervical ring. The remaining left and right aluminum "arms" are bent and positioned along the lateral thorax and abdomen. A second extension piece of aluminum can be added using surgical tape if the arms are too short to complete a dorsal support arch. The aluminum extension contours to the dorsal lumbar area and is sufficiently long to allow the lateral bars to rest in the mid-thoracic and lateral abdominal area. Padding is applied to its surface. Elastic adhesive tape is used to secure the brace to the dog by applying strips between each bar above and below the trunk. Tension on each elastic strip can be adjusted to position the aluminum arms at the mid-thoracic/abdominal region to inhibit the dog from bending its trunk (Fig. 5-29). See Plate 8.

Tape Hobbles

Tape hobbles have been employed to restrict limb abduction and motion of the forelimb or hindlimb. They also can be used to prevent the dog from using the front or hind paws to scratch at a surgical site. The author also has used rear leg hobbles to restrict cats from licking at perineal wounds and urethrostomy incisions.

Tape hobbles are applied with the opposing limbs in a normal vertical position in relation to the trunk width. Tape bands are applied below the opposing carpal or tarsal joints. Tape is never applied in a dangerous circular ring pattern around the limbs. Rather, the tape ends arc around the limb and the adhesive surfaces are pinched or sandwiched together. This tape pattern has less likelihood of restricting circulation; swelling is better able to spread or separate the tape-to-tape interface. There are two variations of tape hobbles used in dogs and cats (Plate 9). There are also commercially available hindlimb hobbles available for dogs (Rear Leg Hobble System, DogLeggs, York, PA, www.dogleggs.com).

Elizabethan Collars and Cervical Collars

A variety of commercial Elizabethan and cervical collars are available to veterinarians to prevent dogs and cats from licking or chewing at surgical sites. Alternatively, the plastic collar can protect the head and neck from scratching and rubbing.

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FIG. 5-29 (A) Open wound on the left hindlimb. The dog chewed the surgical area apart where a skin tumor was resected. This occurred despite the use of an appropriate-sized Elizabethan collar. Infection was treated before closure was attempted. (B) Transposition flap (open arrow) used to close this skin defect. (C) A body brace was fashioned to prevent the patient from repeating his earlier performance.

Note

Elizabethan collars can be effectively used to reduce the risk of being bitten by more aggressive dogs and cats. It should be noted that some dogs can be disoriented with Elizabethan collars, especially following recovery from anesthesia; as a result they are reluctant to stand and walk. In this case, temporary removal of the E collar is indicated. Some of the technicians at Angell humorously refer to this as "E-collar paralysis."

A soft, coated fabric variation of the classic Elizabethan collar is commercially available that may be better tolerated by some feline patients. Veterinarians must remember that dogs are particularly effective at bending plastic collars against cage doors, pushing the collar backward, or chewing the collar borders sufficiently to gain access to their bandage and surgical incisions. When appropriately applied and properly maintained, Elizabethan collars can be very effective in protecting wounds, although the veterinarian must be certain the patient is capable of eating and drinking while wearing one (Fig. 5-30). Owners may need to elevate food and water bowls. In cooperative animals, the collar may be temporarily removed when the patient is fed. Owners are warned that removal of a collar requires direct supervision of their pet; leaving the room even for a minute can allow ample time for the patient to damage the surgical site.

There are a variety of plastic and inflatable cervical collars for use in dogs. Some dogs that are intolerant of the Elizabethan collar may better tolerate these devices.

Elizabethan Collar Tips

Selection of the appropriate size is critical to prevent the dog and cat from licking at a surgical area. The edge of an Elizabethan collar can be somewhat sharp, and some dogs occasionally will accidentally rub it on the surgical site. In some cases dogs will learn to use the collar to scratch at an irritated area. This can be detrimental to a flap, graft, or open wound.

Pipe insulation (see Chapter 7), such as Armaflex® Self Seal (Armacell, Chapel Hill, NC), can be purchased at most hardware stores and home supply businesses. This versatile material can be applied around the perimeter of the collar. Duct tape can be used to enhance its adherence to the Elizabethan collar border. The soft layer prevents rubbing and is sufficiently light that it does not weigh down the collar excessively (Fig. 5-30). Alternatively, duct tape can be folded lengthwise around the perimeter of the collar, creating a softer, flexible edge to reduce abrasiveness.

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FIG. 5-30 (A) An Elizabethan collar was used to prevent the patient from chewing at a caudal superficial epigastric axial pattern flap used to close an extensive flank defect. Note the reservoir of the closed suction unit attached to the patient's collar. (B) Pipe insulation was used to pad the edge of an Elizabethan collar. A transposition flap was used to close a problematic wound of the left forelimb. Duct tape also can be used to create a softer edge to the collar. (Pipe insulation is best avoided if the patient has a history of chewing and consuming foreign objects. From the author's experience this is a rare occurrence.) (C) Close-up view of the flap, 10 days postoperatively.

Slings

Slings have limited use for most wound closures. They can be employed to restrict motion of a limb when movement could promote wound dehiscence. Examples include axillary, inguinal, and flank wounds closed under tension. The sling should not be applied in a position that could interfere with regional circulation (extreme flexion) or healing of the affected limb. The Velpeau® sling (Velpeau, Remiremont, France) can be used for the forelimb. The hindlimb sling can be fashioned with a loop of elastic adhesive tape from the lower foot over the lumbar area to prevent weight bearing (usually for flank wounds closed under tension). For a male dog, the hindlimb must be positioned so that the patient does not urinate on his foot or the sling. (A variation of this simple sling is the Robinson sling; see Robinson and McCoy 1975.) If the sling is intended simply to limit a wide range of motion and weight placement on the limb, placement of the limb in extreme flexion is unwarranted. Mild elevation of the limb is capable of restricting motion and preventing weight bearing without compromising comfort.

Slings must be assessed closely to ensure they do not cause swelling to the lower extremity, compromise regional circulation, or irritate the underlying skin. Slings

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must be kept clean and dry to prevent dermatitis. Similarly, skin folds and flexion creases should be assessed for moisture accumulation and dermatitis. Talcum or medicated powders may be useful in managing these skin-fold areas until sling removal. In general, the author rarely uses slings.

Miscellaneous Commercial Protective Devices

A variety of protective devices are commercially available to the veterinarian for use in dogs, including elbow pads, protective boots, body slings, and protective covers: DogLeggs; Walkin'Pets (www.walkinpets.com); TAPEless wound-care products (Tapeless Medical LLC, Brandon, WI). Many of these products can be examined at major veterinary conferences to determine their potential usefulness for a given veterinary practice.

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Plate 2 Basic Bandage Application for Extremities

DESCRIPTION

Basic bandage application can be uncomplicated if a few general rules are followed.

TECHNIQUE

(A) In this example tape stirrups have been applied prior to the application of standard cast padding (Specialist Cast Padding, BSN Medical, Charlotte, NC). The key to a stronger, more secure bandage is to overlap each revolution by 50% as the material is spiraled up the leg. This process is repeated with every subsequent layer applied. Note that the skin depression around the accessory carpal pad was padded (arrow) prior to application of the roll cotton, preventing a "pressure cone" effect on the accessory carpal bone.

(B) Note that the axillary skin fold can be pressed or flattened with the index finger, thereby allowing the forelimb bandage to cover the lower humeral region more effectively.

(C) In the hindlimb the flank fold is pushed upward, facilitating the more proximal extension of the bandage into the upper thigh region. *Note:* The tape stirrup strips can be separated and folded proximally prior to application of roll gauze or the tertiary wrap, giving added security to keep the bandage from slipping off the foot.

(D) When possible, exposure of the central two toes allows the veterinarian and owner to assess the lower extremity for soft tissue swelling. In the average dog, the index figure can be inserted between the central toes. Excessive swelling would preclude this maneuver. The exposed digits also can be examined more closely for swelling and warmth. *If swelling is present, immediate bandage removal and inspection of the limb are indicated*.

COMMENTS

When building a bandage, cotton cast padding is commonly used as the bulk of the secondary bandage layer. Overlapping by 50% reinforces the strength and thickness of each layer. This is followed by a layer of self-adherent or elastic gauze; this roll gauze is periodically employed to compress the cast padding as each subsequent cotton/gauze layer is applied. As subsequent layers are added and the bandage thickness increases, gauze can be applied with progressively greater tension to create a firmer bandage. Bandage thickness is dependent on the purpose of the bandage (restricting motion, protective padding, absorption of exudate/transudate). An outer tertiary wrap (Vetrap, Elastikon, etc.) completes the bandage.

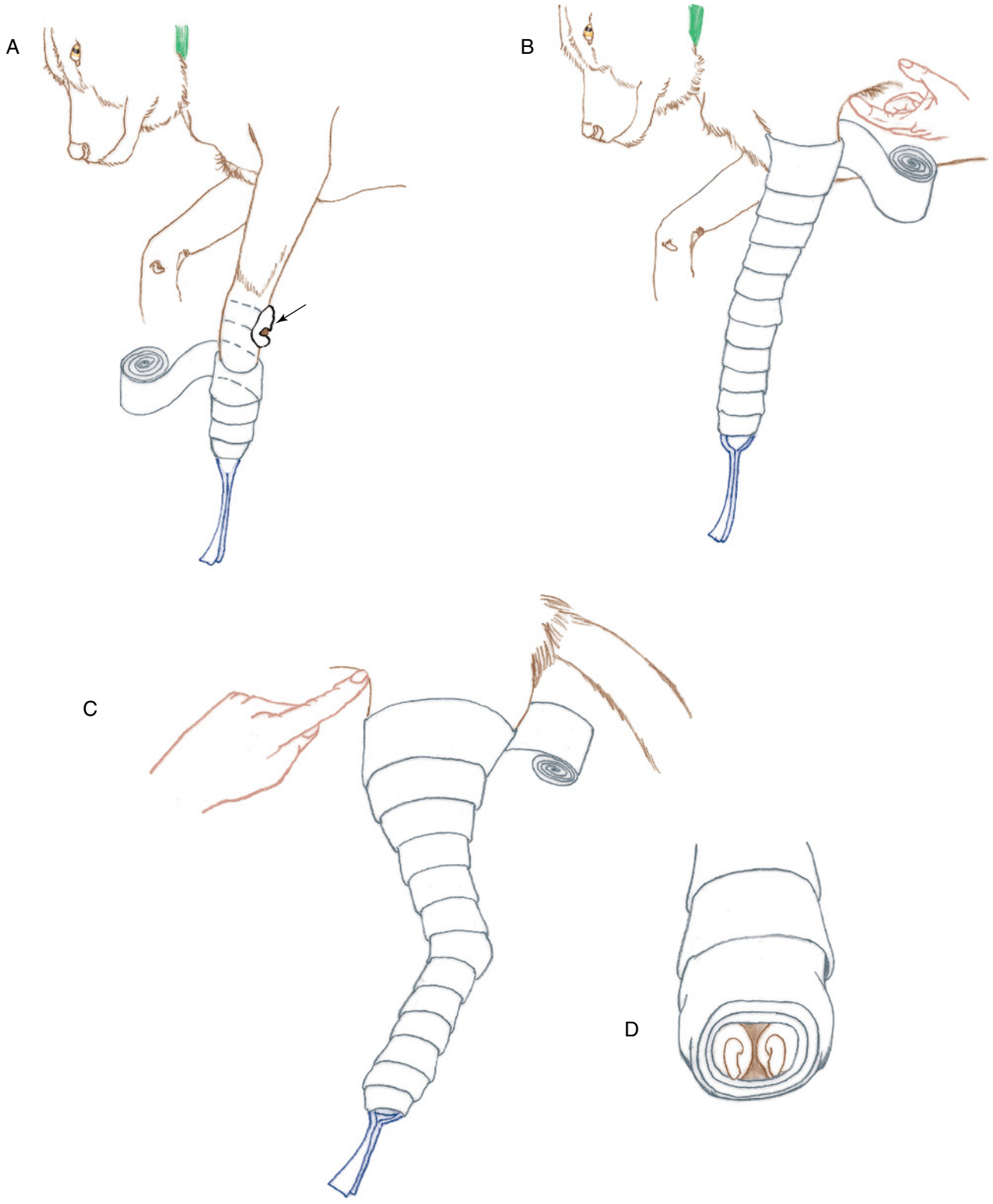
For greater security, distal-extremity bandages are more secure if the bandage is extended proximal to the carpal or tarsal joints. Small, tight bandages are best avoided for lower-extremity wounds. The author commonly overlaps a band of Elastikon between the upper border of the final bandage and the adjacent skin to reduce the risk of bandage slippage. This band is applied *without* stretching this elastic tape.

A surprising number of complications arise from improperly applied or supervised bandages. Wet bandages secondary to external contamination or progressive moisture accumulation within the bandage can have an adverse effect on the skin. These problems could have been avoided by careful bandage application and proper maintenance and vigilance by the owner. Proper bandage care must be discussed with the owner; basic handouts on proper bandage and splint care are a useful reference for veterinary clientele. Water proof bandage covers ("bandage booties," MediPaw) are ideal to protect bandages when the dog is taken outdoors; once the dog returns to the house they are removed to avoid moisture accumulation in the bandage. Thick plastic bags may be used for temporary bandage coverage but are not ideal.

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Plate 2



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Plate 3 Tape Stirrups and Padding Dos and Don'ts

DESCRIPTION

Common safety tips pertaining to tape stirrups and protection of bony prominences are discussed. Tape stirrups help prevent bandages from slipping off the limb and secure bandages to coaptation splints. Stirrups can be used to apply gentle traction to the extremity and may be used to temporarily suspend a limb when changing dressings/bandages.

BANDAGING TECHNIQUES

(A_1,A_2) Tape stirrups can be placed on the paw in two fashions: (1) over the anterior and posterior surfaces of the paw or (2) over the lateral and medial aspects of the paw. The strips cover the metacarpal and metatarsal surfaces. (*Warning*: do *not* apply a caudal tape stirrup over the accessory carpal pad; traction can result in pressure necrosis of the pad. The tape is applied just distal to the lower border of the accessory pad.) The placement of the stirrups may be determined in part by the condition of the skin. Tape segments can be sandwiched together when traction is required during splint application; these conjoined strips can be secured to the secondary layer of the bandage with tape. Alternatively, each stirrup strip of tape may be separately reflected back and incorporated into the secondary layer of the bandage. There is a potential danger in the lateral–medial application of stirrups: if both strips stick together, subsequent tape traction can compress the toes together and occasionally result in one or more nails compressing into the skin of the adjacent toe, causing pain, skin inflammation, local ischemia, and infection that can lead to tissue necrosis. Traction on stirrups placed over the cranial–caudal surface of the paw does not cause this problem.

(B) Supplemental bands of tape are occasionally used to support tape stirrups.

1. Encircling bands or tape must be avoided: under traction, they can shift, creating a tourniquet effect. If left undetected, ischemia and necrosis of the paw can occur.
2. A safer alternative is an open spiral strip that can help secure the stirrup without the risk of creating a tourniquet.

(C, D) A key point in protecting bony prominences is to pad the depressions around their base. Placement of padding over the surface of a bony prominence actually can enhance the pressure cone effect on the overlying skin, especially if a cast or rigid splint material is applied over these structures. Padding around the prominences better protects the area by distributing direct pressure over its surface, rather than over the bony prominence exclusively. Examples include padding around the point of the elbow, fibular tarsal bone, accessory carpal pad, and first digit. Padding between the toe pads and metacarpal/metatarsal crease (arrows) can reduce moisture accumulation and secondary dermatitis prior to covering the paw with a protective bandage.

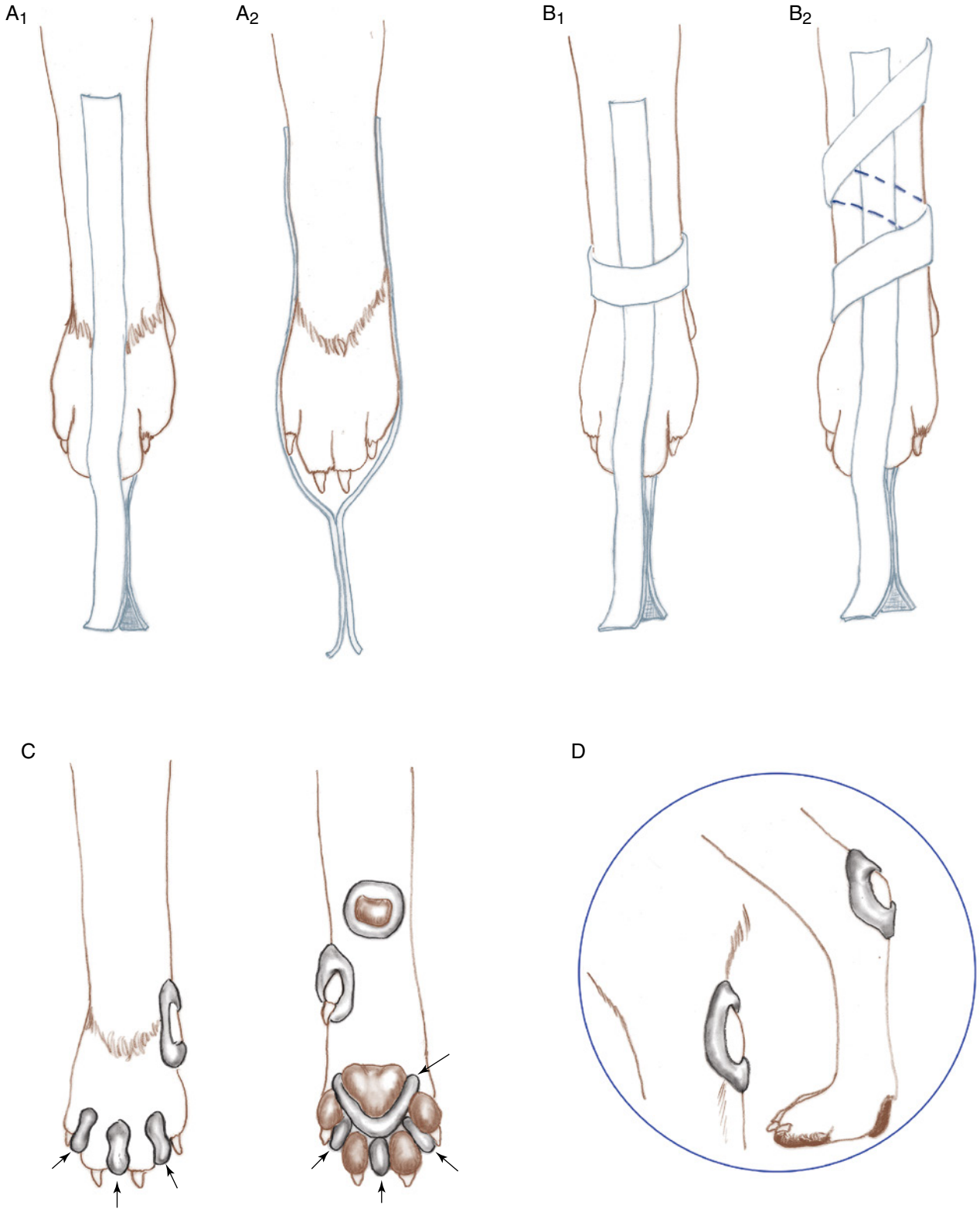
COMMENTS

Tape stirrups are not necessary or practical for every bandage application but can provide added security to prevent a bandage from slipping. The problems noted here, namely skin infections, skin necrosis over bony prominences, necrosis of the accessory carpal pad, necrosis of the paw, and skin necrosis involving the digits, have all been seen by the author.

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Plate 3



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Plate 4 Elastikon Bandage Platforms and Saddles

DESCRIPTION

Securing bandages to the trunk, limbs, and tail can be problematic. The tapered thorax and abdomen result in a tendency for bandages encircling the trunk to slip or shift caudally. Regional bandages of the forelimb and tail, for example, are difficult to maintain as a result of slippage secondary to gravity and motion of the patient. Adhesive Elastikon or a similar product can be used to create a "friction platform" to help prevent the bandage from slipping. The bandage proper overlaps the Elastikon base; subsequent bandage changes are performed without removing the Elastikon until healing is complete.

TECHNIQUE

(A) An Elastikon "saddle" is applied over the back of the dog or cat by running strips parallel or perpendicular to the long axis of the body. In most cases, this elastic adhesive tape is applied to a clean, flat hair coat. The rough surface of Elastikon provides a friction surface to help maintain the bandage in its proper position. The Elastikon is left in place during subsequent bandage changes. (*Note*: applying an encircling band of Elastikon (around the trunk) to the cranial and caudal borders of the bandage (tertiary layer) with adherence to the adjacent skin can further reduce the tendency of the trunk bandage to slide caudally.)

(B) Two Elastikon strips are applied proximal and distal to a forelimb wound prior to application of the bandage without stretching the material. The Elastikon is applied without tension.

(C) *Note:* Elastikon is sandwiched to itself when applied to the limbs and tail to reduce the risk of circulatory compromise, rather than being wrapped around the limb in a circular fashion (cross-sectional view). The bandage subsequently overlaps the Elastikon anchors, preventing bandage displacement. The Elastikon is left in place during subsequent bandage changes. Two strips of Elastikon also can be applied, creating two "sandwiched seams." These tape junctions are a safety feature: the tape junctions can separate in the face of unanticipated tissue swelling.

(D) As with the forelimb, this technique can be effectively applied to secure bandages to the tail.

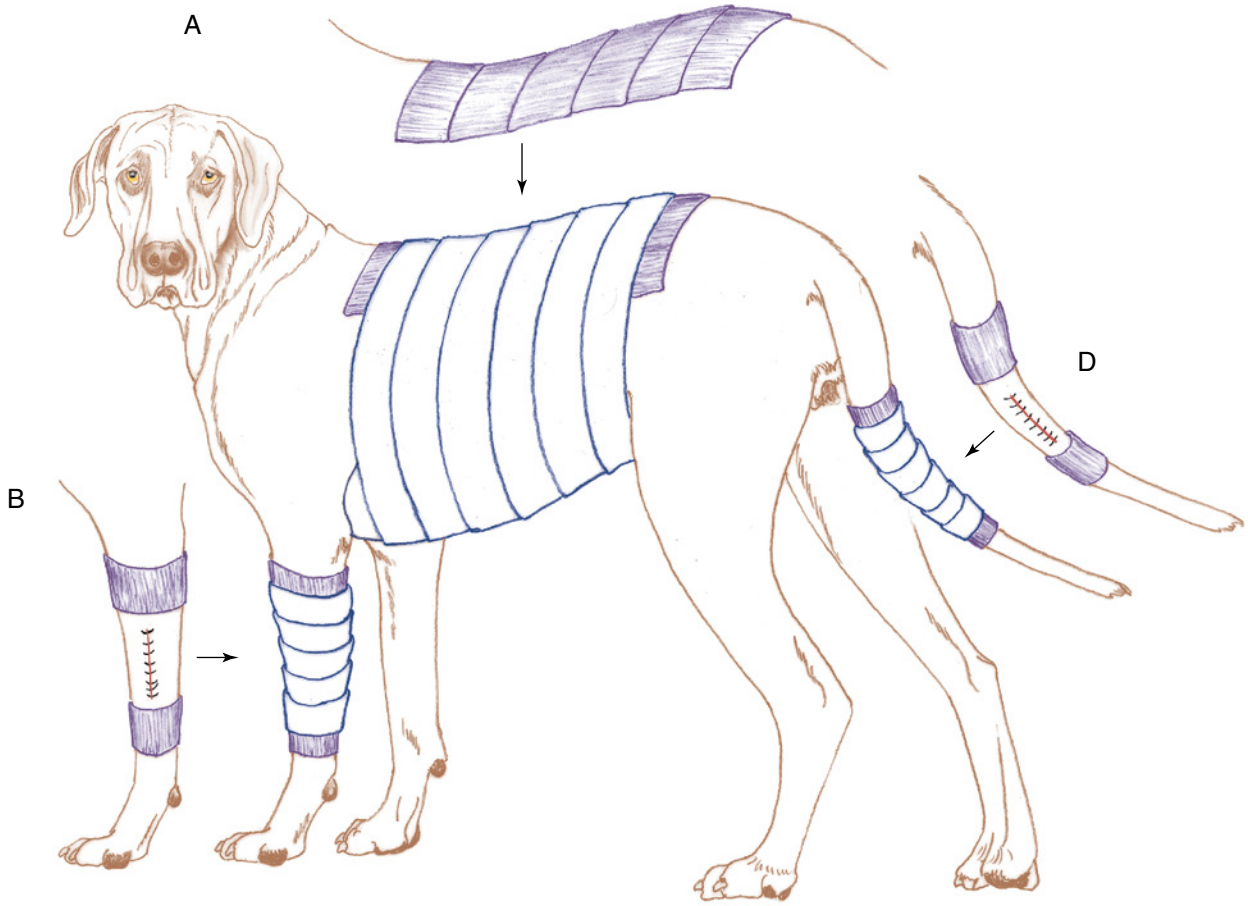
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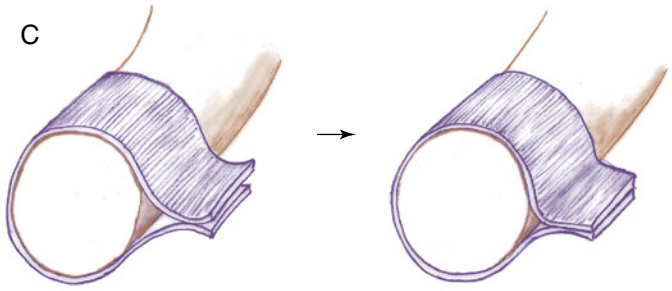
Elastikon saddles or anchors are simple to apply and effective in keeping most bandages in place. Elastikon is placed on the extremities without stretching it, in order to avoid circumferential tension. For the forelimb, less bandage material is required when compared to applying a bandage encompassing its entire length. When applied to the fur, removal is relatively simple and pain free by pulling the Elastikon off in the direction of hair growth. Elastikon applied directly to the skin surface is best removed using commercially available medical solvents (see text).

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Plate 4





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Plate 5 Spica Bandages/Splints

DESCRIPTION

Spica (Latin for ear of grain) is used to describe a bandage, splint, or cast that envelops an extremity and the circumference of the trunk. It is especially useful for immobilizing the upper extremity and restricting motion of the entire limb. In cats the spica technique can effectively prevent the patient from removing bandages on the extremities, a particularly important consideration when skin grafting the limbs.

TECHNIQUE

(A) The bandage is applied by adding alternate layers of cast padding and self-adherent gauze. The thickness of that portion of the bandage overlying the limb is built up so that it better approximates the lateral shoulder silhouette. Layers of the cast padding, roll gauze, and outer wrap are extended around the trunk.

(B) On the forelimb, the spica encircles the trunk behind the opposing leg. On the hindlimb, the bandage encircles the trunk cranial to the opposite leg. Care must be taken to avoid compression of the penis and to provide access for normal urination. Elastikon, Vetrap, or a combination of materials can be used for the tertiary layer. *Note*: care must be taken to ensure the bandage is not abrading the axillary and flank regions of the opposite limb. Keep in mind that these materials can curl and bunch, causing abrasive injuries or cuts to the skin in these areas. Owners should be instructed to watch these areas closely for signs of skin irritation.

(C) Fiberglass strips can be incorporated into the tertiary bandage layer to immobilize the extremity. Alternatively, a rigid aluminum bar can be bent and curved at the top of the arch to conform to the scapular area and curvature of the back. Although rarely used today, ¼-inch plywood can be used to form a narrow silhouette of the limb for added rigidity. In cats and small dogs, tongue depressors can be overlapped and taped to the outer bandage.

COMMENTS

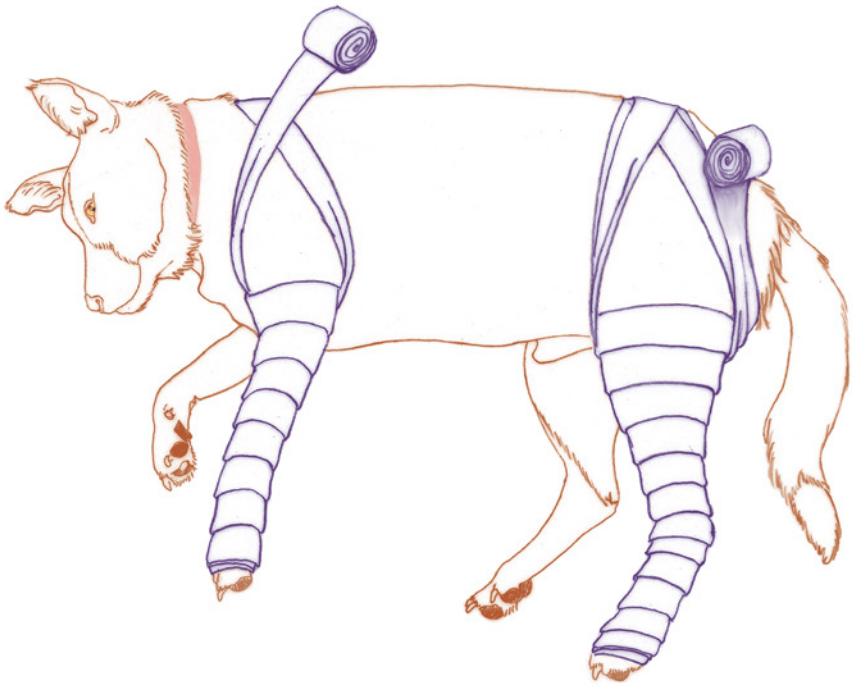
Spica bandages are a must when grafting the forelimb or hindlimb in the cat. This effectively prevents complete removal of the bandage. They are a potential alternative to the Schroeder-Thomas splint for immobilizing and protecting surgical areas susceptible to movement and trauma (for example the elbow). In some instances, a window can be cut out of the area overlying a surgical site and patched with bandage material and tape to facilitate future bandage changes without removal of the entire spica. Spicas usually require replacement within 2 weeks; bandage materials have a tendency to stretch and loosen from the underlying limb. Muscle atrophy may further contribute to loosening.

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Plate 5

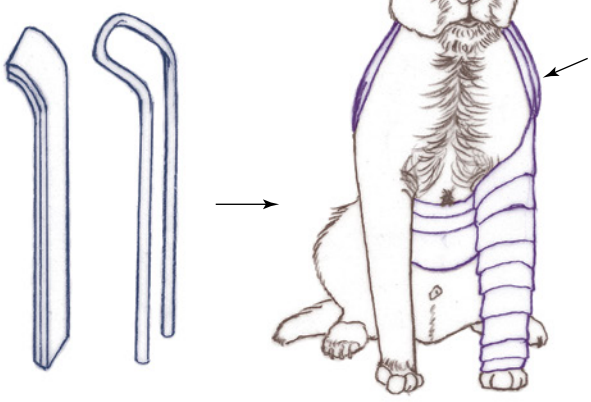
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Plate 6 Schroeder-Thomas Splint

DESCRIPTION

The Schroeder-Thomas splint is a modification of the Thomas splint used to stabilize fractures in humans. Dr. Erwin F. Schroeder, a former staff member at Angell Memorial Animal Hospital, modified and adapted this splint for fracture repair in small animals. In the 1958 edition of *Canine Surgery*, the Schroeder-Thomas splint was called "one of the most widely used and adaptable splints for small animals," permitting both traction and fixation of many types of fractures. A variety of angles can be bent into the aluminum bars to facilitate fracture alignment, depending on the nature and location of the fracture.

Proper design and application of this splint are now a lost art due to the advent of superior internal and external fixation techniques. However, the Schroeder-Thomas splint is occasionally very useful in immobilizing the forelimb and hindlimb for problematic wound closures, especially those involving the elbow, fibular tarsal bone, or knee. It also can be used to immobilize grafts applied to the radial and ulna region or tibial region. Commercially available Schroeder-Thomas splints are inferior to manually creating a splint specifically crafted to conform more exactly to the shape of the patient's extremity. Construction of the splint does require more time and patience compared to other bandage and splinting techniques used to protect problematic wound closures in small animals.

SPLINT TECHNIQUE

(A) The forelimb and hindlimb angular circumference are assessed by molding your hands around the upper extremity. This will serve as a general guideline regarding the size and shape of the aluminum ring needed to conform to the upper extremity. (The Thomas ring molds—if they still make them—are not necessary for proper ring formation.) The forelimb ring forms an oval, whereas the hindlimb ring is circular in shape.

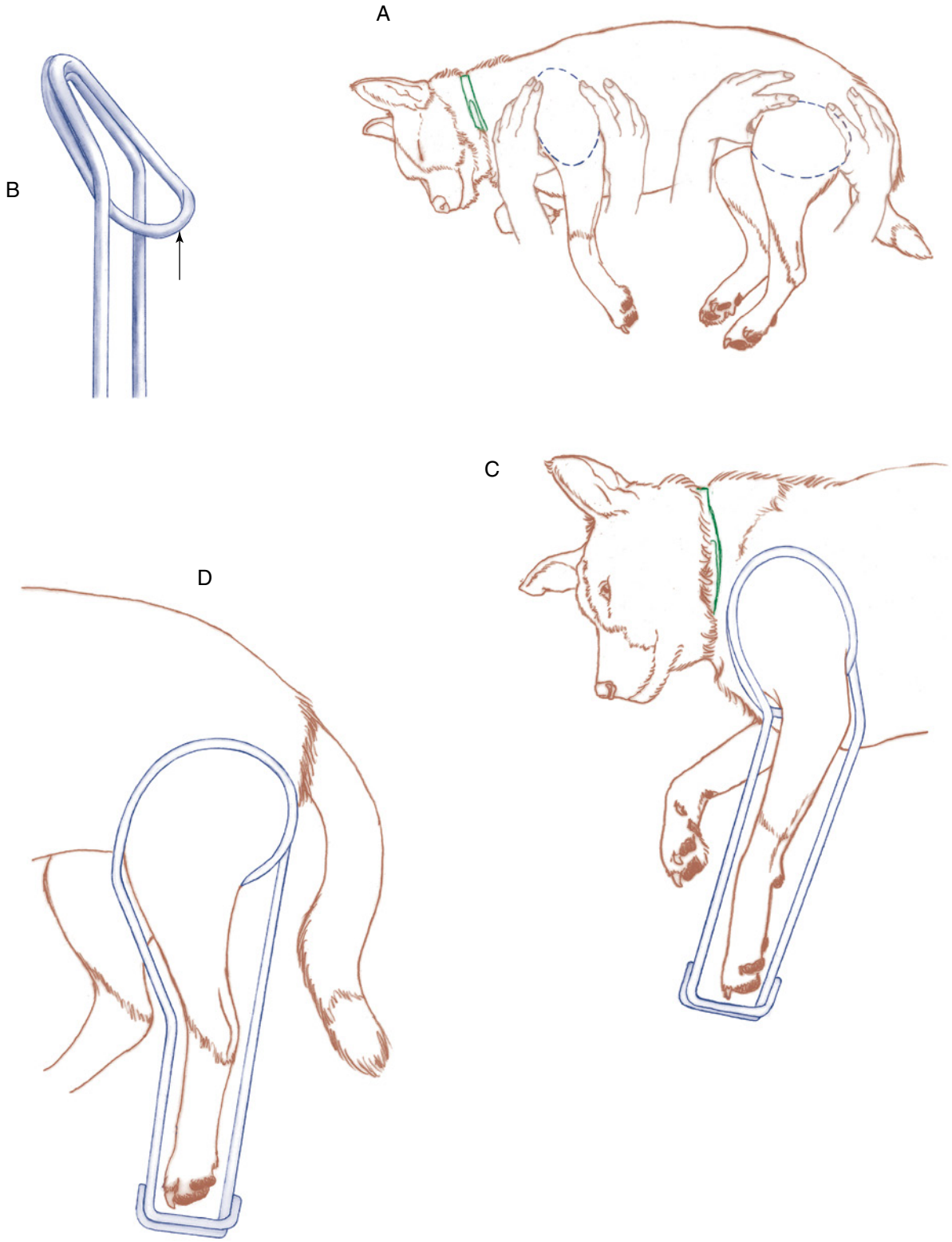
(B) The center of the aluminum splint rod (6 foot length) of sufficient rigidity (Patterson Veterinary Supply) is the starting point for bending the ring. As the ring is symmetrically bent, it is periodically applied to the limb (patient in lateral recumbency) and its shape adjusted accordingly. Allowance must be made for padding the ring, if so desired (see Comments). Once the ring is of sufficient size to comfortably slide over the upper extremity, the limbs of the bar are initially bent at approximately a 30° angle at the midpoint of the ring. The base of the ring will partially contact the lower thorax and pelvis. The angle can be adjusted so that the limbs or the aluminum bar will support the affected limb, parallel to the lateral silhouette of the trunk. A rubber hammer and vise can be used to slightly bend or cup the lower ring border to better conform to the lower thorax and pelvis if necessary (arrow).

(C, D) The limbs of the aluminum rod are bent to conform to the elbow, knee, and tarsus as illustrated. Otherwise, the bars remain parallel to each other. The end of each rod is bent at right angles and overlaps with the opposing bar end as illustrated. If the aluminum limbs are too short, a common problem in long-legged patients, a second short segment of aluminum rod is bent to overlap each aluminum limb by several inches. Overlapped bar segments are taped together with 1-inch surgical tape. *Note*: it is important that an index finger can be comfortably inserted between the inner ring and thigh (G) to prevent tissue compression.

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Plate 6



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Plate 6

(Continued)

(E) A long tape stirrup is applied to the cranial and caudal aspects of the paw. *Warning*: do not extend the tape over the accessory carpal pad, as this can lead to pressure necrosis. The tape stirrups are compressed together and split down the middle lengthwise to the level of the central toes.

(F) The stirrups are crisscrossed over the inner bar and tied together in a knot on the central area of the bar. Note that the outer overlapped bar protects the stirrup from erosion when the dog bears weight on the splint (or simply drags it over the floor). The stirrup is important to the proper alignment and security of the limb to the splint.

(G, H) Support bands are positioned to keep the limb cradled between the bars while providing exposure of the wound closure site. *Note*: an Elastikon band (G) is applied to the caudal-dorsal portion of the ring and wrapped around the thorax to prevent its tendency to rotate forward. Bandage changes can be performed without disturbing the splint and support bands. See Plate 7, a supplement to this plate.

COMMENTS

See Plate 7 regarding the proper application of the Schroeder-Thomas splint bands. The splint requires the close attention of the clinician and owner to ensure no swelling of the toes is noted and that the tape stirrups and bands remain in place. In intact male dogs, it is important to make certain that the scrotum and testicles are not accidentally trapped between the ring and inner thigh. Because the limb bends to the shape of the bars, there is a tendency to overestimate the length of the splint. Unnecessarily long splints make it difficult for the dog to ambulate. Fortunately, the length can be adjusted by shortening the terminal portion of the splint, as needed.

The rings can be padded by applying surgical tape over the metal prior to application of a layer of cast padding, gauze, and a tertiary wrap (Elastikon or Vetrap). Padding the ring may not necessarily improve patient comfort: the padding can chafe the inner inguinal and axillary skin, whereas the smooth aluminum surface does not rub or irritate the skin. Most patients do not fully bear weight on the Schroeder-Thomas splint and have a tendency to push or drag it.

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Plate 6

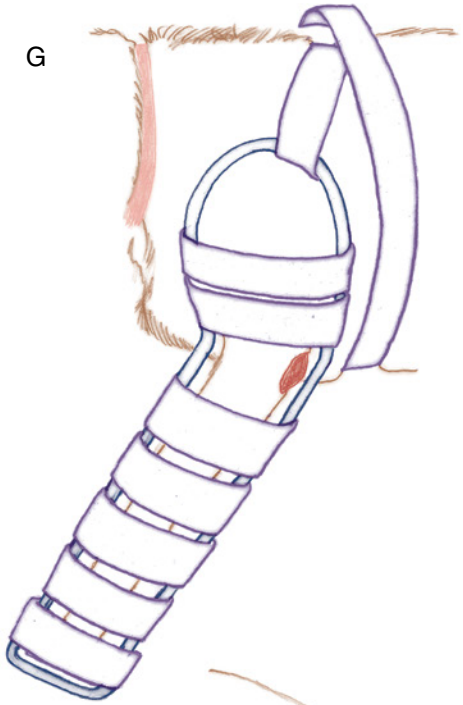
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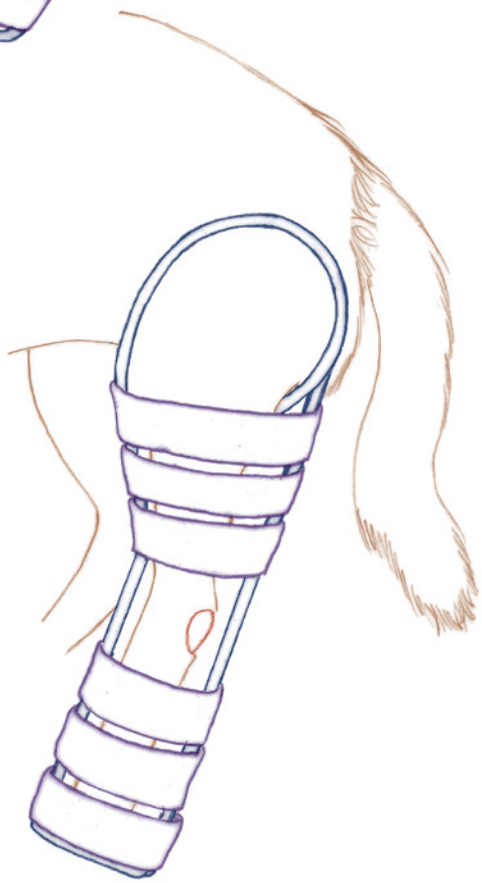
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G



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Plate 7 Schroeder-Thomas Splint: Security Band Application

DESCRIPTION

Many veterinarians unfamiliar with the Schroeder-Thomas splint attempt to secure the limb to the bars with gauze and tape, encircling the splint and leg together. The proper method of applying rings is discussed here.

TECHNIQUE

(A) Prior to band application, a layer of white tape is sandwiched or spiraled over the aluminum bars (arrows): this creates a friction surface to ensure the bands do not slip on the otherwise smooth surface of the aluminum rod. The bands are applied only after securing the paw's tape stirrup to the bottom of the splint (see Plate 6). In this example, the band is folded or looped around the front bar with the end tucked securely medial to the limb. The band is composed of stockinette (from Tex-Care Medical, Burlington, NC, or 3M Healthcare, St. Paul, MN). In general, 1 inch (25 mm) is used in small dogs and cats; 2–3 inches (50–75 mm) in medium-sized dogs; 3–4 inches (75–100 mm) in large-breed dogs.

(B) The band completes one revolution around the limb and the front bar.

(C) Under slight tension or traction, the band is rotated around the lateral aspect of the back bar and directed forward to the front bar.

(D) The band is continued around the lateral surface of the front bar and the limb.

(E) Under traction, the band rotates around the back bar a few centimeters.

(F) A long strip of surgical tape is used to secure the band.

COMMENTS

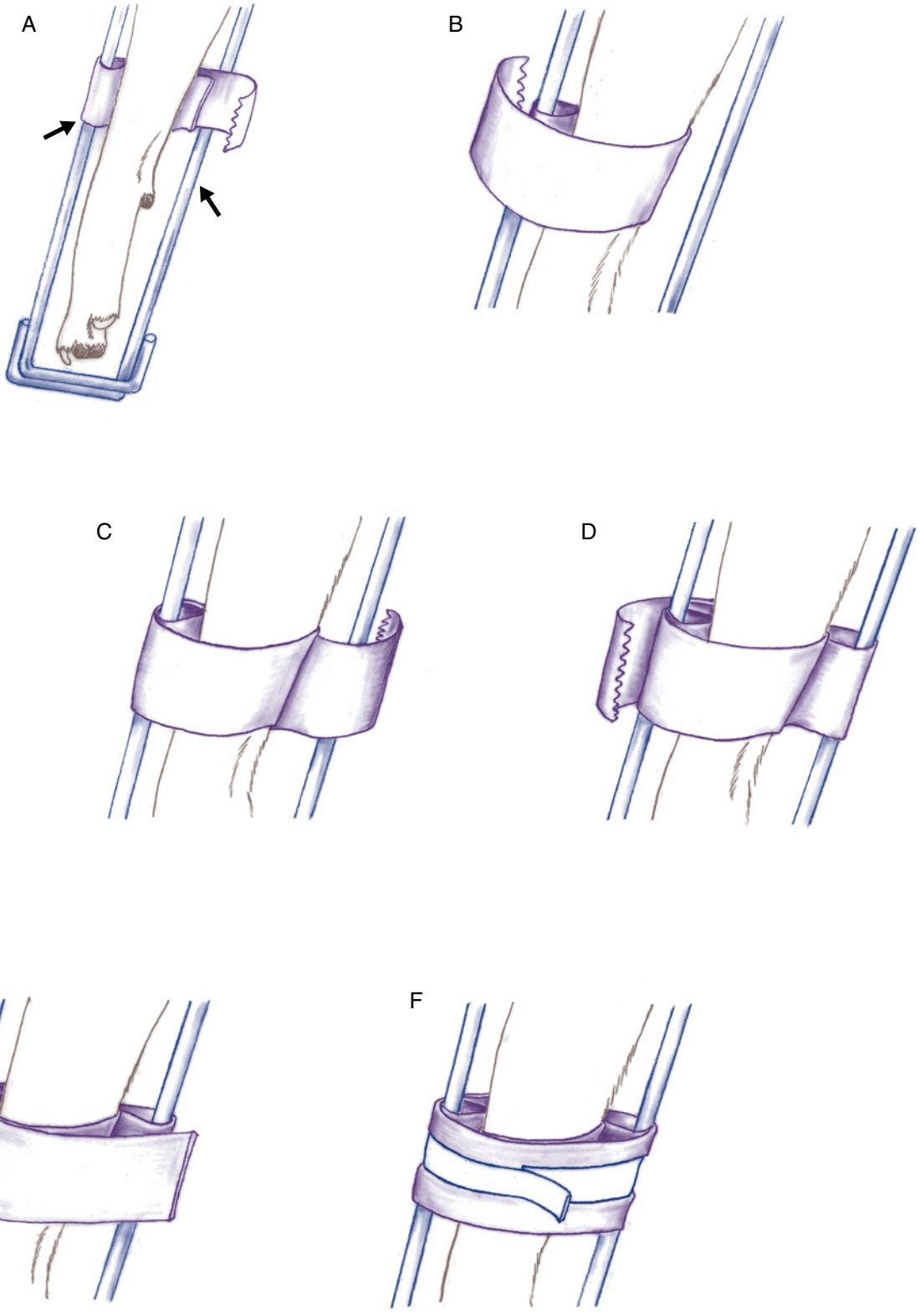
Stockinette is the most effective product to create bands for the Schroeder-Thomas splint. Note that this banding technique essentially creates a supportive sling for the leg, elevating the limb somewhat lateral to the bars of the splint. Splints normally will maintain themselves over a 2-week period before adjustment of the stockinette bands is necessary. Weekly examinations of the splint coincide with assessment/management of the surgical area. Band placement is adjusted so that proper dressing and bandage application to the surgical area can be performed. Subsequent bandage changes do not require removal of the splint or the security bands, greatly simplifying wound care.

On completion of the splint and bandage application, a strip of wide stockinette can be stretched over the entire Schroeder-Thomas splint as a protective shroud. The proximal end of this stockinette sock can be secured to the top of the ring with a few loops of umbilical tape. The bottom of the stockinette can be folded over the end of the splint and taped into place; the tape can be removed and the stockinette sock rolled up to expose the bandage as needed.

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Plate 7



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Plate 8

Body Brace

The body brace is a simple aluminum rod device designed to prevent the dog from twisting its body to reach a caudal body region. They are most commonly used to prevent a patient from disturbing a surgical area or surgical drain involving the hindlimbs and perineum when other protective devices have failed.

TECHNIQUE

(A) An aluminum rod (Patterson Veterinary Supply) of appropriate rigidity is selected. The diameter of the bar circle must accommodate the passage of the patient's head and neck. As the estimated circle is progressively bent (beginning at the center of the length of the bar), it is periodically passed over the patient's head and neck to ensure it comfortably encircles the lower cervical area. (Keep in mind that the ring diameter will require adjustment in size if padding is applied.) The two straight arms are bent backward, at the midpoint of the aluminum ring. The angle of the rod limbs, relative to the circle, is adjusted to ensure the ring seats over the cervical region without compressing or irritating the neck. A second "back rod" is bent in a curve to rest over the mid to lower lumbar area, anterior to the hindlimbs.

(B) The body brace is aligned in place prior to taping the two components together. Note that the long arms of the rods run along the mid to upper third of the lateral thoracic and abdominal walls.

(C) Elastikon is used to create an adhesive sling support: bands are secured to one bar and run over the back to the opposite bar. This is alternated with bands placed over the lower thorax and abdomen in a similar fashion.

COMMENTS

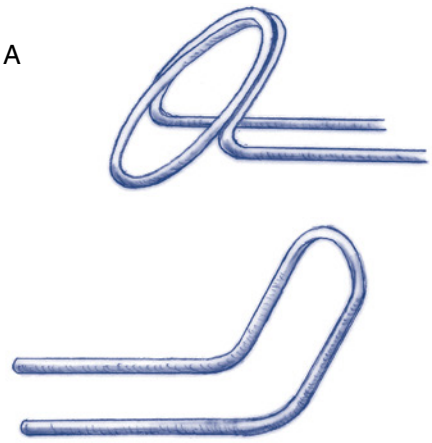
Although uncommonly required, the body brace is highly effective in preventing dogs from reaching their hindlimbs and perineal area. It is normally reserved for those clever dogs adept at removing Elizabethan collars or bending the collar and contorting their body sufficiently to reach the surgical area. The material costs are relatively modest, but it does take about 30 minutes to properly shape and apply the body brace. The cervical ring and top of the back bar can be lightly padded for added comfort and to compensate for small errors in its design. (Padding is not illustrated in this example.) Surgical tape is spiraled around the ring and back bar to create a nonslip surface prior to applying a layer of cast padding, gauze, and outer wrap (Vetrap).

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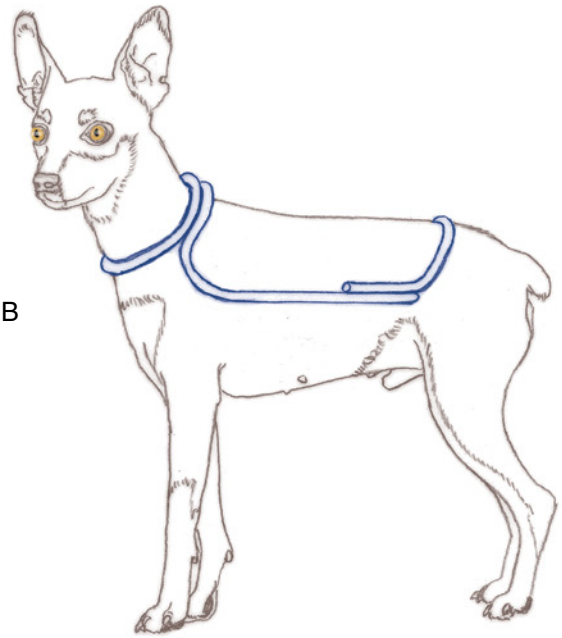
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Plate 8

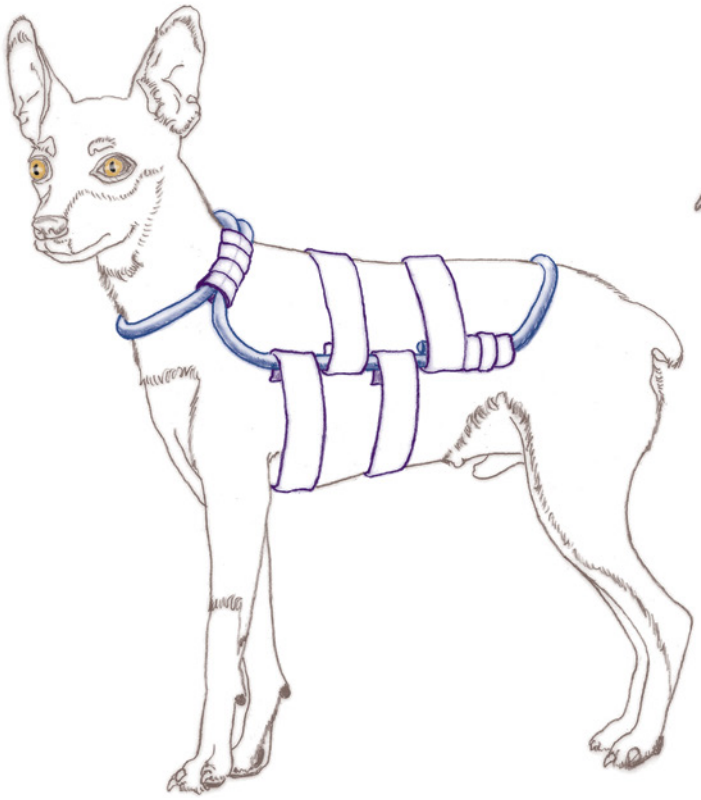
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Plate 9

Tape Hobbles for the Rear Extremities

DESCRIPTION

Rear-leg hobbles are used to restrict motion of the rear legs; they are normally considered to protect incisions in the flank or inner thigh/pelvic regions from dehiscence. There are two variations of rear-limb tape hobbles: (1) tape hobbles positioned below the tarsus and (2) padded hobbles placed proximal to the tarsus.

TECHNIQUE

(A) The patient is placed in a normal standing position. In this example, a long strip of 2-inch tape is placed around the metatarsal area. The tape ends are sandwiched around each limb; the sticky surface of the tape is affixed to the front strip of tape. (*Note*: as noted in Plate 4, this tape technique allows for any swelling to separate the tape junction.)

(B) Tape hobble variation. In this example a layer of cast padding and gauze is used as a padded surface for tape application above the tarsus.

(C) In this example, 2-inch tape encircles the padding and the sticky tape surfaces are compressed together. As noted in (A), there is no encircling tape: the tape junction has the ability to spread in the face of tissue swelling (see Plate 4).

COMMENTS

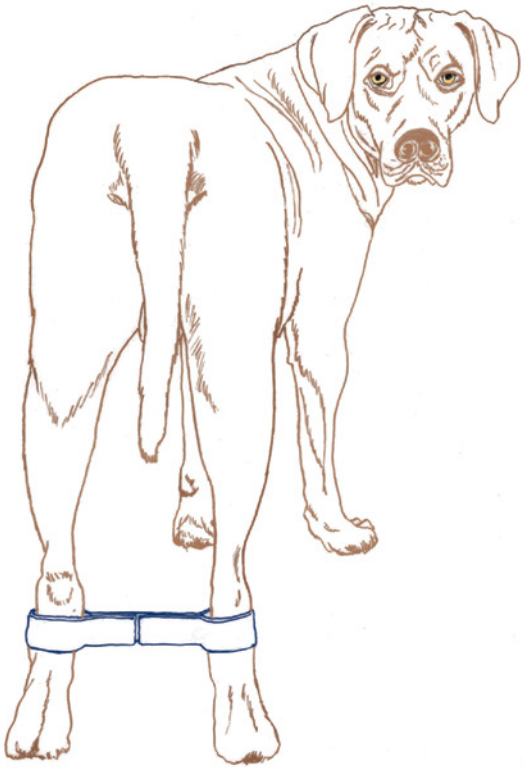
Both hobble methods work, although the padded variation may be more comfortable to the patient and less irritating to the skin compared to tape application to the skin. Although hobbles are not commonly used, they are useful in protecting the closure of flank and inguinal wounds where rear-extremity motion/tension can result in dehiscence. Hobbles normally are used for 5–10 days. Owners must be educated to assess the rear paws for signs of swelling: if suspected, the owner should return the dog immediately to the hospital to assess the hobbles for circulatory compromise. Tape hobbles can be removed if necessary.

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Plate 9

A



B

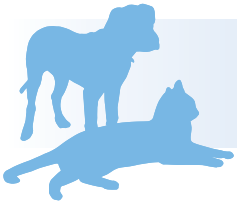


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6

Common Complications in Wound Healing

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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IMPROPER NUTRITIONAL SUPPORT

The majority of our veterinary patients heal in a normal and predictable fashion. As a result of improved health care and nutrition, pets are generally healthier today than at any time in the past. Despite this, a percentage of pets fall outside this category due to neglect and/or ignorance on the part of the owners. Gastroenteric disease also may reduce food digestion and absorption. Disease, trauma, and prolonged stress increase the nutritional needs of veterinary patients. A malnourished patient, under these adverse circumstances, is at significant risk for delayed healing with an increased risk of infection. Patients may have a problem in eating and swallowing: they may wish to eat but lack the ability to consume sufficient calories. Chronic inflammatory conditions result in the increasing expenditure of energy and catabolism of the patient's lean body mass. Severe acute illness or trauma also results in severe inflammation and accompanying metabolic stress that can lead to malnutrition.

The following are common examples of patients that may present malnourished to referral centers:

- Neglected stray animals
- Animal cruelty/starvation cases
- Chronic gastrointestinal anomalies/disorders
- Oral anomalies (major palatal defects, severe dental disease, etc.)
- Advanced neoplasia

Malnutrition is defined as any nutritional imbalance. Dehydration also may be present. Clinically, the affected patient may display weight loss, loss of subcutaneous fat and muscle mass, and progressive weakness. The cause(s) of malnutrition must be determined, with the goal of meeting the caloric needs of the patient with a balanced nutritional diet. This includes not only meeting the maintenance needs of the patient, but also the supplemental caloric requirements for covering the caloric loss secondary to trauma and disease (hypermetabolism).

There are six major classes of nutrients: water, minerals, vitamins, carbohydrates, proteins, and fats. Carbohydrates provide energy and prevent body protein loss from gluconeogenesis. Protein supplementation is essential to forming the protein components of the body, including collagen and connective tissues. In humans, glutamine, cysteine, and arginine are indispensable amino acids under severe stress. L-arginine functions to stimulate insulin-like growth factor and can enhance immune function and collagen deposition. Fats and fatty acids are a concentrated source of calories.

The first year of life is particularly critical to the growth and normal development of the dog and cat. Nutritional impairment from congenital defects, disease, or neglect not only restricts the growth and development of the patient but also can have serious adverse effects on wound healing. In animals suffering from protein depletion, particularly actively growing animals, impairment of collagen production may delay healing. This has been reported to occur if serum protein concentration falls below 2 g/100 ml. While feeding DL-methionine or cysteine alone can prevent a delay in healing in protein-deficient animals, a balanced nutritious diet is indicated. A plasma protein level of 6.0 g/dl slows healing (normal is 7.0–7.5 g/dl); a plasma protein level below 5.5 g/dl increases the risk of wound disruption by 70%.

Sufficient calories must be provided to help spare body protein from being metabolized to supply amino acids for gluconeogenesis. Glucose is the primary source of energy for fibroblasts and leukocytes and its loss will impair cellular function. Although this breakdown of body protein does yield substrate for wound repair, it places the patient in a harmful state of negative nitrogen balance. In malnourished animals, skin and muscle protein is preferentially metabolized. The protein-depleted kitten, puppy, or debilitated geriatric patient is in particular jeopardy of healing complications (Fig. 6-1). It is advisable to delay performing an elective surgical procedure in an undernourished animal. Prompt enteral or parenteral feeding is



FIG. 6-1 Siamese cat approximately 1 year of age. The patient weighed less than 1 kg. A chronic rhinitis was present as a result of a congenital cleft palate. The poor nutritional status of the patient resulted in serious stunting of growth, as noted in the facial features of this adult cat. Any elective surgical procedure should be preceded by a balanced nutritional program to correct the long-standing effects of protein depletion and imbalance.

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particularly important to the seriously ill or injured surgical patient in order to minimize delays in wound healing and reduce the risk of complications during hospitalization. Whether the patient is healthy or malnourished, severe stress, illness, and trauma increase the metabolic demands on the patient and the need for supplemental nutritional support. Urgent or emergency surgical procedures require thoughtful use of surgical materials that will support tissue apposition for prolonged periods of time as a result of a delay in healing. For example, a bowel anastomosis, hernia repair, or routine closure of a laparotomy incision would necessarily require the selection of nonabsorbable (or very slowly absorbable) suture material that would retain tensile strength well beyond the normal range of healing in a healthy patient.

The following should be considered for prolonged nutritional support for those patients that will not or cannot ingest food to maintain their normal nutritional intake. Selection is based on the specific needs of the patient.

- Esophagostomy tubes
- Gastrostomy tubes
- Jejunostomy tubes
- Pharyngostomy tubes
- Total or partial parenteral nutrition

Vitamins are essential to proper wound healing. Vitamin C, required for hydroxylation of proline and lysine for collagen synthesis, is normally not required as an exogenous source in the dog and cat. However, supplementation should not be overlooked in severely stressed, debilitated, or traumatized patients with a history of inadequate nutritional support.

Vitamin B_{12} and folate are required for normal protein synthesis, vitamin B_6 is necessary for amino acid metabolism, and iron is required for hemoglobin production and cellular respiration. Excessive vitamin A *labilizes* lysosomes, thereby enhancing inflammation. Vitamin A at high levels can counteract the effects of corticosteroids, which *stabilize* lysosomes. Vitamin E at high levels also stabilizes lysosomes: like cortisone, excessive vitamin E can inhibit wound healing. Vitamin A can counteract the effects of vitamin E, which may or may not be beneficial to a given patient.

Zinc has been reported to be necessary for normal epithelial and fibroblastic proliferation. Absence of trace amounts of zinc slows epithelialization and fibroblast multiplication, and impairs protein synthesis. However, oversupplementation of zinc stabilizes lysosomal and cell membranes and can inhibit macrophage function, thereby reducing phagocytosis. High zinc levels may interfere with collagen cross-linkage. Since small amounts are required for patient health, most balanced diets contain sufficient zinc without the need for additional supplementation. Copper is another essential trace mineral and is important in preserving the strength of blood vessels, the skin, and connective tissue. The ratio of copper to zinc is important to their respective functions. Iron is needed for hemoglobin formation and collagen formation: it is essential to cell generation, amino acids, and hormone generation.

While the healthy patient normally obtains adequate amounts of these vitamins and elements, the debilitated patient may not be in a position to meet the increased demands of disease, chronic wounds, and previous nutritional inadequacies. In these patients, supplemental water- and fat-soluble vitamins are as essential for a favorable surgical outcome as the caloric and protein supplementation.

MEDICATIONS AND THEIR INFLUENCE ON HEALING

Some medications can interfere with the patient's appetite and gastrointestinal function, thereby reducing the total amount of food ingested and possibly absorbed. Drugs used in veterinary medicine that may have this effect include adrenal corticosteroids, chloramphenicol, sulfonamides, diuretics, salicylates, tetracyclines, and trimethoprim.

Moderate levels of exogenous corticosteroids can have an adverse effect on the early stages of healing, especially administered prior to surgery and over a prolonged period of time. A single dose of corticosteroids will not impair healing. Corticosteroids can reduce vascular permeability; inhibit macrophage migration, fibroplasia, and collagen deposition; and delay angiogenesis. Early suppression of the inflammatory phase of healing delays the subsequent onset of the proliferative and maturation phases of healing. These negative effects are less pronounced if corticosteroids are administered in the latter phases of wound healing. As an immunosuppressant, they have the potential to promote wound infection. If a patient has been on corticosteroids for an extended period of time and requires surgery, nonabsorbable or slowly absorbable suture materials should be considered. Skin sutures or staples should not be removed in 8–10 days; rather, it may be advisable to leave the skin sutures in place for at least 3 weeks as a cautionary measure. An intradermal suture pattern in conjunction with skin sutures or staples also can reduce the risk of dehiscence.

Case Example

At one time, prolonged use of corticosteroids was common in conjunction with laminectomy procedures for patients with thoracolumbar disc disease. There were a few occasions where patients had skin sutures removed 8–10 days postoperatively. As the dogs walked to the owner's vehicle, the skin incision

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spontaneously separated. Although the patients recovered after resuturing the incisions, this problem could have been avoided.

Leaving sutures in the skin several days beyond the last dose of corticosteroids is a practical option to reduce the risk of wound dehiscence; reinforcing the skin closure with an intradermal pattern provides an added measure of safety.

From the author's experience, leaving sutures in the skin for long periods of time has no adverse effect on the skin, although suture scars may be more pronounced. Epithelial cells will migrate down the suture tract, which may elicit an inflammatory reaction along with the retained suture. In fur-bearing animals, this is normally a minor consideration.

Chemotherapeutic agents in cancer therapy can interfere with B_6, B_{12}, folic acid, ascorbic acid, zinc, and iron metabolism to variable degrees. Prolonged use of these drugs warrants close assessment of the patient's nutritional status and, possibly, nutrient supplementation. Although chemotherapy has the potential to interfere with wound healing, there are no exact wound-healing guidelines pertaining to its use. Again, if a healing delay is of potential concern, use of nonabsorbable or slowly absorbable sutures may be advisable. Like corticosteroids, cytotoxic agents (including cyclophosphamide, methotrexate, and doxorubicin) may exert their greatest negative effect in the early phase of wound healing. Perhaps the greatest concern with drugs that cause immunosuppression is the risk of infection (Fig. 6-2).

Extravasation of chemotherapeutic agents may result in tissue necrosis and wounds that are slow to heal. Doxorubicin, vincristine, and vinblastine are three commonly used drugs known to cause tissue damage that may require surgical debridement and surgical closure of the defect (see Perivascular Injection of Irritating Drugs, later in this chapter).

HYPOVOLEMIA AND ANEMIA

Dehydration can lead to tissue breakdown, poor appetite, constipation, and renal impairment. Hypovolemia can be particularly devastating to healing by reducing circulation to the wound. Without an adequate blood supply to provide oxygen and nutrients, healing can come to a complete standstill. Surprisingly, anemia must be relatively severe before it has a significant effect on healing as long as blood volume, cardiac output, and the nutrient supply are adequate. Impairment of oxygen delivery has been reported when the hematocrit is below 15%. However, considering blood loss and the dilutional effects associated with intravenous fluid therapy, whole-blood transfusion cannot be ruled out based on the initial hematocrit alone.

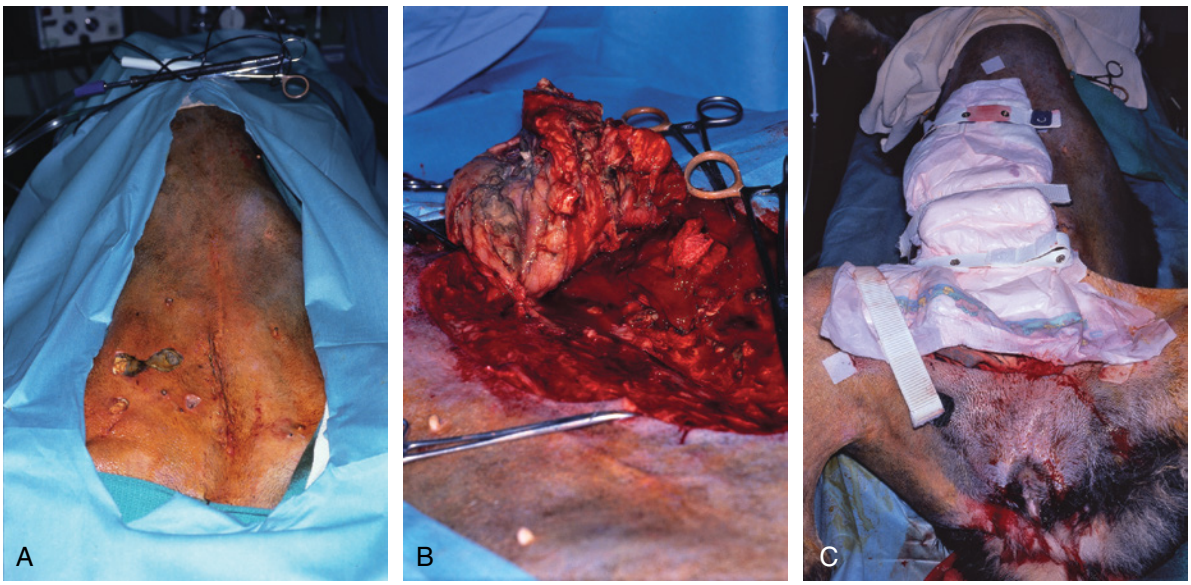


FIG. 6-2 (A) Patient being treated for carcinoma; the biopsy site became infected after initiation of chemotherapy. The patient became profoundly septic. (B) Massive tissue necrosis, secondary to a fulminating infection, necessitated wide excision of necrotic tissue. (C) Initial use of a medicated tie-over dressing secured with skin stretchers (see Chapter 10). The patient died within 24 hours from overwhelming sepsis.

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THE NONHEALING WOUND: GENERAL CONSIDERATIONS

Acute wounds are the result of a sudden insult: most acute wounds heal in an orderly fashion. Chronic wounds do not heal in an orderly fashion as a result of an underlying pathologic process. *Chronicity* indicates a prolongation of, or delay in, the healing process. *Acute* suggests an organized or rapid healing process. The term *chronic wound* is used to describe wounds that fail to heal in a timely fashion. Sussman and Bates-Jenson (2007) define a chronic wound as "one that deviates from expected sequence of repair in terms of time, appearance, and response to aggressive and appropriate treatment." Lazarus et al. (1994) define chronic wounds as wounds that "fail to progress through a normal, orderly, and timely sequence of repair or wounds that pass through the repair process without restoring anatomic and functional results."

A variety of factors have the potential to impede key steps in the three phases of wound healing. Abnormal prolongation of the inflammatory response has been suggested as a primary factor in chronic wound formation. The release of tissue-damaging proteinases from leukocytes and neutrophils and pro-inflammatory cytokines delays or prevents the normal processes of wound healing. Ischemic reperfusion injury, recurrent trauma, and foreign bodies are supplemental factors. There is a great deal of focus on infection and formation of bacterial *biofilms* as another major factor in chronic wound healing (see Infection and Biofilm Formation later in this chapter).

Successful wound management requires the identification and elimination of those factors contributing to delayed healing. In otherwise healthy patients, the surgeon has the ability to minimize or eliminate many of the complications noted in wound healing by adhering to the basic surgical principles outline by Halsted and Esmarch (see Chapter 3). Healthy tissue is surprisingly resistant to infection. As previously discussed, the presence of necrotic tissue can have a devastating effect on the wound environment. Dead tissue promotes bacterial infection and delays healing. Surgical closure cannot be performed without completely excising areas of necrotic tissue. Injuries heal more slowly and are more susceptible to infection in the presence of ischemia; minimizing surgical trauma is essential to the promotion of optimal healing.

A necessary component to wound management is proper assessment of the injury and the patient's history to determine whether surgical closure of a wound is the best option. Surgery can bypass the difficulties associated with prolonged management of an open wound. In a debilitated patient, primary closure requires less physiologic effort compared to healing by second intention.

Chapter 4 discusses a variety of wound-care products, including the use of platelet-rich plasma to facilitate wound management and closure.

Neoplasia can be mistaken for a chronic nonhealing wound, abscess, or ulcer. Chronic nonhealing wounds also can result in the development of malignant tumors (e.g., squamous cell carcinoma [Marjolin ulcer] in chronic burn wounds). If there is any doubt, submit tissue samples for histopathologic examination (Fig. 6-3).

FAILURE TO HEAL BY SECOND INTENTION

There are a variety of reasons for failure to heal by second intention. Granulation tissue and the processes of wound contraction and epithelialization will be discussed separately.

Problems in Granulation Tissue Formation

A healthy granulation bed is composed of a well-developed capillary network; fibroblasts, macrophages, and neutrophils; and an extracellular matrix. Granulation tissue develops only from viable vascularized regional tissues. Once formed, the granulation bed affords significant protection from microorganisms that survive on the surface transudate. Its formation is surprisingly rapid in healthy puppies and kittens. In adult animals, early granulation tissue formation may be noted as early as 4–5 days in an uncomplicated open wound. (Chapter 2 details wound healing in the dog and cat.) Granulation tissue serves as a "body putty," filling in gaps within the wound. Collagen deposition increases tensile strength within the area as healing progresses.

In time, capillary channels and fibroplasia subside as collagen content increases in the older wound. In a long-standing open wound a chronic granulation bed forms, which is poorly suited to healing without appropriate surgical intervention (Fig. 6-4).

Chronic (collagen-laden) granulation tissue is characterized by a dull, pale pink to gray wound bed as a result of a decline in the capillary population. The wound is fibrotic and is an unsuitable wound bed for supporting epithelial cell migration. The collagen-dense bed lacks the environment necessary for wound contraction.

If the underlying tissues are healthy, chronic granulation tissue can be excised tangentially; a healthy granulation bed quickly reforms 4–5 days after chronic wound excision (Fig. 6-4). Resection of the wound surface helps to remove any biofilm that may be forming.

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FIG. 6-3 Example of neoplasms mistaken for infection. (A) An acute nail bed infection (arrow) was later diagnosed as squamous cell carcinoma, with significant bone lysis noted on radiographs. (B) A cat being treated for a chronic draining abscess beneath the left ear had, in fact, metastatic squamous cell carcinoma to a regional lymph node. The small ulceration on the nose (arrow) was the primary site of the neoplasm. Squamous epithelium can elicit a foreign-body reaction, resulting in abscessation. A secondary bacterial infection, based on culture, masked the underlying cause until biopsies confirmed neoplasia. (C) This thin geriatric patient was referred for assessment of an ulcer involving the soft palate area. Physical examination detected large, irregular kidneys secondary to renal lymphoma. This case underscores the importance of a complete physical examination.

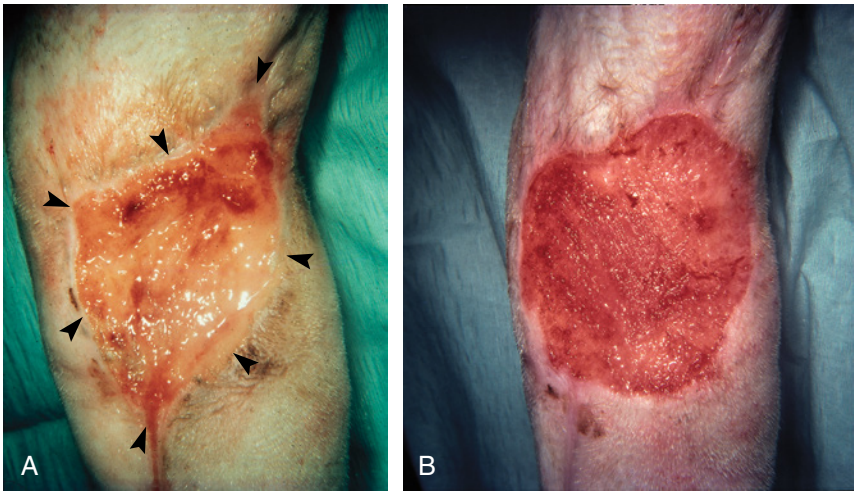


FIG. 6-4 (A) Dense fibrotic bed involving the antecubital surface of a dog. The pale collagen-laden bed was tangentially excised down to the viable underlying tissues (arrows) to stimulate formation of a new granulation bed. (B) A healthy vascular granulation bed reformed within 5 days, suitable for closure.

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A healthy granulation bed serves as a vascular scaffold for epithelial cell survival and migration toward the center of the defect. Independently, myofibroblasts within the granulation bed promote wound contraction. Delay in formation of granulation tissue usually is due to a lack of vascularity in the wound bed. Debridement of necrotic tissue, control of local infection, preservation of regional tissue viability, and maintenance of normal cardiovascular output are practical measures to promote a granulation bed.

On occasion, local tissue injury and circulatory compromise may result in a wound area incapable of forming and supporting healthy granulation tissue. A chronic irradiated wound bed is one such example (see Chapter 7). Under these circumstances, local muscle flaps, omental transplantation, or skin flaps (local or axial pattern flaps) may be required since they have an inherent blood supply on proper elevation and transfer. Muscle flaps and omental flaps are capable of "bringing" new circulation to the area; in turn, the surface of the muscle or omentum can support the survival of a skin graft. However, distant direct flaps and free grafts placed on an ischemic wound cannot survive in the long term, since their revascularization is dependent on the recipient bed.

Perivascular Injection of Irritating Drugs

Some intravenous drugs are capable of causing extensive tissue trauma and necrosis if accidentally injected into the perivascular tissues (read the drug insert) (Fig. 6-5). The extent of tissue injury is, in part, dependent on the pH, volume, and concentration of the drug. Diluting the offending agent by instilling sterile saline or lactated Ringer's solution into the area is the single best therapeutic measure. Doxorubicin, however, is an exception.

The chemotherapeutic agent doxorubicin is capable of causing massive tissue sloughing; dying cells can release the drug, helping to perpetuate the cycle of tissue destruction. (*Note*: at the time of perivascular injection of doxorubicin, the area should be aseptically prepared for surgery. A skin incision is used to expose the area, allowing for the surgical debridement of the

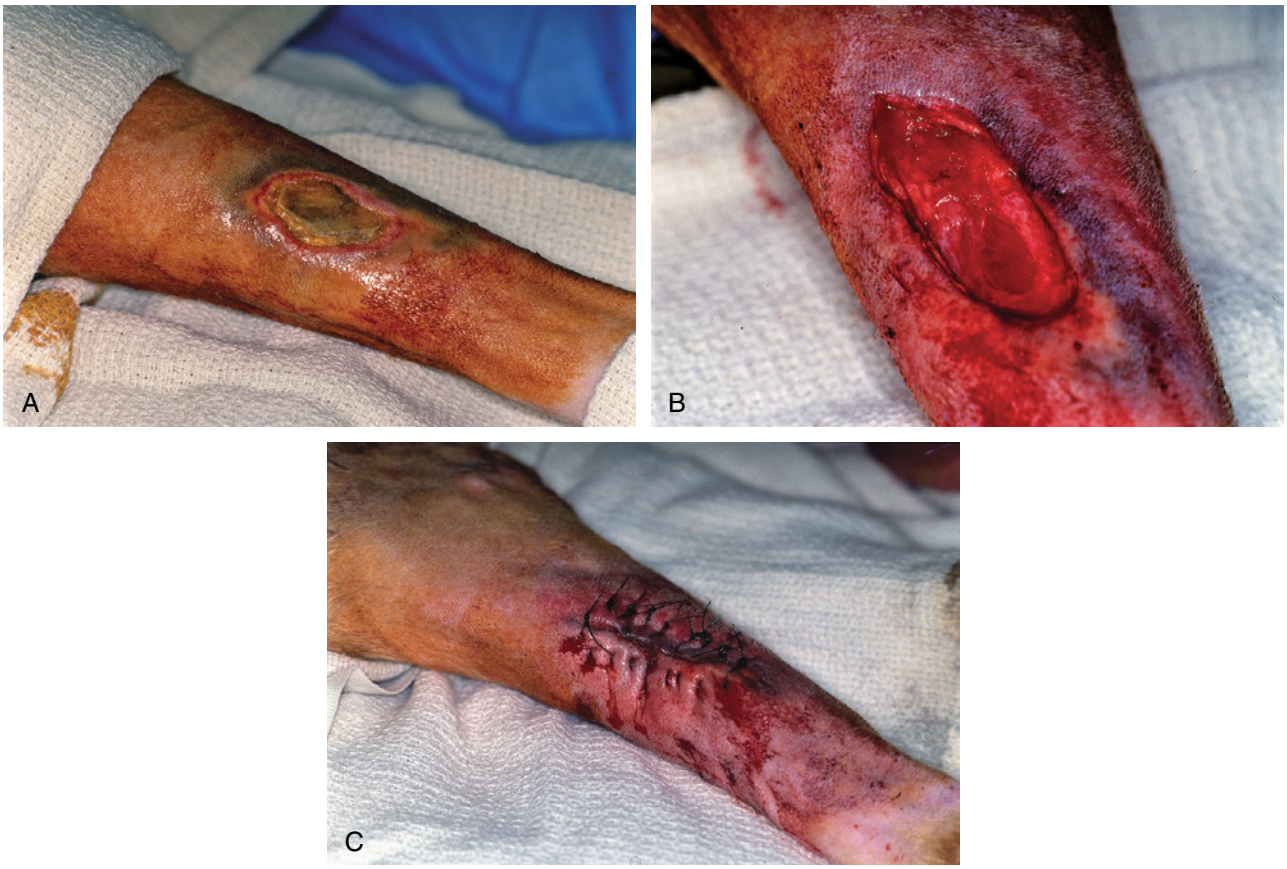


FIG. 6-5 (A) Extravasation of doxorubicin, resulting in a nonhealing slough. (B) Excision of necrotic tissue was performed, down to viable tissues. (C) Closure was performed with vertical mattress sutures (3-0 monofilament nylon).

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involved tissues, including the infused vein. Skin debridement is kept to a minimum, and open wound management is initiated for several days before closure is attempted.)

The brown recluse spider bite is another example of a toxin capable of destroying tissue and impairing the normal healing process. Debridement of the damaged and necrotic tissue may be advisable to prepare the way for healing (see Chapter 7).

Failure in Wound Contraction

As discussed in Chapter 2, myofibroblasts are responsible for wound contraction. The contractile properties of these cells "pull" the skin toward the center of the defect in a centripetal fashion. Experimentally, square wounds contract more readily than round wounds since the linear borders of skin do not impair skin advancement. By 42 days, wound contraction is nearly complete. Thereafter, the body must rely on epithelialization to close the remaining defect. Wounds on animals less than 1 year of age (especially within the first 6 months of life) demonstrate a remarkably rapid ability to contract.

Keep in mind that wound contraction has a time limitation. As a general rule, the maximal amount of contraction is within 6 weeks of injury. Any remaining defect likely will need to heal by epithelial cell migration after this time. Over time, the granulation bed's capillary population also decreases: chronic granulation beds lack the blood supply to support epithelial cell migration. Surgical intervention may be advisable if epithelialization is unlikely to complete this final task.

The two most common factors noted by the author that halt wound contraction are (1) significant peripheral skin tension (counter-tension from a lack of loose/elastic skin), which neutralizes myofibroblastic contraction and (2) restrictive fibrosis (within the granulation bed and adjacent skin border), which mechanically impairs skin advancement. A thickened eschar can mechanically "splint" the wound margins and halt contraction. Similarly, rigid adherent hydrocolloid dressings also can impair contraction by preventing the centripetal advancement of the cutaneous margins.

Unless surgical intervention (e.g., flaps, grafts, scar excision, release incisions, cutaneous undermining) is performed, the burden of wound coverage is dependent on epithelial cell migration alone. Complete epithelialization is not likely to occur in many of the larger defects encountered in small animals.

It also must be kept in mind that excessive contraction and scarring may cause sufficient tissue distortion (e.g., contracture formation) to warrant surgical correction in these situations (see Scarring and Wound Contracture, later in this chapter). Periodic assessment of the patient during the healing process is necessary so that corrective surgery can be performed in a timely fashion.

In fur-bearing animals, contraction of large wounds plays a more important role in wound closure than epithelialization. Wounds that close primarily by wound contraction are far more cosmetically pleasing than defects that heal by epithelial cell migration. Epithelialized scars are thin, hairless, and relatively sensitive to external trauma. Wound contraction literally pulls healthy, fur-bearing skin centripetally, covering the defect. As a result, the cosmetic outcome may be remarkably good.

Failure in Epithelialization

Wound epithelialization is independent of wound contraction. As noted in Chapter 2, cells from the germinal epithelial layer migrate down the dermal edge onto the granulation surface as they extend toward the center of a full-thickness skin defect. Partial-thickness wounds that have viable hair follicles (external root sheaths) are capable of reepithelializing the exposed dermis. In some situations, deeper hair follicles located in the hypodermis may survive after complete loss of the overlying skin. Small islands of epithelium may be noted as a granulation bed develops during open wound management (see Fig. 2-3).

Epithelial cells require direct contact with a viable vascular tissue bed for survival. Ischemic wounds, including chronic granulation beds, cannot support this process. Epithelialization occurs optimally in a protective moist environment. Necrotic tissue and dense fibrotic scar tissue are incapable of supporting healthy epithelial coverage without debridement and promotion of a vascularized wound bed. One of the more common factors impairing epithelialization in small animal practice is repeated surface trauma. Improperly applied bandages may abrade the wound surface, preventing normal healing by second intention.

The epithelial layer overlying scar tissue is only a few cell layers thick; this thin layer of coverage is much more susceptible to external trauma compared to normal skin. As a result, epithelialized scars overlying bony prominences and body regions subject to repeated "use and abuse" are susceptible to abrasion and ulceration. Similarly, *improperly applied bandages and dressings can abrade migrating epithelial cells* from the wound bed during normal body movements. External fixation or immobilization with

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splints and bandages is occasionally necessary to provide local wound protection for optimal epithelialization.

Antecubital wounds are particularly challenging and are quite susceptible to bandage trauma. Flexion of the forelimb places direct bandage pressure over the wound. Rubbing and abrasion to the wound surface occur during ambulation. Immobilization of the elbow is needed to prevent this problem from occurring.

If second-intention closure fails, a local skin flap often can be used to effectively close these small but problematic skin wounds.

The optimal period for an open wound to heal by second intention is finite; repeated interference or insults in the wound-healing process will result in the formation of an indolent ulcer (Fig. 6-6). The use of exogenous growth factors, and more effective topical agents that "stimulate" growth factor production, can provide a role in the closure of many problematic wounds; the use of stem cells may be a future option to promote healing (see Chapter 4). As already noted, a variety of topical dressings can be used to retain cytokines and the moist wound environment to promote epithelialization. Surgical closure of problematic wounds can bypass the prolonged care required in slowly healing open wounds.

Healing may slow on a small wound. On occasion, rubbing the granulation surface with a silver nitrate applicator can stimulate healing by creating a superficial slough and jump-starting the inflammatory process.

Indolent "Pocket" Wounds

On occasion, skin wounds fail to contract and epithelialize despite the presence of a healthy granulation bed surrounded by pliable skin. The surrounding skin margins remain separated or elevated from the underlying muscle fascia despite the formation of granulation tissue on opposing surfaces. The wound forms a pocket or pouch beneath the skin margin. These indolent wounds are most commonly seen in cats, especially in the axillary area.

Normal wound contraction and epithelialization cannot occur properly because the elevated skin has not attached to the granulation surface overlying the body surface. Healing quickly reaches an impasse. Myofibroblastic contraction is limited to the skin margin, causing the cutaneous surface to curl inward on itself. Similarly, epithelial cells migrate down the inner (granulation-covered) dermal surface. The inguinal, axillary, and flank areas appear to be especially prone to pocket formation. Why the dermal surface and underlying granulation bed fail to heal together remains uncertain. Like other chronic wounds, infection (biofilm formation), with



FIG. 6-6 (A) Geriatric German shepherd with nonhealing skin wounds secondary to vehicular trauma. Contraction and epithelialization failed to close these comparatively small wounds. Multiple topical ointments touted to promote healing failed. Occlusive dressings failed. (B) Closure was accomplished successfully by full-thickness mesh grafting and proper bandage application.

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enzymatic fibrinolysis and tissue injury, may destroy those components of the extracellular matrix necessary for fibroblast migration and collagen deposition. Motion between the surfaces also may impair healing or conjoining of the two granulation surfaces.

Successful closure of indolent wounds is possible using a few basic surgical techniques, depending on the size and location of the defect. Any infection must be addressed with appropriate wound care and topical/systemic antibiotic therapy based on aerobic and anaerobic cultures. Biofilm formation may be a contribution factor to a failure to heal (see later). Under these circumstances, excision of the fibrotic wound bed and epithelialized skin margins would be advisable. Dead space after closure is best controlled with a vacuum drain: evacuation of residual air and fluid by the vacuum will draw the wound surfaces together. If sufficient skin is present, the skin margins can be sutured together to close the defect. If the underlying dermal collagen surface is impairing skin elasticity, carefully placed *release* incisions can be used to divide the restrictive dermal granulation surface. Incising the restrictive "dermal scar" surface requires a delicate touch, using a no. 15 scalpel blade: the granulation surface is lightly incised until the overlying subcutaneous fat is seen. Care is taken to avoid a deeper incision that may compromise circulation to the skin. Successful division of the scar surface will result in widening of the surgical gap as the skin is retracted. A series of parallel and perpendicular grid incisions can be used to improve skin advancement to close the defect. Skin margins must be sutured directly to each other or firmly anchored to the granulation bed to promote wound closure (Figs 6-7 and 6-8).

Transposition flaps are useful to close most problematic pocket wounds. It is the author's experience that omental flaps are not necessary to close these challenging wounds.

Local skin flaps or axial pattern flaps are practical choices when primary closure cannot be achieved by scar release and skin advancement (Fig. 6-9). Skin grafts also are a consideration when skin flaps are not feasible. As discussed in Chapter 10, elastic skin stretchers can be used to pre-stretch skin in combination with scar release to achieve closure.

In more difficult wounds, omentum (see Plates 185 and 186) passed through a slit created in the abdominal wall can be used to manage problematic pocket wounds: the omentum obliterates the cavity and is a supplemental source of circulation to the area. While omentalization of feline axillary wounds has been reported, the author has not found this technique necessary.

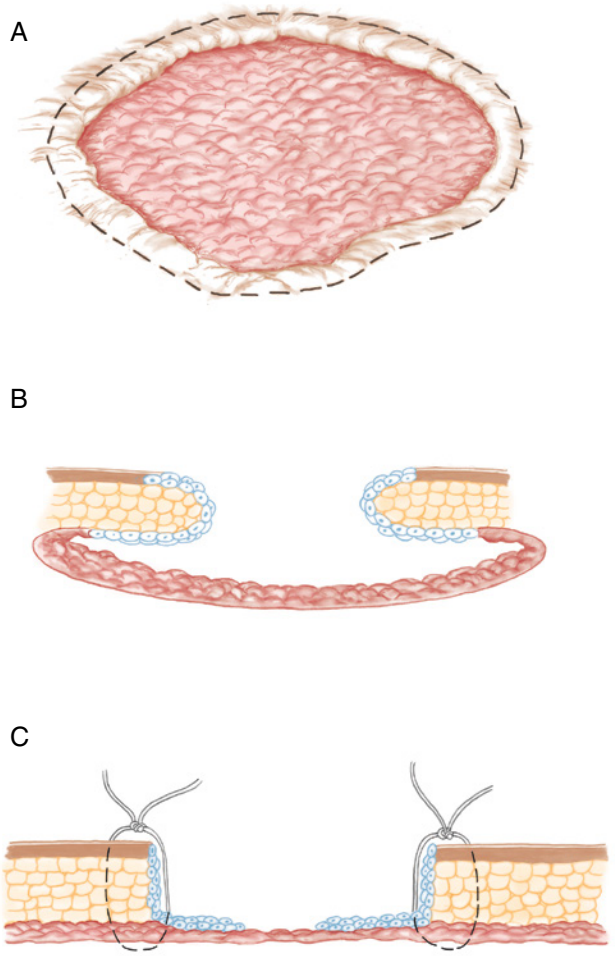


FIG. 6-7 (A) Pocket wounds include those wounds where the skin along the perimeter of the defect fails to heal to the surface of the underlying granulation. (B) Cross-sectional view of the pocket wound. Note the epithelial cells are migrating along the undersurface of the unattached skin. Effective wound contraction and epithelialization of the wound cannot occur. (C) In this illustration the skin edges are debrided. After cleansing the wound, the skin margins are sutured to the granulation bed. Once healed into position, contraction and epithelialization can proceed over the wound surface.

SCARRING AND WOUND CONTRACTURE

Formation of scar tissue is a normal response to healing. While scarring is beneficial in some injuries, its formation in other wounds is undesirable. Formation of granulation tissue and deposition of collagen are desirable for many shearing injuries involving the carpal or tarsal joints. Collagen deposition improves joint stability and creates a soft tissue surface, promoting closure of the defect.

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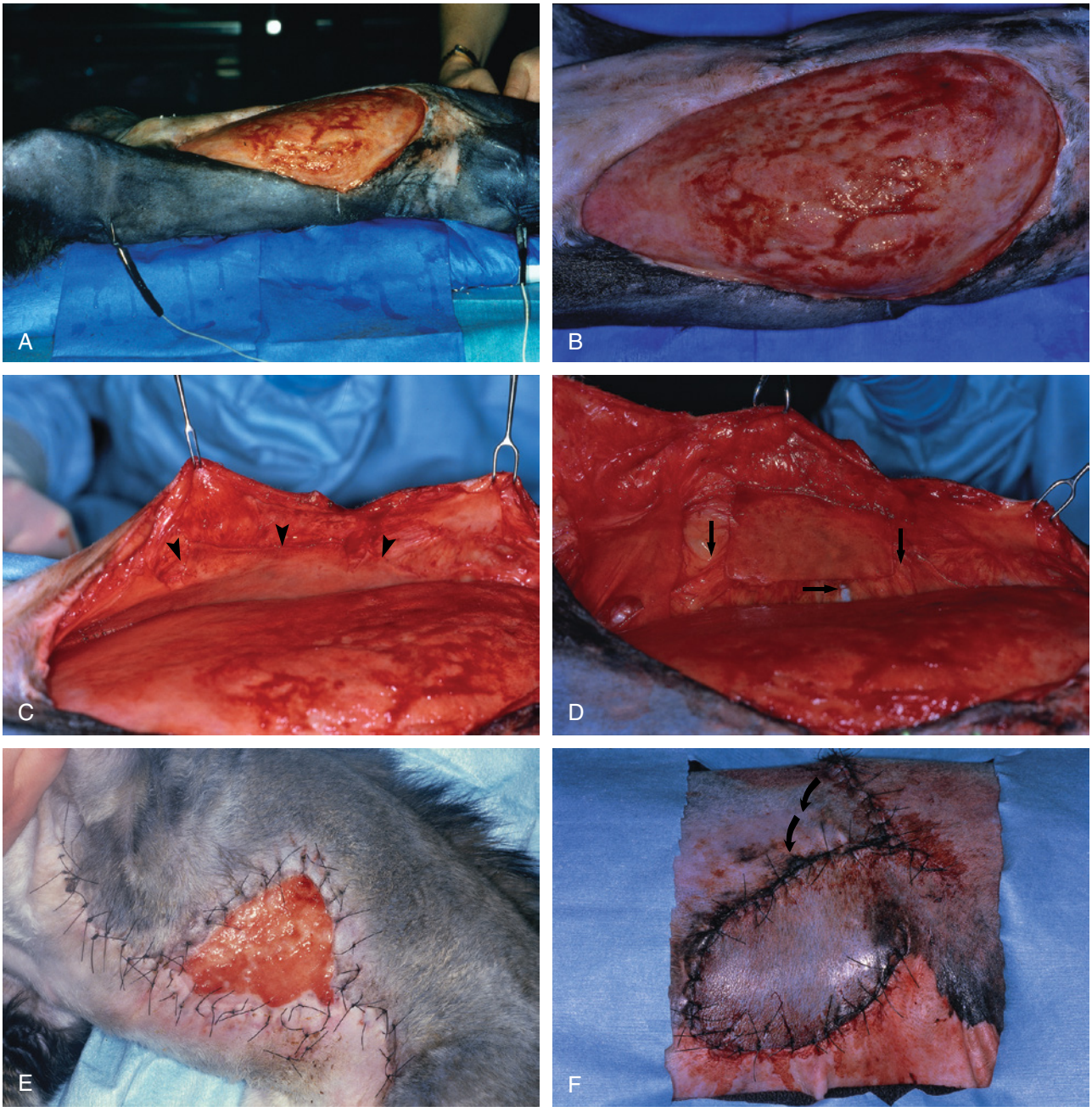


FIG. 6-8 (A) Example of a feline indolent pocket ulcer secondary to a bite wound sustained 6 months previously. (B) The nonhealing wound involving the ventral thorax and abdomen. (C) After topical antimicrobial management, 48 hours prior to surgery, the patient was anesthetized. Note the subcutaneous pocket lined by a flat granulation bed (arrows). (D) Release incisions (arrows) were made in horizontal and vertical directions through the restricting membranous connective tissue layer, with care taken to avoid division of direct cutaneous vessels in the overlying subcutis. (E) The wound was primarily closed. However, because of excessive tension a portion of the wound was left open, although skin borders were sutured directly to the granulation bed. (F) When contraction and epithelialization failed to occur after 1 month, a transposition flap was rotated into position to successfully complete the closure (see Fig. 5-14).

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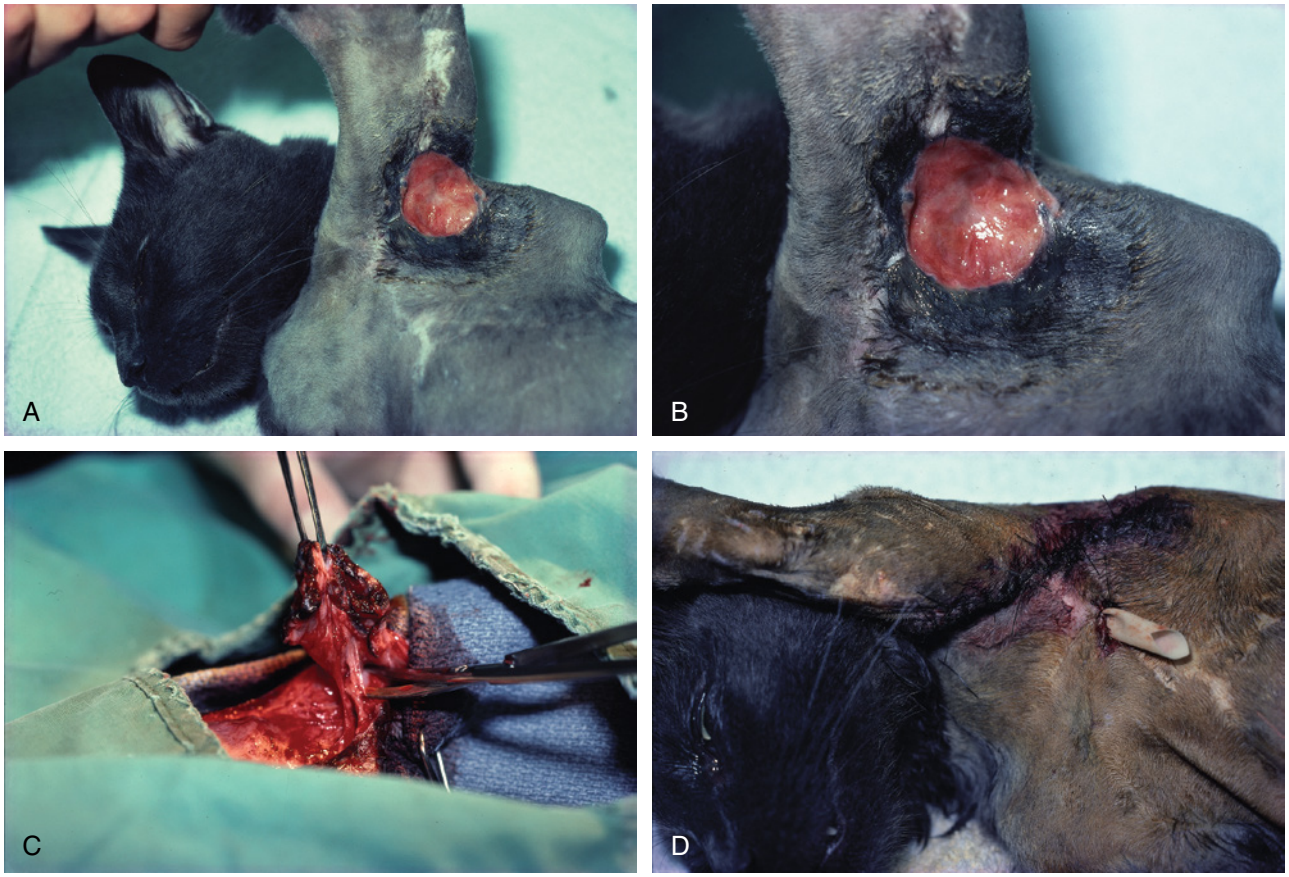


FIG. 6-9 (A) Chronic, nonhealing axillary ulcer in a cat. (B) Close-up view of this chronic granulation bed. (C) *En bloc* excision of the entire wound bed, down to healthy tissue. (D) The skin margins were carefully undermined: interrupted intradermal sutures were followed by the use of vertical mattress and simple interrupted monofilament 3-0 nylon sutures. The key to successful closure of axillary wounds includes (1) minimal skin tension, (2) use of a two-layer closure to maintain accurate apposition, (3) accurate skin apposition, and (4) cage confinement of the cat to minimize activity for 1 month postoperatively. (Cats often prefer a small box they can crawl into for privacy, thereby reducing their activity level.)

Large skin defects, particularly those involving flexion surfaces (usually of the extremities), may result in restrictive scar formation during second-intention healing. The term *wound contracture* implies a loss or restriction of motion and function to an area (e.g., joint), usually as a result of excessive scarring. Muscle atrophy and fibrosis also may contribute to contracture formation. Infection can prolong the inflammatory response and further contribute to scar tissue deposition.

Large skin wounds involving a flexion surface are most susceptible to contracture formation. From the author's experience, this is most evident when dealing with large skin defects involving the popliteal area. Patients will naturally hold the involved area in flexion, which decreases pain by reducing the surface area exposed to the environment and reduces movement.

Unfortunately, collagen deposition "connects" the contact surfaces of the wound, resulting in contracture formation. Surgical division of the scar, followed by closure of the skin defect, usually prevents contracture recurrence. Physical therapy can be useful in accelerating recovery.

Prevention of wound contracture requires early recognition of the developing problem and the proper steps to combat it. In veterinary medicine, early appropriate coverage of open wounds with skin flaps and related Z-plasty techniques or by free grafts, followed by physical therapy, can *prevent* wound contracture. Scar excision, partial myotomies, flap or free graft coverage, and physical therapy may be required once a contracture has developed (Figs 6-10 and 6-11). Temporary traction or splintage to the area occasionally is used to combat recurrence until healing is complete and physical therapy can be

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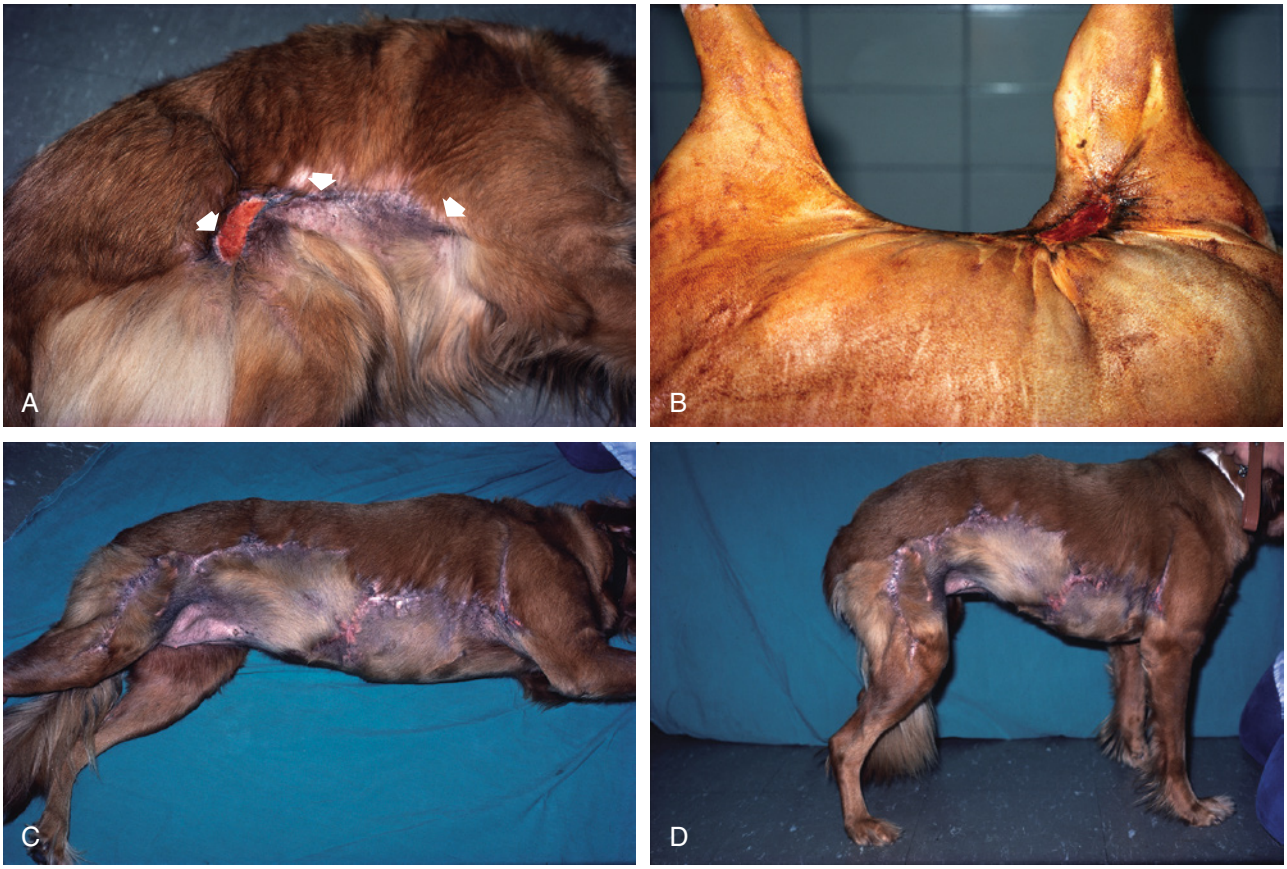


FIG. 6-10 (A) Bowstring contracture (arrows) in a golden retriever secondary to an electrical heating pad burn to the right lateral thorax and abdomen. Healing was incomplete after 1 year. (B) The restrictive scar seriously impeded use of the involved limbs. (C, D) Following surgical removal of the scar tissue, the large defect was closed with a series of skin flaps, including the caudal superficial epigastric axial pattern flap. Note restoration of the range of motion to the right forelimb and hindlimb.

implemented. Physical therapy can be effective in modifying collagen deposition and cross-linkage to improve mobility of the affected region. Early resumption of normal physical activity in a staged fashion generally is the best form of physical therapy for veterinary patients.

INFECTION AND BIOFILM FORMATION

Bacterial infection results in the release of toxins and associated inflammatory infiltrates that can lead to cell death and vascular thrombosis. Resistance to infection and promotion of healing critically depend on maintaining adequate circulation to the wound. Delivery of antibiotics also depends on maintaining perfusion to the compromised tissues. Infection can be considered as an imbalance between bacterial population and virulence versus host resistance. The mere presence of organisms is less important than the level of bacterial growth. Bacterial growth greater than 100,000 organisms (10^5) per gram of tissue is necessary to cause wound infection. Although surgeons cannot alter systemic host defense factors in many trauma cases presented, they can play a significant role in adversely affecting local wound properties that can promote infection and deter host defense mechanisms in the wound.

> Obtaining quantitative cultures, based on the gram weight of tissue samples submitted, is an experimental gold standard of confirming infection. Clinically, this technique is rarely used or needed. Its use may be limited to particularly problematic wounds, the identified presence of resistant/virulent organisms, and in debilitated immunocompromised patients.

Although a laceration and puncture wound may have the same degree of tissue injury, the environment of each wound is vastly different. Open wounds rarely are the source of invasive infection. A puncture wound lacking drainage forms a closed, hypoxemic pocket that provides

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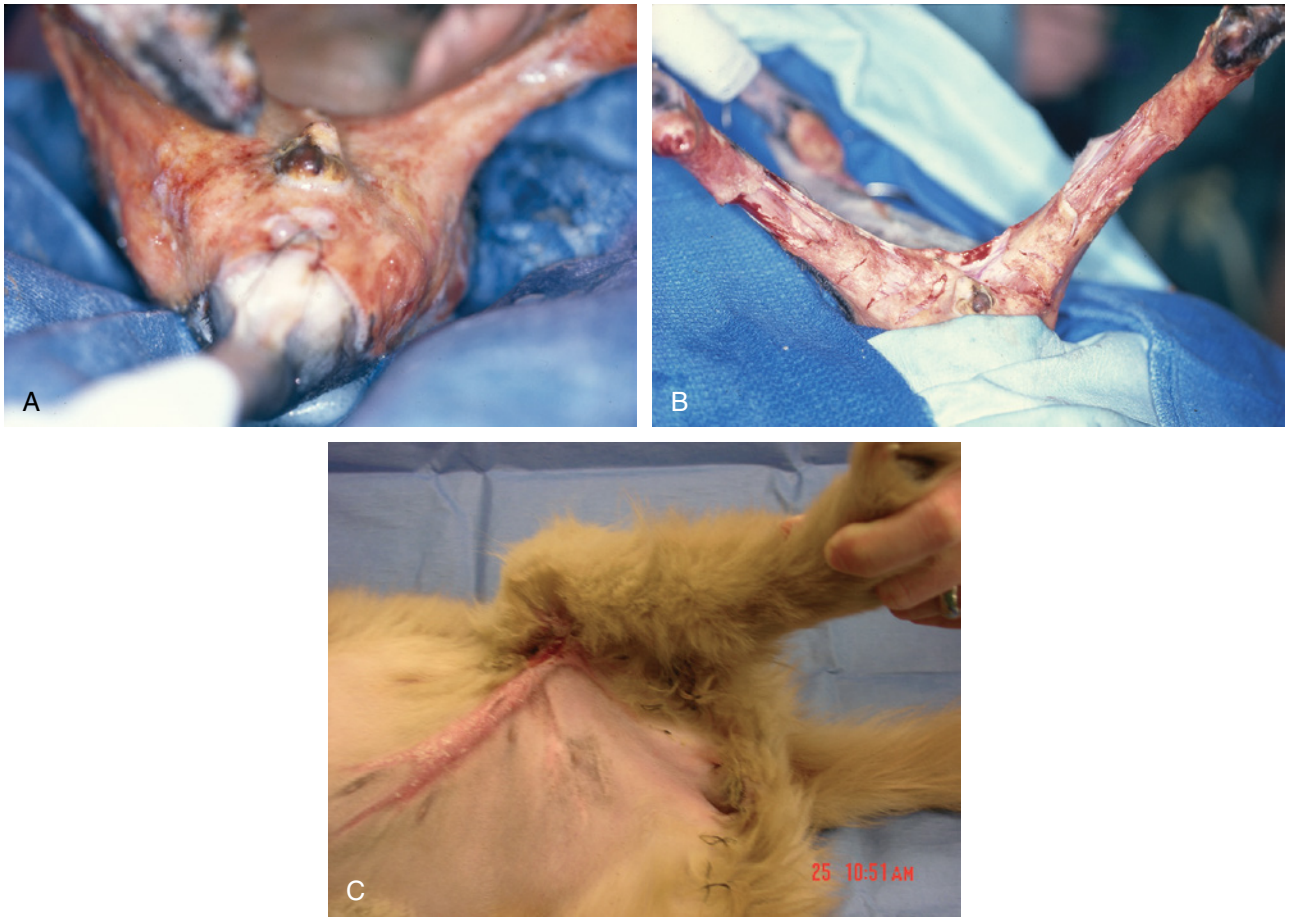


FIG. 6-11 (A) Note contractures behind each knee of a cat, secondary to extensive burns. Contractures were managed by incising the scar, thereby "releasing" the restrictive tissue bands. (B) A no. 15 scalpel blade was used to make "feather-light" incisions through the restrictive granulation layer without damaging the underlying musculature. Traction was applied to straighten the leg as the scar bed was incised. A mesh graft was successfully applied to each site. A spica splint was used to keep each limb extended and immobilized (see also Figs 5-10 and 5-26). (C) A second example of wound contracture in a golden retriever puppy. The dog fell onto a sump pump motor, burning the left inner thigh on the exposed hot metal. A severe contracture restricted motion of the left hindlimb and contributed to severe angular limb deformities that necessitated its amputation.

an ideal environment for bacterial proliferation unless steps are taken to prevent infection (open, lavage, debride, establish drainage) (Fig. 6-12). Chronic infections can be more problematic to manage as a result of the prolonged inflammatory response and fibrosis associated with this condition.

Systemic (prophylactic) antibiotics have potential value to blunt the occurrence of infection if tissue levels can be achieved within 4 hours of wounding. After this time, bacterial lodgment will occur; antibiotics at this point generally are ineffective in preventing infection. Cases of cellulitis associated with early bacterial colonization may respond to antibiotics, whereas a purulent discharge or abscess requires the wound to be opened for inspection, lavage, debridement, and drainage.

Bacterial Cellulitis: Treat with Antibiotics?

Whether or not to treat bacterial cellulitis with antibiotics is a common clinical question. In the presence of a foreign body, abscess formation will inevitably result following cessation of antibiotic therapy. *Early* cellulitis without foreign bodies may be more responsive to antibiotics than cases of advanced cellulitis, in which edema, inflammation, and fibrosis are noted during examination (palpation, ultrasonography). In the latter case, infection is coalescing into an abscess; warm compresses alone (usually for 12–24 hours) may be considered to facilitate abscess formation. Surgical drainage, bacterial cultures, debridement, lavage, topical therapy, and systemic antibiotics can then effectively resolve the definable abscess.

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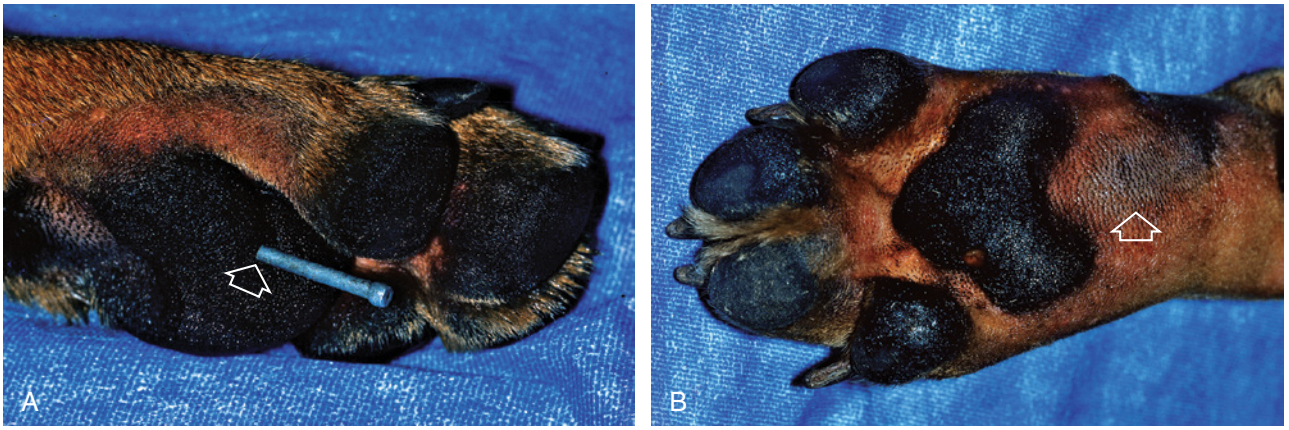


FIG. 6-12 (A) Finishing nail driven deeply through the metacarpal pad (arrow). (B) A severe cellulitis culminated in an abscess proximal to the metacarpal pad (arrow). The area proximal to the metacarpal and metatarsal pads is a common area for abscesses to "point."

Biofilms

Biofilms are complex microbial (bacterial or fungal) communities that synthesize a protective matrix that adheres firmly to the wound surface. In essence biofilms are a microbial colony encased in a protective polysaccharide matrix attached to the surface of chronic wounds. The biofilm is a hostile microbial aggregate protected by this polymeric cocoon matrix, shielding the organisms from antimicrobial therapy while attacking host defenses. Biofilms are a major concern in the management of chronic, nonhealing wounds in humans; it is quite likely that biofilms are an important component in chronic problematic wounds in veterinary medicine.

The biofilm population may be a single species or (more commonly) polymicrobial in nature. The dynamic bacterial population may change over time. Biofilms create a chronic inflammatory response: leukocytes and macrophage populations are stimulated to release destructive proteases (metalloproteinases and elastase) and reactive oxygen species (ROS) in an attempt to separate the biofilm from the wound surface. Unfortunately, these ROS and proteases also damage the normal surrounding tissues and impair the normal healing processes. Increased vascular permeability increases production of exudate. A variety of factors can promote biofilm formation, including tissue ischemia, trauma, and impairment of the patient's immune system. The biofilm surface can appear gel-like and shiny and have the gross appearance of a wound slough. The presence of a slough should alert the clinician to the possible presence of a biofilm. Bacterial culture results may not reflect the polymicrobial nature of biofilms.

As in the management of chronic fibrotic wounds, excisional debridement of the biofilm down to a healthy wound bed is an important component of treating biofilms; follow-up management with microbicidal dressings and topical agents is the second component in the management of biofilm and prevention of its reformation, along with the effective selection of systemic antibiotics based on aerobic and anaerobic cultures. Wound closure can be considered once a healthy wound bed forms.

A 20-minute wet-to-moist cleansing with various irrigation solutions has been studied to reduce bacterial bioburden in chronic open wounds. Hypochlorite/hypochlorous acid solutions (Dakin's solution) and povidone–iodine were useful in this endeavor. The antiseptic polyhexamethylene biguanide (polyhexanide; PHMB) with zinc and betaine was effective in reducing bacterial bioburden when followed by a 0.2% sodium hypochlorite in 03% saline flush.

Abscesses

Abscess formation is common in dogs and cats. Feline abscesses are typically the result of bite wounds from other cats. The small puncture holes readily seal and the closed wound pocket is an ideal incubator for bacterial infection. Common examples of infectious microorganisms include *Staphylococcus* spp. (including methicillin-resistant *Staphylococcus aureus*—MRSA, commonly pronounced "mersah"), *Streptococcus* sp., and *Pseudomonas* sp. *Pasteurella* spp. is a common oral contaminant in small animals and frequently is responsible for bite-wound infections. Other infections, uncommonly seen, include norcardiosis, actinomycosis, and atypical mycobacterial infections.

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Case Example of a Methicillin-Resistant *Staphylococcus intermedius* Infection

The author noted a 1 cm area of an incision that failed to heal after closure of a large wound overlying the olecranon. Two attempts at minor debridement and suture closure failed to resolve the issue as expected. The area was debrided a third time and the tissue was submitted for culture. The author's suspicion of a focal methicillin-resistant *Staphylococcus* sp. infection was confirmed. The patient responded to chloramphenicol based on the culture results.

Bacteria-generated cellulitis precedes abscess formation. The use of systemic antibiotics may halt abscess formation in some cases, unless an underlying foreign body is present, under which circumstances an abscess normally forms on completion of the course of antibiotic therapy. When attempting this conservative course of therapy, owners must be warned of this possibility.

Areas of bacterial cellulitis eventually coalesce to form the abscess cavity. Abscesses are drained ventrally once they have "pointed." Warm compresses can facilitate their coalescence. Many of the smaller abscesses in small animals readily respond to this regimen followed by gentle exploration, flushing, debridement, and systemic broad-spectrum antibiotic support for 7–10 days (Fig. 6-13). Warm compresses are useful to promote drainage, maintain cleanliness to the area, improve regional circulation, and promote healing.

Cervical–pharyngeal abscesses in the dog are most commonly seen in the late summer/early fall in New England. They are usually attributed to dogs eating stiff, dry blades of grass, fragments of which perforate the pharyngeal mucosa and migrate into the cranial cervical region. This abscess is characterized by a rapidly forming, firm edematous swelling. (Many patients have a history of chewing wood and grass.) A variation of this condition is the retrobulbar abscess. With retention of this plant material, infection commonly recurs with antibiotic therapy alone. In these cases the abscess should be opened, explored, debrided, lavaged, and drained. (In a low percentage of these cases, the grass fragment can be identified floating in the pus being evacuated from the abscess cavity.) Owners are informed that recurrent abscess formation is likely if any foreign debris remains (Fig. 6-14).

Larger abscess cavities can be packed open for 2 or 3 days with moistened medicated cotton gauze packs, changed daily. Partial drying of the pack facilitates the absorption of the discharge and helps to strip out necrotic tissue adhered to the cotton fibers (Fig. 6-14). Other useful packing materials include alginate dressings and absorptive foam pads after surgical exploration–debridement. In large, deep pockets, vacuum-assisted closure (see Chapter 4) may be considered after debridement and lavage of the wound. If the wound is left open to heal by second intention, pet owners can facilitate healing by applying warm compresses (2–3 times daily for 10–15 minutes for approximately 1 week) followed by the application of a topical antimicrobial agent/dressing to protect the developing granulation bed from desiccation. In some deeper body abscesses, closed vacuum drains can be effectively employed to remove pus and inflammatory tissue fluids for several days, but only after necrotic tissue and any foreign debris have been removed to help ensure their more effective use.

Most abscesses are contained in a single pocket. On occasion, abscesses can be separated by fibrous septa,

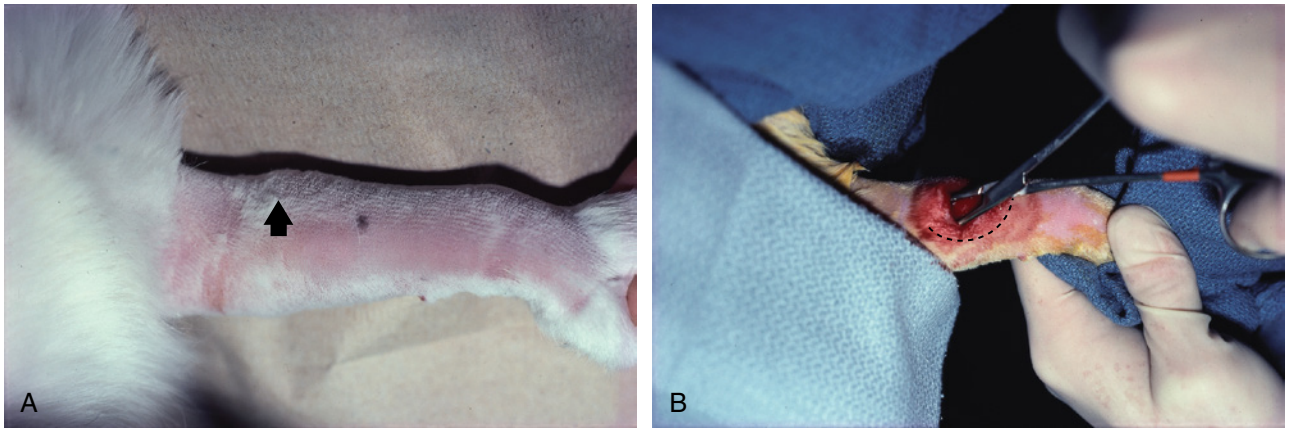


FIG. 6-13 (A) Abscess (arrow) as a result of a bite wound from another cat. (B) After sterile surgical preparation, a scalpel blade was inserted into the dependent area of the abscess. Pus was evacuated followed by insertion of a hemostat to gently explore and examine the cavity. A few millimeters of skin were excised (dotted line) to enlarge the drainage site.

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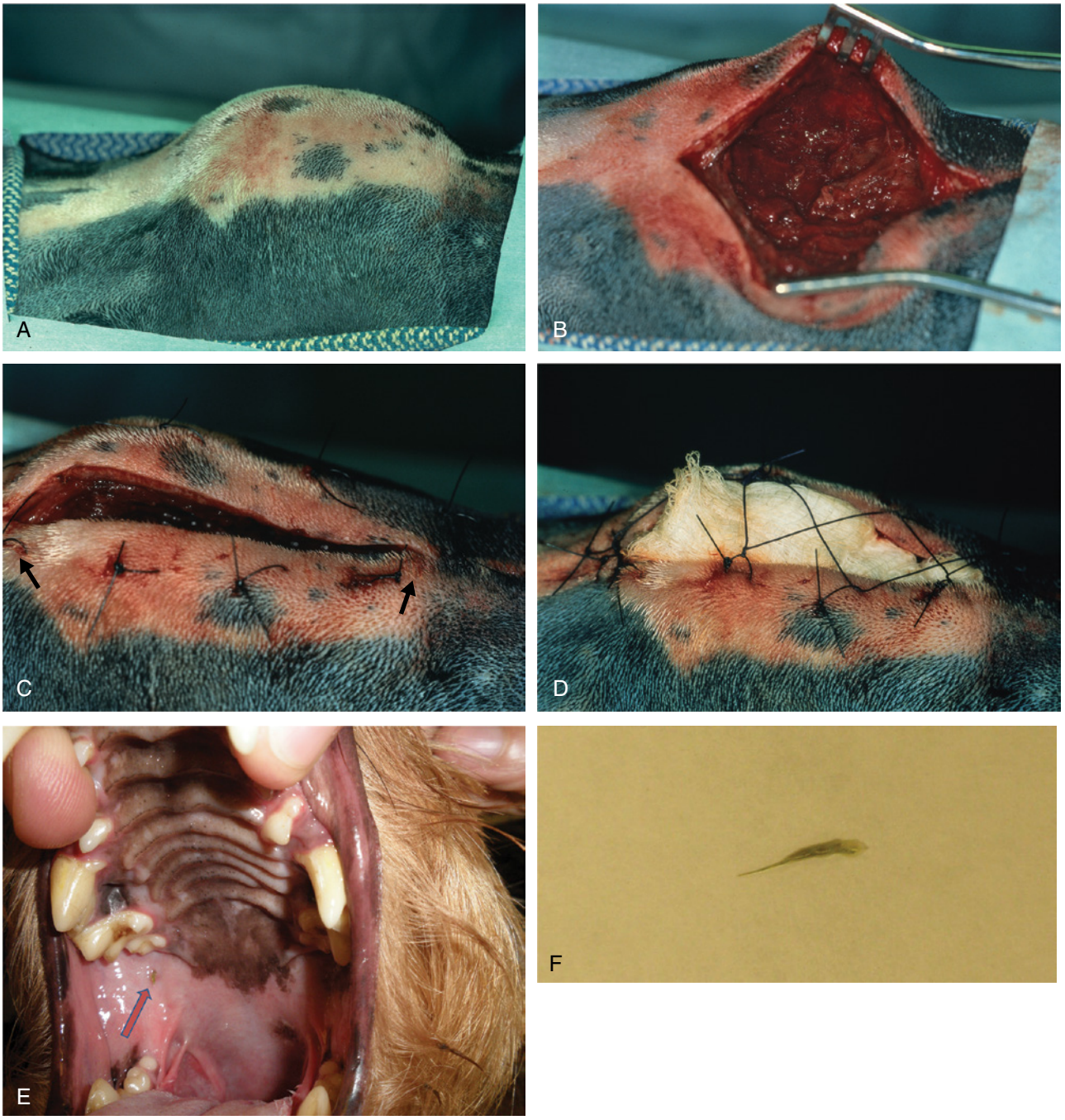


FIG. 6-14 (A) Deep ventral cervical abscess from a migrating fragment of grass. (B) The abscess cavity was explored, lavaged, and suctioned. Surgical debridement also was performed. (C) The cranial and caudal wound borders were partially closed and this was followed by the placement of suture loops around the periphery of the wound (arrows). (D) Tie-over dressing. A medicated wet dressing was inserted into the cavity and secured by lacing suture material through opposing loops. Wet-to-dry dressings were used to mechanically debride the cavity for 48 hours. Thereafter, sutures were placed through opposing loops to loosely approximate wound edges. It is important to count the number of gauze sponges used to pack wound cavities in order to prevent their accidental retention in the healing wound. (E) In New England, cervical abscesses are most commonly seen in the late summer and early fall. The dry grass tips are stiffer, facilitating oral mucosal penetration and perforation. During an oral examination in a golden retriever, the author noted a grass fragment perforating the oral mucosa as an incidental finding. (F) Close-up view of the grass fragment. Grass fragment migration is a common cause of cervical and retrobulbar abscess formation.

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FIG. 6-15 (A) Multiple fistulous interconnecting tracts involving the upper aspect of the left rear leg of a dog. Cultures and tissue biopsies confirmed the presence of a mycobacterium. (B) Debridement of the tracts, exposing subcutaneous pockets. The fibrous septa present were broken down with the gloved index finger to improve drainage. (C) Placement of a medicated povidone–iodine polyurethane dressing covered by a Telfa™ pad (Cardinal Health). The tie-over dressing secures the wound cover from displacement. Dressings were changed every other day. (D) Healing of the draining tracts. Two other debridement procedures were required in other body areas. Prolonged antibiotic therapy based on cultures and clinical response was essential to resolving this problematic mycobacterial infection.

forming smaller pockets (*locules)*. This compartmentalization of infected pockets is referred to as *loculation*. Drainage of loculated abscesses requires breaking down the fibrous septa to drain the entire area (Fig. 6-15).

Culture and sensitivity testing and Gram stains usually are not warranted for the smaller abscesses seen in small animal practice; deep abscesses, recurrent infections, persistent or recurrent draining tracts, and potentially life-threatening infections do warrant these additional diagnostic techniques. These clinical observations should alert the practitioner that the condition is not a "minor" local infection but one that warrants a detailed clinical work-up, examination, and, if necessary, surgical exploration (Figs 6-16 and 6-17). Aerobic and anaerobic cultures should be submitted for bacterial analysis under these circumstances. The most effective method of obtaining an accurate culture from an infected pocket is by taking a sample of the abscess wall for culture. Deep aspiration of the cavity is preferable in order to obtain a representative culture. Cultures obtained from the purulent drainage are more likely to contain bacterial contaminants rather than the primary organism responsible for infection.

Fungal infections can mimic bacterial infections, and culture and biopsy samples should be taken when this condition is suspected. Fungal infections have a regional incidence pattern in the United States (Fig. 6-18). A detailed patient history should include the pet's travel history.

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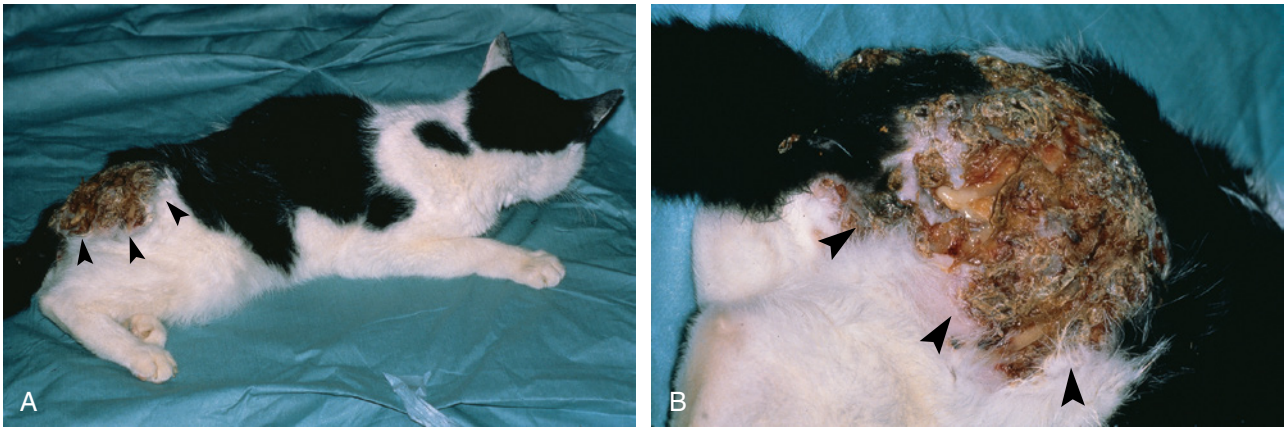


FIG. 6-16 (A) Diffuse suppurative abscesses (arrows) involving the skin and subcutis of a domestic short-hair. (B) Close-up view revealed multiple small abscesses coalescing and interconnecting through numerous tracts (arrows). Histopathologic analysis and aerobic and anaerobic cultures were submitted revealing *Nocardia asteroides*. The patient was negative for feline infectious peritonitis, toxoplasmosis, and feline leukemia virus.



FIG. 6-17 Multiple draining tracts entering the thoracic wall of a Walker hound (hunting dog). Diagnosis was actinomycosis secondary to embedded wood fragments.

Fungal Infections

- Blastomycosis
- Coccidioidomycosis
- Histoplasmosis
- Mycetomas
- Phaeohyphomycosis
- Pythiosis
- Sporotrichosis
- Zygomycosis (mucormycosis, phycomycosis)

Other Contributing Factors Associated with Infection

As discussed, neoplasia with an ongoing infection can be diagnosed with the submission of appropriate biopsy samples. Immunosuppression by various chemotherapeutic agents or underlying disease (e.g., feline leukemia, feline infectious peritonitis) may explain an animal's susceptibility to infection and poor healing, and these possibilities should be investigated. Autoimmune disorders and immune-mediated vasculitis can present as a cellulitis with progressive necrosis. Appropriate diagnostic tests (antinuclear antibody [ANA], direct antiglobulin test, Coombs test) should be performed (Fig. 6-19).

FOREIGN BODIES AND DRAINING TRACTS

Foreign bodies are objects originating from outside the body. In humans many foreign bodies are secondary to gunshot injuries, car accidents, or explosions. In contrast, foreign bodies in dogs and cats often include plant material in the form of embedded sticks, grass fragments, or grass awns. Teriyaki sticks used in cooking occasionally are swallowed by dogs and fragments have the potential of migrating through the gastrointestinal tract and into various body regions. Glass foreign bodies are uncommon, but most typically involve a fragment of glass embedded in a foot pad. Porcupines are native to most

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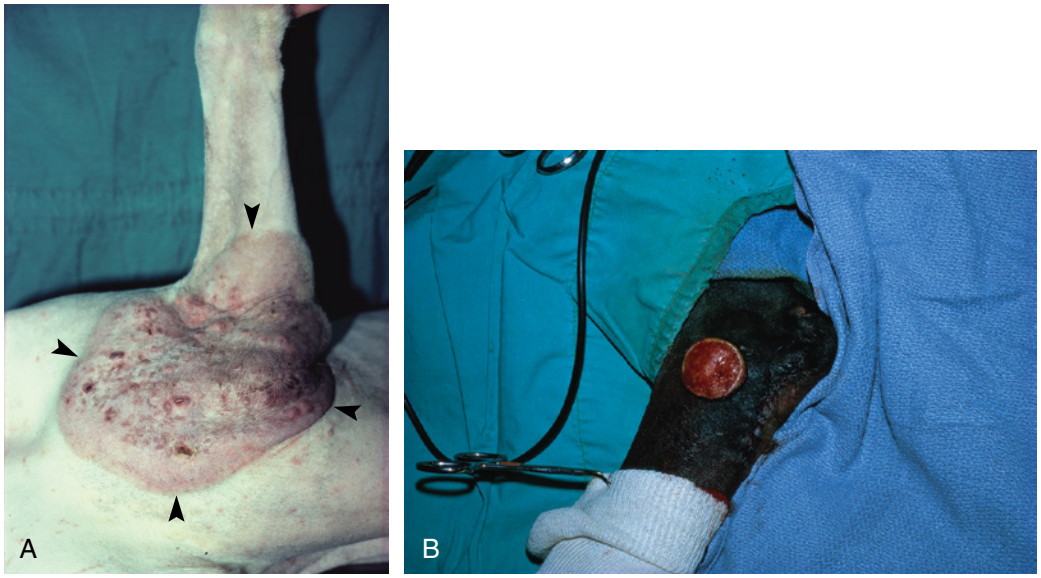


FIG. 6-18 (A) Large granulomatous mass with multiple draining tracts involving the axilla and inner brachium of a malamute (arrows). Histopathologic analysis of biopsy samples revealed phycomycosis. Deep, wide excision and closure with a thoracodorsal axial pattern flap were curative. (Source: Pavletic MM, MacIntire D. 1982. Phycomycosis of the axilla and inner brachium in a dog: surgical excision and reconstruction with a thoracodorsal axial pattern flap. *J Am Vet Med Assoc* 180:1197. Reproduced with permission from the American Veterinary Medical Association.) (B) Expanding, ulcerated mass overlying the lateral aspect of the left elbow of this young Labrador retriever. Histopathologic analysis revealed cutaneous histoplasmosis; thoracic radiographs were within normal limits. Surgical excision was curative.



FIG. 6-19 (A, B) Two case examples of immune-mediated vasculitis resulting in loss of digits to the hindlimbs. Both patients were positive on the Coombs test and for the presence of antinuclear antibodies. (See the discussion of foot pad salvage techniques in Chapter 18.) (C) Infarction and mummification of the entire cartilaginous external nose secondary to immune-mediated vasculitis.

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of Canada, New England, New York, Pennsylvania, Michigan, Wisconsin, and the western United States. Porcupine quills, left untreated, can embed in the dog and migrate into the body if left untreated, establishing a foreign-body reaction (see Chapter 7). Although rare, secondary to a dog fight a (canine) tooth fragment can be retained in a patient, oftentimes between the radius and the ulna.

Surgical implants are a common source of draining tracts in dogs and cats, including braided nonabsorbable suture material (silk, Vetafil, cotton, polyester, etc.) (Fig. 6-20) as well as metallic implants including bone plates and screws (Fig. 6-21). The veterinarian also should be aware of the fact that some neoplastic conditions (with or without the presence of microorganisms) can mimic infection.

Such conditions can result in the formation of a draining tract. By definition a sinus tract is an abnormal soft tissue channel that originates or ends in one opening. A *fistula* refers to a pathologic pathway between two anatomic spaces or a pathway that leads from an internal cavity or organ to the body surface. *Tracts* are essentially tunnels comprised of granulation tissue formed by the body to expel the purulent discharge and causative agent.

Although uncommon today, braided nonabsorbable suture materials used in ovariohysterectomies have the potential to initiate a draining tract. Tracts involving the ovarian pedicle normally drain through the sublumbar area; the uterine pedicle may form tracts exiting the caudal abdominal area. Surgical correction requires removal of all suture material fragments.



FIG. 6-20 (A, B) Draining tract and subcutaneous abscessation secondary to the use of braided nonabsorbable suture material from an ovariohysterectomy. Computed tomography facilitated location of the granulomatous area in the abdomen. Cannulation of the sinus tract and subcutaneous abscess helped confirm this location as the likely source of infection. The granuloma was excised and the infected tract was successfully managed postoperatively with a vacuum drain. (C) Foley catheter insertion into fistula in the flank of a retriever for injection of diatrizoate meglumine. The fistulogram revealed a diffuse tract extending from the inguinal area to the midlumbar vertebrae. The cause was a migrating porcupine quill.

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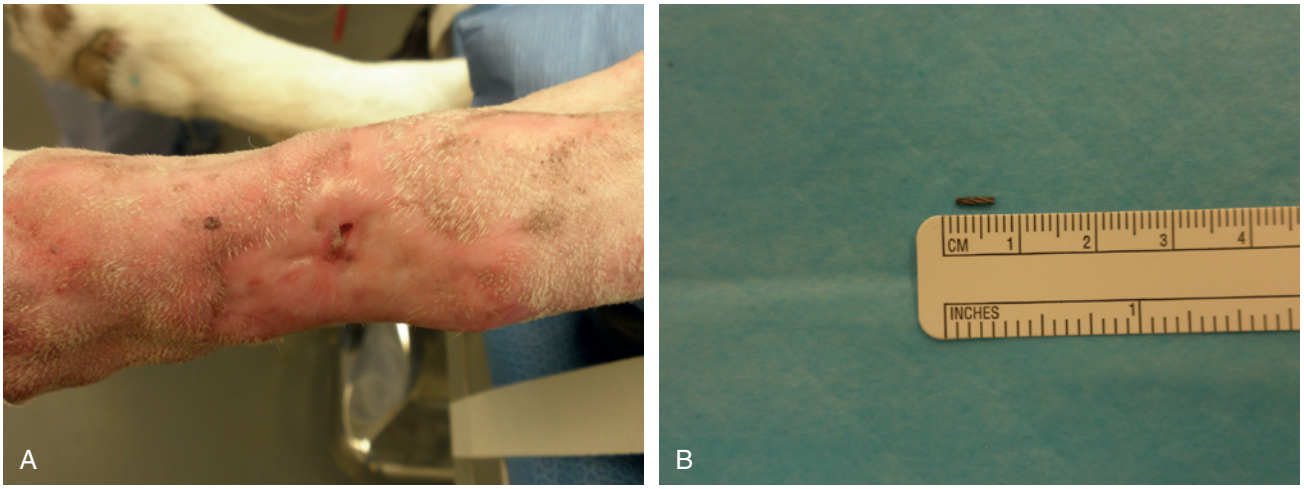


FIG. 6-21 (A) Small draining tract secondary to retention of a broken drill tip. (B) Removal of the drill-tip fragment resulted in resolution of the tract.

The most common imaging modalities used to identify foreign bodies include conventional plain radiography, computed tomography (CT), and ultrasonography. CT and ultrasonography are particularly useful for foreign-body detection in soft tissues. Ultrasonography has been shown to be relatively accurate for detecting radiolucent foreign bodies. One study compared CT and ultrasonography in detecting wood, plastic, glass, stone, and metal foreign bodies. In this study ultrasonography was effective in detecting wooden foreign bodies up to 4 cm in depth; CT was unable to detect wood particles. CT depicted deeply impacted glass particles more clearly than ultrasonography, although superficial particles were equally well demonstrated. Metal particles embedded at less than 4 cm depths were detected with the same accuracy for both modalities. Plastic particles up to 4 cm in depth were detected more effectively by ultrasonography. For stone particles less than 4 cm in depth, both CT and ultrasonography were similar in accuracy. In summary, ultrasound was superior to CT for detecting wood and plastic. CT was more efficient at detecting glass particles. There was no significant difference in CT and ultrasonography for detecting stone or metal fragments. The depth and size of the particle can impact visibility.

In the past, contrast studies (fistulogram or sinogram) occasionally were useful in highlighting foreign bodies, determining the magnitude or direction of the tract(s), and examining their relationship with regional anatomy (Fig. 6-20). CT has largely replaced the need for contrast procedures. Using both modalities is a consideration for the most vexing cases. Although cannulation and injection of sterilized methylene blue dye have been used to stain the draining tract, facilitating its identification and dissection, the author has not considered this technique useful or necessary (Fig. 6-22).

Definitions to Remember

Sinus: A sinus tract is a small, uncharacteristic channel or tract in the body that usually goes from the source/cause to the skin's surface.

Fistula: A fistula is an abnormal pathway between two anatomic spaces or a tract that leads from an internal cavity/organ to the body surface.

Foreign bodies can be elusive by migrating through tissue planes or they can be hidden by layers of scar tissue and necrotic debris. For example, wood/bamboo teriyaki sticks used for grilling food may be swallowed by dogs. Rigid stick fragments can exit the gastrointestinal tract and migrate into a body cavity and adjacent soft tissues. CT was noted to be useful in identification of vegetal foreign bodies in approximately 25% of cases in one study (Manzoni et al. 2023). Surgical exploration may be required to locate and remove these foreign bodies. Intraoperatively, careful palpation of the body region often identifies the teriyaki stick, facilitating its removal and resolution of the draining tract (Fig. 6-23).

In surgery, the most direct approach for draining tracts is to cannulate the tract and dissect around the tract while minimizing spillage of its contaminated contents into the neighboring tissues. Dissection is extended down to the base or origin of the sinus tract and the entire area excised with its source. On completion of the surgical procedure, the excised tissue is opened and examined, culture samples

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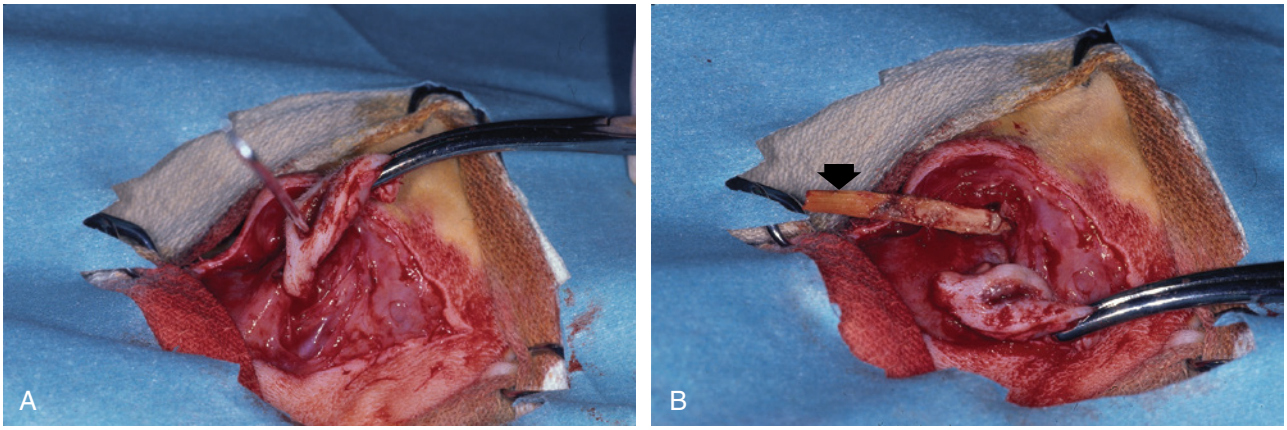


FIG. 6-22 (A) Case example of plant material causing a draining tract. Chronic draining tract caudal to the left mandible. A fistulogram demonstrated a linear object medial to the digastricus muscle. A metallic probe was inserted into the tract, serving as a guide during surgical dissection. (B) The tract led to a small cavity containing several fragments of plant material. The owner later reported the cat had a habit of chewing on a broom used for sweeping ashes from the fireplace. Surgeons must look closely for more than one foreign body, as this case demonstrates.

are taken, and the tissue submitted for histopathologic examination. Deep-wound biopsy cultures should be obtained for aerobic and anaerobic microorganisms. Fungal cultures also should be considered based on geographic location and historical exposure. Vacuum drains are normally used to control dead space postoperatively.

Many surgical implants have the potential to develop draining tracts, secondary to tissue irritation, foreign-body reaction, and/or secondary infection.

The accidental retention of Penrose drains or fragments of a drain will initiate a foreign-body reaction and formation of a sinus tract. Radiographs normally will highlight these radiopaque drains. Their removal is usually curative (Fig. 6-24).

Dermal Sinuses

A pilonidal sinus (dermoid sinus) is a congenital defect in which ectodermal cells fail to cleanly separate from the neural tissue during embryogenesis. As a result, an epithelial tube forms below the skin surface to variable depths; in extreme cases it can extend to the dura mater. Because the sinus tract is lined by cutaneous epithelium, hair and epithelial debris will accumulate in the tract and elicit a foreign-body reaction. Bacteria can secondarily infect the sinus tract, compounding the problem. Although rare, for those cases in which the sinus attaches to the dura mater, a septic meningitis and the onset of neurologic signs may be noted.

Rhodesian ridgebacks most commonly present with this condition, and it is considered to have a simple recessive mode of inheritance (Fig. 6-25). However, the condition also has been reported in other dog breeds, including the boxer, chow chow, English bulldog, shih tzu, Siberian husky, and springer spaniel. (The author has removed one pilonidal sinus from the dorsum of the head of a black Labrador retriever, with the winding tract terminating at the level of the occipital crest.) The mode of inheritance in these breeds is unknown. In Rhodesian ridgebacks the sinus opening is usually found along the spinal column and normally opens in the midst of a whorl of hair. Palpation of the subcutaneous tissues between the thumb and index finger often reveals a cord-like structure extending into the deeper tissues (Fig. 6-26).

Radiographs can be taken to assess the underlying spinal column. Contrast studies have been suggested to outline the extent of the tract, although filling the cavity with a contrast medium can be problematic due to the accumulation of discharge and tissue debris. If neurologic signs are present, CT and magnetic resonance imaging (MRI) are advisable to assess the extent of the condition prior to surgery.

Surgical excision is the best course for managing a pilonidal sinus. The area should be liberally clipped to compensate for the occasionally irregular course of the tract. A circular skin incision is made around the sinus opening; skin incisions can be used to simplify exposure of the deeper aspects of the sinus tract. Most pilonidal sinuses tend to taper as dissection progresses into the deeper tissues (Fig. 6-25). Insertion of a feline urinary catheter or metallic probe can orient the surgeon during this process. Self-retaining retractors improve visualization of the deeper portions of the tract. If the sinus extends to the dura mater, a small dorsal laminectomy may be needed to

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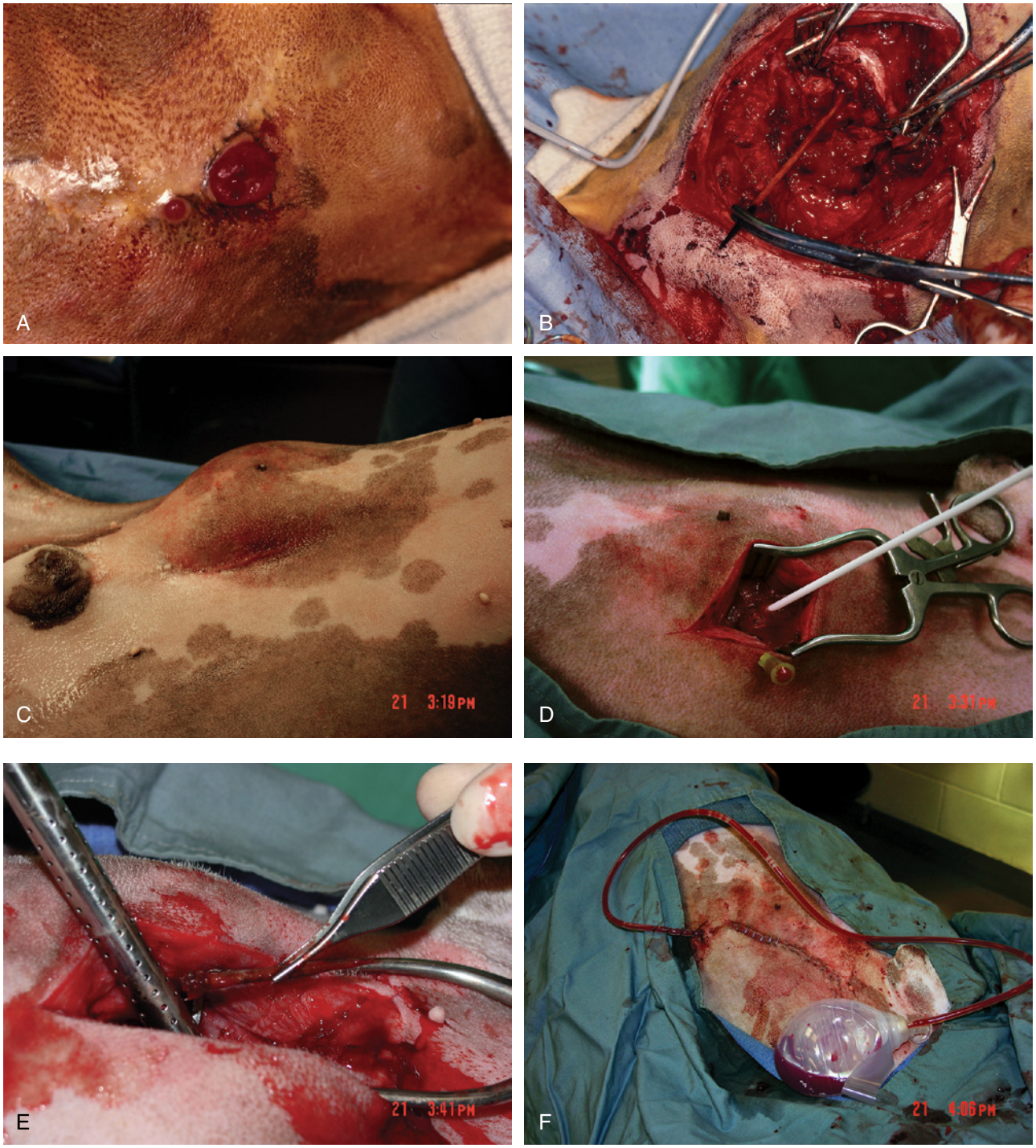


FIG. 6-23 Two case examples of migrating teriyaki sticks. (A) Chronic draining tract overlying the sternal area in a boxer. Previous attempts to locate the source of the infection failed to locate the cause. (B) Careful dissection of the draining tract uncovered a teriyaki bamboo stick of the sort the owner frequently used for barbecuing. The migrating stick was firmly lodged in thoracic cavity muscle and fascia adjacent to the sternum. The bamboo shaft likely migrated through the esophagus. The author has removed similar sticks from the abdominal cavity and retroperitoneal space that migrated through the gastric wall, resulting in abscess formation. (C) Lower abdominal wall abscess. Ultrasonography noted a 5 cm linear foreign body. (D) Insertion of a hypodermic needle to locate the depth of the abscess cavity after surgical preparation of the area. The needle is left in place, serving as a guide for surgical incision. The white pointer denotes the outer abscess wall. (E) The abscess pocket was suctioned; digital palpation located the teriyaki stick segment and forceps were used to remove this foreign body. (F) After flushing and suctioning the abscess cavity, the wound was closed using a vacuum drain. The patient healed uneventfully. *Note*: the author strongly advises owners to immediately dispose of teriyaki sticks by placing them in a secure refuse container. Dogs love to chew on the sticks, which absorb the flavor of the meat and marinade. Teriyaki sticks can perforate the gastrointestinal tract or esophagus and migrate to a variety of body regions (see Hunt et al. 2004; Pennick and Mitchell 2003; Walmsley et al. 2009 in Suggested Reading).

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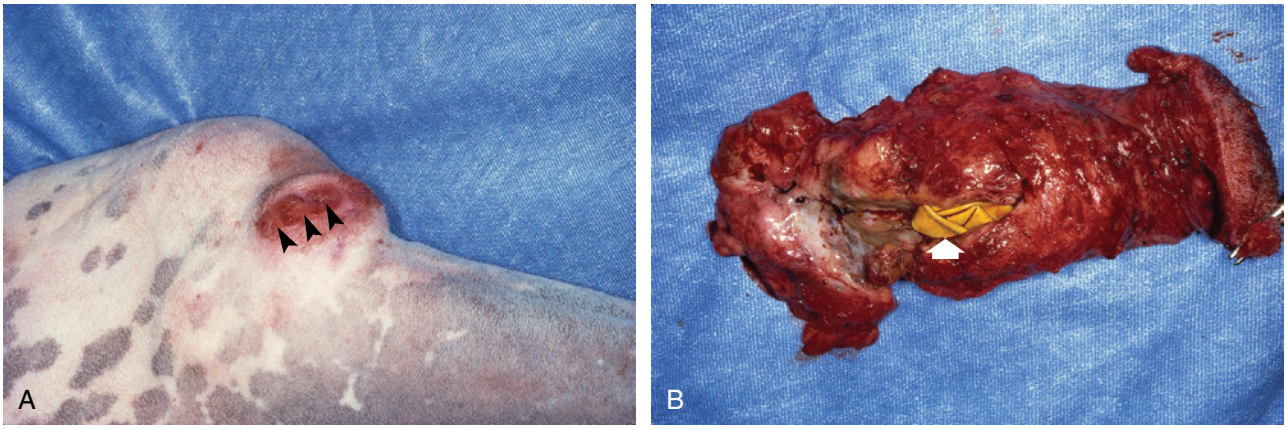


FIG. 6-24 (A) Multiple fistulous tracts (arrows) associated with an elbow hygroma of several months' duration. (B) Preoperative radiographs taken to assess the underlying bone demonstrated a radiopaque Penrose drain retained in the granulomatous mass (arrow). Excision of the large granuloma and drain (from a previous surgical attempt to manage the elbow hygroma) was curative.

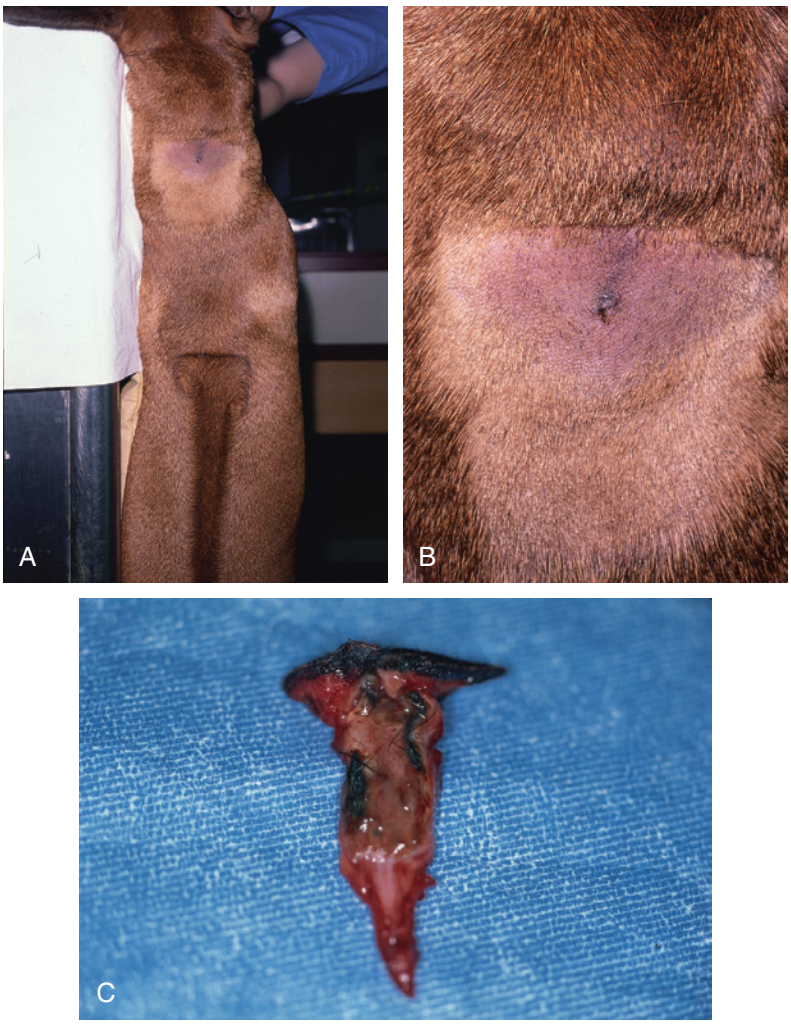


FIG. 6-25 (A) Pilonidal sinus in a Rhodesian ridgeback. (B) Close-up view of the tract. (C) The tract was cannulated with a tom-cat catheter to outline it. A circular incision was made around the sinus tract; skin incisions can be used to improve exposure. The entire sinus "cylinder" progressively tapered and ended dorsal to the vertebral surface. Epithelium, hair, and tissue debris are commonly observed when the tract is dissected open.

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FIG. 6-26 (A) Dermoid sinus involving the head of a golden retriever. The tract was palpable in the subcutaneous tissue. (B) Close-up view of the dermoid sinus. (C) Dissection of the dermoid sinus. (D) Close-up view of the entire sinus, which terminated as a blind pocket (arrow).

ensure that complete removal of the sinus is accomplished. A culture of the deeper portion of the sinus tract is advisable in the face of infection; broad-spectrum antibiotic therapy can be initiated pending the final culture results.

In general, it has been the author's experience that removal of most pilonidal sinuses is not difficult surgery, but complete removal of the entire tract is critical for a successful outcome.

Nasal Dermoid Sinus Cyst

Nasal dermoid sinus cysts (NDSC) are uncommon congenital lesions with an embryologic origin similar to the pilonidal sinus. NDSC are recognized in golden retrievers. During embryologic development, the meninges in the frontal bones protrude through the foramen cecum. This canal normally closes, but persists in NDSC cases. As a result, a sinus opening can be found in the dorsal midline of the skull, caudal to the external nares. The sinus passes through an incomplete suture line in the nasal septum. In the young adult golden retriever with NDSC, a sebaceous discharge may be noted caudal to the nasal planum. Surgical removal is indicated, with the assistance of a probe or catheter to facilitate dissection of the entire tract (Fig. 6-27). Communication with the meninges has been reported in humans; although meningitis has been reported in humans, it has not been reported in the dog to date.

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FIG. 6-27 (A) Nasal dermoid sinus in a golden retriever, cannulated with a tom-cat catheter. (B) Surgical marker outlining the surgical approach. (C) Removal of the sinus required a small dorsal rhinotomy to gain access to the terminal end of the sinus entering the nasal cavity.

USE OF TOURNIQUETS FOR LOWER-EXTREMITY PROCEDURES

A tourniquet is useful in creating a bloodless field for exploration of draining tracts for foreign bodies in the limbs of small animal patients. However, tourniquets should be avoided in traumatized limbs or limbs with vascular injury or circulatory compromise. Pneumatic tourniquets are the best available method of applying uniform pressure to a wide area. Venous blood is expelled prior to tourniquet application by elevating the affected limb for 5 minutes.

An Esmarch bandage (tourniquet) or elastic wrap can be used as a short-term tourniquet by applying it from the digits proximally without excessive tension (or tissue compression). An Esmarch bandage can be used alone or in conjunction with a pneumatic cuff. Exsanguination should not be done in the presence of local suppuration, deep venous thrombosis, or neoplasia. A thin layer of cotton padding may be applied before wrapping the limbs for more uniform pressure distribution. The elastic wrap is removed on inflation of the pneumatic cuff. The cuff is positioned at the point of maximal limb circumference

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where the bulk of the muscle protects underlying nerves and vessels from compression over bone.

Tourniquets are not without risk. Muscle ischemia, nerve palsies, and tissue necrosis may result from improper application or prolonged usage of tourniquets. When using a pneumatic cuff, pressure should be kept to the minimum required to provide a bloodless field; pressures greater than 300 mmHg should be avoided. While a properly applied tourniquet can be applied for up to 3 hours, the surgeon should minimize its usage. Some recommend releasing the tourniquet 10 minutes for every hour of inflation, although the benefits of this maneuver are questionable. Fortunately, most cases of tract exploration involving the extremities can be performed within 30–45 minutes. Removal of the tourniquet is normally followed by a variable degree of hemorrhage, allowing the surgeon to identify and target the individual bleeders with electrocautery and ligatures prior to closure.

Vetrap (3M) can be autoclaved and used effectively as a short-term tourniquet to obtain a relatively bloodless surgical field. After wrapping the limb, beginning at the toes and working proximally, scissors can be used to cut the Vetrap and expose the surgical area for exploration. Retaining the roll of Vetrap allows the surgeon to add additional loops if hemostasis is not sufficient. Care must be taken to avoid excessive elastic tension during application and to minimize the time of application, as discussed previously.

SEROMAS

Seromas are pockets in which serum accumulates, usually as a result of trauma. Seroma formation is most commonly associated with surgery, especially in areas where considerable dissection has been performed, leaving a dead space or pocket where serum can accumulate. Capillary leakage and lymphatic injury secondary to inflammation result in fluid accumulation. Traumatic surgical technique, harsh wound-cleansing techniques, the presence of foreign debris and irritants, and areas subject to constant movement also contribute to seroma formation. Small seromas beneath the skin are of no major consequence and resolve in time. Larger seromas on many occasions will require drainage (in Chapter 4, see the sections Passive Drains and Active Drains). Postoperative seroma of an abdominal incision may be difficult to distinguish from a hernia. Careful aspiration can help confirm a seroma; removal of the fluid can facilitate palpation of the abdominal incision for any hernia ring or herniated tissue in the area.

Microscopic examination of fluid from a seroma normally shows a variable number of red blood cells and very few white blood cells. They are easily distinguished from infection, where the neutrophil population clearly predominates.

Treatment and Prevention

Warm compresses for 10-15 minutes three times per day for approximately one week can facilitate small seroma resorption. A single aspiration is generally insufficient for treatment of large seromas. On occasion, the application of a firm compression bandage after aspiration may help to control dead space to promote healing of the separated tissue planes. Intermittent seroma drainage by aspiration every few days is occasionally successful (usually over a 2-week period): however, rapid fluid reformation (typically within 24 hours) after initial aspiration is a clear indication that drain insertion is required to definitively manage the serum pocket. Prior to any attempt at aspiration, the area must have a basic surgical preparation before introducing a sterile hypodermic needle. An 18-gauge hypodermic needle and 35–60 ml syringe may be used to aspirate the serum pocket; the addition of a three-way stopcock will facilitate evacuation of the syringe. Butterfly catheters are useful for aspiration in restless patients, since the tube extension reduces the risk of needle displacement during movement. Larger-gauge needles or a trocar (6–14-gauge) can facilitate drainage but would require a lidocaine block at the point of insertion. Serum may be allowed to escape passively from the dependently placed trocar (facilitated by the manual compression of the serum pocket) or by application of a syringe and three-way stopcock or vacuum pump. A compression bandage may be applied to help prevent reformation. There is minimal risk of infection after seroma aspiration provided that strict aseptic technique is maintained.

Aspiration is a simple method of managing seromas, but is frequently unsuccessful. Rapid reformation (less than 24 hours) after aspiration is an indicator that a drain is required. (This should be clearly stated to the owner prior to using this technique.) Aspiration with a syringe can be frustrated by the bevel of the hypodermic needle contacting soft tissue as the fluid pocket collapses during aspiration. The needle will require repositioning within the fluid pocket to continue serum removal. Owners who travel a distance to your practice may prefer the more reliable drain.

Nearly all seromas respond well to the use of a Penrose or vacuum drain system, depending on the size and location of the seroma. Vacuum drains are preferred for large seromas; Penrose drains (¼-inch) are useful for smaller seromas. Depending on the patient, sedation/lidocaine block or general anesthesia can be used to insert a surgical drain as a day case or on an outpatient basis.

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Drains are most commonly required both to prevent and to treat seromas. A Penrose drain is retained for 2–5 days in most cases. When applicable, a compression bandage is useful to protect the drain from contamination, restrict movement, and collapse the dead space. Alternatively, closed-suction units can be highly effective in removing fluid and obliterating dead space instead of Penrose drains. As noted in Chapter 4, syringes (35 or 60 ml) can be adapted as closed-suction reservoirs for smaller seromas, but are considered inferior to the commercially available vacuum drain system. Compression bandages, Penrose drains, or closed-suction units should be employed any time the surgeon feels that the accumulation of fluid is likely in an area where dead space is present.

Buried "tacking" sutures also can be employed to discourage seroma formation in small, sterile, dead-space areas. However, large areas of dead space may be impossible to tack down completely. Excessive use of buried sutures may promote wound infection and cannot be advocated for routine use in contaminated wounds. Buried sutures also may result in the formation of smaller seroma pockets that may not communicate with one another for simple drainage.

The author has found these surgical areas especially prone to seroma formation: dorsal cervical area, lateral facial area, and flank/inguinal area.

HEMATOMAS

Hematomas usually are the result of external trauma or hemorrhage secondary to incomplete hemostasis after completion of a surgical procedure. Small hematomas normally require no specific treatment. Large hematomas, however, are capable of pushing tissue planes apart and creating pressure beneath the suture line. Large clots can take considerable time to resorb and delay the normal healing of the tissues displaced by their presence. When feasible, the surgical area should be opened, the hematoma evacuated, and the area suctioned and lavaged. Bleeders should be identified and ligated; small bleeders may respond to electrocautery. A vacuum drain can be inserted into the dead space prior to closure of the surgical incision.

On a few occasions, Jackson-Pratt vacuum drains have provided an effective "early-warning system" of significant postoperative bleeding. Examples include postoperative hemorrhage secondary to removal of a massive thoracic lipoma and removal of a vascular thyroid carcinoma. Rapid filling of the Jackson-Pratt reservoir with blood (packed-cell volume assessment) prompted immediate return to surgery to ligate the residual bleeders.

EXPOSED BONE

Exposed bone is most commonly associated with shearing and avulsion injuries to the lower extremities. The metacarpal and metatarsal surfaces are especially prone to injury when the foot of the dog is trapped beneath the tire of a moving vehicle. The foot is compressed and ground into the pavement, avulsing skin and grinding soft tissue and bone. Avulsion of skin over bone surfaces lacking muscle immediately exposes the periosteum or cortex to the external environment (Fig. 6-28).

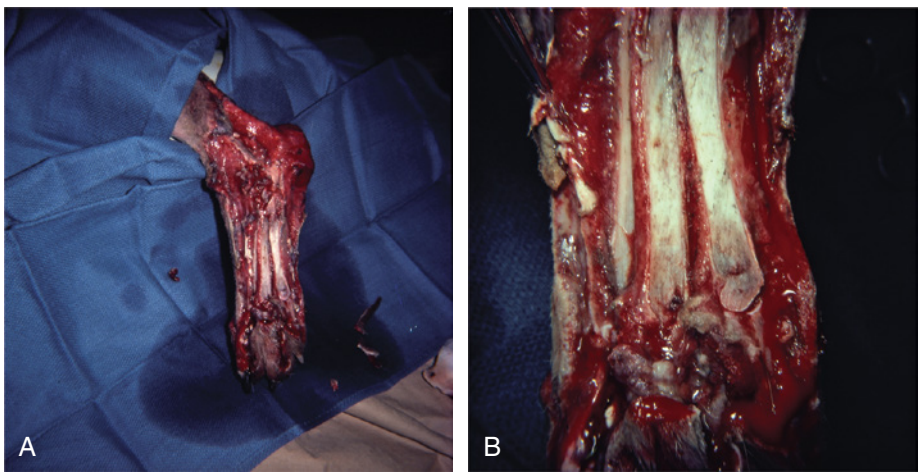


FIG. 6-28 (A) Severe shearing injury to the lower portion of a canine hindlimb. (B) A close-up view revealed that 50% of the metatarsal bones were sheared off, leaving multiple joints exposed. Despite the severity of this injury, the leg was potentially salvageable. However, the owner's financial restrictions required hindlimb amputation.

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In the dog and cat, most exposed viable bone will be covered by granulation tissue arising from the viable periosteum, from the exposed viable medullary cavity, or by "creeping coverage" from granulation tissue arising from viable soft tissue adjacent to the bone surfaces. Tissue between exposed metatarsal and metacarpal bones frequently is the source of granulation tissue coverage after road pavement shearing injuries. In many of these cases, the periosteum and bone below the wound surface are viable despite the significant loss of the outer "half" of their circumference. Because portions of the periosteum and the cortical and medullary bone are destroyed in these injuries, there is a potential for osteomyelitis or sequestrum formation. However, many cases encountered in the dog and cat do not require the removal or "decortication" of exposed bone (Fig. 6-29). Exposed necrotic bone is not incorporated into the healing process; once identified, it can be removed. Dead bone normally is not covered by granulation tissue from the adjacent viable soft tissues. Loose bone fragments can be grasped with forceps and removed. Superficial bone necrosis can be removed with a Hall air drill or sharp bone curette (Figs 6-30 and 6-31).

As noted in Chapter 3, osteostixis (surgical puncture of bone) refers to the technique of drilling small holes through the exposed cortical bone, penetrating the underlying cancellous bone. These small channels allow capillary buds and the cellular components of wound healing to blossom to the cortical surface, promoting granulation tissue coverage (Fig. 3-14). A blood clot over the surface of the bone can provide an extracellular matrix for the ingrowth of fibroblasts and capillary buds. The resultant granulation bed can, in turn, support a free graft. Caution must be exercised, however, when using this technique for metatarsal and metacarpal bones due to the risk of fracturing bones already weakened by trauma. A small drill tip has the potential to snap off in the bone; removal of the drill will reduce the risk of formation of a draining tract.



FIG. 6-30 Massive skin loss to the rear paw of a cat. A healthy granulation bed has formed although the exposed third phalanges were nonviable. The exposed bone (arrows) was resected below the granulation surface and a full-thickness mesh graft was used to close the wound.

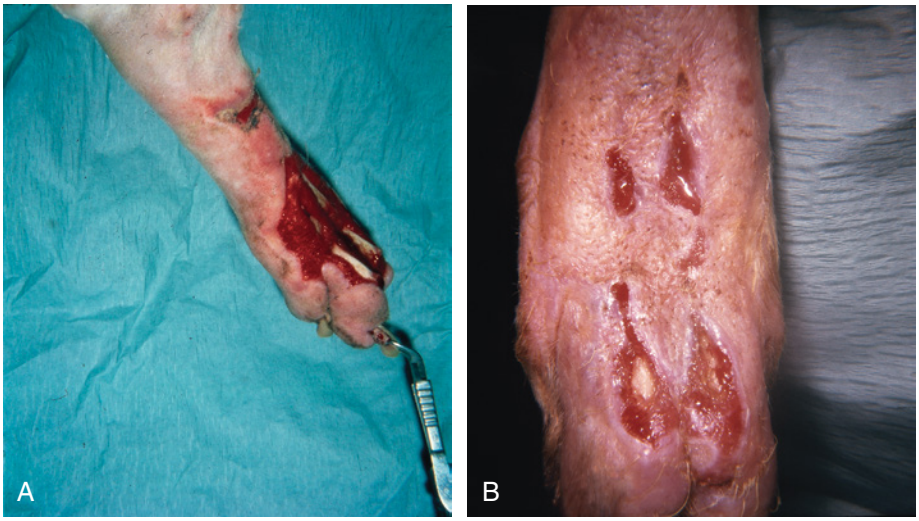


FIG. 6-29 (A) A healing shearing wound overlying the metatarsal surface. Metatarsal bones and first phalanges were exposed. Over the next 4 weeks, a healthy granulation bed formed from viable soft tissue surfaces. Granulation tissue slowly covered the exposed bone. (B) A skin graft was applied to the granulation bed. Slits were created in the graft over areas of exposed bone. Note that bone coverage by granulation tissue is nearly complete, with final wound coverage over the bony surface by second-intention healing.

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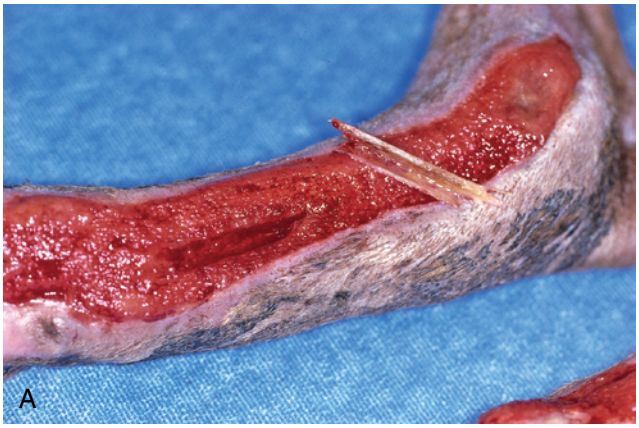




FIG. 6-31 (A) Devitalized metatarsal fragment. Granulation tissue typically will not fully cover necrotic bone; in this case the loosened fragment was removed with forceps. (B) Devitalized radius, ulna, and carpus secondary to extensive bite-wound trauma. Granulation tissue will circumvent completely devitalized bone. The limb required amputation.

Most lower-extremity shearing wounds seen in practice heal by second intention; skin grafts can be considered for the more extensive injuries. Joint instability of the tarsal joint is commonly noted secondary to loss of collateral ligamentous support. This may require wire stabilization using cortical screws, or the use of bone anchors with suture material to substitute for the lost ligamentous/fascial support. Over time, collagen deposition can stabilize the joint, usually by the time the temporary wire/suture breaks from cyclic stress within weeks after placement. Alternatively, prolonged splint support can be used to stabilize an unstable joint. Failure in obtaining sufficient stability may necessitate arthrodesis once skin closure is complete.

Despite the rather gruesome appearance of lower-extremity shearing wounds, most heal satisfactorily by second intention using the basic wound-management principles previously discussed. The rate of infection is remarkably low, and the wound size is exaggerated by the soft tissue swelling that normally accompanies these wounds.

After debridement and lavage, partial approximation of portions of the wound, without excessive tension, will reduce the magnitude of the defect. This can shorten the time required for second-intention healing. Drainage is preserved through the open portions of the wound.

Serial applications of medicated dressings can provide a protective medium to support granulation tissue formation, wound contraction, and epithelialization. In turn, fibroblasts will provide the collagen needed to stabilize the exposed joint(s).

WOUND DEHISCENCE

Wound dehiscence, or the disruption of apposed surfaces of a wound, is the result of several factors, *either alone or in combination*. The following are the most common causes noted by the author:

1. Wound closure under excessive tension, with suture cut-out, secondary to ischemic necrosis
2. Suture placement too close to incisional border with cut-out (collagenase activity within 5 mm cutaneous zone bordering skin incision)
3. Improper suture material selection (size, tensile strength, suture pattern, placement, rate of resorption/degradation)
4. Closure of severely compromised skin, with subsequent necrosis
5. Suture placement, compromising cutaneous circulation
6. Moisture accumulation contributing to tissue overhydration, maceration
7. Underlying pocket of infection, necrosis, foreign body, neoplasia
8. Lack of postoperative protection/support from motion, licking, external trauma
9. Premature suture removal
10. Delayed healing precipitated by corticosteroids and other agents
11. Suture placement in scar tissue, which has poor suture-holding ability
12. Underlying healing disorder or delay in healing, excluding the above causes, suspected

Critical evaluation of the separated wound can assist the surgeon in determining the most likely

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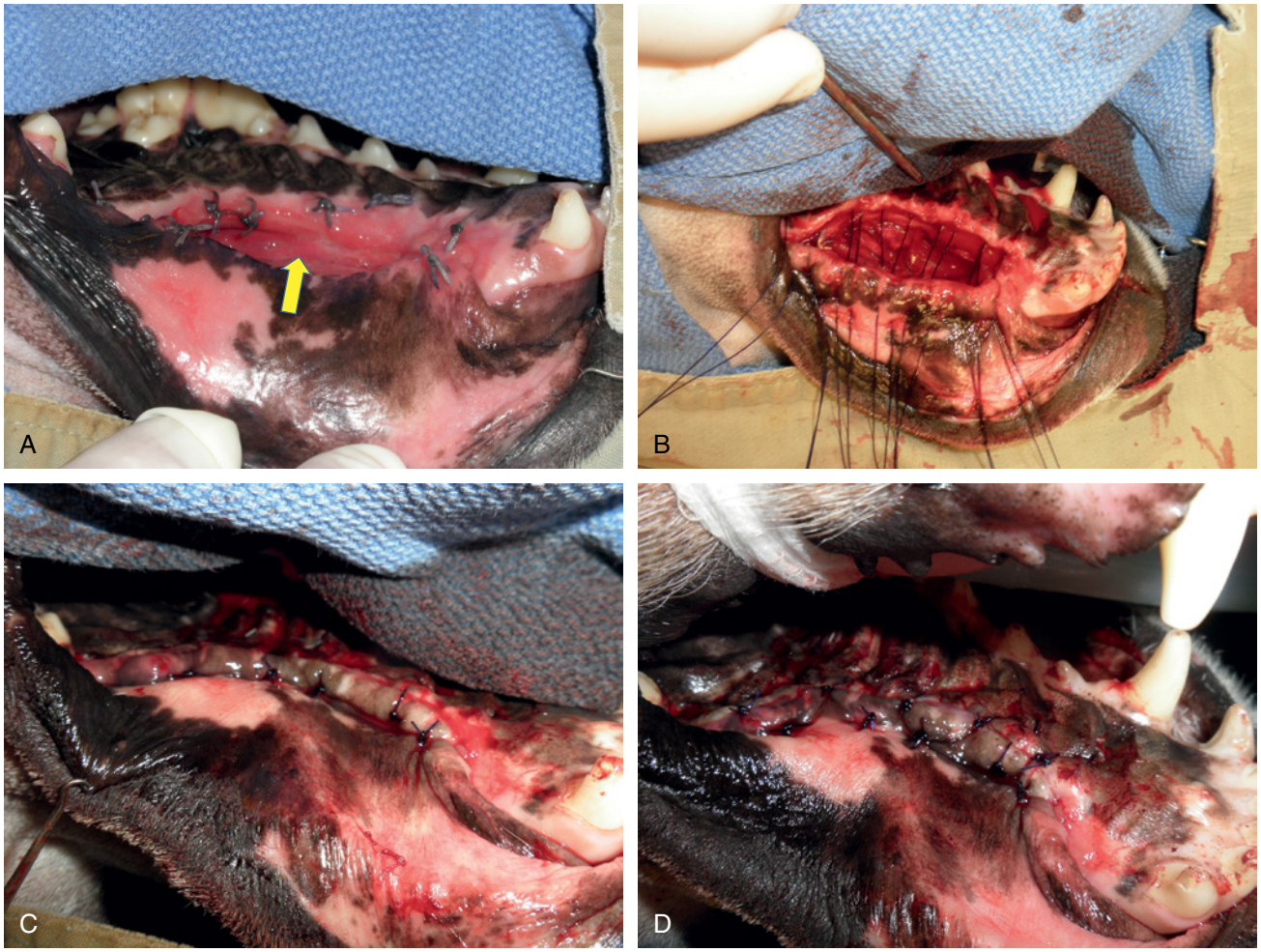


FIG. 6-32 (A) Partial maxillectomy dehiscence (arrow). Note the sutures primarily pulled out of the labial mucosal side of the closure. Dehiscence was attributed to the placement of the sutures too close to the incision lines. Interrupted sutures were used in the closure; the author prefers the use of vertical mattress sutures alternated with interrupted sutures. (See Cleft Palate Repair, Chapter 17.) (B) Following elevation of the incisional margins, a series of 3-0 polydioxanone vertical mattress sutures were preplaced. (C) Closure using vertical mattress sutures. (D) A few interrupted sutures were used to accurately align the everted margins created by the vertical mattress sutures.

cause(s) of dehiscence (Fig. 6-32). Incisional gaps with absent sutures suggest the premature removal of sutures, usually by the patient. Presence of the sutures often demonstrates suture cut-out from one side of the incision, with an irregular right-angle tear from the suture hole to the incision. An intact suture with the presence of an incisional gap usually is associated with stretching or deformation of suture material (from incisional tension or sutures deliberately placed loosely). Often a veterinarian may place sutures loosely when edema of the skin is evident or anticipated. When swelling subsides, the incisions retract, leaving an incisional gap (Fig. 6-33).

Unfortunately, many surgical instructors at teaching institutions overemphasize "loose suture placement" to offset anticipated swelling. It is the author's opinion that surgical instructors should emphasize atraumatic surgical technique that minimizes postoperative swelling, thus enabling the surgeon to place sutures that more effectively appose and immobilize the incision.

Suture cut-out can occur from placement too close to the incision. Because collagenase activity remains high within 5 mm of the skin incision, sutures placed near or within this zone are more likely to cut through the weakened

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dermal collagen weave, especially in the presence of motion and incisional tension. Larger suture bites are less likely to pull out. Cutting needles have the cutting edge within the curvature of the needle. Under tension, with placement in susceptible skin, the suture is more likely to cut along the V-shaped cut created by the suture, in the direction of the incision. Most surgeons use reverse cutting needles (cutting edge on the outer curvature of the needle) almost exclusively, since the flat edge of the needle hole facing the incision line is more resistant to tissue tear. Today taper-point needles are remarkably sharp and produce a circular hole in the skin that is resistant to suture cut-out.

It is useful to select an elastic suture material that can stretch to a limited degree to accommodate possible tissue swelling but of sufficient size and strength to prevent permanent stretch deformation. Suture material size and selection should be tailored to the skin thickness, durability, and location, and the anticipated postoperative incisional forces that require neutralization. All surgeons

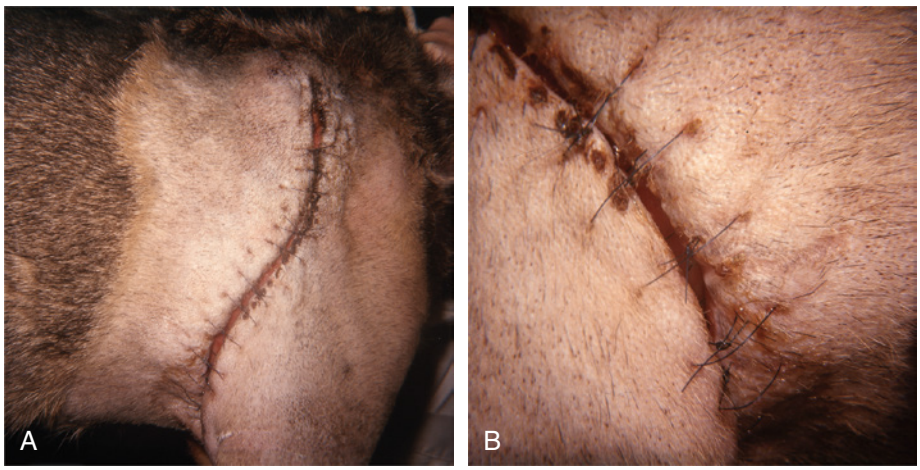


FIG. 6-33 (A) Closure of a long laceration along the caudal shoulder and upper extremity. Dehiscence is evident several days after surgery. (B) A close-up view reveals no sutures cut out. Rather, the 3-0 monofilament nylon has stretched as a result of patient activity. Sutures also were placed loosely for anticipated postoperative swelling. Intradermal sutures, the addition of vertical mattress sutures, the use of 2-0 monofilament material, restricted activity, and other methods to offset incisional tension could have prevented this case of dehiscence.

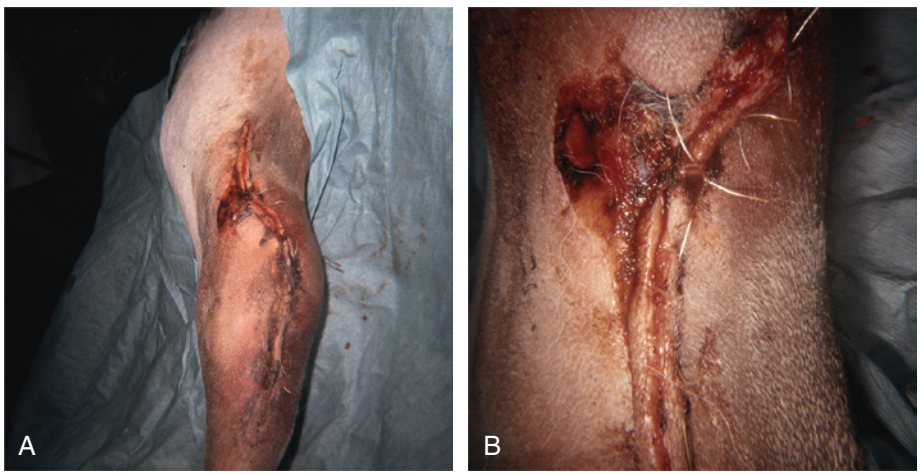


FIG. 6-34 (A) Closure of a laceration over the right stifle area, secondary to vehicular trauma. Early dehiscence noted approximately 48 hours later. (B) Horizontal mattress sutures were placed too snugly, aggravating tissue swelling as a result of circulatory compromise. Early tissue necrosis also is evident in this view. A vertical mattress tension suture pattern, in combination with alternating simple interrupted sutures, would have been a better choice for stabilizing the incisional border. In cases of moderate trauma and swelling, delayed closure may be a better choice of wound management. Resolution of swelling and hemorrhage would improve the likelihood of subsequent successful skin closure.

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have a preferred suture material for skin closure. This preference may be based on the materials with which they were trained and their familiarity with the handling (physical) properties of the product. While many of us prefer monofilament nylon and polypropylene for closure, other materials may be quite acceptable for many of the wounds encountered. In more difficult wound closures, complete familiarity with the physical properties of a given suture material is essential for more consistent success in wound closure.

Closure of an incision under moderate tension increases the likelihood of dehiscence. Closure under tension, with the addition of motion, can further promote suture serration of the skin and cut-out (Fig. 6-34). Although mechanical creep and stress relaxation of skin can, almost miraculously, reduce incisional tension within hours after closure, a veterinarian cannot rely on this natural dermal collagen phenomenon as a reliable "bail-out" for all difficult closures. Techniques to offset skin tension should be considered (see Chapter 9) in concert with immobilization of the area to promote uncomplicated healing.

My favorite combination of suture patterns, for closure of wounds under tension, is the following:

- Initial apposition with interrupted intradermal sutures
- Simple interrupted sutures to accurately align the incisional margins
- Supplemental vertical mattress sutures in areas of incisional tension

External surgical glue can be added to seal the incision and provide a small amount of additional security. The application of skin stretchers (see Chapter 10) postoperatively can be applied to further neutralize problematic regional skin tension. See Figure 9-20.

Delays in healing from inflammation, trauma, or malnutrition, for example, will further increase the likelihood of dehiscence. Suture placement, pattern, and selection are particularly important under these circumstances. It is not always clear at the time of traumatic wound closure whether the onset of necrosis was the result of "dying skin" or additional ischemia precipitated by tight suture placement. Large areas of skin necrosis would suggest that preceding trauma was primarily responsible for necrosis. In areas with ample regional skin, aggressive debridement could prevent dehiscence by removal of compromised or potentially compromised tissues. Necrosis limited to the suture site would be compatible with suture compromise to the skin (Fig. 6-34).

Underlying pockets of infection, necrotic tissue, or foreign bodies will result in persistent wound drainage at the expense of incisional closure until the underlying causes are alleviated. Future continuous discharge and prolonged moisture exposure can hydrate or soften the skin, enhancing the likelihood of suture cut-out. As a result, failure to abide by basic wound-management principles can have a negative, cascading effect on wound healing and closure until the problems are recognized and remedied.

Finally, proper bandage and external support can be critically important in preventing dehiscence in areas subject to motion or weight bearing. Care is used to avoid circulatory compromise during bandage application along with proper bandage care.

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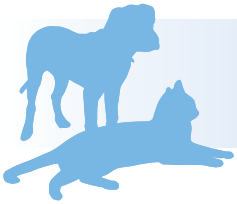
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7

Management of Specific Wounds

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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BITE WOUNDS

Bite wounds are among the most serious injuries seen in small animal practice and can account for 10–15% of all veterinary trauma cases. The canine teeth are designed for tissue penetration, the incisors for grasping, and the molars/premolars for shearing tissue. The curved canine teeth of large dogs are capable of deep penetration, whereas the smaller, straighter canine teeth of domestic cats can penetrate directly into tissues, leaving a relatively small cutaneous hole. The jaws of larger dogs in particular can generate tremendous crushing (compressive force up to 450 psi) and shearing forces, and the canine teeth can tear and lacerate the skin, hypodermis, and underlying musculature. Tensile force on the skin occurs when the teeth strike at an angle of less than 90° relative to the skin surface; as a result skin avulsion may occur.

A struggling victim may promote additional tissue injury while attempting to wrest free of its attacker. Small dogs and cats are at special risk since most portions of their body can be completely grasped by a large dog (Fig. 7-1). In one study, male dogs weighing less than 10 kg presented with more severe multiple bite wounds. (Miniature pinchers, Pekinese, and small terrier breeds were overrepresented.) Many of these victims are lifted and violently shaken by the attacker. Direct and indirect trauma to internal organs frequently occurs. The kidneys in small animals are particularly susceptible to bite wounds over the back. In addition, bone fractures, joint injuries, and spinal trauma also may occur.

The untrained observer can mistakenly dismiss the gravity of the bite wounds since the only obvious injuries may be a few puncture wounds or indentations confined to the skin. Wounds may be covered by a thick hair coat and go unrecognized. The skin and underlying issues can be lacerated, stretched, crushed, and avulsed. Circulatory compromise from the division of vessels and compromise to collateral vascular channels can result in massive tissue necrosis. It may take several days before the severity of tissue loss becomes evident. All bites are considered contaminated wounds: the presence of bacteria in the face of vascular compromise can precipitate massive infection.

Wild Animals and Bite Wounds

Bite wounds from the black bear (*Ursus americanus*) and the grizzly bear (*Ursus arctos horribilis*) are infrequent, but are most commonly seen in hunting dogs or unsupervised dogs where these bear species are most prevalent. Although bears frequently attack the head and neck area, hunting dogs may be bitten (or clawed) in the trunk and pelvic regions, most likely when the bear lunges at a retreating dog. Tissue trauma can be massive. Coyote (*Canis iatrans*) attacks on dogs and cats have been reported throughout the United States as a result of their expanding range. Wolves (*Canis* spp.) are less prevalent and are limited to selective areas of the northern United States. Both wolves and coyotes may hunt in small groups, increasing the risk for a fatal attack.

Attacks from other large carnivores, including mountain lions (*Felis concolor*), alligators (*Alligator mississippiensis*), and crocodiles (*Crocodylus acutus*), are far less prevalent due to their comparatively small populations and limited range. Of particular concern are bite wounds from wild animals, including raccoons, skunks, and bats, in which

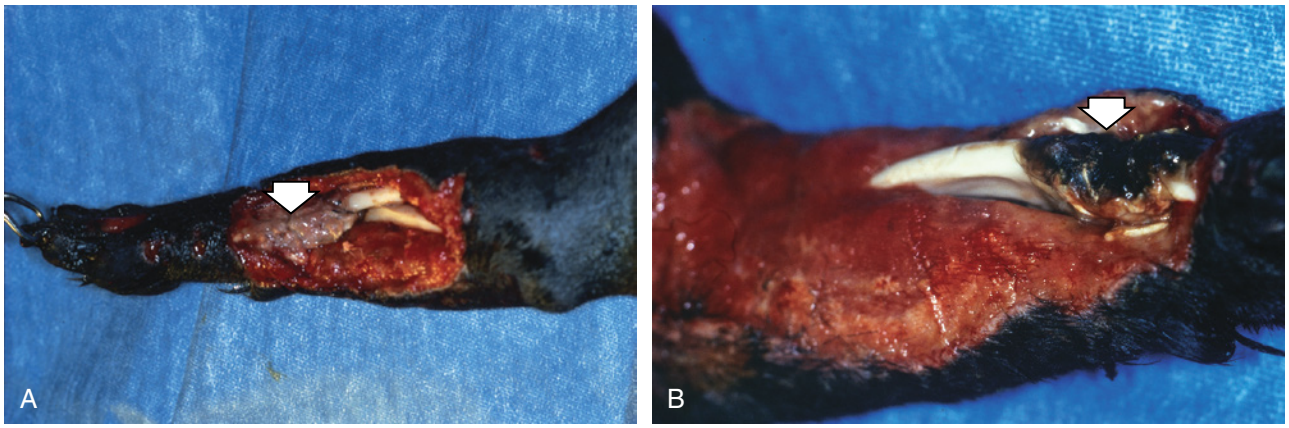


FIG. 7-1 (A, B) Medial and lateral view of extensive tissue necrosis to the left forelimb of a Scottie. A neighborhood pit bull attacked the dog and refused to let go of the patient's limb. Due to extensive skin, muscle, and bone necrosis, with destruction of the carpal joint (arrows), amputation was performed.

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rabies is an endemic problem (see Rabies and the Transmission of Infectious Diseases, later in this chapter).

Initial Patient Assessment

A complete physical exam is required. A history of the attack may help in locating the body region(s) bitten. Latex gloves must be worn during the examination and management of open wounds.

A complete medical history should include the patient's medical history and current rabies vaccination status.

The patient's head should be restrained or muzzled during examination to protect the practitioner from injury. The hair coat must be parted and skin areas visualized. Small spots of dried blood and matted hair frequently overlie puncture wounds. Careful palpation and observation may demonstrate muscle tears or hernias.

Keep in mind that Elizabethan collars also can be useful in shielding veterinary personnel from being bitten, especially in the less aggressive canine and feline patients.

Care must be taken to minimize pain to the patient and avoid manipulating unstable fractures or spinal injuries. Analgesics or sedation may be used in an otherwise stable patient. (A neurologic examination would be advisable prior to using medications that could obscure these injuries.)

Blood loss, shock, and respiratory distress (including laryngeal wounds, tracheal injuries, pneumomediastinum, pneumothorax, hemothorax, flail chest) are emergency situations that frequently require the clinician's immediate attention before completing the examination (Figs 7-2 and 7-3). The prognosis of the patient, definitive course(s) of action required, and potential complications in managing the patient are essential to the owner's decision regarding whether or not to proceed with treatment in the seriously injured pet. In the interim, basic life-support procedural guidelines include the following areas of emergency resuscitation: (1) airway, (2) breathing, (3) cardiac function, and (4) hemorrhage control. Intravenous fluid support and whole blood would be indicated in the presence of extensive tissue trauma and blood loss. Details on emergency management can be obtained in standard textbooks. A complete blood count, serum chemistry profile, and urinalysis can serve as baseline data for the seriously injured patient.

Treatment of hemorrhage requires (1) recognition of the condition, (2) control of further blood loss, and (3) intravenous fluid support to treat the patient's hypovolemia.

In many cases, blood loss is not the result of an obvious spurting artery. Internal hemorrhage can be difficult to quantitate. Individual bite wounds may result in little hemorrhage; collectively, multiple bite wounds can result in a sizable loss of blood.

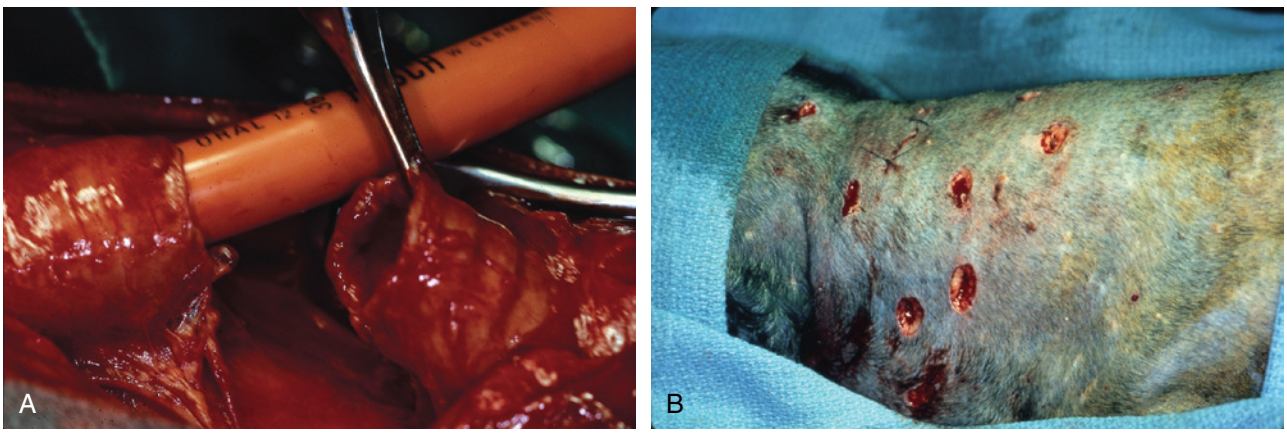


FIG. 7-2 (A) Massive cervical trauma to the trachea and cervical muscles as a result of a dog fight. The patient was administered oxygen prior to anesthesia. The cervical area was prepared for surgery. Anesthetic induction was immediately followed by a cervical incision, with placement of a sterile endotracheal tube into the lacerated trachea. The gas anesthetic machine was connected to this tube. Once the patient was stable, the technician passed a sterile endotracheal tube through the larynx. The surgeon then guided the tube past the tracheal tear. (B) Surgical repair included tracheal anastomosis, thorough debridement of necrotic muscle, copious lavage, and delayed primary closure. Small puncture wounds were uncapped and locally assessed using a pair of mosquito hemostats as tissue retractors. These wounds were left open to heal by second intention. However, complete excision of small puncture wounds can permit primary closure.

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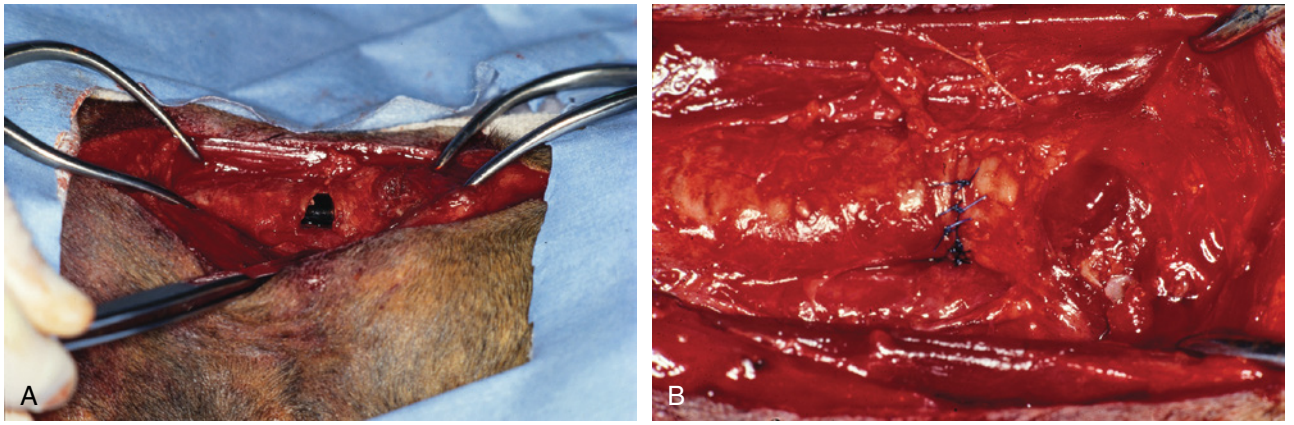


FIG. 7-3 (A) Puncture to the cervical trachea as a result of a dog bite, intraoperative view. A canine tooth created the opening that enabled air to pass into the cervical tissues, impairing the ability of the patient to breathe. Manual compression of the skin over the puncture site halted the air excursion until anesthesia and intubation could be accomplished. (B) Closure was accomplished by conservative debridement of the wound borders followed by placement of 3-0 polydioxanone sutures.

Fully equipped emergency units with a dedicated staff address the critically injured patient. Critical care clinicians, surgeons, and the anesthesiology team working in concert will give the patient the best chance of surviving.

Systemic Effects

Multiple and severe bite wounds can initiate a systemic inflammatory response syndrome (SIRS). Exaggeration of the inflammatory response has an adverse systemic effect on patient stability. The presence of infection would be a major contributing factor. Tumor necrosis factor α and interleukin 1 are considered important mediators of SIRS. Peripheral vasodilation with increased vascular permeability, combined with small vascular thrombosis, results in compromise to tissue circulation and shock. Resection of necrotic tissue and aggressive management of infection are critical to the prevention and management of this condition. Acute respiratory distress syndrome (ARDS) may be noted as a sequela to SIRS.

Bite-Wound Management

All penetrating bite wounds are ideally explored under anesthesia. If the patient is in a critical condition, exploration, debridement, and definitive repair may be necessarily delayed until the patient can be stabilized. However, basic wound management can be instituted in the interim. The procedures for short-term treatment before definitive exploration are described next.

Temporary Bite-Wound Care in the Critical Patient

The following steps should be taken for the initial management of bite wounds in the critical-care patient in which general anesthesia cannot be administered:

1. Minimize further contamination of open wounds prior to preparing the wound for surgery. Cover the open wound with sterile gauze sponges; sterile water-soluble gel or saline is applied to the gauze before application.
2. Liberally clip hair around each puncture wound.
3. Gently cleanse the skin around each wound with warm sterile saline and a surgical preparation solution.
4. Inject small amounts of lidocaine with a 25-gauge hypodermic needle into and around the bite-wound punctures. Trim off any tattered borders. Insert a pair of sterile hemostats and inspect the underlying tissues.
5. Perform liberal pressure lavage of the puncture site using an 18-gauge needle and 35 ml syringe with warm sterile saline. The wound should be opened sufficiently to permit fluid to flow out freely. A three-way stopcock valve connected to sterile intravenous tubing can be used to facilitate refilling the syringe. A dilute povidone–iodine (1%: 1 part solution/9 parts sterile saline) or chlorhexidine (0.05%: 1 part solution/40 parts sterile saline) solution can be made by adding these stock solutions to the lavage receptacle. The access site must be sufficiently large to allow the lavage solution to exit the area (see Chapters 3 and 4).

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6. Apply a topical antimicrobial ointment and dressing over the open wound.
7. Systemic broad-spectrum antibiotics may be administered if deemed necessary (see later in this chapter).

The primary goal of this short-term therapy is to reduce the amount of contamination present and reduce the possibility of further contamination from organisms in the hospital environment (nosocomial infection).

Once stabilized, the patient can be anesthetized for wound exploration if necessary (see the next section). On occasion, critically injured patients with serious underlying injuries cannot be stabilized to the desired degree. Under these circumstances surgical intervention would be necessary, since these wounds are the primary cause of the patient's deterioration (bowel rupture, sepsis, etc.). Such a serious endeavor requires the coordinated efforts of the emergency clinician, anesthesiologist/anesthetist, and surgeon.

Definitive Management: Bite-Wound Exploration

The following steps summarize the approach for the definitive management of bite wounds:

1. General anesthesia.
2. Open wounds should be temporarily covered or packed with sterile gauze sponges moistened with saline; a water-miscible lubricant can be applied to the sponges in place of saline in order to protect individual wounds from contamination associated with preparing the area for surgery.
3. The bite-wound area should be clipped *liberally*. In particular, the thoracic and abdominal areas should be completely clipped and prepared for surgery in the event the exploration requires conversion to a thoracotomy or exploratory laparotomy. The surgical area then is prepared and draped for aseptic surgery.
4. Puncture wounds are "uncapped" using a scalpel blade by excising the puncture-wound borders, thereby creating a circular opening of at least 1 cm. Sterile mosquito hemostats are inserted into the opening and spread to expose the underlying hypodermis, fascial tissues, and muscle. Wounds with little or no underlying tissue damage may be left open to drain and heal by second intention or may be closed with one or two skin sutures after lavaging the wound.
5. If significant tissue damage is suspected, a skin incision is made over the puncture site; tissue retractors are inserted to permit exploration and debridement of traumatized tissues. Adjacent puncture wounds may be connected with a single incision to facilitate exploration (Fig. 7-4). Care must be taken not to inadvertently divide direct cutaneous arteries, especially those vessels supplying skin already compromised by bite-wound trauma.
6. Any hair or foreign debris is removed. Shredded or necrotic muscle, fat, and fascia are excised. A more aggressive debridement can be performed for those tissues of questionable viability that are not essential to normal function. As noted, additional care is warranted when exploring bite wounds over the thorax. Retraction of muscle and fascia may unseal penetrating thoracic wounds. Sucking sounds may emanate from the area as air enters the thoracic cavity, necessitating assisted ventilation, aspiration of the thorax, or temporary insertion of a thoracostomy tube.
7. Debridement ideally is accomplished in one stage, especially in critical areas (thoracic cavity and abdominal cavity involvement) where the presence of necrotic tissues can promote life-threatening sepsis. In less critical areas, such as the extremities, a more conservative daily or staged debridement (open wound management followed by delayed primary closure, secondary closure, healing by second intention) is indicated for tissues of questionable viability, where important muscle groups and the limited availability of skin could compromise salvage of the limb.
8. Skin viability may be difficult to determine on initial presentation. Necrosis may not be evident for 5–7 days after injury. The loose skin available over the cervical area and trunk permits more aggressive debridement of skin of questionable viability. However, a more conservative "wait-and-reassess" approach is indicated for compromised skin of the lower extremities. With the limited amount of loose skin available for closure, unnecessarily wide debridement will increase the likelihood that reconstructive surgery will be required to close the resultant defect.
9. Wound drainage is necessary in areas where dead space is present, especially after wide debridement of contaminated bite wounds. Closed vacuum drains or Penrose drains may be considered (see Chapter 4).
10. Open wound management is advisable, if practical, in the presence of infection and tissues of questionable viability (see Chapter 3).

"Uncapping" the Puncture Wound

A simple method of assessing a puncture wound is by lifting the puncture site with forceps and excising the area with a scalpel blade, thereby creating a 10–15 mm opening to inspect the underlying tissues. A mosquito hemostat can be inserted and spread open, serving as a tissue retractor or speculum to examine the subcutaneous tissues and underlying muscles. If the subcutaneous fat is undisturbed, the wound is considered minor. If the fat has been separated and fragmented, the underlying muscle is examined. Lavage and suctioning facilitate visualization of the tissues by removal of tissue fragments and debris.

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If tissue damage is minor, the wound can be lavaged and apposed with one or two skin sutures; if there are any doubts, the wound may be left open to maintain postoperative drainage and open wound care.

If more significant tissue trauma is noted or suspected, a scalpel blade is used to incise over the area for wound inspection, debridement, lavage, and repair. Adjacent punctures can be connected through a single incision.

Prolonged wound drainage is common after extensive muscle trauma and formation of dead space. It is not unusual to retain use of drains for several days under these circumstances. Closed-suction units (as discussed in Chapter 4) limit the risk of ascending infection and can be used to prevent air entry into the wound cavity. Subcutaneous emphysema associated with sucking wounds of the flank and axilla may be prevented with vacuum drains. Similarly, they can

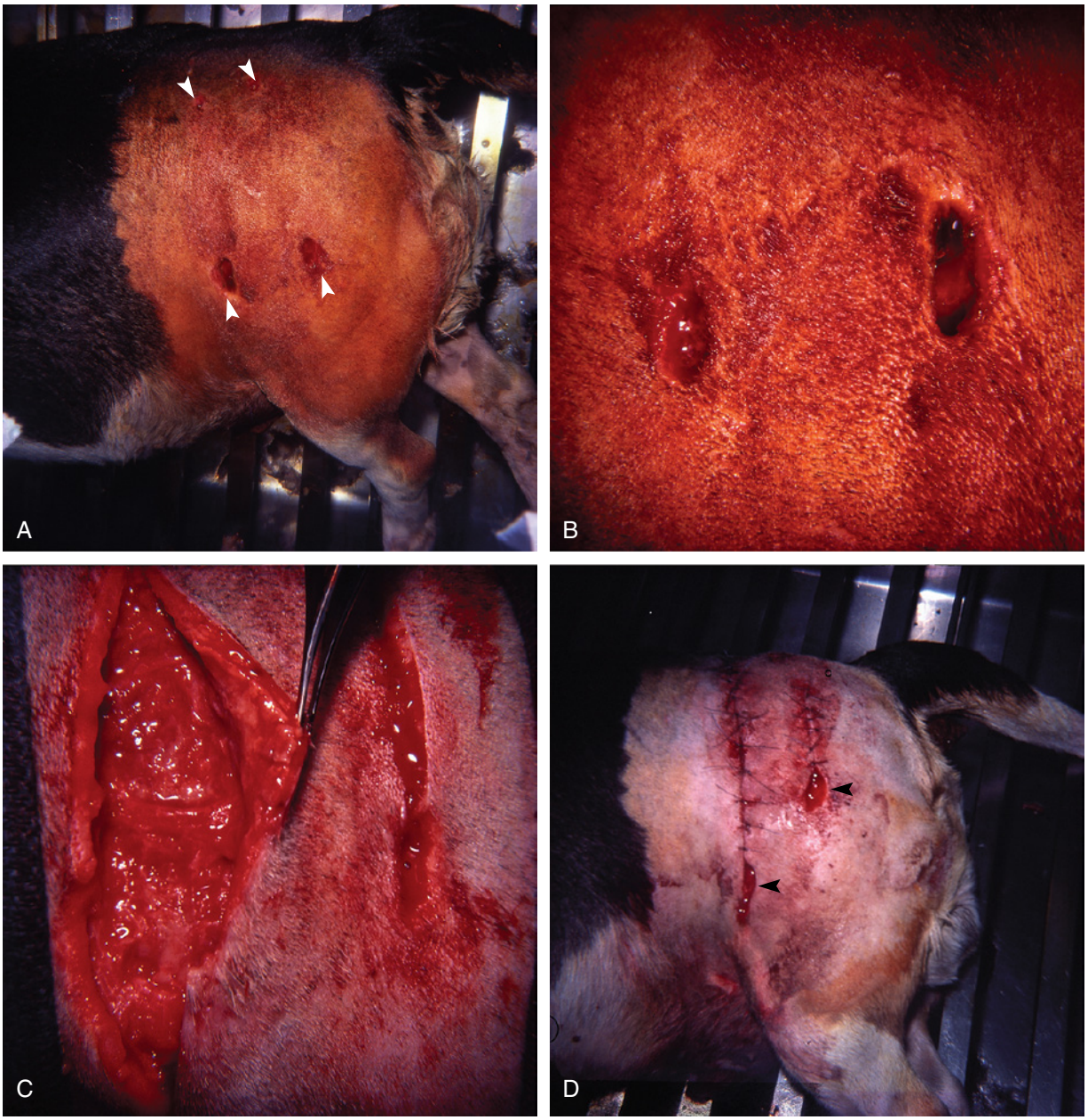


FIG. 7-4 (A) Bite wound involving the left hindlimb. The injury was sustained 1 week before presentation for a persistent purulent discharge. Arrows denote the four canine puncture wounds. (B) A close-up view of the puncture wounds. The comparatively benign appearance of these injuries masks the more serious underlying tissue destruction. (C) Two parallel incisions were made between the respective left and right canine puncture wounds, demonstrating a layer of necrotic subcutaneous fat. This tissue was excised and the wound lavaged. (D) Partial closure was performed; the lower 2 cm (arrows) was left open for drainage. The narrow tracts were poorly suited to drain insertion.

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provide wound drainage overlying the thorax or thoracic inlet where air entry (with the use of Penrose drains) may result in pneumothorax. Vacuum drains can be used effectively for the drainage of abdominal wall wounds and the abdominal cavity simultaneously (as needed).

Teeth can crush the tissues without penetrating the skin. (One analogy is crushing a banana without breaking the outer skin.) Bruising or a depression in the skin and underlying tissue may be visualized; palpation of the area can confirm this suspicion.

Regional Considerations

Head and Neck

The head and neck areas are those most commonly attacked by predators. Small dogs and cats can sustain skull fractures from larger predators (Fig. 7-5). Injury to eyes and ears is occasionally noted. Bite wounds involving the pinna are common; occasionally, the ear canal will sustain punctures, lacerations, or avulsion injuries (at the junction of the vertical and horizontal ear canals, or canal avulsion at the external acoustic meatus). Cervical wounds must be closely assessed for injuries to the trachea, larynx, esophagus, pharynx, major vessels, and salivary glands in particular. The spinal column is most susceptible to trauma in small dogs and cats. Skin and muscle are most prone to injury. A tracheostomy may be necessary when upper respiratory distress is evident. Traumatic division of the trachea may require a prompt cervical incision on anesthesia induction for proper intubation before tracheal repair can be instituted. Alternatively, an endotracheal tube can be temporarily inserted into the tracheal tear to stabilize the patient until proper placement can be instituted intraoperatively (Fig. 7-2). Puncture or laceration of the rigid trachea also can result from penetrating canine teeth without tearing of the overlying skin (Fig. 7-3). Lastly, central nervous system trauma, including trauma to the brain and cervical spinal cord, must be assessed by the emergency clinician. Assessment may require the use of radiographs or computed tomography (CT) to determine the extent of the trauma of the head and neck.

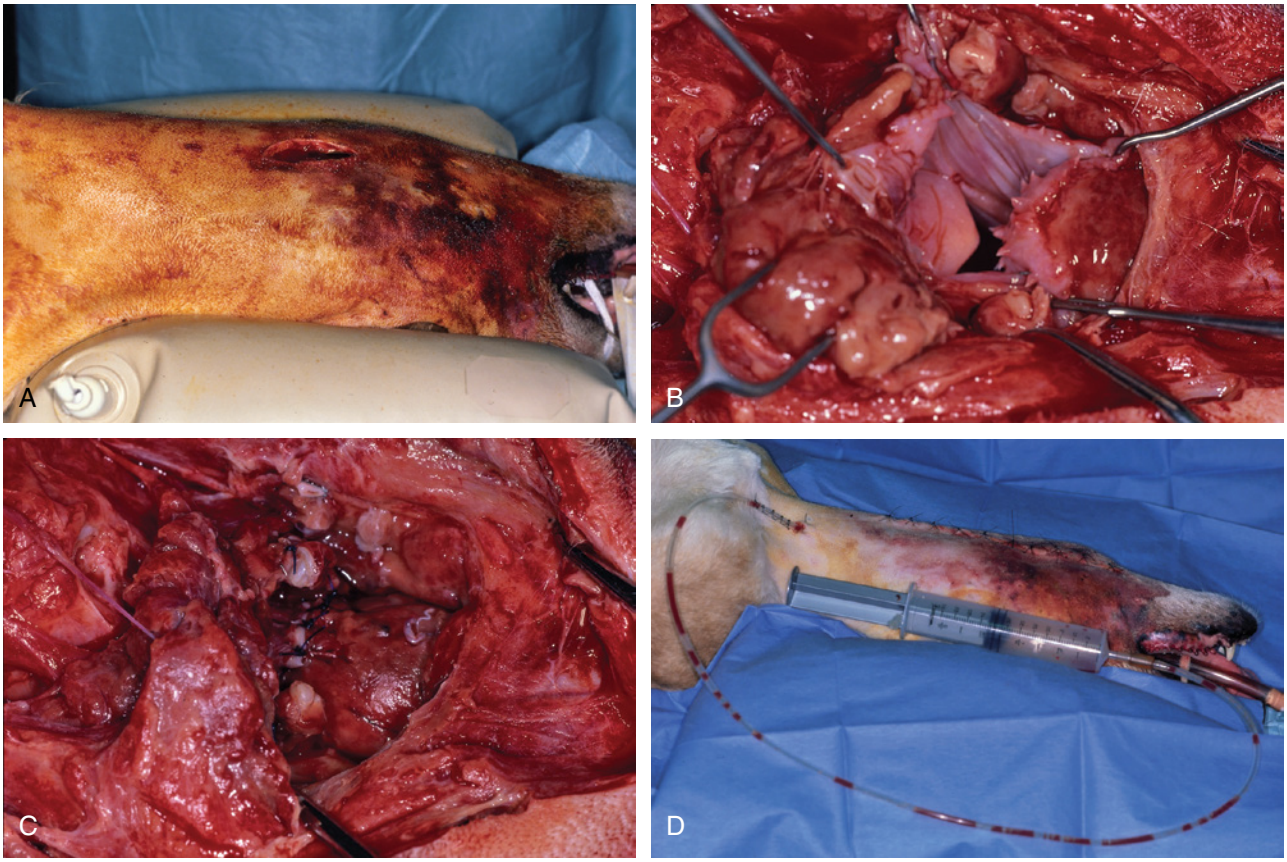


FIG. 7-5 (A) Bite wounds involving the larynx and pharynx should be explored. (B) Pharyngeal tears permit extensive tissue exposure to saliva and oral contaminants. (C, D) Debridement, closure of the pharyngeal laceration, and repair of the damaged hyoid apparatus was followed by wound lavage and closure over a closed-suction unit. Skin hooks are invaluable in elevating the borders of the pharyngeal mucosa, facilitating suture apposition of this surface.

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Extremities

The comparatively narrow diameter of the extremities makes them particularly susceptible to extensive bite-wound trauma (crushing, laceration), especially in the smaller patients. Circulatory compromise to the skin, muscle, and bone can result in massive necrosis, necessitating limb amputation in many cases. Overlooked puncture wounds involving the elbow, carpal, knee, and tarsal joints may result in problematic infections. A complete neurologic examination of the involved limb and close assessment of circulation are in order in the days following bite-wound care. Radiographs are indicated when orthopedic trauma may be present. Fracture repair and stabilization normally are performed at the time of bite-wound exploration. However, in the face of extensive swelling and circulatory compromise, a delay in fracture repair may be advisable: surgical trauma could further compromise circulation to the lower extremity and precipitate loss of the limb. As discussed, when debriding extremity wounds, a more conservative approach is in order when tissue viability is equivocal (see Orthopedic Injuries and Spinal Trauma).

Retention of fractured teeth is rarely seen in small animals. The dense interosseous ligament between the radius and ulna is the most common region where the tip of a canine tooth can be broken off. Its retention will result in a draining tract. Radiographs will easily identify the denser tooth fragment in contrast to the adjacent bone (Fig. 7-6).

Thoracic Trauma

Small patients are more susceptible to thoracic wall trauma, although the canine teeth in larger dogs are capable of penetrating the intercostal area of most dogs. Open wounds at the thoracic inlet can result in pneumomediastinum; direct open wounds involving the thoracic wall can result in fatal pneumothorax. On occasion, flaps of tissue may overlap and seal the thoracic wall defect, limiting the severity of the pneumothorax until surgical repair can be performed.

Both pneumothorax and hemothorax should be immediately suspected in patients presenting with respiratory distress. Pyothorax may be noted in patients with older bite wounds (Fig. 7-7). Hyperresonance would suggest pneumothorax, whereas dull areas of percussion would suggest fluid accumulation in the dependent areas of the thoracic cavity. In relatively calm

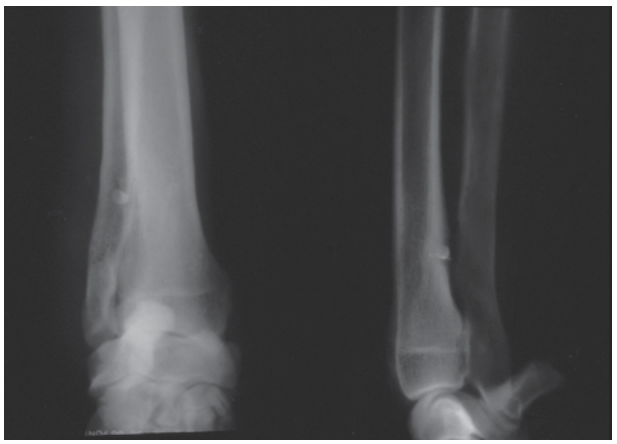


FIG. 7-6 Radiographs of the distal forelimb in a dog, demonstrating retention of the tip of a canine tooth in the interosseous ligament between the radius and ulna. The tooth fragment and associated draining tract were removed. The greater density of the retained canine helps to distinguish it from the adjacent bone. (Radiograph courtesy of Dr. Paul Gambardella.)

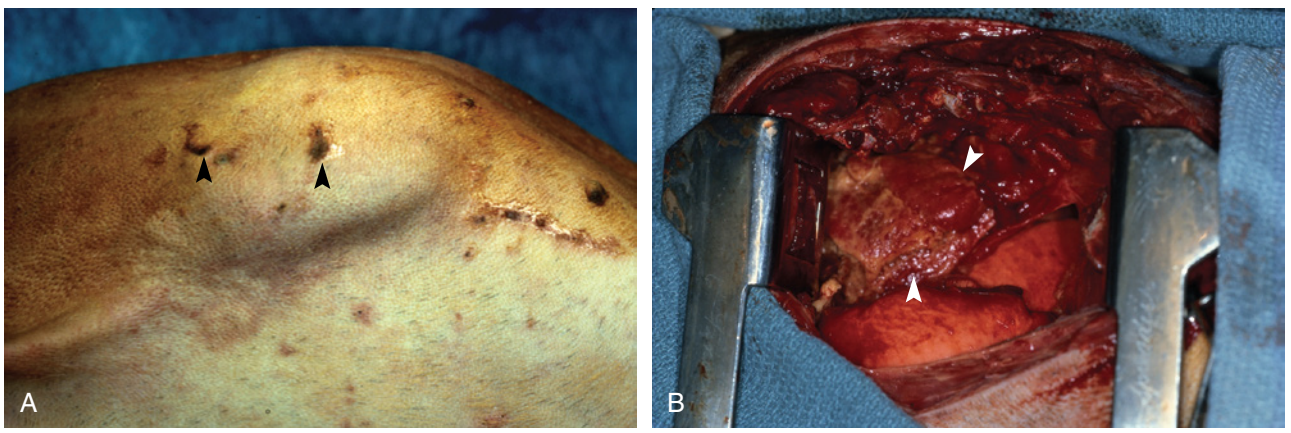


FIG. 7-7 (A) Bite wounds (arrows) overlying the sternum 4 days prior to presentation. The dog presented with respiratory distress as a result of pyothorax. Necrotic sternal bone was excised followed by a thoracotomy. (B) A restrictive pleuritis (arrows) was noted as a result of fibrin deposition and early fibrous connective tissue. Decortication of this layer with gauze pads was followed by closure after placement of a thoracostomy tube for continuous closed suction postoperatively.

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and stable patients, a lateral thoracic radiograph may be obtained to confirm each condition. Thoracocentesis is both a diagnostic tool and a treatment modality: it can be used to initially alleviate respiratory distress and confirm the presence of air or fluid. The diameter of a bronchus noted on radiographs can serve as a relative guideline for estimation of the size of the thoracostomy tube that may be required. Immediate placement of a thoracostomy tube may be preferable when tension pneumothorax or significant hemothorax is diagnosed at presentation. The tube can be connected to a continuous thoracic suction unit in more serious cases. Drainage may be continued for 48 hours after cessation of air leakage. Significant, unabated leaks beyond the initial 72-hour period may require surgical (re)intervention. Similarly, brisk continuous hemorrhage following initial evacuation of blood in the thoracic cavity would justify prompt surgical intervention.

The hypodermic needle or, preferably, butterfly catheter, attached to a three-way stopcock and 35–60 ml syringe, can be used for thoracocentesis. The needle is angled slightly with the bevel toward the patient to reduce the risk of lung laceration. Plastic intravenous catheters also may be used to reduce the risk of lung laceration.

- If the patient is in lateral recumbency, air is drawn from the central third of the midthorax
- If the patient is standing, air is withdrawn from the upper third of the midthorax
- If the patient is standing or in lateral recumbency, fluid is removed from the lower third of the thorax, between the third and eighth ribs; care is required to prevent advancement of the needle into the pericardium

Open skin wounds can be temporarily stapled or sutured to limit air entry prior to surgery. Alternatively, a bandage containing a heavy layer of ointment can be cupped over the wound temporarily. Bite wounds entering the thoracic cavity are best explored, due to the significant risk of tissue necrosis and pyothorax present in these cases. Surgical staplers (TA™, Medtronic, Minneapolis, MN) are useful in removing traumatized pulmonary tissue.

Fractured ribs with significant displacement can be repaired at the time of exploration. Sharp, pointed edges can be trimmed with rongeurs to reduce the risk of lung laceration. Cases of flail chest can be stabilized in a similar fashion with fine wire or nonabsorbable suture to realign the fracture segments. Holes can be drilled approximately 1 cm from the fracture ends. Stainless steel orthopedic wire (22 gauge) is commonly used to realign the rib segments; overtightening should be avoided in this soft bone. In most cases of flail chest, preoperative external stabilization of the area is usually unnecessary.

Bite wounds involving the caudal thoracic and cranial abdominal areas are capable of tearing the underlying diaphragm: the pars costalis and pars sternalis are relatively superficial at the area of the xiphoid and caudal thoracic cage. Rents in the diaphragm may not be visible on initial thoracic radiographs; additional radiographs are indicated if deterioration of clinical signs warrants reevaluation of the patient. The diaphragm should always be inspected during exploratory laparotomy.

Abdominal Trauma

The larger canine teeth are capable of deep penetration through the soft and compressible abdominal wall into the peritoneal cavity, especially in smaller patients. It is important to note that the skin and abdominal wall may appear to be intact, although internal organs can be crushed. The kidneys, bowel, mesenteric vasculature, spleen, and liver can be traumatized by direct contact with the canine teeth or indirectly as a result of the stretching and tearing of tissues if the patient is shaken during the attack. Ultrasonography may be used to assess the integrity of the internal organs; abdominal radiographs can be used to assess the abdomen and determine the presence of free air and fluid. An intravenous pyelogram may be used to assess traumatized kidneys based on these findings.

Internal hemorrhage can have an insidious onset and can be easily overlooked in the trauma patient. A fist-sized hematoma may vary from 300 to 500 ml of blood. Retroperitoneal hemorrhage may not be apparent on physical examination. For example, half the patient's blood volume (40 ml/kg body weight) must be present to cause overt abdominal distention. If 20–25% of the blood volume is lost or sequestered over a 10-minute period, profound hypovolemic shock will occur.

It is also worth noting that small volumes of blood loss from multiple small bite wounds and contusions cumulatively can result in a significant loss of red cells.

A midline celiotomy is advisable when teeth have penetrated or crushed the abdominal cavity (as occasionally noted in small dogs and cats). Superficial bite wounds limited to the outer abdominal wall can be managed as discussed earlier. However, the abdomen should be prepared for possible exploratory surgery in the event that more significant trauma is noted during surgery.

Orthopedic Injuries and Spinal Trauma

As discussed, smaller dogs and cats are more susceptible to injury as a result of *direct trauma* (crushing, penetration) or *indirect trauma* (violent shaking of the victim with wounds created distant to the point of direct contact). Most fractures can be stabilized at the time of bite-wound management. External fixators may be particularly useful

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in fracture stabilization, thereby reducing the risk of internal fixation in proximity to a contaminated bite wound. As noted, surgery should be delayed in those cases where circulatory compromise to the lower extremity is of concern. Resolution of tissue swelling normally follows improvement in circulation and lymphatic drainage. A modified Robert Jones bandage or supportive splints may be used to stabilize the fracture while managing the bite wounds.

A complete neurologic examination is essential to diagnosing spinal trauma. Radiographs and supplemental diagnostic imaging are used to confirm vertebral fracture/luxations. Depending on the nature of the injury and the severity of clinical signs, external stabilization, internal stabilization, and/or decompression of the spinal cord may be necessary.

PERINEAL TRAUMA

Both dogs and cats may sustain bite wounds to the perineum and adjacent tail-base area. Of particular concern would be trauma to the anus, rectum, and urogenital tract (Fig. 7-8).The author has seen more cats with bite wounds to the perineum, likely the result of the cat being pursued and bitten as it attempts to escape. In some cases, the rectum may be penetrated by the canine teeth unilaterally or bilaterally. Infection and local tissue necrosis follow as a result of the bite-wound trauma and fecal contamination of the subcutaneous area. Closure of the rectal wounds is required. Based on the author's experience, it is best to leave the skin incision open followed by the use of medicated tie-over dressings changed on a daily basis. This allows for daily inspection of the rectal area to ensure the surgical closure is secure; if leakage of feces is noted, the rectal defect should be debrided and resutured. With successful closure of the rectal defects, wound closure may be considered (5–7 days) later; the formation of granulation tissue to the area is one indicator that healing is progressing well and skin closure can be considered, including the use of a drain.

Injury to the urogenital tract may be noted along the caudal arch of the penis. Bite-wound trauma to the scrotum and vulva is uncommon based on the author's experience.

Infection and Bite Wounds

The polymicrobial flora of the oral cavity can inoculate wounds with aerobic and anaerobic bacteria. Bite wounds resulting in perforation of the gastrointestinal tract can result in the spillage of additional bacterial contaminants (Fig. 7-8). In human studies, aerobic infections are more common than anaerobic infections alone. (Bite wounds have a 5–10% risk of infection in humans; by contrast, nonbite lacerations have an infection rate of 5%.) However, with the presence of anaerobic bacteria, the severity of the infection is often increased. *Pasteurella* spp. are Gram-negative, nonmotile pleomorphic coccobacilli that are commonly isolated from the oral cavity of dogs and cats. In one report, up to 50% of canine and 90% of feline bite-wound infections in humans were the result of *Pasteurella* spp. Management of *Pasteurella* infections in humans can be problematic, especially in older, debilitated patients; individuals with orthopedic implants and internal prosthetic devices; and persons with a compromised immune system.

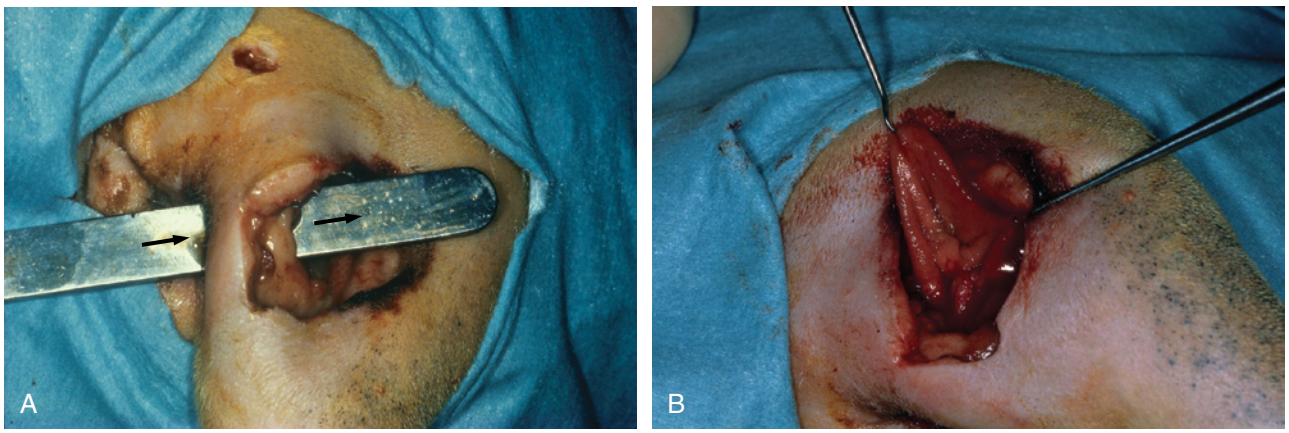


FIG. 7-8 (A) Bite wounds to the perineum completely severed the rectum from the anocutaneous junction, as noted by passage of a spay-hook handle (arrows) from the anus into the bite wound. (B) Skin hooks were used to manipulate the rectum. Polydioxanone 3-0 sutures were used to repair this laceration. Skin wounds were only partially closed. It is best not to attempt primary skin closure with grossly contaminated rectal wounds.

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The risk of infection is affected by several factors, including:

- Overall health of the patient
- Body region bitten
- Severity of tissue trauma including circulatory compromise
- Presence of necrotic tissue and contaminants
- Bacterial inoculum and virulence
- Delays in proper medical management

In one study (Holt and Griffin 2000) *Staphylococcus intermedius* was the most common organism cultured, with *Enterococcus* spp. being cultured more frequently than *Escherichia coli*. Culture results were variable. In the face of this acute tissue trauma, the selection and use of antibiotics remain somewhat controversial. One retrospective study (Kalnins et al. 2021) noted that amoxicillin–clavulanic acid was most commonly used in canine bite-wound management, with the high-importance antimicrobials being used for the more severe bite wounds. Routine susceptibility profiles were recommended to optimize antimicrobial stewardship. Over the last decade, the prophylactic use of antibiotics has been demonstrated to be of limited clinical efficacy in preventing infection. Prophylactic use of antibiotics is of proven value only for carefully selected high-risk procedures when properly administered before surgery. Antibiotics are normally administered after bite injuries, and several hours may pass before administration and effective blood levels are achieved. In general, 3 hours is considered the maximum acceptable delay in administration of antibiotics in bite-wound management. To avoid the several-hour delay to achieve an adequate serum level associated with oral antibiotics, intravenous administration is advisable for seriously injured patients and is 4–12 times faster than intramuscular administration for developing an effective tissue-fluid concentration at the wound.

Bactericidal antibiotics are best employed in bite wounds. Cephalosporins, ampicillin, and penicillin rapidly enter the wound (within 1 hour). In contrast, erythromycin and gentamicin take 2–4 hours for wound concentrations to match serum concentrations, whereas tetracycline and clindamycin never reach wound levels equivalent to serum levels. Cephalosporins are generally effective against *Pasteurella* spp. and a variety of other microorganisms. Amoxicillin or clavulanate potassium can be useful against *Pasteurella multocida* resistant to penicillins and β-lactamase *Staphylococcus* spp. Fluoroquinolones are useful for resistant Gram-positive and Gram-negative infection. In the presence of Gram-negative organisms, an aminoglycoside such as gentamicin should be considered. Antibiotics are *not* a substitute for the appropriate surgical management of bite wounds.

In the presence of infection, wound cultures (aerobic, anaerobic) are advisable in order to select the most appropriate antibiotic(s), especially in the septic patient. Culturing the acute uninfected bite wound is normally considered to be useless in determining the potential infection organisms. Culture samples should be submitted from deep within the wound by aspiration or incision, drainage, and exploration of the area. Aspiration of lymph nodes or areas of cellulitis also can be employed to obtain accurate culture samples. More superficial wound cultures are more likely to include contaminants that will lead to misleading results. The most accurate source for culturing infected wounds is from tissue samples from the abscess wall.

Although uncommonly performed in practice, Gram stains may be useful in determining the type of organisms present and the most appropriate initial antibiotic selection prior to obtaining definitive culture and sensitivity results.

Rabies and the Transmission of Infectious Diseases

Of the infectious diseases transmitted by bite wounds, rabies is the single greatest concern because of the human health implications of this viral disease.

It has been recommended that unvaccinated pets bitten by a wild mammal (unavailable for testing) should be euthanized. If the owner refuses, the pet must be isolated for 6 months and vaccinated 1 month before release.

Vaccinated pets should be revaccinated immediately, confined by the owner, and monitored carefully for 45 days. *For specific details, the veterinarian should consult with local and state authorities to ensure that regulations are precisely followed.*

Cats have the potential to transmit feline leukemia virus and feline immunodeficiency virus through bites. Assessment of transmission can be evaluated by serologic testing 6 months after the injury. These two diseases can result in nonhealing wounds.

BURNS

Veterinarians see few burns compared to human physicians. Most burns seen by the author are not life-threatening but are referred for definitive closure of the wound.

Types of Burns Seen in Veterinary Practice

1. Fire/flame burns
2. Scalds (kitchen, bath, garden hoses)
3. Electrical heating pads
4. Hot air dryers
5. Heating lamps

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6. Exothermic (chemically activated) heat packs
7. Electrical cords
8. Faulty electrocautery units; improper ground plates
9. Wood-burning stoves
10. Household radiators
11. Stove tops
12. Automobile mufflers
13. Solar (actinic) radiation
14. Chemical burns
15. Radiation burns

Ironically, the most common thermal injuries seen by the author are caused by veterinarians using various heat sources to warm the patient (Fig. 7-9). Local burns may result from close contact with hot water bottles, heat packs, or heating lamps. Electrical heating pads in particular can generate considerable heat: prolonged contact in combination with local tissue retention of heat can produce full-thickness burns of considerable dimension (Figs 7-10 and 7-11). Less commonly seen are faulty ground plates used with electrocautery units, resulting in contact burns (Fig. 7-12).

Burn Classification

The severity of the burn is evaluated by the degree or depth of the injury, as well as the percentage of the surface area involved. A full-thickness burn site usually has three concentric zones of tissue injury: a central zone of coagulative

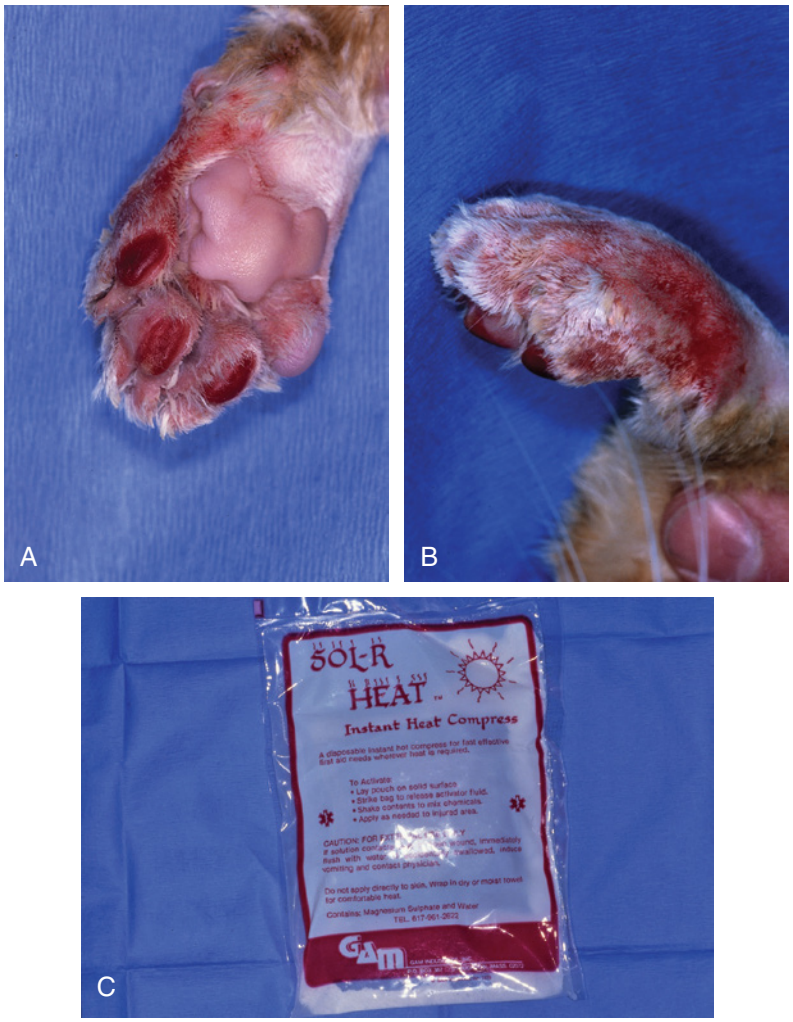


FIG. 7-9 (A, B) Contact burns involving a foot of a feline patient recovering from anesthesia. (C) Unfortunately, chemically activated heat packs were placed in direct contact with the foot, resulting in full-thickness skin necrosis. Hot water bottles and other supplemental heat sources should be well covered with towels to prevent burns from occurring.

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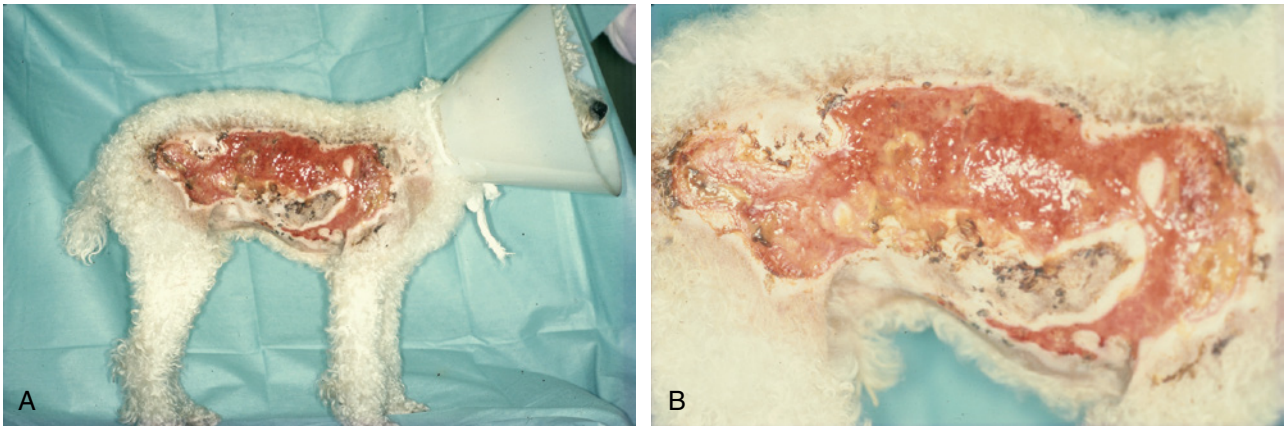


FIG. 7-10 (A) Electrical heating-pad burn in a poodle. (B) Close assessment of the wound suggested that sufficient loose skin was present for closure by wound contraction and epithelialization. (Source: Parritz DL, Pavletic MM. 1992. Physical and chemical injuries: heat stroke, hypothermia, burns and frostbite. In: Murtaugh R, Kaplan P, eds. *Veterinary Emergency and Critical Care Medicine*. St. Louis, MO: Mosby-Year Book. Reproduced with permission from Mosby-Year Book.)

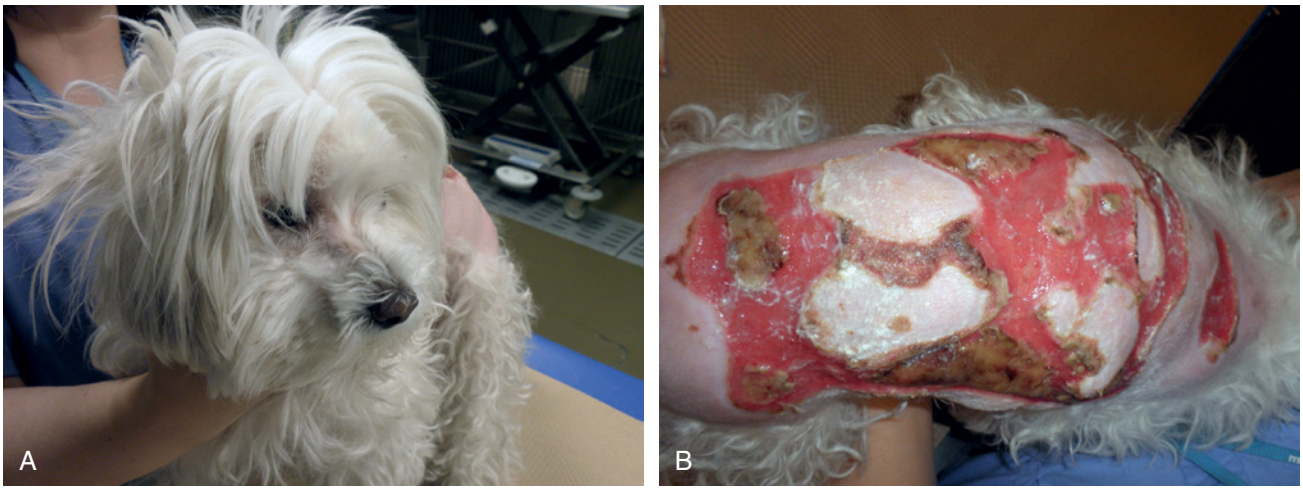


FIG. 7-11 (A) Thermal burn in a dog secondary to prolonged contact with an electrical heating pad during anesthesia. (B) Islands of skin survived (partial-thickness burn areas) and were instrumental in promoting healing by second intention of the exposed granulation bed (full-thickness burn areas). The degree of final scarring is less for wounds that heal primarily by wound contraction versus wounds healing primarily by epithelialization.

necrosis, a middle zone of vascular stasis with compromised tissue perfusion, and an outer zone of hyperemia. Progressive circulatory compromise can result in necrosis extending into the middle zone, in an outward direction.

Superficial burns (first degree) are burns confined to the outermost epidermis. The skin can appear erythematous and is hyperesthetic to the touch. Properly managed, healing can be rapid and complete within a week after injury. Partial-thickness burns (second degree) involve a variable depth of the dermis. Burns confined to the more superficial layer normally have a favorable outcome when properly managed, with healing noted approximately 3 weeks after injury. Deep dermal burn healing, however, is more problematic, especially when involving large surface areas. Healing can be prolonged since the epidermis and a majority of compound hair follicles, residing in the dermis, are destroyed.

The third-degree burn classification indicates complete destruction of the epidermis and the dermis (Figs 7-13 and 7-14). Initially it can be difficult to ascertain the burn

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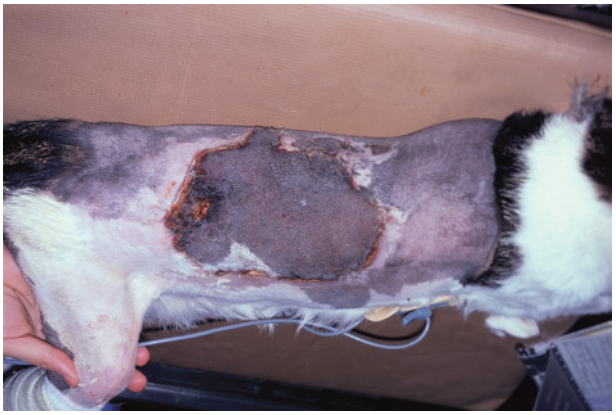


FIG. 7-12 Improperly grounded electrocautery units can result in contact burns, as noted in this patient. The eschar was excised and the wound was closed primarily.



FIG. 7-13 Muffler burn in a dog. Animals can tumble beneath a car on impact, coming in contact with the hot muffler. Animals also may suffer from deep abrasions when dragged beneath the car for a distance.

depth based on visual assessment. With evaporative loss of moisture, third-degree burn skin usually feels dry and leathery. Fissuring may be noted around the perimeter of the third-degree burn as the viable skin perimeter begins to separate from the necrotic skin. Deeper or fourth-degree burns indicate the tissue destruction extends to the underlying subcutaneous tissues, tendon, or bone (Fig. 7-15). Accurate assessment of the depth of the burn, however, can be problematic in the first several days after sustaining a thermal injury in both humans and veterinary patients.

Estimating the Surface Area of the Burn

An estimation of the size of the burn can be somewhat subjective in animals that have comparatively greater amounts of loose elastic skin covering their body



FIG. 7-14 Thermal injury in a dog struck by an automobile. The burn was sustained by friction/abrasion on the road pavement. This wound had a central third-degree burn (note burn eschar) with more peripheral second- and first-degree burns. (Source: Parritz DL, Pavletic MM. 1992. Physical and chemical injuries: heat stroke, hypothermia, burns and frostbite. In: Murtaugh R, Kaplan P, eds. *Veterinary Emergency and Critical Care Medicine*. St. Louis, MO: Mosby-Year Book. Reproduced with permission from Mosby-Year Book.)

Burn Classification Based on Depth of Injury (see Fig. 7-15)

- Superficial (first degree): limited to the epidermis
- Partial thickness (second degree): epidermis and a variable portion of the dermis
  - Superficial partial thickness: epidermis and upper one-third of the dermis
  - Deep partial thickness: epidermis and deep dermal tissues
- Full thickness (third degree): complete involvement of the entire skin thickness
- Fourth-degree burns are those that extend to the deeper tissues, including muscle and bone

(as compared with humans). A basic estimation of the surface area in humans can be determined by employing the "rule of nines" formula; this guideline must be modified for children less than 15 years of age. The Lund and Browder Chart is a more accurate chart for use in humans, by taking into account changes in body surface area for specific body areas for various age groups. Neither guideline is accurate for morbidly obese humans.

A small study performed in nine male/female mesocephalic dogs, using full-body CT, was employed to assess body surface area in fresh adult canine cadavers (8–35 kg). A similar study was performed in cats. (See later chart.)

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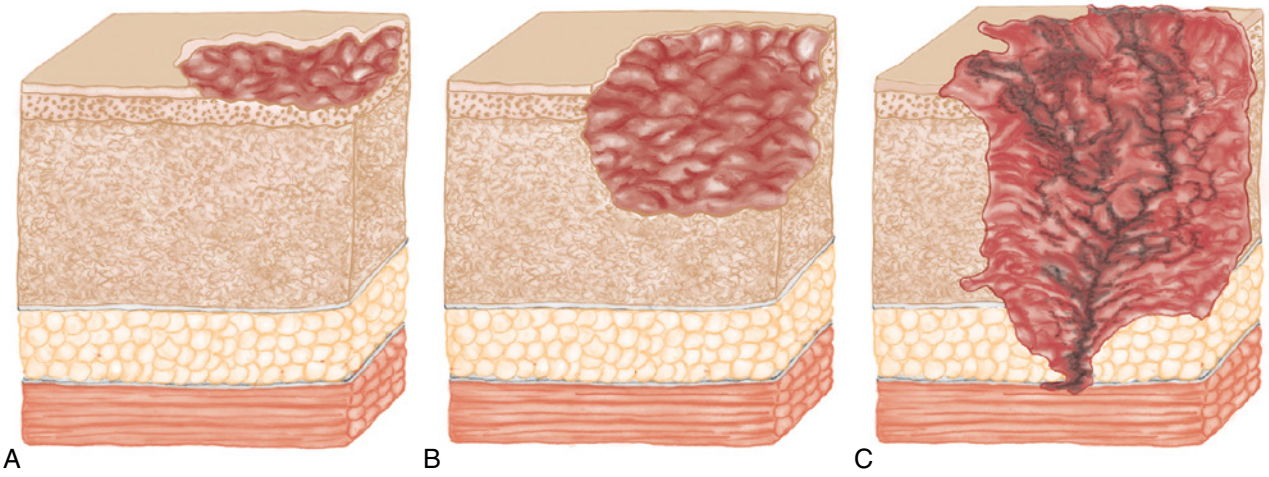


FIG. 7-15 Illustration of cutaneous burn depth and degree designation. (A) Superficial (first degree): limited to the epidermis. (B) Partial thickness (second degree): epidermis and a variable portion of the dermis. (C) Full thickness (third degree): complete involvement of the entire skin thickness. (Note that a burn extending to the deeper underlying tissues would be called a fourth-degree burn.)

Body Surface Area of Humans vs. Dogs

Humans (Rule of Nines)		Dogs		Cats	
Arms	9%	Forelimbs	9%	Forelimbs	7%
Legs	18%	Hindlimbs	11%	Hindlimbs	12%
Head and neck	9%	Head and neck	23% (14% + 9%)	Head and neck	18% (13% + 5%)
Thorax	18%	Thorax	18%	Thorax	20%
Abdomen	18%	Abdomen	14%	Abdomen	15%
Groin	1%	Pelvis and tail	5%	Pelvis and tail	28% (15% + 9%)

Although conversion charts and surface area formulas are available (see Table 7-1), a working estimate can be determined using the general guidelines already given. The estimates will serve as the initial point for fluid therapy in patients with probable full-thickness burns over greater than 20% of their body surface area.

A major limitation of accurately estimating the burn area in veterinary patients is the degree of skin laxity relative to the human patient. Many dogs and cats have a remarkable degree of inherent skin elasticity, especially on the neck and trunk. A large patch of burned skin can be excised and closed by taking advantage of the available elastic skin, unlike in human burn patients.

As noted, burn severity is a combination of the body surface area involved and the depth of the burn(s). Of particular concern are full-thickness burns over a large surface area. Most superficial and less serious partial-thickness burns are capable of restoring the integrity of the epidermis in humans and fur-bearing animals. In dogs and cats, the surviving hair follicles are a major source of epithelial cells. Complete loss of the skin requires healing from the viable skin forming the perimeter without surgical intervention. For large full-thickness burns, second-intention healing may not be a realistic option. The specific area of burn involvement also produces its own challenges. For example, complete loss of foot pads presents a major challenge for salvaging the extremities, particularly for larger animals.

Speaking to the Client

After evaluating a patient with extensive burns, it is critically important to discuss the care required and the high costs associated with managing the pet. The cost of managing these patients can easily run into thousands of dollars.

When a major surface area of the patient is involved with probable full-thickness burns, euthanasia becomes a realistic option. When in doubt, consult with a board-certified surgeon familiar with these injuries.

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TABLE 7-1 Body weight to surface area conversion.

Body Weight		Surface Area*	
Kilograms	Pounds	Square Centimeters	Square Meters
2	4.4	1600	0.16
4	8.8	2500	0.25
6	13.2	3800	0.33
8	17.6	4000	0.40
10	22.0	4600	0.46
12	26.6	5200	0.52
14	30.9	5800	0.58
16	35.3	6400	0.64
18	39.7	6900	0.69
20	44.1	7400	0.74
22	48.5	7900	0.79
24	52.9	8300	0.83
26	57.3	8800	0.88
28	61.7	9000	0.92
30	66.1	9700	0.97
32	70.6	10,100	1.01
34	75.0	10,500	1.05
36	79.4	10,900	1.09
38	83.8	11,300	1.13
40	88.2	11,700	1.17
42	92.6	12,100	1.21
44	97.0	12,500	1.25
46	101.4	12,800	1.28
48	105.6	13,200	1.32
50	110.0	13,500	1.35
52	114.4	13,900	1.39
54	118.8	14,300	1.43
56	123.2	14,700	1.47
58	127.6	15,000	1.50
60	132.0	15,300	1.53
62	136.4	15,700	1.57
64	140.8	16,000	1.60
66	145.2	16,300	1.63
68	149.6	16,600	1.66
70	154.0	17,000	1.70

* Calculated from the following equation: area (in meters)^2 = 0.1 × Wt.$^{2/3}$ (in kg).
Source: Modified from Davis LE. Thermal burns. In: Swaim SF, ed. 1980. *Surgery of Traumatized Skin: Management and Reconstruction*, p. 222. Philadelphia, PA: WB Saunders.

Burn Pathophysiology

The pathophysiology of major thermal injuries can create serious metabolic derangements beyond the margins of the wound. Among the potential problems associated with partial- and full-thickness burns involving a wide surface area (greater than 20%) are hypovolemic burn shock; sequestration of fluid in the extravascular extracellular space; red-cell destruction; cardiac dysfunction or "burn shock" (negative inotropy), arrhythmias, and high-output cardiac failure; postburn pneumonitis, acute respiratory insufficiency, and pneumonia; immunosuppression with impaired function of leukocytes, macrophages, and T-cells; reticuloendothelial cells; fluid and electrolyte derangements; acid–base imbalance; disseminated intravascular coagulation and thromboembolism; hepatic and renal failure; adrenal insufficiency; increased gastrointestinal mucosal permeability with disruption of the intestinal barrier and gastrointestinal ulceration or Curling's ulcers; burn sepsis; hypermetabolism; nonhealing wounds, contracture, and Margolin ulcer (squamous cell carcinoma); scarring; and poor cosmetic results.

Experimentally, dogs that sustain 50% scald burns without intravenous fluid support demonstrate a sharp decline of cardiac output and an abrupt rise in hematocrit value from a loss of plasma volume. Although the body can institute compensatory mechanisms to improve cardiac output, early aggressive intravenous fluid replacement therapy is essential to correct the abnormalities noted.

Clinical Observations

A number of referral burn patients who have sustained burns estimated to be somewhat greater than 20% of their body surface area have been noted to be surprisingly stable (oftentimes days after injury) despite the fact they received little or no fluid therapy.

This may have to do with the fact that most dogs and cats have loose, elastic skin, resulting in a tendency for clinicians to overestimate the burn surface area.

Appropriate medical therapy should be instituted to ensure the patient is in the best possible health for the wound-care/surgical procedures required to close the cutaneous defects.

Phases of Major Burns

After major burns, major physiologic changes occur and can be divided into two distinct phases: resuscitation phase and hyperdynamic/hypermetabolic phase. The resuscitation phase (hypodynamic or ebb phase) is noted in the first 24–72 hours in humans. There is a hemodynamic instability with increased vascular permeability and fluid shifts with intravascular volume depletion. In this phase the primary goal is restoring tissue perfusion to avoid hypovolemic shock. With the shift of fluids and protein loss from the circulation and into the extravascular space (edema), there are further losses through the burn surfaces. There is an immediate derangement in the wound-healing processes (discussed in Chapter 2).

With successful supportive management, the patient enters a hyperdynamic and hypermetabolic phase beginning 3–5 days following the injury. This is characterized by a decrease in vascular permeability, increased heart rate, and restoration of microvascular integrity. This period of hyperdynamic circulation and an increased metabolic rate can persist over several months in humans.

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As will be noted, there is less fluid support required during this phase; supportive care is focused on addressing the nutritional and caloric needs of the patient.

Fluid Therapy for Major Thermal Injuries

After sustaining a serious burn (>20% surface area), capillary permeability increases rapidly, not only at the burn site itself but also throughout the body, resulting in a free exchange of all noncellular elements of the blood within the extravascular space. The loss of plasma, electrolytes, and plasma proteins (less than 350,000 Daltons) occurs at a rate of 4–4.5 ml/kg/h during fluid administration of seriously burned humans. This extracellular fluid (edema) is sequestrated from the vascular compartment proportional to the severity of the burn. The dramatic loss of plasma volume results in a notable rise in hematocrit, despite the fact that red cells have been destroyed and their life span is reduced to 30% of estimated normal value. The loss of fluid combined with polymerization of plasma protein increases blood viscosity. However, capillary integrity does improve 18–24 hours after the burn. Adequate fluid replacement at this time results in early restoration of cardiac output. After 24 hours, colloids may be useful in expanding plasma volume as capillary permeability declines.

The fluid loss of burn patients is essentially iso-osmolar; isotonic fluids are used as the basic replacement solution. Hypertonic saline (3%) had been reported in the 1980s and used to a limited degree: one study noted increased mortality associated with hypertonic resuscitation and it is no longer recommended for use in humans. Crystalloid solutions are normally used during the first 24 hours: lactated Ringer's solution is commonly used for volume expansion since large saline infusions can precipitate hyperchloremic acidosis in humans. To maintain normal renal function, fluid administration should be adjusted to maintain a urine output of 1 ml/kg/h. In the first 24 post-burn hours, fluid input may be as much as three to four times urine output (3–4 ml/kg/h) because of the increased capillary permeability. An initial shock dose of 80–90 ml/kg intravenously may be indicated during the first hour of critical presentation. The color, concentration, and volume of urine are carefully monitored.

Fluid Resuscitation Formulas

Burn formulas (Consensus formula [formerly called Parkland] and modified Brooke formulas) have been developed as a general guideline for initial treatment of human patients sustaining major burns. These formulas combine both maintenance and replacement volumes based on the weight of the patient and surface area burned. The Consensus formula, commonly employed in humans, uses the percentage of surface area burned to estimate fluid needs: 4 ml/kg body weight × percentage of burn area. Half of this volume is given within the first 8 hours after injury. One-quarter of this volume is given during the second 8-hour period, followed by the remaining quarter in the last 8 hours. In some human patients, the average volume of fluid was greater than the formula prediction, exceeding 6–7 ml/kg of the total surface area of the burn. Careful monitoring of the patient is required to avoid "fluid creep" or the excessive use of crystalloids; overresuscitation can result in pulmonary edema, pleural and pericardial effusion, and the accumulation of fluid in the extremities and abdominal cavity. Use of this formula can be employed in dogs, in one paper (Vaughn and Beckel 2012) reducing the volume in cats by 25–50%. Fluid is titrated to maintain mean arterial pressure and urine output.

Colloid, plasma, or 5% albumin can be administered in this last 8-hour period if urine output remains below normal value. (Human albumin is best avoided due to the risk of hypersensitivity reactions in the small animal patient.) Lyophilized canine-specific albumin solutions are available for use in dogs and appear to be well tolerated. Dextrans and hydroxyethyl starches are an alternative, but run the risk of impairing coagulation. In the absence of hemodynamic instability, it has been suggested to wait at least 8–12 hours post burn injury before utilizing colloids due to their loss from increased capillary permeability during the early stages of major thermal trauma. Although this formula has been adapted to small animals, treatment must be tailored to the individual needs of the patient. Central venous pressure monitoring may be useful in assessing the rate of fluid administration.

All formulas are potentially imprecise. Treatment is based on the patient's response to monitoring by:

Vital signs
Mental status
Serial blood work
Blood-gas analysis
Heart rate
Central venous pressure and mean arterial pressure
Urine output and analysis

Adjustments in the rate of fluid administration are based on the serial measurements of these parameters.

When capillary permeability returns to near normal levels after 24 hours, less Ringer's intravenous fluid support is required for intravascular volume expansion and

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urine output. With evaporative loss of water through a large burn surface area, 5% dextrose in water is additionally used to offset this deficit in the second 24-hour period: 1–2 ml/kg × percentage of burn per day. If needed, colloid or plasma at 0.3–0.5 ml/kg per percentage of burn or 0.5% albumin at 1 g/kg/d has been used in persons during this time period. These also have potential use in the veterinary patient. Body weight; urine output (0.5–1 ml/kg/h); blood analysis of hematocrit, serum protein and albumin, electrolytes, blood urea nitrogen (BUN) and creatinine, blood glucose, and blood gas determination; and serum/urine osmolality are closely monitored to determine the adequacy of fluid administration. BUN, hematocrit, total protein, and blood glucose samples can be repeated throughout the day until chemistry profile results are obtained. Blood chemistry units that are common in many veterinary hospitals can be used for more frequent testing if necessary.

After 48 hours, mobilization of burn-wound edema occurs and the body weight gradually returns to preburn levels over the following days. Less intravenous fluid support is required as the patient begins eating and drinking during this resorptive phase, although evaporative water loss must be assessed during this period. Continued analysis of blood and urine samples is necessary. Fluid therapy is judiciously tailored to maintain serum values in a low normal range as edema fluid is mobilized. Urine output is closely monitored. It is desirable to maintain serum protein between 3.5 and 6.5 g/dl and hematocrit above 25% to prevent hypoxia during the patient's hypermetabolic state. Anemia may become apparent in this stage, necessitating packed red cells or whole-blood transfusions.

Common Fluid and Electrolyte Problems

Hypernatremia

Hypernatremia is the most common electrolyte abnormality encountered in human burn patients and it is a result of unreplaced evaporative water loss from the burn surface. It can be noted in dogs under similar circumstances. The clinical response to this fluid deficit is loss of weight and blood volume. There is a rise in serum sodium and chloride above 145 mEq/l and 110 mEq/l, respectively. There is a concomitant rise in BUN as well as serum and urine osmolalities. Osmotic diuresis can cause similar signs in uncontrolled hyperalimentation regimens and sepsis. Serum sodium level rising to 170–180 mEq/l leads to delirium, convulsions, and death. Electrolyte-free fluids (5% dextrose in water; D5W) or hypotonic solutions are used to reexpand the extracellular fluid loss and correct this abnormality.

Hyponatremia

Hyponatremia, or water intoxication, is most prevalent in children who receive large volumes of electrolyte-free (D5W) or hypotonic solution during resuscitation. Dogs allowed to consume large amounts of water before proper fluid resuscitation may also manifest this condition. Convulsions ensue when serum sodium and chloride levels plummet below 130 mEq/l and 80 mEq/l, respectively. Serum and urine osmolalities decrease and an increase in urine output with low specific gravity can be seen. This problem can be corrected by restriction of free water and sodium replacement (3–5% solution) administered slowly over 6–12 hours.

Hyperkalemia

A modest degree of hyperkalemia is a common result of hemolysis and tissue necrosis in the first 48 hours in burned animals. Acidosis can enhance potassium elevation. Renal failure can cause a dramatic rise in serum potassium levels. Adrenocortical insufficiency in humans can promote hyperkalemia. Electrocardiograms can reflect the severity of hyperkalemia. Therapy for hyperkalemia is directed at protecting the heart from potassium's depressive action on the conducting system and toward reducing those levels, while correcting the underlying cause(s). Serious cardiac conduction toxicity can be reversed with the judicious administration of calcium. Serum potassium can be decreased by sodium bicarbonate or glucose and insulin to promote the shift of potassium from the extracellular space. Peritoneal dialysis, hemodialysis, and cation-exchange resins have been used in severe cases of hyperkalemia in humans.

Potassium levels are ideally maintained at 3.5–4.5 mEq/l. Intravenous administration of fluids low in potassium, including 0.9% saline or lactated Ringer's, should be used.

Hypokalemia

After 48 hours, renal excretion of potassium is accelerated and may result in hypokalemia unless supplementation is instituted. Potassium (15–20 mEq/l) may be added to commercial replacement solutions (4–5 mEq/l) to maintain serum potassium in the normal range. Supplementation should be increased to 80 mEq/l if serum potassium falls below 2.5 mEq/l as long as renal function is maintained and an electrocardiogram is monitored for signs of potassium toxicity (mild hyperkalemia: peaked T waves, widening QRS, decreased P wave; moderate hyperkalemia: amplitude prolonged P–R; severe

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hyperkalemia: ventricular fibrillation, asystole). A safe rate of potassium administration is 0.5 mEq/kg/h.

A second method to maintain adequate potassium levels is alternating commercial replacement fluids (containing 4–5 mEq/l potassium) with maintenance fluids (containing 13–35 mEq/l) on an equal basis.

Acidosis

Acidosis is most commonly seen in the early postburn period. Metabolic acidosis is the result of poor tissue perfusion but may be compounded by respiratory acidosis secondary to smoke inhalation or pulmonary disease. Patients attempt to compensate with an increased respiratory rate to reduce pCO_2. Blood and urine pH may drop below 7.35 and 5.5, respectively.

Treatment consists of improving tissue perfusion, maintaining adequate oxygen saturation, and the judicious use of sodium bicarbonate, if necessary, based on a blood gas analysis and base-deficit calculations.

Overload Syndrome

Administration of crystalloids and colloids in excess of volume losses results in overexpansion of extracellular fluid spaces. One should be suspicious of fluid overload if urinary output approaches intravenous fluid administration. In animals, rales on thoracic auscultation and the appearance of pulmonary edema on radiographs are most commonly noted. Peripheral edema unrelated to the burn injury, a decreased urine specific gravity, and an elevated serum sodium level should alert the clinician to this complication. Treatment consists of decreasing volume replacement, diuretics, and closely monitoring serum electrolytes.

Oliguria

The most frequent cause of oliguria is hypovolemia from inadequate fluid resuscitation in relation to fluid losses from evaporative water loss, diarrhea, hemorrhage, and increased capillary permeability. Acute tubular necrosis due to myoglobin casts in the kidney or administration of nephrotoxic drugs can result in complete renal failure.

Increased fluid volume replacement can reverse prerenal oliguria by improving renal blood flow and restoring vascular volume. Additional medical management directed at improving renal perfusion may be necessary, including the judicious use of intravenous dopamine. Mannitol or furosemide can be instituted. Failure to respond suggests acute renal tubular necrosis. Acute renal shutdown necessitates intensive monitoring and dialysis to maintain the patient until renal function (if possible) can improve. Acute renal tubular necrosis in the face of major thermal injuries is particularly foreboding in the veterinary patient.

Anemia

Assuming patients have a normal hematocrit in the preburn period, anemia in severely burned patients is the result of direct red-cell destruction and a significant reduction of the life span of red cells. Following successful fluid resuscitation, the artificially high hematocrit noted in the early postburn period will decline after 48 hours. Hemolysis from sepsis, internal bleeding, and related complications can worsen the anemia. Whole-blood or packed-cell replacement should be instituted to maintain a hematocrit above 25%. Supplemental oxygen is advisable in seriously burned patients due to increased oxygen consumption in their hypermetabolic states. Conditions contributing to red-cell destruction or a fall in production require correction.

Intraabdominal Hypertension

In extensively burned humans, there is a concern for intraabdominal hypertension and a secondary abdominal compartment syndrome. This may be noted in patients with a decrease in abdominal wall compliance associated with extensive torso burns along with abdominal wall tension associated with pain. This is also aggravated by accumulation of intraabdominal fluid. This has not been reported in the dog.

Left untreated, intraabdominal hypertension can result in abdominal organ dysfunction and failure. In dogs, pressures >10 cm H_2O are considered mildly elevated and therapeutic intervention is indicated with pressures >20 cm H_2O.

Nutritional Support

In view of the hypermetabolic state of the severely burned patient and the expenditure of energy from evaporative heat loss through the burn wound, efforts must be initiated to keep the patient in a state of positive nitrogen balance. Enteral nutrition is superior to parenteral nutrition in order to maintain gut motility. Nutritious high-calorie, high-protein diets can be introduced provided that renal and liver function is adequate. A balanced diet can be offered in increasing amounts after 48 hours. Vitamin supplements can be added to the nutritionally balanced diet. Keeping the room temperature at 31 °C can reduce the caloric expenditure of the patient. Patients who are able to display a healthy appetite are introduced to greater amounts of food up to 2–2.5 times maintenance

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requirements, depending on the severity of the burn. Weighing patients is useful to determine how they are responding, keeping in mind that resorption of extravascular extracellular fluid after 48 hours will account for initial weight reduction to a preburn weight.

Assessment of the Thermal Injury

Following initial patient stabilization, the primary goal in the management of all burn patients is early wound closure. Burn depth and regional involvement must be determined in order to develop a proper medical/surgical plan. A complete physical examination is indicated to assess the extent of the thermal injuries. In facial burns, the eyes should be closely examined.

Early assessment of burn depth can be difficult. Pinching of the skin to assess burn depth by the fissure created is inaccurate in the early hours after injury unless the wound is obviously deep. Advanced full-thickness thermal necrosis is distinguishable as a thickened, leathery, brown-black eschar (Fig. 7-14). In some cases full-thickness burns are a bloodless "pearl" white. A fissure or separation at the interface between viable and nonviable tissue commonly forms within 7–10 days after full-thickness thermal injury. Superficial burns may appear as reddened, inflamed skin with a thin scab or crust formed on the surface. Partial-thickness (second-degree) burns, however, may be indistinguishable grossly from full-thickness (third-degree) burns in the initial days until separation of viable and nonviable tissue occurs. Unsinged hair may be plucked effortlessly from deep partial-thickness and full-thickness burns (Fig. 7-16). Adding to the confusion is the fact that progressive circulatory compromise from thrombosis may result in further tissue loss within the first 72 hours after injury. Depending on the heat source and its application, the veterinarian may see a halo effect of first- and second-degree burns surrounding a third-degree burn.

Partial or Full Thickness?

With the presence of a burn eschar, it may not be possible to determine immediately the amount of dermis damaged or destroyed. During conservative management, the necrotic surface may delaminate over several days, allowing assessment of the surviving tissues.

At the time of surgical debridement, a scalpel blade can be used to partially incise through a portion of the eschar, giving a cross-sectional view of the skin edge. In the case of partial-thickness burns, viability can be observed in the lower dermal segment. The depth of the burn is easier to assess in the thicker skin overlying the dorsum of the trunk and cervical areas using this technique.

As noted in Chapter 1, the poorly developed capillary loops of the superficial plexus explain the general lack of blister formation with thermal injuries.

Extreme burns can result in destruction of tissues below the skin (fourth-degree burns). A detailed physical examination is required to assess other regional structures, including the eyes, ears, oral cavity, respiratory tract, urogenital tract, anus, and footpads. However, patients may be subject to multiple forms of trauma simultaneously: neurologic injuries, fractures, and other internal injuries should not be overlooked. As previously stated, a complete physical examination of the patient is essential.

Burn-Wound Infection

Sepsis presents the greatest threat to the seriously burned patient. Protection from sepsis includes containment and control of bacteria colonizing the burn wound, prevention of the accumulation of purulent discharge on the burn wound, prevention of secondary contamination, avoidance of additional tissue trauma, promotion of an environment conducive to healing, and removing all

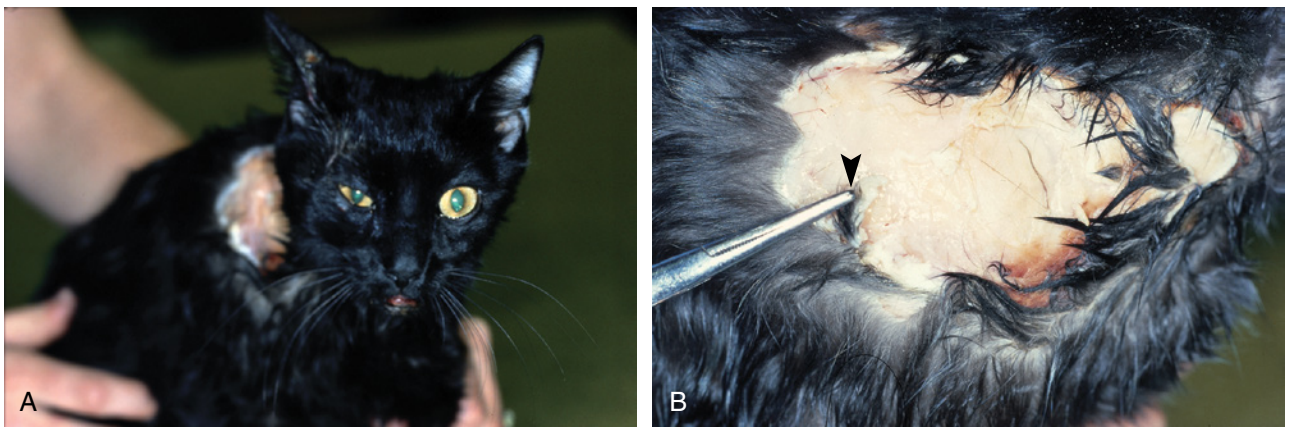


FIG. 7-16 (A, B) Hair easily plucks out (arrow) of the third-degree scald injury on the shoulder of this cat.

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nonviable tissue as early as possible. In the case of large areas of necrotic skin, the author firmly believes in early surgical excision of the necrotic eschar. Early eschar removal does more to control infection and promote a viable vascular bed suitable for closure than any other treatment modality. This is reserved only for areas of distinguishable full-thickness skin necrosis. Superficial- and partial-thickness burns are not routinely excised: topical management is instituted to control infection, promote separation of the nonviable surface, and promote epithelialization of the denuded areas. Systemic antimicrobials are typically reserved for infected burns, rather than used prophylactically to prevent infection in most cases. Topical antimicrobials are most commonly used to manage the burned areas.

Extensive burns generate extensive costs. Materials, supplies, medication, surgery, and hospitalization easily can result in bills up to several thousand dollars. Owners must be prepared for the financial and emotional commitment they will face in seriously burned animals. In some cases euthanasia is a humane and logical alternative.

Initial Wound Management

After excessive hair is carefully clipped from the burn area, the wound is examined to help determine its depth and extent. Because skin has low thermal conductance and releases retained heat slowly, thermal damage can continue after the initial injury. Application of chilled saline or water to the burn wound within 2 hours after injury can decrease the duration of thermal retention and reduce the depth of tissue injury. The optimal liquid temperature is 3–17 °C and the burned area should be cooled by immersion or compresses for at least 30 minutes. Unfortunately, most cases are not presented promptly.

Avoid packing areas in ice and be aware that prolonged cold may further injure compromised tissues. Discretion must be employed when cold fluid is applied over a broad burn area in order to avoid hypothermia in a shocky patient. Topical cool water with a spray nozzle also is useful in removing caustic agents from the skin surface.

Analgesics are an integral part of burn-wound management. Sedatives or general anesthesia also may be required during procedures in which pain may be inflicted. Good systemic analgesics include oxymorphone at 0.02–0.06 mg/kg intravenously (IV) every 4 hours (dogs); butorphanol 0.05–0.20 mg/kg IV every 6–12 hours (dogs, cats); methadone at 0.1–0.3 mg/kg IV or intramuscularly (IM) every 4–6 hours (dogs); and morphine sulfate 0.20–0.50 mg/kg subcutaneously (SQ) or IM every 4 hours (dogs). Consultation with an anesthesiologist is advisable, not only to discuss optional analgesics and dosages but also to select the most appropriate anesthesia protocols for surgery.

Topical Agents

Detergents, peroxides, and harsh antimicrobials should not be applied to burns. Additional tissue trauma and circulatory compromise can convert a partial-thickness burn to a full-thickness loss. Copious lavage with sterile isotonic solutions followed by a broad-spectrum antimicrobial ointment is satisfactory for small superficial and partial-thickness thermal injuries. Until the veterinarian can clearly delineate between partial-thickness and full-thickness thermal injuries, this initial conservative approach is appropriate.

Topical agents can be applied beneath a bulky, sterile, protective bandage. This is most effective when dealing with the lower extremities in order to protect the wound from contamination and external trauma. Extensive burns involving multiple regions are more difficult to cover. In many cases, topical agents may be applied more easily without a bandage. "Open therapy" by buttering burn ointment on the areas with a sterile glove or applicator can be performed two or three times daily. Areas can be gently dabbed or rinsed with warm isotonic solutions to remove debris prior to reapplication of the ointment. Serial debridement also may be performed as necrotic tissue separates.

A variety of nonirritating topical antimicrobial agents are available on the market. Selection is of minor importance in small thermal injuries. In large thermal wounds, a broad-spectrum ointment that is easily applied and rinsed is desirable. Furthermore, the ointment should be nonpainful, nonirritating, minimally absorbed systemically, and nontoxic. Of the agents commonly available, including polymyxin–bacitracin, furacin, povidone–iodine, gentamicin, mafenide, and silver sulfadiazine, only silver sulfadiazine fulfills most of these criteria. This water-miscible ointment is sold in jars or small tubes (see Chapter 4).

Escharotomy

A burn eschar that embraces the circumference of the trunk or extremity can form a biological tourniquet that impairs blood and lymphatic flow. In the thoracic area, respiration can be impaired. Although a rare event in veterinary medicine, an escharotomy (eschar-relaxing incision) is indicated. Escharotomy incisions can be used to facilitate the penetration of enzymatic debriding agents (see Chapter 4).

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Debridement

Debridement, or the removal of devitalized tissue, is a key component to the management of deep partial-thickness and full-thickness burn areas. Conservative mechanical debridement (e.g., wet-to-dry dressings), aggressive surgical debridement, and enzymatic debridement are commonly employed to remove necrotic tissue in humans. Removal of dead tissue is essential to the control of sepsis and the promotion of a viable vascular bed suitable for surgical closure.

Conservative Debridement

For larger surface area burns in a stable patient, conservative debridement in veterinary medicine may include the application of sterile isotonic solutions (hydrotherapy) or the application of wet dressings. Hydrating the tissues can facilitate softening and separation of necrotic tissue from the underlying viable tissues. Stainless steel surgery buckets also can be sterilized and filled with warm sterile saline for immersion of small dogs and cats. Alternatively, small containers could be covered with sterile plastic liners for the same purpose (Fig. 7-17). The patient is immersed in warm sterile saline for 15–30 minutes once or twice daily until removal of major areas of necrotic tissue is complete. Following soaks, loose necrotic tissue is removed with thumb forceps and scissors. "Floating" the affected area improves visualization of strands of attached necrotic tissue for removal. Hydrotherapy is most difficult and time consuming in large dogs and topic saline spray and wet dressings are a more practical option. After dabbing saline from the patient's body with sterile pads, silver sulfadiazine ointment is applied prior to returning the patient to a heated cage. The cage must be cleaned with antiseptic agents periodically to prevent wound contamination from urine and feces.

As noted, wet-to-wet dressings are an alternative to immersion hydrotherapy. They are best used for extremities or local areas of the trunk. Periodic application of sterile saline or lactated Ringer's solution using a syringe is necessary to offset moisture evaporation from the bandage surface. Alternatively, a plastic perforated catheter can be incorporated into the secondary or absorptive layer of the bandage for easier fluid infusion with a syringe (see Chapter 5). Bandages are left on the wound for several hours. Antimicrobial agents can be included in the wetting agent employed. Wounds can be debrided during bandage changes as required.

Conservative debridement is used by the author when aggressive surgical debridement is difficult or inadvisable.



FIG. 7-17 Kitten with extensive burns. The patient was immersed in warm saline placed in a sterilized stainless steel bucket. This facilitated softening dried, necrotic skin adhered to the wounds. Forceps and scissors were used to trim off the tissue in a serial fashion.

This includes the removal of small areas of necrotic tissue adherent to tendons, ligaments, or underlying body structures where no clear delineation of a fascial plane can be employed for accurate excision. When necrotic tissue is largely removed and infection is under control, other topical dressings and agents also may be considered (see Chapter 4).

Aggressive Debridement

Aggressive debridement or "wound excision" is the removal of the entire burn. Large areas of full-thickness skin necrosis impede granulation-bed formation and dramatically increase the risk of infection. Several days or weeks may pass before spontaneous separation of the necrotic tissue can occur with more conservative treatment. Under these circumstances, surgical excision using general anesthesia has the potential to eliminate the necrotic wound in a single stage. Grafting knives can facilitate tangential excision of the nonviable tissue at the level of the hypodermis (Fig. 7-18). A healthy granulation bed, suitable for flap or graft closure, rapidly forms within 5–7 days. Electrocautery, vascular clips, and ligatures are essential for hemostasis.

The author has been an advocate of early surgical debridement of large areas of full-thickness cutaneous burns. Infection can be blunted or prevented. Closure reduces pain and facilitates the recovery and subsequent discharge of the patient to the pet owners. The costs associated with surgical debridement/closure are offset by the costs associated with prolonged open wound management. This approach is also favored in the management of full-thickness thermal wounds in human patients.

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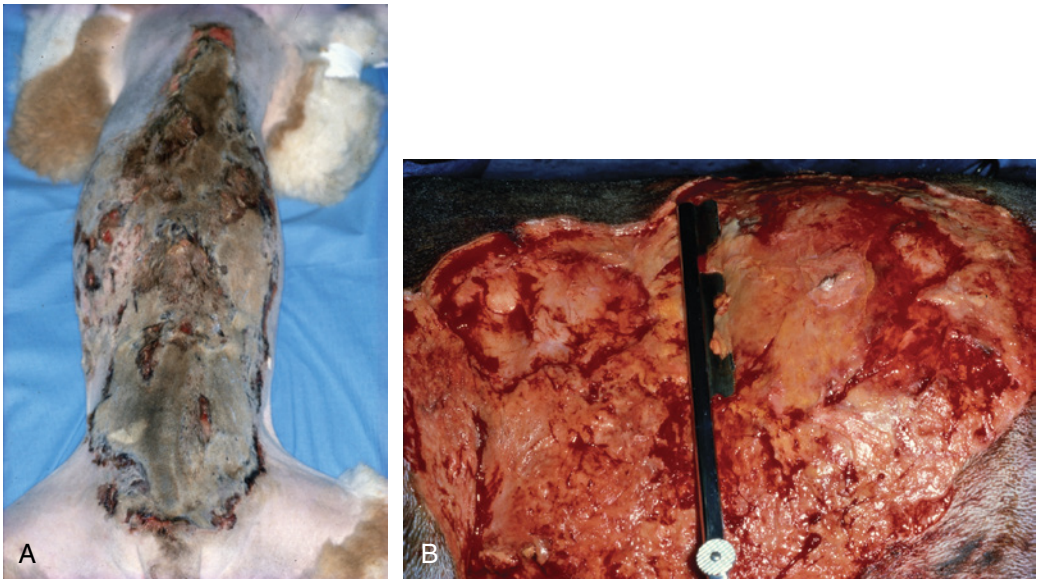


FIG. 7-18 (A) Extensive thermal wound in a dog. The burn eschar contained numerous abscesses. (B) A graft knife facilitated excision of the necrotic skin and hypodermis. A healthy granulation bed formed within 1 week, which was suitable for wound closure using a combination of axial pattern flaps, skin advancement, and punch grafts (see Fig. 2-3). (Source: Pavletic MM. 1990. Massive trunk wound caused by thermal trauma. *Vet Med Report* 2:159. Reproduced with permission from Veterinary Medicine Report.)

Wound-Closure Options

Once a viable vascular wound bed is free of necrotic tissue and infection, there are several options for closure. Superficial and partial-thickness burns frequently reepithelialize within 3 weeks with supportive care. Deep dermal partial-thickness burns take longer. Full-thickness skin defects may heal by contraction and epithelialization from the bordering skin. Extensive burns usually require closure with skin grafts or skin flaps, depending on the extent and location of the wound(s). Skin stretchers can be used effectively for full-thickness trunk burns (see Fig. 10-8).

While allografts and xenografts have been used for temporary coverage of thermal injuries in humans, autogenous free grafts are required for permanent coverage of large full-thickness thermal wounds. A partial-thickness graft harvested with a dermatome and meshed with a 3 : 1 ratio is considered the best free-grafting technique for resurfacing large wounds. On occasion, axial pattern flaps can be used alone or in combination with free grafts and/or skin advancement techniques. AVITA's RECELL® technology (AVITA Medical, Inc., Valencia, CA) shows promise in epithelizing large burn surface areas in humans; there in one case report on its use in a dog. The system creates a slurry of epithelial cells from a small harvested skin graft from the patient. This slurry of epithelial cells is sprayed onto the vascular wound bed and protected by a dressing. Chapter 2 discusses artificial skin and replacement options (see also Chapters 11, 12, 13, and 16 on skin flaps and Chapter 14 on skin grafting).

Excessive scarring and wound contracture are serious complications in the burned patient, often occurring when preventative medical/surgical intervention was not instituted for serious wounds. Areas subject to constant motion, such as flexion surfaces, are most susceptible to wound-contracture development if major cutaneous losses occur. Splints, braces, and other devices have been employed to minimize these complications in humans. Z-plasty, pedicle grafts, and free grafts with scar division may be necessary to prevent and treat contractures. Prevention of contracture is obviously preferable to their treatment after formation.

Cosmetic results depend on the extent of the burn. In contrast to humans, hair growth is an essential component to the cosmetic outcome of the veterinary patient. Superficial and minor partial-thickness burns may heal and retain a majority of their hair follicles for regrowth of the hair coat. Deeper burns result in a greater loss of dermis and hair follicles. Complete surgical coverage with skin flaps and full-thickness grafts can provide an adequate hair coat, whereas split-thickness grafts provide fewer follicles and are less durable than full-thickness skin coverage. On occasion, wound contraction, combined with the overlapping of hair, can reduce the visibility of the burn scar with a satisfactory cosmetic outcome. It is important to discuss cosmetic results with owners who may have unrealistic expectations (Fig. 7-19).

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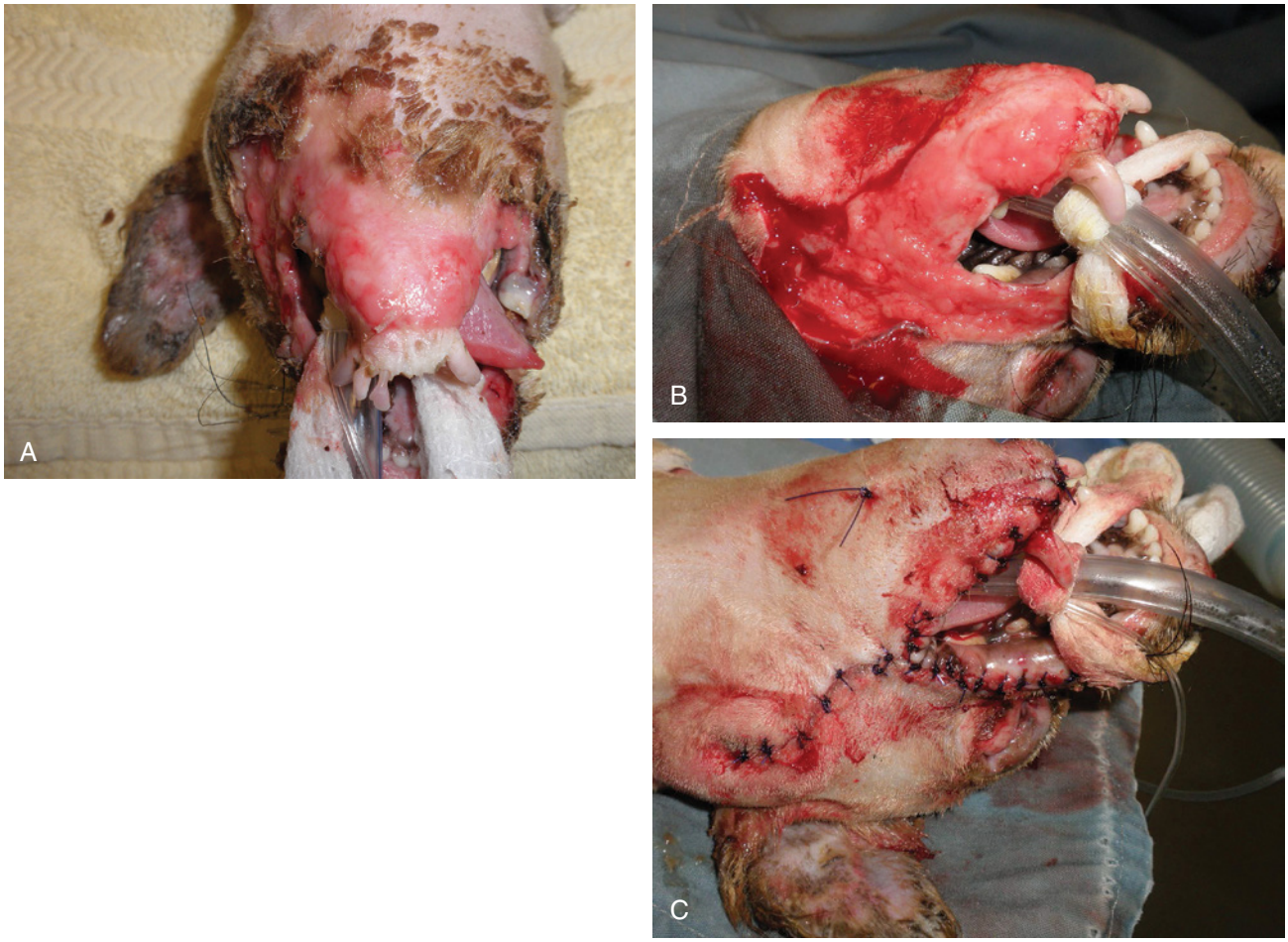


FIG. 7-19 (A) Full-thickness burns to the face of a Pomeranian trapped in a house fire as a result of arson. Note the loss of the skin involving the left and right buccal areas, lower chin, and lower incisive bone. (B) Intraoperative view of the patient. The necrotic bone was resected, as was the marginal epithelialized granulation bed. (C) The adjacent facial skin was carefully undermined and advanced over the granulation beds. This procedure (stage 1) was performed in 1 hour followed by anesthetic recovery. See Fig. 10-8 for stage 2 and stage 3 closures involving the dorsal trunk and pelvic area. Each stage was planned for separate 1-hour surgical sets. Absent in these surgical descriptions is the considerable amount of critical care management required to care for this patient.

Clinical Considerations and Prognosis

In summary, surgical management of burns is primarily limited to full-thickness skin wounds, especially when the wound involves a significant area of the patient. Once defined, large burn eschars are best treated by surgical excision; a healthy granulation bed is expected within 5–7 days after careful and thorough debridement of the dead skin. Topical silver sulfadiazine, with nonadherent dressings, is commonly employed to protect the wound and reduce the bacterial population until split-thickness mesh grafts, axial pattern flaps, or skin undermining and advancement can be employed for wound closure.

Skin Substitutes

There is no permanent, complete skin substitute at this time. Full-thickness burns are closed by second-intention healing, skin advancement, skin flaps, and autogenous skin grafts (see Chapter 2).

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INHALATION INJURIES

Smoke contains several toxic gases including CO, SO_4, NO_2, aldehydes, H_2SO_4, HCl, benzene, halogens, and hydrogen cyanide. Many of these compounds combined with inhaled particulate matter (superheated soot) can reach the pulmonary tissue, causing serious damage.

Soot and the toxic by-products of a fire adhere to the respiratory mucosa, causing chemical irritation. Inflammatory mediators released by the cells increase capillary permeability and edema formation of the upper respiratory tract. Copious exudate forms. Bronchial spasm, laryngeal spasm, pulmonary edema, mucosal edema, loss of ciliary function, and compromised pulmonary surfactant will aggravate hypoxia associated with a smoke-filled room. Hot, dry air has a low specific heat and respiratory injuries are confined to the upper respiratory tract. Live steam, with a high specific heat, is capable of causing atelectasis, severe pulmonary edema, and alveolar damage. Exfoliation of the epithelial lining may occur: the cellular debris, mucous, and contaminants from the upper respiratory tract can migrate and obstruct the lower bronchi, bronchioles, and terminal bronchioles. Exfoliation of the epithelial lining of the trachea and main-stem bronchi may be noted 3–5 days following severe smoke inhalation. Pulmonary atelectasis and pneumonia may be noted.

Dogs and cats trapped in burning buildings often have a strong smoke odor. The hair coat may be covered with soot particles. Pets close to flames may have singed hair. These clinical findings should alert the clinician to closely assess the patient for smoke- and heat-related pulmonary injury.

Pulmonary parenchymal dysfunction from severe smoke inhalation is frequently fatal in humans. Hypoxemia refractory to oxygen therapy, with the presence of bronchospasm/pulmonary edema, requires aggressive treatment to save the patient. High mortality rates (60–70%) are associated with humans who develop pulmonary edema within 72 hours after injury. Upper-airway edema is one of the immediate concerns with smoke-inhalation injuries. Bronchospasm may be noted. In humans, hoarseness and stridor may prompt endotracheal intubation and mechanical ventilation. Upper-airway edema normally resolves in 2–3 days. In 48–72 hours, humans may develop respiratory failure secondary to endobronchial sloughing, airway occlusion, and edema; infection can rapidly follow. If the human patient survives, they may have normal long-term clinical function impairment.

Clinical Signs

Overt clinical signs in dogs suffering from smoke inhalation include coughing, gagging, and respiratory distress. Occasionally ataxia, foaming at the mouth, rubbing at the eyes, and nasal bleeding are noted.

Overt clinical signs in affected cats suffering from smoke inhalation include dyspnea, vocalization, open-mouth breathing, lethargy, wheezing, gagging, nasal mucoid discharge, third eyelid protrusion, and foaming at the mouth.

Loss of consciousness may be indicative of hypoxia and possible brain injury.

In two case reviews in the dog and cat (Drobatz et al. 1999), most patients with nonthreatening smoke inhalation clinically improved within 24 hours; severe cases worsened within this time frame.

With major inhalation injuries an adequate airway must be established. Intubation and ventilatory support with positive-pressure ventilation are indicated in severe cases. Temporary tracheostomy should be considered for problematic patients; ventilatory support also can be used in conjunction with the tracheostomy tube. In mild cases of smoke inhalation and direct thermal injury, oxygen therapy alone may suffice. Nebulization of saline and coupage may facilitate clearance of respiratory secretions. In most cases, the tissue injury associated with mild direct thermal injury resolves within 5 days. Serial thoracic radiographs are useful in assessing changes in the respiratory tract. Bronchoscopy can be used to assess the severity of injury. It may be advisable to transfer the more serious patients to a veterinary emergency referral center that is better equipped to handle these challenging cases.

Carbon monoxide poisoning is suspected if the mucous membranes and blood are cherry red. Carbon monoxide blocks the oxygen-carrying capacity of hemoglobin. Blood oxygen levels may be low despite normal levels of dissolved oxygen in the bloodstream. Carbon monoxide poisoning requires 100% oxygen therapy to rapidly reduce the level of carboxyhemoglobin. Standard care for humans exposed to carbon monoxide is 6 hours of normobaric oxygen. Mild cases of carbon monoxide poisoning in small animals may benefit from placement in an oxygen cage. In humans, the half-life of carboxyhemoglobin is 4 hours breathing room air, whereas this is dramatically reduced to 45–60 minutes with oxygen administration by mask or nasal tube. If accessible,

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hyperbaric oxygen can reduce the half-life of carboxyhemoglobin to 30 minutes or less. Carboxyhemoglobin can be measured to assess the severity of carbon monoxide poisoning and progress in treatment of the patient. Local human hospitals may be required for precise measurements in problematic patients. Hyperbaric oxygen therapy is normally not warranted in humans and is not without risk.

As previously stated, additional caution is necessary during the administration of intravenous fluids. Efficacy with short-term (12–24 hours) use of corticosteroids is questionable: prolonged use can compound the immunosuppression already seen with concomitant major thermal injuries. Diuretics (furosemide) may decrease intravascular volume without significant benefits in the treatment of pulmonary edema. Bronchodilators (albuterol) and expectorants may be beneficial. Prophylactic antibiotics are ineffective and may select out resistant organisms. Their use should be based on airway culture. Many respiratory infections in animals are noted to be caused by Gram-negative bacteria. Because respiratory equipment is a potential source of bacterial infection, care must be taken to ensure that sterile tubes and uncontaminated equipment are used.

Progressive respiratory failure is a common complication in humans with serious inhalation injury. Fluid overload, hypoproteinemia, airway occlusion, and pulmonary edema are contributing factors that may be complicated with the advent of pulmonary infection. Radiographic infiltrates or lobar consolidation suggests pneumonia. Prolonged respiratory support may be required under these circumstance.

CHEMICAL BURNS

Many caustic agents are available for home and industrial use. On occasion these chemicals cause "burns" to animals accidentally or from their malicious application to pets (Fig. 7-20). The extent of the injury depends on the chemical, its concentration, the duration of contact and penetration, and its particular mechanism of action. Chemical burns in humans are often associated with accidental contact with caustic agents in an industrial setting. However, a number of potentially hazardous chemical agents are commonly used around the home and are a more likely risk for pets. For example, common drain cleaners typically include highly corrosive sulfuric acid, hydrochloric acid, or sodium hydroxide (alkali). Household oven cleaners (sodium or potassium hydroxide) and household bleach and pool cleaners (sodium hypochlorite) are capable of significant chemical injury. Toilet cleaners typically contain hypochlorite, hydrochloric acid, or sulfuric acid precursors. Hypochlorite, potassium permanganate, and chromic acid are oxidizing agents and cause protein coagulation. In contrast, picric acid, tannic acid, acetic acid, formic acid, and hydrofluoric acid cause protein denaturation. Halogenated hydrocarbons, gasoline, ethylene oxide, and cantharides are vesicants, liberating tissue amines (histamine and serotonin) and creating vesicles or blisters. Some solvents used for painting (turpentine, mineral spirits), furniture strippers, and concentrated flea-dip solutions are examples of household chemical agents also capable of causing superficial and partial-thickness skin injuries with prolonged contact.

The pathologic end result of chemical burns is similar to thermal injuries. While thermal burns cause rapid coagulation of protein, chemical burns cause denaturation of physiologic proteins, including reduction, oxidation, vesication, corrosion, and cellular poisoning. In general, chemical agents can be classified in one of the following categories: acids (proton donors), bases (proton acceptors), organic solutions (dissolving lipid membranes), and inorganic solutions (denaturation mechanisms). Secondary sequalae of chemical burns may include cellulitis, infection/sepsis, and scarring. Unlike thermal burns, chemical burns will continue to induce tissue injury until they are removed. Their immediate removal is critical to limiting the severity of the chemical insult.

Caustic agents generally destroy skin by coagulation necrosis. Vascular thrombosis may be noted with prolonged exposure to stronger agents. Strong alkalis in particular are capable of causing deep-tissue destruction by liquefactive (or colliquative) necrosis, extraction of water, and precipitation of protein (Fig. 7-21). An alkali–albuminate bond may form and redissolve in excess water. Alkalis form soluble soaps and protein complexes within the tissues, which facilitate the passage of hydroxyl ions into deeper layers. In contrast, hydrogen ions from acids are not complexed and the burn depth is somewhat more limited.

Management of Chemical Burns

The medical history may reveal the nature of the injury, chemical concentration, and duration of contact. Many of the cases of caustic burns noted by the author are the result of malicious attacks in which the agent in question is unknown. Inhalation of vapors or consumption of the material should be determined by physical examination, thoracic radiographs, and oral/laryngeal/pharyngeal examination. Eyes should be examined very closely. When chemical burns are suspected, attending veterinary staff should wear gloves, protective eye/facial shields, and protective plastic aprons when handling patients

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FIG. 7-20 (A) Acid burn to the face of a golden retriever. (B, C) Debridement and open wound management were followed by closure with a local transposition flap. (D) Close-up view after early hair growth. (Source: Pavletic MM. 1993. Pedicle grafts. In: Slatter DH, ed. *Textbook of Small Animal Surgery*, 2nd ed. Philadelphia, PA: WB Saunders. Reproduced with permission from WB Saunders.)

splashed with these caustic liquids. It is important to remember that some chemicals can be absorbed and result in systemic toxicity, including metabolic disturbance and acid–base and electrolyte derangements. With major exposure to toxic chemicals, patients will require close monitoring.

For most chemical burns, copious irrigation with warm water is indicated. Eyes in contact with chemicals should be copiously flushed with water; in the veterinary hospital sterile saline is preferred. Lime (calcium oxide) is used in cement and plaster as well as in industrial cleaners in solvent form. In powder form it should be brushed off the patient before performing copious lavage. Once mixed with water it forms the caustic alkali agent calcium hydroxide; in this case copious lavage is immediately implemented.

Exceptions to lavage include elemental metals that produce an exothermic reaction in contact with water. Although contact with phenol (carbolic acid) would be considered rare in animals, lavage has the potential of causing deeper infiltration. While polyethylene glycol (with hydrophilic and hydrophobic properties) has been

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FIG. 7-21 (A, B) A patient that fell into a caustic soda pit at a petrochemical plant. Extensive chemical burns were present. The patient was bathed extensively with a water spray to remove any residual caustic soda. (C) Close-up view of the patient demonstrating coagulation of the dermis. The patient went into acute renal failure despite aggressive medical therapy and was euthanized.

advocated for topical management of phenol chemical burns, one study in animals did not show a significant difference in phenol plasma absorption levels when comparing it to irrigation with water alone. (Phenol, as an aromatic hydrocarbon derived from coal tar, has a characteristic strong, sweet odor. A primary concern is its systemic toxicity to the heart and central nervous system.)

Irrigation for chemical burns should be started promptly. Gentle irrigation of chemical burns under low pressure is indicated, since high-pressure irritation could result in deeper infiltration of the chemical into the exposed tissues. Moderately warm water is recommended to reduce the risk of hypothermia in the patient. Litmus paper can be used to assess the pH of the skin. When a neutral pH is achieved, it is recommended to recheck this measurement 10–15 minutes following discontinuation of "final" irrigation. Under experimental conditions, the results of chemical burn treatment required returning skin pH to normal and varied between acid and alkali burns. While lavage of 30% acid burns for 2 hours returned the skin to normal pH, it took over 12 hours of lavage to reestablish normal pH following a burn with 50% sodium hydroxide. In general, 0.5–2 hours may be required to maintain a cutaneous pH of 5–11 in humans. Deep chemical burns from alkali compounds may require deep surgical excision if the contact has been prolonged. Alkali residue has a soapy feel and can be assessed by rubbing the gloved thumb and index fingers together.

The use of neutralizing agents is somewhat controversial: the primary concern is the exothermic reaction that may occur that could further enhance the chemical injury. They are not a substitute for copious lavage and should never be applied to an undiluted chemical. Table 7-2 summarizes several chemical compounds and their neutralizing agents.

Removal of fur facilitates close examination of the skin surfaces. Management of superficial and partial-thickness

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TABLE 7-2 **Injurious chemical agents.*+**

Agent	Clinical Presentation	Mechanism of Systemic Toxicity	Immediate Cleansing	Neutralization
Common Acids				
Sulfuric, nitric, hydrochloric, trichloracetic	Yellow, brown gray, or black eschar	Vapor	Water and soap	$Mg(OH)_2$ or $NaHCO_3$ solution
Hydrofluoric	Erythema with central necrosis	None	Water	Calcium gluconate (10%) subcutaneously
Oxalic	Chalky white indolent ulcers	Ingestion only	Water	Calcium gluconate (10%)
Phenol (carbolic) and analogs	Painless, white, or brown skin burn	Skin absorption	Water	Ethyl alcohol (10%) or glycerol
Chromic	Ulceration, blisters	Vapor	Water	Sodium hyposulfite
Hypochlorous (Clorox®, The Clorox Co., Oakland, CA)	Second degree	None	Water	Sodium thiosulfate (1%)
Other Acids				
Tungstic, picric, tannic, cresylic, formic (cavity fluid)	Hard eschar	Skin absorption	Water	Cover with oil
Lyes				
NaOH, KOH, $Ba(OH)_3$, $Ba_2(OH)_3$, LiOH	Bullous erythema; slimy or slick eschar	Ingestion only	Water	Weak (0.5–5%) acetic acid; lemon juice
Ammonia (NH_4OH)	Bullous erythema; slimy or slick eschar	Vapor	Water	Weak (0.5–5%) acetic acid; lemon juice
Lime	Bullous erythema; slimy or slick eschar	Ingestion only	Brush off lime in water	Weak (0.5–5%) acetic acid; lemon juice
Alkyl mercury salts	Erythema, blisters	Skin absorption from blisters	Water and remove blisters	Copious irrigation
Sodium metal	Painful deep burns	None	Cover with oil	None, except excision
Vesicants				
Mustard gas	Painful bullae	Vapor	Water; open vesicles during copious lavage	British anti-Lewisite (BAL)
Tear gas	Erythema, ulcers	Vapor	Water	No specific agent
Phosphorus	Erythema to third-degree burn	Tissue absorption	Water; cold water packs	Copper sulfate ($CuSO_4$) for identification only
Ethylene oxide (ETO)	Erythema to third-degree burn	None	Allow to vaporize; then water lavage	No specific agent

* For complete discussion of chemicals and antidotes see Jelenko C. 1974. Chemicals that burn. J *Trauma* 14:65–73.
+ A complete listing and description of injurious chemical agents may be found in *Fire Protection Guide on Hazardous Materials*, 7th ed. Boston, MA: National Fire Protection Association.

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chemical burns, excluding the potential systemic effects of absorption, is similar to that for thermal burns. Once defined, deeper necrosis involving the skin and underlying tissues is best managed by excision and closure, unless the minor size, depth, and location of the wound warrant spontaneous separation and healing by second intention.

ELECTRICAL INJURIES

The severity of the electrical injury is dependent on the type of circuit, voltage, amperage, duration of contact, pathway of the current, tissue resistance, and the tissue's spatial relationship with the current. Electrical injuries are classified as low voltage (<120 V), intermediate voltage (120–1000 V), or high voltage (>1000 V). Most dogs and cats present with low-voltage (alternating household current in the United States) injuries. High-voltage injuries are rarely seen but are often fatal; wild birds, cats, and animals capable of climbing poles occasionally come into contact with high-tension power lines, usually causing instant death. High-voltage injuries are more common in humans as a result of industrial accidents or accidental contact.

Aqueous electrolyte solutions are relatively good electrical conductors with electrical current carried by mobile ions rather than free electrons. Tissues with high electrolyte fluid concentrations conduct electricity the best. Nerves, muscle, and blood have the least resistance. In contrast, skin and bone have the greatest amount of resistance to electrical flow.

Electrical current preferentially flows along low-resistance pathways. Tissue resistance to electrical flow in decreasing order: bone, fat, tendon, skin, muscle, vessel, nerve.

The frictional interaction of colliding molecules generates heat. An electrical current generates heat as it passes through body tissues; electricity can generate temperatures greater than 100 °C. The rate of heating tissues depends on the current intensity, the electrical and thermal properties of the tissues, and the spatial relationship of the tissue with the current. As noted, tissues have different electrical conductivities and dissipate heat at different rates. In tissues electrically parallel relative to the source of the current, heat generation occurs at a rate directly proportional to tissue conductivity. In tissues that are electrically in series, heat generation is inversely proportional to tissue conductivity. In experimental models, muscle generates the highest temperatures; on cessation of the current, the muscle can heat other adjacent tissues, including bone. Convective transport of heat through blood is critical for rapid cooling. Tissue injury is severe where the current density is greatest—at the point of contact. Electrical contact with a small surface area results in a concentration of energy that causes coagulation necrosis. As a result, injuries to the tissue deep to the contact burn can be extensive.

Electrical contact with a broad surface area of the body decreases the current density with dissipation of the energy. No burns may be noted in these cases, although fatal ventricular fibrillation may occur. More recent studies indicate that the local electrical field can be of sufficient magnitude to cause electrical breakdown of cell membranes. Muscle destruction may be caused in part by *electroporation*, in which electrical current causes the formation of enlarged pores in the lipid cell membrane; this results in cellular rupture. Muscle and nerve cells appear to be more vulnerable to electrical breakdown.

Electrical current follows the path of least resistance, particularly with low-voltage sources. Skin resistance depends on the thickness of skin; resistance is lowered, however, when the surface is wet. Neurovascular channels offer the least resistance followed by muscle, skin, and bone. Nerves and vessels are particularly sensitive to electrical injury whereas bone is least sensitive to injury. Studies suggest that all tissues beneath the skin function as a single conductor (or resistor). Tissue damage is normally the result of converting electrical current to heat. Current intensity is greater in small cross-sectional areas such as the extremities, whereas large areas dissipate current over a wider area. Small vessels undergo thrombosis, whereas large vessels may maintain blood flow despite the occasional formation of mural thrombi. Small nutrient vessels in skeletal muscle are particularly sensitive to thrombosis, resulting in deep muscle necrosis in selected cases. Due to the electrical resistance property of bone, electricity can flow along the skeleton and generate high temperatures, which in turn damage the adjacent musculature. Production of thromboxane A, a vasoactive prostanoid that causes vasoconstriction, thrombosis, and ischemia, enhances tissue necrosis.

The majority of small animal electrical injuries in the United States are associated with low-voltage household alternating current (60 Hz) within the frequency range known to cause striated muscle tetany and nervous tissue paralysis. This tetanic muscle contraction results in the "no-let-go" phenomenon in humans. Grasping a live electrical source causes the stronger forearm flexors to contract, overpowering the weaker forearm extensors; this results in a (no-let-go) locked grip.

The heart and respiratory centers are more sensitive to alternating current than direct current. Low-amperage 60 Hz current passing through the head of the dog and cat produces convulsions and respiratory paralysis. Low-voltage current is capable of causing fatal ventricular

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fibrillation, whereas a high voltage (>1000 V) can produce respiratory and cardiac arrest. Ventricular rhythm may resume in those cases when the high-voltage current is removed. Cardiopulmonary resuscitation may be necessary once the patient is separated from the electrical source.

Resultant low-voltage oral burns commonly involve the commissure of the lips, gums, tongue, and palate in small animals (Fig. 7-22). A centroneurogenic-mediated increase in peripheral vascular resistance has been implicated as the cause of the fulminating pulmonary edema occasionally seen with oral electrical burns in young dogs and cats that bite live electrical cords. Pulmonary edema would appear to be a greater problem in dogs. Aggressive treatment with oxygen, diuretics, and corticosteroids is indicated (see the next section).

As noted, high-voltage current injuries are uncommon in pets and are usually fatal. The contact or entry point is usually depressed, charred, and leathery, whereas the exit wound at the ground point may be explosive. Electricity can cause thermal burns due to arcing of the current between the source and the conductor or when the arc crosses a flexor surface, causing flame burns when the arc ignites materials adjacent to it. Electrical arcs occur

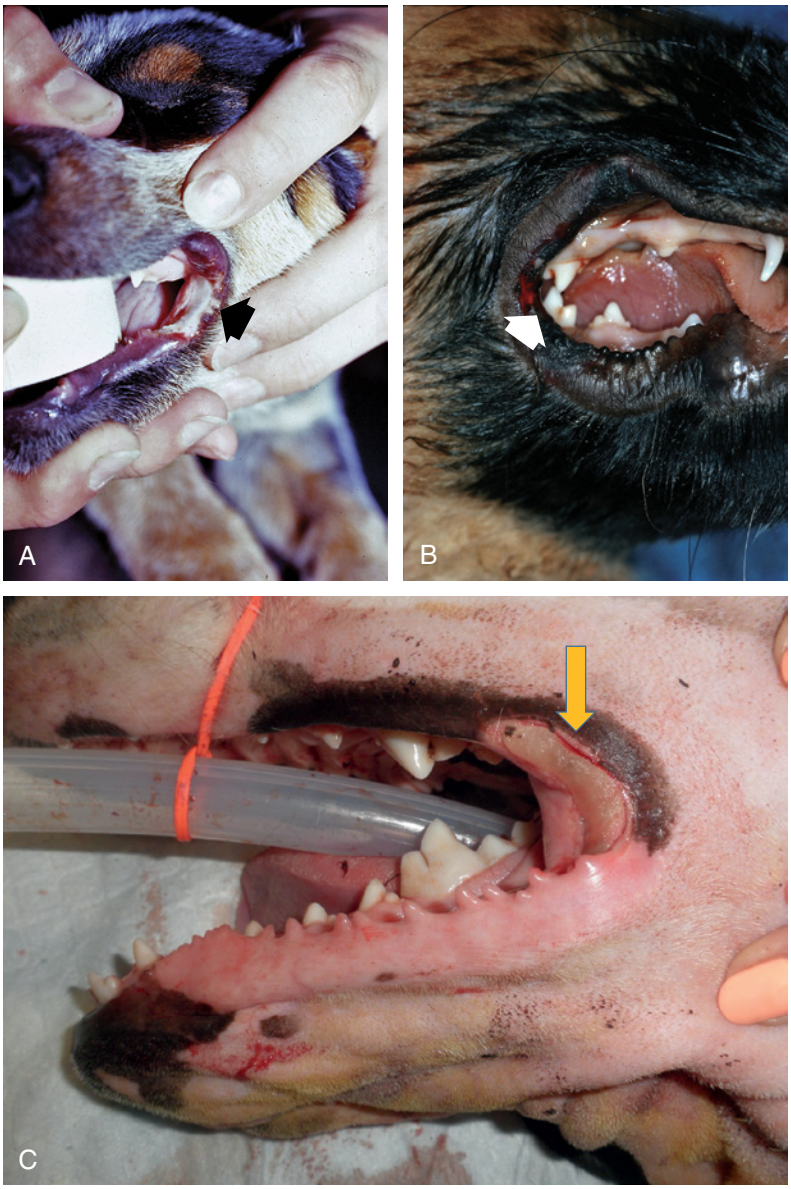


FIG. 7-22 (A) Electrical cord burn involving the oral commissure. Note the pale, bloodless wound (arrow). (B) Other electrical burns can appear brown to black, with possible local hemorrhage (arrow). (C) Hird example with a pale brown eschar (arrow).

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at temperatures up to 4000 °C. Electrical current also can arc to an adjacent area if immediate grounding does not take place. Among the organs injured in association with high-voltage electrical passage through the body of humans are the esophagus, pancreas, gall bladder, small intestine, colon, skeleton, and lungs, depending on the point of contact, the course of the current through the body, and the point of exit. Immediate and delayed spinal-cord injuries have been reported in humans from vascular and thermal damage. Such injuries may be temporary or permanent.

Necrosis of small intestine, secondary to low-voltage injury, has not been reported in animals but has been reported in humans. This may be explained by current passage down the anterior mesenteric artery, with heat dissipation in the terminal arteriolar branches causing bowel infarction. Paralytic ileus may also be noted. Despite the fact that this injury has not been noted in small animals, the veterinarian should be alert to vomiting and abdominal pain that may suggest bowel injury in animals known to have been injured by electrical current.

Management of Electrical Wounds

Electrical burns have three potential types of injury: (1) injury from current flow, (2) arc injury as electricity jumps from the source to an object, and (3) flame injury secondary to burning of clothing (humans) or adjacent flammable materials. Typically, the owner will report seeing their pet bite an electrical cord or encountering their pet in a state of tetany with the cord in its mouth. After the cord is disconnected from the electrical outlet, many dogs will resume breathing. On occasion, owners will report that they resuscitated their dog or cat by breathing through the pet's nose. Intravenous fluid therapy must be performed with caution, since many dogs and cats will develop pulmonary edema, as discussed previously. Close auscultation of the patient may detect moist rales, indicative of edema, which can be confirmed with thoracic radiographs. Cardiac and renal function must be closely assessed on presentation.

In the presence of life-threatening pulmonary edema, oxygen therapy and the intravenous administration of a fast-acting diuretic, such as furosemide, are indicated. Corticosteroids may be useful. Analgesics (morphine, etc.) are useful to reduce pain and patient anxiety. Morphine can have a sympatholytic and vasodilatory effect; bronchodilators (aminophylline) also may improve respiration and cause vasodilation. In refractory cases, sodium nitroprusside has been cautiously administered. Readers are directed to standard medical textbooks for further information.

As noted, most electrical burns from household current occur in and around the oral cavity. The burns are usually slow to slough and heal (Fig. 7-22). Many of the mild injuries slough and heal within 3 weeks without the need for surgical debridement. Oronasal fistula development in dogs and cats requires closure with mucosal flaps, labial advancement flaps, or skin flaps (Fig. 7-23). Damage to the adjacent dental arcade in young dogs and cats can result in deviation of teeth, possibly necessitating their extraction.

Like other major thermal injuries, large areas of necrosis warrant debridement and eventual closure as the severity of the wound becomes more apparent. In humans, fasciotomy has been required for injured muscle groups in order to prevent development of the compartmental syndrome secondary to high-voltage electrical burns.

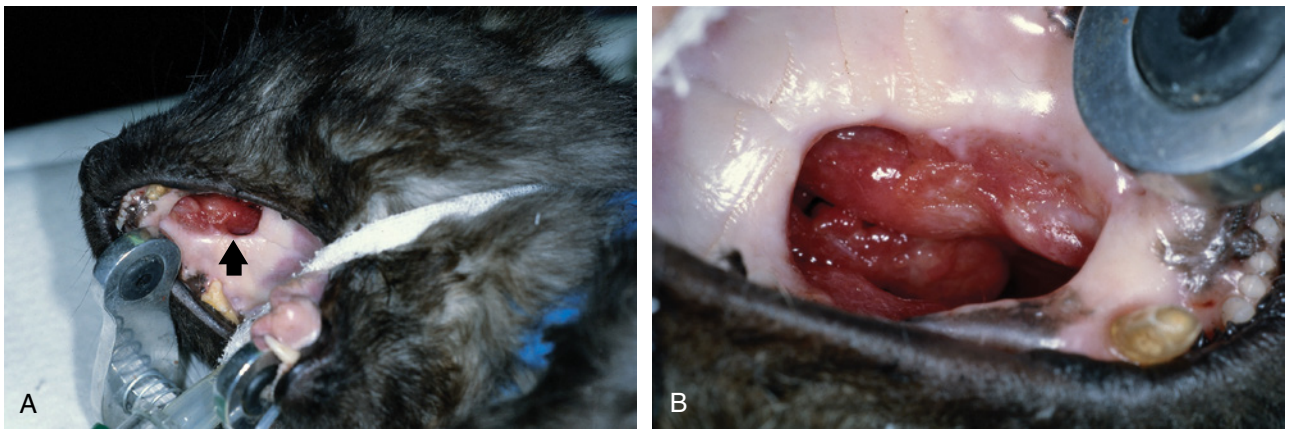


FIG. 7-23 (A) Oronasal fistula (arrow) in a cat secondary to biting an electrical cord. (B) Full-thickness necrosis of the hard palate is evident. Closure was accomplished with a labial advancement flap (see Plate 115).

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RADIATION INJURIES

Radiation is a general term for any form of radiant energy emission from roentgen ray tubes, radioactive elements, luminous bodies, or fluorescent substances. Burns from solar (actinic) radiation are not a common problem in veterinary medicine; however, in regions where solar intensity is the greatest, body areas lacking hair and pigmentation are susceptible to actinic injury (Fig. 7-24). The majority of the discussion in this section, however, is devoted to complications associated with radiotherapy. Radiation injury concerns the veterinary surgeon from two perspectives: first, its influence on healing in association with surgery, and second, management of nonhealing radiation ulcers.

Ionizing radiation therapy is an important component in the treatment of a variety of neoplasms in small animals. Radiation particles are one of three types: alpha particles, beta particles, and gamma particles. Alpha (helium nuclei) particles emitted by radium implants have limited penetrating ability. Beta particles (negatively charged electrons) can penetrate tissue by 1–2 cm; their use in radiation therapy generally is limited to skin cancer and other superficial lesions. Gamma particles are capable of deep tissue penetration and are the major form of therapeutic radiation for cancer. Orthovoltage radiotherapy is delivered by X-ray–producing units capable of a power range of 250–500 kV. Photons at this energy level are concentrated in the skin and superficial tissues. Orthovoltage may be useful for superficial neoplasms. If used for more invasive tumors, excessive doses can result in a greater likelihood of significant skin damage. Orthovoltage is uncommonly used today in favor of megavoltage therapies.

Megavoltage radiotherapy is delivered by radioisotope teletherapy or linear accelerator units in the form of high-energy X-rays, gamma rays, or electrons. Photons provided by megavoltage units have an energy range of 1–35 million volts. High-energy photons are capable of deeper penetration and a skin-sparing effect. Neutron radiotherapy involves neutron bombardment of tissues but is not commonly used these days in veterinary medicine.

The success of radiation therapy resides in applying lethal doses to cancer cells, while subjecting normal tissues to sublethal levels. Unfortunately, because high doses of radiation may be required to achieve cancer control, there is an increased likelihood of damage to normal tissues, including tissue necrosis, extensive fibrosis, and compromise to local tissue circulation.

Changes occur in irradiated tissue that can have early or acute effects and delayed or late effects on healing. Acute radiation side effects occur within the first few weeks following radiation treatment as a result of the death of rapidly dividing cells and inflammation. The initial acute reactions in skin or mucosa are erythema and desquamation. Acute radiodermatitis has been classified into four degrees: a first-degree or Grade 1 reaction is cutaneous reddening; a second-degree or Grade 2 reaction is characterized by a dry desquamation resulting from a loss of the outer epidermis; a third-degree or Grade 3 reaction is characterized by moist desquamation resulting from destruction of the basal epidermal layer; and a fourth-degree or Grade 4 burn is characterized by complete skin necrosis (Fig. 7-25). These changes are dose and volume related. In humans, one report noted that 85% of patients will have a moderate to severe skin

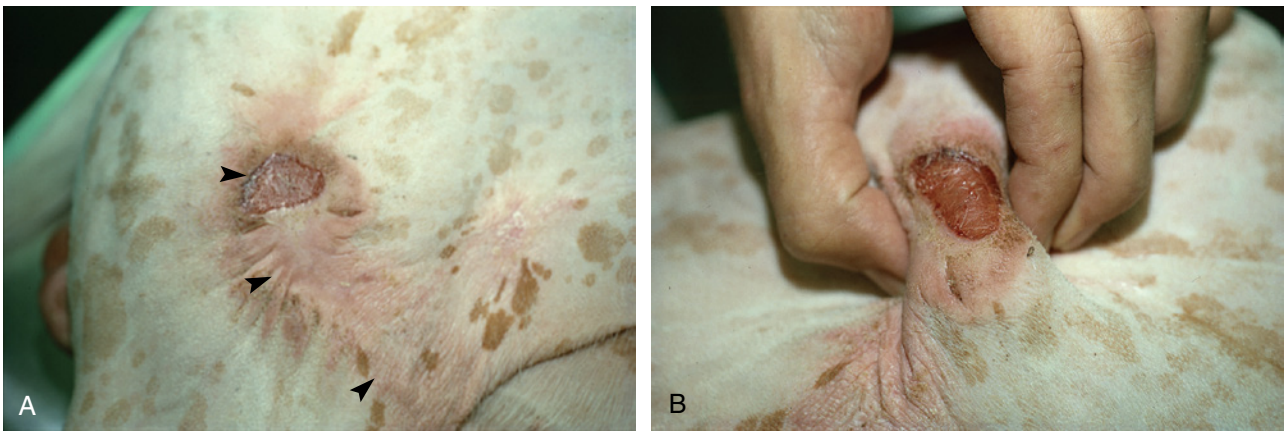


FIG. 7-24 (A, B) Repeated blistering and ulceration (arrows) of an epithelialized scar in a field trial dog from prolonged solar exposure (actinic radiation). The scar was the result of the dog falling out of a moving pickup truck several months before presentation. Scar excision and advancement of hair-bearing peripheral skin were curative. Tissue was submitted for histopathologic examination to assure squamous cell carcinoma was not present.

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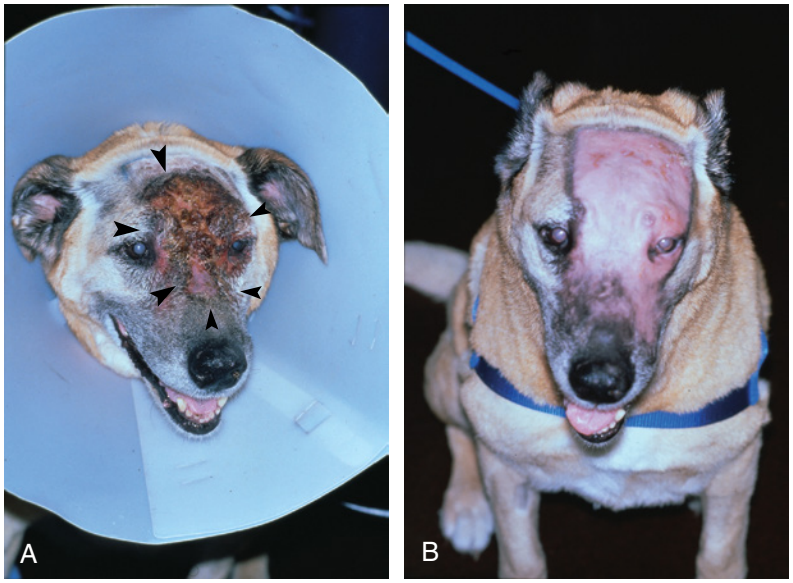


FIG. 7-25 (A) Erythema and moist desquamation after completion of orthovoltage therapy (arrows) for the treatment of a nasal carcinoma. (B) The patient 10 days later. Moist crust patches have disappeared, the result of reepithelialization from germinal epithelial cells of the epidermis and cutaneous adnexa.

reaction with blistering, ulceration, and erosion; severe adverse effects can delay the course of treatments.

Severe erythema shortly after radiation therapy indicates a more serious burn injury. Later changes observed following radiation therapy include hair loss and alterations in skin pigmentation, depending on the radiation dose, area irradiated, and individual sensitivity. Hair-covered skin is less sensitive compared to hairless skin. In the skin, surviving germinal cells (basal layer) repopulate areas when epithelial cells are destroyed. Around 2–4 weeks following completion of radiation therapy, dry desquamation (nonpainful flaking of the upper cutaneous layers) can progress to painful moist desquamation with exudation. Severe radiation damage can result in acute ulceration with a loss of germinal cells required for epithelial repopulation.

Many of the acute side effects are transient and normally begin to heal within 2–3 weeks following completion of the radiation therapy. Most cases of simple radiation dermatitis can be managed with a variety of basic topical agents. Surgeons, however, are concerned with the management of the more severe wounds, particularly in chronic ulceration where healing is problematic. Because hair follicles and adnexal glands are radiosensitive at relatively low doses of radiation, hair loss may be temporary or permanent.

Certain anatomic locations are noted to have an increased risk for severe dermatitis during radiation therapy. They include footpads, perineum, periocular skin, and skin folds, including the facial folds of brachycephalic dogs.

Late or chronic changes noted in previously irradiated skin include thinning and flattening of the epidermis, a decline in adnexal structures, and obliteration of rete pegs. Grossly, the skin may demonstrate dryness, thinning, induration and loss of pliability from fibrosis, and increased pigmentation with a reduction of hair growth (Fig. 7-26).

The most significant late change is a progressive decline in circulation over time. Chronic obliterative endarteritis is noted, characterized by endothelial proliferation, subintimal fibrosis, and gradual reduction in lumen diameter. Perivascular infiltrate also is present. The ischemia that ensues will impede healing to a variable degree. If incising into a previously irradiated field is unavoidable, the surgeon should avoid or minimize surgical maneuvers that may further compromise tissue. Precautions are essential to prevent contamination during surgery, since ischemic tissues are more susceptible to infection. Open wounds have a particularly difficult time healing by second intention, since neovascularization, wound contraction (myofibroblastic activity), fibroplasia, and epithelialization are impaired. A loss of fibroblasts and their stem cells also impairs the formation of blood vessels. The low capillary content and collagen-laden wound bed present form an unstable base for migrating epithelial cells. Any epithelialized surface formed is more susceptible to trauma. Split-thickness grafts and direct distant flaps cannot be sustained on wound beds characterized by these chronic changes (Fig. 7-27).

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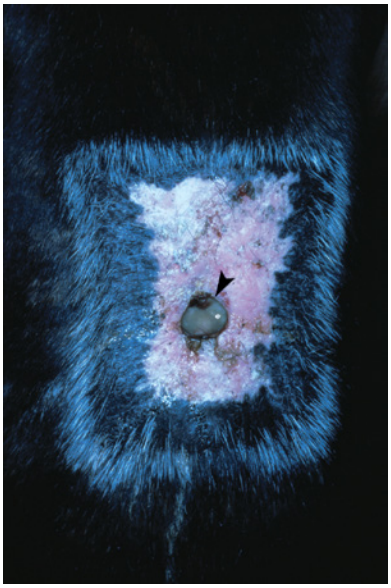


FIG. 7-26 Chronic ulcer several months after completion of radiotherapy (arrow). Note the sparse hair growth, the nonpigmented hair at the periphery of the radiation field, and the dry, flaky epithelial surface.



FIG. 7-27 Necrosis of skin, muscle, and tendon overlying the carpus as a result of radiation therapy. Necrotic tissue, infection, and impaired regional circulation create a major challenge to the veterinary plastic surgeon who attempts to close this wound.

In general, an uncomplicated closed surgical wound can safely receive radiotherapy as early as 1 week postoperatively. Similarly, elective surgery can be performed 4–8 weeks after radiation therapy is discontinued, because inflammation secondary to irradiation is subsiding and circulation is still satisfactory. As time passes, however, tissue loses vascularity to a degree proportional to the radiation source, size of the area irradiated, fractionation of the total dose, and length of time during which the total dose was administered.

Management of Radiation Wounds

Grade 1 injuries can be treated with hydrophilic moisturizers. Corticosteroid use appears to have little efficacy. Grade 2 and 3 radiation burns focus on preventing secondary infection. Hydrogel dressings, topical hydrocolloids, or the use of silver sulfadiazine ointment are treatment options. For pruritus, diphenhydramine can be administered and Elizabethan collars can be used to prevent self-mutilation. In cases of severe exudative wounds, the area should be gently clipped of fur and cleansed followed by the administration of broad-spectrum antibiotics. Grade 4 burns, with the complete destruction of the skin, likely will require debridement followed by the use of pedicle grafts or skin grafts (provided the wound bed has sufficient vascularity to support the free graft). Pain medication including gabapentin, amantadine, and nonsteroidal anti-inflammatory drugs (NSAIDs) can be administered as needed. Stronger analgesics may be required in more severe cases of patient discomfort.

In most patients, chronic changes following radiation therapy are primarily cosmetic, including alopecia, change in hair coloration (white or gray: leukotrichia), alterations in skin pigmentation (both hypo- and hyperpigmentation), and fibrosis. Chronic wounds require follow-up assessment since surgical intervention may be required over time. Radiation ulcers can develop 10–20 years after exposure in humans. In small animals, ulceration is more likely to occur within weeks to months after therapy. Treatment includes debridement of necrotic tissue, control of infection, and early wound closure. If the wound can be excised down to healthy vascular tissue, skin grafts can survive. However, skin grafts are unlikely to survive on an incompletely excised, chronic, irradiated wound bed. It must be noted that more powerful radiotherapy units can damage deeper tissues, making complete excision down to viable vascular tissue difficult or impossible. Tissue excised should be submitted for histopathologic examination to ensure neoplasia has not recurred. Additionally, neoplasms can develop as a result of irradiation or chronic inflammation such as Margolin ulcers (squamous cell carcinoma) in nonhealing burn wounds.

Skin flaps, myocutaneous flaps, muscle flaps, and omentum may be used to close chronic ulcers (see Chapters 15, 16, and 24). Properly created flaps have their

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own inherent circulation and do not require circulation provided by the wound bed, as long as their vascular pedicle is maintained. Local skin flaps can be attempted in order to close smaller debrided ulcers, although the veterinarian must consider that the regional skin also may have been affected by the previous radiation treatment. Local flap failure is more likely than flaps created outside the general region irradiated. Axial pattern flaps may be ideally suited due to their excellent circulation and length compared to flaps based on the subdermal plexus alone. Muscle flaps can contribute circulation to ischemic areas and provide a vascular surface for free graft coverage. Myocutaneous flaps can provide simultaneous wound coverage while providing a muscle surface to supply circulation to ischemic areas. Omentum can be mobilized and passed through a small abdominal access incision, delivering this vascular tissue to poorly vascularized ulcers within its reach. Improvement in regional circulation will enable the surgeon to apply a graft to the viable omental surface, if needed. See Plate 101 pertaining to nasocutaneous fistula reconstruction.

Ischemic radiation ulcers normally do not support free grafts in humans. Local flaps may not be possible if the skin peripheral to the ulcer also was exposed to the radiation field. In the face of an ischemic wound bed, distant direct flaps will likely fail, since division of the pedicle(s) relies on revascularization of the transferred flap from the recipient bed. As a result, any tissue flaps require an intact vascular pedicle to support their long-term survival in areas with marginal circulatory support.

FROSTBITE

Frostbite is a severe thrombotic ischemic disorder that results from tissue vascular damage from subzero temperature tissue exposure. Contact with metal and other materials that rapidly conduct cold, including water, gasoline, and other industrial chemicals, can rapidly accelerate the freezing process. The thermal conductivity of water, for example, is 32 times greater than that of still air. Cold air alone, however, is not nearly as dangerous a freezing factor as the combination of chilling air and wind. Animals who lose their insulation properties are susceptible to hypothermia and frostbite as peripheral circulation is diverted to maintain body core temperature. Children and the elderly are more prone to frostbite injury due to their reduced capacity to generate metabolic heat. Other health conditions, including diabetes, hypothyroidism, hypoglycemia, and adrenal insufficiency, result in decreased metabolic heat production. Neuropathies and spinal-cord damage also can impair the cold-reflex vasoconstriction. In humans the freezing point of tissue is –0.53 °C to –0.65 °C.

High-altitude locations with lower oxygen content in the air can increase the likelihood of cold injury in animals and persons unaccustomed to it. Exertion and labored breathing in this environment accelerates heat loss through the lungs. Inadequate caloric intake can reduce the ability of the animal to generate heat. Wind speed also is a factor inducing frostbite. The heat-production capacity of the body and the ability to conserve heat are two of the most important factors in the prevention of cold injuries. Frostbite can occur in above-freezing temperatures from prolonged immersion in animals who lack the insulation and protective physiologic mechanisms that other species possess for adverse conditions.

Several mechanisms have been proposed to explain tissue injury and death after exposure to cold. Extracellular ice-crystal formation may damage cells. As these extracellular crystals form, osmotic pressure increases in this space, with the loss of intracellular water leading to cellular dehydration and hyperosmolality. Intracellular electrolyte imbalance and damage to cellular proteins/membranes contribute to cell necrosis. Rapid freezing can result in fatal intracellular ice-crystal formation. Endothelial cell injury may precipitate thrombosis. Arteriolar vasospasm and vasoconstriction, combined with shunting of blood from arterioles to venules, direct oxygen, nutrients, and warmth from the frozen tissue in an effort to preserve central core temperature. Ischemic perfusion/reperfusion injury plays a significant role in the loss of tissue. As blood viscosity increases, sludging and thrombosis also may occur. Unless the source of cold is removed, tissues continue to freeze and the depth of the damage increases with prolongation of contact. A transient (5–10 minutes) vasodilation response may be noted to an affected limb (called the "hunting response"), which is a physiologic response in an attempt to protect the extremities from cold injury. As cooling progresses, the blood is progressively shunted to preserve core body temperature.

In humans, frostbite is classified into four categories. Grade 1 injuries are limited to superficial exposure with redness and hyperemia. This superficial first-degree frostbite is most commonly seen in persons and normally involves the toes followed by the hands. The nose and pinna of the ear are also common sites of grade 1 frostbite. Grade 2 injuries include full-thickness skin freezing, blister formation, erythema, edema, desquamation, and black eschar formation. Grade 3 injuries include freezing of the skin and subcutaneous freezing, hemorrhagic blisters, and skin necrosis with a blue-gray discoloration. Grade 4 injuries include freezing of the skin, subcutis, muscle, tendon and bone. Grade 4 injuries

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normally have little edema and the tissue appears mottled, with a deep red discoloration that may eventually result in dry, black, mummified tissues without surgical intervention.

Nonfreezing cold injuries can be noted from prolonged exposure to cold water at near freezing temperatures. Resultant capillary damage can result in tissue ischemia and necrosis. "Trench foot" is the term used for this cold-tissue injury in soldiers exposed to cold, damp conditions in association with poor hygiene.

Lastly, accidental or inappropriate use of liquid nitrogen and nitrous oxide during cryosurgical procedures can result in serious injury to adjacent healthy tissues as well. In all, the type and duration of cold contact are the two most important factors in determining frostbite.

Frostbite Assessment

On initial manual examination, superficial frostbite is classically characterized by soft and resilient tissues underlying the outer layer of rigid tissue. Deep frostbite is characterized by firm or stiff tissue beneath the outer rigid tissue layer. Unless the injury is obviously minor, the severity of the frostbite injury cannot be determined initially. Mild and severe cases of frostbite may be indistinguishable for 2–4 weeks in humans.

In humans, the Hennepin Frostbite Score is used to quantify injury and tissue loss associated with frostbite. It enables the clinician to determine the efficacy of treatment through calculation of the salvage rate. As a result, more accurate assessment of treatment modalities can be determined. In more recent years, assessment of the microcirculation and degree of vascular impairment is considered key to determining the severity of tissue trauma. Radiography, angiography (digital subtraction), multiphase bone scintigraphy with photon emission CT, speckle contrast imaging, and laser Doppler blood flowmetry are modalities used to assess blood supply to the frostbite tissues. Microangiography with fluorescent indocyanine green (IcG) also has been used effectively without the need for radioisotopes or exposure to radiation. Doppler flowmetry can assess cutaneous microcirculation to the depth of 0.5 mm.

Management of Frostbite

If a patient presents with early frostbite, the affected area(s) should be rewarmed (Fig. 7-28). Immersion of the affected area in a receptacle of sufficient volume to maintain a uniform temperature of 104–108 °F (40–42 °C) for approximately 30 minutes or until rewarming is judged complete is ideal. Tissues should never be rubbed or massaged. Soft, dry protective bandages are indicated in small animals. Restriction of activity is required when the feet are involved.

The use of thrombolytic drugs, including tissue plasminogen activator and prostacyclin, has shown considerable efficacy in reducing the need for amputation of extremities affected by severe frostbite; they are most effective when administered within 6–24 hours of rewarming. Iloprost, a synthetic analog of prostacyclin PG12, can be beneficial in reducing the need for amputations when administered within 48–72 hours of rewarming. Pentoxifylline has been noted to be beneficial in increasing the deformability of red blood cells, facilitating their passage into the smaller damaged vessels when given for 2–6 weeks. It also is an anti-aggregatory drug, reducing the viscosity of blood. The drug alpha-trinositol also has been used in the acute inflammatory phase of frostbite, reducing cold-induced edema and interstitial fluid pressure. Hyperbaric oxygen therapy also shows promise in improving tissue survival. Newer drug treatment regimens (*Ginkgo biloba*, *Ganoderma* triterpenes, low-frequency electromagnetic pulse field treatment, essential oils, botulinum toxin, calcium channel blockers, and topical L-arginine hydrochloride are currently under investigation.

Maintaining hydration and a balanced diet is essential. Analgesics may be indicated. Topical antiseptics and judicious debridement of necrotic tissue as necrosis defines itself are required. Systemic antibiotics should be considered. As noted, because of the low incidence of frostbite in small animals and the initial lack of its recognition by most owners, the veterinarian is usually contacted only after signs of necrosis become evident. Surgical debridement or amputation of the affected area may be necessary if natural separation has not occurred.

PROJECTILE INJURIES

Gunshot wounds to pets and wildlife are not uncommon in rural and inner-city areas of the United States. Gunshot wounds may be deliberate or accidental. For example, hunting dogs occasionally may be in the line of fire during bird hunting, sustaining pellet injuries. Most veterinarians have limited knowledge of the subject of ballistics and the treatment of projectile injuries. This section reviews the basic concepts of this surprisingly complex subject.

Ballistics is the science of motion of a projectile during its travel through the barrel of a firearm (interior ballistics), its subsequent path through the air (exterior ballistics), and its final path into the target (terminal ballistics). The seriousness of bullet wounds often is considered to be limited to those tissues in the direct path of the projectile.

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FIG. 7-28 (A) Close-up view of a kitten with severe frostbite to its paws as a result of being trapped in a freezer for several hours. Extensive edema is noted. The patient reportedly climbed into the refrigerator when the owner's children left the door open. Direct contact with the cold metallic shelving enhanced the freezing process. (B, C) Within days, a clear demarcation of viable and nonviable tissue was noted (arrows); digits on all four paws subsequently sloughed. (D) Necrotic tissue was trimmed; portions of the skin wounds were sutured. Other areas healed by second intention. The patient did well as a house cat despite these unfortunate circumstances. A similar injury in larger dogs would be considered catastrophic.

However, under some circumstances the wounding potential of projectiles can occur beyond the pathway of a projectile.

Missiles are any projectiles, including bullets, pellets, fragments from grenades, and explosive shells. A cartridge (round) is composed of four basic components: primer, case, powder, and bullet. The primer, located at the base of a centerfire or rimfire cartridge, usually contains the compounds lead styphnate, barium nitrate, and antimony sulfide. Small arms cartridges are classified as *centerfire* or *rimfire*, depending on the location of the primer. In centerfire cartridges there are two types of primers: Boxer and Berden. American centerfire cartridges are Boxer primers. When struck, the primer at the cartridge base explodes and ignites the powder charge (propellant) in the casing as the flame passes through the flash hole(s) (Fig. 7-29). Black powder, a mixture of charcoal, sulfur, and potassium nitrate, was the propellant used until the end of the nineteenth century. Modern weapons use smokeless powder, composed of a single- or double-base nitrocellulose. Burning of the propellant within the confines of the casing releases gas to propel the bullet. Pyrodex, a synthetic black powder, has replaced the original black powder for older black-powder weapons and replicas. Spiral grooves cut in the interior bore or barrel (rifling) impart rotation or spin along the bullet's

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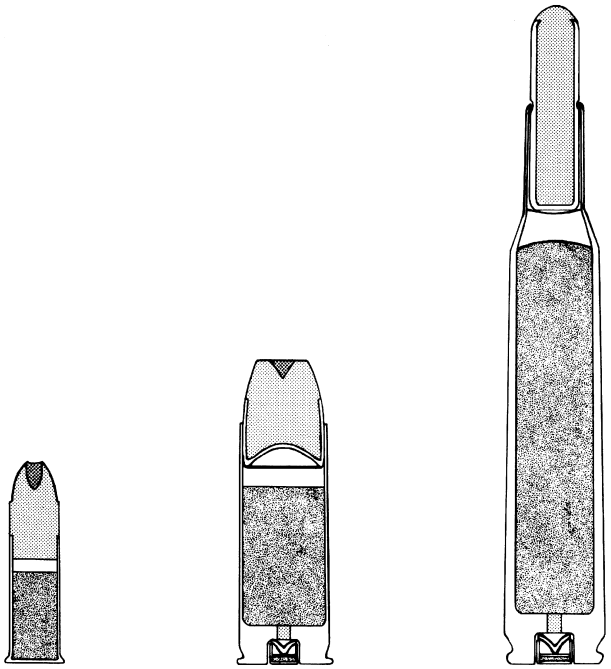


FIG. 7-29 Cross-section of three cartridges (rounds) demonstrating the components of a cartridge: primer, case, powder, and bullet. The example includes (left) a .22 caliber hollow-point rimfire cartridge, (center) a .38 caliber partially jacketed centerfire handgun cartridge, and (right) a .30 caliber partially jacketed centerfire hunting rifle cartridge. The priming mixture in the .22 rimfire is located at the rim base of the cartridge case, unlike the centrally located primer in the centerfire cartridges. (Source: 1981 Winchester Sporting Arms and Ammunition Catalog, Olin Corp., Winchester Group, New Haven, CT. Modified with permission.)

longitudinal axis, thus stabilizing its flight in a gyroscopic fashion. The metal between the "twist" or length of a complete revolution of rifling varies by manufacturer. The grooves are called *lands*.

The three basic theories that have been used to explain the wounding capacity of projectiles in the medical literature include momentum theory, kinetic energy theory, and power theory. None takes into account all the factors that influence bullet destructiveness. The kinetic energy theory, however, is the most popular and is considered the most accurate in describing the potential lethal effects of projectiles:

$$\frac{\text{Mass} \times \text{Velocity}^2}{2g\left[\text{where acceleration of gravity}\left(32.16\,\text{ft}/\text{s}^2\right)\right]}$$

The formula demonstrates an important fact pertaining to the kinetic energy of a given projectile: doubling the missile mass increases the energy of the projectile by a factor of 2, but doubling the velocity quadruples the kinetic energy. Lighter bullets can be driven at greater velocities and maintain a commensurately lower chamber pressure than can larger projectiles, with a lower recoil or rifle "kick." Moreover, a smaller projectile traveling at a high velocity has a flatter trajectory for greater accuracy. The mass, shape, design, and composition of a bullet also will influence its function and capacity to inflict trauma.

Projectile Caliber and Design

Bullet caliber generally is considered to be the diameter of the slug or weapon bore (from land to land) measured in millimeters or thousandths of an inch (two digits, hundredths; three digits, thousandths). However, caliber may be given in terms of bullet, land, or groove diameter. Unfortunately, caliber specification using the US system is neither accurate nor consistent. Although US ammunition has been measured in fractions of an inch in the past, many manufacturers presently employ metric terminology, including the 5.56 mm M-16 and 7.62 NATO. For historical reasons, some cartridges corresponding to caliber .30 rifles show cartridge designations made of two figures: the first referring to the caliber and the second to the year of introduction or the original powder charge. For example, a cartridge designated .30-06 means a .30 caliber bullet introduced in the year 1906. This is a common cartridge employed in the M-1 and other rifles. A .30-30 and .30-40 designation indicates the caliber and the number of grains of gunpowder (30 grains, 40 grains) in the cartridge. Occasionally, the second number indicates the muzzle velocity of the projectile (250–3000 ft/s). Some of the caliber .30 designations include the name of the manufacturer or person who developed the cartridge (.30 Remington, .30-30 Winchester, .30-40 Krag, .30-06 Springfield, etc.). US cartridges that originally used black powder are designated by caliber, powder charge, and bullet weight (for example, .45-70-405). Some manufacturers refer to bullet caliber and cartridge length. In all, literally thousands of handgun and rifle cartridges have been developed over the years, with nomenclatures that are modified and formulated by manufacturers.

It is important to note that bullets of the same caliber can vary according to their weight, velocity, design, shape, composition, and, accordingly, potential wounding capacity. Most military rifle bullets throughout the world weigh between 40 and 200 grains, including the .223 caliber (5.56 mm) M-16 cartridge with a slug weight of 55 grains. Hunting bullets range from 50 to 350 grains, depending on their intended use. Shotguns are measured according to their gauge and are capable of firing pellets of variable diameters.

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Low-velocity projectiles travel less than 1000 ft/s, medium-velocity projectiles between 1000 and 2000 ft/s, and high-velocity projectiles faster than 2000 ft/s. However, 2500 ft/s and above generally is selected as the designated speed for high-velocity projectiles. Most handguns fire bullets in the low- to medium-velocity range, whereas most rifles fire bullets in the medium- to high-velocity range. The projectile design and composition also will influence how rapidly the bullet loses its velocity and the wounding capability on impact. High-velocity bullets are of two basic designs: full patch (military) and expanding (hunting). In 1908 the Hague Convention (and the subsequent 1949 Geneva Convention), recognizing the horrendous wounding potential of expanding (deforming) bullets, advocated the use of fully jacketed (full-patch) bullets in warfare (Fig. 7-30). The outer jacket, composed of metals with a higher melting point than the lead alloy core (copper, cupronickel, brass, soft steel), restricts bullet deformation during passage through the barrel, lead residue fouling of the barrel, and deformation on impact with the target. Most bullets are composed of 90% lead with 10% antimony or tin employed as a hardener. In the case of bird shot, the US Fish and Wildlife Service mandated the replacement of lead with steel shot to prevent lead poisoning in waterfowl and protect avian species from its accidental ingestion. However, some are composed of zinc, magnesium, clay, wood, plastic, rubber, or wax, depending on their intended purpose. Fully jacketed bullets have greater penetration into the target than partial or nonjacketed bullets that flatten or "mushroom" to a variable degree on impact, thus increasing their resistance during penetration and passage (Fig. 7-31).

The conically shaped tract formed by mushrooming hollow-point, or soft lead-tipped, partially jacketed hunting projectiles can form wounds up to 40 times the volume of a military bullet of similar weight and velocity, although the full-patch projectile also is capable of causing sizable tracts due to flight instability and occasional fragmentation achieved at very high velocities.

As noted, bullets can be modified in various fashions to enhance deformation by exposing a variable portion of the soft lead alloy at the tip (partially jacketed bullet), by designing a bullet with an exposed hollow tip, or by flattening the bullet and scoring two crossed grooves on its surface (improperly termed *dum-dums*). Other bullet designs are on the market that promote deformation on impact. A hollow-point soft-tip bullet can expand twofold to threefold. A partial jacket may be included to protect the soft lead from deformation and fouling during its passage through the barrel and to provide controlled expansion and penetration in the

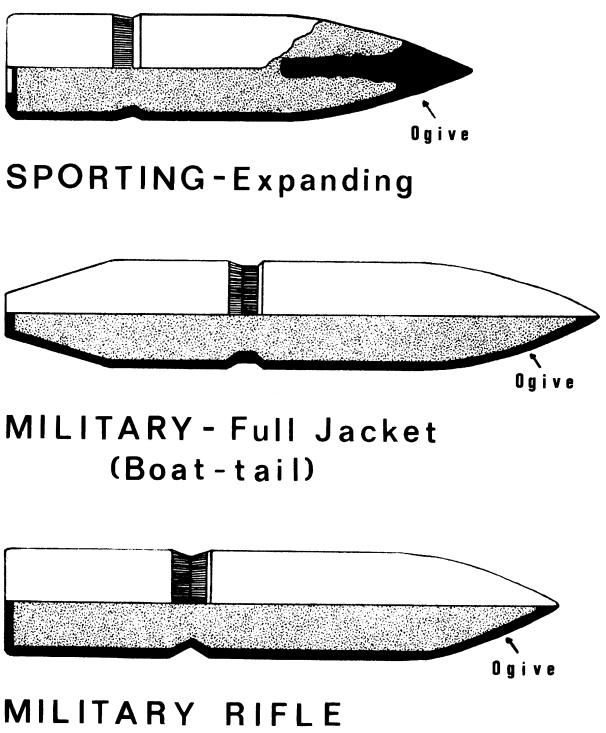


FIG. 7-30 Cross-section of the sporting or hunting bullet and military fully jacketed (full-patch) spitzer bullets. Note the exposed soft-lead tip in the hunting bullet, which promotes expansion (mushrooming) and fragmentation on impact. Fully jacketed bullets have the lead core encased in an outer metallic sheath to minimize expansion on impact; however, many military bullets have been known to fragment on impact at high velocity. The boat-tail design has a minor influence on the bullet's velocity. (Source: DeMuth WE. 1966. Bullet velocity and design as determinants of wounding capability: an experimental study. *J Trauma* 6:222. Modified with permission.)



FIG. 7-31 Illustration of bullet performance on impact with bone. The bullet on the left is an unjacketed .22 handgun bullet that traversed the abdomen of a cat before striking the wing of the ilium. The bullet on the right is a .25 caliber fully jacketed bullet that fractured a lumbar vertebra. Note the lack of deformation compared with the soft-lead .22 slug. (Source: Pavletic MM. 1986 / CAB International. Gunshot wounds in veterinary medicine: projectile ballistics—Part I. *Compend Contin Ed Pract Vet* 8:47–60.)

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target. Rapid deceleration and instability of the expanding bullet as it passes through the target may promote bullet fragmentation and enhance tissue destruction (Figs 7-32 and 7-33). Some bullets are not jacketed but have an outer metallic plating (copper, copper–zinc) and lubricant, as exemplified by the common .22 caliber rimfire cartridge (Fig. 7-34). These thin "protective veneers" do not restrict bullet collapse on impact. Air-powered projectiles, shotguns, and exploding bullets have a few unique features that are worthy of discussion separately. Bullets may have circumferential indentations, called *cannelures*, in which a lubricant is inserted to improve passage through the barrel. A cannelure may be present to allow the casing to crimp onto the bullet and seal the propellant.



FIG. 7-32 Various rifle rounds (from left to right): 5.56 mm full-patch M-16; .243 Winchester hunting; 6 mm hunting; .30 military, armor piercing; .30-06 Springfield hunting; .444 Marlin hunting; .45-70 Government hunting. The partial copper jacket of the sport or hunting bullet provides controlled expansion of the exposed lead core on impact. (Source: Pavletic MM. 1986 / CAB International. Gunshot wounds in veterinary medicine: projectile ballistics—Part I. *Compend Contin Ed Pract Vet* 8:47–60.)



FIG. 7-34 These .22 cartridges demonstrate the various sizes and designs of these rounds (left to right): 5.56 mm (.223), 55 grain, full-patch centerfire M-16; .22 Magnum jacketed rimfire; .22 Winchester long rifle high power, 29 grain hollow point; .22 Remington long rifle, high velocity, 36 grain hollow point; .22 long rifle with uncoated lead bullet. The .22 Winchester and .22 Remington have a metallic coating that has little influence on minimizing bullet deformation. The decorative coating is reported to shun dirt, grit, and lint. A waxy coating or priming on the rimfire long rifle illustrated lubricates the bullet and minimizes fouling of the gun barrel. Note that the .22 designation does not indicate the projectile's weight, composition, design, or velocity, only its diameter. (Source: Pavletic MM. 1986 / CAB International. Gunshot wounds in veterinary medicine: projectile ballistics—Part I. *Compend Contin Ed Pract Vet* 8:47–60.)

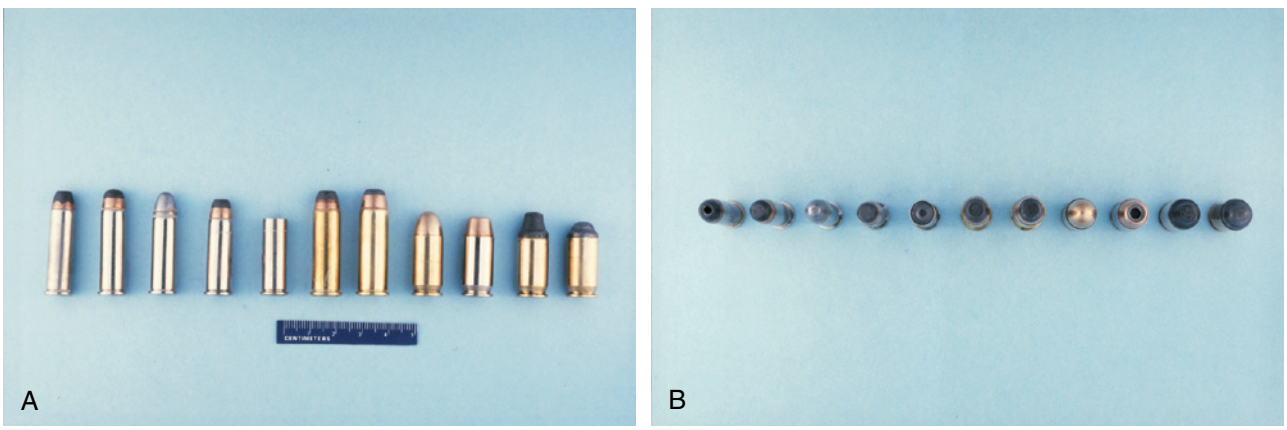


FIG. 7-33 (A) Side and (B) top views of various handgun rounds (from left to right): .357 Magnum, partial jacket, hollow point; .357 Magnum, partial jacket; .38 Special unjacketed; .38 Special partial jacket; .38 caliber wad cutter (flat face); .41 Magnum partial jacket; .44 Remington Magnum; .45 caliber full-patch military; .45 copper jacketed hollow point; .45 caliber unjacketed; .45 caliber unjacketed. Each bullet varies in weight, velocity, and performance on impact. Bullets with an exposed lead core, especially with a hollow point, would be expected to deform on impact compared with a full-patch bullet. The full-patch bullet would be expected to have greater penetration, other factors being equal. (Source: Pavletic MM. 1986 / CAB International. Gunshot wounds in veterinary medicine: projectile ballistics—Part I. *Compend Contin Ed Pract Vet* 8:47–60.)

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Air-Powered Projectiles

Air-powered rifles, developed in sixteenth-century Germany, use compressed air to drive the projectile in place of gases released by exploding powder. Today, air rifles, air guns, and air pistols are used for target shooting and small-game hunting. The air gun is distinguished from the air rifle in that the gun is a smooth-bored barrel whereas the rifle has a rifled barrel. Air pistols may have a smooth or rifled barrel. Standard calibers for air arms in the United States include .177, .22, and .20 (5 mm). The basic types of air-gun ammunition are the BB and "air rifle" shot. These plated balls are steel of .175 caliber. The most common missile employed in the air rifle is the waisted diabolo pellet, which possesses an hourglass shape. The diabolo pellet weighs an average of 8.2 grains in .177 caliber and 15 grains in .22 caliber. The Sheridan rifle employs a .20 or 5 mm pointed conical bullet weighing 15.3 grains with a hollow base that expands to seal the bore and engage the rifling (Fig. 7-35). Because of their extremely light weight, these pellets rapidly lose velocity and become nearly harmless at 100 yards.

All modern air rifles operate on one of three gas-compressing systems: the pneumatic system, the spring-air system, or the gas-compression system. Despite their modest size, velocity, and poor aerodynamic design, air-driven pellets are capable of causing serious injuries and fatalities at close range. Today's air-powered rifles have considerable capacity to inflict serious injuries (Fig. 7-36). Indeed, many air pistols and rifles have muzzle velocities comparable to the low-velocity bullets propelled by gunpowder. The skin has the ability to absorb a considerable amount of energy and will limit the penetration of low-velocity projectiles. It is not uncommon to find air pellets or BBs on radiographs, residing in the hypodermal and adjacent muscle/fascia.

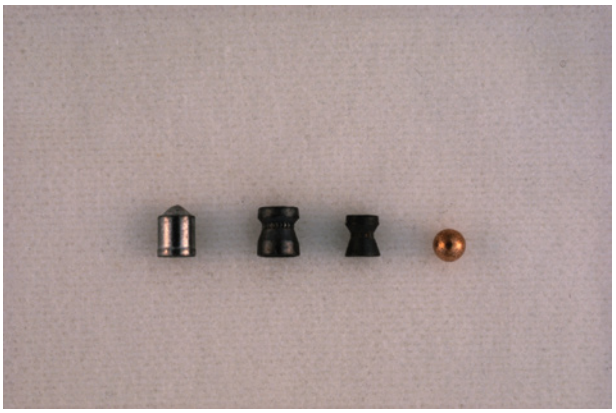


FIG. 7-35 Side view of air-powered projectiles (from left to right): .20 (5 mm) Sheridan pellet; .22 diabolo pellet; .177 diabolo pellet; .175 BB copper-plated steel sphere. Each pellet has a hollow base. Sheridan pellets are harder than the conventional diabolo pellet. These projectiles are commonly encountered as incidental findings subcutaneously or in a muscle during radiographic examination. At close range, these projectiles are capable of seriously wounding or killing small animals. (Source: Pavletic MM. 1986 / CAB International. Gunshot wounds in veterinary medicine: projectile ballistics—Part I. *Compend Contin Ed Pract Vet* 8:47–60.)

Shotguns

Shotguns, by design and function, differ from handguns and rifles. Shotguns are smooth-bored long-barreled guns designed to fire a shot charge consisting of a large number of small spheres that form a pattern depending on the distance and "choke" of the barrel. Although there are handgun and rifle cartridges that fire bird shot, the comparatively low number of these small pellets limits their effective use to small varmints.

The shotgun shell is composed of a paper or plastic casing, fused into a metallic cup or base that contains a centerfire primer. Brass or steel casings occasionally are employed outside North America. In the bottom of the shell casing, the powder charge is located adjacent to the primer. Wads of plastic, felt, paper, or cork are used to compartmentalize the powder and shot charge; the wadding also plays a role as a compressor or shock absorber to improve shot dispersion. The shot charge is in turn sealed within the casing by a thin wad or by crimping the end of the shell casing (Fig. 7-37). On discharge, the shot and wadding materials in front of the propellant are pushed forward. At close range, this wadding may enter the body, along with the advancing shot charge or deer slug.

In the United States and other countries, the caliber of shotguns is expressed in *gauge* or *bore*. This unit of measurement is derived from the early nineteenth-century method of measuring the weight of one cannon ball in pounds; the caliber of a shotgun is a comparison with lead balls of the same diameter contained in 1 lb of lead for a specific gauge. A 12-gauge shotgun, for example, has a caliber corresponding to the diameter of a lead ball, 12 of which are equivalent to 1 lb. Shotgun gauges in common use are the 10 (.775 inch), 12 (.73 inch), 16 (.670 inch), 20 (.615 inch), and 28 (.550 inch). Another common shotgun is the .410, a number that designates a caliber of 410 thousandths of an inch.

Shot charges spread from the muzzle in a cone-like fashion. The pattern is influenced by the shotgun's choke or constriction at the barrel end. Choke variations

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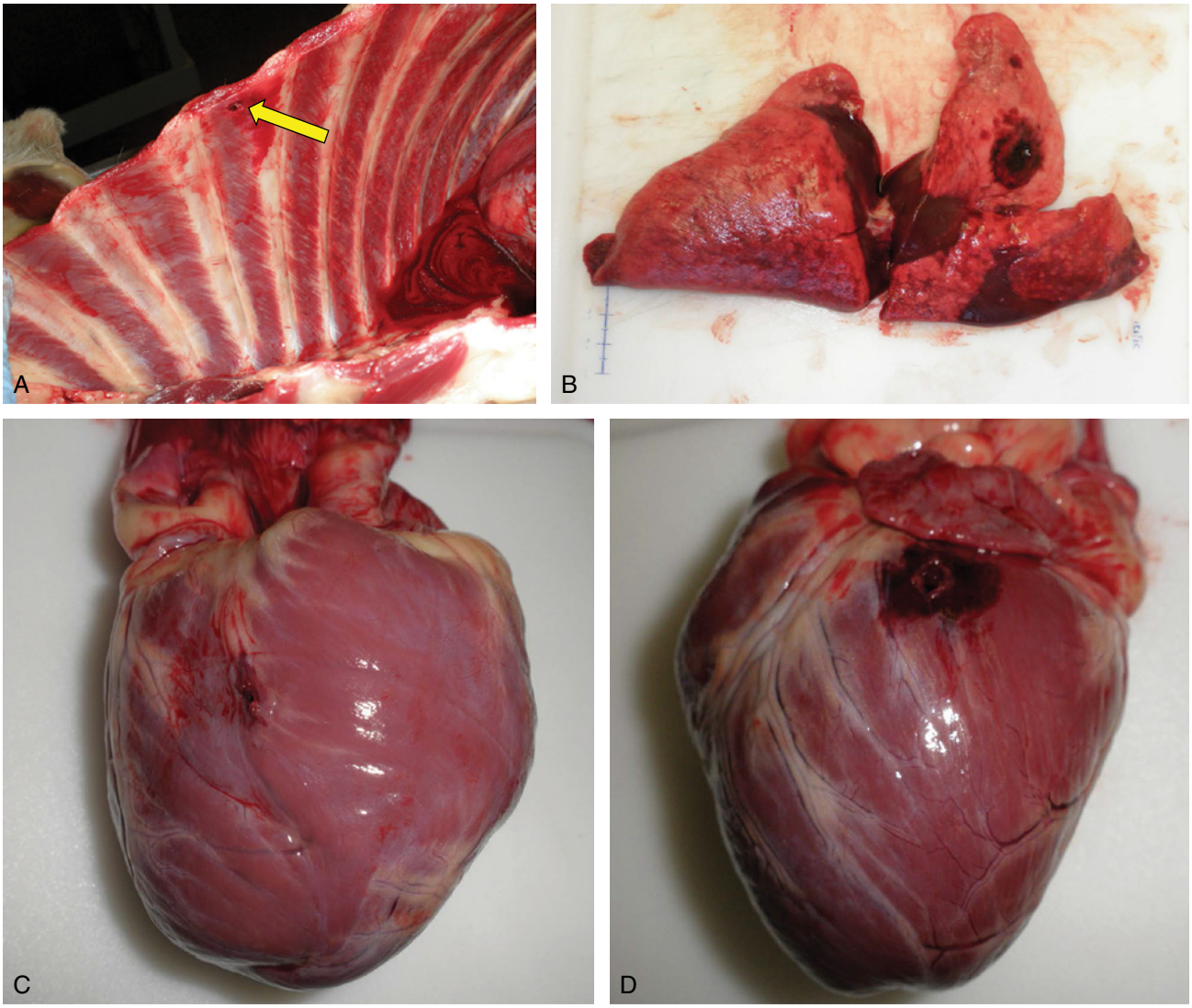


FIG. 7-36 (A) Fatal projectile wound from a .22 caliber diabolo pellet. Note the pellet passed through the intercostal muscle (arrow), missing the adjacent ribs (left thorax). (B) Note the perforation of the left middle lung lobe. (C, D) Note the left entry wound (C) and right exit wound (D) of the heart, causing a fatal cardiac tamponade. Today's air rifles are capable of generating considerable velocity and fatalities. Had this pellet struck a rib on entry, perforation of the lung and heart may not have occurred: the rib likely could have absorbed the majority of the kinetic energy of this light-weight projectile.

include full-choke (maximal constriction or tighter cluster pattern over a greater distance), modified choke, improved cylinder, and skeet bore or cylinder bore (little or no constriction with a wide pattern for hunting at close range). In the game field, 30–40 yards is the effective range for most shotguns. Within 20 yards the dense pattern is too destructive, whereas beyond 40 yards the wide dispersion of shot and the loss of velocity limit the effectiveness.

Various gauges of shotguns are capable of firing a variety of pellet or shot sizes (Fig. 7-38). As previously noted, the US Fish and Wildlife Service mandated the replacement of lead bird shot with steel shot to prevent lead poisoning in waterfowl and to protect avian species from its accidental ingestion in the environment. Occasionally, shotguns are used for hunting large animals by shooting buckshot or single slug loads. Foster "deer" slugs, most commonly used in North America, compare favorably with high-powered rifles at ranges of 100 yards, but perform poorly past that range due to their mass and design, resulting in rapid dissipation of energy Fig. 7-39. Although uncommonly used, shotgun shells designed to fire metallic arrowlike darts, called flechettes, have been employed primarily as a military weapon.

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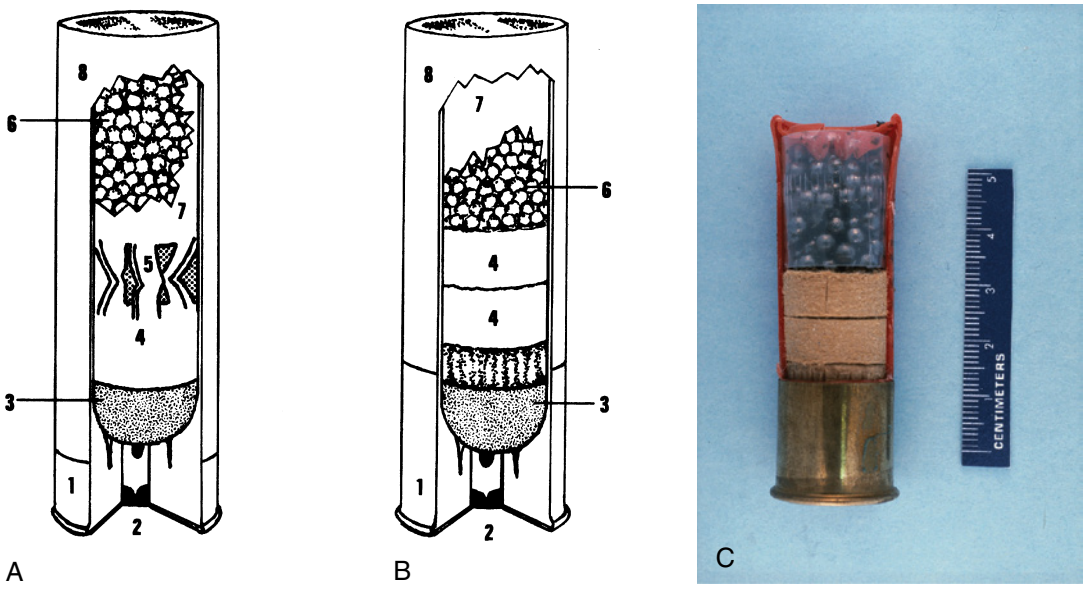


FIG. 7-37 (A) Cross-section of shotgun shell: (1) metal head, (2) primer, (3) gunpowder propellant, (4) plastic wad, (5) plastic baffle, (6) shot, (7) plastic collar, (8) outer plastic hull. (B) Cross-section of shotgun shell with (4) cardboard wadding. The other numbers correspond to the descriptions in (A). (Source: Adapted from 1981 Winchester Sporting Arms and Ammunition Catalog). (C) Cross-sectional view of a shotgun shell. A portion of the casing was removed to show its contents. Compare this shell to (B).

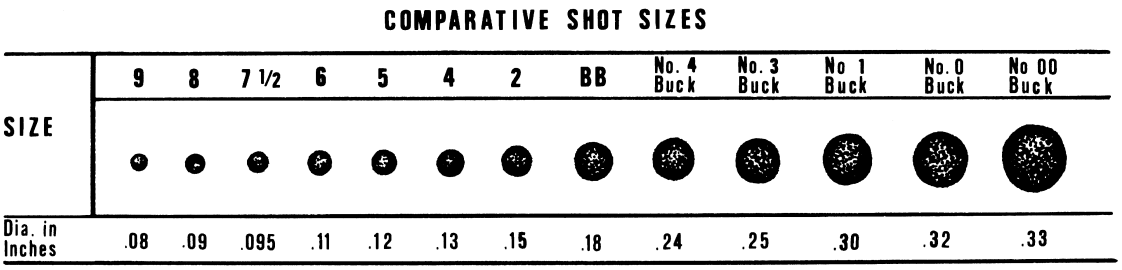


FIG. 7-38 Comparative sizes of shot fired from shotguns. (Source: From 1980 Browning Catalog, Browning, Morgan, UT. Modified with permission.)

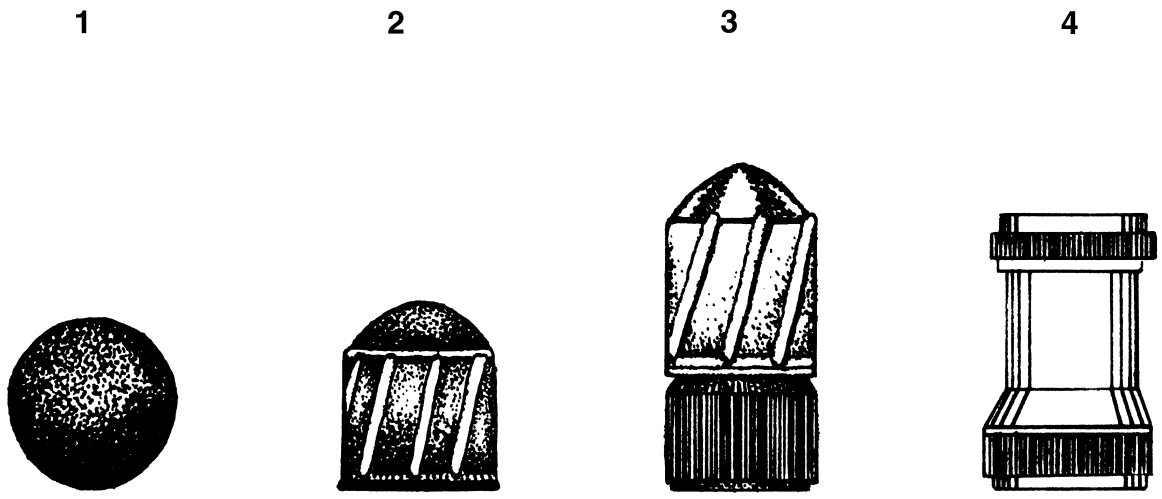


FIG. 7-39 Single projectiles (enlarged) used in shotguns throughout the world: (1) pumpkin ball, (2) rifle slug, (3) Brenneke slug, and (4) Balle Blondeau. (Source: DeMuth WE. 1979. The mechanism of shotgun wounds. *J Trauma* 11:219. Redrawn with permission.)

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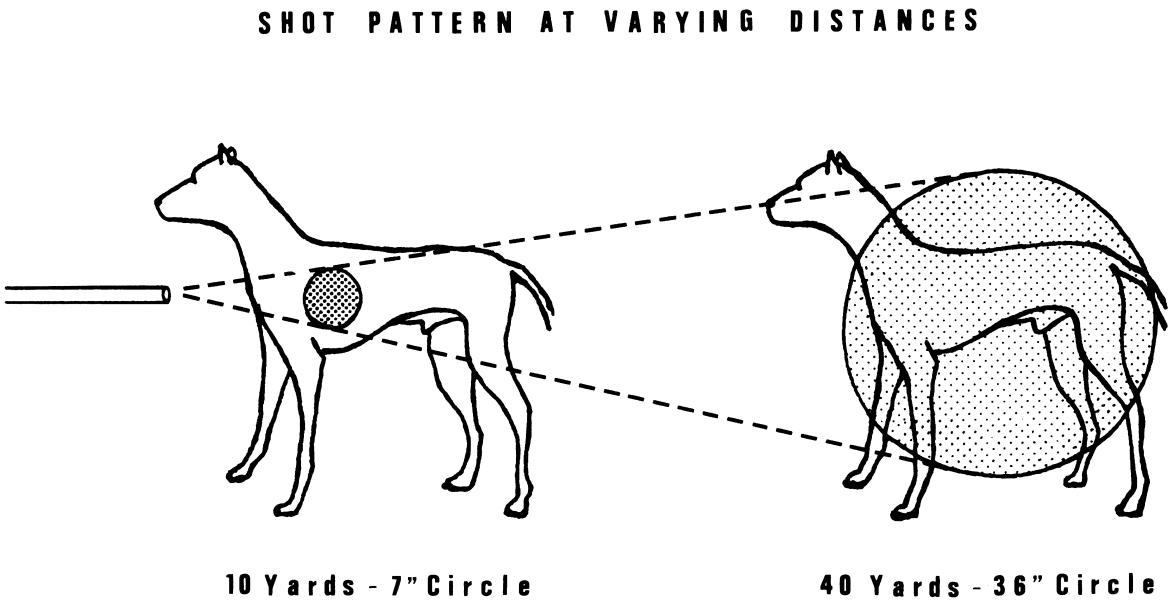


FIG. 7-40 Shot pattern at varying distances. (Source: Adapted from Bell, MJ. 1981. The management of shotgun wounds. *J Trauma* 11:522.)

Charges fired from shotguns of all types have a muzzle velocity between 1100 and 1350 ft/s, although rifle slugs may reach a velocity of 1850 ft/s. Strikes to an animal in which the shot pattern is contained within a 12-inch diameter will have a velocity of 1000–1350 ft/s (Fig. 7-40). Considering that a single pellet or shot imparts a striking force of 9.56 ft-pounds at a muzzle velocity of 1295 ft/s and the combined force of 235 pellets at point-blank range delivers 2247 ft-pounds, there is a formidable comparison to the muzzle energy of the 1250 ft-pounds of an M-16 rifle. Buckshot and slugs, by virtue of their greater mass, maintain their velocity more effectively at longer ranges. Considering that large shot can have a weight comparable to a .22 bullet, with a velocity over 1000 ft/s, the combined wounding potential of the larger shot is evident.

The use of shotguns as weapons against dogs is not uncommon. The variety of loads, pellet sizes, and their wounding capability in relation to the distance from the muzzle add a number of additional factors for the veterinarian to consider when confronted with such injuries.

Sherman and Parrish classified shotgun wounds into three basic types based on the pattern of distribution, depth of penetration, and range. Type I injuries, reflecting a relatively long distance between animal and shooter, are wounds in which the subcutaneous tissue and deep fascia are penetrated; type II injuries, produced at closer range, perforate structures beneath the deep fascia; and type III wounds, inflicted at point-blank range (less than 3 yards), produce an extensive central zone of tissue destruction with a small peripheral halo of pellet holes. Extensive tissue destruction at close range is due to the high velocity and wider total surface area formed by the pellet group in flight as compared to a single projectile. Thus, at very close ranges, the shotgun is one of the most destructive weapons available (Figs 7-41 and 7-42).

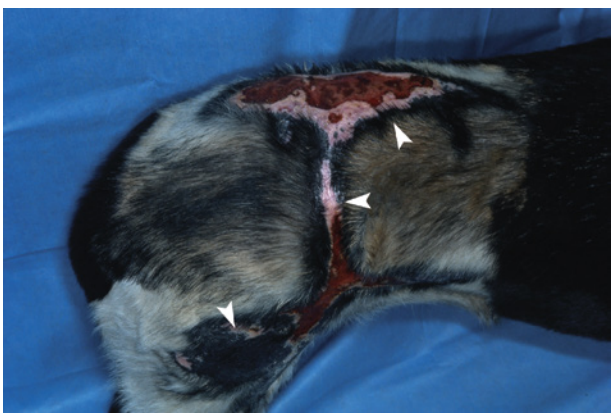


FIG. 7-41 Shotgun (type I) injury to the flanks, caudal lumbar area, and hindlimbs (no. 6 birdshot) (arrows). The dog presented several weeks after injury: considerable skin loss had occurred. Healing by second intention was nearly complete. The shotgun blast occurred at the level of the deep circumflex iliac artery and vein. Destruction of these major direct cutaneous vessels and regional collateral circulation was the major factor involved in the skin loss.

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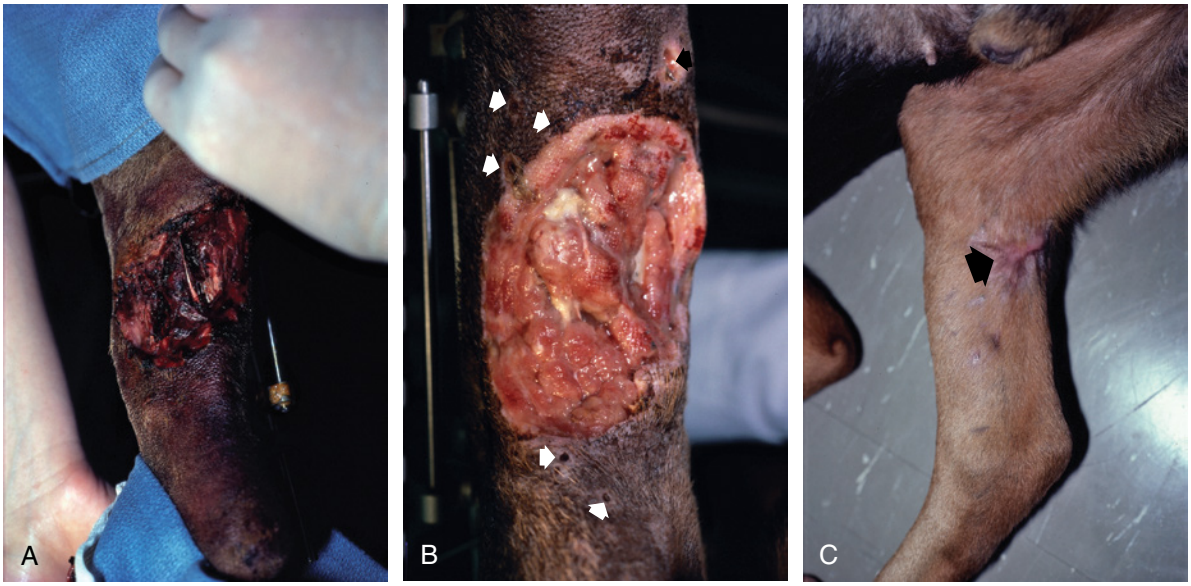


FIG. 7-42 Example of a Type III Shotgun wound. (A) Massive soft tissue injury and a comminuted tibial fracture. Some pellet entry wounds are still evident (arrows). Maggots were present, but were manually removed during the initial debridement procedure. (B) Serial debridement was performed on a daily basis. (C) The wound healed by second intention. The external fixation was later replaced by internal fixation with a bone plate and cancellous bone graft (successfully).

Exploding Bullets

Although presently illegal to purchase and very difficult to obtain, exploding bullets were available in the 1980s to the public and law enforcement sectors for defense purposes. Exploding bullets initially were developed by the British in the early 1800s to penetrate barriers and ignite enemy powder caissons. They were subsequently employed in limited quantities during the American Civil War for antipersonnel use. There are several variations of exploding bullets. Bullets have been designed to split or fragment on impact. Alternatively, bullets containing an explosive charge were designed to explode on impact. These latter projectiles can be somewhat troublesome if they fail to detonate on impact with the patient: rough handling of the projectile during retrieval can result in their explosion. Undetonated bullets retained in the animal present a potential hazard to the patient and to the surgeon attempting to remove them.

Exploding bullets generally are semi-jacketed hollow-point bullets filled with an explosive powder charge covered by a single lead shot and a percussion cap (or simply a primer anvil) covered by a wax coat. Deceleration of the bullet on impact ignites the percussion cap or primer, resulting in the explosion of the powder charge. From a historical perspective, the .22 bullet that struck President Reagan contained an aluminum canister in its nose filled with the explosive lead azide that is detonated by impact or high heat. Bullet deformation and the release of projectile fragments on impact reportedly increase the local tissue destruction compared to a regular bullet of similar size. However, this contention has been questioned by some authorities.

Frangible Bullets

Frangible bullets are projectiles manufactured to break into multiple fragments and particles on impact. Most are subject to brittle failure on impact with a hard target. Law enforcement has used frangible bullets both to reduce the risk of ricochets and to prevent the passage of a projectile through a suspect and striking innocent people within the line of fire. Specific frangible bullets are useful in target practice and military/police training, since they contain no lead and turn into powder on impact with metal targets and other dense materials; this eliminates the dangerous ricochets noted with standard lead bullets.

Frangible bullets are basically fabricated by compressing powdered metals (typically tin, copper, zinc, tungsten) to form a high-density projectile. The resultant material may or may not include a frangible metallic jacket. Frangible projectiles also can be formed by other means, including cold weld bonding or binding the powdered metal with an adhesive polymer for injection molding.

Frangible bullets can come in a variety of designs that affect their individual ballistic properties. In general, on

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impact with animals they typically break apart, creating shallower wounds than a comparable-diameter lead bullet. Small metallic particles may be noted along the projectile's path. Others are capable of deeper penetration before fragmenting. More recently, "radically invasive projectiles" were designed to release metallic splinters on impact (Ditkovsky et al. 2020). Although they are less common that other projectiles, nonetheless veterinarians should be aware of frangible bullets, both for the surgical management of the wounds and for their identification for law enforcement purposes (Fig. 7-43).

Interior and Exterior Ballistics

Modern bullets are fired from barrels that contain helical grooves (rifling) that serve to spin the projectile on its longitudinal axis to stabilize its flight. Rifling improves the flight characteristics of a bullet in much the same way as the helical fletching of an arrow serves to improve its flight. Despite rifling, projectiles traveling at a high velocity can become unstable in flight. A bullet can deviate from its longitudinal axis: it can yaw or tumble prior to or after impact with a body region, thereby increasing its profile in contact with tissues, resulting in greater tissue trauma. Flight instability enhances the likelihood of greater tissue destruction and promotes bullet fragmentation.

From an "offensive" standpoint, the ideal projectile has the following characteristics: (1) good ballistic shape (needle-like design), (2) high sectional density (ratio of projectile mass to area of presentation), (3) high velocity, and (4) the capability of deep penetration with a controlled expansion.



FIG. 7-43 (A) Radiograph of a frangible bullet wound to a dog: note fragmented jacket. (B) Note that the tissue destruction on the lumbar area is comparatively superficial. (C) Debridement was followed by surgical closure over a closed-suction drainage system. (D) Note half of the frangible jacket recovered from the dog. Source: Frangible bullet photographs courtesy of Gary Spodnick DVM, DACVS.

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Terminal Ballistics

The seriousness of bullet wounds is often considered only in relation to those structures in the path of the bullet. Although this generally is true for low-velocity projectiles and stab wounds, it does not account for the severity of injuries associated with some high-velocity missile injuries. Bullets damage tissue in three ways: tissue laceration and crushing, shock waves, and cavitation. Both low- and high-velocity projectiles create permanent tracts as they pass through tissues. Expanding bullets increase the tissue damage of a projectile by creating a larger wound cavity and enhancing energy absorption by the tissue. The tissue trauma from low-velocity projectiles primarily is restricted to the crushing and laceration of tissues at the permanent tract. By comparison, high-velocity projectiles can expend considerable energy to adjacent tissues in the form of shock waves and cavitation. Cavitation, a temporary cavity (5- to 30-microsecond duration) up to 30 times the diameter of the projectile, is most evident as a projectile's velocity markedly increases (Fig. 7-44). Following the temporary lateral and cranial expansion of the surrounding tissues, a negative pressure forms with a sucking effect that has the potential of drawing debris and contaminants into the wound. The stretching and compression of tissues as a result of cavitation can enhance the magnitude of tissue destruction, especially if circulatory compromise occurs secondary to vascular disruption or thrombosis: fractured bones, torn vessels, bowel ruptures, and contusions of the heart and lungs may occur without direct contact from high-velocity projectiles.

A projectile may penetrate or perforate various tissues or structures, depending on its impact velocity, mass, design, and the composition of the target struck. A penetrating wound has an entry point with no exit, whereas a perforating wound has an entry and exit (through-and-through) without the projectile's retention in a specified structure or region. To avoid confusion, it is best to restrict the terms *penetrating* and *perforating* to the anatomic structure in question. Projectiles that exit the body make it more difficult to determine the weapon involved.

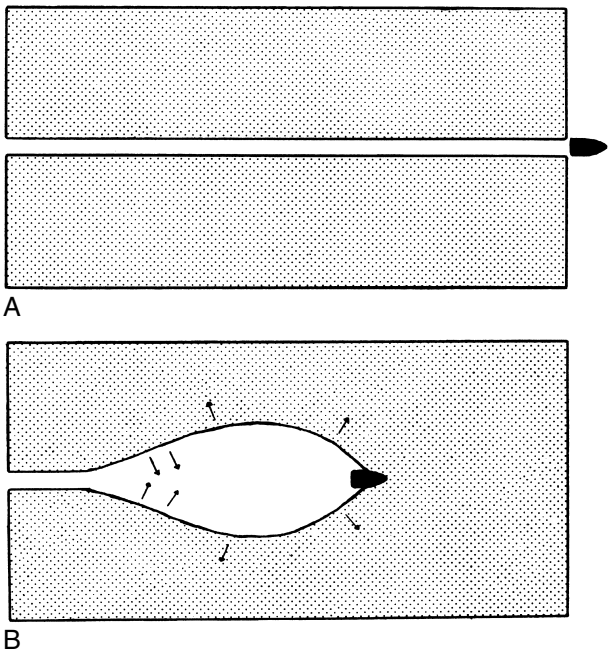


FIG. 7-44 (A) Note low velocity, no cavitation, and small entrance and exit. (B) Greater cavitation is noted as velocity increases. Note that the size of the exit wound is influenced by (1) target thickness or depth, (2) tissue density, (3) projectile velocity and composition, and (4) the amount of kinetic energy expended as the projectile(s) exit the target area. (Source: Swan KG, Swan RC. 1980. *Gunshot Wounds*. Littleton, MA: PSG Publishing. Modified with permission.)

Projectiles retained in the patient without impacting bone are more likely to be lower-velocity projectiles.

Besides velocity and mass, three factors are responsible for the greater destructiveness of projectiles, especially in higher-velocity weapons: tumbling prior to impact, which permits a variety of positional contacts with the tissues; flight instability, apart from tumbling, thus adding a further motion of the projectile; and secondary projectiles formed by missile fragmentation and bone shattering (Fig. 7-45).

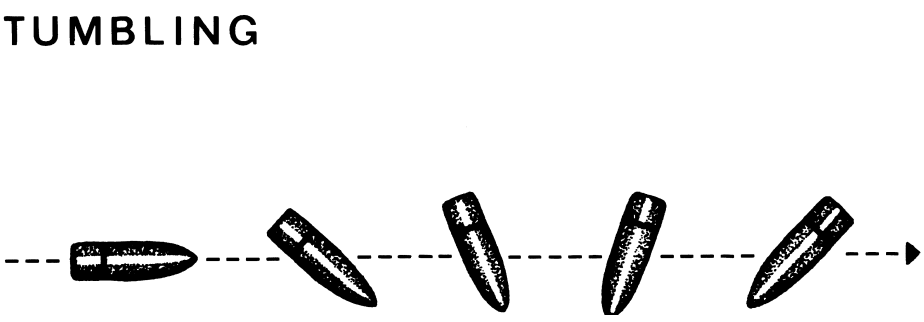


FIG. 7-45 Schematic diagram illustrating tumbling (forward rotation around the center of the mass). This unstable flight pattern increases the projectile's surface presentation to the target, enhancing tissue damage. (Source: Swan KG, Swan RC. 1980. *Gunshot Wounds*. Littleton, MA, PSG Publishing. Modified with permission).

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The entry wound usually is smaller than the exit wound because bullet tumbling, distortion, fragmentation, and secondary projectile formation increase the bullet's destructiveness in a cone-like fashion as it passes through the body. This general rule on wound size, however, is misleading. If the gun muzzle is placed very close to the target when fired, expanding gases are released that accentuate the size of the entry wound and powder burns also would be noted. The magnitude of the temporary cavity is proportional to the energy imparted by the projectile during target penetration, with the missile's energy decreasing exponentially with the distance penetrated. Smaller projectiles may dissipate their energy more rapidly than larger projectiles with equal energy. A projectile that has expended a majority of its energy in the center of the target may exit without the gaping exit wound that would be expected.

The specific gravity of the tissues struck also will influence the wounds produced. Tissues with greater density, such as bone, are affected more adversely than are soft tissue structures. The retentive forces that combat the disruptive forces of the projectile also vary with the tissue struck. Skin and lung have elastic properties that better accommodate the energy insult, which helps maintain the organ's integrity. Liver and muscle have a similar specific gravity and absorb energy from a high-velocity projectile in similar fashion. However, the temporary cavity and permanent tract formed in the liver are greater in magnitude compared to skeletal muscle because the liver parenchyma is less cohesive and resilient. Cavitation in pulmonary tissue is comparatively minor due to the elastic fibers within the spongy network of their parenchyma.

At high velocities, cavitation has also been recorded in bone. The explosive effect on the bone drives splinters of bone ahead of the projectile, increasing the magnitude of soft tissue damage and possibly the exit wound. Greater fragmentation will occur where cortical bone predominates. Thus, long bones composed of large amounts of cortical bone have greater density compared to flat bones, such as the ribs, with a greater proportion of cancellous bone. High-velocity rounds are more likely to cause massive tissue destruction when bone is struck. Paradoxically, any high-velocity rounds can pass through soft tissue structures and exit the body without resulting in massive tissue necrosis. This can be explained primarily by the fact that a considerable proportion of the projectile's kinetic energy (mass, velocity) is not "deposited in" or "captured by" the body.

High-velocity projectile injuries to the abdomen of anesthetized cats have demonstrated that the abdomen swells immediately and collapses, followed by a second expansion of less intensity but with a prolonged duration. Damage to the abdominal contents can occur with the first expansion, but the explosive injury noted develops during the second expansion. Intestinal gas expands, resulting in multiple bowel perforations. The explosive shock wave displaces viscera, tears the mesentery, and can rupture blood vessels away from the permanent tract. The extent of soft tissue necrosis associated with high-velocity projectiles is variable and can be difficult to assess. Muscle tissue is extremely resilient and damage may occur only a few centimeters from the muscle tract. The tissue destruction occasionally noted hours to days later in some high-velocity injuries most likely is attributable to progressive vascular compromise to the tissues involved. Cavitation and the associated shock wave apparently result in blunt contusion of the associated tissues. The volume of necrosis is influenced by the severity of the vascular compromise.

Vessels need not be struck directly by a high-velocity projectile. Stretching and tearing of the vessels can occur, resulting in hemorrhage or thrombosis of the damaged vessel. The resulting damage has been likened to a crushing-type injury. However, the large arteries, such as the canine femoral artery, are more resistant to indirect trauma. Circulatory insult and tissue necrosis increase the likelihood of infection. Various studies using the thigh muscles of goats and dogs for high-velocity projectile studies have demonstrated the surprising resilience of wound healing in the face of moderate trauma, as long as the circulation to the area remains predominantly intact. From clinical experience in humans, it is known that the extent of devitalization is affected by time.

Many researchers contend that bullet fragmentation better explains the size and severity of high-velocity projectile wounds. Bullet fragmentation and the dispersion of secondary projectiles causing muscle tearing enhance the absorption of the projectile's energy by the target and are more likely responsible for the magnitude of the large conical-shaped tracts formed by hunting bullets. In these cases, radiographs can help define the boundaries of the wounded tissue for debridement by the location of metallic fragments deposited in the area. Fragmentation of projectiles, in association with bone impact and fragmentation, best explains the massive trauma noted with high-velocity rounds and the more powerful handguns.

The severity of tissue injury by a given projectile in large part is determined by the total kinetic energy absorbed by the patient. For example, a jacketed, high-velocity bullet that perforates an upper extremity and exits intact without a significant loss in velocity would cause substantially less tissue injury compared to a bullet that deforms and rapidly decelerates in the same tissue. If this projectile is completely retained, the area has absorbed the damaging energy of the round. Thus, tissue trauma is better understood in terms of how rapidly and completely the energy is lost (absorbed by the body) and the tissues in which the energy is dissipated. As noted, certain body tissues that are elastic and maintain their architectural integrity better sustain projectile trauma.

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Gunshot-Wound Infection

All gunshot wounds are contaminated. Low- and high-velocity projectiles are capable of driving or dragging topical debris (dirt, hair, etc.) into the permanent tract. Bacteria also are driven into the wound. As noted, the negative pressure formed during formation of the temporary cavity associated with high-velocity projectiles also is capable of "sucking" contaminants into the wound to a variable degree. The notion that projectiles, especially high-velocity projectiles, are sterile due to heat generated during passage of the bullet through the barrel and air is a fallacy. The risk of infection is higher in the case of high-velocity projectile injuries where extensive tissue damage and circulatory embarrassment in the region are more likely. In general, the incidence of infection associated with low-velocity rounds limited to skin, muscle, and fascia is remarkably low.

Diagnosis and Management Considerations

In many cases, the owner is unaware of their pet being shot; clearly, pets that are allowed to roam unsupervised are at greatest risk of being shot. Without a history, skin wounds may be mistaken for bite wounds or vehicular trauma. There are occasions in which the owner, a witness, or a police officer may provide specific information pertaining to the weapon. Knowledge of the weapon can help the veterinarian determine the potential tissue damage and appropriate surgical management of the injuries.

Most gunshot wounds to dogs and cats in a city are due to low-velocity handguns (Figs 7-46 and 7-47). High-velocity gunshot wounds from hunting rifles are seen more commonly in rural areas. Data from Angell Memorial Animal Hospital (Pavletic 1996) indicated that



FIG. 7-46 (A) German shepherd shot in the lower cervical area (arrow) during a robbery attempt. (B, C) The .38 caliber round entered the thoracic inlet and passed through the anterior mediastinum before coming to rest in the triceps musculature. Because the projectile round passed through soft tissue only, without exiting the body, it was considered a low-velocity round. Treatment consisted of only local wound preparation, lavage, and application of a sterile dressing. The pneumomediastinum resolved without incident. No attempt was made to remove the projectile.

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FIG. 7-47 Example of a .44 magnum handgun round to the foot of a German shepherd (arrow). The dog was shot by the owner's former boyfriend during a heated argument. The considerable power of the .44 magnum is evident. The paw was suspended by remnants of two metatarsal bones and soft tissue. The limb required amputation.

shotgun wounds occurred in urban, suburban, and rural areas. Radiographs of the patient are useful to determine the presence and location of retained bullets or fragments.

Low-velocity projectile injuries cause comparatively less tissue destruction, except to those tissues in their path (Figs 7-48 and 7-49). Such wounds confined to the skin and underlying muscle generally are treated by local debridement of the entry and exit wound (if present), local wound lavage, and the application of a sterile dressing. Systemic antibiotics may be advisable in selected cases. Bullets that are easily and safely accessible can be removed. They generally are not pursued unless they involve a joint or vital structure. Attempts to probe and explore the wound simply to find a bullet should be discouraged to reduce the likelihood of further tissue damage and infection. Occasionally, however, bullet retrieval may be required for legal purposes. In one study, steel bird shot implanted in dogs resulted in local inflammation secondary to the corrosion of the steel. This raises the possibility of draining tract

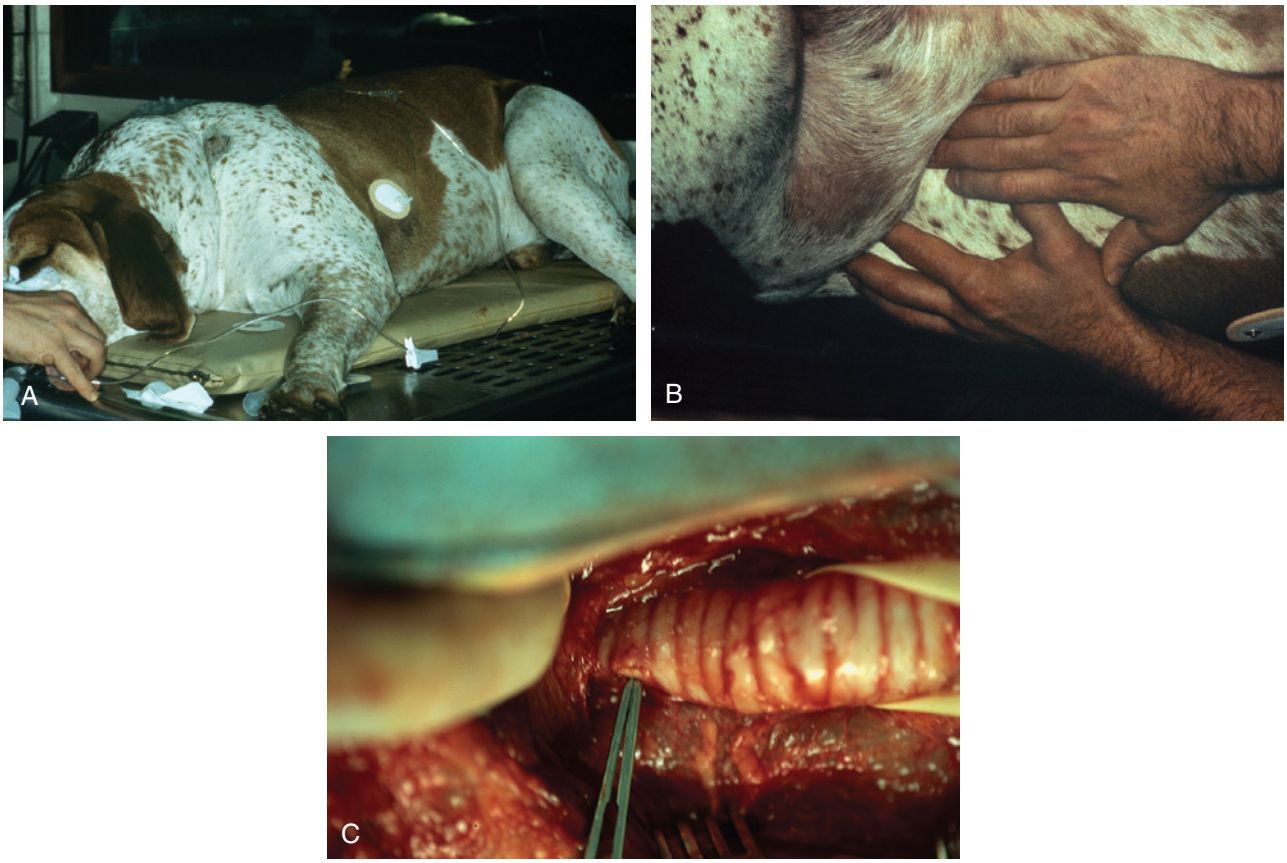


FIG. 7-48 (A) Cervical gunshot wound with extensive subcutaneous emphysema. (B) Compression of the skin easily displaces the extensive pocket of air. (C) Tangential perforation of the trachea by the handgun round. This area was minimally debrided and sutured closed. Within 24 hours over half the air was resorbed; by 48 hours most of the subcutaneous air was gone. (A large-gauge needle and vacuum pump can remove a portion of the air that has accumulated in patients with extensive subcutaneous emphysema. With closure of the air leak, the ability of the patient to resorb the air can be dramatic.) (Source: Pavletic 1996. Gunshot wound management. *Compend Contin Edu Pract Vet* 18:1285-1299. Reproduced with permission from Compendium of Continuing Education.)

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FIG. 7-49 Great Pyrenees with a urethral tear dorsal to the scrotum. A second hole was noted in the tail. What initially appeared to be two gunshot wounds was actually one. The dog was shot from the rear with his tail between his legs. The hole in the patient's tail lined up with the cutaneous hole above the scrotum.

formation secondary to the inflammatory response elicited. Although uncommon, the author has seen two cases of training tracts secondary to retained lead projectiles. Removal of the bullets was curative.

Lead absorption from retained projectiles is uncommon. (The author has seen one dog with elevated blood lead levels secondary to multiple retained lead bird shot.) Retained bullets and shot normally are encapsulated in scar tissue, limiting lead absorption. However, elevated blood lead levels have been noted when lead projectiles are exposed to synovial fluid. Over time they can corrode and are subject to continual wear if retained in the joint.

High-velocity projectiles, because of their greater kinetic energy, may require wound exploration and debridement due to the greater tissue destruction present. This is most evident when bone is struck, allowing the effect of the projectile's kinetic energy to be more fully expressed. Many of these cases may require considerable debridement, orthopedic repair, and a variable amount of open wound management.

The amount of kinetic energy lost by a bullet depends on four factors: (1) the kinetic energy possessed by the bullet on impact, (2) deviation of the longitudinal path of the bullet (yaw, tumble) enhancing projectile retardation, (3) loss of kinetic energy by loss of bullet mass and shape during passage through tissues, (4) the tissues' density, elasticity, and inherent integrity. High-velocity hunting bullets, with an exposed soft lead tip or hollow point, can deform and fragment readily secondary to flight instability and tissue retardation, especially when bone is struck. A direct hit on dense cortical bone will cause a catastrophic deceleration of the bullet and its fragmentation. Bullet fragments and shards of bone are driven into the adjacent soft tissues (Figs 7-50 and 7-51). Disruption and purification of tissues combined with circulatory compromise result in massively destructive wounds. Skin, muscle, and fascia are sufficiently elastic to absorb a portion of this energy while maintaining their integrity, although cavitation is a major disruptive force during passage of a high-velocity projectile through tissues. Passage of a high-velocity round through the soft tissue of the upper thigh, for example, may not result in a wound that necessarily will require wide debridement; treatment may be more conservative than that suggested by the literature.

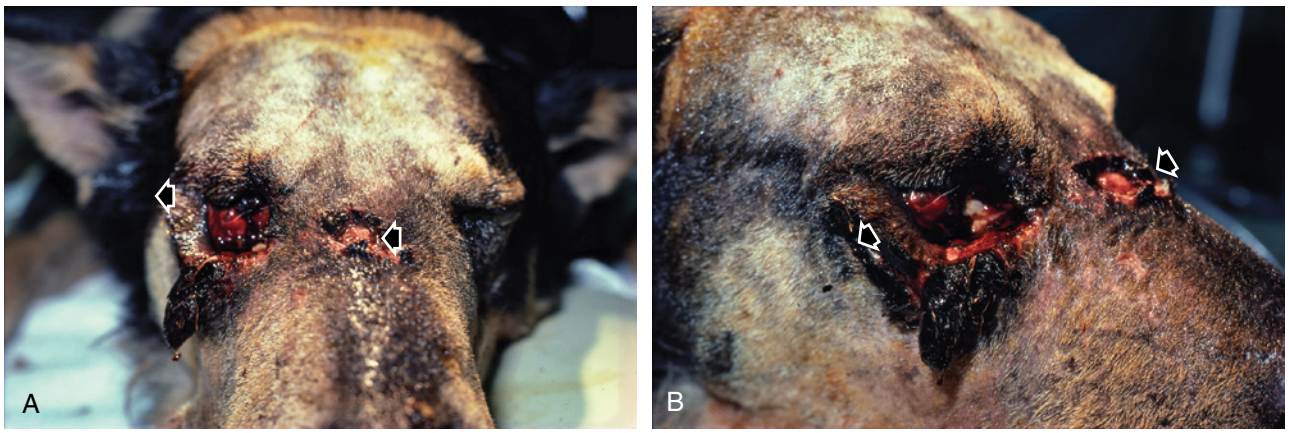


FIG. 7-50 (A) High-velocity rifle round to the head of a German shepherd farm dog. Arrows denote the pathway of the projectile. Massive bone and soft tissue destruction were evident. (B) Lateral view demonstrates the large exit wound through the bony orbit with destruction of the right eye. A long incision was made connecting the entry/exit wounds, and bone fragments and necrotic soft tissue excised. The cosmetic and functional results were comparable to a patient subjected to eye enucleation.

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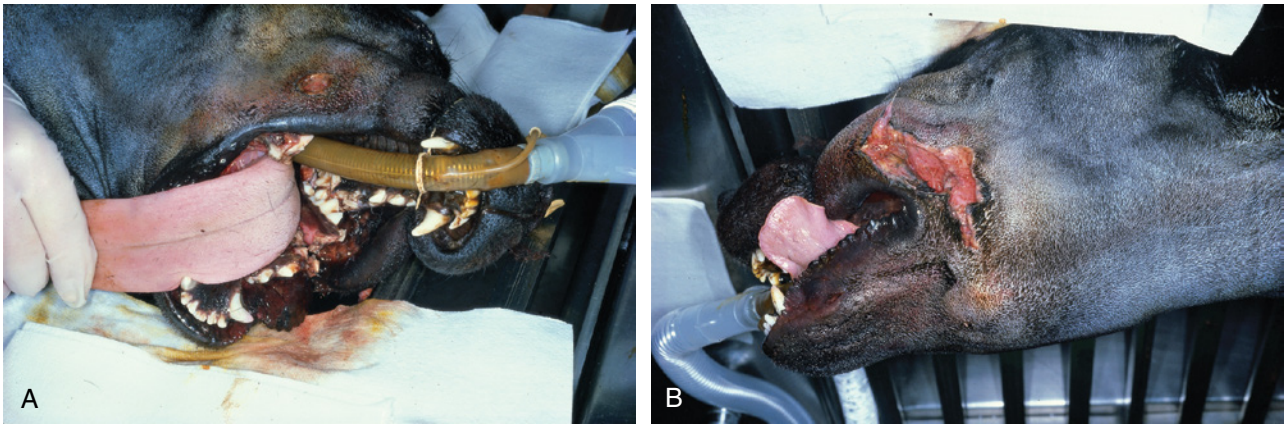


FIG. 7-51 (A) Extensive trauma secondary to a high-velocity rifle round. The entry wound was on the left side of the face of this Labrador. Note the extensive trauma to the mandible. (B) The large irregular exit wound is noted on the right. There were fine fragments of the projectile associated with the bilateral mandibular fractures. The majority of the high-velocity round exited the patient, despite impact with this dense bone.

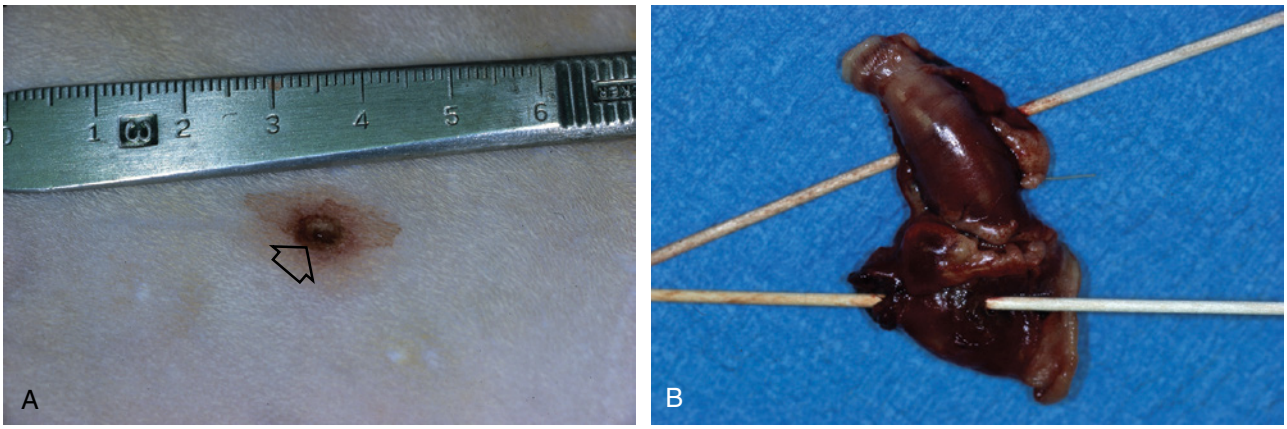


FIG. 7-52 (A) Air-powered BB gun injury to a Siamese cat. Note the small, seemingly innocuous-appearing entry wound (arrow). The patient presented as depressed with abdominal pain. Abdominal radiographs demonstrated the retained projectile. (B) Laparotomy revealed the bowel wall was perforated in two places (highlighted by probes), prompting intestinal resection and anastomosis. Prompt surgical intervention prevented the development of peritonitis. However, veterinarians should be aware that retained air-powered projectiles are a common incidental finding.

With few exceptions, gunshot wounds to the brain and abdominal cavity require surgical exploration in the human. This approach can be justified in the small animal as well, although data are lacking regarding the successful management of gunshot wounds to the brain, primarily because of their grim outcome in most cases. Because abdominal gunshot wounds carry a high incidence of bowel injury and peritonitis, exploratory laparotomy is advisable (Figs 7-52 and 7-53). Thoracic gunshot wounds in the human are second in fatalities only to bullet wounds to the brain. Paradoxically, many cases in the human and the dog may be treated by conservative management. A chest tube may be required to treat a hemothorax and pneumothorax, but a thoracotomy is often unnecessary unless the esophagus has been penetrated or perforated, the heart has been struck, a major tear in the tracheobronchial tree has occurred, or hemorrhage and air leakage into the thoracic cavity remain unchecked. Gunshot wounds to the neck in humans are explored routinely by many surgeons due to the risk of esophageal injury and the presence of vital vessels. However, it is controversial whether mandatory cervical exploration is justifiable in small animals, depending on the severity of the wound and the neurologic status of the animal.

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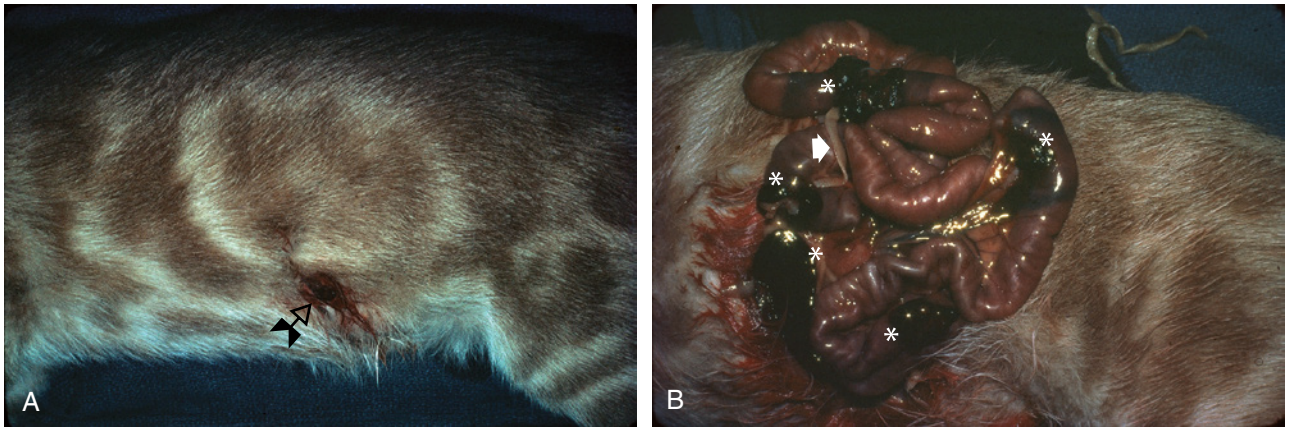


FIG. 7-53 (A) A .22 Rimfire round to the lower abdomen of a cat. The bullet lodged against the wing of the ilium (arrow). The owner's boyfriend accidentally shot the cat with his handgun. (B) The owner elected to euthanize the cat. The abdomen was opened on postmortem, revealing multiple bowel perforations (asterisks) with the presence of tapeworm segments throughout the abdominal cavity (arrow). Exploration is mandatory for projectile wounds to the abdomen.

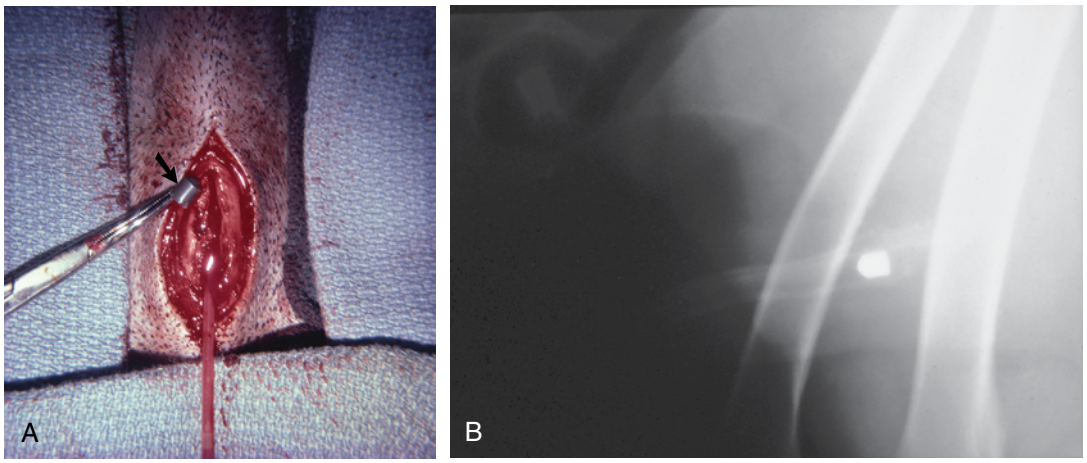


FIG. 7-54 (A) An unusual case of a migrating projectile. A Sheridan pellet was retrieved via urethrotomy at the level of the os penis (arrow). The dog presented with an acute urinary tract obstruction during a walk with the observant owner. (B) Radiographs detected the pellet. Close examination of the lateral abdominal wall revealed a healed entry scar. The dog had apparently been shot some weeks before, with the pellet entering the urinary bladder. Its abrupt passage into the urethra caused the immediate urinary obstruction.

If the bullet cannot be located, it has either exited the body or has passed into another area of the body. The body compartment above and below the area shot should be radiographed in these situations. A bullet passing through the thorax into the abdomen will, at the very least, require an exploratory laparotomy, although a bullet passing in the opposite direction does not automatically mandate a thoracotomy. Bullets have been known to migrate and embolize if they gain access to the circulatory system. Major vascular obstruction may lead to serious consequences. Similarly, bullets have been known to enter the tracheobronchial tree of a human only to be coughed up and swallowed (Fig. 7-54).

A Few Tips

- If a projectile enters and exits a soft tissue area, it may not be possible to determine low versus high velocity by examination of the entry and exit wounds
- If a projectile enters soft tissue and is retained in the tissues, it is most likely a low-velocity projectile
- If a projectile impacts dense bony structures and exits the body, the projectile is likely a high-velocity round
- Keep in mind that high-velocity rounds decelerate over a distance and can impact a target with a significantly lower velocity

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Arrow Wounds

The bow and arrow has been an effective weapon for centuries. An adept archer can discharge up to six arrows in a minute. Despite its primitive origins, the bow and arrow is a highly lethal weapon in the hands of an experienced archer. Arrows lack the knockdown power and destructive capacity of high-velocity rifles. Rather, arrows rely on striking a vital area (lungs, heart, major vessels, liver, etc.), resulting in fatal hemorrhage. If an arrow weighing 450 grains has a velocity of 250 ft/s, it generates only 26 ft-pounds of kinetic energy, considerably smaller than that generated by a rifle.

Bows are measured by their draw weight, which is the number of pounds required to pull the drawstring to a full draw (full length of the arrow). In order to reduce the effort required to draw the bowstring of a conventional longbow or recurve bow, compound bows were developed in 1967 that employ a series of pulleys, elliptical wheels, and cables. Improvements in the compound bow can reduce draw weights by 50–86%. Some US states limit compound bows to those with a reduction of no greater than 65%. It also should be noted that small carbon dioxide–actuated arrow pistols have been developed that fire small arrow projectiles.

A variation of the longbow is the crossbow. A weapon more than 2000 years old, it gained popularity in the Middle Ages. The crossbow fires a bolt or quarrel approximately half the length (14–18 inches) of the average longbow arrow. A crossbow can have a draw weight from 125 to 200 lb. One crossbow has been developed with a draw weight of 300 lb, whereas the upper draw weight of a longbow is around 70 lb. A 125 lb draw crossbow produces the same energy as a 60 lb draw compound bow. A crossbow can fire a bolt with velocities of over 250 ft/s with an amazingly flat trajectory and short-range accuracy. Crossbows have been criticized as silent, accurate, and highly lethal weapons that could be used to advantage by poachers. However, studies have indicated they are not silent and can be a difficult weapon to master. Furthermore, rifles, especially of a lower caliber with a sound suppressor, are a preferred weapon for illegal hunters compared to a single-shot crossbow. Crossbows are required by law to have a safety to prevent discharge of the bolt from jarring or dropping. Many states restrict the ownership and use of crossbows for hunting.

Arrows vary in length, weight, shaft composition, fletching, nock style, and arrow point (head). Arrow shafts are commonly composed of cedar, aluminum, or carbon fiber. Composite arrows of aluminum–carbon fiber or wood–fiberglass also have been introduced. Shaft length, width, and weight can be varied depending on the game hunted and bow employed (Fig. 7-55).

Arrow fletching is the guidance system of the arrow to help stabilize its glide or flight. The fletching can be angled to better impart spin on the arrow, thus creating "gyroscopic stability" in flight. Arrows normally rotate 1–2 revolutions per yard of travel. There are specialized, "helical fletched arrows" for long-range shooting or hunting in which the pronounced helical (spiral) fletching imparts more pronounced spin for improved stability and accuracy over longer distances. Turkey feathers once were the material of choice for fletching, but have been progressively replaced by plastic because of its durability and greater availability (Fig. 7-56). The arrow nock adjacent to the fletching is the portion of the arrow that is notched to engage the "serving" area of the bowstring. The nock design varies according to the personal preference and requirements of the archer (Fig. 7-57).



FIG. 7-55 Arrows of various designs and materials. Note the short (aluminum) quarrel of the crossbow (top) and 1800s North Dakota Sioux Indian arrow, second from top (the feathered fletching has long since deteriorated). The remaining arrows are composed of wood, fiberglass, and aluminum. The bow-fishing arrow (orange shaft) is composed of heavier fiberglass for greater penetration through water.



FIG. 7-56 Fletching improves flight stability and glide. The left and middle arrows have plastic fletching; the right arrow has turkey feather fletching.

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FIG. 7-57 The arrow nock. On the right is an example of a Sioux arrow.

The head or point is the engaging end of the arrow and varies in shape, design, and weight. The arrowheads made by the early Native Americans were chipped into points using flint, obsidian and other hard rock, antler, or bone. Some tribes later created metal points from scraps of iron (Fig. 7-58) and others use wooden tips formed by tapering the shaft that lacks fletching.

Modern arrowheads are exclusively metal and are broadly classified as field points and hunting points (broadheads). Field points lack cutting blades but have a pointed or dull tip for small game or target practice (Fig. 7-59). In contrast, broadheads generally have two to four balanced cutting blades for larger game. There is a wide variety of broadhead designs. Many arrow shafts have threaded tips that allow the hunter to change hunting heads. Some of the older arrows have a tapered shaft



FIG. 7-58 (A) Stone-tipped arrows, Plains Indian arrows, 1800s. From the author's collection. (B) Close-up view of the knapped stone arrowheads. Strips of sinew were used to secure the arrowhead to the arrow shaft. (C) Fletching and arrow nocks are visible. Note the position of the nock, used to seat the bowstring, in relation to the arrowhead position in (B). The nock is perpendicular to the flat surface of the arrowhead. These arrows are designed for killing humans: the arrowhead is more likely to glide into their intercostal space. In hunting four-legged animals, the nock is placed parallel to the flat surface of the arrowhead, better enabling the arrow to penetrate their intercostal space. The fletching is secured to the shaft with sinew spiraled over the feather. (D) Comparison of various arrow designs, including metal arrowheads. Arrow lengths vary. The lower fifth arrow is an Apache arrow (1800s) with a spiral fletching. The lowest arrow is a Mohawk arrow from the French and Indian War (circa 1754–1763). Arrow design is basically identical to the 1800s Plains Indian arrows. (E) Close-up view of metal arrowheads (left two arrows) in comparison to three representative stone-tipped arrows.

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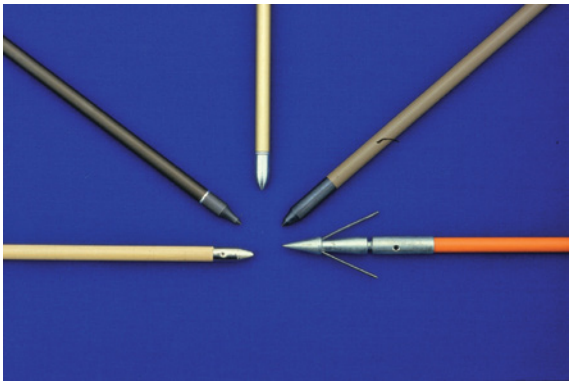


FIG. 7-59 Field points and arrowhead for bow fishing. Field points have a round silhouette that lacks cutting blades. Note that the bow-fishing arrow has a metallic barb to capture the fish on penetration.

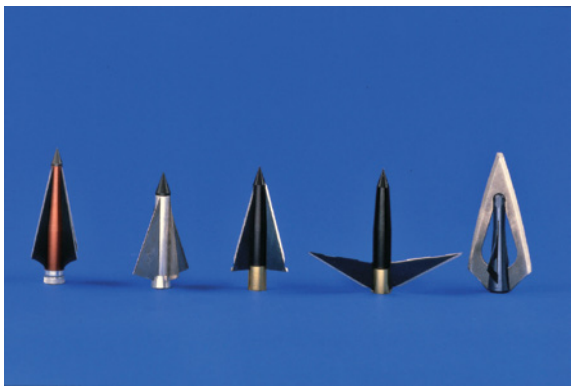


FIG. 7-60 Broadheads vary in shape, design, weight, and number of blades (usually two, three, or four). They are frequently threaded and screwed onto the arrow shaft. The broadhead third from the left has three blades that open in a tripod fashion (fourth from left) on penetration in order to enhance its cutting surface area.

with the head applied with adhesives and crimping. Broadheads are usually razor sharp for maximum penetration and laceration. They are usually designed to slide past bone (ribs) to ensure a clean strike to a vital spot.

Broadheads are of three general types. Fixed-blade broadheads are fixed to the shaft and sharpened manually. Modular broadheads contain a center column or ferrule holding three to four replaceable blades. Mechanical broadheads are designed to have recessed blades that fly open on impact; in a closed position, they have excellent ballistic properties. Barbed heads are illegal for hunting game (except for bow fishing) since the head will not work out of a wounded animal that receives a nonfatal shot (Fig. 7-60).

Arrow wounds in humans and companion animals are uncommon in the United States compared to gunshot wounds. Few cases are reported in the human and veterinary medical literature. Many cases go unreported, however.

Management of Arrow Wounds

Historically, removal of arrows from humans in part depended on the body location and the depth of the arrow penetration. If the arrow passed through most of a body region, the arrow could be removed by pushing the arrowhead to the surface of the body (emergence) and incising the overlying skin to facilitate its removal. The alternative was to extract the arrow with careful traction. Barbed arrows were a particular challenge to extract; displacement of the arrowhead from the shaft made its removal more problematic. Native American arrowheads were secured with animal tendon: in contact with body fluids, the tendon would soften, increasing the risk of arrowhead retention. Stone arrowheads were capable of shattering bone, whereas the iron arrowheads had greater penetration (Fig. 7-61).

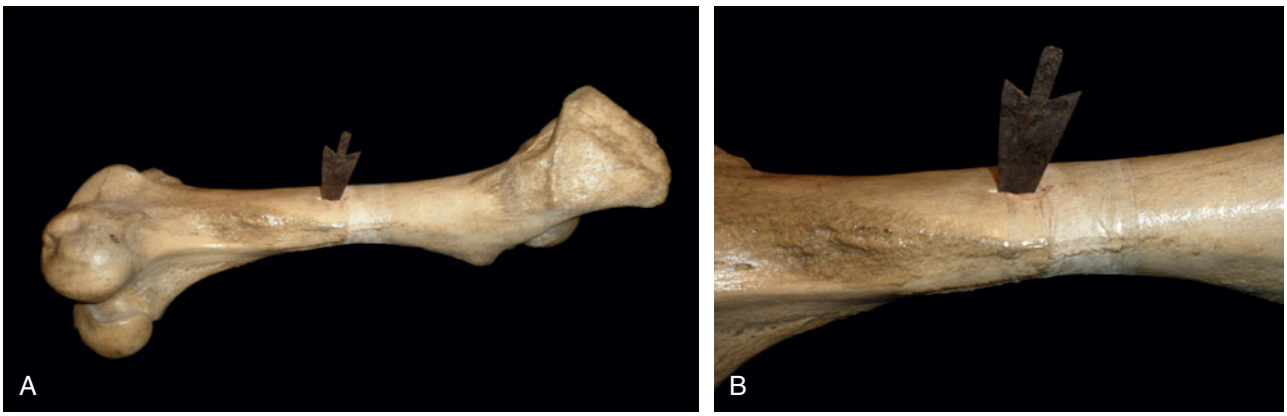


FIG. 7-61 (A) 1870s Plains indian arrowhead embedded in left lateral femur of a bison. (B) Close-up view of embedded metallic arrowhead. The fact that the arrow penetrated the skin and muscle before embedding into the dense lateral femoral bone of this bison attests to the power of the American Indian bow. Source: From the author's collection.

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Native American arrows were modified according to the prey being hunted. The "nock point" (the position of the bowstring where the nock of the arrow is placed) was altered in position in relation to the flat surface of the arrowhead. If the nock point was notched perpendicular to the flat face of the arrowhead, the arrowhead would be better able to penetrate the horizontal intercostal space of erect humans. Arrows designed for penetrating the thorax of bison and deer, for example, have the nock point parallel to the flat face of the arrow. As a result, the arrowhead is more likely to penetrate the intercostal space between the vertical ribs (see Fig. 7-58).

Much of our knowledge regarding arrow wounds was described by Major Joseph H. Bill in a publication dated 1862. General anesthesia, using chloroform or ether, was performed for the more serious arrow wounds. A 72% mortality rate was noted with chest injuries that penetrated the underlying lung. In contrast, 90% of penetrating abdominal wounds were fatal, the result of either acute hemorrhage or secondary peritonitis. To facilitate retraction of arrows, specially designed arrow-extracting forceps or wire loops were used.

Hunting arrows today are not barbed and may be able to be removed without great difficulty. Target (field-tip) arrows have a smooth field point equal to the diameter of the shaft and should slide out unimpeded. The round hole created by a target arrow resembles a simple gunshot wound. Broadheads (hunting arrows), with their rotating cutting edges, can "corkscrew" deep into the body, making removal more difficult. Their razor-sharp cutting edges have the potential to lacerate tissue when withdrawn. Tangential strikes to the skin can resemble a typical laceration.

If the arrow is lodged near a vital area or vessel (based on radiographs, CT, and examination), surgical exploration and removal are advisable. There are reported instances when vital organs (e.g., heart) have been penetrated with a foreign object, which paradoxically plugs the hole created and prevents fatal hemorrhage by its presence. Surgical exploration and removal is obviously the safest option in this situation.

From the surgical standpoint, retention of the arrow would allow the surgeon to determine the depth and location of the arrow wound prior to surgical exploration (Fig. 7-62). Owners may have removed the arrow before the animal is brought to the clinic. In the field, removal can be attempted if the arrow is lodged in a nonvital area to facilitate transport of the animal. Alternatively, the exposed shaft can be cut off to prevent accidental jarring of the arrow. The animal should be immobilized to prevent additional injury with a retained arrow during transport. In the emergency clinic, bolt cutters can be used to divide the exposed shaft. Sedatives, analgesics, and/or general anesthesia should be used when manipulating the patient.

It should be kept in mind that broadhead arrows have thin, metallic razor-sharp blades that may break on impact with bone. Wood or carbon-fiber shafts can break and it is possible for fragments to be retained in the wound. Ultrasound can be useful to locate retained fragments.

Radiographs and a complete examination are followed by surgical preparation of the area, exploration, and extraction of the arrow. If the arrow has perforated a structure and the broadhead is accessible, the broadhead can be unscrewed from the threaded shaft or cut off with bolt cutters to prevent further trauma as the shaft is withdrawn.

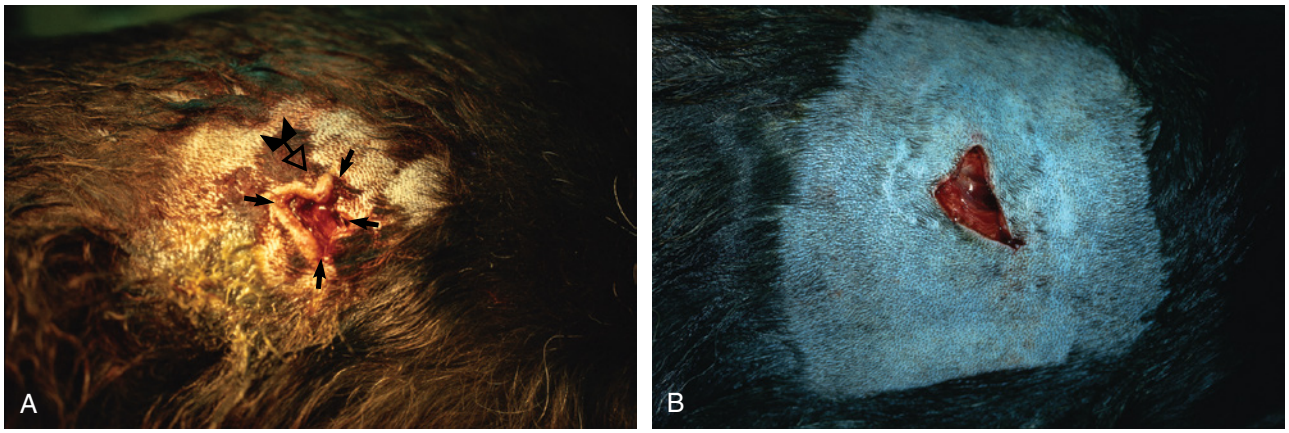
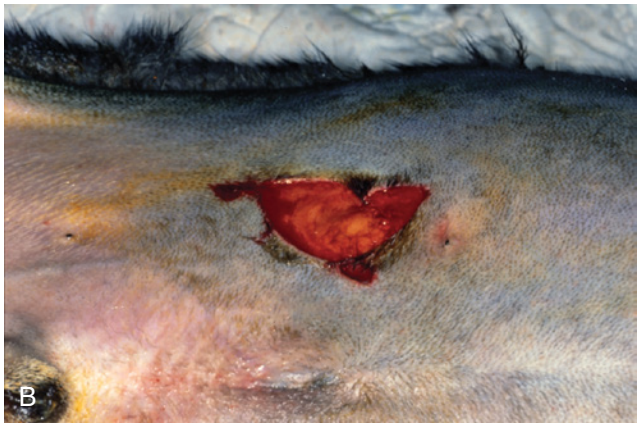


FIG. 7-62 (A) Arrow wound over the lumbar area. Trajectory of the arrow suggested the patient was shot by a hunter from an elevated position. Note the "cross" wound (arrows) created by a four-blade broadhead hunting arrow (symmetrically placed blades). Management consisted of local wound debridement, lavage, and a sterile dressing. Because of the large lacerations created, it was possible to close the skin wounds with establishment of separate ventral drainage. (B) Lumbar arrow wound: the triangular cut was created by a broadhead arrow with three blades.

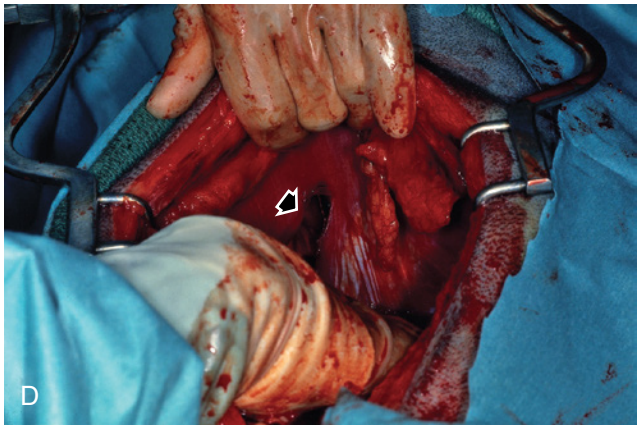
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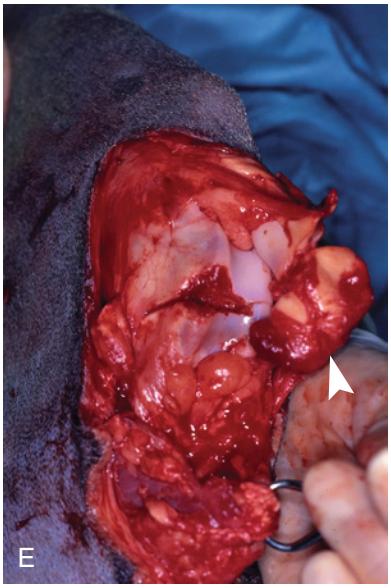


FIG. 7-63 (A) A broadhead arrow wound entering the abdominal cavity of a dog. The arrow initially perforated the stifle area before penetrating the abdomen. A neighbor admitted to shooting the dog for "self-defense." However, entry of the arrow from a caudal, lateral direction would suggest the dog was not in an offensive position when struck. (B) Note the triangular entry wound to the abdomen created by the three blades of the broadhead arrow. (C) Under anesthesia, the arrow was cut with bolt cutters and removed just prior to the laparotomy. (D) The arrow penetrated deep into the thoracic cavity (intraoperative view), cutting the liver and diaphragm (arrow). (E) Exploration of the knee. Note the patellar tendon was severed (grasped with forceps) from its attachment to the patella (arrow).

Wide aggressive surgical debridement is not indicated for most arrow wounds. Wound lavage and establishing adequate drainage are important. Exploration is necessary when major organs or structures are involved. Like other penetrating/perforating abdominal wounds, laparotomy is indicated (Figs 7-63 and 7-64).

Legal Considerations

In today's litigious society, veterinarians can find themselves involved in lawsuits, primarily to present testimony as to the physical findings of a given case. Forensic evidence of a shooting may be requested by owners,

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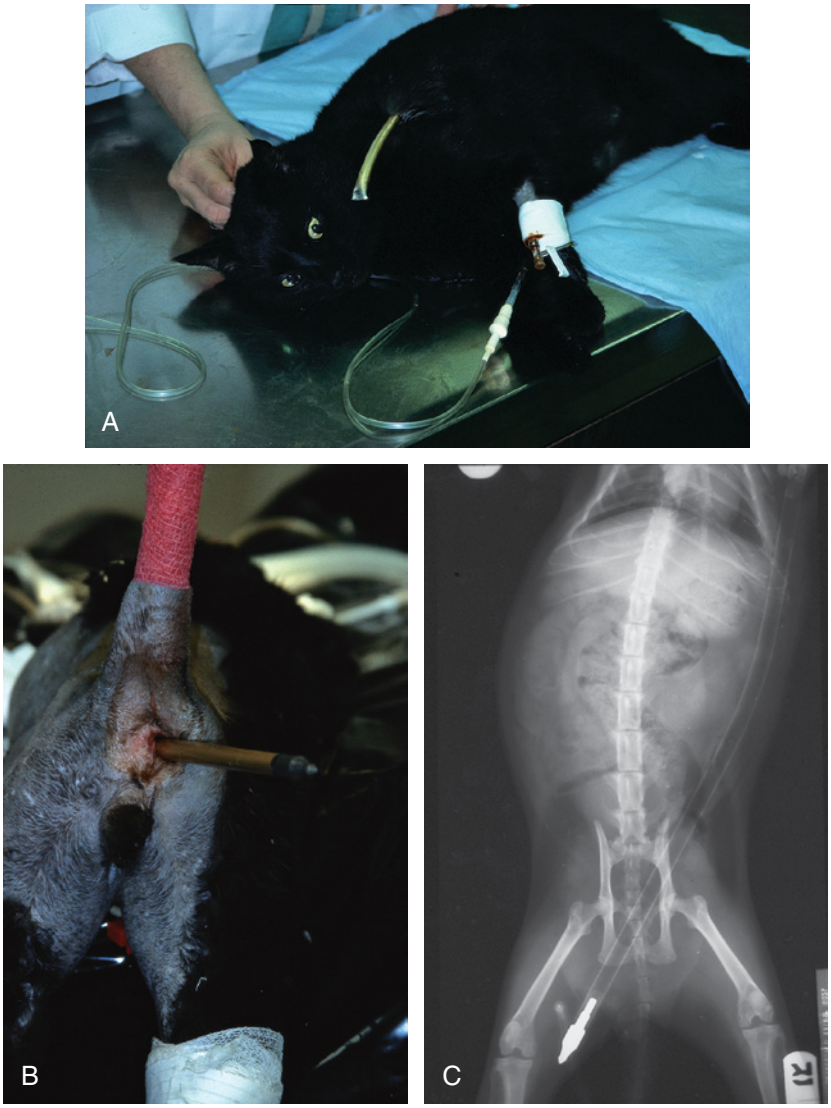


FIG. 7-64 (A) Field-point arrow wound in a black cat. The arrow traversed the thoracic and abdominal cavities. (B) The arrow exited the anus. (C) Radiograph of the patient with the arrow. Despite the gruesome nature of the wound, the patient recovered completely following exploratory surgery and repair. Field points pierce tissue but lack the cutting blades of broadheads (hunting arrows). If no vital structures are impacted, soft tissue trauma is relatively minor. (Courtesy of Gary Spodnick, DVM, DACVS.)

game wardens, and attorneys. Veterinarians must be able to document such evidence or request assistance from an experienced pathologist. Basic protocols and responsibilities involved with handling forensic evidence must be followed, or legal cases will be contested easily. Detailed records should include notes of conversations.

The objectives of the examination of projectile wounds include (1) proper identification and recording of the animal and any objects removed, (2) complete and accurate description of any lesions present, (3) ensuring continuity of possession of any exhibits, and (4) handling specimens carefully to minimize damage to the objects removed. A complete, detailed necropsy is indicated, including the examination of the digestive tract and gastrointestinal contents. Information gathered includes recording the number of wounds, features of the wound and adjacent tissues, probable angle of fire, course of the projectile(s) in the carcass, retrieval of foreign matter (projectiles, wadding, hair, and debris), estimated period of survival after wounding, and final cause of death.

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A complete set of quality radiographs and color photographs of the entire animal should be taken to illustrate the general position of the injuries. This will help orient those reviewing the case. Close photographs of individual injuries should include an area 15 cm around the wounds. A metric ruler should be included in the photographs to indicate scale. A label should be included in the photographs including the names of the owner/pet, date of the necropsy, case number, and examiner's name/initials. Projectiles should be photographed *in situ* before their removal. Metallic probes are not recommended; flexible plastic probes are best used to highlight the course of a projectile. Care must be taken to avoid scratching projectiles with metallic instruments that could distort rifling marks.

When feasible, an experienced, board-certified veterinary pathologist should perform the detailed postmortem examination. Consultation with the pathologist and knowledgeable law enforcement officials is advisable to ensure evidence is obtained, handled, and transferred properly so that the legal aspects of the case are properly maintained. Other preexisting medical or physical conditions may have affected the circumstances of the animal's demise.

Tissue samples are taken to confirm the presence of any suspected diseases, determine the age of a wound, and help distinguish entry from exit wounds. Tissue samples occasionally are taken for more detailed testing and analysis by law enforcement officials.

Information commonly requested in court relates to the number and location of wounds, features of the wounds and related tissue areas, course of the projectiles, angle of fire, projectiles and foreign debris recovered, cause and time of death, and details pertaining to the handling and disposition of specimens collected. Entry wounds are closely inspected to determine the proximity of the weapon to the animal. A 15 cm square around entrance wounds should be removed, pinned to a piece of rigid material, and then frozen for analysis to determine the presence of propellant and projectile residue. This tissue specimen should not be washed or placed in formalin.

Careful examination and collection of tissues surrounding the path of a projectile are useful in determining whether game has been illegally killed by a gun during a restricted bow-hunting season. Illegal hunters may insert an arrowhead into a gunshot wound to simulate an arrow kill. When this is suspected, a 5 cm square of skin around the wound is taken along with a separate skin sample that can serve as a control. These skin samples can be tested for lead residue by atomic absorption spectrophotometry. Examination of gastric contents can also help the pathologist determine the circumstances of the incident.

The lands (elevated borders) and grooves of a rifled barrel embed marks on jacketed and nonjacketed bullets. Occasionally, the lead core separates from the outer jacket. Retrieval of the jacket is of great importance because the rifling marks are scored on its outer surface. The bullet should be washed with water and alcohol and then allowed to air dry. The washing removes blood and tissue fragments. Close-up photographs of the bullet may help ensure its identification.

Projectiles can be wrapped in facial tissues and placed in vials, a glass jar, or a pillbox that can be sealed with tape. Some pathologists place projectiles in sealed envelopes. The body region from which each projectile was retrieved must be clearly identified and each projectile must be placed in a separate, marked container. The container is identified with the date, time, case number, and owner's name, and it is initialed by those present at the necropsy. An indelible marker should be used on the container or on a nonremovable label. The projectiles should be secured from tampering or access by other individuals. Projectiles are turned over only to a qualified law enforcement officer. Any persons receiving the specimens must add the time and date of the transfer and their initials to the container.

Arrows can have latent fingerprints on the shaft, unless blurred by passage through body tissues, contact with the entrance environment, or manipulation by individuals. Depending on the exact nature of the case, arrows can be removed without touching the shaft and placed in a secure area for presentation to law enforcement officials. Arrows are not rinsed: they should be placed in a clean plastic bag and labeled.

Under no circumstances should the projectile be transferred to the owner, which would reduce the credibility of the evidence gathered.

Carbon-fiber arrow shafts can leave a black ring deposit on the skin that mimics gunshot residue that can be noted from bullets. This tissue can be chemical "spot tested" to determine if the tissue discoloration is the result of a bullet. Archery wounds have very inconspicuous abrasion rings compared to the often prominent abrasion rings of gunshot wounds. The entry point of a target arrow is more likely to be oblong or slit-like in appearance when compared to the typical round entry wound of bullets.

Attention to the legal issues discussed in this section will help clinicians avoid the embarrassing errors and pitfalls associated with inappropriate case preparation in a court of law.

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EXPLOSIVE MUNITIONS: BALLISTIC, BLAST, AND THERMAL INJURIES

Military dogs, like soldiers in combat, are susceptible to explosives. Ballistic injuries are the result of flying shrapnel or fragments of metal, wood, glass, and concrete and other debris scattered by the explosion. Blast injuries are the result of the sonic shockwave from the explosion. Internal organs (and hollow organs in particular) are susceptible to shockwave force; the dog also may be thrown violently against an object. Thermal injuries are a third form of trauma that may be associated with close proximity to the blast. Incendiary explosives disperse hot chemicals that also cause thermal injuries. Dogs with multiple injuries require a team approach to stabilize the patient and prioritize the steps to manage the patient. A plan can be devised to approach wounds in a few "set surgeries" rather than undertaking multiple surgical procedures in a single prolonged anesthesia.

IMPALEMENT INJURIES

Impalement by definition is piercing or transfixing with a sharp object. In dogs and cats, this is most commonly the result of running or falling onto a sharp object. Occasionally, the history includes a dog running through the woods prior to presentation. Dogs in particular are more susceptible to oropharyngeal and esophageal impalement wounds when chasing or carrying sticks. There are two common scenarios. (1) Dogs occasionally run after a stick or piece of wood tossed by the owner: as the object tumbles or momentarily imbeds into the ground, the dog grabs the end in its mouth. The momentum of the dog drives the stick through their oropharynx, in many cases deep into the cervical tissues (Fig. 7-65). (2) Dogs occasionally run with a stick or piece of wood in their mouth: if the end of the stick strikes the ground while the dog is running, the dog again impales their oropharynx.

Dogs occasionally run into a stationary pointed object, resulting in an impalement wound usually involving the head, neck, or anterior thorax (Fig. 7-66). Dogs can impale their trunk by chasing and overrunning a tumbling stick tossed by the owner. One end of the stick contacts the ground while the vertical end of the stick impales the pet (Fig. 7-67). Rarely, dogs and cats impale themselves by falling from an elevated position, striking fencing or other objects on impact (Fig. 7-68).

Impalement injuries can be deceptive, with the dog presented with what appears to be a simple skin laceration or puncture wound. Impalement injuries, especially those involving sticks, should be explored to ensure that no plant material (bark, wood splinters, leaf fragments, pine needles) is retained in the body. Such retained material normally results in abscess formation and draining tracts. Smooth-surfaced objects (finished lumber, metal, plastic) are less problematic. Deeper cervical wounds should be explored through a ventral midline cervical approach. More superficial oropharyngeal wounds can be explored and repaired with an oral approach. Impalement wounds entering the thoracic or abdominal cavities require exploration.

It is an advantage for the surgeon to have the impalement object left in place: exploration can be focused on the exact path and optimal approach to its removal. This also facilitates lavage, debridement, tissue repair, and postoperative drainage. If the object has been removed,

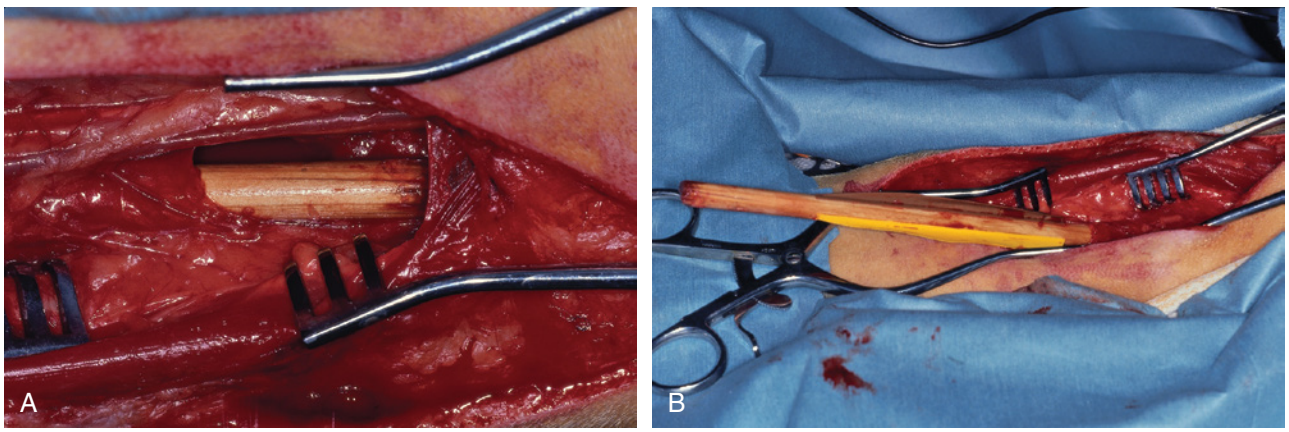


FIG. 7-65 (A) This canine patient chased an arrow in flight. When the arrow struck the ground the dog grabbed the nock end of the arrow. His body momentum drove the arrow through his oropharynx deep into the cervical tissues. (B) A ventral cervical incision was used to remove the arrow and inspect the wound tract. The oropharyngeal tear was sutured. The cervical wound was lavaged and closed with a vacuum drain. The patient made a complete recovery.

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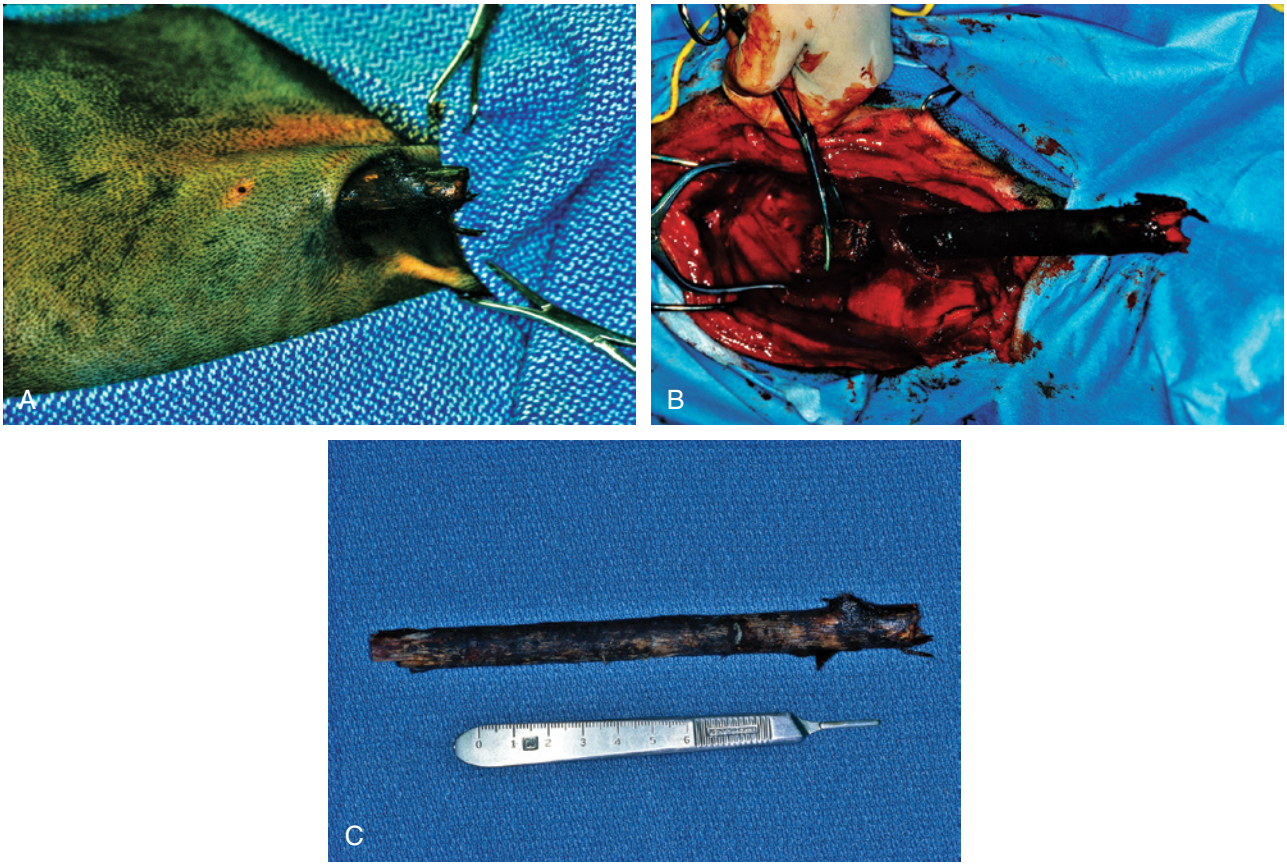


FIG. 7-66 (A) Thoracic impalement on a stick. The dog staggered back to the owner after running into the neighboring woods. The stick entered the thoracic inlet to the level of the diaphragm. (B, C) The stick was left in place to facilitate exploration of the entire wound. A thoracotomy also was performed to ensure no fragments of bark or wood splinters remained. The patient made a complete recovery.

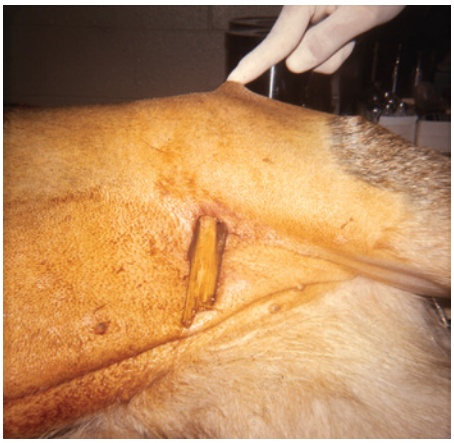


FIG. 7-67 Impalement on a piece of wood. The dog overran the piece of lumber, tossed by the owner, with the stick penetrating the left flank area. Sticks and twigs are more likely to leave fragments of plant material behind and warrant closer inspection than finished lumber, metal, or plastic. The author has removed bark, wood slivers, pine needles, and leaf fragments, all associated with stick-impalement injuries.



FIG. 7-68 Tomato stake impalement injury at the base of the tail of a cat secondary to a fall. The external end of the stake was removed and the wound explored. The retained stake segment served as a guideline to its path during wound exploration.

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examination of the object by the surgeon combined with the owner's description of the wound can help determine the relative depth and direction of the impalement tract. Radiographs, CT, and ultrasonography of the involved region(s) can be useful in determining the best surgical approach to problematic impalement wounds. Ultrasound can be especially useful in detecting wood fragments. Endoscopic examination also may be useful in assessing the location of an esophageal tear. Magnetic resonance imaging has been suggested for better defining the location of problematic esophageal injuries, although most tears should be visible by surgical exploration of the cervical area. Radiographic evidence of cervical emphysema is a frequent finding with acute penetrating oropharyngeal and esophageal impalement. Repair of esophageal tears can be challenging, depending on the size and location of the tear. Most oral impalement wounds necessarily require debridement and closure of the mucosal wound to prevent oral contaminants from gaining access to the underlying tissues.

Overlooking retained sticks or delays in treatment can result in life-threatening infections. Similarly, overlooked oropharyngeal/cervical esophageal tears can result in life-threatening infection and extension into the anterior mediastinum. Prompt assessment followed by surgical intervention can dramatically reduce this risk.

Exploration includes careful inspection for retained plant material and debris. Following exploration and corrective surgery, copious lavage and suction of the area are indicated. A closed-vacuum drain can be very effective in controlling dead space and assessing the fluid volume/composition retained in the reservoir after completion of surgery. Infected wounds are cultured: broad-spectrum antibiotic administration is advisable (see Chapter 6).

PRESSURE ULCERS

Pressure ulcers ("pressure sores") are caused by prolonged compression of the skin over bony prominences, resulting in progressive ischemia. Shearing forces can contribute to their formation. They also can form from prolonged compression from an external medical device, most commonly improperly fitting casts or splints. Animals unable or unwilling to change body positions are prone to pressure ulcer formation, unless close attention is given to their prevention. *Pressure ulcer* is the accepted term because it is more descriptive and encompasses the variety of pressure ulcers encountered. The older term for pressure ulcers, *decubitus ulcers* (derived from the Latin term *decumbere*, meaning "to lie down"), is limited to pressure ulcers that form while the patient is restricted to a bed.

Sick, debilitated, and paralyzed dogs are most susceptible to the formation of pressure ulcers. Weight loss, protein depletion, and poor nutritional support increase the likelihood of their development. Loss of subcutaneous fat and muscle mass enhances the silhouette of bony prominences including the greater trochanter, ischial tuberosity, acromion, lateral tibial condyle, lateral humeral epicondyle, tuber coxae, olecranon and calcaneal tuber, lateral malleolus, lateral surface of the fifth digit, and sternum. Denervated skin may be more prone to trophic ulcer development. Debilitated dogs with Cushing's disease have been seen by the author presenting with pressure ulcers.

As noted, casts and splints are capable of causing pressure ulcers by compression of the skin overlying a bony prominence. Most commonly, this involves the accessory carpal pad (Fig. 7-69). Prevention is directed at proper padding around the bony prominences to avoid a pressure-cone effect to the area.

The intensity and duration of the pressure, along with the relative susceptibility of the tissues, influence pressure ulcer formation. Large dogs are more prone to pressure ulcer formation due to their greater weight (Fig. 7-70). Debilitated greyhounds and other breeds with thin skin and a sparse hair coat may be prone to pressure ulcer formation. The skin overlying the greater trochanter is the most common site for their development. Ischial tuberosity pressure ulcers are more common in smaller paraplegic dogs who have a tendency to sit up on their perineal region for prolonged periods of time on unpadded surfaces. In paraplegic dogs, the loss of sensation (denervation) increases the susceptibility of the tissues to pressure ulcer formation. Moreover, the patient is unaware of pain normally associated with prolonged compression of the skin overlying bony prominences and is incapable of adjusting their body position.

Cats rarely develop pressure ulcers due to their small size and less frequent spinal-cord injuries. However, they occasionally develop pressure ulcers over the calcaneal tuber. In cats that have a plantigrade stance, there is an increased risk of developing ulceration in this area. Orthopedic and soft tissue trauma, weakening of the gastrocnemius tendon, and an underlying neuropathy (diabetes, etc.) may be contributing factors. The underlying cause must be addressed in addition to wound closure for long-term resolution of this condition.

Nursing care is more difficult for larger dogs. Unfortunately, if they cannot be lifted from their cage, they may be inappropriately dragged out of the cage for treatments and cleaning. The fragile skin overlying the bony prominences then is stretched and abraded against the floor surface. Moisture accumulation on the skin from sweating, environmental moisture, urine, and feces can promote tissue maceration and infection. A dense hair coat affords some natural (padding) protection but may promote moisture retention, mask early stages of pressure ulcer formation, and delay institution of additional preventative measures.

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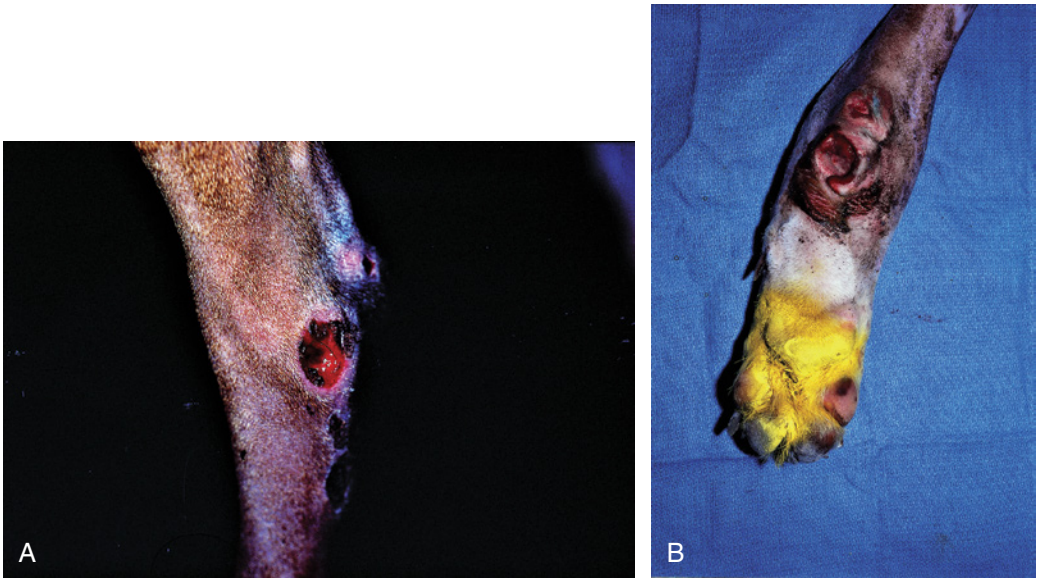


FIG. 7-69 Pressure ulcers associated with improper casting/padding. (A) Ulcer overlying the calcaneus. (B) Sloughing of the accessory carpal pad.



FIG. 7-70 Pressure ulcer (grade II) over the elbow of a large Labrador retriever. The dog developed the wound during its hospitalization for a serious illness. Closure required the application of a skin flap.

Prevention

Prevention of pressure ulcers requires an educated and devoted nursing staff, veterinarian, and owner. The following management steps should be implemented:

1. Provide proper nutritional and fluid support
2. Keep the patient's skin clean and dry
3. Change the patient's body position every 2 hours (left lateral, sternal, right lateral)
4. Keep the patient on well-padded surfaces (artificial washable fleece pads placed over easily cleaned support pads) placed on elevated grates or racks to separate the dog from urine and feces; water or air mattresses; disposable absorbent foam egg crate sheets (convoluted foam pads, Allegiance Health Care Corp., Wilsonville, OR); or coated or closed-cell foam pads (Dubicrest Padding 4700, Alpha Protech, Tulsa, OK)
5. Assess skin overlying bony prominences daily for erythema, the first sign of pressure ulcer development
6. Avoid dragging the patient over or dropping them on hard surfaces – if the patient cannot be lifted, slide them on a rug or fleece pad to prevent cutaneous abrasion
7. Place weak or paralyzed dogs in a sling support for 2–4 hours daily to reduce pressure on lateral bony prominences
8. Periodically, use hydrotherapy to keep the patient clean while improving muscle tone and circulation to the skin. The patient must be dried appropriately after each session
9. Make appropriate use of applied padding to elevate the bony prominences, especially when patients are regaining the ability to ambulate (see Plates 2, 3, 10, and 11).

Properly maintained, a closed collection system can prevent urine scalding and skin maceration in patients incapable of urinating voluntarily. The perineal area can be clipped of hair to facilitate cleansing in the event of

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fecal incontinence. Water mattresses are useful as long as they support the weight of the dog. Covers should be applied over the mattresses to protect them from punctures and to facilitate cleaning. Unfortunately, many dogs will bite, chew, and scratch mattresses and foam pads. Because replacement can be costly, one option is to have the owner purchase pads, which they later can take home with them when the dog is discharged from the hospital. Many dogs will not cooperate with periodic attempts to change body position unless barriers (cardboard boxes, pads, etc.) are used to restrict their movements. Providing large patients with appropriate nursing care is time consuming and expensive. However, the cost of pressure ulcer treatment far outweighs the cost of prevention.

Pressure Ulcer Classification

Pressure ulcer gradation is done according to the depth of injury to tissues overlying bony prominences (grades I to IV) (Fig. 7-71). Table 7-3 summarizes this classification.

Management of Pressure Ulcers

Permanently debilitated or paralyzed dogs prone to pressure ulcer formation also are prone to redevelopment of them after successful closure. Patients who regain ambulation have the greatest likelihood of maintaining permanent closure. Until patients reach this point, continuous preventative medicine is required to protect the area from reulceration. Several options are available for management of pressure ulcers; selection of the appropriate technique depends on the severity of the lesion:

1. Open wound management—healing by second intention
2. Delayed primary closure
3. Secondary closure
4. Excision of the bony prominence in combination with (2) or (3)
5. Muscle-flap coverage of the bony prominence in combination with (2), (3), or (4)
6. Skin-flap coverage in combination with (2), (3), (4), or (5)



FIG. 7-71 (A) Debilitated geriatric patient with a pressure ulcer (arrow) over the left acromion. Note the dog was placed on a sheepskin. (B) A closer view indicates a grade II pressure ulcer (arrow). (C) Two pressure ulcers also were noted over the wing of the ilium (grade II) and greater trochanter (grade I progressing to a grade II) (arrows).

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TABLE 7-3 Pressure Ulcer Classification.

Grade I	Erythema; superficial to partial-thickness skin loss
Grade II	Full-thickness skin loss with variable involvement of subcutis
Grade III	Ulceration extends to deep fascia overlying the bony prominences
Grade IV	Ulceration extends to bone. Osteomyelitis or joint infection may be present

Grade I and grade II pressure ulcers may be amenable to second-intention healing, unless they are persistent or recurrent ulcers. In many cases, grade II pressure ulcers are better closed by wound excision and primary closure, delayed primary closure, or secondary closure. Grade III, grade IV, or recurrent pressure ulcers may require open wound management to control infection followed by excision of a portion of the bony prominence. A local muscle flap may be used to add padding between the bone and skin. Muscle flaps can contribute circulation to diseased bone and help control chronic infection. The outer muscle surface, in turn, provides a stable vascular bed for skin flaps or cutaneous advancement.

In practice, the author will close most pressure ulcers by advancing healthy skin over the prepared ulcer, either by undermining and advancement of skin or by the use of a skin flap. If there is insufficient skin available for simple closure, skin flaps (including local flaps and axial pattern flaps) can provide a layer of subcutaneous tissue to cushion the skin over the bony prominence. Moreover, rotational flaps can provide full-thickness skin coverage while placing the suture line peripheral to the bony prominence. On occasion the author will burr down the prominence with a Hall-style Air Drill to slightly flatten the most pointed surface beneath the skin prior to closure.

It must be noted that skin-closure techniques that place the incision line directly over the bony prominence increase the likelihood of dehiscence; this is not considered desirable for closure of pressure ulcers in humans who suffer from paralyzing injuries. Muscle flaps and skin flaps with resection of the bony prominence would be the most aggressive approach for problematic ulcers in these human patients. However, the author has used simple skin appositional techniques, which are normally effective in dogs. Postoperatively, prolonged protection of the surgical closure area well into the maturation phase of wound healing is recommended (Fig. 7-72). The key for long-term success is getting the patient ambulatory, which includes the use of physical therapy.

Healing by second intention may not provide a durable epithelial surface to prevent reinjury. The author normally recommends closing pressure ulcers with healthy skin, unless you are dealing with an early pressure ulcer that can be managed conservatively. In dogs, closure of pressure ulcers does require prolonged wound protection. Even then, postoperative protective measures must be instituted to avoid trauma and ischemia to the flap until the animal becomes ambulatory.

In practice, the author has had the best results by debridement of the pressure ulcer, culturing the wound, and closing the wound with the inclusion of a vacuum drain system. While closure of pressure ulcers with the incision overlying a bony prominence is not ideal, it does work in most cases. Long-term successful closure includes (1) prolonged protection of the surgical closure (6 weeks), (2) clean and dry soft bedding for the patient, and (3) rehabilitation of the patient to regain patient mobility (Fig. 7-73).

Pressure ulcers over the elbow can be particularly challenging, especially in thin-skinned breeds such as the greyhound.

In many cases local flaps can be used to close the defect, the simplest being the use of bipedicle advancement flaps (release incisions). The thoracodorsal axial pattern flap is considered only for the most problematic skin defects overlying the elbow area.

Postoperative Care

Preventative measures, as described in the previous section, must be continued postoperatively. In addition, bandages are advised in order to protect the healing wound from moisture, microorganisms, and compression and shearing forces that promote ischemic necrosis and dehiscence. Soft, thick, "doughnut rings" fashioned from roll gauze have been used to protect the trochanteric area and lateral prominence of the limbs. The ring encircles the circumference of the bony prominence and protects it from contact with hard surfaces when the dog is placed in lateral recumbency. However, these can be difficult to properly maintain. The use of doughnut rings also is controversial since the ring can create a "halo" compression over the skin surrounding the bony prominence and compromise the cutaneous circulation required to promote healing to the injured area. Doughnut rings require close observation when used. Another option is the use of parallel pads made from gauze rolls. These pads can provide protection without the complete skin encirclement of doughnut rings. Spray adhesive used for plastic surgical drapes can be applied around the neighboring skin, followed by the application of surgical tape (Fig. 7-72).

Soft foam pads, spicas, and tie-over dressings may be used to protect bony prominences on the lateral surface

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FIG. 7-72 (A) Chronic pressure ulcer over the greater trochanter. The dog developed the wound previously during hospitalization for the repair of pelvic fractures. (B) Complete excision of the pressure ulcer was performed. Electrocautery and ligatures were required to control the considerable hemorrhage that occurred during this procedure. (C) Skin borders were undermined, advanced, and apposed with a subcuticular suture pattern, followed by skin sutures (vertical mattress and simple interrupted suture patterns). A Penrose drain was used to control dead space. (D) A nonadherent dressing was applied over the incision. Two 6-inch soft gauze rolls were placed in parallel fashion cranial and caudal to the incision. Spray adhesive, used for the application of plastic surgical drapes, was used to stick the gauze sponges into position. (E) Spray adhesive was used to provide additional adhesive power to the surgical tape placed over the area. (F) The wound 14 days later. The ability of the patient to freely move and ambulate is critical to the treatment and prevention of recurrence of pressure ulcers. (See Plate 11 for an alternative method to protect the greater trochanter.)

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FIG. 7-73 (A) Geriatric German shepherd with bilateral pressure ulcers overlying each acromion. The patient has a neuropathy; the owner assists the dog in rising and walking with a body harness. (B) Close-up view of the left pressure ulcer. Note skin and muscle necrosis down to the acromion. (C) After debridement and lavage, a round Hemaduct drain was trimmed and inserted into the prepared wound pocket. A Jackson-Pratt reservoir was attached to the external drain. The local skin margins were mobilized and closed with intradermal absorbable skin sutures, followed by the use of monofilament nylon interrupted skin sutures. (D) The Jackson-Pratt reservoir was attached to the adjacent harness. Note the pipe insulation attached to the harness, raising the shoulder profile from the bedding when the patient reclines. Detailed instructions on drain care and soft bedding were discussed with the owners prior to discharging the patient.

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of the trunk and limbs. Schroeder-Thomas splints may be useful to manage pressure ulcers overlying the olecranon and calcaneal tuber after surgical closure.

Foam pipe insulation used in plumbing is a useful material for padding of pressure sores (Figs 7-73 and 7-74). The author has had excellent results a simple foam padding system (using pipe insulation) to protect the elbow region while allowing the dog to ambulate normally (Fig. 7-75) (see Plate 10). Another technique used by the author to protect the greater trochanter is the pipe insulation loop technique (Fig. 7-76) (see Plate 11).

Once healing is completed and sutures removed, splints and protective bandages may be removed on a trial basis, although proper nursing care is continued for as long as the dog is not ambulatory. Regrowth of the hair coat provides additional protection to the underlying skin.

The most difficult pressure ulcers to manage in the dog involve the olecranon and greater trochanter. This is most commonly noted in large-breed dogs.

Grade II–IV ulcers are best closed after the wound has been properly managed (debridement, control infection). Prolonged protection is critical in the postoperative period. Veterinarians commonly mistakenly think that healing is complete once the skin sutures are removed. Unfortunately, the surgical area may reulcerate days later.

As noted in Chapter 2, healing occurs for months. The key to improving durability at the surgical site is protecting the wound well into the maturation phase of healing, giving time for circulation and collagen deposition to improve and remodel the wound. Protecting the wounds for 4–6 weeks is key to long-term success in closure of pressure ulcers. Dogs that regain the ability to walk and stand on their own are less likely to have recurrence of pressure ulcers. Physical therapy can play an instrumental role in this endeavor. Soft, clean, dry bedding is also important to long-term protection of these susceptible areas.

HYGROMA

An elbow hygroma is a serous subcutaneous fluid pocket overlying the olecranon in large- to giant-breed dogs (great Danes, Irish wolfhounds, St. Bernards, and Newfoundlands), usually less than 2 years of age (Fig. 7-77). Hygromas form as a result of repeated blunt trauma from the patient striking and compressing the skin against hard floor surfaces. The skin and subcutis in turn are compressed against this bony prominence. Although rare, hygromas have been reported overlying the carpus, nuchal crest, os calcis, and tuber ischium. Today elbow hygromas are relatively uncommon when compared to the population of cases seen by the author in the 1970s and 1980s. This may be due to changes in the dog population or the fact that most dogs live in the house with beds, couches, and rugs available for their resting spots. Owners of giant-breed dogs also may be aware of hygromas and make an effort to provide their pet with soft bedding.

Most hygromas are painless fluctuations. Some hygromas remain relatively small and change little in size. Over time, hygromas can enlarge and ulcerate as the overlying skin thins and stretches over the fluid pocket. Ulcerated hygromas frequently become infected. Poor aseptic technique from attempted fluid aspiration can result in abscess formation; this problem may be compounded by futile attempts at prevention by injecting corticosteroids into the hygroma pocket. Both techniques are not advisable.

Conservative prevention and management are essentially the same: soft padded bedding (see bedding options for pressure ulcers in the preceding section) and protective elbow pads (protective dog leggings, https://walkinpets.com; www.dogleggs.com). This would be

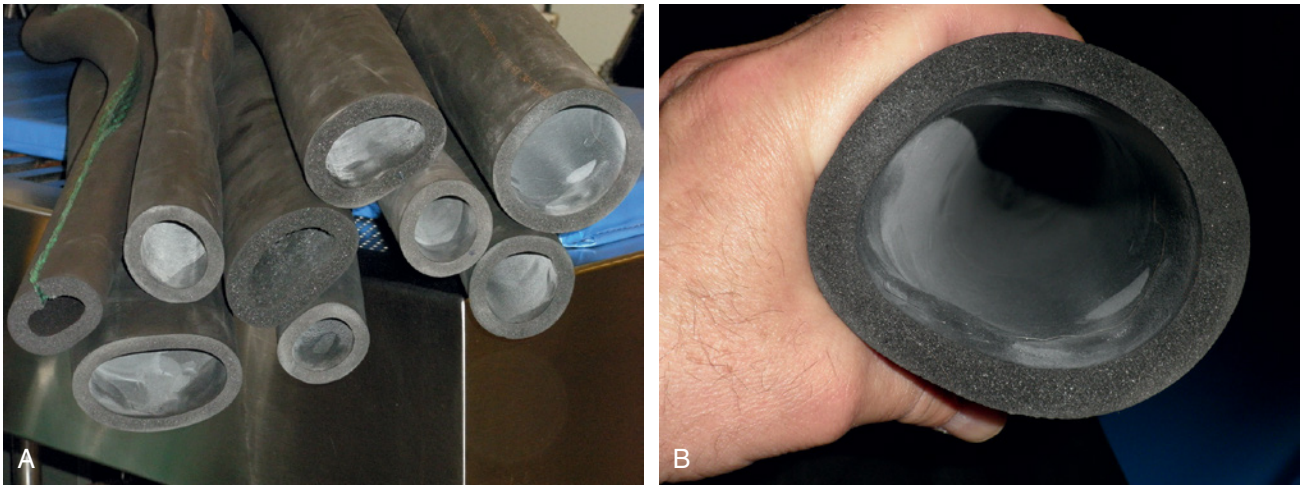


FIG. 7-74 (A) While commercial hardware stores provide the smaller-diameter pipe insulation for home use, plumbing supply houses have a variety of sizes (diameter and thickness) depending on the size of the dog and use for this material. Pipe insulation normally is sold in 6 foot lengths. Pipe insulation also can be purchased on the internet. (B) Close-up view of one of the large-diameter foam rubber pipe insulators.

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FIG. 7-75 (A) Nonhealing elbow dehiscence overlying the olecranon secondary to resection of large calcinosis cutis lesion. (B, C) Medial and lateral views of release incisions, with closure of the elbow defect with bilateral bipedicle advancement flaps (arrows). Intradermal sutures were used to approximate the incision followed by a combination of vertical mattress and interrupted skin sutures. Source: (A–C) Pavletic MM. 2011. Use of commercially available foam pipe insulation as a protective device for wounds over the elbow joint area in five dogs. *J Am Vet Med Assoc* 239:1225–1231, reproduced with permission. (D) Following trimming of the fur, strips of 2-inch surgical tape are placed along the length of the extremity and overlapped around the circumference of the forelimb, distal to the surgical closure. A space is provided over the accessory carpal pad. Today, the author prefers to use Elastikon strips because they have a greater adhesive property compared to the current surgical tapes on the market. Tape strips end proximal to the border of the metacarpal pad. (E) Placement of the foam rubber pad, with the split length facing the front of the forelimb. This first pad layer extends just distal to the elbow incision to the level of the metacarpal pad. (F) Anterior view of the rubber foam and exposed tape base or foundation. Elastikon bands are initially applied to the white tape layer and then encircle the foam padding. (G) Close-up view of 3-inch Elastikon. The end of the Elastikon is secured to the white tape. (H) The Elastikon encircles the foam pad and extremity. (I) The proximal end of the pad is secured in similar fashion followed by a third layer encircling the middle of the pipe insulation padding. (J) The longer second layer of rubber foam padding is secured to the first layer. The proximal end is measured to fully protect the elbow on flexion. The proximal end and corners of the insulation are trimmed so they do not "catch" on the axillary skin. In large, heavy dogs, a third short foam layer (equivalent to the length of the first layer) can be applied over this second layer for added protection. (K) The proximal end of the secondary layer forms a shield over the olecranon area. The end is folded down to expose the surgical area. A dressing and thin layer of cast padding is applied over the area during healing. The combined layers of pipe insulation provide a slot for its application, preventing its displacement between subsequent dressing/bandage changes. It is important to place this dressing/bandage layer loosely to prevent binding and rubbing of the materials on the surgical closure; this dressing layer is thinner than the innermost insulation layer to prevent pressure cone formation over the olecranon area. (L) The thin dressing includes a nonadherent dressing (Adaptic, Johnson & Johnson) covering the closure, the release incisions, and any Penrose drain segment. A small amount of triple antibiotic ointment is applied to the dressing prior to its application. This is followed by a single revolution of cast padding. A self-adherent gauze layer is placed over the cast padding. The cut end of the gauze is secured with a strip of surgical tape or Elastikon to prevent it from unraveling. As noted in (K), this thin dressing must be narrower that the first layer of pipe insulation: preserving this space or gap ensures the surgical closure does not contact the floor when the dog is at rest. (See Plate 10.)

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FIG. 7-75 (Continued)

the initial treatment of choice for small hygromas. Larger, persistent hygromas are likely surgical candidates. Large, ulcerated, and infected hygromas normally require more aggressive surgical intervention, including debridement and open wound management before attempting closure.

Surgical Options

Useful drainage options include the use of Penrose drains and the more recent introduction of the Jackson-Pratt vacuum drain system. The Penrose drain technique is an effective method to manage hygromas,

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FIG. 7-76 (A) Protection of a German shepherd after spinal surgery secondary to disc disease. A grade I pressure ulcer was forming during patient care and rehabilitation. Note that the large pipe insulation loop (6 ft segment) is positioned round the hindlimbs. The arrow denotes the intersection of the pipe insulation: these junctions are secured with Elastikon or duct tape. Once secured, the dorsal pelvic portion of the pipe insulation is secured to a loop of Elastikon tape that encircles the caudal abdominal area. (B) Elastikon secures the pipe insulation to the Elastikon band encircling the caudal abdomen (arrow). (C) Right lateral view. An additional tape loop (arrow) is placed at the junction of the pipe insulation loops to improve its positioning cranial and caudal to the greater trochanteric areas. This device was effective in promoting healing of this early pressure ulcer overlying the left greater trochanter while protecting the right greater trochanter. (See Plate 11.)

although one recent study noted 4/12 cases employing this technique had recurrence. Of the two techniques, the Jackson-Pratt drainage system does not require bandaging and is simple to use. The fluid accumulating in the Jackson-Pratt reservoir can be measured quantitatively and serves as a general guideline for when to remove the drain. Both techniques are described here. Successful surgical resection and reconstructive surgery employing the thoracodorsal axial pattern flap has been reported; this should only be considered for the most problematic hygromas. Most can be handled with long-term drainage options.

Penrose Drain Technique

Large, uncomplicated hygromas are managed with the prolonged use of Penrose drains (Fig. 7-78):

1. Liberally clip the elbow area
2. Use sterile surgical preparation and draping
3. Make a stab incision in the proximal and distal borders of the hygroma
4. Drain the fluid and inspect the interior of the hygroma
5. Remove fibrinous debris with forceps and sharp scissors

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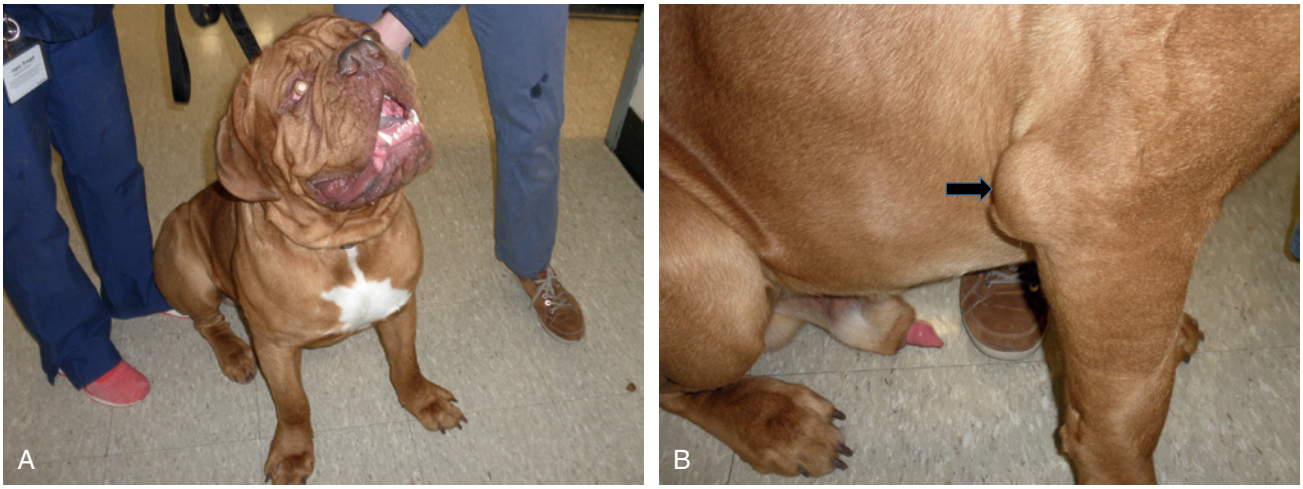


FIG. 7-77 (A) A 1-year-old Dogue de Bordeaux presenting with an early right elbow hygroma. (B) Small hygroma of the right elbow. Conservative therapy is initially warranted for the smaller hygromas, including the use of soft bedding and discouraging the dog from reclining on hard floor surfaces.

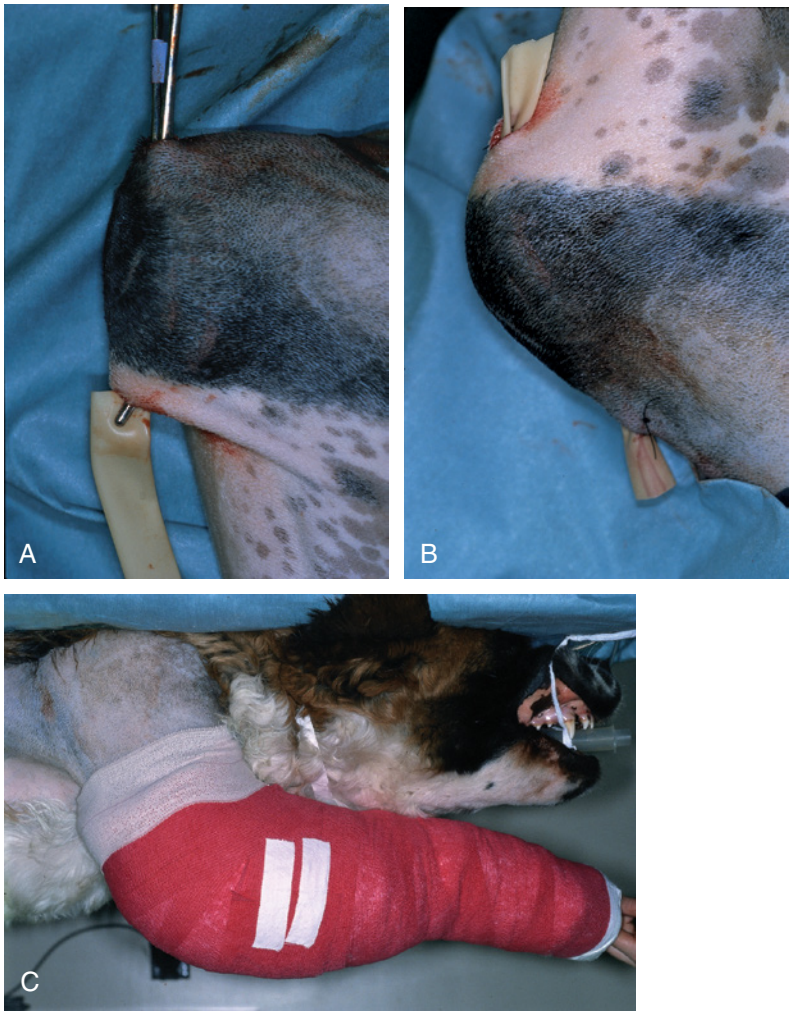


FIG. 7-78 (A) Elbow hygroma in a young St. Bernard. (B) Stab incisions are made with a no. 10 blade at the proximal and distal ends of the swelling. Hemostats can be used as a tissue retractor to examine the cavity. Insertion of two ¼-inch Penrose drains. Sutures are used to secure both ends of the drains. (C) Application of a bulky compression bandage. The bandage extends down to the paw to prevent distal limb edema.

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6. Direct one ¼-inch or two ¼-inch Penrose drains through both stab incisions
7. 3–4 cm of the drain length should extend from each drain hole and be secured to the skin with 2-0 monofilament sutures at each end of the hygroma
8. Apply a nonadherent dressing and topical antimicrobial ointment over the area, followed by a firm, bulky protective bandage. Apply ample padding over the elbow
9. Inspect the bandage every 4–5 days. The bandage overlying the drain site requires local removal and replacement due to accumulated discharge from the drain site
10. Continue this procedure for 3–4 weeks. The drains are removed at the time of the last bandage change. Thereafter, elbow pads and soft bedding are advisable to prevent recurrence

The Penrose drain provides continuous wound drainage while the compressive wrap helps to compress the dermal surface to the opposing side of the hygroma. Collagen will connect the surfaces together, obliterating the hygroma dead space.

Vacuum Drain Management of Large Hygromas

Jackson-Pratt vacuum drains can be effectively used to manage elbow hygromas without the need for bandages and the expense associated with subsequent changes. The Jackson-Pratt reservoir retains the fluid while keeping the hygroma collapsed. The volume of the fluid is recorded to quantitate the drainage (Fig. 7-79). Plate 12 outlines the guidelines for this technique.

Surgical Resection

Problematic hygromas less commonly present with ulcerated skin, draining tracts, and an ongoing bacterial infection. Considerable scarring may be noted in the area. Under these circumstances, surgical resection of the ulcerated skin and underlying fibrotic scar should be considered. This surgical procedure runs the risk of wound dehiscence if skin closure is performed under tension. A Schroeder-Thomas splint or rigid spica bandage may be needed for 2–3 weeks to prevent elbow flexion during the healing process. (See Plate 10 for additional protection.) An incision lateral to the olecranon is best used to dissect the underlying diseased tissues from beneath the skin. (An incision directly over the olecranon has a higher probability of dehiscence.) Surgical efforts must be directed at preserving healthy elbow callus and as much skin coverage as possible. Failure to do so will likely result in wound dehiscence.

Postoperatively, wound drainage (vacuum drains or Penrose drains) and protective bandaging are essential to control dead space and minimize motion until suture removal. Closure of smaller skin defects overlying the olecranon may be achieved with the assistance of lateral/medial release incisions. In extreme cases, wide skin resection will require reconstructive surgery, usually with the thoracodorsal axial pattern flap.

> From my clinical experience, removal of hygromas is *not* necessary and rarely advisable over establishing drainage using a Jackson-Pratt drainage system. It is worth remembering that wounds overlying the olecranon are among the most difficult defects to close successfully. Dehiscence secondary to hygroma resection is common and successful closure can be a frustratingly expensive experience for the pet owner and veterinarian.

SNAKEBITE

Although relatively uncommon, snakebites are occasionally seen in the United States, primarily in those areas populated with poisonous snakes. In one report, an estimated 15,000 domestic animals are bitten by snakes annually in the United States. There are two main families of venomous snakes:

- Elapidae: elapids include coral snakes, cobras, mambas, kraits, and the tiger snake. Coral snakes can be found in the southeastern areas of the United States
- Vipers: rattlesnakes, copperheads, and cottonmouths (water moccasins) are found in various areas throughout the United States. Copperheads have a relatively low order of toxicity. Toxicity can vary between species. Rattlesnakes account for 80% of the poisonous snakebite wounds in North America

In North America, 90% of snake bites occur between April and October. Toxicity is increased in young or very large snakes during the springtime.

Toxins in elapids are neurotoxic and hemolytic in nature; viper toxins cause local tissue damage (necrogenic) and may initiate systemic bleeding/coagulation (vasculotoxic). Diamondback rattlesnake venom may contain a myocardial depressant factor that can result in cardiac dysrhythmias. Fang marks are a distinguishing feature of vipers; nonvenomous snake bites are characterized by a series of small punctures that reflect the curvature of the mouth. Almost one in four bites of vipers is "dry," with little or no envenomation of the dog or cat. Coral snakes have short fangs and a small mouth, leaving a characteristic convex row of pinpoint puncture wounds.

Unless witnessed by the owner, snakebites can be difficult to diagnose. Typically, viper bites cause local

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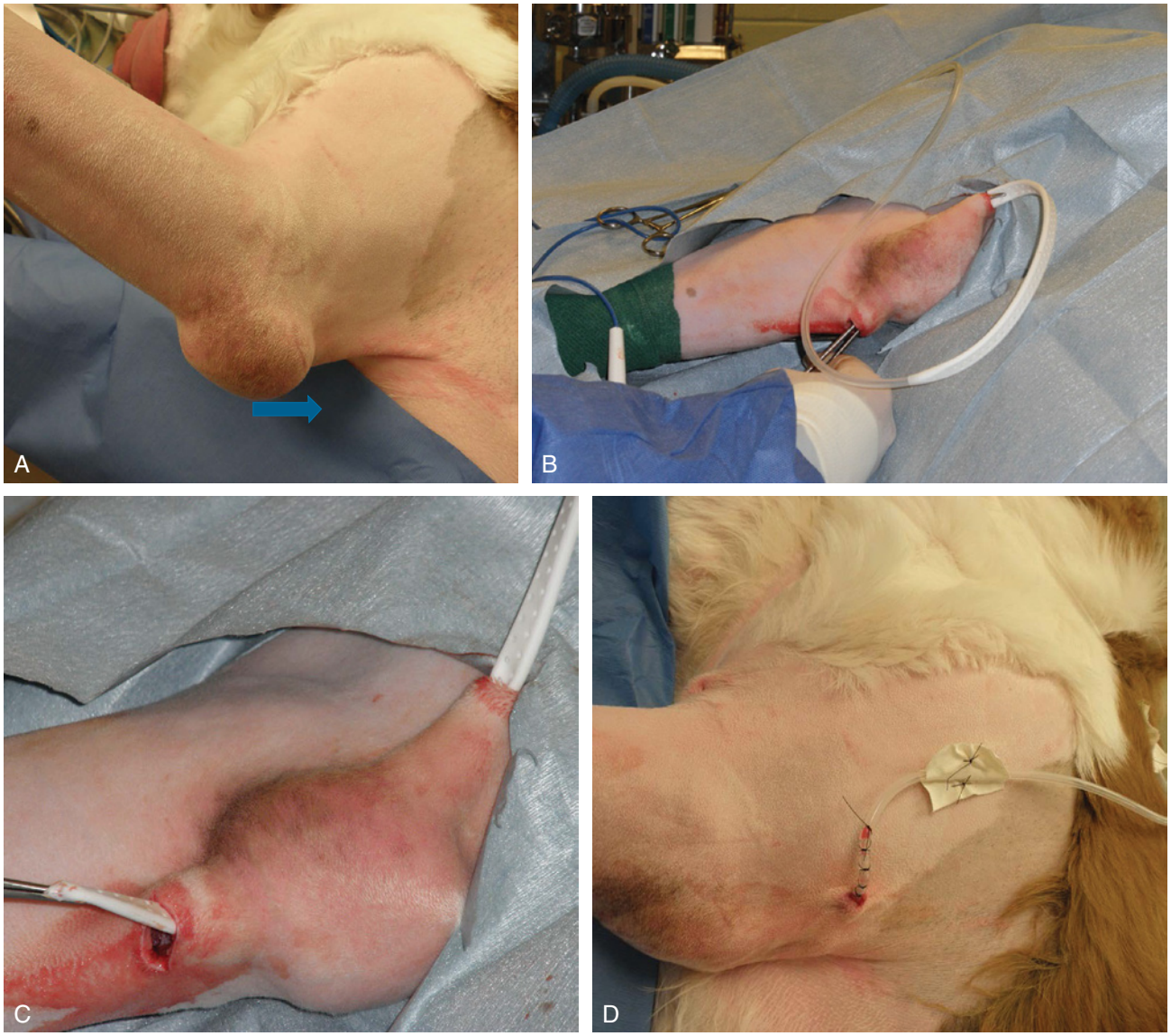


FIG. 7-79 (A) Large elbow hygroma (arrow) in a St. Bernard. (B, C) Placement of the 10 mm flat drain. (D) Closure of the two access incisions. Note the proximal finger trap knot and butterfly tape strip used to secure the external drain. The reservoir is attached to the patient's collar. (See also Plate 12.)

swelling, pain, erythema, petechiae, or ecchymoses, and later cyanosis with subsequent tissue necrosis. Close inspection may reveal fang marks. Most dogs are bitten in the head and facial area and less commonly the paws. Facial swelling may be pronounced and the patient's airway is closely monitored in the event a tracheotomy is needed. In severe cases tissue around the fang marks may darken and ooze dark blood. Swelling may worsen over the first 24–48 hours and the damaged tissues may form a hematoma. Copperhead bites, from the author's limited experience, primarily result in regional tissue swelling, but lack the severity of local and systemic changes noted in the more toxic rattlesnake and water moccasin envenomation (Fig. 7-80).

Elapid venom may have a delayed onset of 1–7.5 hours. Signs include salivation, vomiting, and apprehensive behavior, followed by convulsions, quadriplegia, and respiratory paralysis. Fortunately, documented coral snake envenomation is rare.

Baseline blood work (complete blood count, profile) and a urinalysis should be submitted on presentation. A coagulation profile is also advisable. Hemoconcentration, leukocytosis, echinocytosis ("burred" red blood cells may be noted 24–48 hours after envenomation), hypokalemia,

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FIG. 7-80 Louisiana dog that sustained a copperhead bite; note the facial swelling. No tissue loss was noted: copperhead venom has a relatively low order of toxicity compared to that of rattlesnakes. Supportive fluid therapy resulted in complete recovery.

elevated creatine kinase, hematuria, and myoglobinuria may be noted. Prolongation of activated clotting time (ACT), prothrombin time (PT), partial thromboplastin time (PTT), and increased fibrin degradation products (FDPs) also may be noted.

Therapeutic goals include prevention of hypotension (monitor blood pressure, electrocardiograms) and neutralization of the local and systemic effects of the venom. Crystalloids (lactated Ringer's solution or 0.9% saline) comprise the bulk of intravenous fluid support, with the use of colloids and plasma as needed. Urine output is closely monitored.

Antivenin (polyvalent Crotalidae) can be administered to critical patients. One to three vials is typically given to dogs; there is no specific dosage. Antivenin administration is based on patient response in humans. One canine study involving eastern diamondback rattlesnake poisoning found an 80% survival when antivenin was administered within 30 minutes of envenomation. The survival rate dropped to 62% if antivenin was given 4 hours after envenomation. Antivenin is administered slowly intravenously; it can cause an anaphylactic reaction. Unfortunately, antivenin is expensive ($1000–3000 per vial) and has limited availability. (Fort Dodge Veterinary Supplies carries antivenin for veterinary use; Wyeth-Ayerst Laboratories, Philadelphia, PA, carries antivenin for humans.) In emergencies, veterinarians can contact human medical facilities to obtain antivenin. Pain control (opiates), corticosteroids, and antibiotics (cephalosporins) are advisable. In one recent retrospective study, three antivenoms were used for treating crotalid envenomation, all of which were effective, with 96.1% of the 282 dogs surviving.

Most patients recover from viper envenomation. Tissue necrosis can be significant and will require standard wound care. Reconstructive surgery may be required for the larger tissue defects (Fig. 7-81).

BROWN RECLUSE SPIDER BITES

Although there are a number of poisonous insects in the United States, only the brown recluse (*Loxosceles reclusa*) has surgical significance due to its potential to cause tissue necrosis. The brown recluse venom contains a variety of enzymes (sphingomyelinase-D, hyaluronidase, esterase, alkaline phosphatase, 5′-ribonucleotide phosphorylase, necrotizing enzymes, and several proteins/polypeptides) capable of causing circular areas of skin necrosis that are slow to heal (referred to as loxoscelism or dermonecrotic arachnidism). Potency varies between species of this spider: the Arizona recluse (*L. rufscens*), desert recluse (*L. deserta*), and Mediterranean recluse (*L. arizonica*) spider envenomations are less potent.

The characteristic coloration of the bite wound in humans (central red area inflammation, white middle ring ischemia, and outer blue ring thrombosis) may be noted 3–8 hours after envenomation. Systemic signs that may be noted from the bite include hemolytic anemia, thrombocytopenia, hematuria, pyrexia, and myalgia. The hair coat of fur-bearing animals effectively conceals the bite wound; owners note the problem only when a circular necrotic patch of skin becomes evident. Lesions may be 1–25 cm in diameter. The diagnosis of dermonecrotic arachnidism is normally a "default" diagnosis only when other causes are ruled out. Methicillin-resistant *Staphylococcus aureus* (MRSA) infections in humans can mimic recluse lesions.

Brown recluse spiders prefer dry, undisturbed areas, including woodpiles, sheds, garages, closets, and cellars. They favor cardboard and paper piles, but can be found in shoes, in dressers, behind baseboards, and near furnaces. They have a wide distribution, from the southern Midwest to the Gulf of Mexico. They are rarely found west of the Rocky Mountains.

Recluse spiders are a variable brown to a deep yellow and usually have a violin-like marking on the dorsal side of the cephalothorax, with the neck of the violin extending caudally. They vary from 6 to 20 mm (¼ to ¾ inch). Multiple websites have photographs of this spider to facilitate identification.

The known presence of recluse spiders, possible exposure of the pet to an area frequented by this arachnid, and any supporting clinical signs would reinforce this "after-the-fact" diagnosis. Bite wounds in humans can result in significant medical complications; this does not appear to be the case in small animals. In humans, wounds can be slow to slough and subsequently heal. There is a variety

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FIG. 7-81 (A) Rattlesnake bite to a 6-year-old wire-haired fox terrier. The dog was bitten rostral to the right eye. The dog received antivenin (Antivenin Crotalidae Polyvalent, Wyeth-Ayerst Laboratories) and supportive therapy. Within 4 hours after envenomation, the local skin darkened with serous exudation from the area. (B) The necrotic wound at 2 weeks. (C) The wound at 6 weeks. Debridement and open wound management resulted in a healthy granulation bed. (D) Enucleation was performed, followed by elevation of a transposition flap. (E) Completion of the surgical procedure. The small remaining area will heal by second intention. (F) The patient, 14 weeks after injury. (Source: Kostolich M. 1990. Reconstructive surgery of a rattlesnake bite. *Canine Pract* 15:15–19. Courtesy of Marilyn Kostolich, DVM, DACVS.)

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of treatments advocated for treatment of verified *acute* brown recluse bites in humans; this is not the case in veterinary patients. Areas of necrotic tissue and any slow-healing wound usually can be excised and closed in veterinary patients with little difficulty.

PORCUPINE QUILLS

Dogs and cats with embedded porcupine quills are referred to as being "quilled." Porcupine quill injuries are normally noted in dogs, the majority of wounds being in the facial area. Occasionally, some owners will attempt to remove quills with pliers, but most will seek out veterinary assistance, especially when multiple quills are embedded in their pet.

Quills vary from 2 to 10 cm in length. Only the external tip of the quills is barbed; the opposite tip located in the cutaneous follicle of the porcupine is smooth (Fig. 7-82). Heavy sedation or general anesthesia is advisable since quill extraction can be painful. The fur should be parted to visualize embedded quills; fingers are carefully run through the fur to identify the exposed point of shorter or more deeply embedded quills. Needle holders can be used to grasp and remove each quill. Lightly embedded quills can be extracted with a firm tug, whereas deeply embedded quills can be extracted with quarter turns of the wrist with traction. A no. 11 scalpel blade can be aligned along the surface of problematic quills to create a small cutaneous stab incision to facilitate their removal. Few quill sites become infected after their removal; systemic antibiotics may be administered along with analgesics when the patient is discharged from the hospital.

> Contrary to popular folklore, cutting a quill does not cause the quill to deflate, facilitating its removal.

The barbed surface of the quill ends facilitate their migration deep into the body. Retained quills can result in recurrent abscess and fistula formation. Locating migrating quills can be problematic. Ultrasound can be useful in locating porcupine quills; CT may be helpful in determining the general area of involvement.

Migrating quills can cause significant trauma to small animals. Quills have been reported in the abdomen, joints, eyes, nasal cavity, and lungs. A porcupine quill was removed from a canine brain abscess on postmortem examination of a patient at Angell Memorial Animal Hospital: the quill had migrated through one of the foramina of the skull. The author has also removed a number of quills from the lungs of dogs that have presented with spontaneous pneumothorax and lung abscessation (Fig. 7-83). Involved areas of the lung can be removed using surgical staplers. In one recent study, five dogs presented with pneumothorax or pericardial effusion from migrating porcupine quills. A median sternotomy was performed. Quills embedded in the lungs were removed using gentle traction, purse-string sutures, and mattress sutures. An exploratory pericardiotomy was required in three dogs to remove epicardial/myocardial and intravascular quills. Because cardiac quills may be present despite the lack of CT findings or the presence of visual pericardial injury, exploratory pericardiotomy should be considered in conjunction with median sternotomy.

LOWER-EXTREMITY SHEARING WOUNDS

Shearing wounds are common in dogs and cats; they are invariably associated with vehicular trauma. The patient may be dragged on the pavement or the distal extremity is caught beneath the spinning wheel, resulting in a variable degree of tissue avulsion with the paw trapped between the tire and road pavement (see Fig. 3-13). Loss of skin, muscle, bone, and ligamentous support of the involved joint (carpal or tarsal) is commonly noted. Rear-extremity wounds are more common than forelimb shearing wounds. Loss of the dorsal extensor tendons overlying the metatarsal/carpal area is common, but not consequential to the eventual use of the extremity.

Despite the rather gruesome appearance of shearing wounds, most can be managed as an open wound with appropriate stabilization of the involved joint. The digits can be assessed for circulation and sensation to help determine whether salvage of the limb is feasible. There are a variety of options to stabilize the unstable joint, including the use of screws, anchors, suture or wire, and external fixators. Arthrodesis may be necessary for severely unstable joints. Over time, granulation tissue formation with subsequent collagen deposition may stabilize the slightly unstable joint with conventional bandage/splint application.

Skin loss is often exaggerated by the elastic retraction of the cutaneous margins aggravated by tissue edema. Conservative open wound management may be advisable to allow time for resolution of tissue swelling over the first 7–10 days. This will allow time to more accurately assess the magnitude of the wound before considering free grafts. If skin loss is less than 25–30% of the limb circumference, healing by second intention is likely to close the wound. Osteostixis (Chapters 3 and 6) may be used to facilitate granulation coverage of exposed bone. In this area, larger wounds may require a skin graft to close the cutaneous defect.

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FIG. 7-82 (A) A "quilled" retriever. (B) Note the multiple quills involving the right forelimb and paw. (Slides A and B courtesy of Dr. Patti Ewing.) (C) Porcupine quills previously extracted from a dog. Note the finely tapered quill tip. (D) The external tip of the quill contains multiple small barbs on the fine narrow tip. The opposite base/tip of the quill is smooth. (E) Close-up view of the quill tip. Noted the flattened V-shaped barbs (resembling fish scales) along the circumference of the quill tip. The raised barbs are bent slightly backward as a result of their extraction from the skin. The angular barbs hook onto the dermal collagen fibers on entry into the skin of the dog; this impairs their extraction and explains why the barbed quills are capable of migrating into the body. (F) Recurrent facial abscess in a dog secondary to a retained porcupine quill. Ultrasound identified the general location of the quill: this area was subsequently excised.

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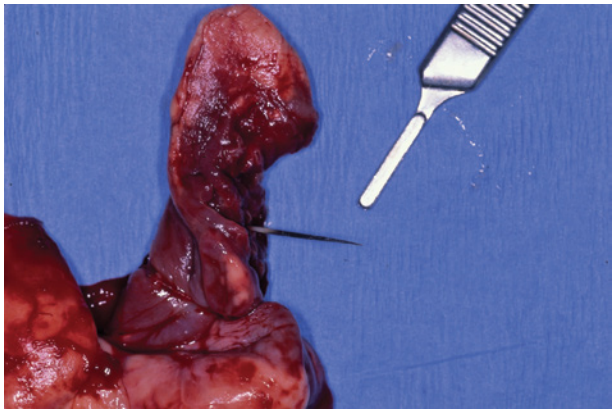


FIG. 7-83 Porcupine quill in the left cranial lung lobe resulting in pneumothorax. A detailed history revealed the dog encountered a porcupine some months before presentation for pneumothorax.

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Plate 10

Pipe Insulation Protective Device: Elbow

DESCRIPTION

Pipe insulation is used by plumbers and homeowners to insulate water pipes. There are a few varieties available at hardware stores. Black plastic foam pipe insulation (ArmaFlex® Self-Seal, Armacell), available at many local hardware stores, is a soft, light, flexible foam, with a linear split to facilitate its application around a pipe. Pipe insulation obtained from hardware stores normally comes in 6-foot lengths to cover copper pipes of ½-inch, ¾-inch, and 1-inch diameters. For medium- to giant-breed dogs, plumbing supply stores carry larger-diameter pipe insulation that varies in thickness (Fig. 7-74). Some of the larger-diameter insulators do lack a split seam but are easily divided with standard surgical scissors. Although they are more expensive, the author prefers these larger sizes for the larger dogs. The author designed the pipe insulation protection for the elbow (PIPE) technique to protect incisions overlying the olecranon and lateral epicondylar areas in dogs, usually for the management/closure of pressure ulcers and skin loss secondary to infection.

TECHNIQUE

(A) Cut two pieces of pipe insulation. Measure the shorter internal piece below the flexion surface of the antecubital area to the metacarpal–phalangeal joints. The outer segment extends from the metacarpal–phalangeal joints and overlaps the entire elbow surface proximally.

(B) In medium to large dogs, apply strips of 2-inch surgical tape (Zonas®, Johnson & Johnson) to the limb in a linear fashion. For greater adherence over the fur, Elastikon (Johnson & Johnson) also can be used. On patients with longer hair coats, remove the fur. The parallel strips of tape begin below the flexion surface of the antecubital area down to the metacarpal–phalangeal joints. Avoid placing tape over the accessory carpal pad. This layer of tape forms a friction surface for application of the pipe insulation.

(C) The inner segment of pipe insulation is cupped around the extremity. In this example, the open split of the insulation is positioned over the anterior surface of the forelimb. (The thin plastic strip is removed from the insulation adhesive that covers the split border of the insulation.) Use strips of Elastikon to secure the pipe insulation to the exposed white tape overlying the anterior aspect of the limb. Contact of the Elastikon with the white tape prevents the pipe insulation from slipping. Cut the longer (outer) piece of pipe insulation to comfortably overlap the entire olecranon, extending approximately 2–3 inches (5–8 cm) proximally. (In this illustration, this outer pipe insulation layer is transparent, allowing us to see the short pipe segment secured with bands of Elastikon.) Secure the insulation to the exposed surgical tape in a fashion similar to that of the first layer. Avoid excess tape application over the carpus to maintain limb mobility.

(D) To change wound dressings, temporarily fold down the proximal end of the foam insulation, which forms an "overlapping shield" for the elbow, to change dressings. Once released, the foam springs back to its original position. The overlapping foam insulation provides a "slot" to maintain the position of a thin protective dressing/bandage layer. A nonadherent dressing, topical ointment, a light layer of cast padding, and a gauze wrap are normally used to cover the wound. Do *not* apply a tight bandage that will rub on the elbow during ambulation and elbow flexion. It is important *not* to use a thick bandage that could create a "pressure-cone effect" on the elbow, thereby defeating the purpose of the bandage. The owner can change this simple bandage daily over the first 7–10 days and every 2 days thereafter.

COMMENTS

Figure 7-75 demonstrates the step-by-step application of the PIPE technique. With a cost around $2–$4 per foot, pipe insulation is economical to use. The pipe insulation bandage is light and flexible, enabling the dog to use the leg unimpeded. The author prefers to use this protective device when wound closure is achieved without excessive incisional tension, or to protect a healing wound.

The overlapping layers of the foam insulation effectively elevate the olecranon and lateral epicondyle from directly contacting hard flooring. After application of the long segment, an additional (third) short segment may be applied. Soft bedding also is strongly recommended to prevent recurrent trauma. Owners are advised to keep the patient's activity level to a minimum when using this technique.

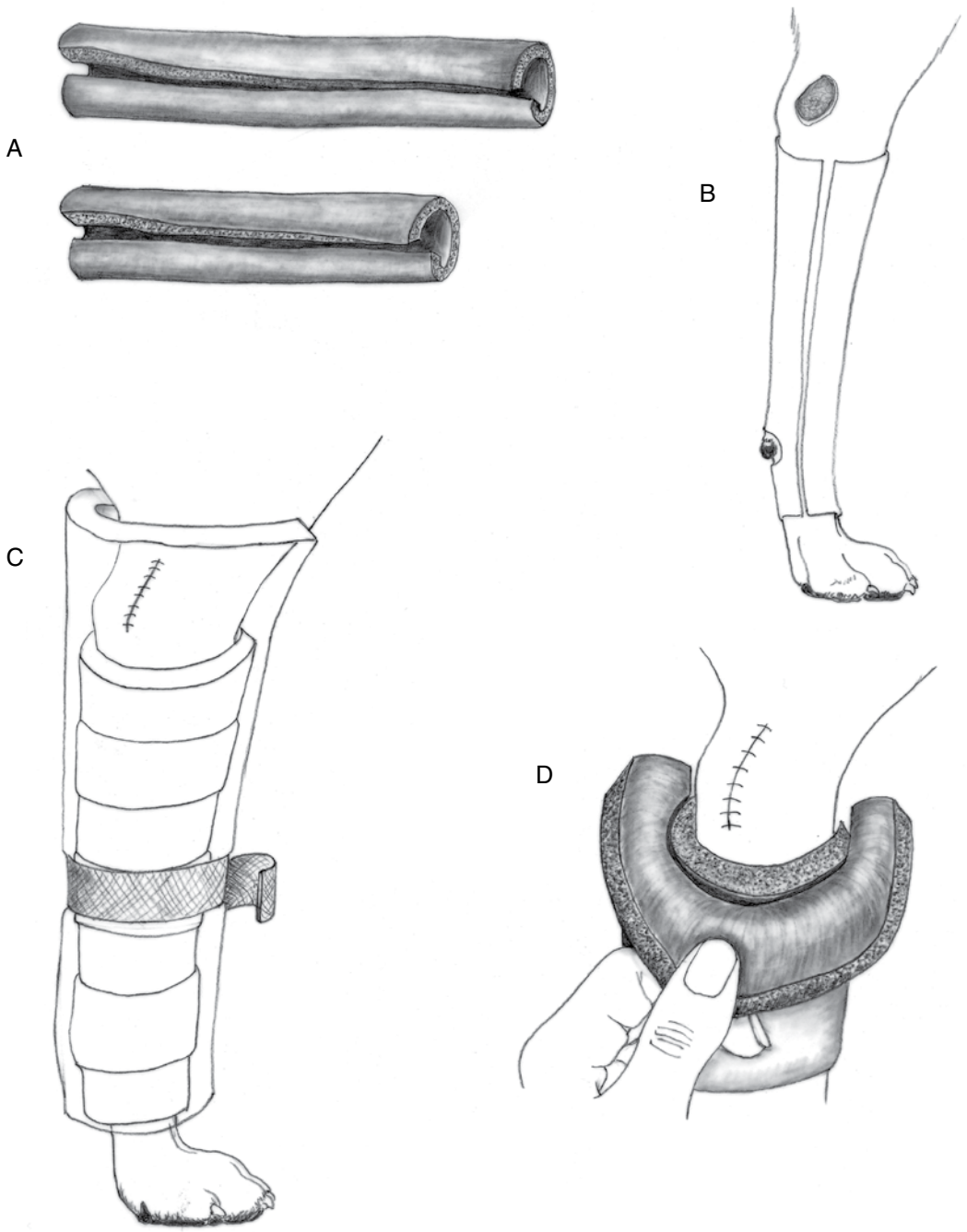
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Plate 10

Normally, PIPE will maintain itself for 2–3 weeks, at which time the entire protective wrap is replaced. During this time the adhesive tape applied to the skin surface may loosen. Moreover, the foam cells tend to compress with continuous pressure application by the second or third week, according to the weight of the dog. Depending on the healing process, the author normally uses this device for 6 weeks after the surgical closure of pressure ulcers or surgical incisions in this area. Owners must keep the insulation and skin free of moisture to reduce the likelihood of dermatitis. The black foam can temporarily stain the skin, but most of this residue can be washed off with surgical soap and tap water. An Elizabethan collar is advisable for dogs that have a history of chewing on bandages.

If postoperative incisional tension is a significant concern, a reinforced spica bandage (Plate 5) or a Schroeder-Thomas splint (Plates 6 and 7) may be considered until healing is initially achieved in 10–14 days. PIPE can then replace the external splints. PIPE allows the dog to ambulate, maintaining muscle tone, limb circulation, and joint mobility. Dogs do not walk on the extremity immobilized by spicas or the Schroeder-Thomas splint.



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Plate 11

Pipe Insulation to Protect the Great Trochanter

DESCRIPTION

As noted in Plate 10, pipe insulation is an effective method of protecting the olecranon area after wound closure. The author has adapted the PIPE technique to help protect the greater trochanter after closure of pressure ulcers.

TECHNIQUE

(A) A single 6-foot length of pipe insulation is centered over the dorsal pelvis. (The adherent borders are compressed together before application.) Each end is looped along the inner thighs and rotated back to the dorsal pelvis. Elastikon or duct tape is used to secure each limb loop to the pelvic pipe insulation segment. To prevent the pipe insulation from slipping caudally, a loop of Elastikon is placed around the caudal abdomen; tape loops are used to secure the dorsal insulation segment to this Elastikon tape girdle.

(B) Lateral view of the trochanteric protector. Additional tape strips can be used to tighten the limb loop (asterisk) at the outer junction of the loop intersection with the dorsal pelvic segment. When the patient reclines, the segment cranial and caudal to the greater trochanter should take the brunt of the pressure when the patient reclines.

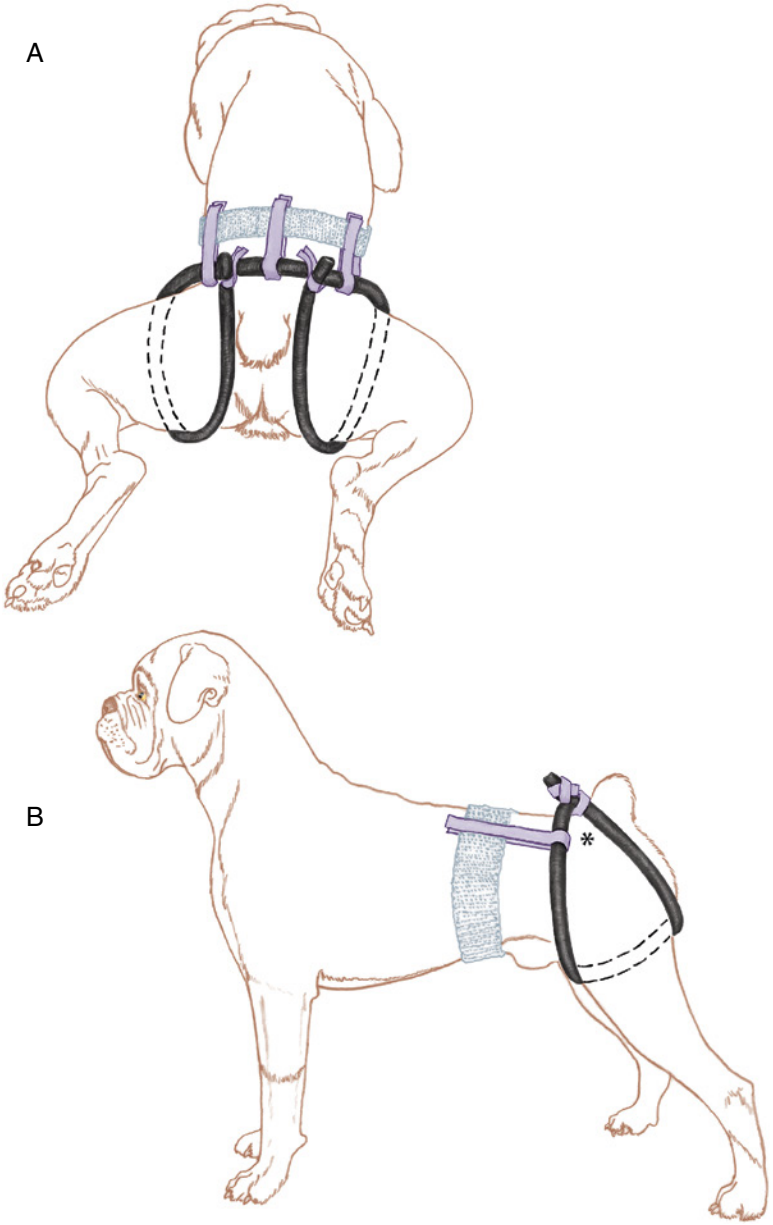
COMMENTS

To increase the thickness of the insulation, a smaller-diameter pipe insulator can be inserted into a second, larger-sized insulation tube. The author normally uses the larger-diameter (1 inch) Armacell pipe insulation with a ½- or ¾-inch insulator as an insert. The device can be used for 6 weeks; it may be changed/adjusted every 2–3 weeks depending on the weight of the dog.

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Plate 11



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Plate 12

Vacuum Drain Management of Elbow Hygromas

DESCRIPTION

Vacuum drains can siphon fluid accumulating in hygromas continuously; the collapsed hygroma pocket can close after fibrous connective tissue connects the opposing walls. This system is simple to implement and postoperative care is minimal. There are no bandages so the multiple bandage changes associated with the use of Penrose drains can be avoided. The volume of exudate can be quantitated to help determine the best time for drain removal. Normally the drain can be removed in 3–4 weeks. This time frame is selected as it corresponds to the maturation phase of healing (see Chapter 2).

TECHNIQUE

(A) In this example, the patient will be placed in right lateral recumbency. The hair overlying the circumference of the left elbow and lateral humeral regions is clipped, prepared aseptically for surgery, and draped.

(B) A 2 cm skin incision is created approximately 4 cm below the distal border of the hygroma. A long-handled curved forceps with a tapered tip is inserted into the lower wall of the hygroma; the forceps are opened and closed several times to widen the hole before exiting the dorsal wall in a similar fashion. Long, curved forceps are then directed subcutaneously approximately 10 cm dorsal and cranial to the hygroma. A small stab incision is created in the skin, over the tip of the forceps. The tip of the 10 mm wide flat suction drain is grasped and retracted to the level of the lower skin incision. (The white fenestrated portion of the drain is 20 cm long; the clear nonfenestrated external drain component is 80 cm long.)

(C) A small subcutaneous pocket is created with Metzenbaum scissors below the hygroma to accommodate the terminal 6 cm of the fenestrated drain segment. The lower access incision is then sutured closed with 3-0 monofilament nylon interrupted sutures. The central 8 cm of the fenestrated drain traverses the hygroma pocket, with the remaining 6 cm of the fenestrated drain segment residing in the subcutaneous pocket dorsal to the hygroma. The 4 cm of the nonfenestrated drain segment is inserted subcutaneously followed by application of a purse-string suture using 2-0 monofilament nylon. The two strands of this suture are tied around the external drain segment, using a "finger-trap" suture pattern, to help prevent drain displacement.

(D) Two or three butterfly strips of 1-inch surgical tape are applied to the external tubing dorsally, spaced along the length of the drain. 2-0 monofilament nylon sutures are used to secure the applied tape tabs, on each side of the tubing, to the skin. The drain is attached to the 100 ml vacuum reservoir (Jackson Pratt, Cardinal Health) and the activated reservoir is secured to the dog's cervical collar. An Elizabethan collar is advisable to prevent the dog from chewing or displacing the vacuum drain system.

COMMENTS

This is a simple, minimally invasive technique that can be performed as a day-case procedure. Patients are normally discharged on a broad-spectrum antibiotic (Clavamox®, Pfizer Animal Health, New York, NY, USA) and the analgesic Tramadol® (Amneal Pharmaceuticals, Hauppauge, NY, USA) orally every 12 hours for 7 days and 3 days, respectively.

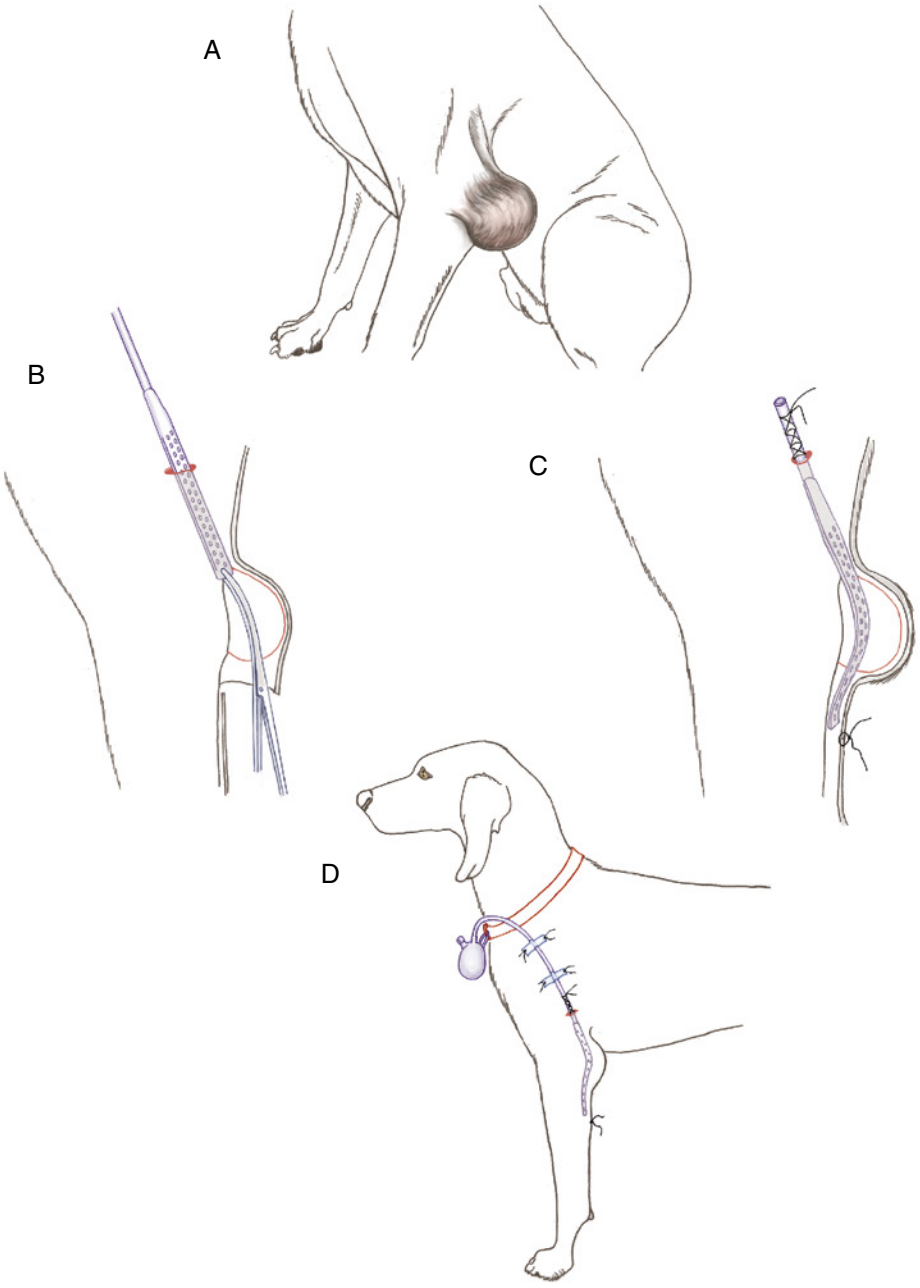
Owners are instructed on the use of the vacuum drain system (see Table 4-1). Thick, soft bedding is procured for the dog to recline on at home; this is essential for long-term prevention of hygromas. On a daily basis, the owner records the volume of fluid as well as its color and clarity. Patient activity is minimized until drain removal.

The patient is examined weekly over the next 3–4 weeks. Skin sutures are removed at the time of the second visit. If drainage is uniformly low over the 3-week period, the reservoir and drain tube are removed with instructions to continue using soft bedding to protect the elbows from future trauma. If in doubt, retain the drain system for 1 additional week. (See Fig. 7-79.)

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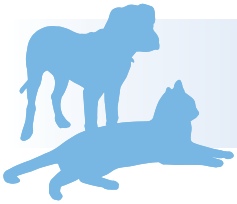
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Plate 12



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8

Regional Considerations

The Canine and Feline Profiles *288*

Plate 13: Surgical Technique Menu *290*

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THE CANINE AND FELINE PROFILES

Description

In dogs the thinnest skin is located along the ventral body surface, the medial surface of the limbs and inner pinna. Thicker skin is located along the dorsum. The most pliable skin regions include the axilla, flank, and dorsum of the neck. The hair coat is thicker over the back and sides of the body, with thinner hair growth located inside the ears, on the inner surfaces of the flanks, along the ventral abdomen, and beneath the tail. Optimal cosmetic results are achieved by selecting closure techniques that match skin thickness and hair-growth pattern (hair length, color, and growth direction). By using skin adjacent to a defect, one is more likely to be able to achieve these goals. However, large defects frequently warrant skin coverage from a distant source. In this situation, closure and restoration of function should be accomplished by the simplest techniques that minimize stress and discomfort to the patient, rather than by techniques selected primarily for achieving the optimum cosmetic result.

Over the years, the author has found that clients have not complained about hair-growth variations since the results are far more pleasing than the wound or disease process that has been corrected. Owners recognize normal variations in their pet's hair coat and generally accept these variations when the facts are explained prior to the procedure.

Both the dog and the cat have pliable and elastic skin over most areas of the body, except for extremely obese individuals. Skin laxity varies in each body region along with skin thickness and hair growth. Variations naturally occur between species, breeds, and individual animals.

Pronounced obesity in dogs and cats will dramatically reduce skin laxity. As a result, wound closure can be problematic in these patients, unlike their normal-weight counterparts.

These cutaneous variations also make universal rules pertaining to flap size and regional applicability difficult. For example, a caudal superficial epigastric axial pattern flap in long-bodied dogs with short legs, such as dachshunds, is capable of extending to the foot, whereas the same flap employing identical anatomic guidelines may not extend beyond the knee in a dog with long extremities, such as an Irish wolfhound. In the cat, this same flap normally can extend to the metatarsal region. Clearly, careful preoperative measurements are required to determine wound coverage.

The elastic properties of skin vary based on the species, breed, individual, and body location. These elastic properties can be manipulated in some cases for the closure of problematic wounds by using skin-stretching techniques discussed in Chapter 9.

Although dog and cat breeds generally conform to most of the flap techniques discussed, one clinical exception is the greyhound. The author has found that the thin, delicate skin of the greyhound is more prone to dehiscence and partial flap necrosis compared to other breeds. This likely is the scenario for similar breeds such as the whippet and Italian greyhound. Care must be taken to use meticulous surgical technique, avoid unnecessary tissue manipulation, minimize the size (especially length) of skin-flap dimensions (when feasible), and keep skin tension to a minimum during wound closure.

Greyhounds and whippets have thin skin with less "extra" skin compared to other breeds. Keep skin flaps as short as possible. The conventional guidelines for axial pattern flaps do not accurately apply to these breeds. It is prudent to keep the flaps' length approximately 20% shorter to reduce the risk of terminal flap necrosis.

Certain skin regions are closely attached to the underlying bone, muscle, and fascia. These areas include the skin over the dorsum of the muzzle, the caudolateral aspect of the upper thigh (overlying the biceps femoris and semitendinosus/semimembranosus muscles), and the skin overlying portions of the superficial pectoral muscle. Undermining skin in these regions is more difficult; care must be taken to avoid injury to the subdermal plexus when elevating the skin free from the underlying structures. In some cases, it may be advisable to retain the epimysium of the underlying muscle with the skin used for pedicle grafts. From a clinical perspective, the author has noted that skin around the caudal thigh and perineum is not particularly amenable to local flap development. Subdermal plexus flaps developed in these regions are more prone to partial necrosis compared to similar flaps created in other body regions. This is most likely attributable to regional variation in cutaneous circulation.

Ample loose skin is located over the dorsal and lateral aspects of the neck and trunk. Even moderate-sized skin defects are frequently amenable to primary closure. Second-intention healing can take advantage of neighboring loose elastic skin for optimal wound contraction. When skin is required for coverage of large wounds involving the extremities, the trunk is the obvious source of donor skin in the form of axial pattern flaps, free grafts, and the less frequently used distant-flap techniques.

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Wounds involving the most distant areas of the body, including the rostral facial area, tail, distal extremities, and ears, are naturally more difficult to close due to the paucity of loose skin and their greater distance from potential donor areas. As skin loss approaches 180° of the circumference of an extremity, some form of skin-flap or free-grafting technique will be necessary.

Skin loss of the distal extremities need not be great to create wound-closure difficulties. Wounds less than 90° of the circumference have the potential to heal by second intention. As wounds approach 180°, closure will require a skin graft or possibly skin flap.

Assessment of true wound size is exaggerated by edema. The surgeon should defer closure decisions until improvement in circulation is followed by resolution of tissue swelling. Tissue edema can make open wounds appear approximately 25% greater than their true size: skin margins retract and dermal fluid accumulation pushes collagen fibers apart.

Large defects involving the ventral thorax (sternal region), dorsal pelvic, and inguinal area are similarly troublesome, although somewhat more amenable to closure due to their proximity to the loose skin of the lateral thorax and abdomen. The axilla, flank, and inguinal areas present closure difficulties in association with patient ambulation unless restriction of activity is achieved by cage rest or limb immobilization. Similarly, wounds involving joints may require postoperative immobilization to prevent wound dehiscence. Special care must be taken to assess range of motion during closure of defects involving the limbs, eyelids, and oral cavity to avoid distortion of anatomic structures and compromise of normal function.

Skin folds represent redundant skin that has "donor potential" for wound closure. Skin folds can be used as a source for local flap development. Dorsal tail folds, vulvar folds, and facial folds are a few examples. However, facial folds in brachycephalic breeds give these dogs their characteristic appearance; care must be taken to avoid dramatically changing the pet's facial features if other closure options are available.

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Plate 13(A, B)

Surgical Technique Menu

DESCRIPTION

Based on the anatomic region, the following techniques have potential application for closure of major skin, mucosal, and epithelial defects. Selection of the technique(s) depends on the size of the defect, the regional skin tension, the regional and distant cutaneous circulation, and the practicalities and individual limitations of the technique(s) selected. Other techniques, however, may be employed in selected cases based on the individual surgeon's preference and needs of the patient. Open wound management is not on the technique menu, although it remains a viable option for wound closure using the guidelines previously described. The reader is directed to the respective sections illustrating these surgical techniques.

1. Tension-relieving techniques (Chapter 9)
   - (A) Undermining
   - (B) Relaxing/release incisions
   - (C) Multiple relaxing incisions
   - (D) Subcuticular suture patterns
   - (E) Walking sutures
   - (F) Z-plasty
   - (G) W-plasty
   - (H) V–Y advancement
   - (I) Stents
   - (J) Skin stretchers
   - (K) Hidden dermal release incision
   - (L) Suture options to offset tissue retraction
   - (M) Foley catheter technique

2. Skin-stretching techniques (Chapter 10)
   - (A) Skin expanders
   - (B) Presuturing technique
   - (C) Skin stretchers: open wound management
   - (D) Skin stretchers: preoperative use
   - (E) Skin stretchers to enhance length of axial pattern flaps

3. Local flaps (Chapter 11)
   - (A) Single-pedicle advancement flap
   - (B) Bipedicle advancement flap
   - (C) Rotational flap
   - (D) Transposition flap
   - (E) Interpolation flap
   - (F) Forelimb-fold flap
   - (G) Transposition flap (oblique angle)
   - (H) Lateral facial skin vs. auricular axial pattern flap
   - (I) Transposition flaps in partial wound closure
   - (J) Chin flap closure techniques
   - (K) Skin-fold flap techniques
   - (L) Dorsal nasal flap closure

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Plate 13(A, B)

4. Axial pattern flaps (Chapter 13)
   - (A) Omocervical
   - (B) Thoracodorsal
   - (C) Deep circumflex iliac (dorsal branch)
   - (D) Deep circumflex iliac (ventral branch)
   - (E) Deep circumflex iliac (ventral branch): flank-fold flap (hindlimb)
   - (F) Caudal superficial epigastric
   - (G) Cranial superficial epigastric
   - (H) Brachial
   - (I) Genicular
   - (J) Reverse saphenous
   - (K) Caudal auricular
   - (L) Lateral caudal (tail)
   - (M) Superficial temporal
   - (N) Angularis oris: mucosa
   - (O) Perineal axial pattern flap

5. Free grafts (Chapter 14)
   - (A) Punch/pinch grafts
   - (B) Strip grafts
   - (C) Stamp grafts
   - (D) Sheet grafts
   - (E) Mesh graft: mesh graft expansion unit
   - (F) Mesh graft: hand mesh

6. Distant flaps (Chapter 12)
   - (A) Direct flap
   - (B) Indirect flap
   - (C) Direct flap: closure of stifle defects

7. Myocutaneous flaps and muscle flaps (Chapter 16)
   - (A) Latissimus dorsi myocutaneous flap
   - (B) Cutaneous trunci myocutaneous flap
   - (C) Latissimus dorsi muscle flap
   - (D) External abdominal oblique muscle flap
   - (E) Caudal sartorius muscle flap
   - (F) Cranial sartorius muscle flap
   - (G) Temporalis muscle flap
   - (H) Transversus abdominis muscle flap
   - (I) Semitendinosus muscle flap
   - (J) Flexor carpi ulnaris muscle flap
   - (K) Latissimus dorsi muscle flap: bipedicle variation
   - (L) Triceps replacement with latissimus dorsi muscle
   - (M) Cranial tibial muscle flap
   - (N) Internal obturator muscle flap
   - (O) Superficial gluteal muscle flap

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Plate 13(A, B)

(Continued)

8. Facial reconstruction (Chapter 15)
   - (A) Labial avulsion closure techniques
   - (B) Triangular excision/closure: lip
   - (C) Rectangular excision/closure: lip
   - (D) Labial advancement: upper lip
   - (E) Labial advancement: lower lip
   - (F) Buccal rotation technique: lip and cheek
   - (G) Labial lift-up technique
   - (H) Labial pull-down technique
   - (I) Skin substitution for oral mucosa
   - (J) Cleft lip repair
   - (K) Rostral labial pivot flap
   - (L) Oral commissure advancement
   - (M) Brachycephalic facial-fold resection
   - (N) Cheilopexy technique
   - (O) Unilateral rostral labial pivot flap
   - (P) Facial axial pattern flap: dog
   - (Q) Facial axial pattern flap: cat
   - (R) Upper labial flap for nasocutaneous fistulas
   - (S) Lower labial rotation flap

9. Oral reconstruction surgical techniques (Chapter 17)
   - (A) Oral mucosal flaps
   - (B) Von Langenbeck palatoplasty: bipedicle advancement
   - (C) Overlapping/hinge mucoperiosteal flap technique
   - (D) Extended overlapping/hinge-flap option
   - (E) Palatine (artery) mucosal flap
   - (F) Soft palate and pharyngeal mucosal flaps
   - (G) Full-thickness labial advancement flap
   - (H) Cartilage graft technique
   - (I) Angularis oris mucosal flap
   - (J) Partial maxillectomy
   - (K) Upper labial flap for major palate defects
   - (L) Superior labial musculomucosal flap
   - (M) Soft palate advancement flap
   - (N) Partial glossectomy

10. Nasal reconstruction techniques (Chapter 20)
    - (A) Septal resection technique
    - (B) Septal coverage: cutaneous advancement flap
    - (C) Bilateral sulcus flap
    - (D) Alar fold flap
    - (E) Musculofascial island labial flap
    - (F) Cantilever suture technique
    - (G) Labial mucosal inversion technique
    - (H) Dorsal nasal split technique (for enhanced assess to the cartilaginous septum)

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Plate 13(A, B)

(I) Nasal reconstruction with "lip-to-lid" variation
(J) Mucosal grafting with nasal stents
(K) Intranasal septal window technique
(L) Alaplasty for brachycephalic dogs
(M) Alar fold lift-up/sulcus pull-down for feline stenotic nares

11. Foot-pad reconstruction (Chapter 18)
(A) Digital pad transfer
(B) Metatarsal/metacarpal pad transfer
(C) Whole-pad grafting
(D) Segmental pad graft
(E) Digital flap technique: interdigital defects
(F) Digital flap technique: digit 2, 5 defects
(G) Fusion podoplasty

12. Major eyelid reconstruction (Chapter 19)
(A) "Lip-to-lid" procedure
(B) Mucosal graft/transposition flap reconstruction
(C) Third eyelid reconstruction of lower eyelid
(D) Skin-flap options for cutaneous defects of the eyelid regions
(E) Hubner technique

13. Preputial reconstructive surgery (Chapter 22)
(A) Preputial ostium enlargement
(B) Preputial ostium reduction
(C) Preputial advancement technique
(D) Phallopexy
(E) Urethral reconstruction for subanal hypospadias
(F) Preputial urethrostomy technique
(G) Urine-diversion technique

14. Miscellaneous reconstructive surgical techniques (Chapter 24)
(A) Omental flaps
(B) Scrotal flaps
(C) Caudectomy for tail-fold intertrigo
(D) Episioplasty
(E) Fascia lata sling and silicone banding for managing fecal incontinence
(F) Spiral rectal diaphragm technique
(G) Atresia ani reconstruction

15. Surgery of the pinna (Chapter 23)
(A) Skin advancement for defects of the rostral pinnal base
(B) Skin advancement for defects of caudal pinnal base
(C) Transposition flap technique for small medial pinnal defects
(D) Transposition flap technique for small lateral pinnal defect
(E) Large transposition flap technique for major medial pinnal defects

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Plate 13(A, B)

(Continued)

(F) Large transposition flap technique for major lateral pinnal defects
(G) Direct flap reconstruction of the pinna
(H) Central pinnal defect closure options
(I) Partial vertical ear canal resection in cats

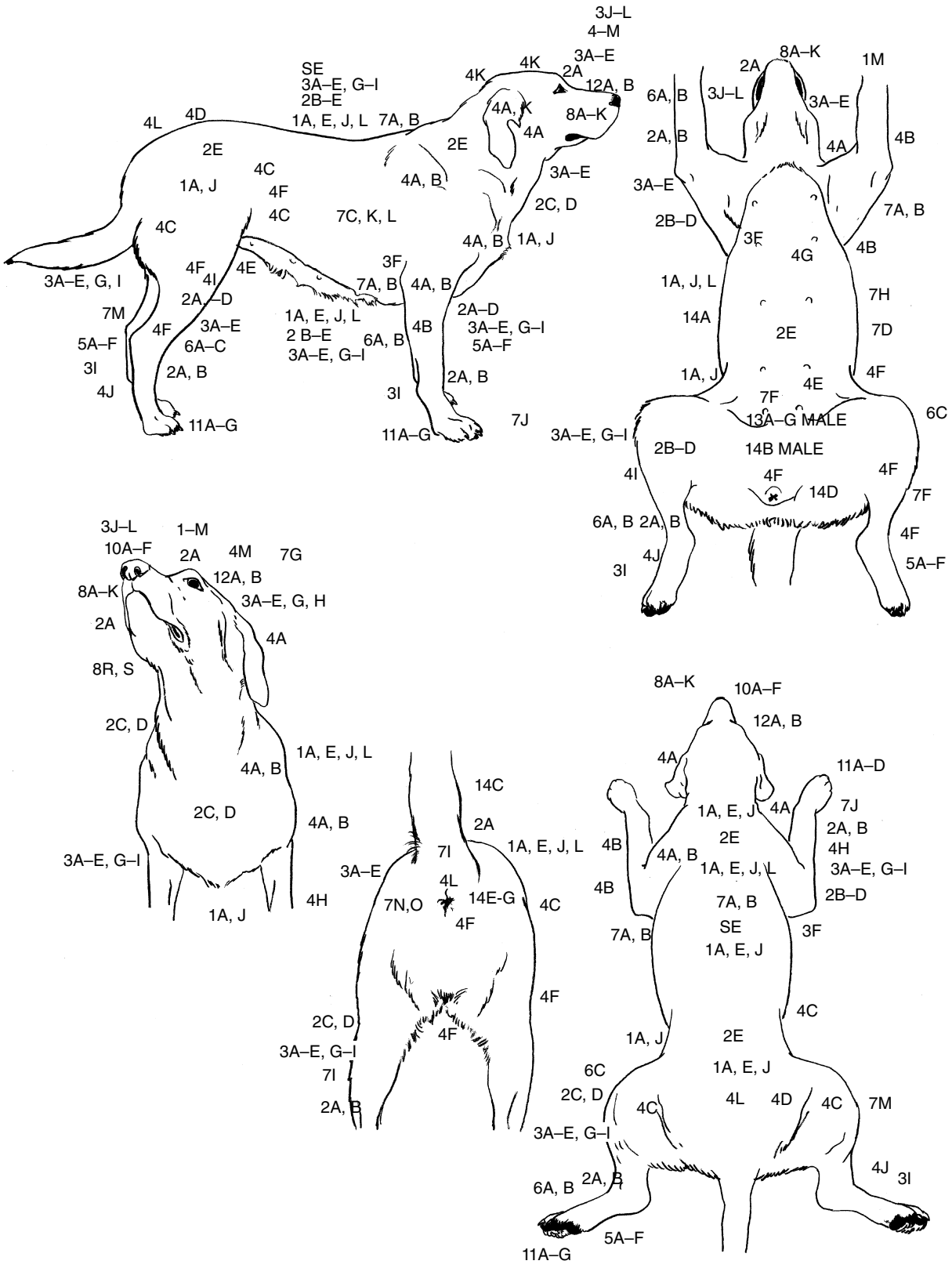
COMMENTS

The surgical menu serves as a general site reference for the surgeon. Only the most common techniques are identified on a regional basis. Other techniques can be used for specific defects in a variety of body areas. The size and location of the defect, the condition of regional donor areas, and the preference of the surgeon generally dictate the selection of the technique(s).

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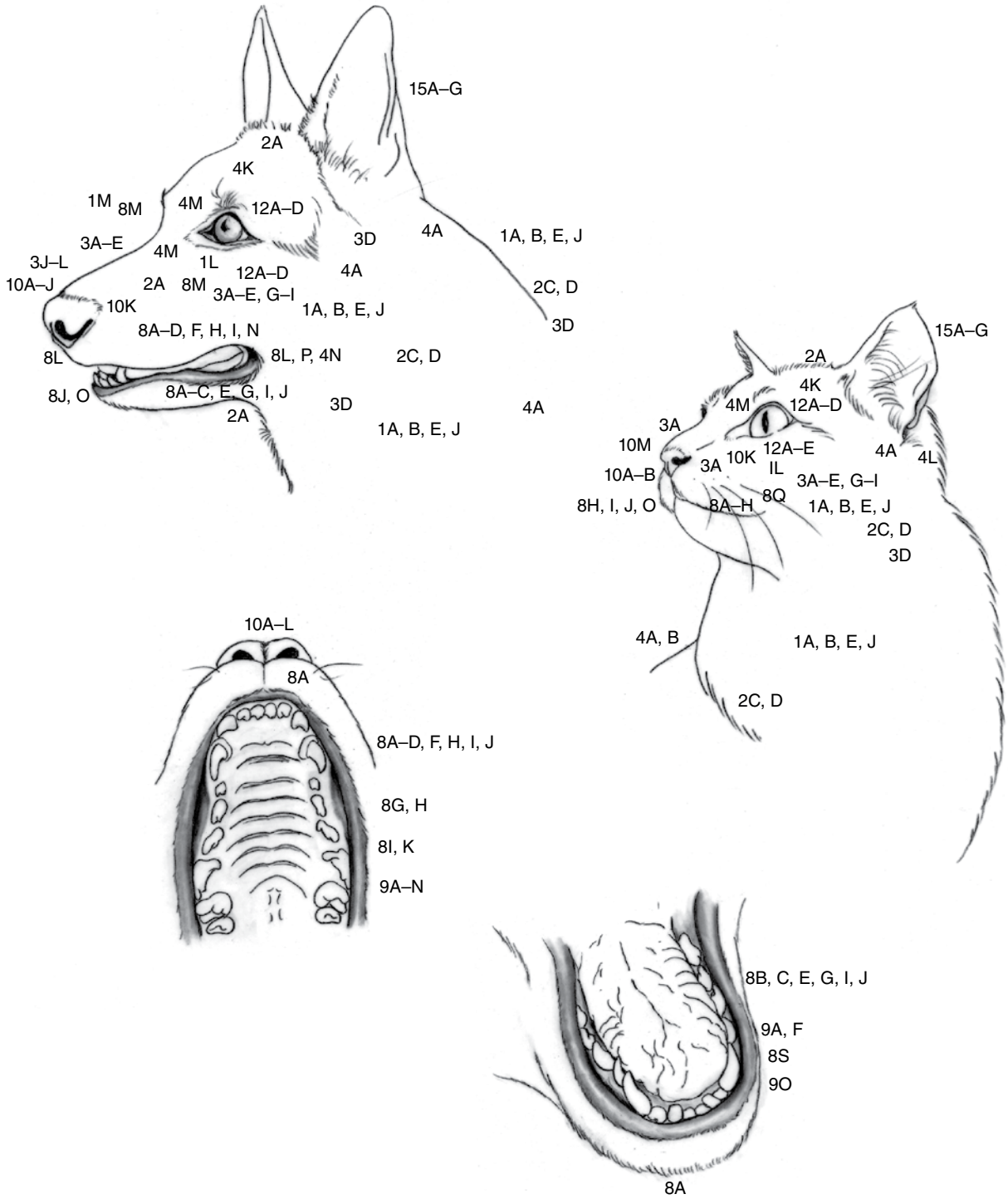
Plate 13A



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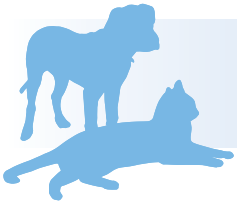
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Plate 13B



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9

Tension-Relieving Techniques

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INTRODUCTION

Excessive tension during wound closure can result in circulatory compromise, retarded wound healing, dehiscence, and skin necrosis. Tissue swelling, underlying hematomas, and increased collagenase activity within the 5 mm border of the wound edges also can contribute to sutures "cutting out" (see Chapter 6).

Whether performing a skin closure or bowel surgery, sutures should be placed more than 5 mm from the incisional border to reduce the risk of dehiscence secondary to the increased collagenase activity within this zone.

Tension-relieving techniques are methods of reducing wound tension or distributing the tension more uniformly in order to prevent the complications associated with wound separation (see Chapter 6). In veterinary medicine, the most common method used to mobilize cutaneous margins for wound closure is undermining. However, studies have demonstrated that skin can stretch beyond its natural or "inherent elasticity" by the processes of mechanical creep and stress relaxation when continuous tension is applied over time to the cutaneous tissues. Skin stretchers (Pavletic, Angell Animal Medical Center, Boston, MA) and tissue expanders are examples of techniques that mobilize skin for wound closure using these processes. Skin stretchers can be used to stretch prior to wound closure; they also may be used postoperatively to reduce incisional tension (see Chapter 10).

Various suture patterns can be used to help offset and distribute tension during wound closure. This chapter discusses techniques for assessing and minimizing skin tension for successful skin closure.

SKIN TENSION IN THE DOG AND CAT

Patient Variations

Skin differs in thickness, pliability, and tension in various body regions, and there are also variations between breeds and species. Bloodhounds and Basset hounds, for example, have ample loose skin over many body regions, whereas whippets and greyhounds have comparatively less skin. Whippets and greyhounds also have considerably thinner, less durable skin compared to other dogs. As a result, skin repairs can be more problematic in these canine patients.

Dogs and cats have a similar cutaneous distribution, although feline skin appears to be more pliable and the limbs more flexible than in the average dog. Extremely obese animals can lose considerable skin laxity from heavy deposits of fat beneath the dermis (Fig. 9-1). As discussed in Chapter 10, the skin is stretched in obese animals, potentially making wound closure more problematic.

Surgical Considerations

Skin over the dorsal and lateral surfaces of the trunk is pliable in a craniocaudal and dorsoventral direction. The excision and closure of small wounds in this area are not critical. As one removes larger areas of skin in an elliptical fashion, the length of the incision is best created (when feasible) parallel to the lines of greatest tension: this facilitates mobilizing the more elastic skin for apposition of the cutaneous borders of the wound created. If the elliptical excision is created at an angle to the lines of

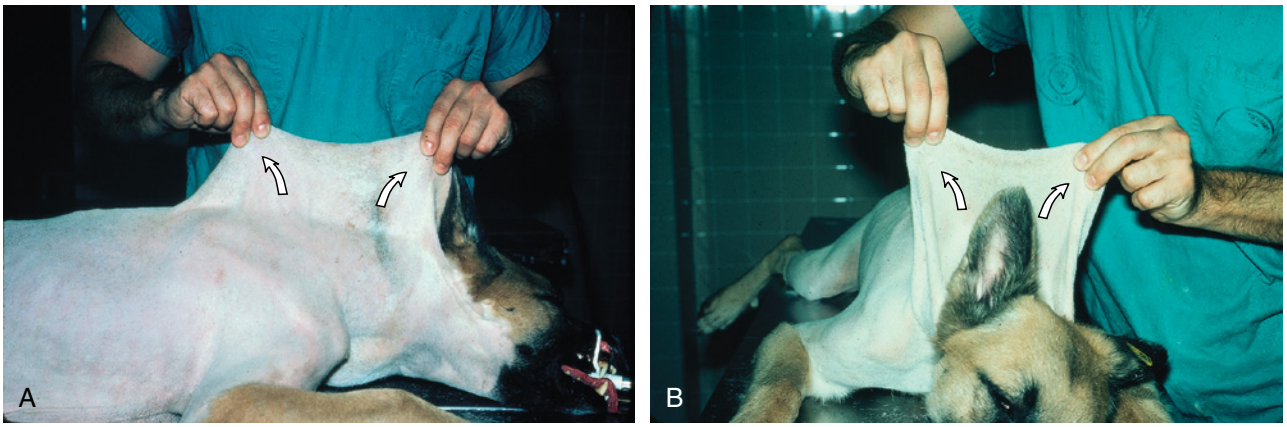


FIG. 9-1 (A, B) Example of skin laxity in a German shepherd cross. Lines of tension have limited use in areas where ample elastic skin prevails. The arrows indicate the upward lifting and retraction of the skin.

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tension, angular tension lines may promote closure in a curvilinear fashion. The flank and axillary skin folds are elastic and mobile skin areas that adjust to limb motion. Although this skin would be considered a potential "donor" area for wound closure, the closed donor site is more prone to dehiscence in an active pet. The author avoids using this area for most closure techniques.

Closure of wounds resulting in intersecting incisions is occasionally necessary, creating a "T" junction. Placed under tension from various traction forces, wound dehiscence most commonly begins at this weakest point of the closure, the "T" intersection. For this reason, closure of wounds in a linear or curvilinear fashion is preferable when practicable.

The middle and distal portions of the extremities have a paucity of loose skin. However, skin can be mobilized to a limited degree in a craniocaudal plane, whereas little skin can be elevated in a proximal–distal direction (Fig. 9-2). As a result, small advancement flaps can be created perpendicular to the limb axis to close small defects. Alternatively, the versatile transposition flap can be used to mobilize loose skin when created parallel to the axis of the limb (Fig. 9-3). Care must be exercised to avoid closing wounds under excessive tension that may result in compromise to the circulation and lymphatic drainage to the distal extremity below the closure site. Release incisions also can be used to offset local incisional tension. Both small and large release incisions can be effective in reducing incisional tension (Figs 9-4, 9-5, 9-6, 9-7, 9-8, and 9-9). Prior to attempting release incisions, there are some cases in which the intraoperative use of "load cycling" with skin hooks may gain the necessary tension relief without their use (Fig. 9-10). Skin stretching is discussed in Chapter 10 in greater detail.

Excessive circumferential skin tension on the lower extremity can result in a "biological tourniquet," effectively compromising venous and lymphatic return from the distal extremity. Swelling will then collapse arterial circulation. Partial wound closure with no circumferential tension always is preferable to complete closure under questionable tension. See Figs 9-11 and 9-12.

Under these circumstances, wounds are better left (partially) open than closed under excessive tension. One alternative is to apply a free graft to cover the open wound bed, as long as the wound surface can provide adequate circulation for its survival (see Chapter 14).

The author has developed a variation of the standard release incision: the hidden release incision (see Plate 24).

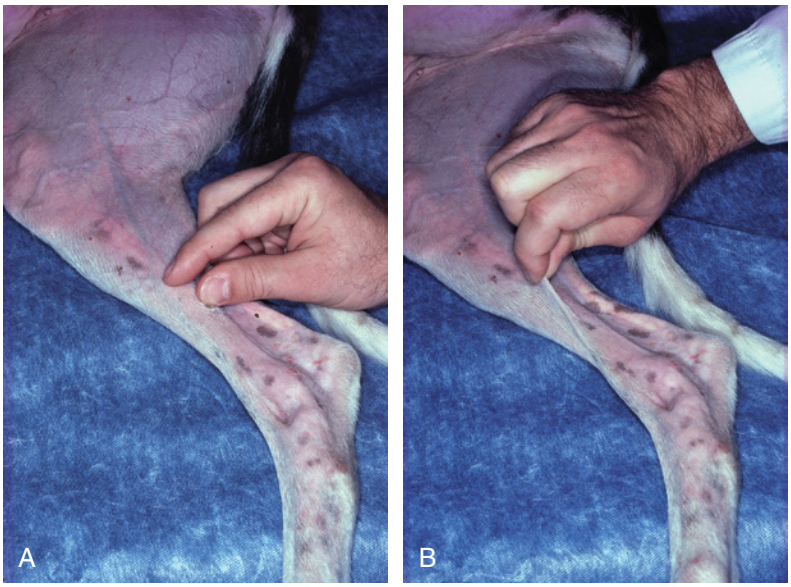


FIG. 9-2 (A) Note the inability to grasp any loose skin in a proximal–distal direction on the rear limb of a greyhound. (B) A ridge of skin can be elevated in the cranial–caudal plane. This parallel fold of skin can be used for transposition flap elevation. This fact is contrary to the tension lines noted in Plate 1. (Source: Pavletic MM. 1990. Skin flaps in reconstructive surgery. *Vet Clin North Am* 20(1):81–103. Reproduced with permission of Elsevier.)

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FIG. 9-3 (A) Lower-extremity defect in a cat. (B) A transposition flap was elevated parallel to the limb axis with the base or pedicle of the flap based distally. Carefully measured prior to elevation, the available loose circumferential skin allowed for closure of the donor and recipient beds.

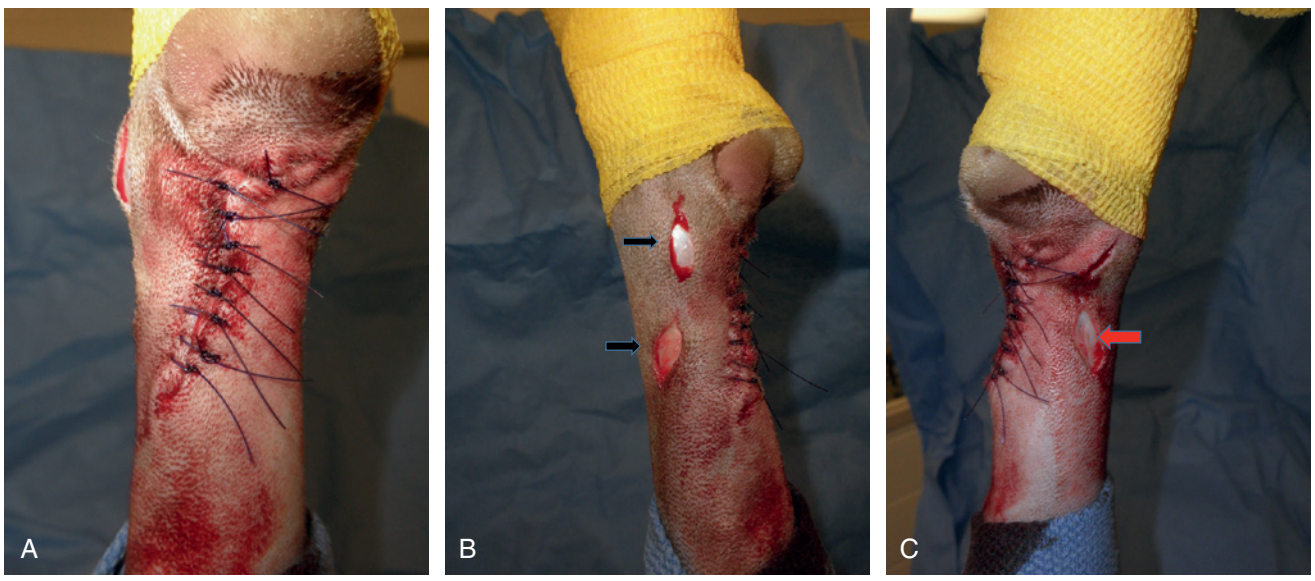


FIG. 9-4 (A) Skin tumor resection, palmar metacarpal surface. (B) Medial release incisions. Note the gap in each incision indicating reduction in incisional tension. Bandaging of the area is required until the release incisions heal by second intention. (C) Lateral release incision (arrow) positioned to reduce central incisional tension.

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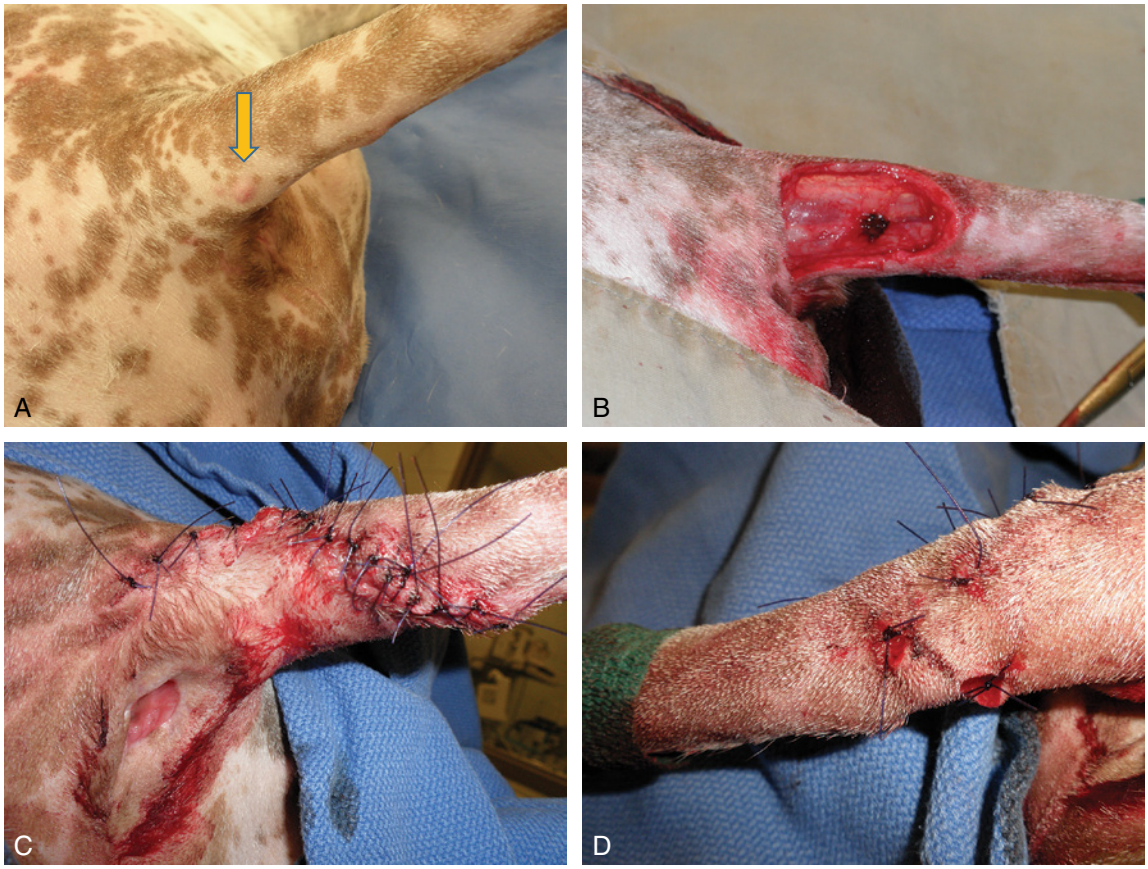


FIG. 9-5 (A) Mast cell tumor, left base of the tail (arrow). (B) Resection of the mass. (C) Closure of the skin in a spiral fashion. (D) To further reduce circumferential skin tension after closure, mini-release incisions were used. Following creation of the incisions, perpendicular to the line of tension, the mini-release incision may close (partially or completely) in the opposite direction.

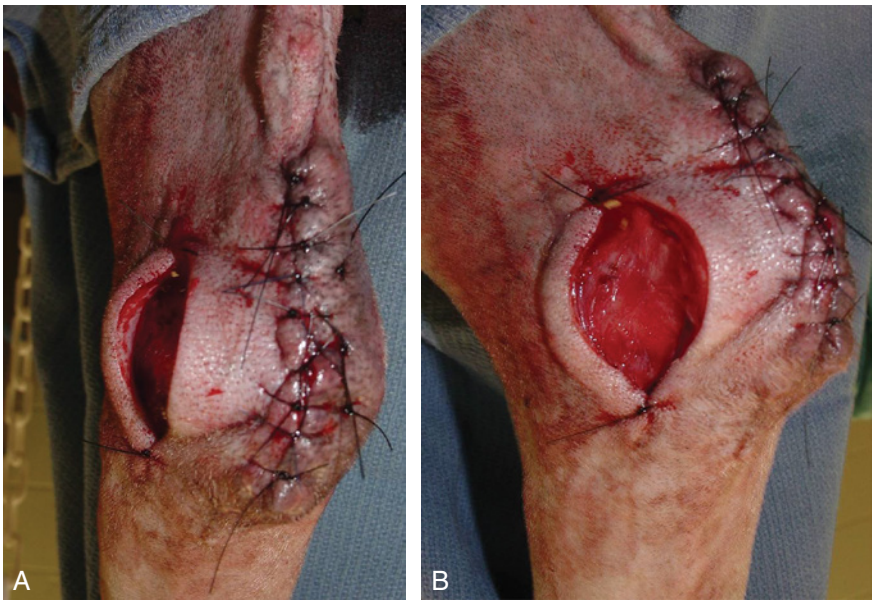


FIG. 9-6 (A, B) Medial and lateral views of release incisions, with closure of the elbow defect with bilateral bipedicle advancement flaps. (See Plate 10.)

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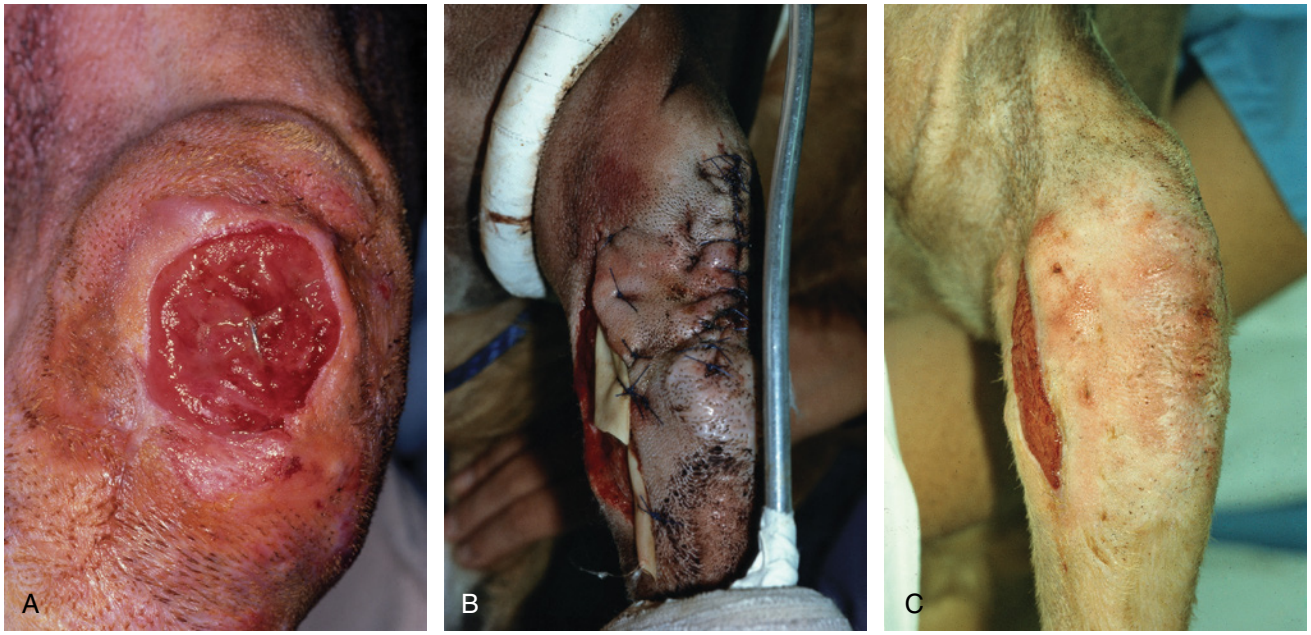


FIG. 9-7 (A) Pressure sore overlying the left elbow. Note the exposed orthopedic wire used to repair the fracture. (B) Release incision made over the lateral surface of the elbow region, creating a bipedicle advancement flap. The flap was advanced over the elbow defect and sutured into position. The lateral donor defect is left open to heal by second intention. A Schroeder-Thomas splint was used to immobilize the elbow until suture removal. (C) Healing of the lateral release incision occurred without complication. Use of the thicker lateral skin is preferable to the thinner medial skin of the extremity. Bilateral release incisions also can be used to facilitate closure of problematic elbow defects. (See Plates 6 and 7.)

Harnessing the Viscoelastic Properties of Skin

As discussed in Chapter 1, the skin, and the dermis in particular, is a viscoelastic medium, based on the physical properties of collagen and the surrounding mucopolysaccharide ground substance. Regional variations in skin thickness and pliability primarily are the result of collagen fiber size and weave (see Chapter 1). While skin normally stretches and deforms during normal physical activity and pregnancy, research has demonstrated that these inherent properties also can be harnessed to promote wound closure. Skin can be "prestretched" within hours to promote wound closure under less tension. A skin-stretching device also can be used to effectively offset incisional tension postoperatively (Figs 9-13, 9-14, and 9-15) (also see Chapter 10).

The surgical techniques discussed in this chapter offset skin tension by a few basic mechanisms. Incisional techniques (release incisions, Z-plasty, V–Y-plasty) divide collagen fibers and partially reduce tension in a fashion similar to cutting a rubber band. Z-plasty and some local flap techniques transpose additional skin into a skin tension plane perpendicular to an incision. Simply undermining skin will improve the elastic advancement of skin by dividing underlying, restricting hypodermal/fascial attachments to the dermis. Skin can then be shifted or "directed" into adjacent defects by taking advantage of its regional and directional elastic properties (Figs 9-16 and 9-17).

Surgeons normally consider closure of wounds either parallel or perpendicular to the axis of the affected extremity. Oftentimes linear closure parallel to the axis, in an attempt to harness the limited circumferential skin, runs the risk of dehiscence or potentially catastrophic formation of a biological tourniquet that may lead to loss of the lower portions of the extremity. Closure in the opposite direction is often limited by the difficulty of mobilizing skin in a proximal–distal direction. The author has found angular closure a useful solution for closure by shifting the skin diagonal to both

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FIG. 9-8 (A) Acute skin loss in a cat, exposing the Achilles (gastrocnemius) tendon. This structure is particularly sensitive to desiccation. (B) A release incision is created on the opposite anterior tibial surface (arrow), creating two bipedicle advancement flaps. (C) Anterior view of the release incision. (D) Reciprocal closure of the wound, protecting the Achilles tendon from exposure. (E) The proximal portion of the release incision is closed. The remaining wound is managed as an open wound using a reinforced bandage to prevent motion of the tarsal joint. (See Plate 25.)

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FIG. 9-9 (A) Mast cell tumor resection, partial closure of forelimb surgical defect. Note the exposed tendons. (B) Medial release incision was performed, allowing closure of the lateral surgical defect to cover the exposed tendons. (C) Closure of the lateral surgical defect. (D) Medial release incision, healing by second intention 3 weeks later. (E) Lateral surgical closure after 3 weeks. Bandaging is required during the healing process. Optional closure of the surgical defect would include the use of a free graft.

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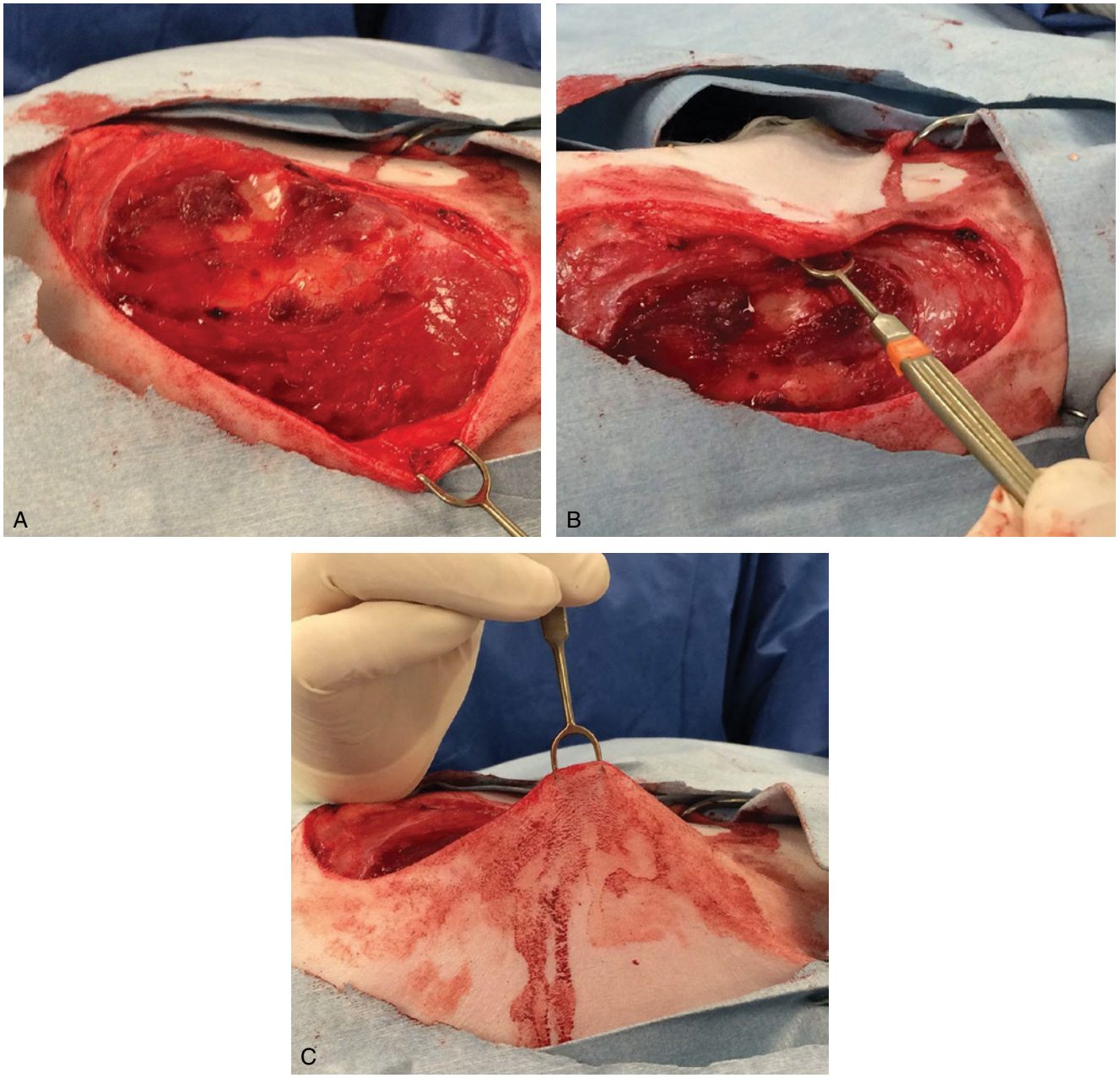


FIG. 9-10 (A) Wide resection of a mast cell tumor involving the ventral thoracic area. (B, C) Use of a dual-pronged skin hook to "load cycle" the skin over a 10-minute time frame. This facilitated primary closure of this surgical defect.

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FIG. 9-11 (A) Right forelimb tumor resection and closure; the patient returned 24 hours later when the owner noted swelling of the toes. The dog was also quite painful. Note the biological tourniquet effect (arrow) and the edema immediately distal to this point. (B) Close-up view of the swollen paw and digits. If not identified early, there is a risk of loss of portions of the paw. (C) The key to emergency management: removal of all sutures (intradermal, skin) to eliminate circumferential tension. The necrotic skin borders were debrided. (D) A soft supportive medicated dressing and overlying bandage are used to support the extremity. The central digits are exposed, allowing for assessment of postoperative swelling. (E, F) Lateral and anterior views of the affected limb 24 hours later. Most of the swelling has resolved. The surgical wound subsequently healed by second intention.

axes (Figs 9-18 and 9-19). In so doing, tension is distributed in a spiral fashion to help avoid excessive circumferential tension.

Tension suture patterns and walking sutures reduce tension, in large part, by distributing tension more uniformly to the surrounding cutaneous tissue surface by variable degrees. Skin stretchers recruit the viscoelastic properties of regional skin by distributing tension over the comparatively large footprint of contact between the skin pad and skin surface.

Combining Suture Patterns to Reduce the Risk of Dehiscence

Each suture pattern has inherent advantages and disadvantages. To reduce the risk of dehiscence in challenging wound closures, the author often combines suture patterns. Interrupted intradermal sutures are used to initially approximate the skin. This is followed by interrupted skin sutures to accurately approximate the

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FIG. 9-12 (A) Infected cutaneous granuloma, lateral aspect of the lower right hindlimb. (B) Resection of the mass. The skin margins were tacked to the adjacent fascia, preventing retraction of their borders. This smaller wound is protected with a medicated dressing and bandage to promote healing by second intention. Closure of this wound under circumferential tension, with the risk of creating a biological tourniquet, is eliminated. (C) The wound at week 2 and (D) at week 3. Notice the wound is nearly healed by second intention at 21 days.

cutaneous borders. Vertical mattress sutures are used to offset that portion of the closure under the greatest skin tension; this often is associated with the central portion of the closure (Fig. 9-20).

Surgical cyanoacrylate glues (with the holding power of 5-0 suture materials) can be used to further supplement incisional closure after placement of skin sutures. Surgical glues also can be used to decrease rotation of skin staples. There is the added advantage of sealing the skin incision to reduce contact contamination in the postoperative period (Fig. 9-21). Combined closure also can be supplemented with skin-stretcher pads and cables placed at the incisional area under the greatest surgical tension (Fig. 9-22).

In the face of excessive tension, tension sutures cannot accentuate skin deformation as effectively as skin-stretcher pads due to their small point of contact with the skin and limitations in their physical placement in the areas surrounding the surgical site. Unlike skin stretchers, skin sutures placed under great tension can "cut out" and cause circulatory compromise to the skin.

Selection and use of the techniques discussed in this chapter will depend on the individual circumstances of a given wound closure, the condition of the skin, and the regional circulation. With experience, surgeons develop their own preference(s) for the techniques listed.

The positioning of the patient on the surgery table can have a significant effect on wound closure. For example, a common error in closing a large skin defect over the dorsal–lateral pelvic area is the placement of the patient in sternal recumbency, with the rear limbs in a "frog leg" position. This greatly reduces dorsal skin tension, facilitating closure. The postsurgical problem is discovered by the surgeon only after surgery is completed: skin closure tension results in the abduction of the rear limb(s), necessitating immediate revision of the closure.

This can be avoided by closing the defect with the patient in lateral recumbency (giving a true picture of regional skin tension). Thoughtful preoperative planning can prevent this problem regardless of patient positioning.

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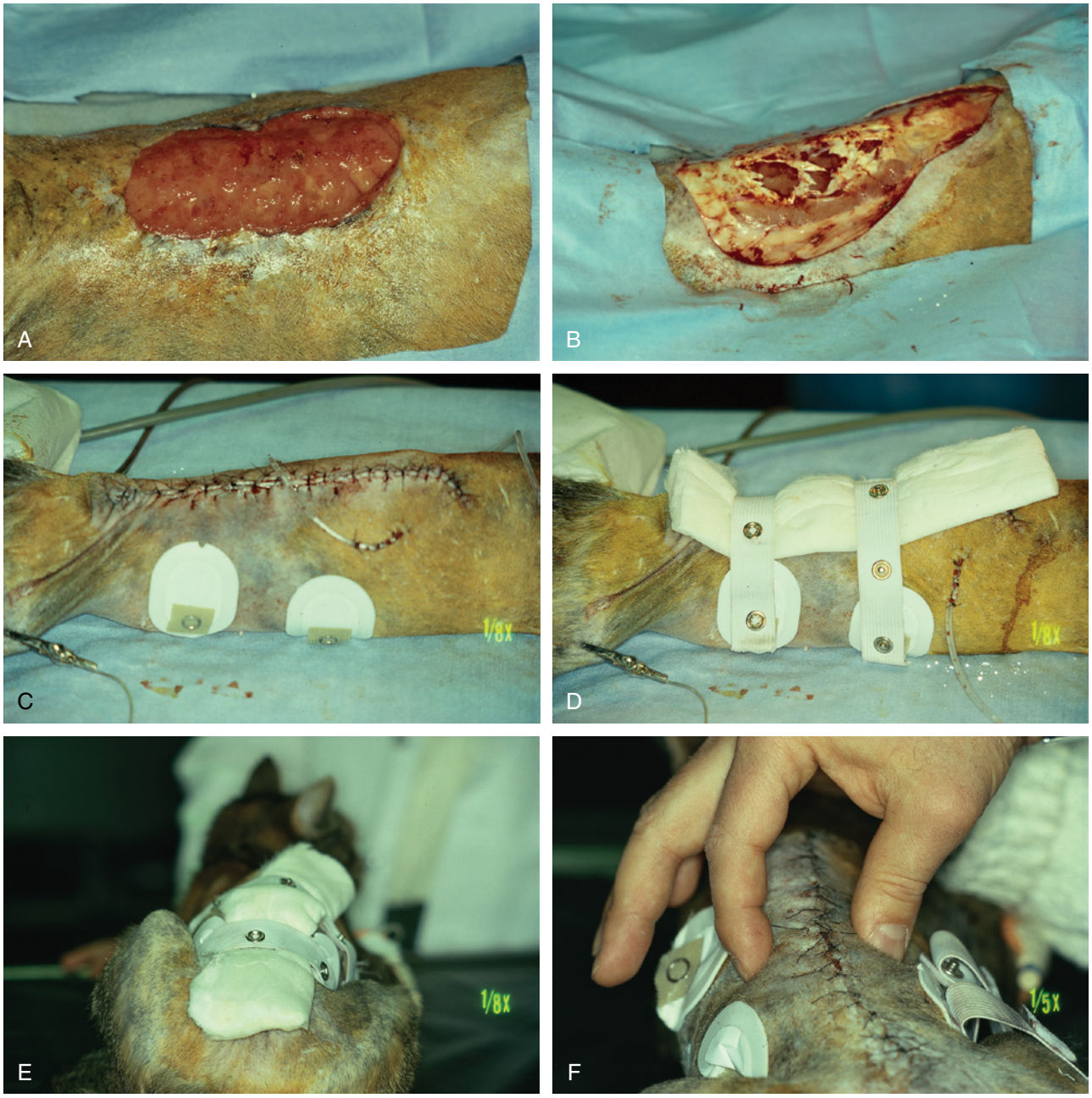


FIG. 9-13 (A) Radiation ulcer over the dorsal lumbar area of a cat. A carcinoma was surgically removed from the area and the surgical field irradiated. A slowly expanding radiation ulcer developed several months later. (B) Wide resection of the ulcer and bordering epithelialized scar. Tissues resected did not reveal tumor recurrence, based on histopathologic analysis. (C) Wound closure was accomplished, but the incision was under moderate tension. (D) Two pairs of skin-stretcher pads were applied lateral to the incision, followed by application of elastic cables over a protective cotton dressing. A mild amount of tension was applied to each cable; cables were not adjusted prior to reexamination of the patient the following day. (E) Dorsal view of the patient 24 hours after surgery. (F) Uncoupling of the stretcher cables at 24 hours. Note the relaxation of the skin along the border of the incision. Pads and cables were removed 72 hours after surgery; skin sutures were removed by day 14.

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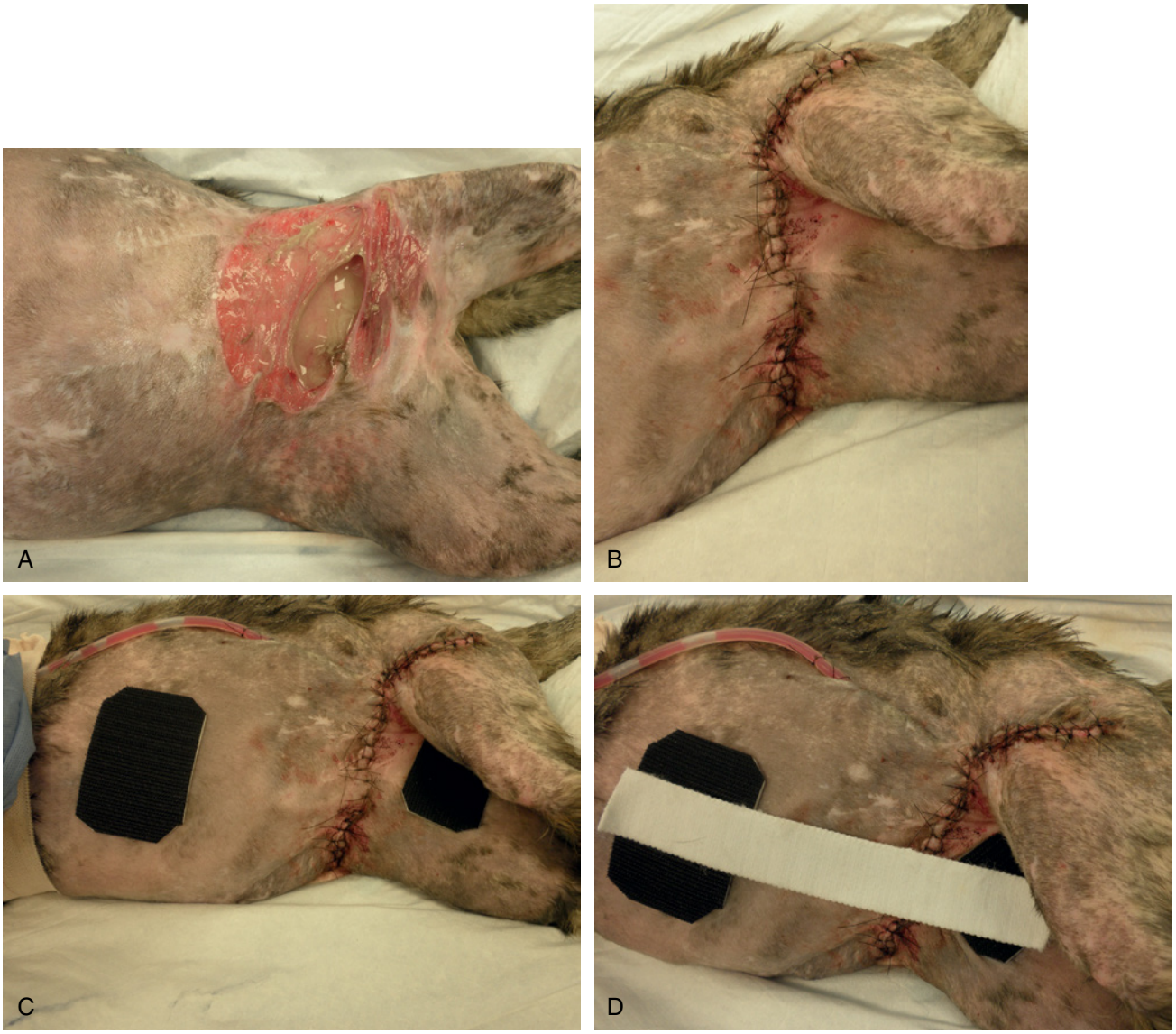


FIG. 9-14 (A) Traumatic flank wound in an outdoor cat. (B) Extensive debridement and lavage of the wound was followed by wound closure. A closed-suction drain was inserted into the wound cavity prior to closure. (C) Skin stretcher pads were placed in alignment to the area of greatest tension on the incision, cranial and caudal to the closure. Note that the corners of the pads were trimmed to reduce the risk of irritating the cat. (D) Placement of the stretcher cable. Sufficient stretch was placed on the cable to reduce incisional tension.

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FIG. 9-15 (A) Wound dehiscence in a mixed-breed dog following tumor resection. (B) Placement of skin stretcher pads. Note the corners have been trimmed to reduce irritation to the dog. (C) Placement of a medicated dressing using polyurethane foam. Stretcher cables have been applied to stretch the skin while maintaining the position of the dressing. (D) The wound after 72 hours of stretching. (E) Surgical closure using an interrupted intradermal suture pattern followed by placement of skin sutures using a cruciate pattern.

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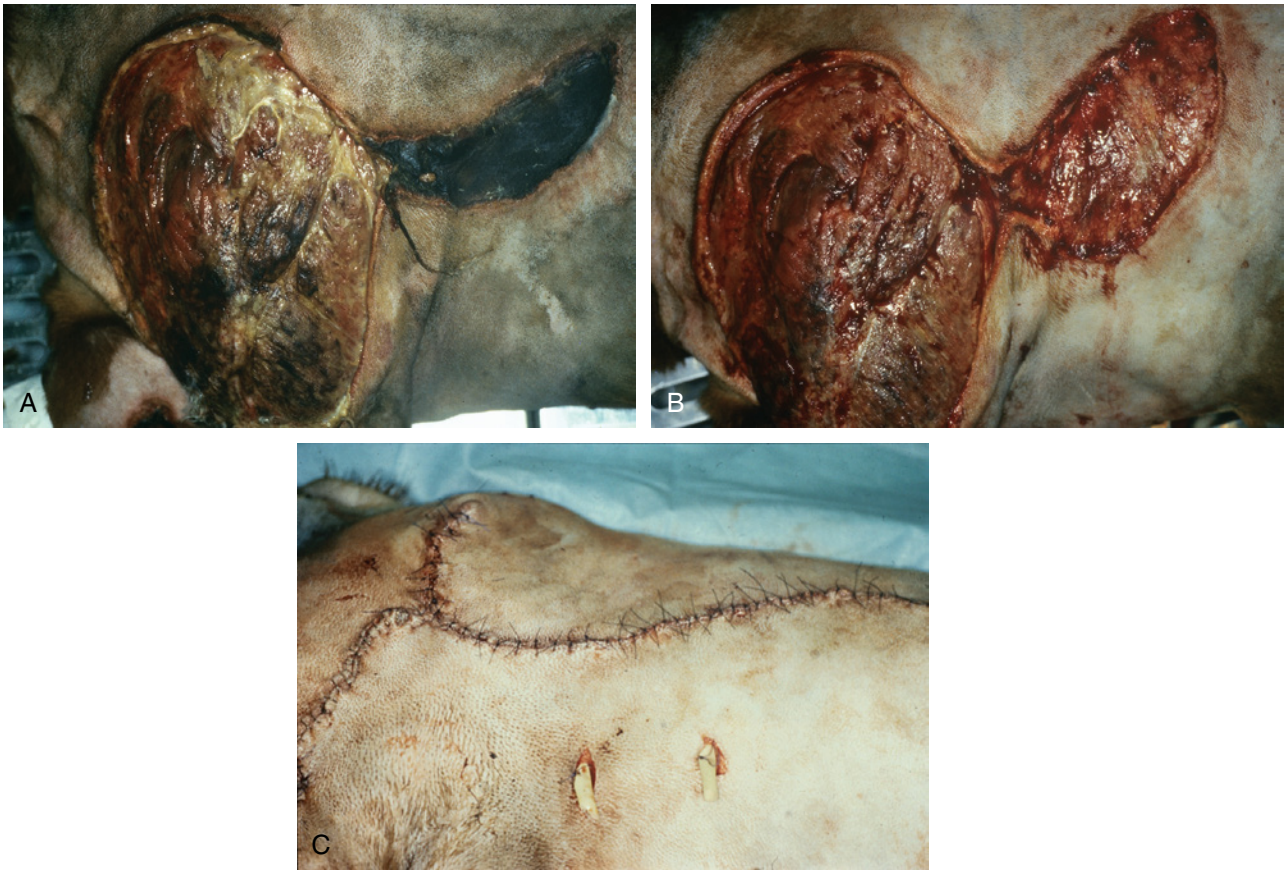


FIG. 9-16 (A) Multiple skin wounds: the dog was tied to a car bumper and accidently dragged. (B) Initial debridement was followed by wet-to-dry dressings. (C) The large left shoulder and thoracic wound was closed by directing the adjacent elastic skin toward the center of this large wound (see Plate 32).

Suture Options to Alter Skin Traction and Retraction

Undermining with skin advancement is one of the most basic methods of closing wounds. Like simple advancement flaps, closure takes advantage of the inherent elasticity of the skin to overlap the cutaneous defect. However, after wound closure, dermal collagen and elastin fibers will contract in an attempt to return to their normal coiled position. This is most evident when using these techniques to close skin defects associated with the eyelids. In some cases, the surgeon may be unpleasantly surprised by distortion of the eyelid and impairment of function postoperatively. When closing more rostral labial defects, labial advancement also can be challenged by the same retraction forces.

There are simple suture options that can maintain tissue advancement or neutralize elastic retraction of the skin (Fig. 9-20). Offset suture placement, a variation of "walking sutures" (see Plate 26), can be used to advance skin and incrementally offset elastic retraction. Suture bites of the underlying fascia ahead of the subsequent suture bite of the dermis will pull the skin in a forward direction. A variation of this technique can be effectively used in labial advancement as sutures are placed to the opposing gingiva. In essence, suture bites of the gingiva are placed several millimeters rostral to the mucosa under advancement. When the suture is tied, the labial mucosa is "tugged" slightly forward. Each subsequent suture further advances the tissue while offsetting the forces of elastic retraction. Buried intradermal sutures, tacked to the more rigid underlying fascia, can serve a similar purpose to

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FIG. 9-17 (A) Fibrosarcoma, right lateral thigh (arrow). (B, C) Wide mass excision, including the underlying musculofascial layer. (D) Extensive undermining of the anterior skin of the flank, preserving the caudal superficial epigastric artery and vein, as well as the subdermal plexus. (E) Notice that the skin was shifted to best utilize the looser, more elastic skin to close the most problematic central area of the surgical defect.

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FIG. 9-18 Spiral closure technique. (A) The cutaneous adenoma involving the dorsal tail region will be resected. (B) After resection, the conventional options include closure proximally–distally or laterally. Either option risks tension after closure with subsequent dehiscence. (C) Closure is accomplished in a spiral fashion, better distributing tension to reduce the risk of dehiscence and the possibility of creating a biological tourniquet from excessive circumferential skin tension. Note that three vertical mattress sutures are used to reduce incisional tension in the central third of the closure where the tension is greatest.

simply maintain the advanced skin or flap's new position by securing it to the underlying fascial tissues (See Plate 26).

Foley Catheters to Reduce Incisional Tension

Another technique the author has developed to reduce incisional tension is Foley catheter placement to support or protect a surgical closure in problematic areas (Plate 34). With slight traction, the elastic catheter can draw the two sides of an incision closer together thereby protecting the area from dehiscence. The tube segments beneath the skin allow the skin to glide over their smooth surface. The Foley catheters normally can be removed in 5–7 days (Figs 9-23 and 9-24).

Summary of Intraoperative Options to Facilitate Wound Closure

- Preplan the surgery to take advantage of regional skin tension
- Undermining with preservation of the regional blood supply to the skin is the most common technique initially used to reduce skin tension
- Intraoperative skin stretching or "load cycling" with skin hooks (Fig. 9-10) can be used to complement skin undermining
- Skin directing is used to shift the undermined skin to the widest portion of the defect (Plate 32)
- Selecting the appropriate suture patterns can be used to appose the incision lines, including walking sutures
- If tension remains a concern, release incisions, Z-plasty, or V–Y-plasty should be considered. The transposition skin flap (Chapter 11) is proven to be invaluable to facilitate problematic wound closure

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- The Foley catheter technique can be considered for problematic areas where other tension-reducing techniques are not ideal (Plate 34)
- If tension is potentially problematic (e.g., for lower-extremity defects), the wound can be left partially open to heal by second intention. In some cases the surgeon may consider skin graft placement over the open wound bed with the presence of adequate circulation (Chapter 14).
- Following closure, surgical stents, although uncommonly used, are one option to protect the incision (Plate 31). Skin stretchers can be used to effectively reduce incisional tension at the conclusion of the closure (Plate 28).

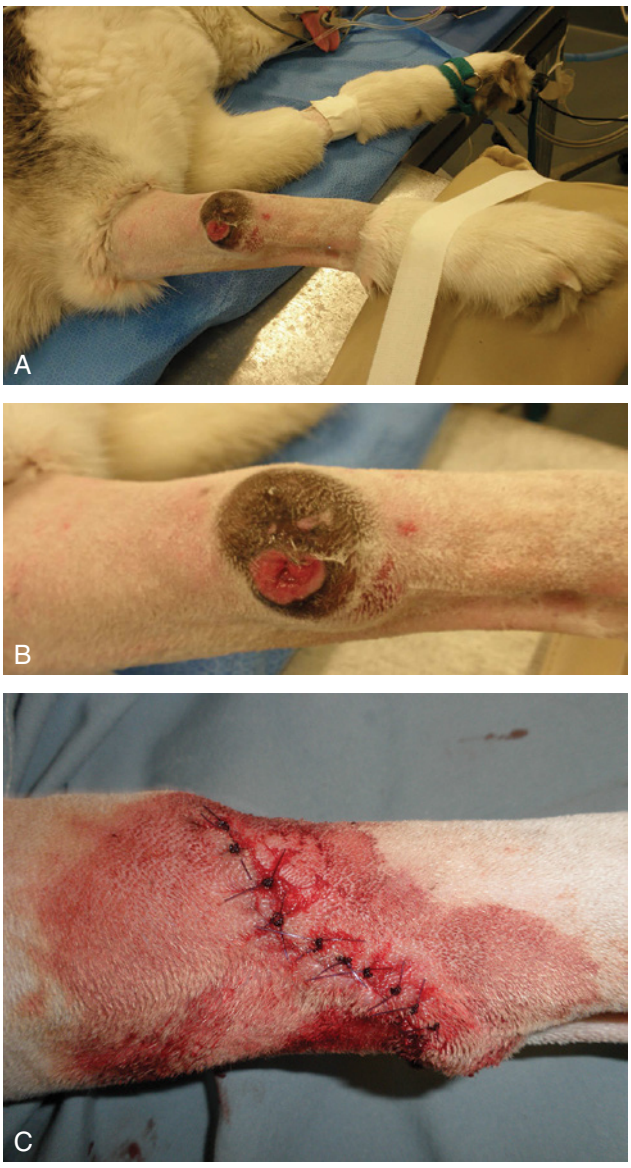


FIG. 9-19 (A) Ulcerated adenoma involving the right lateral forelimb. (B) Close-up view. (C) Resection with spiral closure to better distribute circumferential skin tension.

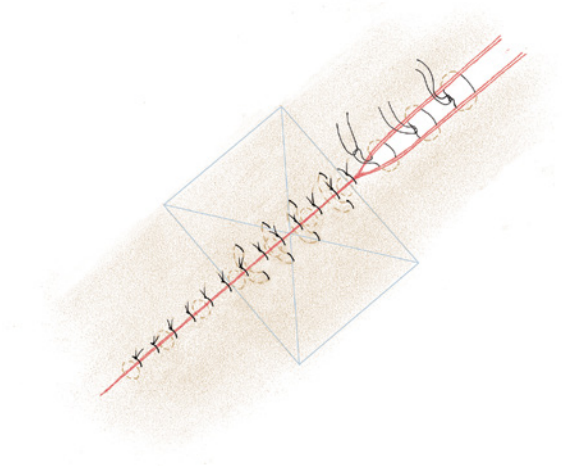


FIG. 9-20 The author's favorite combination of suture patterns is illustrated to close wounds under mild to moderate skin tension. (As noted, closure should not create circumferential tension that could compromise circulation to an extremity.) Buried intradermal sutures are used to align incisional borders. This is followed by external interrupted skin sutures to accurately align cutaneous borders. Incisional tension is normally greatest in the central area of wound closure, as denoted in the "x-box" area. In this "central zone," vertical mattress skin sutures are applied to further reduce the risk of dehiscence. Average-thickness skin is normally aligned with 3-0 intradermal suture material. In thick skin, 2-0 size sutures are used for intradermal sutures. This general size selection also applies to interrupted skin sutures. In most cases, 2-0 suture material is used for vertical mattress sutures. As previously noted, surgical glue can be applied over the incision to seal its surface and give additional security. (Surgical glue has the general suture-holding strength of 5-0 suture material.)



FIG. 9-21 This ventral thoracic incision was closed by careful tissue undermining followed by initial apposition with interrupted intradermal absorbable sutures. This was followed by interrupted skin sutures: three vertical mattress sutures were used to offset the central area of the incision under the greatest skin tension. Vetbond™ glue (3M) was used to seal the incision and provide some additional holding power (see Fig. 9-20).

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FIG. 9-22 (A) Soft tissue sarcoma involving the right lateral thigh of a mixed-breed dog. (B) Wide resection including the underlying biceps femoris muscle fascia. Following undermining of the cutaneous borders, especially the cranial flank skin, a Jackson-Pratt drain was inserted adjacent to the surgical site. (C) Closure was accomplished with interrupted intradermal absorbable sutures; simple interrupted skin sutures; supplemental vertical mattress skin sutures placed in the central area of the incision under the greatest tension; and external surgical glue application. (D) Skin-stretcher pads were placed parallel to the area under the greatest tension. (E) A protective pad was placed over the incision followed by application of the stretcher cable, using only a mild amount of cable tension to reduce local incision tension. Combining closure techniques and methods to offset incisional tension can be highly effective in reducing the risk of dehiscence postoperatively. (See Plate 28.)

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FIG. 9-23 (A) Repeated wound dehiscence secondary to tumor resection in the perineal area. Two Foley catheters were inserted into the skin of the lower perineum after preplacement of the blue intravenous tubing locks. The catheter was guided through the small stab incisions created with a no. 15 scalpel blade. The Foley balloons were inflated, tension was applied to the tubing, and the blue locks were slid over the tubing to maintain tension to the closure. (B) The long ends of the Foley catheters were secured to a tape base on the dorsal lumbar area, secured to the skin with 35W staples. (C) Caudal view of the area with the patient standing. Approximately 1 week later, the Foley balloons were deflated and removed. (D) Removal of the Foley catheters 1 week later. The small holes vacated by the Foley catheters healed by second intention while providing local drainage following catheter removal. The remaining open wound areas healed without further incident. See Plate 34.

Use of Plate Illustrations

Each plate presents a method to reduce skin tension and facilitate wound closure. Determining the direction of wound closure, to take advantage of natural tension lines and using the appropriate closure option(s), will effectively work on many of the day-to-day wounds facing the surgeon. Careful undermining can reduce tension and avoid the risks of circulatory compromise. Picking the correct suture size and pattern can maintain closure and reduce the risk of dehiscence. Skin-stretching techniques used intraoperatively and postoperatively can further offset skin tension. Release incisions are useful in reducing incisional tension and facilitating coverage of important anatomic structures; the downside is that the open release incision wound normally requires postsurgical care until healing is complete. Readers are encouraged to review these plates collectively: singly or in combination, a variety of cutaneous defects can be closed without resorting to the techniques noted in subsequent chapters.

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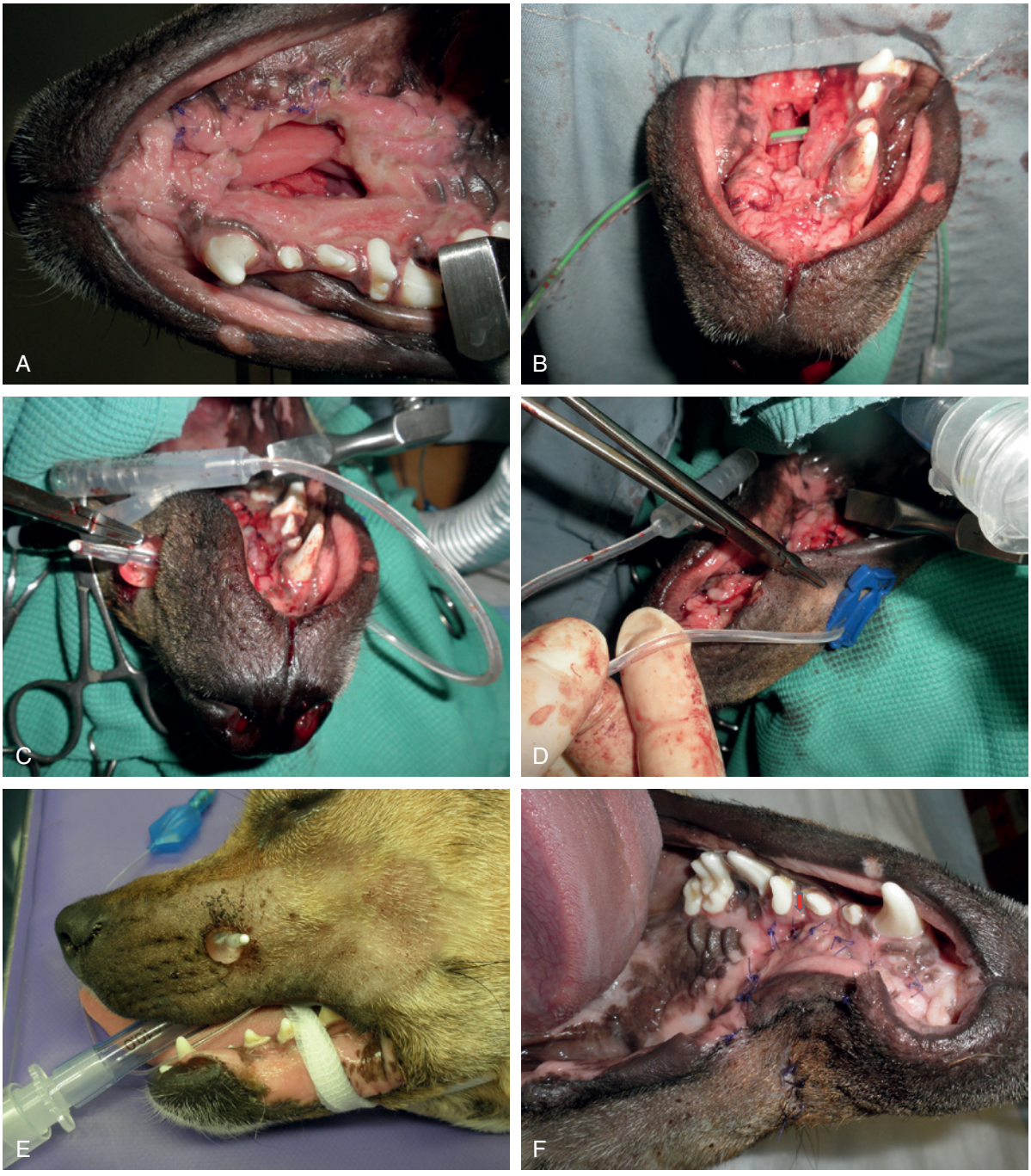


FIG. 9-24 (A) Case (see Fig. 17-8) of large cleft palate defect partially closed with a bipedicle mucoperiosteal flap: the remaining rostral defect. (B) In preparation for a left labial mucosal flap, a Foley catheter was inserted below the level of the palatal defect by drilling a hole through the right maxillary bone. A small stab incision at the right upper labial area allowed insertion of the Foley catheter below the level of the hard palate. Note the end of the catheter exiting a stab incision of the left upper labial area. Prior to its insertion, an intravenous line lock was slid over the catheter to the level of the injection port. (C) A labial mucosal flap was elevated from the left upper lip and sutured into the defect. The Foley catheter balloon was then inflated. (D) Traction is applied to the elastic Foley tubing, resulting in drawing the left mucosal flap over to the right side of the defect. The blue intravenous lock is then tightened to maintain tension. In this case, the Foley tension device was removed in about 1 week. (E) Left lateral view of the facial area and expanded Foley balloon. A small amount of irritation and pressure necrosis should be expected. (F) Removal of the Foley catheter 1 week later. Despite initial success, a small area of dehiscence was later noted along the inner border of the right dental arcade as a result of poor tissue quality. A small labial flap from the right lip was used to further reduce the small remaining defect (see Plate 34).

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Plate 14

Tension Lines

DESCRIPTION

Dominant lines of skin tension in the dog. (Source: Redrawn with permission from Irwin DHG. 1966. Tension lines in the skin of the dog. *J Sm Anim Pract* 7:595–598.)

SURGICAL CONSIDERATIONS

(A) Ventral view, lines of greatest tension.
(B) Dorsal view, lines of greatest tension.
(C) Lateral view, lines of greatest tension.

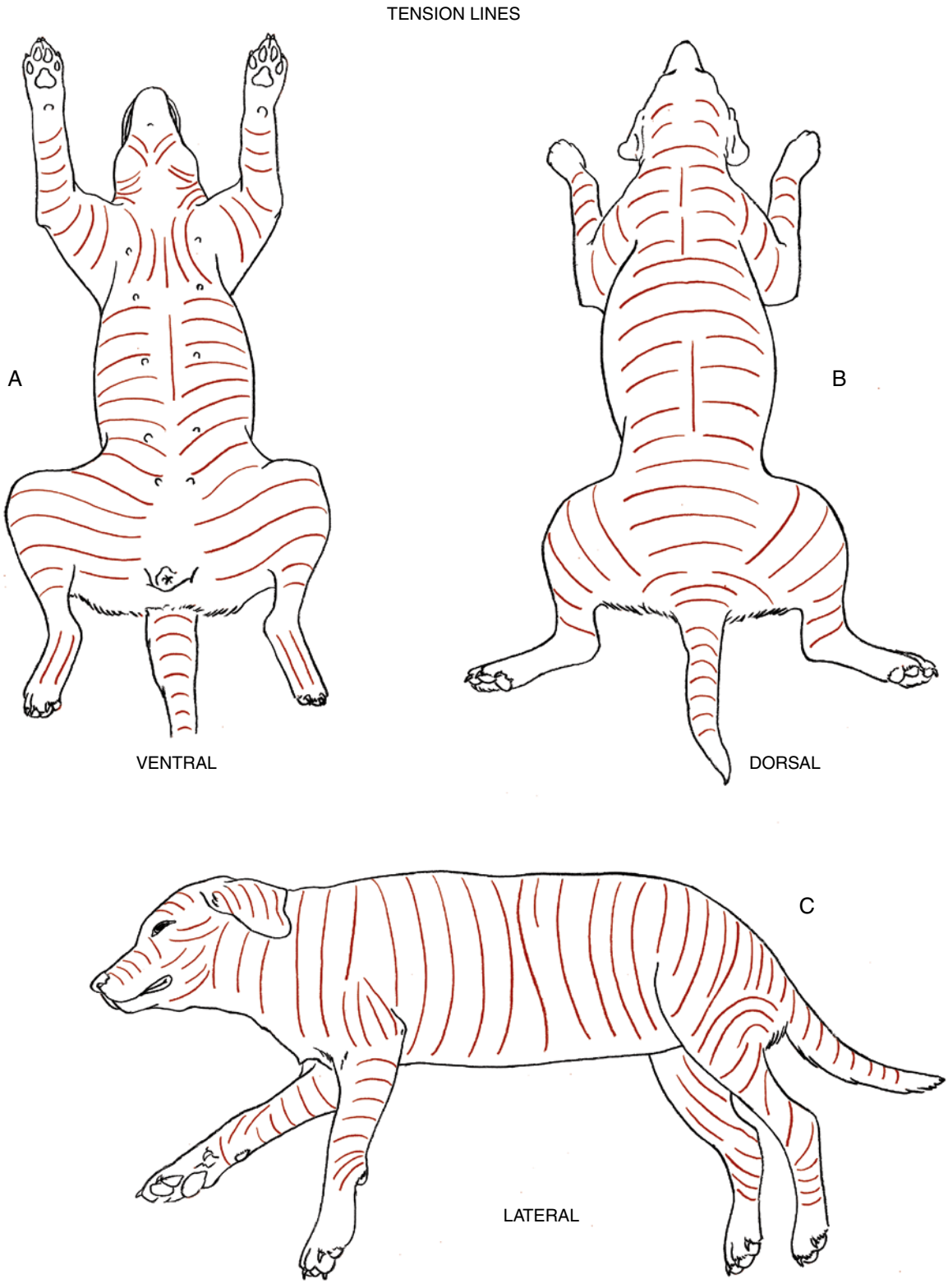
COMMENTS

The lines of tension illustrated were determined by the use of stab incisions in canine cadaver skin. Separation of wound edges indicated the direction of tension "bands." Although similar studies in human cadavers have been considered somewhat inaccurate, these anatomic maps do serve as general guidelines for the small animal surgeon. It must be noted that many small to moderate-sized skin defects can be closed perpendicular to these tension lines since ample loose skin is available for wound closure. For example, tension lines of the limbs would suggest that wound apposition should be performed parallel to these bands to facilitate closure. However, there is more loose skin around the circumference of the limbs compared to the proximal–distal direction. (See Chapter 1.)

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Plate 14



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Plate 15

Effects of Skin Tension on Wound Closure

DESCRIPTION

Elliptical excision and the effects of skin tension.

SURGICAL TECHNIQUE

(A) Elliptical excision *perpendicular* to lines of greatest tension results in widening of the defect as a result of elastic retraction of the skin borders.

(B) Elliptical excision is ideally performed parallel to lines of greatest tension and results in little distraction of wound margins. The closure takes advantage of the looser skin in the opposite direction. The surgeon will note less tendency for the wound to spread open from elastic retraction.

(C) Elliptical excision created at an angle to the lines of tension causes disparate traction of the incision. Closure of the wound will assume a wavy or curvilinear appearance.

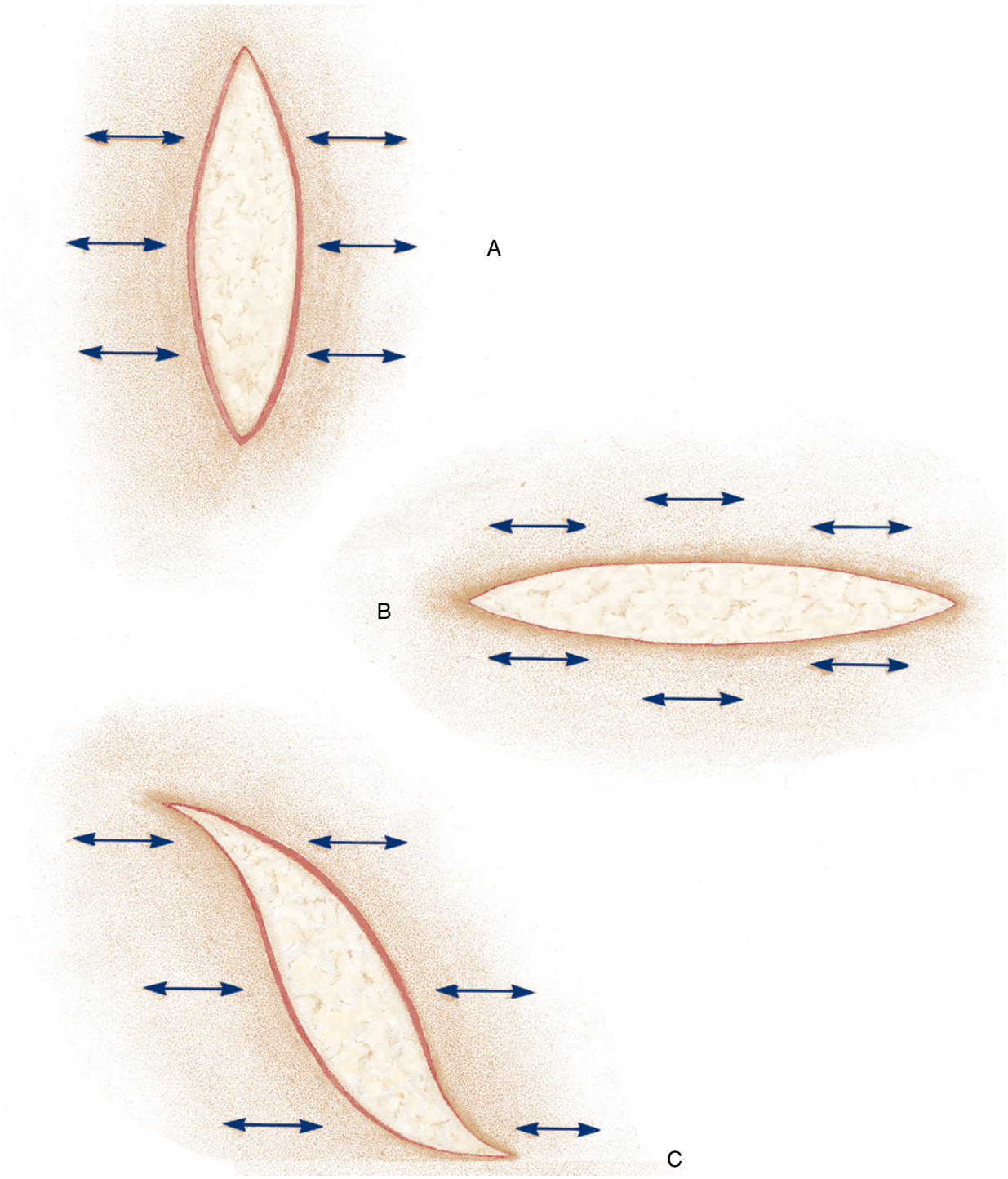
COMMENTS

Closure of a skin defect is primarily determined by the size, shape, and location of the wound. In elective procedures, such as excision of skin tumors, the surgeon may be able to take advantage of regional skin laxity and elasticity to minimize tension on the closure. Cosmetic closure includes positioning the scar so that hair will grow over the region while minimizing excessive tension on the closure that could later result in expansion of the width of the scar. (Source: Burges AF. 1975. *Elective Incisions and Scar Revision*. Boston, MA: Little Brown & Co. Modified with permission from Little Brown & Co.)

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Plate 15



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Plate 16 Patient-Positioning Techniques

DESCRIPTION

When closing defects over the back, ventral abdomen, or lateral surface of the trunk of a large animal, undermining and advancement of skin may be impaired by the animal's weight, which can pin mobile skin against the surgery table. This can significantly impair wound closure. Sandbags, beaded "vacuum" bags, or rolled-up towels can be placed ahead of and behind the surgical region, to elevate the skin trapped against the table.

POSITIONING TECHNIQUES

(A) Padded support placement beneath the cranial sternum and pelvis for closure of a large wound overlying the back.

(B) Padded supports beneath shoulders and pelvis for ventral thoracic and abdominal wound closure. This is ideal for unilateral or bilateral chain mastectomies when closure tension occasionally is a problem.

(C) Padded supports are placed beneath the lateral pelvis and shoulder for closure of large lateral thoracic or abdominal wall defects.

COMMENTS

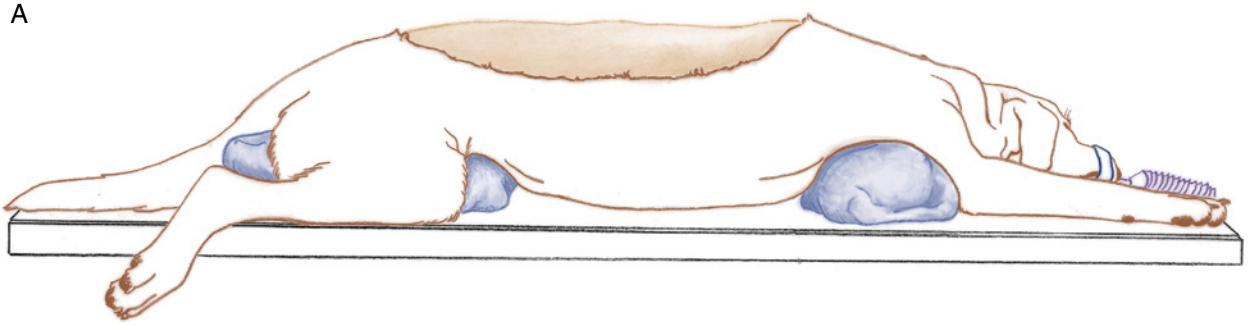
Veterinary surgeons can note a dramatic improvement in the ability to mobilize skin using the appropriate positioning of the patient, as illustrated. This is most commonly noted in larger dogs during unilateral or bilateral chain mastectomy. The surgeon can further reduce skin tension in the inguinal or axillary/sternal regions by loosening rope ties used to secure the respective hindlimbs/forelimbs.

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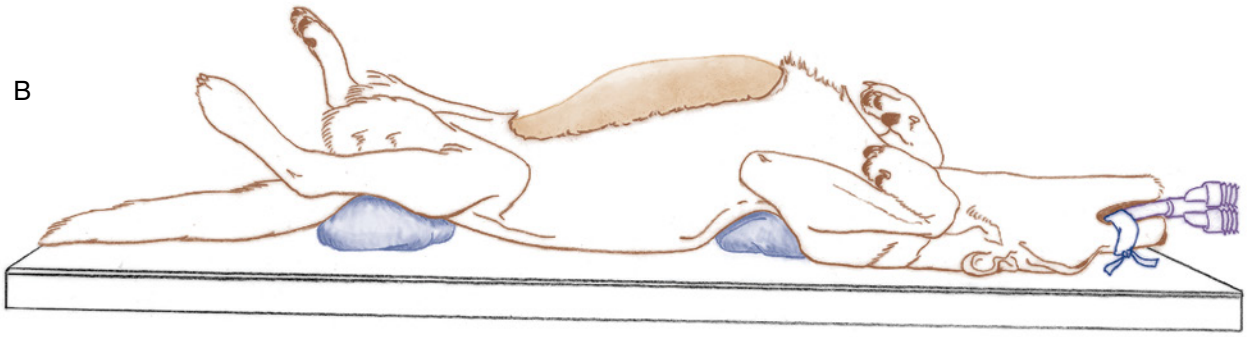
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Plate 16

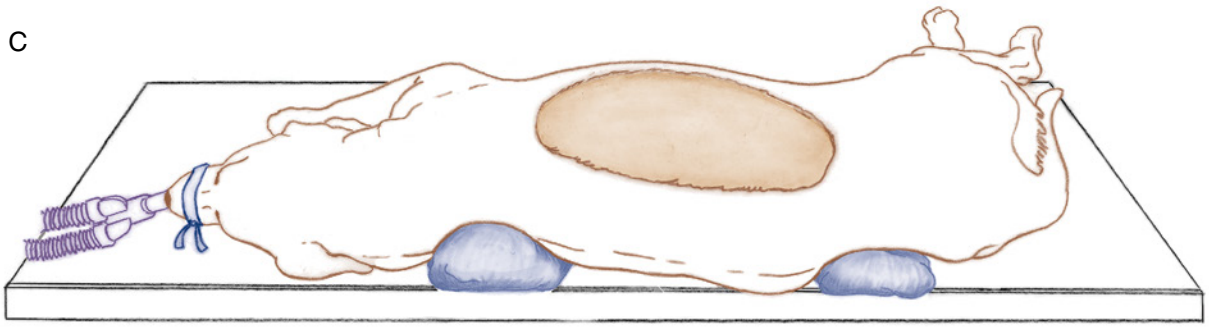
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B



C



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Plate 17 Undermining Skin

DESCRIPTION

The loose skin over the neck and trunk in the dog and cat permits the veterinary surgeon to close many skin defects by undermining alone. The key to the successful surgical elevation of skin is preserving its blood supply. This requires the preservation of the direct cutaneous vessels and associated subdermal (deep) plexus. The following points can be employed by the clinician as general guidelines for undermining skin in small animals.

SURGICAL TECHNIQUE

(A) Skin should be undermined below the panniculus muscle layer, when present, to preserve the subdermal plexus and associated direct cutaneous vessels.

(B) Skin without an underlying panniculus muscle layer (middle and distal portion of the extremities) should be undermined in the loose areolar fascia beneath the dermis to preserve the subdermal plexus.

(C) Preserve direct cutaneous arteries and veins whenever possible during undermining.

(D) Skin closely associated with an underlying muscle should be elevated by including a portion of the outer muscle fascia with the dermis rather than undermining between these structures. This may help minimize injury to the subdermal plexus.

COMMENTS

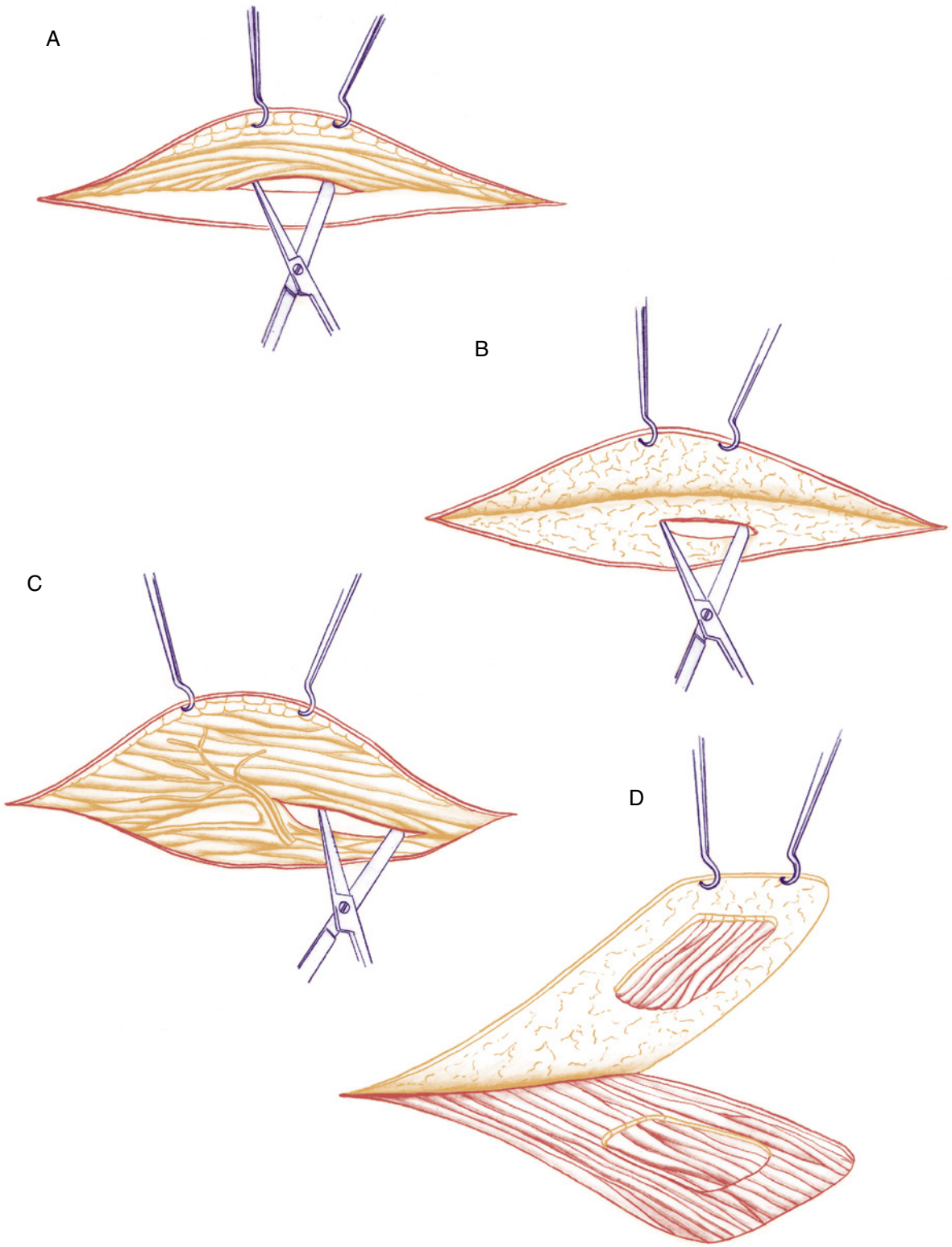
Avoid direct injury to the subdermal plexus by using atraumatic surgical technique. Avoid or minimize the surgical manipulation of skin recently traumatized until circulation improves, as noted by the resolution of contusions, edema, and infection.

Blunt-tipped Metzenbaum scissors are almost universally employed for undermining skin by alternately opening and closing the scissor blades to separate the loose areolar connective tissue. Dense fascial attachments are cut or snipped. A scalpel blade is best reserved for undermining skin adhered to the underlying fascia by dense scar tissue. This situation is most commonly seen in a 1 or 2 cm border of skin around chronic granulation beds.

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Plate 17



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Plate 18 Geometric Patterns to Facilitate Wound Closure

DESCRIPTION

Cutaneous wounds of an irregular shape can be converted to a simpler geometric pattern to facilitate wound closure. Similarly, a cutaneous lesion can be excised by selecting a geometric pattern that best conforms to its shape.

SURGICAL TECHNIQUE

(A) Triangular closure resulting in a Y-shaped scar.
(B) Rectangular closure resulting in an X-shaped scar.
(C) Elliptical closure resulting in a linear scar.
(D) Crescent closure resulting in a U-shaped scar.
(E) Circular excision resulting in a linear scar; dog ears may be noted. Large dog ears can be excised (see Chapter 21).

COMMENTS

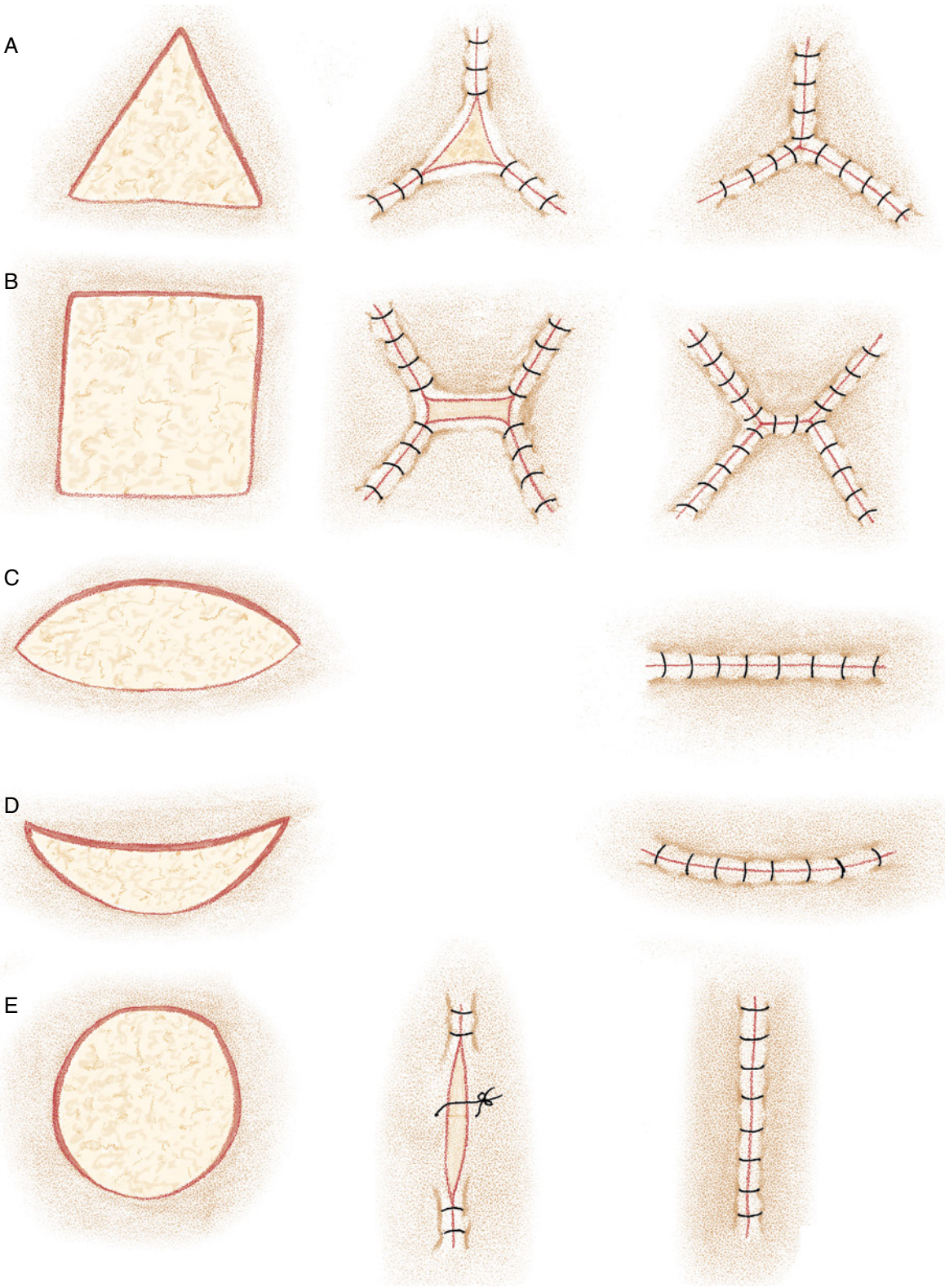
The surgeon should not rely solely on the use of simple geometric designs as the preferred method of wound closure. There are many circumstances where skin flaps may be more reliable for closure of the skin defect. Regional skin laxity or elasticity dictates, to a considerable degree, the method(s) of closure. (See Plate 32.)

It generally is preferable to close wounds in a linear or curvilinear fashion, since wound dehiscence is most likely to occur when two incisions intersect (X or Y closures). The point of intersection is a common location for incisional separation due to the difficulty in accurately suturing this area and the increased susceptibility to additional distracting forces.

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Plate 18



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Plate 19

V–Y-Plasty

DESCRIPTION

V–Y advancement is a lengthening procedure occasionally used to relieve minor tension to a limited area. Conversely, Y–V closure can be used to increase local skin tension. Both techniques are used to alter tension to a narrow band of skin where minor tension modification is desirable.

SURGICAL TECHNIQUE

(A) A V incision is made no closer than 3 cm from the skin incision (as a general guideline). The edges are carefully undermined, if necessary. The arrow indicates the direction of skin advancement.

(B) Closure of the outer incision edges beginning at the tip of the V incision pushes the inner triangular skin flap forward to reduce tension within the plane of the incision.

(C) A Y configuration is created with advancement of the triangular flap.

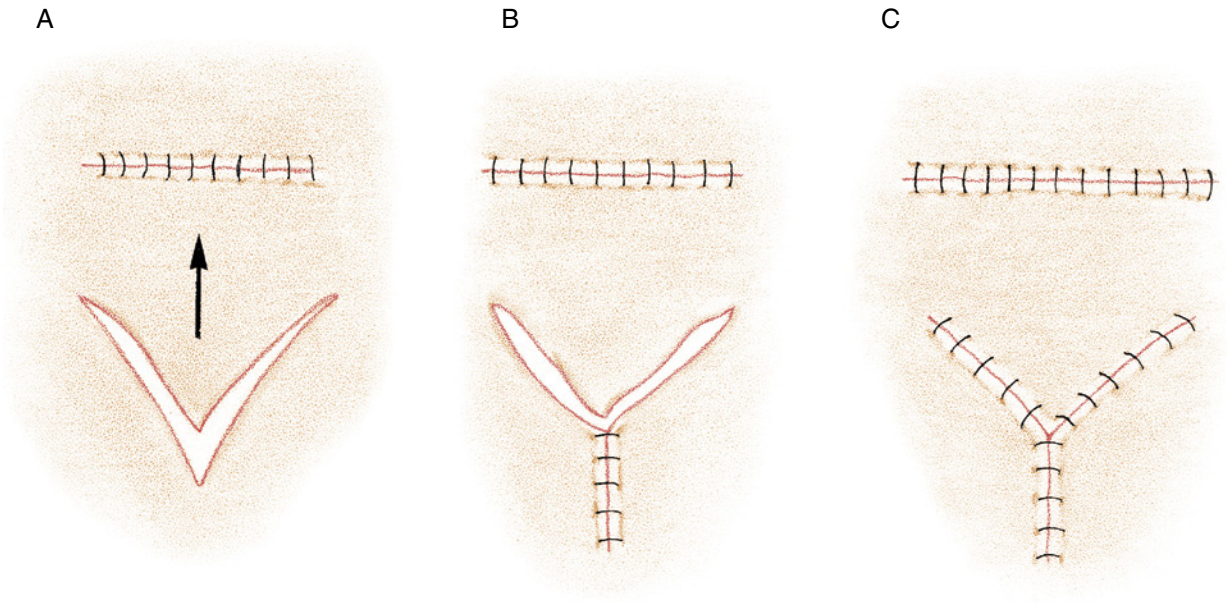
COMMENTS

V–Y-plasty is marginally effective in relieving skin tension; it cannot dramatically reduce tension over a wide area. It may be most effective for minor tension adjustments, especially in eyelid surgery. It is a very simple technique to execute.

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Plate 19



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Plate 20

Z-Plasty (Option I)

DESCRIPTION

Z-plasty is used to (1) alter skin tension adjacent to an incision, (2) lengthen restrictive scars, and (3) change the direction of a linear scar into a less discernible pattern. In the latter case, the human eye has greater difficulty following a zigzag design compared to a linear scar, especially one that crosses a natural skin line or fold in a relatively hairless area. As a result, Z-plasty can change the position of the scar into a less conspicuous skin fold or line. The conventional Z-plasty technique involves forming two equilateral triangles. Each limb and the central member of the Z incision are equal in length; each limb extends at a 60° angle from the central member. Theoretically, the net length gained along the restrictive skin zone is approximately 75%.

SURGICAL TECHNIQUE

(A) Illustrating the theoretical gain associated with Z-plasty. The theoretical gain in length is the difference in length between the long diagonal and the short diagonal. AB − CD = net gain. (In practice, the actual gain is less than the theoretical gain.)

(B) A "Z" is drawn onto the skin. Each limb of the Z and the central member are equal in length. Each limb is drawn at a 60° angle to the central member. The Z design is positioned so that the central member overlies the restrictive scar (shaded area). The thin scar band is normally excised.

(C-E) Each triangular flap (I and II) is undermined and rotated into the opposing donor beds. The tip of each flap can be trimmed (rounded) to preclude the occasional necrosis noted in this area. Lastly, the individual flaps are sutured into place.

COMMENTS

Most Z-plasty procedures are used to increase the length of a skin area, thereby improving mobility. Lengthening restrictive scar bands or zones of tension perpendicular to a sutured incision under excessive tension is the most common use in veterinary medicine. Z-plasty actually is the simultaneous transposition of two equilateral triangular local flaps. As each flap is transposed, additional skin is placed in the previously restricted zone from the immediate area. The resultant scar also is more pliable than the previous linear scar. One or two standard transposition flaps actually may be more capable of lengthening more diffuse restrictive scars.

Z-plasty is somewhat confusing to clinicians unfamiliar with its design and execution. Practicing Z-plasty designs on thin sheets of elastic cloth or foam rubber is the best way to understand this procedure before attempting its use in a clinical situation.

Human reconstructive surgery textbooks demonstrate multiple variations in this standard Z-plasty technique. However, in veterinary surgery the basic equilateral triangle design employing 60° angles is sufficient for most situations where Z-plasty is indicated. Although the creation of wider-angle flaps of 70° or 90° can increase the theoretical length of gain to 100% and 120%, respectively, transposing these wider flaps is more difficult, except for areas of thin, elastic skin.

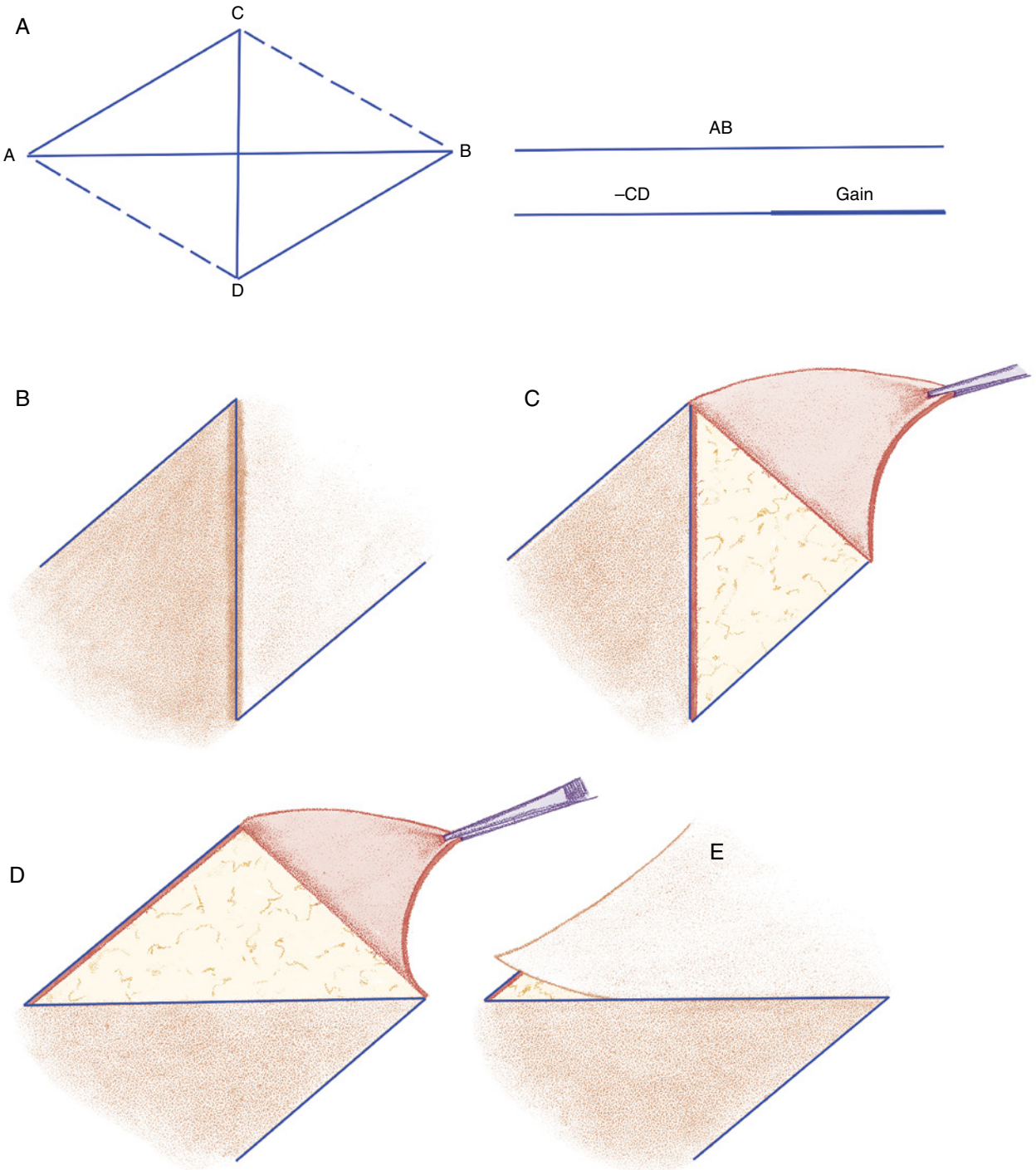
Experimental studies in dogs have indicated that *theoretical gains* in length, based on geometric measurements, were different from the actual gain achieved. For example, Z-plasty on the trunk of dogs has demonstrated that the actual gain of a 60° angle Z-plasty with 8 cm limbs was 28% less than theoretical measurements (a 45% gain as opposed to 73%). As the limb length decreased, the percentage of gain decreased. A Z-plasty with 1 cm limbs had 45% less gain than calculated (73% gain, less 45%, equals a total gain of 28%).

For Z-plasty to work properly, the skin in the base of the flaps created must be loose and elastic enough to rotate and stretch into its new position. If skin is under tension perpendicular to the central member of the Z, it may be impossible to transpose these flaps.

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Plate 20



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Plate 21

Z-Plasty (Option II)

DESCRIPTION

Z-plasty can be used to reduce tension on wound closures otherwise difficult or impossible to close in a given area.

SURGICAL TECHNIQUE

(A) The 60° angle Z-plasty is drawn onto the skin, with the central member of the Z parallel and overlying the line of greatest tension (arrows). It is desirable to create the Z incision no closer than approximately 3 cm from the primary incision. Each triangular flap is gently undermined.

(B) As the primary incision is sutured closed, each flap will begin to transpose into its appropriate position.

(C) On completion of the closure of the incision, the Z-plasty incisions are sutured to complete the procedure. The tips of each flap can be trimmed (rounded) to preclude the occasional necrosis noted in this area.

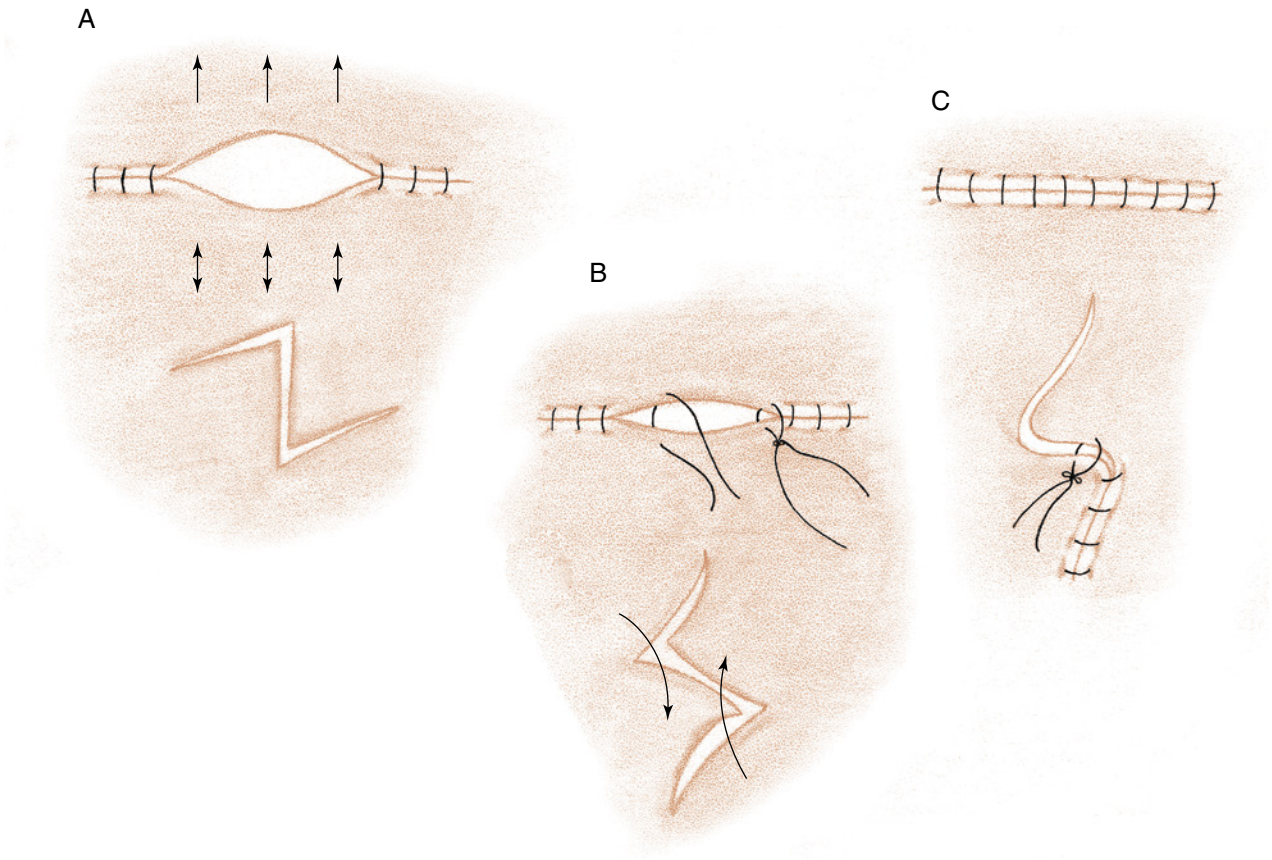
COMMENTS

See Plate 20. Placement of the Z-plasty incision must take into consideration regional blood supply, especially major direct cutaneous arteries.

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Plate 21



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Plate 22

Multiple Z-Plasties

DESCRIPTION

Multiple small Z-plasties have been advocated for use in those areas where insufficient skin is present for using a single large Z-plasty procedure. Multiple small Z-plasties have a cumulative effect in lengthening restrictive areas.

SURGICAL TECHNIQUE

(A) Small 60° angle Z-plasties are created using the design illustrated.

(B) Paired flaps are individually elevated beginning at one end of the incision, transposed, and sutured into place.

COMMENTS

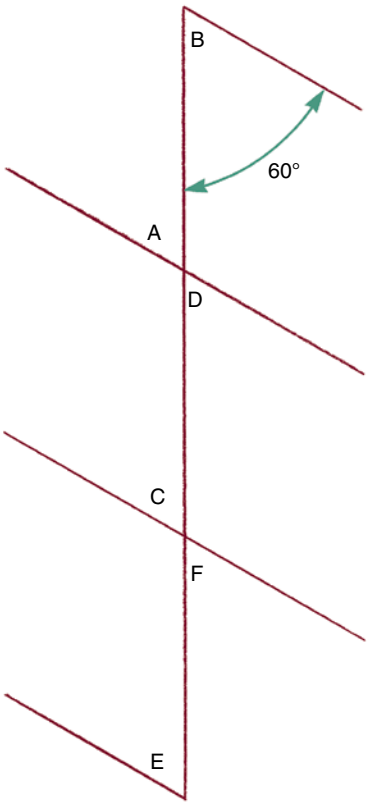
Experiments in dogs have shown that a single large 8 cm Z-plasty provides a greater gain in length compared to a series of eight 60° angle Z-plasties with 1 cm limbs (see Plate 20). However, in areas with sparse hair growth the resultant scar may be superior to one large Z-plasty.

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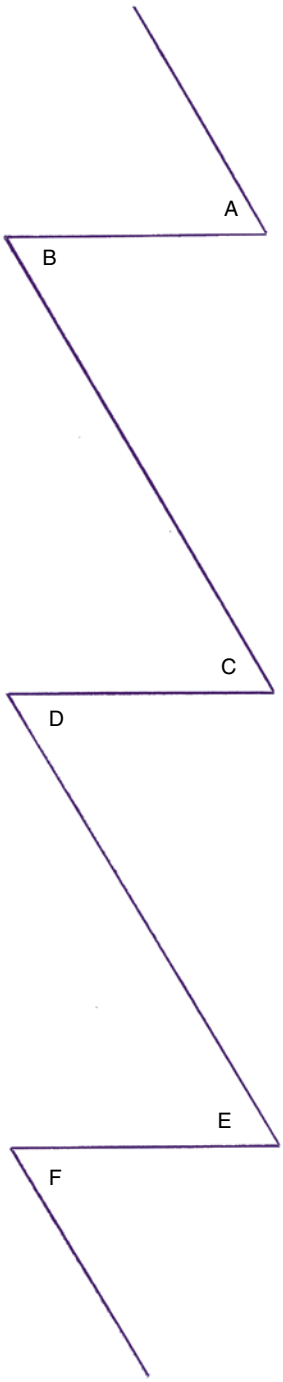
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Plate 22

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Plate 23 Relaxing/Release Incisions

DESCRIPTION

A relaxing or release incision is, by design, a skin incision created parallel to the length of a wound to facilitate closure of the primary defect. This bipedicle flap is carefully undermined and advanced over the wound. A secondary defect is created by this maneuver, which may be either closed primarily by undermining adjacent skin or left open to heal by second intention.

SURGICAL TECHNIQUE

(A) Illustration of a wound in which the line of greatest tension (perpendicular to the length of an elongated defect) is located at the widest portion of the defect.

(B) If the skin edge bordering the wound is thickened or fibrotic, it should be excised with a scalpel blade to improve marginal pliability. A skin incision is then created parallel to the primary defect in a staged fashion, beginning in the center of the zone of greatest tension. In this example, the width of the flap approximates the width of the wound. The cutaneous borders of the wound and bipedicle skin flap created can be gently undermined to facilitate their advancement.

(C) Towel clamps may be used to initially oppose wound borders. The relaxing incision is extended lengthwise in increments (dotted line in diagram B) as required to relieve tension on the remaining portion of the wound.

(D) On closure of the wound, the secondary defect can be left open to heal by second intention. If sufficient skin is available, the adjacent skin can be undermined and the secondary defect closed directly.

COMMENTS

The release incision is a simple and useful procedure to immediately decrease incisional skin tension. A second relaxing incision can be created on the opposite side of a wound if necessary. No guidelines are available to describe how close the relaxing incision should be to the wound. In practice, most relaxing incisions are created 3–10 cm from the wound border, depending on the size of the wound, the regional skin laxity, and the intended position of the secondary defect.

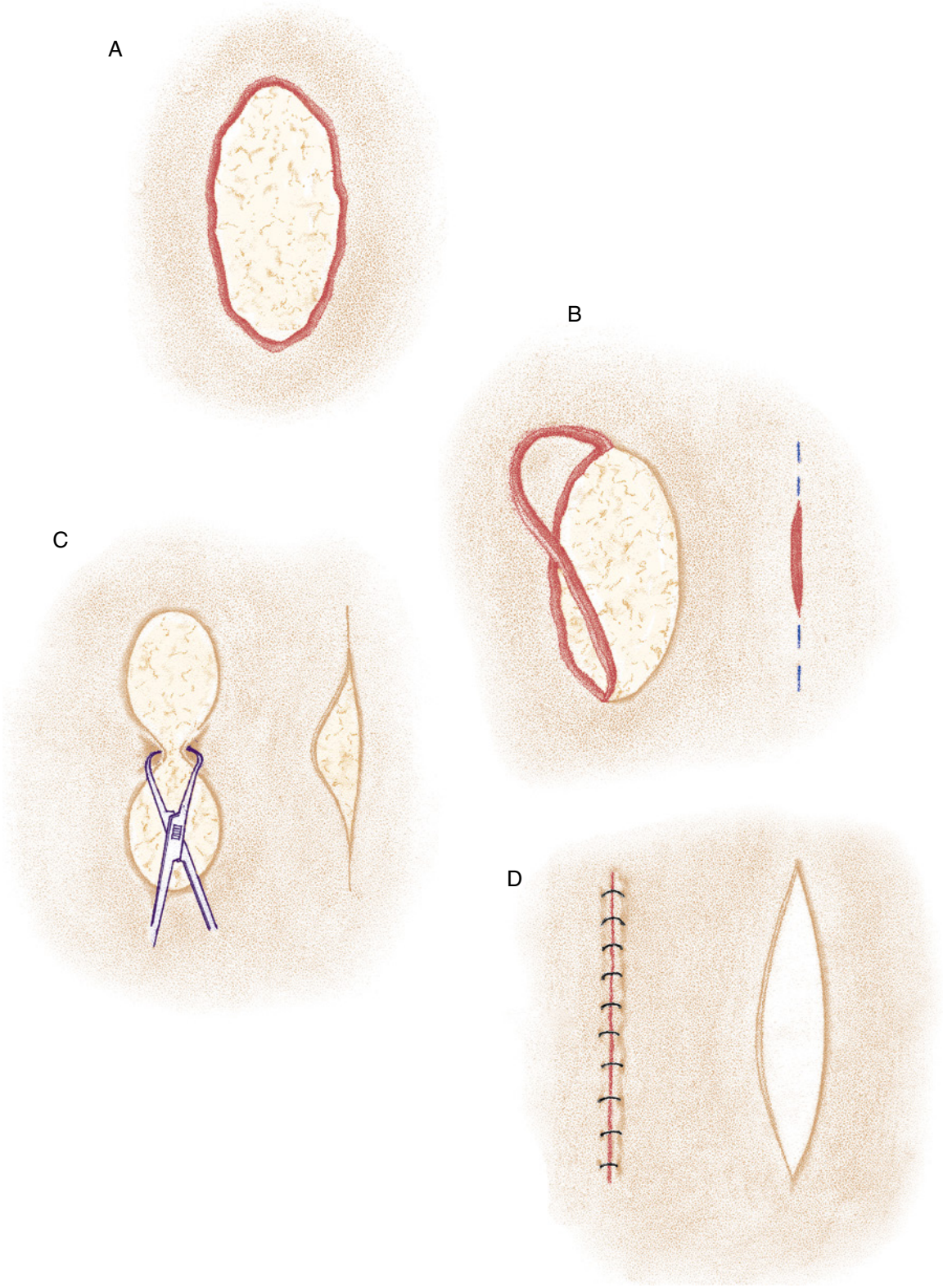
Relaxing or release incisions may seem to be a paradox: closing one defect at the expense of creating a second wound appears illogical. However, there are occasions where closure of a wound that exposes essential tendons, ligaments, nerves, and vessels justifies primary closure in exchange for a defect in a relatively unobtrusive location. Wound closure may be essential to prevent contamination and infection of surgical implants while creating a wound over a muscle surface where second-intention healing can occur more easily. Skin coverage over a bony prominence may be necessary for proper healing compared to a defect created in a "protected" region.

Other wounds susceptible to external trauma and infection can be closed primarily at the expense of creating a secondary defect in an area where an epithelialized scar is less susceptible to future injury or where such a wound would be easier to manage postoperatively. Lastly, chronic nonhealing wounds (as a result of recurrent trauma, radiation, etc.) may heal primarily by using single or paired relaxing incisions (two bipedicle advancement flaps) that have adequate circulation for healing, while creating a secondary defect in a region with sufficient circulation to heal by second intention. Most of these secondary defects, left unsutured, will heal within 3–6 weeks.

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Plate 23



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Plate 24 The "Hidden" Intradermal Release/Relaxing Incision

DESCRIPTION

The standard skin release incision is created by incising through the epidermis and dermis. If regional skin tension is not excessive, this incision can be resutured, usually by undermining the adjacent skin to offset the deficit associated with advancing the bipedicle advancement flap. The author's dermal release incision is useful for similar cases, thereby eliminating the need for resuturing a full-thickness incision.

In place of incising the skin through its surface, a no. 15 scalpel blade is used to gently incise the dermis via the hypodermis. Care is taken not to cut through the thin, overlying epidermal layer. As a result, modest skin relaxation can be obtained without the need to suture the skin, creating an additional scar.

SURGICAL TECHNIQUE

(A) The skin bordering the wound is undermined and elevated with one or more skin hooks. The area for creating the dermal release is identified (see guidelines in Plate 23). A no. 15 scalpel blade is used to incise the dermis with a few delicate strokes to avoid incising completely through the epidermis. Scalpel strokes are repeated until a dermal gap can be seen (visualization is easier in thicker skin). The dermal release incision is made no closer than 3 cm to the cut skin margin.

(B) The epidermal surface is viewed as the dermis is progressively incised. The blade can be seen tenting the epidermal surface during this process. In this illustration, the epidermal surface remains intact: traction on the skin demonstrates the dermal gap or release created (dashed lines).

(C) Completion of the incisional closure, revealing the modest tension relief achieved. Because the epidermis is preserved, no suturing is required when using this technique.

COMMENTS

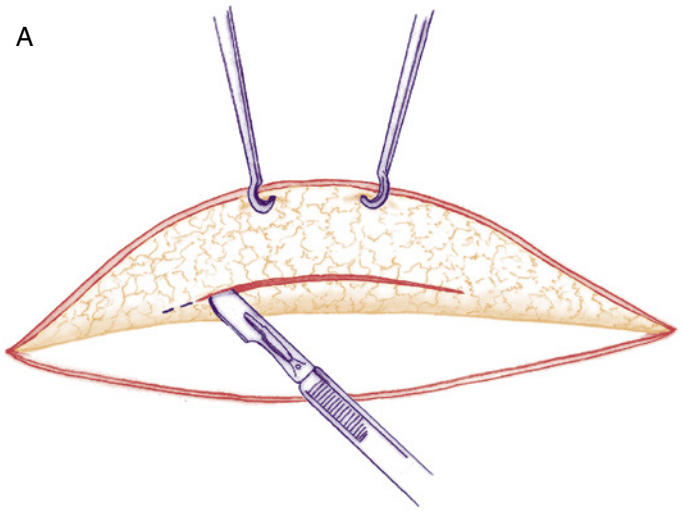
Properly executed, the "hidden" dermal release incision provides a modest gain in skin laxity. This dermal release technique does not provide the degree of skin relaxation noted when the release incision is left open to heal by second intention (see Plate 23). Yet it is a useful way to reduce tension in those cases requiring a comparatively modest reduction in wound closure tension. If the surgeon inadvertently perforates the epidermis, the area can be sutured. There are three modest advantages of this technique: no suturing is required; open wound care is not required, unlike open release incisions; and no visible scar is noted with preservation of the epidermal surface.

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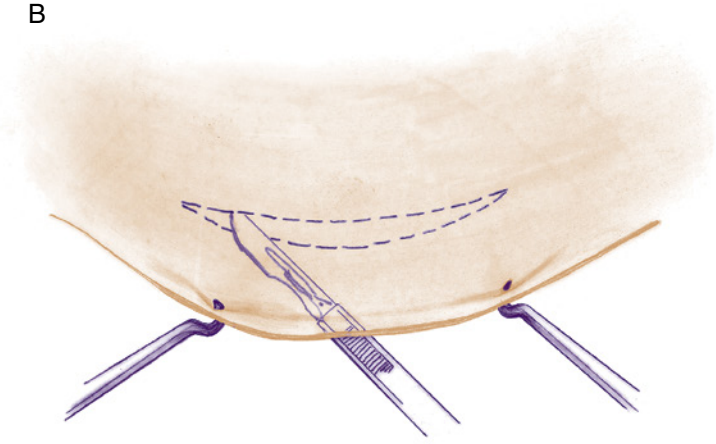
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Plate 24

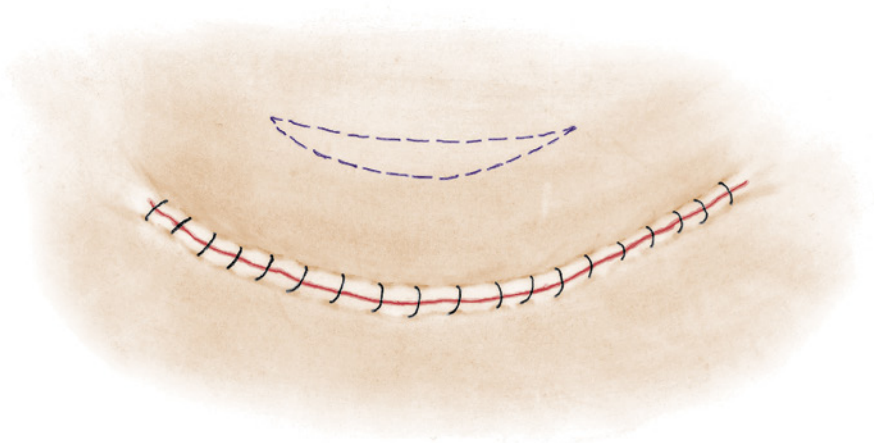
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Plate 25 Multiple Release Incisions for Extremity Wounds

DESCRIPTION

Multiple relaxing incisions have been described for closing wounds involving the lower extremities. Multiple small stab incisions can be placed parallel to the long axis of the wound in a staggered fashion to promote skin advancement without the creation of a single, large secondary defect. The single relaxing incision, however, maximizes skin advancement, creating two bipedicle flaps and a single donor defect.

SURGICAL TECHNIQUES

Multiple Relaxing Incisions

(A) Skin sutures, stay sutures, or towel clamps are used to intermittently attempt apposition of the wound borders during the meshing procedure. Skin borders are carefully undermined.

(B) Mesh incisions are placed no closer than 1 cm from the skin edge. In general, they are approximately 1 cm long and no closer than 1 cm apart. If additional rows are required, holes are made approximately 1–2 cm from the initial row in a staggered fashion. A greater number of holes are usually required at the widest area of the defect under greater tension. When sufficient tension has been relieved, the skin borders are sutured. A medicated nonadherent dressing is applied to the wound before the limb is immobilized in a bandage or splint.

Single Relaxing Incision

(C) In this example, illustrating a nonhealing wound involving the forelimb, a relaxing incision is made along the caudal aspect of the limb. The arrows indicate the direction of skin advancement.

(D) The interposing skin is undermined and the two bipedicle flaps are advanced over the prepared wound bed and sutured together. The solitary defect created on the caudal aspect of the limb (dotted line) generally is managed as an open wound to promote wound contraction and epithelialization.

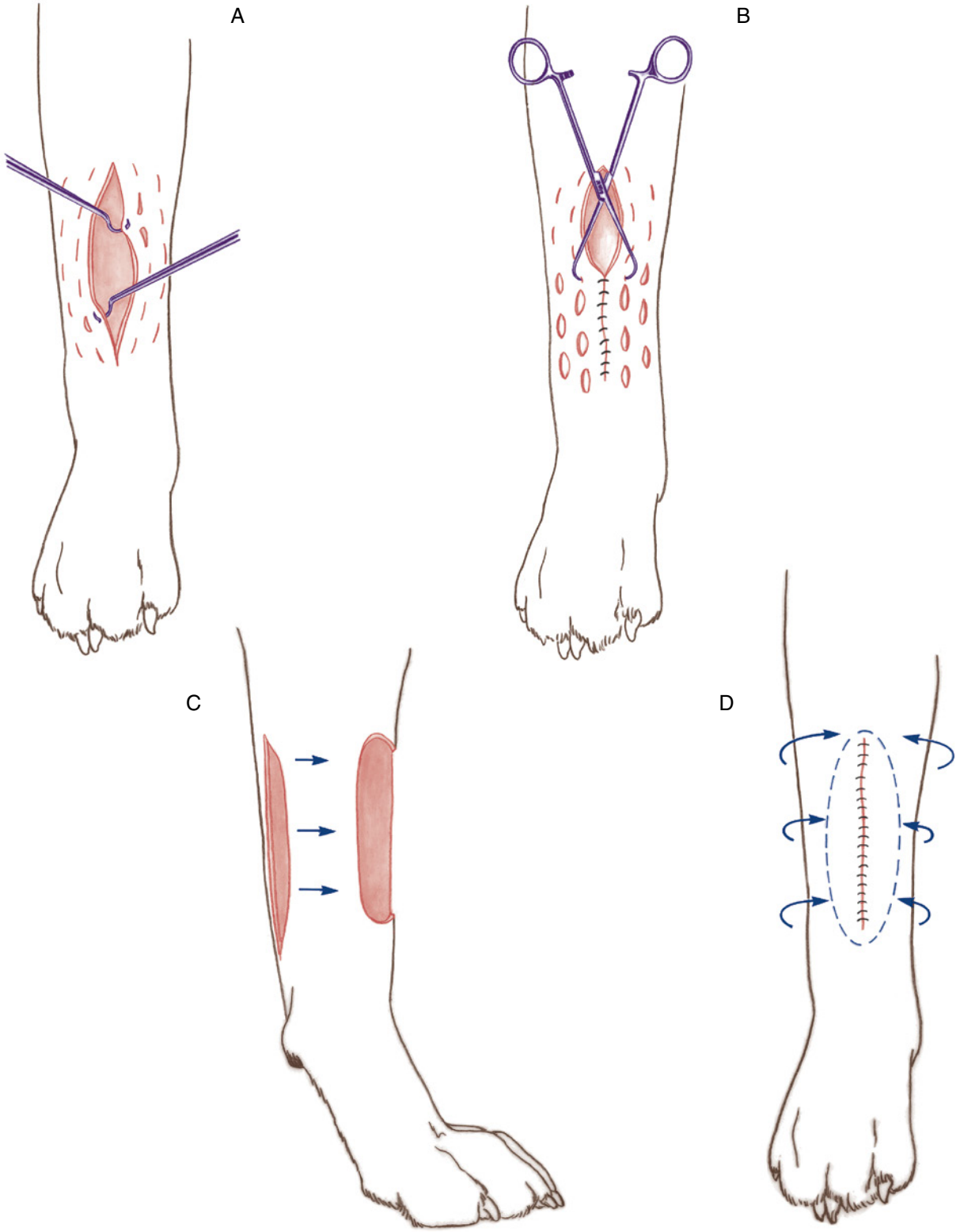
COMMENTS

Although multiple incisions have been used clinically, there is a significant risk of circulatory compromise to the incised skin by accidental division of direct cutaneous vessels and impairment of the cutaneous microcirculation traveling parallel in the skin. A wider dispersion of the multiple incisions would be preferable to minimize this risk, although the gain in tension relief would be less. A single, long relaxing incision generally provides maximum tension relief compared to multiple, small release incisions, and it may be less likely to cause major circulatory compromise to the skin adjacent to the defect.

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Plate 25



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Plate 26

Suture Options to Alter Skin Traction and Retraction

DESCRIPTION

Buried sutures can be used to (1) help advance skin under tension or (2) neutralize the elastic retraction of skin under tension. Two common examples are illustrated.

SURGICAL TECHNIQUE

(A) "Offset suture" placement can be useful in advancing skin, under tension, over a surgical defect. The suture needle grasps the underlying fascial surface *ahead* (closest to the defect) of its subsequent placement in the adjacent dermis. When each suture is tied, the skin creeps forward and is held in position. This technique is effectively adapted to advancing labial mucosa along the gingival margin for closing more rostral oral/labial defects. (When used over a wide surface area they would be collectively called walking sutures; see Plate 27).

(B1) In this example a single-pedicle advancement flap is advanced under tension to close a rectangular defect. If used to close a skin defect overlying the eyelid, postoperative elastic retraction could impair eyelid position and function.

(B2) In this case two sutures are placed through the skin and into the underlying fascia to secure its position. Alternatively they can be placed as buried intradermal sutures and secured to the underlying tissue fascia. Both options can help neutralize retraction of the flap's collagen and elastin fibers. This simple technique also can be adapted to simple advancement of skin margins.

COMMENTS

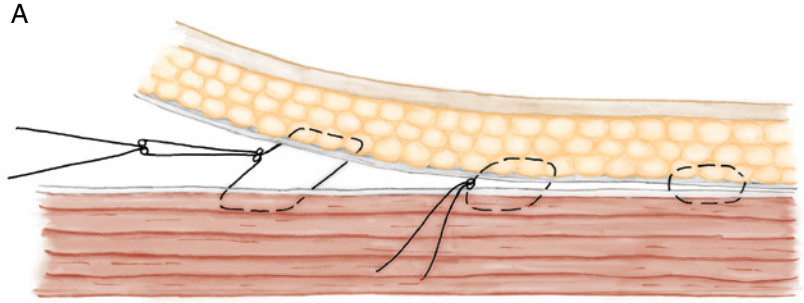
Offset sutures pull the skin or mucosal margins forward incrementally. Alternatively, buried dermal sutures, secured to the underlying fascia, can be used to halt elastic retraction of the skin. This latter application is most effective for closing cutaneous defects involving the eyelid. Alternatively, transposition flaps are effectively used to close larger cutaneous wounds of the eyelids, avoiding the potential issue of elastic retraction associated with advancement flaps or simple skin margin advancement (see Chapter 19).

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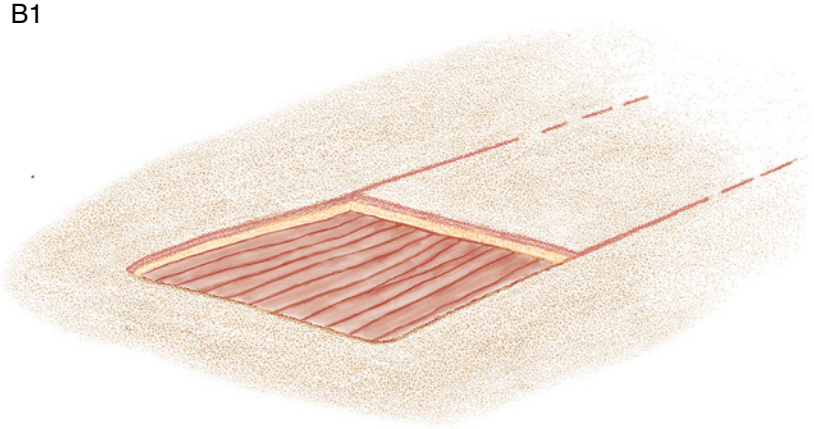
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Plate 26

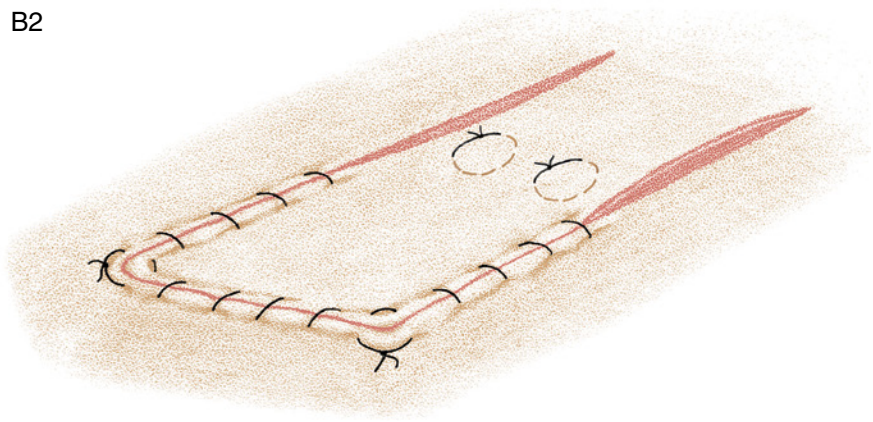
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B1



B2



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Plate 27

Walking Suture Technique

DESCRIPTION

The walking suture technique, popularized by S.F. Swaim, is a method of distributing tension sutures over a wide surface area when skin undermining and suture closure techniques alone are insufficient for wound apposition. Individual "walking" sutures pull the skin toward the defect in small increments. Multiple sutures have a cumulative effect in maintaining the undermined skin in position as it is advanced to the center of the defect.

SURGICAL TECHNIQUE

(A) 2-0 or 3-0 absorbable suture material is usually selected. Suturing begins at the distant limits of the undermined skin. The skin is elevated as the needle is inserted into the dermis. Sutures may pass through portions of the panniculus muscle to gain access to the dermis.

(B) The needle is then inserted into the underlying muscle fascia, generally 2 or 3 cm closer to the midpoint of the wound. Deep placement of the needle into connective tissue is necessary when suture material is placed into a granulation bed in order to prevent suture pull-out.

(C) Walking sutures are no closer than 2 or 3 cm apart. After the "deep" row of sutures is tied, a second series of walking sutures is staggered with the first row.

(D) The skin on the opposite side of the wound can be advanced or "walked" in similar fashion.

(E) Completion of the wound closure. Note the skin depressions or dimples created from this buried suture pattern. A bandage can be used to control dead space with or without evacuation drains.

COMMENTS

Walking sutures are a simple and effective method to stretch skin over a wide defect and anchor the skin into position as gains in skin advancement are made. However, not all wide defects require the use of walking sutures.

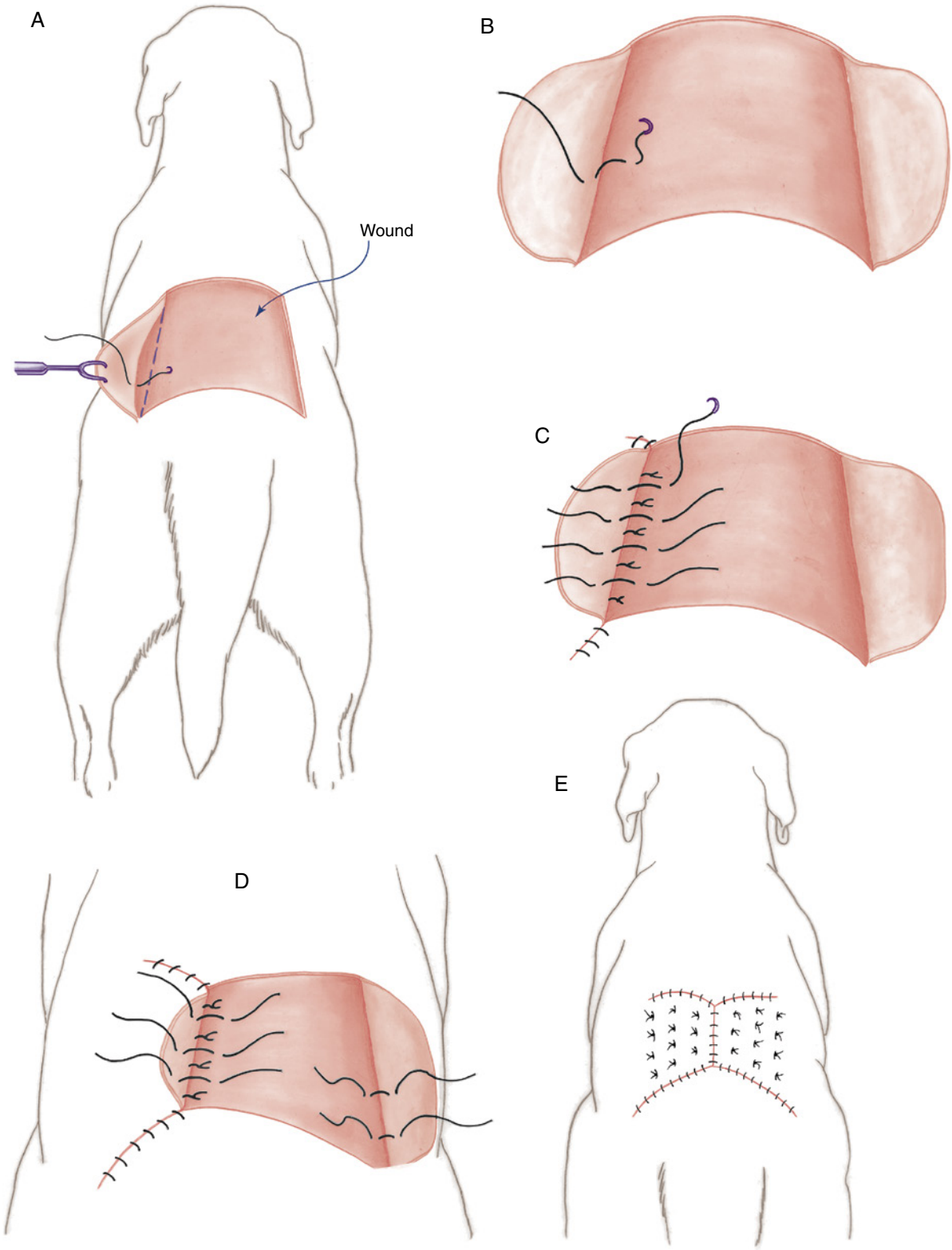
Skin dimples or indentations are noted over the location of walking sutures. These disappear in time with absorbable suture materials. The two greatest concerns voiced with the use of walking sutures are the potential for circulatory compromise to direct cutaneous vessels and the subdermal plexus; and the potential for formation of separate seromas or abscesses that would be difficult to drain separately. Careful placement of sutures and avoiding excessive numbers of walking sutures can minimize circulatory compromise. Clinical results to date have shown that multiple fluid pockets are not a major postoperative complication.

Skin stretchers (Pavletic) may be used to prestretch the skin alone or in conjunction with walking sutures, in order to facilitate skin advancement. Skin stretching also may be used to promote wound closure without the use of walking sutures (see Plates 36, 37, and 38).

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Plate 27



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Plate 28 Skin Stretchers to Offset Incisional Tension

DESCRIPTION

Skin stretchers (Pavletic) can be used to offset incisional tension after wound closure. Skin pads, positioned on opposing sides of the incisional segment under tension, are connected with a segment of elastic cable. Pads may be left in position for 3–5 days, unless conditions dictate their prolonged placement.

SURGICAL TECHNIQUE

(A) A large flank laceration has been prepared for debridement and surgical closure. The skin has been clipped liberally in preparation for skin-stretcher pad application.

(B, C) Closure was accomplished using an absorbable intradermal suture pattern followed by alternating simple interrupted and vertical mattress skin sutures. Drains may be advisable to help prevent seroma formation.

(D) Skin pads are secured approximately 5 cm from the incision (see Plate 35) using cyanoacrylate adhesive.

COMMENTS

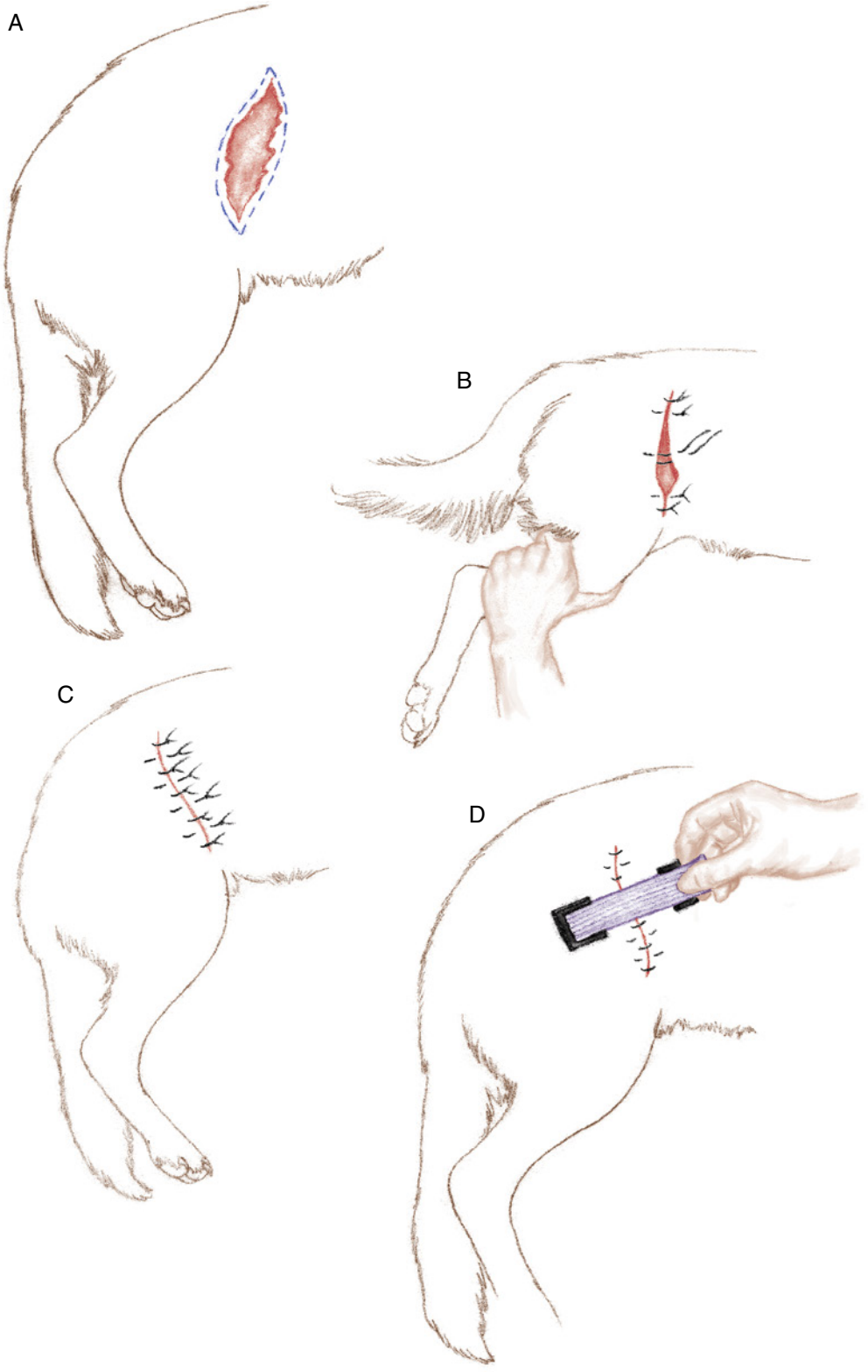
Skin pads have a large "footprint" of surface area contact with the skin, compared to retention sutures (Plate 30). Pad size can be adjusted according to the location of the wound, size of the patient, and degree of adherence required. Larger pads naturally have a larger surface area, thereby facilitating adherence to the skin when elastic (tension) cables are applied.

Because of the large surface area of contact with the stratum corneum and the ability to place them at variable locations around the wound, skin pads are capable of recruiting a larger area of elastic skin to offset incisional tension. The use of this device can accelerate mechanical creep and stress relaxation, often within hours of application, in a fashion similar to the presuturing technique (see Plate 35).

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Plate 28



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Plate 29

"Tension" Suture Patterns

DESCRIPTION

The simple interrupted suture pattern is the simplest and most common pattern used for accurate apposition of skin. Skin staples also can achieve closure rapidly and effectively. However, wounds under moderate tension may require a suture pattern that is better able to maintain tissue apposition and distribute skin tension, and that is less likely to cut through the skin edges.

Vertical mattress sutures and the "far-near-near-far" or "far-far-near-near" suture techniques are useful tension suture patterns. Because they are placed perpendicular to the incision, they cause minimal circulatory compromise, unlike the horizontal mattress suture, which has greater potential for impairing local cutaneous blood flow. Vertical mattress sutures may be used alone or alternated with simple interrupted skin sutures. This combines the tension-reducing capacity of the mattress suture with the cosmetic advantages of the simple interrupted pattern, which more accurately aligns the skin borders directly.

Intradermal sutures may also reduce tension along a suture line and accurately appose the skin. Intradermal sutures can be followed by simple interrupted sutures for added security.

Towel clamps are quite useful for apposing skin edges under tension, while allowing the surgeon to tie sutures. The two-point contact of towel clamps causes minimal trauma.

SURGICAL TECHNIQUE

(A) The continuous intradermal suture pattern is placed in the deep dermal surface.
(B) The interrupted intradermal suture pattern is placed in the deep dermal surface.
(C) The vertical mattress suture pattern.
(D) The horizontal mattress suture pattern. In this example, the suture is placed through short segments of soft rubber tubing stents (see also Plate 31).
(E) The "far-far-near-near" suture pattern.
(F) The "far-near-near-far" suture pattern.

COMMENTS

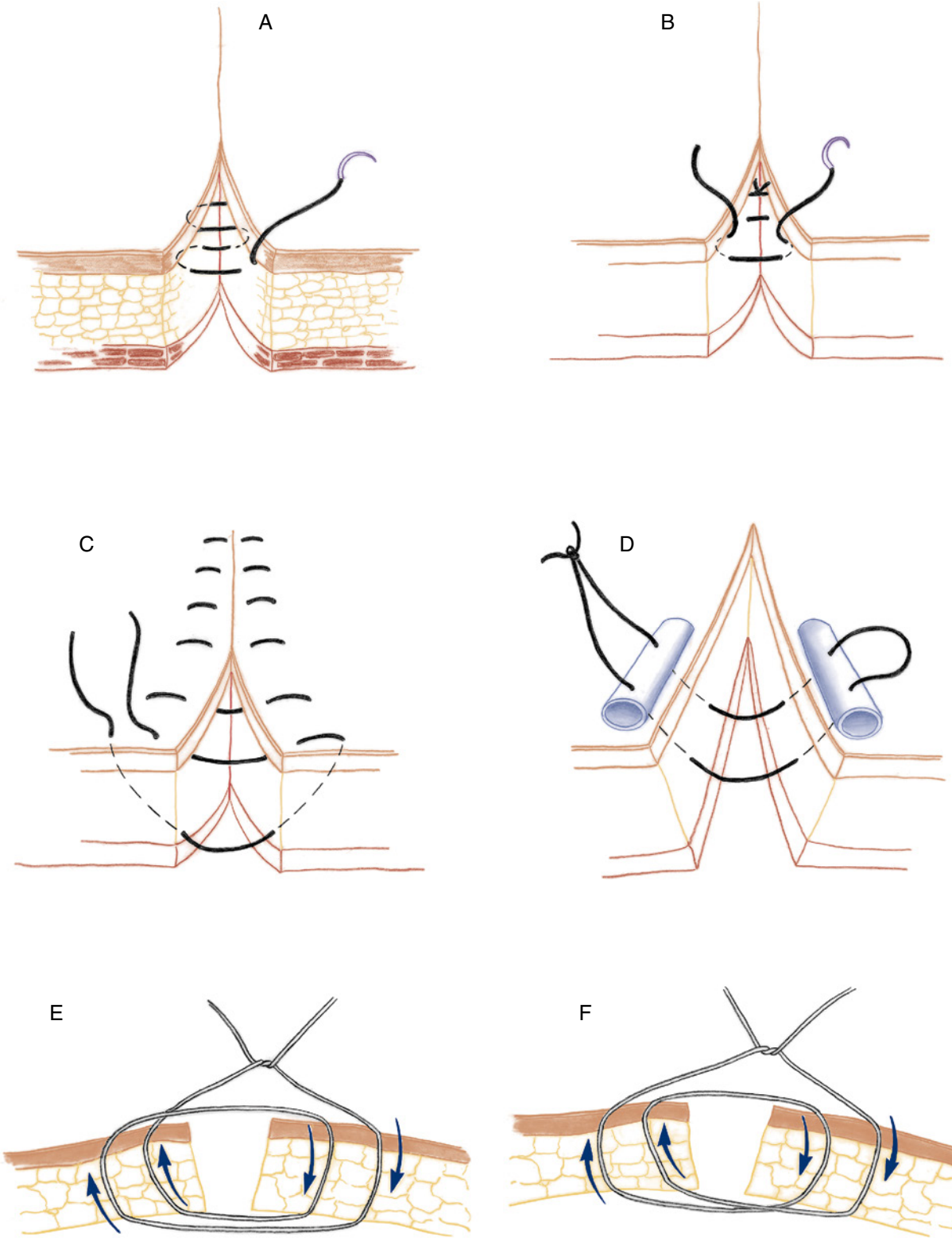
Reverse cutting needles should be used to reduce the likelihood of sutures "cutting out." Taper-point needles generally are more difficult to pass through skin, but produce a circular hole that is more resistant to this problem. Because of increased collagenase activity within 5 mm of the wound border, sutures are better placed outside this zone to reduce the risk of dehiscence. Keeping the skin clean and dry will help prevent tissue maceration that may promote dehiscence from suture cut-out.

Selection of suture material for skin closure is largely a matter of personal preference. Absorbable suture material is commonly used for intradermal patterns (3-0 or 4-0), whereas monofilament or braided nonabsorbable materials are employed for skin closure (2-0 or 3-0). The author's preference for skin sutures is swaged-on monofilament nylon or polypropylene because of its strength, elasticity, and low coefficient of friction. Size 2-0 is occasionally used in the thicker skin over the back of the dog, whereas size 3-0 is used for most other wounds. Small-diameter materials enable the surgeon to place higher numbers of sutures. However, finer suture materials (4-0, 5-0) are used only for cosmetic closure where there is an absence of skin tension. Thin, delicate skin areas also may benefit from the use of 4-0 or 5-0 suture closure. Cotton bandages can help to protect the wounds and limit motion. Areas subject to motion (joint surfaces) also may benefit from additional external support to reduce the possibility of separation of apposed wound borders.

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Plate 29



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Plate 30

Retention Sutures

DESCRIPTION

Retention, stay, or echelon sutures provide a secondary suture line at a distance from the primary closure to relieve excessive tension on the healing wound and prevent cutaneous dehiscence. In small animal surgery, soft rubber tubing, Penrose drains, and buttons have been incorporated into the retention suture pattern as bolsters to prevent sutures from cutting into the skin under stress. Suture materials are usually 00 to 0 diameter.

SURGICAL TECHNIQUE

(A) Vertical mattress retention sutures (echelon pattern) placed around a length of Penrose drain (Penrose drain stents).

(B) Large, interrupted, retention sutures with skin bolsters or bumpers to prevent cutting into the skin. (*Note*: in cases in which the patient is obese and prone to abdominal dehiscence after laparotomy, retention sutures may be incorporated through all layers of the abdominal wall or deep fascial layers prior to standard closure of the laparotomy incision; see also Plate 31).

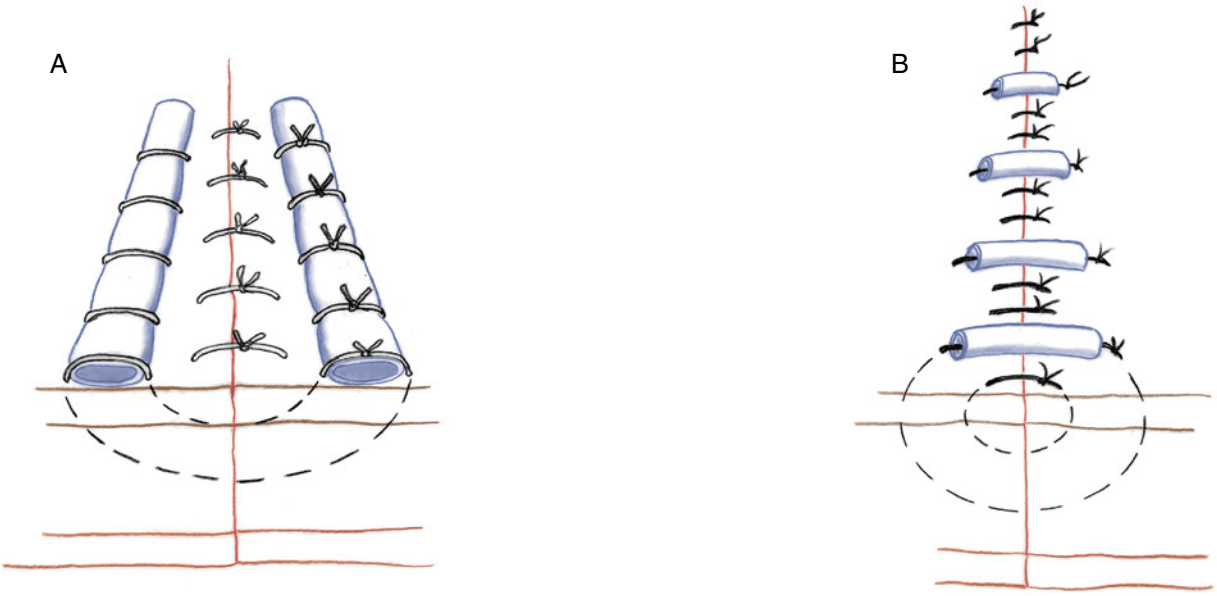
COMMENTS

Retention sutures are not routinely required except for wounds under moderate tension. They can be employed in the primary closure or set back from the incision line as secondary support. When used alone they are usually removed 3 or 5 days later as swelling and skin tension decrease. Retention sutures can be left in for a longer period of time, if warranted. A continuous line of firm tubing connected with a series of mattress sutures should be used with caution, especially when a firm bandage is applied over the entire closure. In this situation, bandage materials may compress the tubing into the skin, compromising cutaneous circulation from the drain to the incision. It may be better to use soft tubing or multiple short segments of soft tubing to avoid this situation. A noninvasive alternative consideration would be skin stretchers (see Plate 28).

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Plate 30



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Plate 31 Stent

DESCRIPTION

A stent, by definition, is any material used to hold tissue in place, control dead space, or provide support to a wound after closure. The most common wound stent in veterinary medicine employs rolls of soft cotton gauze that are secured over a closure site.

SURGICAL TECHNIQUE

(A) After wound closure, soft sterilized rolls of self-adherent gauze are laid over the wound. There are three common options to secure the gauze roll over the wound, as described here.

(B) Through-and-through retention sutures, incorporating all tissue closure layers, can be tied over the gauze rolls.

(C) Suture loops or eyelets can be placed 3–4 cm from the incision: suture material or umbilical tape is placed through opposing loops in a "shoelace" fashion. Loops are sufficiently large (10–15 mm diameter) to facilitate passage of the umbilical tape or suture material.

(D) A continuous zigzag pattern is commonly used to secure the stent into position.

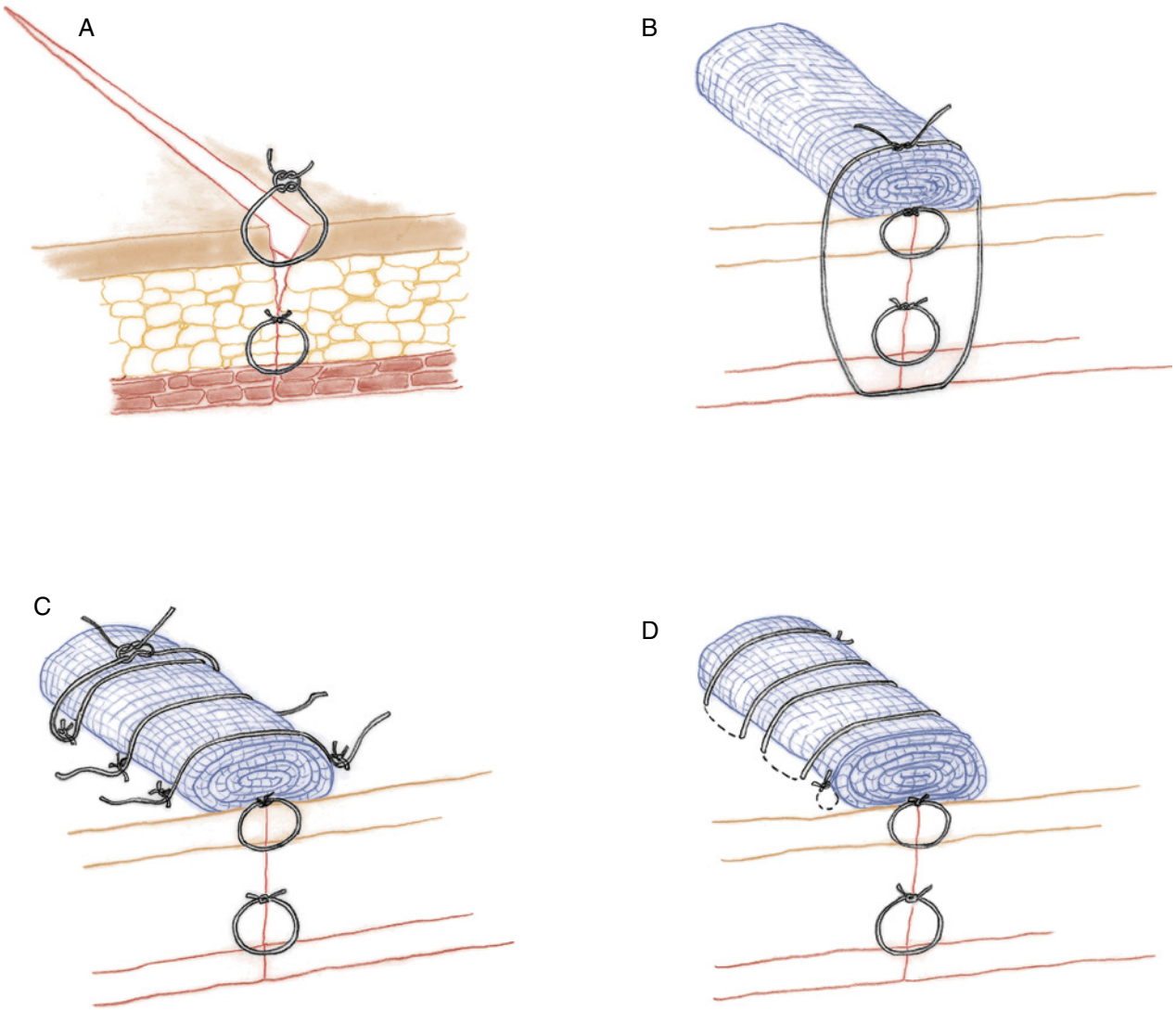
COMMENTS

Wound stents are more commonly employed in large animal surgery to protect wounds from environmental contamination and external trauma. They are not routinely used in small animal surgery. Soft gauze rolls have the potential to promote incisional infection unless they are kept dry and unsoiled. Of the two most common suture techniques used to secure stents, technique (C) gives the surgeon easier access to the gauze rolls for replacement, should contamination occur.

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Plate 31



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Plate 32 Skin "Directing" for Maximum Coverage

DESCRIPTION

When attempting closure of large irregular wounds, skin tension is manually assessed to determine areas where loose, elastic skin can be undermined and advanced over the defect. Smaller areas of the wound may be easily undermined and closed directly by taking advantage of the loose skin available. However, simple closure maneuvers may limit the ability to maximize use of the elastic skin to cover major (or more important) portions of the defect.

The loose skin available for wound coverage is determined by lifting the skin surrounding the wound and pushing the loose elastic skin border toward the central area of the major defect. This will better determine how to "direct" surrounding skin for maximum coverage.

When the surgeon has an estimation of whether undermining alone can achieve optimal wound coverage, it must be determined whether a skin flap employing the elastic donor area(s) would afford better wound coverage over undermining alone, such as that achievable with axial pattern flaps.

SURGICAL TECHNIQUE

(A) This is a clinical example of a skin wound as a result of an automobile accident. No flap design was determined to give better wound coverage than undermining.

(B) The temptation to initially suture the smaller area closed was rejected, since this maneuver would have restricted advancement of the most elastic skin to cover the largest skin defect overlying the shoulder. The dark arrows indicate the proper direction of the skin; the hollow arrows indicate that the skin should not be directed upward in this location.

(C) Directing the most mobile skin over the largest area of the defect provides maximum wound coverage. The smaller area was easily closed by undermining the dorsal skin bordering this defect.

COMMENTS

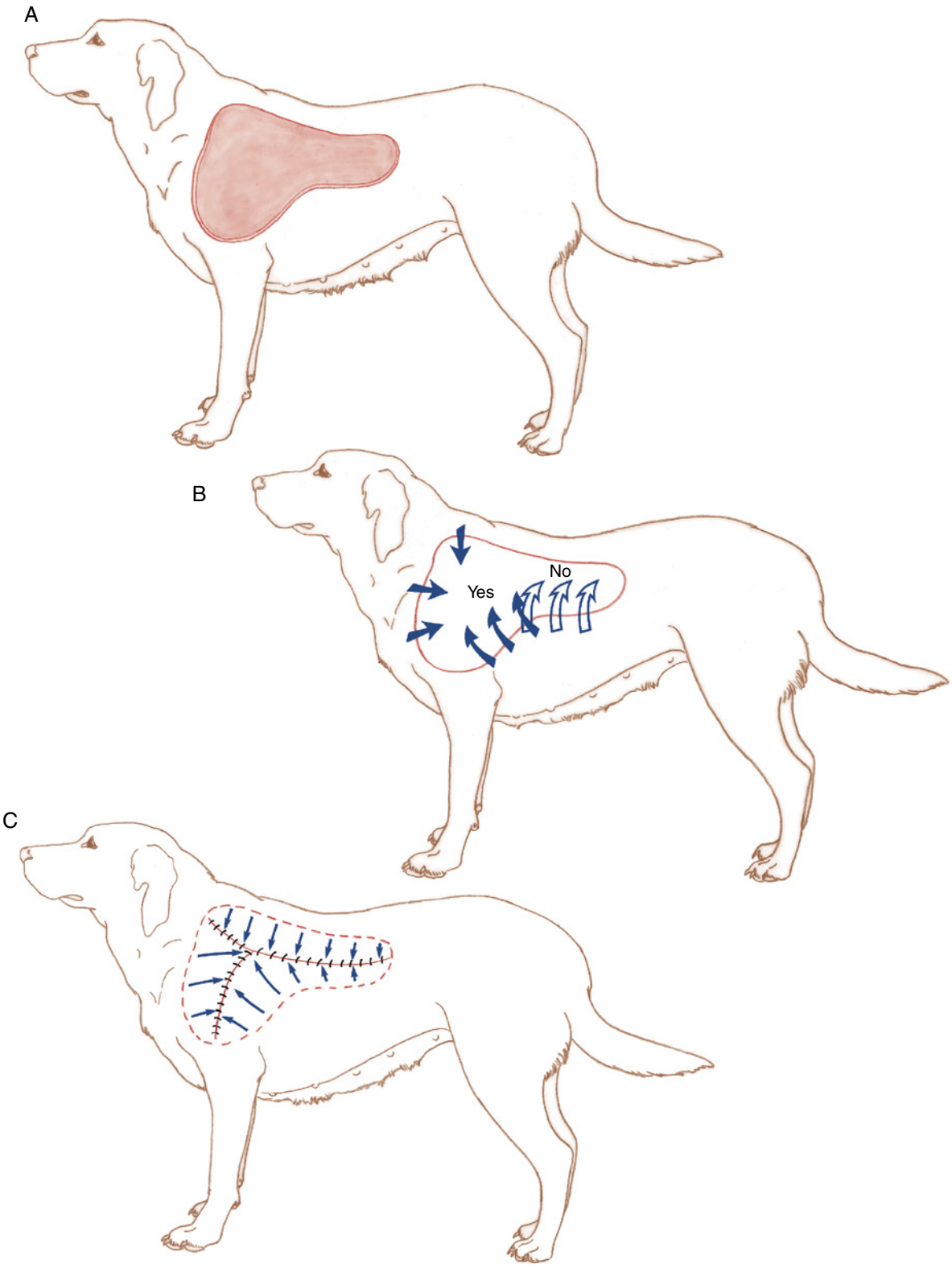
The surgeon should not rule out using a combination of closure techniques including undermining, tension-relieving techniques, skin flaps, second-intention healing, and skin grafts. Closure should be accomplished in the simplest fashion that will restore regional integrity with the least stress to the patient. Lastly, determine which technique(s) can achieve the best cosmetic results without creating additional difficulties in achieving these goals.

If a flap is considered as an option for closure, the surgeon should attempt to reduce the total surface area of the wound with simple closure techniques in order to shorten the length of the flap required for final coverage. Shorter flaps naturally have a greater likelihood to survive completely.

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Plate 32



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Plate 33

Relaxing Incision to Reduce Flap Tension

DESCRIPTION

Improperly designed flaps occasionally result in a flap that is too short to completely cover a wound. A line of tension can be noted along the length of the extended flap (line of greatest tension). A small, carefully placed stab incision can reduce tension, thereby preserving cutaneous circulation.

SURGICAL TECHNIQUE

(A) A no. 11 or no. 15 scalpel blade is used to make a small stab incision perpendicular to the line of greatest tension (located from the pivot point of the flap to its most distant edge). The resultant wound heals by second intention.

(B) A similar alternative is to incise the neighboring cutaneous surface in line with this tension band.

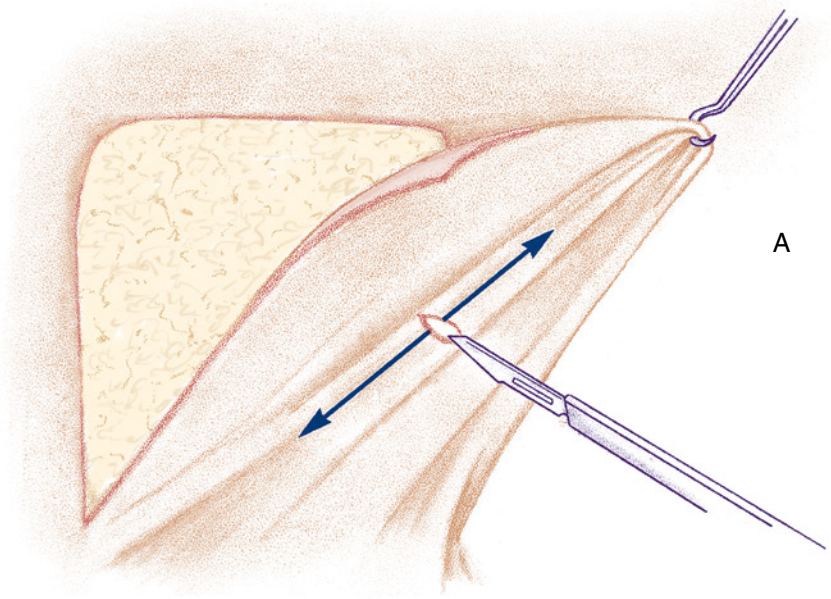
COMMENTS

Care must be taken to avoid dividing direct cutaneous vessels or creating unnecessarily long flap incisions that may compromise cutaneous vascular channels in the flap. The dermal surface of the flap can be inspected to ensure the stab incision will not divide any direct cutaneous vessels. The latter technique (B) can avoid this potential complication. V–Y- or Z-plasty could be substituted for the technique in (B).

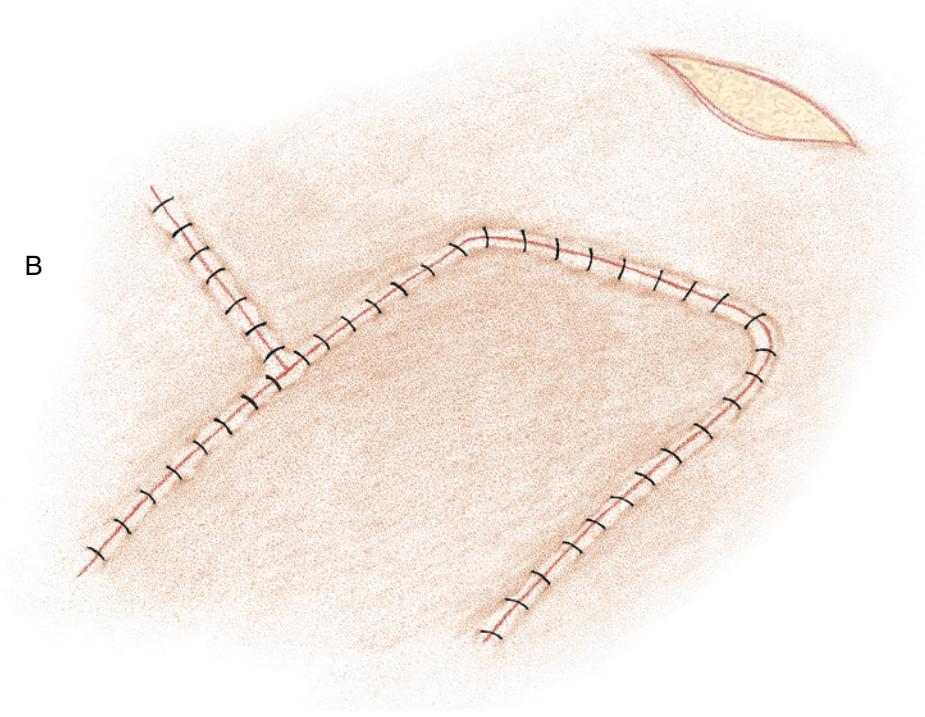
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Plate 33



A



B

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Plate 34

Foley Catheter Placement to Reduce Problematic Incisional Tension

DESCRIPTION

This is a technique that is useful on those areas where reduced incisional tension is problematic. Two clinical examples are noted in Figs 9-23 and 9-24. The Foley catheter technique distributes tension at a wider distance from the problematic incision; the paired tubes provide a glide surface to the overlying skin to facilitate approximation of the incisional margins.

SURGICAL TECHNIQUE

(A) Example of a problematic wound in the perineum. In this illustration, two pair of parallel stab incisions are created approximately 5 cm from the dorsal and ventral borders of the defect.

(B) A slide-lock, removed from an intravenous fluid line, is placed on the Foley catheter and slid up to the level of the drainage port. The Foley is then inserted through the stab incisions followed by removal of the guide wire. The balloon tip is inflated.

(C) The incision is closed using the combined techniques noted in Figure 9-20. Traction is applied to the elastic catheter to reduce incisional tension. The slide-lock is slid closed to maintain the position of the Foley catheter.

COMMENTS

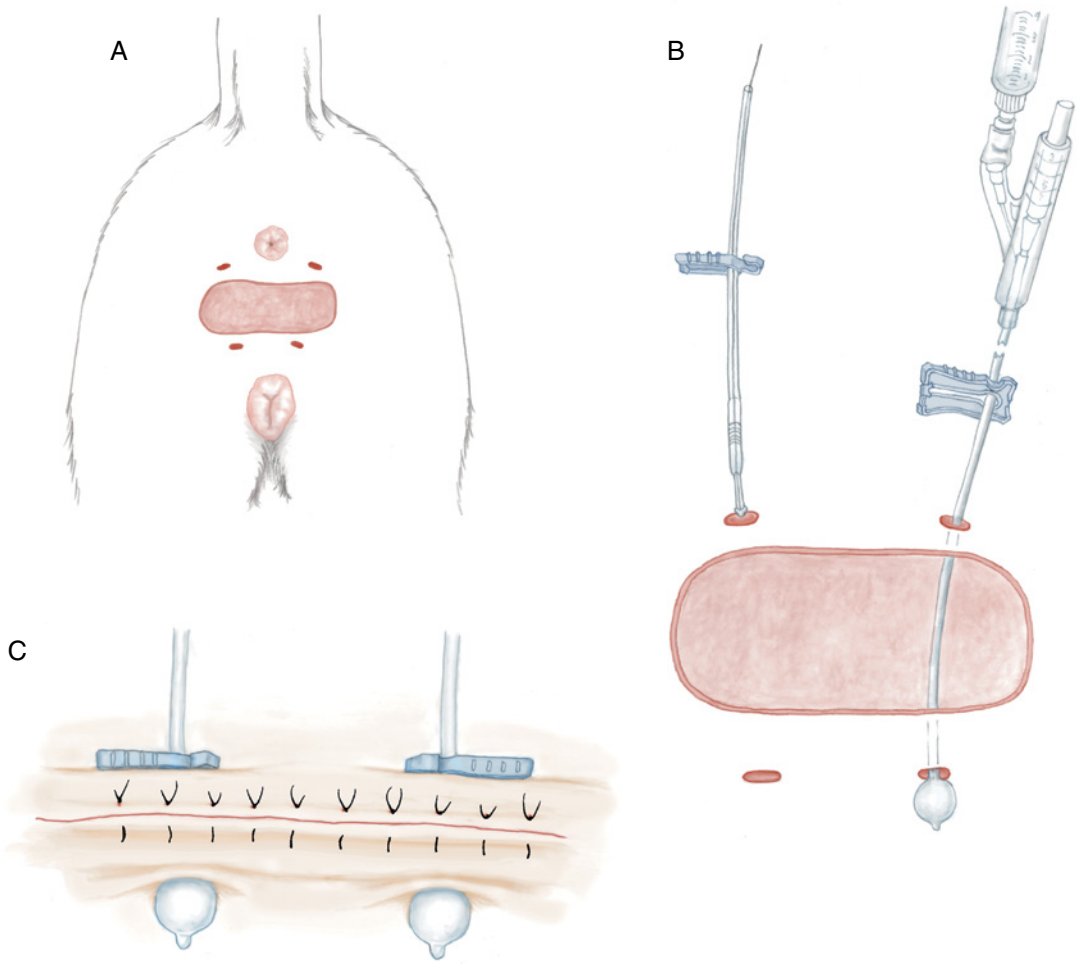
The Foley catheters can be removed in 5–7 days, depending on the individual wound. The balloon tip is deflated and the catheter is extracted. The Foley catheter incisions heal by second intention. The lower incisions will provide short-term drainage until the areas heal by second intention.

This simple tension-relieving technique is not normally required for most wounds, but can provide an effective method of reducing incisional tension in problematic wound-closure areas.

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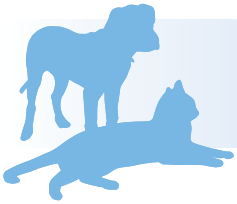
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Plate 34



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10

Skin-Stretching Techniques

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PHYSIOLOGY OF SKIN STRETCHING

Surgeons rely on the inherent elastic properties of the skin to close wounds secondary to trauma or the removal of diseased tissues. The skin's inherent elasticity can vary between species, individuals, body regions, patient age, body conformation, and pathologic conditions involving the cutaneous tissues. To minimize tension during basic wound closure, surgeons may attempt to place incisions parallel to lines of maximum tension. The undercutting of skin margins can further mobilize skin, although the combined effects of excessive undermining and wound closure under tension can result in circulatory compromise with skin necrosis.

> A remarkable degree of undermining can be performed if the regional direct cutaneous vessels are preserved. Consider the development of island arterial flaps, where a large area of skin survives tethered by a single dominant direct cutaneous artery and vein (see Chapter 13).

Skin is capable of further extension beyond its inherent elasticity from the application of a stretching or tension force over time. This phenomenon, termed *mechanical creep*, is complemented by *stress relaxation* or the progressive reduction in force required to maintain the stretched dermal collagen fibers at a given length. During this process, tissue fluid is slowly displaced from around the randomly arranged convoluted dermal collagen filaments as they progressively align and compact longitudinally in the direction of the stretching force. This increase in cutaneous length can be measured within minutes after load application: the greater the force applied to the skin, the sooner maximal extension can be achieved over time.

There are a number of natural examples of skin expansion beyond its normal estimated limits in humans and animals, including advanced pregnancy, obesity, and the expansion of large subcutaneous neoplasms. This form of cutaneous surface area enlargement is the result of *biological creep*, a slower physiologic mechanism of tissue accommodation (Fig. 10-1).

The basic concept of surgically expanding skin, described by Neumann in 1957, led to the development of the modern *tissue expander* by Radovan and Austad in the 1970s. Recruitment of skin from tissue expansion is the result of a combination of acute stretch, the recruitment of adjacent elastic skin, and true expansion as a result of the biomechanical properties of stress/relaxation previously described (Fig. 10-2).

In the literature, various devices have been used experimentally and clinically to stretch human skin. These systems involve the insertion of needles, metallic loops, or other invasive cutaneous anchoring techniques. Sutures, ratcheting devices, or elastic bands are used to connect anchors that are periodically tightened. Unfortunately, the force becomes concentrated on a small area of skin, risking tissue tearing, pain, and infection. Due to this limited skin–anchor interface, care must be taken to limit the "cable tensions" generated with these devices. Human devices are limited to closure of smaller problematic wounds, especially those involving the lower extremities.

The simplest and most effective device for animal use is the skin-stretcher cable system discussed in this chapter. This externally applied device disperses cable tension over a large footprint on the skin surface area. Skin will not tear with this painless device. In one study of small experimental lower-extremity wounds in dogs, hypodermic needles and skin staples were used to facilitate skin stretching. The researchers noted that both methods were useful, whereas the larger skin-stretcher pads were not effective for placement in this small skin surface area surrounding the lower-extremity defects. That being noted, for larger wounds involving the trunk, neck, and upper-extremity areas, the author has found that the skin-stretcher system is superior based on the wider surface area of adhesive pad contact. The force applied by the elastic cables is then distributed to the wide surface area of the stretcher pads for more effective stretching of the skin. This is superior to using any simple suture loop, skin staple, or needle-insertion technique, where the force is applied to a small area of the skin.

Detailed description of skin stretchers and their uses in dogs and cats is given in this chapter. Individuals interested in skin stretchers are welcome to contact the author.

PRESUTURING

The technique of *presuturing* is another surgical method that in part uses the biomechanical properties of mechanical creep and stress relaxation to facilitate the closure of skin wounds. Presuturing relies on the use of tension mattress sutures to imbricate the skin on opposing sides of cutaneous lesions. The sutures primarily exert their effect on the healthy skin immediately adjacent to the proposed surgical site. The force required to close surgical wounds can be markedly reduced within 24 hours after suture application, based on studies performed in swine, with positive benefits noted as early as 2.5 hours after application in humans and pigs (Plate 35). Skin stretchers can be used as an alternative to the presuturing technique (Plates 36, 37, and 38). Presuturing is limited to smaller wounds in humans and is intended to be used the day prior to surgery. It is not adjustable; as a result tension may be initially high after tightening the sutures, but

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FIG. 10-1 (A–C) Massive lipoma attached to the skin below the vulva, 1 year plus in duration. Note how the skin overlying the tumor has increased its surface area by biological creep. Lipoma enlargement, coupled with gravitational pull, played a role in this process. The mass was successfully removed. (D) Small terrier with recurrent infiltrative lipoma involving the left upper forelimb. The skin overlying the area has increased its surface area by slow biological creep. Infiltrative lipomas usually are problematic to remove; recurrence is likely unless surgical margins can be obtained.

as the skin begins to deform the tension drops off. In contrast, skin stretchers allow the veterinarian to continuously adjust cable tension to accelerate the stretching process in 48–72 hours.

LOAD CYCLING

Load cycling refers to the use of skin hooks to stretch skin intraoperatively in order to reduce incisional tension during wound closure. It is a simple method to gain 1–2 cm intraoperatively by taking advantage of the processes of mechanical creep and stress relaxation. It entails the insertion of skin hooks into the dermis adjacent to the cutaneous borders requiring apposition, This is followed by the manual application of moderate traction force to apply continuous tension on the skin, followed by a period of relaxation before resuming the stretching. The time of application varies with the surgeon. In practice, the author normally applies 30–60 seconds of tension to a skin section, followed by 30 seconds of rest, before resuming the application of tension for several cycles (approximately 10 minutes) to both opposing sides of the wound (Fig. 9-10 and Fig. 10-3). With longer incisions, the skin hooks are reengaged to sections of the skin; in most cases the central (widest) area of the defect is the primary region of focus for load cycling. During this procedure, the net gain of elastic advancement of the skin is periodically assessed: when sufficient tension reduction is noted, the wound is sutured closed. There is no dramatic gain stretching skin by this simple technique, but 1–2 cm can mean the difference between primary closure

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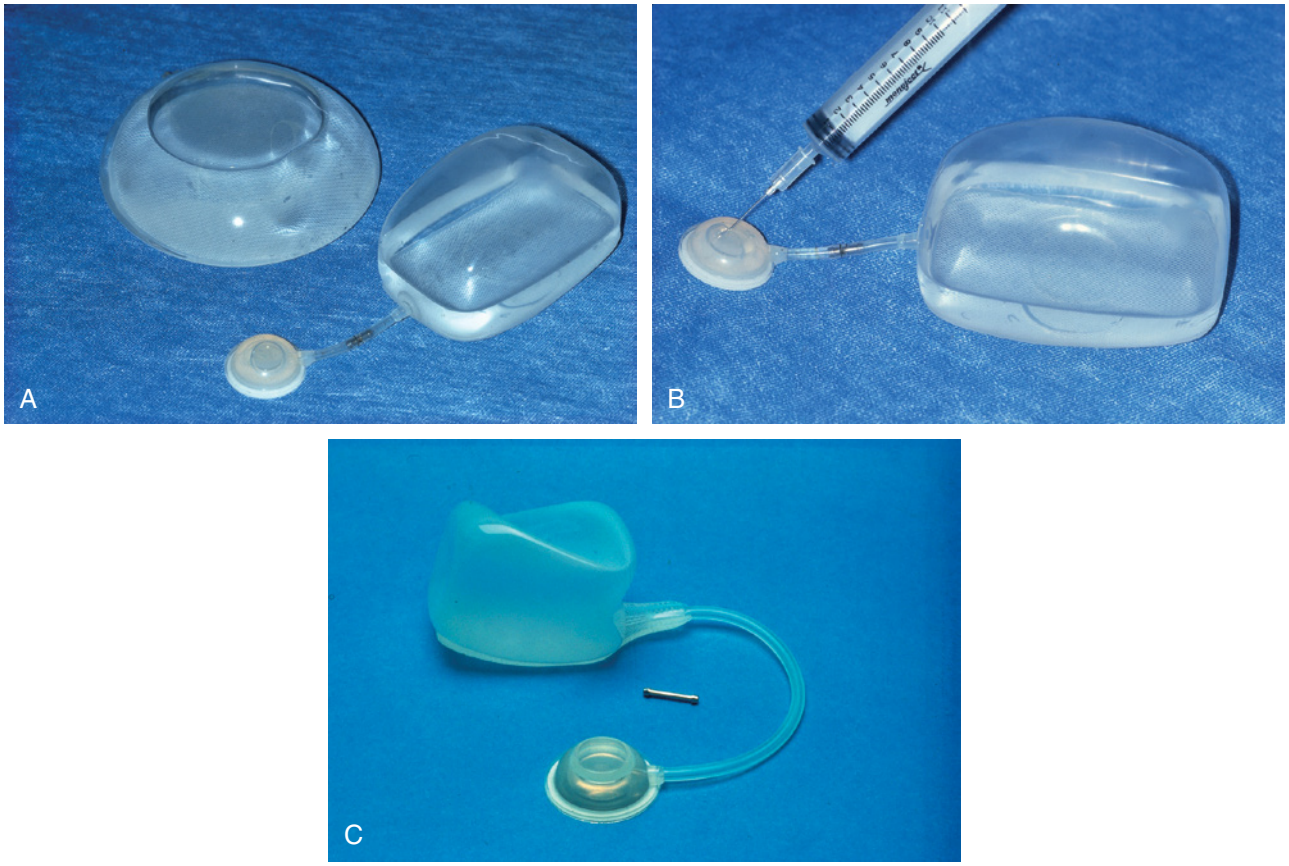


FIG. 10-2 (A, B) Tissue expanders can be purchased or specially designed in a variety of shapes and sizes. Sterile saline or lactated Ringer's solution is used to progressively inflate the reservoir through an injection port connected by a silicone tube. (C) Basic components of a tissue-expander kit include a metallic splice, enabling the surgeon to shorten the extension tube to the appropriate length.

and wound dehiscence. Postoperatively, externally applied skin-stretcher pads, attached by elastic cables (see the following section), can be used to continuously reduce incisional tension.

> Load cycling of skin with the use of skin hooks is a simple intraoperative technique that can be effective in mobilizing 1–2 cm of skin, depending on the body region and thickness of the skin.

SKIN STRETCHERS

The externally applied, noninvasive skin-stretching device described in this chapter is capable of rapidly stretching skin, both adjacent to and distant from a surgical site in animals (Fig. 10-4). Unlike those techniques used to manipulate skin bordering wound margins, this method and device have the capability of achieving significantly greater cumulative gains in skin mobilization by recruitment from large surface areas of skin. This device can be employed to close moderate to large wounds prior to elective surgical procedures or during the course of open wound management (see Plates 36 and 37). Postoperatively, the device also can be used to reduce incisional tension (see Plate 28).

The basic device, as it is presently designed, applies continuous, adjustable tension to skin by means of the following two components:

- Adherent skin pads or anchors applied to opposing sides of a surgical site
- Adjustable, elastic tension straps or cables that engage the skin pads

Of the various skin-stretcher designs researched by the author, the laminate-backed Velcro® Brand pads (2 × 3 inch standard size; Velcro IP Holdings LLC, Manchester, NH), with the accompanying use of an adjustable adherent elastic cable, work effectively in the dog and cat.

The predetermined cutaneous sites for pad application are prepared by removing hair and cleaning the skin with a surgical soap and isopropyl alcohol swabs. The skin is

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FIG. 10-3 (A) Soft tissue sarcoma involving the chin region in a geriatric Jack Russell. (B) Excision of the mass was performed. (C) Intraoperative view of load cycling with a skin hook. (D) Close-up view. (E) Closure of the wound. (F) View of the patient postoperatively.

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FIG. 10-4 Components of the skin-stretching kit, including self-adherent skin pads, elastic connecting cable, supplemental glue, and glue applicators.

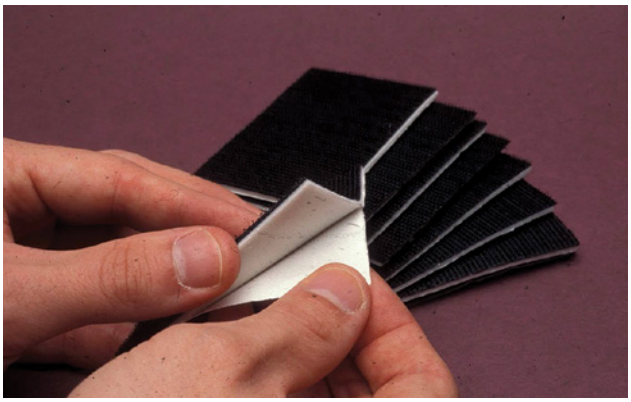


FIG. 10-5 Removal of the backing exposes the sticky surface of the pad prior to its application. Cyanoacrylate surgical glue is spread evenly on its surface immediately prior to its application to the skin.

allowed to dry completely before pad application. Multiple adherent pads can be applied to the skin local to and distant from the surgical site, depending on the amount of skin available or required for recruitment. Skin pads can be manually contoured to the natural curvature of the body region. Cyanoacrylate adhesive is used to enhance pad adherence to the skin as needed (Fig. 10-5).

The pile pad surface of the elastic cables engages the paired cutaneous "hook" pads positioned on opposite sides of the surgical site. The elastic cable is attached to one pad and stretched prior to engaging the opposing pad in order to generate moderate cable tension. As the skin areas progressively stretch from the force applied, cable tension is adjusted every 6–8 hours to generate optimal tension forces during the brief period of application. Elastic cable also helps maintain the position of any dressings or bandages placed over the surgical site; wounds can be easily inspected at the time of cable adjustment. Sufficient skin may be recruited within 48 hours after application, although the devices were maintained up to 96 hours in some subjects (Fig. 10-6). In practice, the author stretches skin for 48–72 hours prior to wound closure.

Pads can displace during the stretching process if the skin is not properly prepared or the glue interface fails to properly bond the laminated membrane to the skin. From the author's experience, partial pad displacement most commonly occurs from the overzealous application of cable tension between opposing pads. It is important to keep in mind that using mild cable tension throughout the 48–72-hour period will get you to the desired result without resorting to applying the cable at "maximum stretch." Partially displaced pads can be reattached with glue. With complete pad avulsion, a new pad is best applied to a clean area of adjacent skin.

On completion of the stretching procedure, the elastic cables are removed and the skin pads are peeled from the skin surface or removed with a glue solvent from the anesthetized patient. Pads left on the skin will begin to separate within days after application as the outer corneal layer desquamates. After surgical preparation of the patient, the recruited skin is advanced to close the skin wound. Generally, little or no cutaneous undermining is required in small animal patients. As noted, skin pads and cables also can be used postoperatively over a 2–5-day period to offset excessive incisional tension (see Plate 28).

Skin stretchers are particularly useful for wounds involving the trunk and cervical areas where there is loose, elastic skin that can be stretched in the direction of the wound. They also can be used effectively for upper-extremity defects. They have less efficacy for lower-extremity defects where there is little skin available for stretching. Larger lower-extremity defects are often managed with free grafts (Figs 10-7, 10-8, and 10-9).

Skin-stretcher cables can maintain the position of topical bandages, especially during the process of skin stretching. The author also uses skin stretchers for two other purposes: (1) to relieve postoperative incisional tension and (2) to prestretch skin around a problematic tumor or diseased skin area prior to surgical removal (Figs 10-10 and 10-11). Prestretching the territory of a thoracodorsal axial pattern flap was reported by Holt and Runge (2011), enabling the flap to extend to a distal-extremity defect. This option has promise to enhance wound coverage of skin flaps, rather than considering a delay procedure (Plate 37).

Today, the author uses skin stretchers for nearly all large skin defects involving the trunk and cervical area. It is a fast, efficient, and economical method of closing problematic wounds. It reduces surgical trauma to the patient by reducing the need for more invasive closure techniques.

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FIG. 10-6 (A) In this canine subject, 2 cm circles were drawn onto the skin using a plastic template. The circles were 2 cm apart; each row also was 2 cm apart. Pads were applied on the left and right sides of the dog, ventral and lateral to the dorsal spinous processes. (B) At 72 hours, note the trunk skin is being stretched dorsally. The rows of circles are being stretched dorsally. Stretching of the individual circles results in their elliptical distortion, revealing the relative vector forces applied to the skin. (Source: Reproduced from Pavletic MM. 2000/ with permission of American Veterinary Medical Association.) (C) Dorsal view of the dog 72 hours after application. Note the stretched skin is being retained between the two sets of pads. (D) Note the considerable gain in elastic skin in relation to the black line that signifies the limits of the inherent skin laxity measured prior to activation of the skin stretchers. This loose skin recruited could be used to close large trunk wounds.

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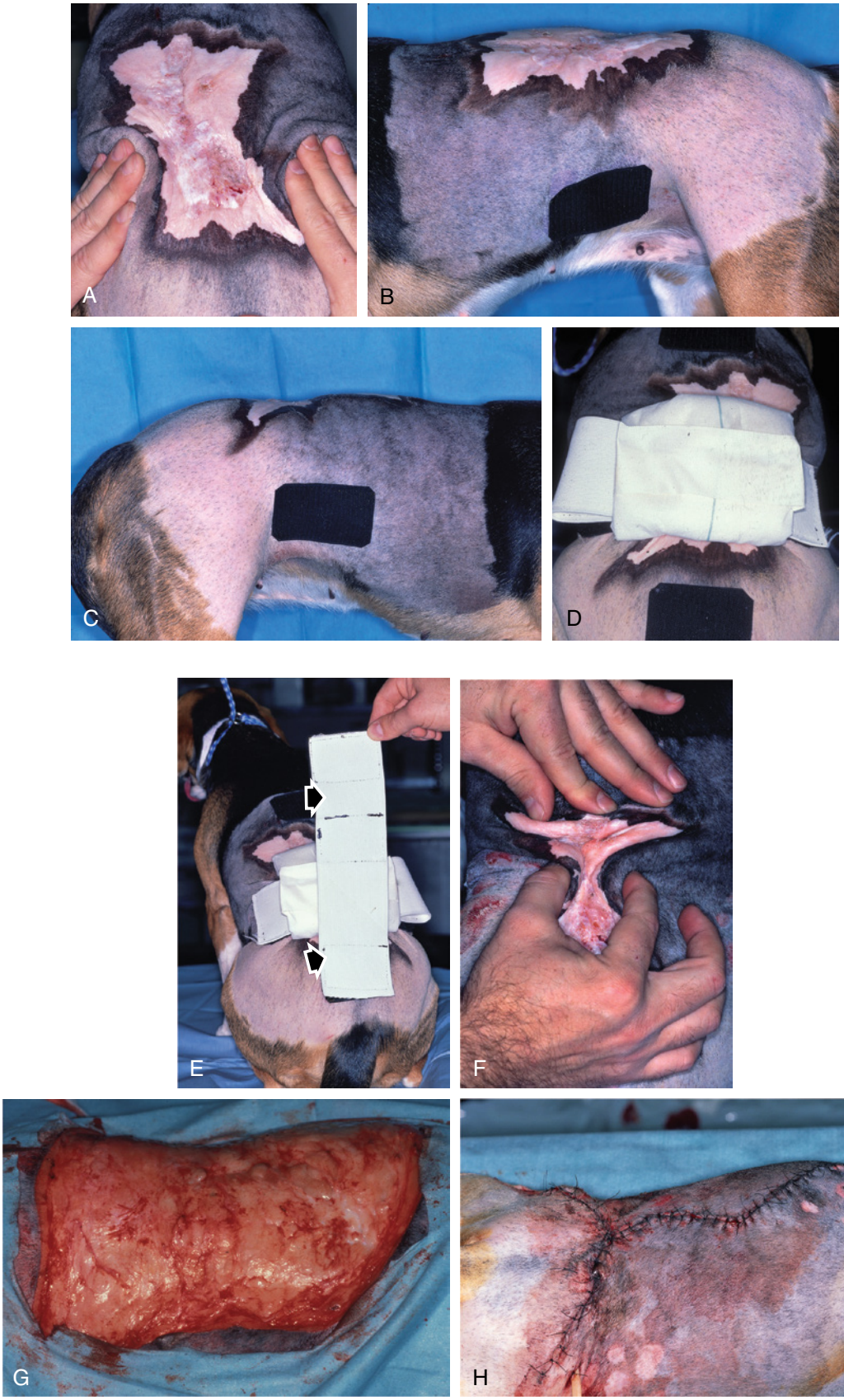


FIG. 10-7 (A) Burn scar overlying the dorsal lumbar and pelvic regions in a beagle. The inherent elasticity of the skin was insufficient for wound closure without resorting to extensive undermining of the skin. (B, C) Application of large skin pads onto the left and right sides of the dog. (D) Attachment of a wide elastic cable to the left and right pads under moderate tension. A second set of pads was applied caudal and cranial to the epithelialized burn scar. A cotton pad was placed beneath both sets of cables to prevent irritation to the scar surface. (E) Note the cable, applied to the caudal pad, being stretched forward for application to the remaining cranial pad (arrows). Cables were adjusted every 6 hours for a total of 72 hours. (F) After 72 hours, note the skin bordering the lesion is approximated with minimal effort. (G) Complete surgical removal of the scar. Incisions were made in the adjacent skin. (H) Wound closure was accomplished with minimal cutaneous undermining.

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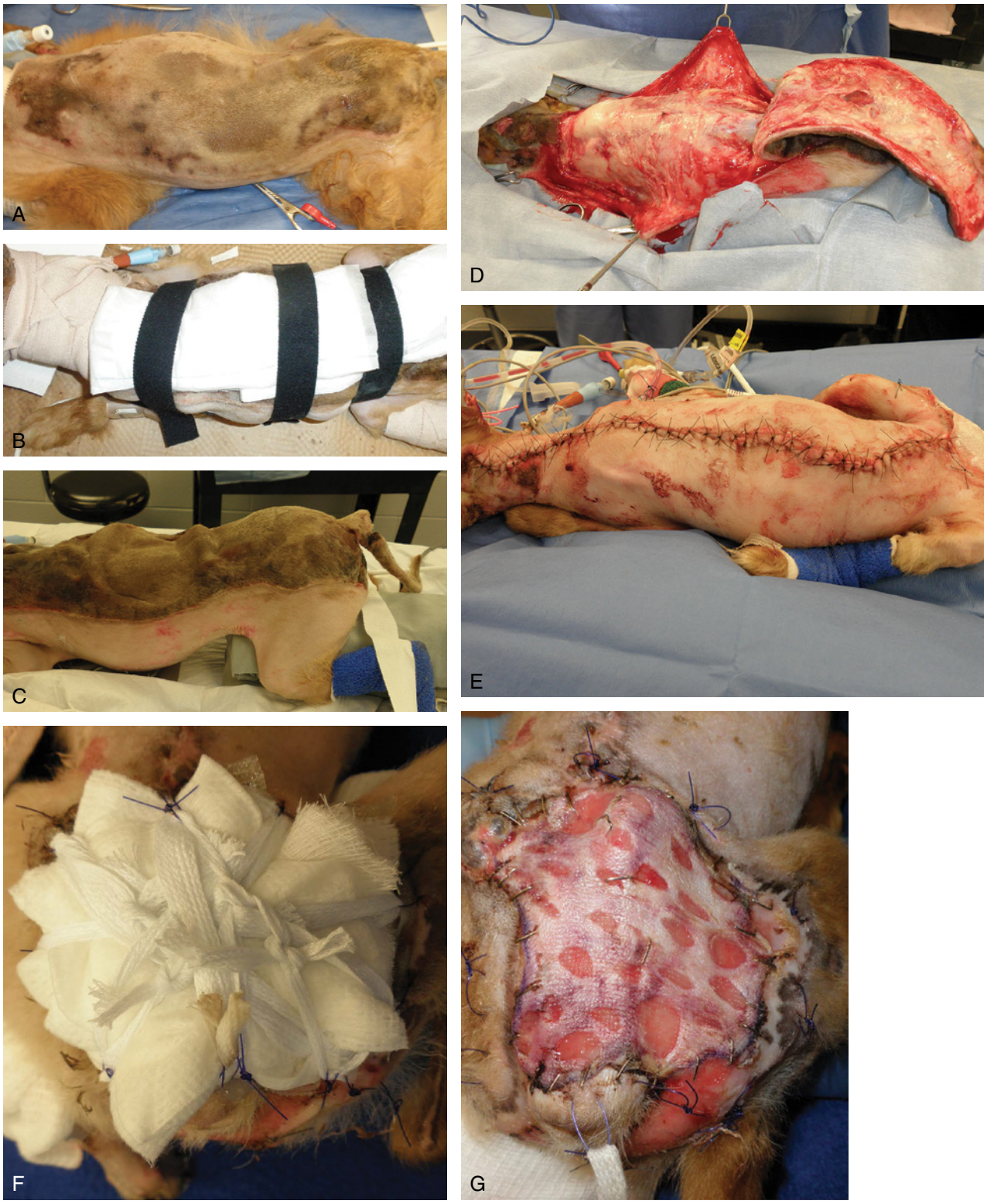


FIG. 10-8 (A) A canine patient with extensive burns. The dog was trapped in a house fire. It took over 2 weeks before it became apparent that the skin overlying the dorsal trunk was a full-thickness burn. (B) The body burns were approached in three stages. (Stage one was restoration of the facial area, Fig. 7-18.) Stage two was resection and closure of this dorsal trunk burn. The viable lower thoracic and abdominal skin was stretched for 72 hours prior to resection of this broad necrotic skin segment. (C) Preparation of the patient for surgery included elevation of the pelvis and anterior sternum. This facilitated mobilization of the skin dorsally. (D) Intraoperative view of the patient. The thick necrotic rectangular segment of skin is reflected caudally. Skin hooks demonstrate the viable stretched lower-trunk skin. (E) Successful closure of the dorsal cervical, thoracic, and lumbar area. Jackson-Pratt drains were inserted to control dead space. The pelvic area was debrided and the necrotic tail was amputated, in preparation for final closure of this skin defect (stage three). (F) Stage three closure was free grafting the dorsal pelvic area 5 days after stage two closure of the trunk defect. Skin was harvested from the left shoulder area. The full-thickness mesh graft was stapled over the prepared dorsal pelvic defect followed by a tie-over dressing to immobilize the graft–recipient bed interface. (G) The graft "take" was successful; the graft at day 4.

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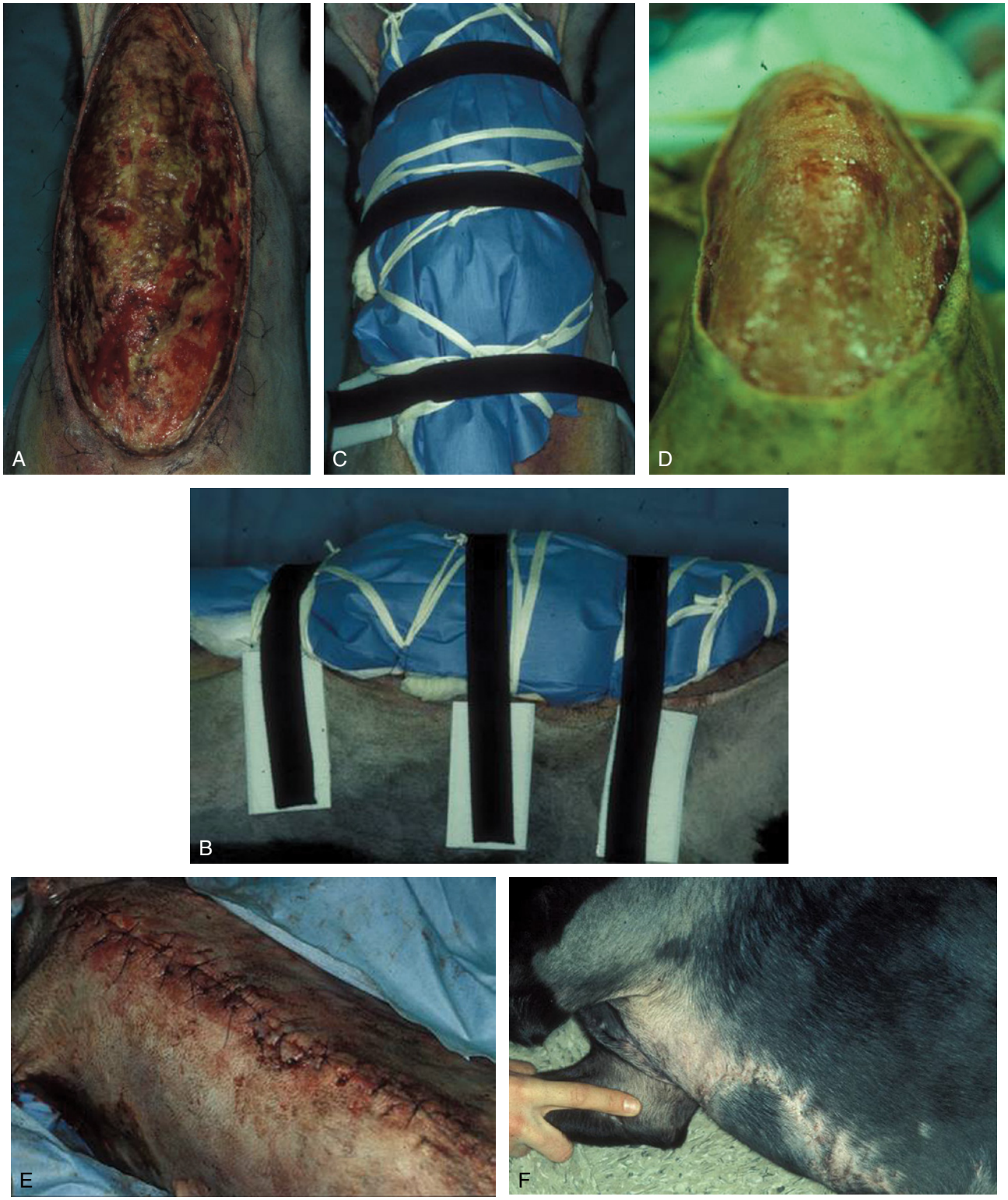


FIG. 10-9 (A) Septicemia with subsequent infarction of the ventral thoracic skin. The wound after initial debridement of the necrotic skin. Wet-to-dry medicated dressings were used to soften the adherent necrotic fat and remnants of dermal collagen. (B, C) The wet-to-dry dressing was covered with a sheet of sterile, water-resistant paper surgical drape to prevent "strike-through" of the moist dressing. A tie-over dressing was used to secure the dressing. Three paired (2 × 6 inch) stretcher pads were attached to the lateral thoracic skin of this large Labrador. The cables were tightened three times daily over a 72-hour period. (B) Lateral view and (C) ventral view of the bandaged area with the stretcher pads and cables. (D) The wound, prepared for surgery after removal of the stretcher pads and dressings. (E) Postoperative view of the closure. The prestretched skin was undermined to facilitate closure. (F) The patient 1 month later. A small area of necrosis was subsequently closed by simple undermining and advancement. Skin stretchers closed this problematic wound with less cost and effort compared to the other practical alternative worth consideration, the cranial superficial epigastric island arterial flap.

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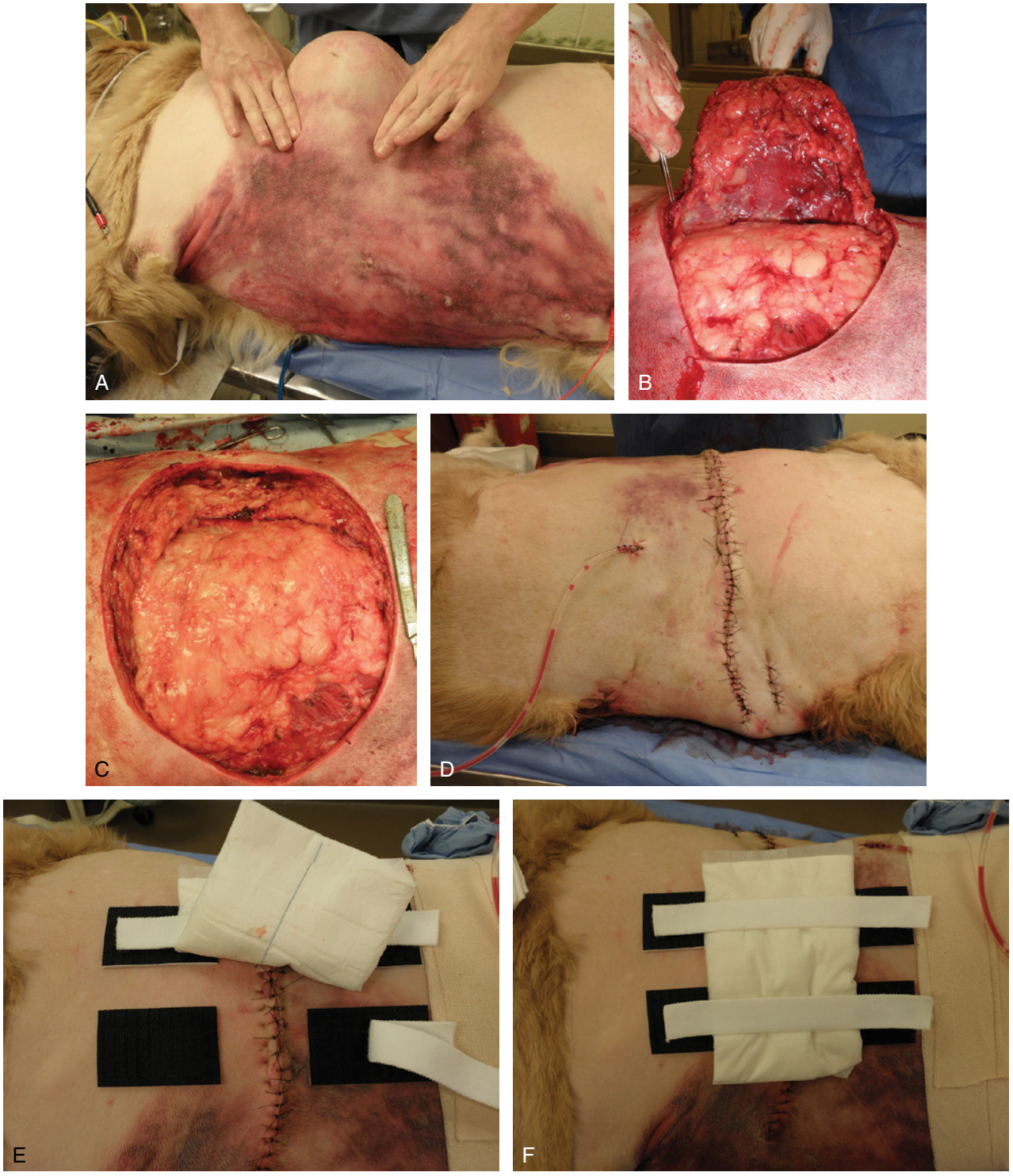


FIG. 10-10 (A) Grade two mast cell tumor. (B) Wide resection included removal of the underlying left latissimus dorsi muscle. (C) The surgical defect. (D) Undermining and closure: a Jackson-Pratt drain. The incision was under tension in this active retriever. (E) Two pairs of skin-stretcher pads were secured with surgical cyanoacrylate glue. A surgical pad was applied over the incision prior to applying the elastic cables under mild elastic tension. The pads were subsequently removed 5 days later. Complete surgical margins were obtained based on assessment of the inked margins of this large tissue segment submitted for histopathologic examination. (F) The stretchers were applied for 5 days and removed by gently pulling the adhered pads off the skin.

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FIG. 10-11 (A) Skin stretchers were used 72 hours prior to resection of this pigmented hamartoma involving the dorsal lumbar area of a retriever. (B) 72 hours after stretching. (C) Close-up view of the outlined lesion. The prestretched dorsolateral lumbar skin will be pivoted to close the surgical defect. (D) After closure under mild tension, two pairs of pads were applied on opposing sides of the closure. One pad was placed sideways to the incision to fit anterior to the base of the tail. (E) A pad was applied over the incision to protect the incision from irritation from the elastic cables applied under mild tension. Pads normally can be removed a few days later, as skin is mobilized by mechanical creep and stress relaxation to reduce incisional skin tension.

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Skin stretchers utilize a 2 × 3 inch rectangular Velcro pad that is laminated to a plastic membrane; this surface allows for effective gluing of the pad onto the skin surface. (Larger pads are available.) The elastic cables have a raised pile surface that adheres to the Velcro surface. Surgical cyanoacrylate glue is used to secure the pads to the prepared skin. Periodic adjustment of cable tension accelerates the stretching of the skin. This is most commonly performed every 8 hours over a 48–72-hour period. The skin-stretcher system is particularly well suited to large trunk wounds. It can be used to prestretch the skin around the perimeter of a skin tumor or diseased skin area prior to surgery. It is also useful for preventing wound dehiscence for skin closures under significant tension. Larger skin pads can be designed for unique case situations. The author can be contacted if skin stretchers are required.

SKIN EXPANDERS

Tissue expansion is based on the inherent ability of skin to respond to mechanical stresses. Small animal veterinarians have long noted the ability of skin to stretch and accommodate to underlying expanding tumors. Inflatable skin expanders can mimic this physiologic process.

During tissue expansion a variable change is noted in epidermal thickness. Epidermal mitosis temporarily increases following each inflation: the intercellular distance increases and the basal lamina displays increased undulation. The dermis displays a variable decrease in thickness during expansion. Large, compact bundles of collagen fibers are oriented in an orderly fashion over the implant surface, forming a dense, fibrous capsule (Plate 39).

The subcutaneous fat decreases. Skeletal muscle above or below the expander can undergo pressure atrophy without loss of function. Initially, this muscle has the capability of regaining mass after implant removal. A transient neuropraxia may be noted in nerves immediately adjacent to the expander.

Interestingly, the vascular supply to the overlying skin and compressed musculature remains intact. Circulation to the skin demonstrates enhancement similar to what is seen with delayed flap procedures. Experimental studies indicate a greater viability of "expansion" flaps compared to acutely raised and delayed flaps. Skin expanders are best employed for secondary reconstructive surgery rather than for acute post-trauma construction. Skin showing irritation prior to surgery is best avoided in tissue expansion. Skin expanders have potential use in small animals, particularly for lower-extremity defects in dogs (Fig. 10-12).

Despite the relative simplicity of their use, tissue expanders have failed to gain popularity in veterinary medicine. This is likely due to the cost of the implants and veterinarians' general lack of familiarity with their use. Moreover, there are a variety of reconstructive techniques that can be used in place of this device. Nonetheless, it can be a valuable option in closing some of the more challenging extremity wounds occasionally encountered.

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FIG. 10-12 (A) Undermining the skin in preparation for tissue expander insertion. The pocket size should be limited to the minimum area needed to accommodate this implant. (B) Placement of a collapsed 100 ml tissue expander into a pocket created over the lateral tibial region. (C) Proximal pocket created to accommodate the injection port. (D) Double-layer closure of the small access incision. Injection of saline in the injection port. (E) Example of an inflated tissue expander, lateral aspect of the lower hindlimb. (F) Transposition flap elevation on completion of the period of expansion. (G) Use of a transposition flap to close a defect overlying the carpal area. (Source: Spodnick G, Pavletic MM. 1993. Controlled skin expansion to mobilized skin in the distal extremities. *Vet Surg* 22:436. Reproduced with permission from Veterinary Surgery.)

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Suggested Reading

Holt DE, Runge J. 2011. Use of skin stretchers to elongate a peninsular thoracodorsal axial pattern flap: for antebrachial wound closure. *Vet Surg* 40:352–356.

Johnston D. 1990. Tissue expanders. *Vet Clin North Am* 20:227–234.

Keller WG, Aron DN, Rakich PM, et al. 1994. Rapid tissue expansion for the development of rotational skin flaps in the distal portion of the hindlimb of dogs: an experimental study. *Vet Surg* 23:31–39.

Liang MD, Briggs P, Heckler FR, et al. 1988. Presuturing: a new technique for closing large skin defects: clinical and experimental studies. *Plast Reconstr Surg* 81:694–702.

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Zingel MM, Sakals SA. 2017. Use of skin stretching technique before bilateral caudal superficial epigastric axial flaps in a dog with severe burns. *Can Vet J* 58:835–838.

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Plate 35 Presuturing Technique

DESCRIPTION

The presuturing technique employs large mattress sutures to stretch skin on opposing sides of an elective surgical site prior to the actual procedure. Skin can stretch by the processes of mechanical creep and stress relaxation when continuous tension is applied to the skin over time. Research in a swine model, and subsequent clinical studies in humans, indicate that this technique can reduce skin tension and thereby facilitate wound closure within 24 hours after application.

SURGICAL TECHNIQUE

(A) In this illustration, the presuturing technique will be used to reduce skin tension prior to surgical removal of this cutaneous lesion. The fur has been clipped from the area and the area is surgically prepared for suture placement. Using reverse cutting needles, 0 or 00 suture materials may be used for presuturing. Lidocaine anesthetic blocks, sedation, or light anesthesia is used to reduce patient discomfort during suture placement. Vertical mattress suture "bites" are applied approximately 3–5 cm from the proposed borders of resection. The number of sutures employed will vary with the length of the proposed surgical site. Application is performed 24 hours prior to surgery.

(B) As the sutures are tied, the skin around the immediate surgical area is placed under tension. Note that the surgeon may consider the use of rubber bolsters (Plate 30).

(C) A cross-sectional view of the presutured area. Imbrication of the skin places tension on the adjacent skin.

COMMENTS

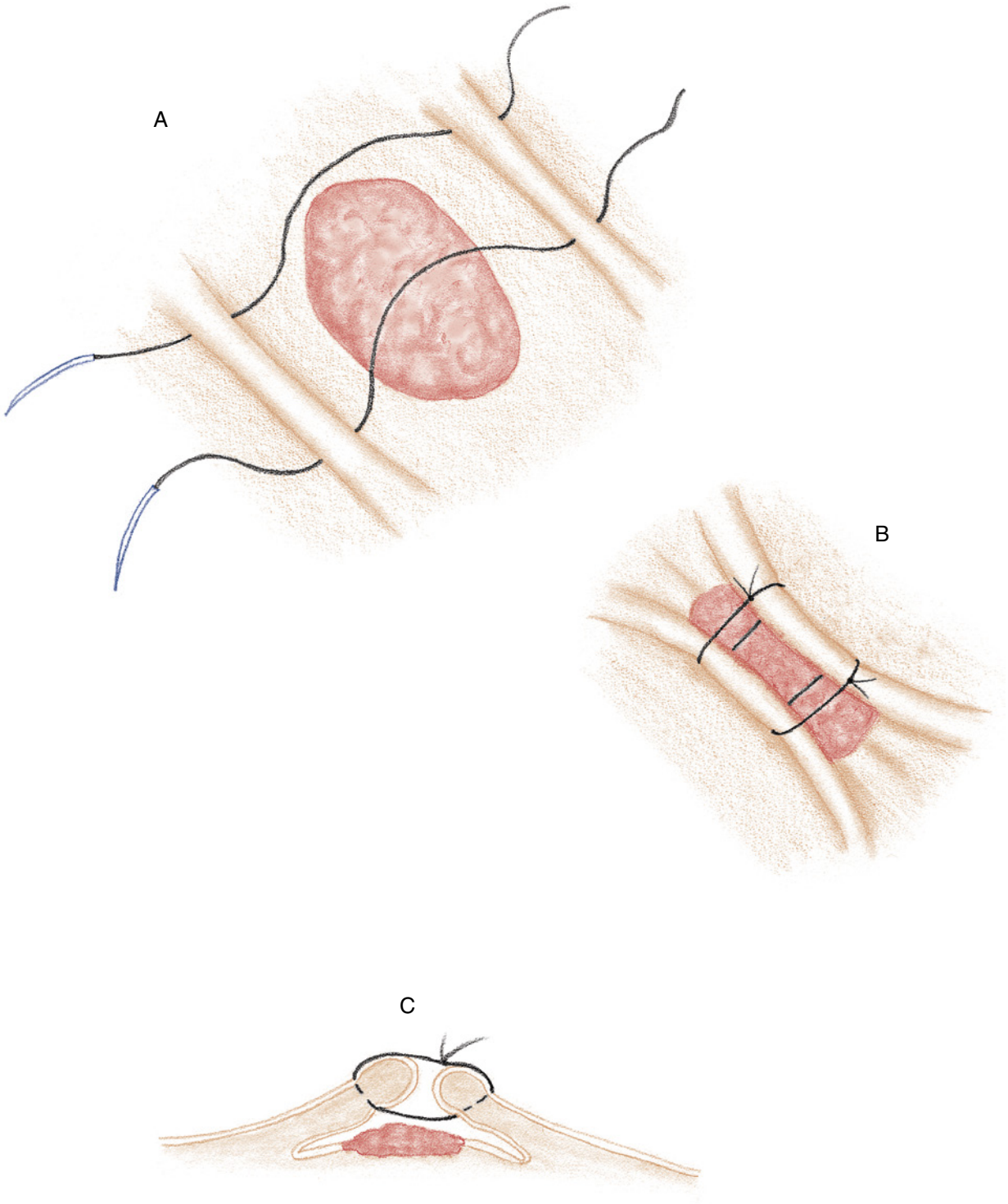
The presuturing technique underscores the potential for skin to deform or stretch beyond the boundaries of its inherent elasticity. Unfortunately, the sutures are not adjustable and the stretching effects are limited to the skin immediately adjacent to the site of suture placement. Additionally, as the skin stretches the sutures will begin to relax, constraining their ability to continuously stretch the skin. Presuturing is effective only in those body regions where elastic skin is somewhat limited, such as the extremities. As such, its practical use is restricted to smaller skin defects. Presuturing will not be effective or even necessary in most body regions where elastic or redundant skin is present.

Skin stretchers (Plate 38) can be a more effective substitute for the presuturing technique described here. The adjustable cables permit the veterinarian to maintain moderate to high levels of skin tension continuously to enhance gains in skin mobilization for successful wound closure.

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Plate 35



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Plate 36 Application of Skin Stretchers

DESCRIPTION

Skin under the continuous application of tension (load) over time can deform beyond its natural or inherent extensibility by the processes of mechanical creep and stress relaxation. Unlike the presuturing technique (Plate 35), the skin stretchers developed by the author employ externally applied adhesive pads. Elastic cables are attached to cutaneous pads that have been placed on opposing sides of a surgical site. The surgeon can adjust the elastic force applied to the skin to maintain a continuous high-tension load in order to accelerate skin stretching or deformation. In 24–96 hours the mobilized or recruited skin is used to close the cutaneous defect.

SURGICAL TECHNIQUE

(A) Illustration of a skin wound. The fur has been liberally clipped around the area. Surgical soap and water are used to remove cutaneous oils and debris. Isopropyl alcohol can be used to swab the skin to further clean the skin and facilitate drying. The skin must be completely dry before skin-pad application. A marking pen can be used to mark the proposed sites of pad application.

(B) The hooked pads can be applied to the skin after peeling off the protective tab. However, a commercially available cyanoacrylate glue is best applied to enhance their adherence to the skin in the dog and cat. A thin layer of cyanoacrylate glue is spread onto the base of the pad and applied immediately to the designated skin site.

(C) Note that the long axes of the rectangular pads have been placed parallel to the direction of tension in order to minimize the potential for pad separation or displacement. Pads are placed approximately 10–20 cm from the wound margins. An additional row or tier of pads can also be applied outside this suggested zone, if additional skin recruitment is required or feasible (e.g., on the trunk). In this illustration, one elastic cable has been attached to paired pads. A small protective bandage has been placed over the wound surface.

(D) Completion of cable application. A mild amount of tension is applied to each cable. The tension then is increased every 6–8 hours as the skin stretches. One end of the elastic cable is disengaged from a skin pad, stretched, and recoupled to the skin pad, as illustrated.

(E) At the completion of the procedure (24–96 hours), skin pads can be peeled off the skin. Nail polish remover can be used to facilitate their separation (although the author has found this to be unnecessary). Manual removal of the pads normally is performed, although this maneuver may strip the outer corneal layer of the skin. (This outer epithelial layer reforms rapidly.) In this example, all four sides of this rectangular wound were advanced to accomplish closure. Note that two pads and a short segment of stretcher cable were reapplied postsurgically in order to reduce incisional tension.

COMMENTS

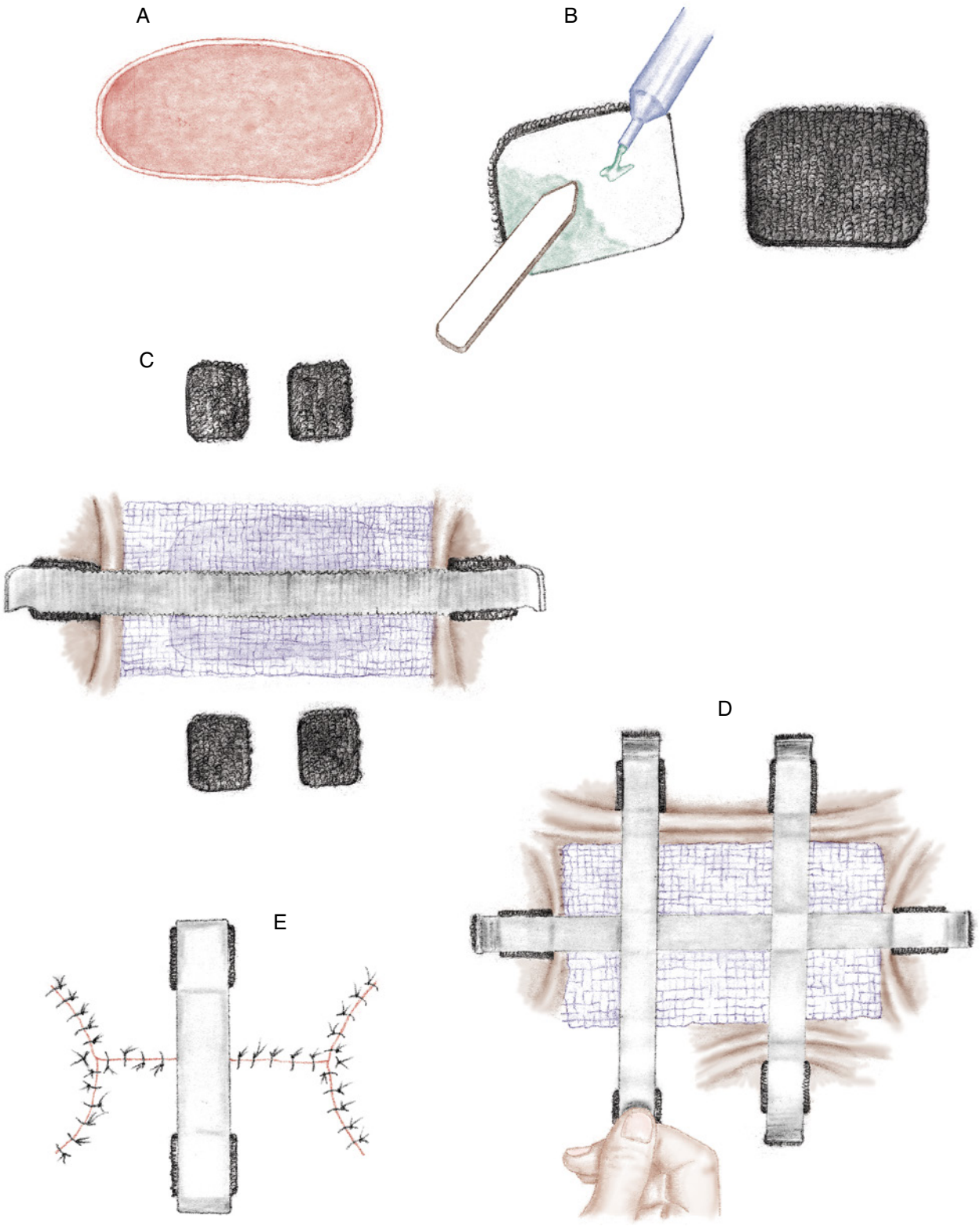
As a general observation, the greatest gains in skin mobilization occur by 48–72 hours. Occasionally skin pads will separate from the skin, necessitating their reapplication with additional adhesive. The greatest gains in skin stretching are in body regions where it is possible to mobilize large surface areas, both local and distant to the surgical site. The neck and trunk are most amenable to effective use of skin stretchers.

Skin stretchers are least effective in the lower extremities. The amount of undermining required, at the time of wound closure, usually is minimal after the use of skin stretchers. As noted, skin stretchers also can be used to reduce incisional tension postoperatively for a few (3–5) additional days. In Plate 38, skin stretchers are used to stretch skin prior to elective surgical procedures to facilitate closure.

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Plate 36



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Plate 37

Skin Stretchers to Enhance Length of Axial Pattern Flaps

DESCRIPTION

As reported by Holt and Runge (2011), skin stretchers can be used to prestretch the cutaneous territory of an axial pattern flap. In this case study the skin comprising the area of thoracodorsal axial pattern flap was stretched for 96 hours prior to flap elevation and transfer to a lower-extremity defect.

SURGICAL TECHNIQUE

(A) Skin-stretcher pads are applied dorsal and ventral to the outlined territory. The skin has been clipped of fur and cleansed prior to their application with cyanoacrylate adhesive (see Plate 36).

(B) The elastic cables are applied to opposing dorsal and ventral pads, affixing the pile surface to the Velcro hook pads. The elastic cable is stretched under moderate tension.

(C) Every 8 hours, the cables are disengaged and further tightened for 48–72 hours.

(D) The thoracodorsal axial pattern flap territory is drawn onto the prestretched skin. Once elevated, the flap can be extended to the lower forelimb skin defect.

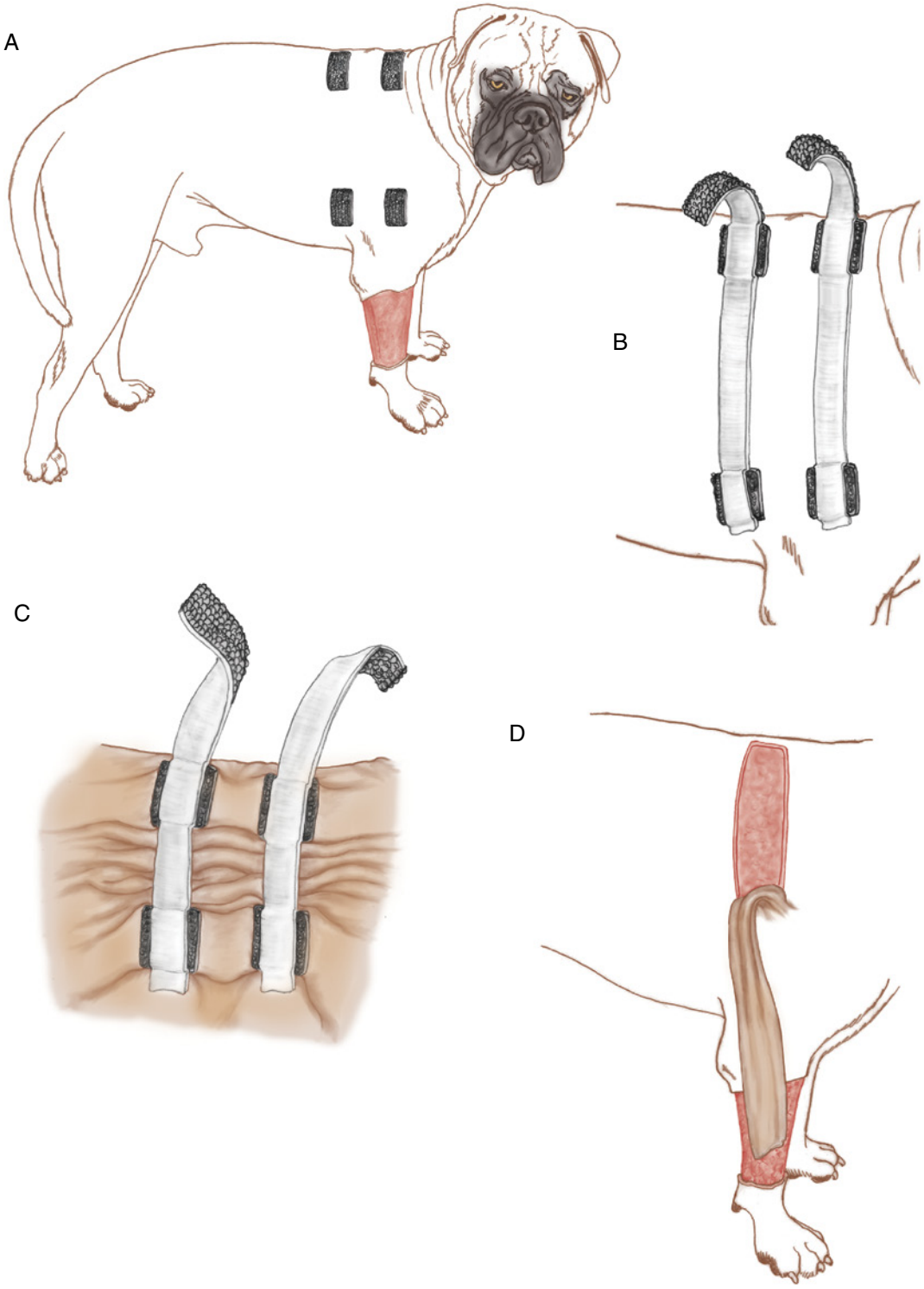
COMMENTS

Prestretching the skin can lengthen distance a given flap can cover, which is especially useful when the axial pattern flap is required to extend down to a large lower-extremity wound. This option is simple and economical to perform, and may eliminate the need to consider a surgical delay procedure (see Plate 56, Indirect Flap: Delayed Tube Flap).

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Plate 37



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Plate 38

Skin Stretcher Substitution for Presuturing

DESCRIPTION

Skin stretchers can be quite effective in recruiting skin prior to elective surgical procedures. This is particularly true when removing diseased skin, including neoplasms.

SURGICAL TECHNIQUES

(A) In this example, a large neoplasm overlying the ilium requires removal. Skin-stretcher pads have been applied around the lesion.

(B) Dorsal view of the stretcher pads.

(C) Elastic cables cross over to the opposing (paired) pads.

(D) Dorsal and lateral views of the elastic cables applied under moderate tension. Cable tension is increased every 6–8 hours for 24–96 hours before surgery. Skin pads are stripped off the patient after anesthetic induction.

(E) After resection of the mass, the wound is closed using an intradermal suture pattern followed by simple interrupted sutures. Vertical mattress sutures can be alternated with a simple interrupted pattern if tension is present at a given point of wound closure (see Figure 9-20). Skin stretchers can be used to further offset skin tension, as previously noted (Plate 28). A closed-vacuum drainage system may be employed to control dead space.

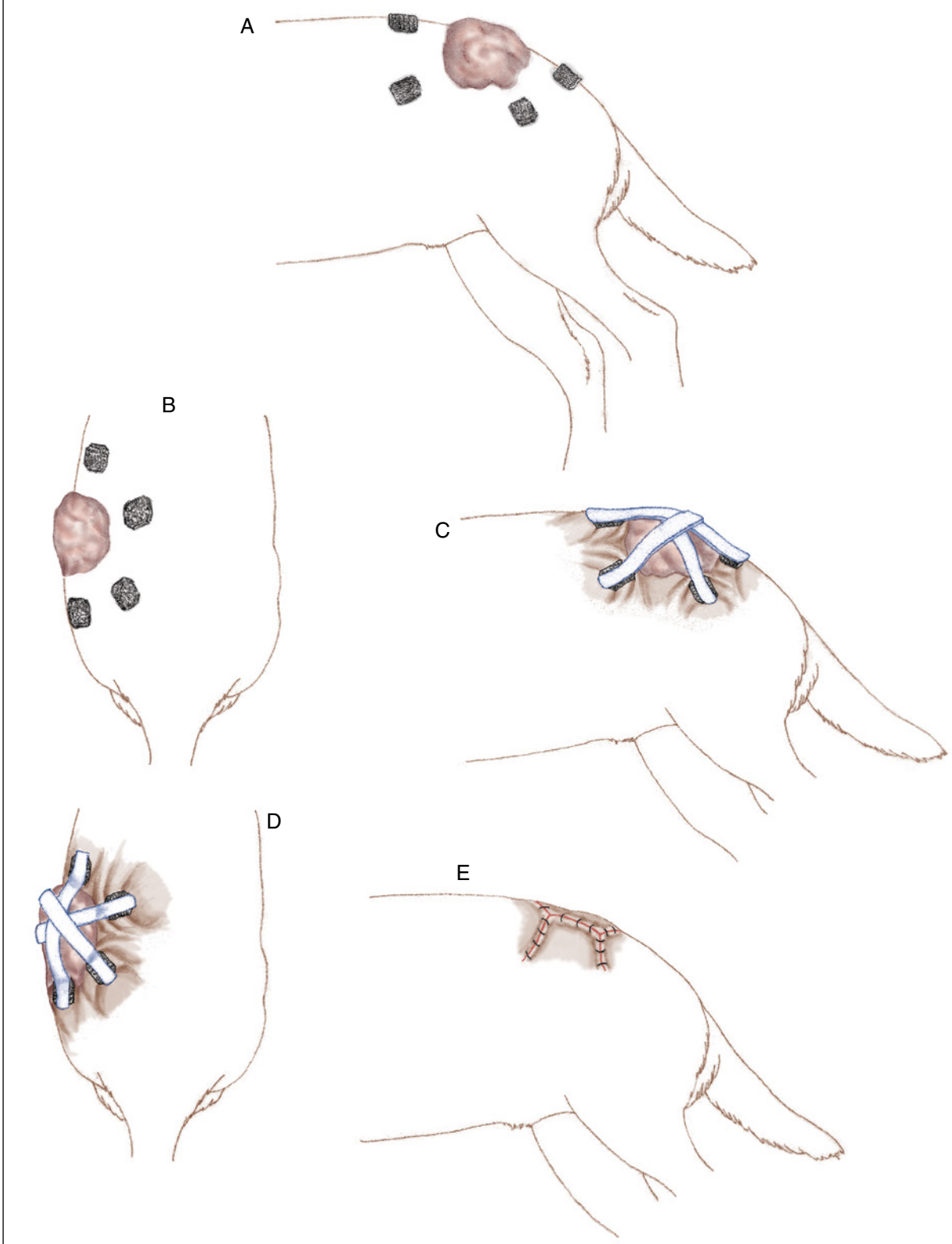
COMMENTS

Skin mobilization is optimal over the neck and trunk of the dog and cat. Stretchers are least effective in the lower extremities, where minimal loose skin is available. Skin stretchers can be very useful to prestretch the thoracic and abdominal skin prior to unilateral or bilateral chain mastectomies. They also can facilitate elevation of both caudal superficial epigastric axial pattern flaps in advance of their elevation and transfer to a large recipient wound bed.

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Plate 38



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Plate 39 Skin Expanders

DESCRIPTION

Skin expanders are inflatable devices comprising an expandable silicone elastomer bag, a silicone connecting tube, and a self-sealing inflation reservoir that serves as an injection port. There are, however, other tissue expanders designed with an injection port incorporated in the reservoir. Self-inflating tissue expanders also have been used in humans. The basic unit described in this plate is the most practical design for veterinary patients. Controlled inflation of this device is capable of creating sufficient donor tissue to elevate an advancement of a transposition flap to close an adjacent skin defect (traumatic or surgically induced).

SURGICAL TECHNIQUE

(A) In this example, a skin incision is made for the insertion of a 100 ml tissue expander (length 6.0 cm; width 4.7 cm; height 5.3 cm; Mentor Corporation, Goleta, CA) in a medium-sized dog. Metzenbaum scissors are used to develop a pocket of sufficient size to accommodate the collapsed expander. Note that the access incision is positioned for eventual incorporation into the flap incision. The incision is not affected by the inflated expander.

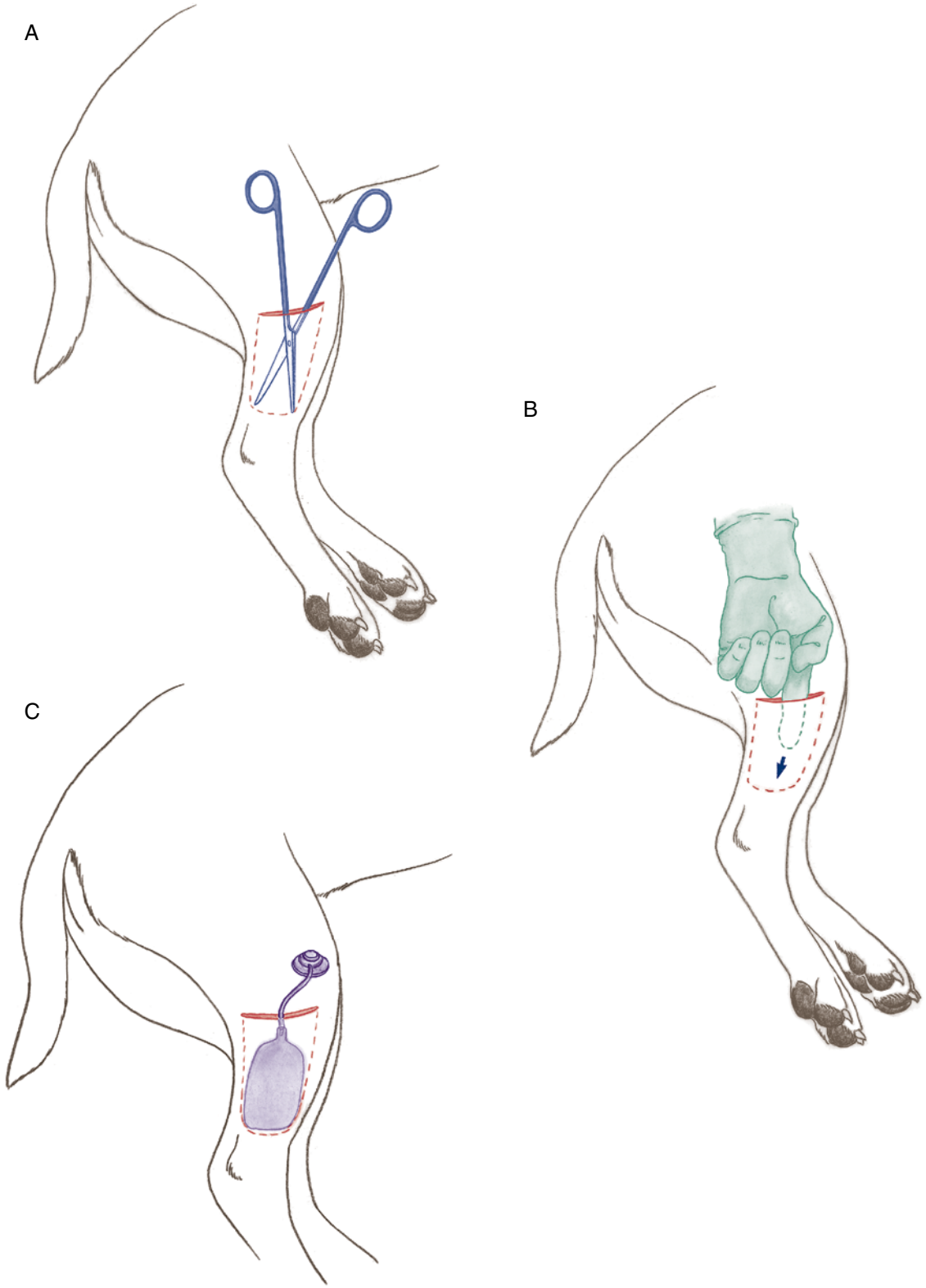
(B) The index finger is inserted into the pocket to assess its size and to feel for fascial bands that require division.

(C) The collapsed expander bag is partially folded and moistened with sterile saline to facilitate its insertion. The thick silastic base is positioned against the limb. The connecting tube is cut centrally and trimmed to the appropriate length for placement of the inflation reservoir in a subcutaneous pocket dorsal to the incision. The ends of the connecting tube are joined by a metallic connecting insert. Two small 3–0 monofilament nonabsorbable ligatures are used to secure the tube ends from leakage or separation. Care is taken to avoid creation of a large pocket that may cause the components of the expander to migrate. The incision is closed with a subcuticular suture pattern and skin sutures.

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Plate 39



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Plate 39

(Continued)

(D) View of the tissue expander during expansion. A 23–25-gauge hypodermic needle is inserted into the inflation reservoir at an angle. A butterfly needle may be used for injection to compensate for patient movement. Sterile saline is injected. From the author's research using 100 ml expanders, initial expansion can be instituted beginning 48 hours after insertion. Injection rates of 10–15 ml every 2 days are equally successful. Flap elevation is initiated 48 hours after the last injection.

(E) On completion of expansion, the planned skin flap is incised beginning at the level of the original skin incision. Care is taken to avoid damaging the expander during its removal. The tube connector is separated to drain the saline from the reservoir and the unit is withdrawn. In this case, a single-pedicle advancement flap is being created to cover the craniomedial skin defect created by the simultaneous removal of diseased skin. In some cases, a distally based transposition flap can be created for lower-limb defects (inset) (see Plate 42). In this example, a dorsally based transposition flap is inadvisable since the access incision would be at the base of the flap, interfering with normal cutaneous circulation.

COMMENTS

There are a variety of standard expanders of variable sizes and shapes for surgical implantation. Specialized designs can be ordered from their manufacturers. At present, the cost of these implants is high and can amount to several hundred dollars, depending on the size and design of the expander. High cost and a lack of familiarity with these devices have discouraged some veterinarians from using them. It must be kept in mind that they can be autoclaved and reused multiple times with appropriate care.

Skin expanders require a degree of skin laxity to accommodate the mass of the collapsed unit. For skin expanders to be effective, implants must be of sufficient size to exert their stretching effect on the overlying skin. The loose elastic skin of the neck and trunk would preclude the need for and effective use of skin expanders in most cases. The greatest clinical potential for skin expanders is in moderate-sized defects of the middle to lower extremities, where primary closure is not feasible and alternate closure options are less satisfactory.

It is unrealistic to expect a skin expander to be effectively employed for large defects of an extremity. They do not permit one-stage surgical reconstruction and are best used for secondary restorative procedures rather than in acute traumatic injuries.

The size of the implant generally is determined by the size of the defect. The flat base of the implant generally corresponds to the net gain expected. Not all body regions, however, can accommodate a skin expander of the size required to achieve coverage. It is possible to select two or more small expanders to accomplish this goal. Skin expanders can be hyperinflated beyond their designated volume capacity by 20–25% for additional tissue gains. The 100 ml expander used in medium-sized dogs, placed in the mid to lower tibial and radial region, was very effective experimentally. It would be possible to employ two such expanders in some situations where additional skin is desirable.

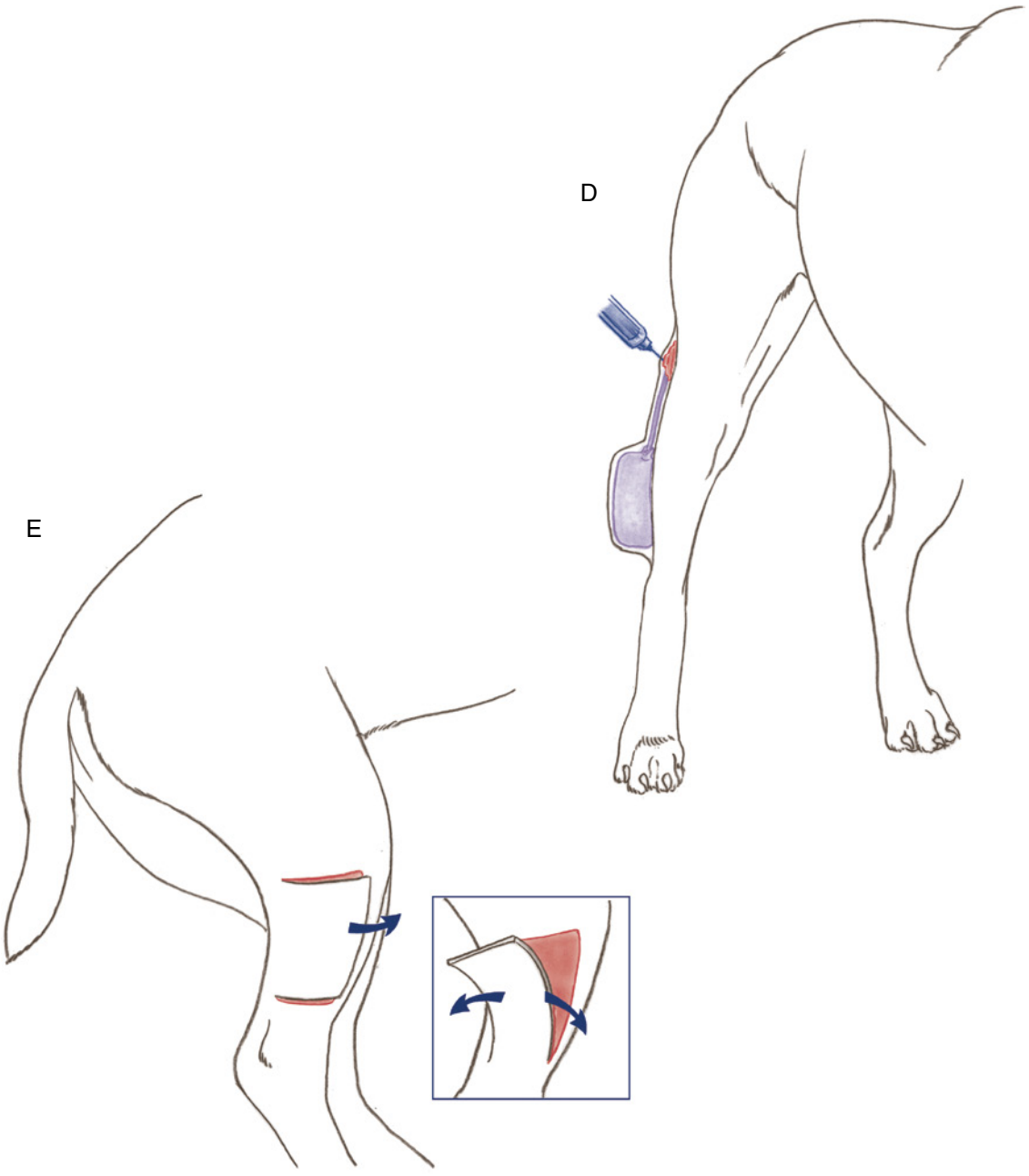
Variable rates of inflation have been used in human surgery. Although a slow rate of expansion may be preferable in elective reconstruction surgical procedures where time is not critical, other situations demand more rapid rates of expansion. The author's research demonstrated that 100 ml expanders can be inflated with equal efficacy within 2 weeks, using an alternate-day injection schedule. It was elected not to partially inflate the expander on initial implantation, although this can be performed to slightly stretch loose skin overlying the implant, potentially saving 2 days. However, a more cautious rate would be indicated in delicate cutaneous tissues, especially those previously compromised by trauma. The use of expanders in previously irradiated tissues is best avoided.

Owners can be trained to inject the expander or the patient can be handled on an outpatient basis. Clinical guidelines for expansion rates in humans include change in skin coloration (ischemia or cyanosis) and patient discomfort. In the author's study, no patient displayed discomfort during injection. Skin blanching or cyanosis

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Plate 39



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Plate 39

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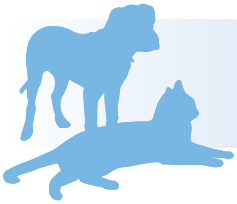
was not noted. Unimpeded hair growth of the expanded skin, compared to the regional skin, suggested skin circulation and viability were not compromised throughout the procedure.

The advancement flap design is simple to execute if the expander can be satisfactorily positioned adjacent to the recipient area. When used for advancement as illustrated, at least one-third of the circumference must be preserved to provide an adequate base to support circulation to the flap. The transposition flap can be rotated into lower-extremity defects, thus enabling the surgeon to develop a donor source proximal to the recipient area. As noted, the initial skin incision used for insertion of the implant should not be incorporated into the base of the skin flap. The author has seen circulatory compromise in flaps that incorporated a linear scar perpendicular to the length of the flap body.

Complications noted with skin expanders include dehiscence, implant extrusion, seroma, infection, implant failure (leakage), and skin necrosis. A thick, fibrous capsule forms around the implant, which reduces the pliability of the flap created. Skin expanders take time to develop and require two surgeries to complete flap transfer. In most situations, skin flaps and free grafts can close wounds very effectively and more economically than skin expanders (at least with respect to their initial cost). Moreover, large skin defects necessarily require flap or grafting procedures. Skin expanders do enable the surgeon to create full-thickness donor skin of similar color, hair growth, and texture adjacent to a defect where no flap can be otherwise employed. They have the greatest potential for some defects involving the extremities (especially distal) and perhaps the rostral facial area. Skin expanders clearly have a place in veterinary surgery, although this niche is smaller than for human patients.

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11

Local Flaps

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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INTRODUCTION

A pedicle graft or skin flap is a partially detached segment of skin and subcutaneous tissue: the base or pedicle of the flap maintains circulation to the skin during its elevation and transfer to a recipient location. Pedicle grafts developed adjacent to the recipient bed are termed local flaps. They represent one of the most practical methods of closing defects that cannot be approximated by simple undermining and suturing. The effective use of these flaps usually depends on forming a flap in a neighboring area in which loose elastic skin prevails. Any secondary defect created by the transfer of the flap to the defect can be closed directly. Local flaps are both simple and economical to perform. They are more likely to maintain a similar pattern of hair growth and color than distant flaps. Local flaps have been effectively used to close defects in dogs, cats, birds, and other species. The 90° transposition flap is particularly useful in this context.

Local flaps are classified according to their method of transfer: flaps that advance in a forward direction are *advancement flaps* and those that rotate or pivot into position are *rotating flaps*. Most local flaps are based over the subdermal plexus circulation unless a direct cutaneous artery and vein are fortuitously included in the base of the flap.

Ideal donor areas have ample skin available to elevate a flap without creating a secondary defect (donor bed) unamenable to simple closure. Donor sites subject to excessive motion and stress should be avoided whenever possible, as they are prone to wound dehiscence or can compromise local mobility. Exceptions include cases in which closure of a wound for the protection of exposed structures has priority over the creation of a secondary defect. The secondary defect, in turn, can be closed by undermining and primary closure, a second flap, a free graft, or healing by second intention.

Local skin tension (inherent skin elasticity) is assessed simply by grasping and lifting the skin around a problematic wound. A ridge of elevated skin is a potential donor source for elevation of the transposition flap. Pushing the peripheral skin toward the center of a defect is the means of determining the possible use of advancement flaps.

Local flap procedures begin with assessment of lines of greatest versus least tension. Local flaps are designed to advance or rotate into place. An advancement (sliding) flap is developed parallel to the lines of *least* tension, to facilitate its forward stretch over the wound. A 90° transposition flap is aligned parallel to the lines of greatest tension, to obtain the bulk of the flap required to cover the defect. When the transposition flap is rotated into place, the donor site can be closed directly because minimal tension lines are perpendicular to the suture line.

Skin Folds: A Donor Source for Transposition Flap Development

Skin folds are natural sites of redundant loose skin for possible transposition flap development. Their presence varies with the individual patient and breed. The vulvar fold and facial folds (brachycephalic breeds) are two common examples (Plates 51 and 192). Other examples reported include the use of the hindlimb skin folds as dorsal advancement flaps and the use of the axillary skin folds as dorsal rotational flaps (Dunn et al. 2011; Nevil 2010). Lacking direct cutaneous vessels, care is required to preserve the subdermal plexus flap circulation and minimizing the flap length required to close the skin defect.

Factors that maximize the circulation to the pedicle graft should be considered during flap planning. Large flaps should include a direct cutaneous artery and vein whenever possible. Unfortunately, the consistent development of axial pattern flaps requires predictable anatomic landmarks and proper patient positioning. When possible, it may be beneficial to position the base of local flaps in the direction of known, direct cutaneous vessels arborizing in their general vicinity, thus improving the perfusion pressure to the pedicle graft.

Increasing the width of a pedicle graft does *not* increase its total surviving length. Flaps created under the same conditions of blood supply survive to the same length regardless of flap width. Increasing the width of the pedicle graft only permits the chance of including direct cutaneous vessels in the flap. Moreover, the cutaneous circulation differs regionally and a set length/width ratio is not applicable. Narrowing of a pedicle can reduce blood perfusion to the body of the flap and increase the likelihood of necrosis. Procedures that narrow the pedicle, such as the back-cut technique (counter-incisions), are best avoided. Axial pattern flaps are an exception to this rule, as long as the direct cutaneous artery and vein are preserved. Creating unduly long subdermal plexus flaps also can result in necrosis. As a rule, the author recommends the following:

- Create flaps with a base slightly wider than their body to avoid inadvertent narrowing of the pedicle
- Limit flaps to the length required to cover the recipient bed without undue tension. When possible, shorten the length of the flap to improve the chance of complete survival

Two or more small flaps may be preferable to a single, large pedicle graft whose effective circulation at the end of the flap may be questionable.

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Keep It Short

A key point in skin flap survival is to *keep the flap as short as possible* to close a given wound without excessive tension.

- If there is sufficient skin laxity at the distant end of the defect, the flap can be reciprocally shortened with a scalpel blade
- When examining a defect, portions of the open wound may be closed by simple apposition; this is especially useful for the area distant to the donor area of the flap

Closing portions of the wound by simple suture closure in turn will require a smaller, shorter flap to close the remaining portion of the defect (see Fig. 11-1).

The surgeon should consider the use of bipedicle flaps when longer flaps are required. A "delay procedure" should be considered when there is a concern regarding the flap's circulation and survival if transferred in a single stage to the recipient site (see Chapter 12). Careful planning and meticulous, atraumatic surgical technique are necessary to prevent excessive tension, kinking, and circulatory compromise to the flap. An alternative to improve the length of flap coverage is to consider prestretching the flap area prior to transfer (see Plate 36).

All measurements of the defect and proposed flap are recorded in centimeters. A flexible sterilized centimeter ruler is commonly used to measure flap dimensions, although some surgeons will use a sterile strip of umbilical tape or string to facilitate the measurements needed for flap development. As a precaution, a cloth or foam-rubber template of the flap can be made to represent the proposed dimensions of the defect and the additional skin required for the flap to reach the recipient bed from the proposed donor site. The flap template is positioned over the defect, and the base of the flap model is held in a fixed position as the model is transferred to the proposed donor site. This procedure is repeated until the template is an accurate model for successful flap transfer. The flap is drawn on the skin with a sterile surgical marking pen to provide reference lines for the skin incisions. Once one becomes familiar with certain flap techniques, the measurements can be drawn directly on the skin without resorting to the templates.

Atraumatic surgical technique is essential to the successful execution of local flaps. Their comparatively limited blood supply from the subdermal plexus requires great care in their development and transfer. Skin hooks and Adson-Brown forceps are best used to manipulate the skin flaps. In general, flaps should be kept as short as possible in order to ensure optimal perfusion to the distant edge.

General Guideline for Subdermal Plexus Flap Length

Based on axial pattern flap studies, approximately 50% of an axial pattern flap will undergo necrosis with loss of the direct cutaneous arterial circulation. In other words, the subdermal plexus blood supply is capable of maintaining circulation to half of the length of an axial pattern flap. This factual information can serve as a guideline for flaps developed in a given body region. If you learn the guidelines of axial pattern flap development, you also know the relative guidelines of subdermal plexus size in the given area of the body (half the length of the axial pattern flap anatomic guidelines).

The Fallacy of the "Length-to-Width" Ratio (Fig. 11-2)

All surgeons would like to have a guideline to safe skin-flap development. As a result, the concept of a mathematical guideline using a proportional "length-to-width" ratio was proposed in the human surgery literature. Ratios of 3 : 1, 2.5 : 1, and 2 : 1 were suggested as a safe guideline for flap development. For example, a 3 : 1 ratio indicated that the flap length should be no longer than three times the flap width.

- A key research paper (Nathanson and Jackson 1975) on dogs proved the following: flaps of the same length but varying in width (based on the same subdermal plexus blood supply) essentially had the same survival areas (comparable areas of necrosis). More simply stated, length-to-width ratios are a fallacy as a safe and accurate guideline to flap development.
- Unlike human reconstructive surgery, veterinarians face the challenges associated with surgery on a variety of breeds and species. In lecturing to veterinarians, I discuss the concept of "flap proportion." For example, a 10 cm-long flap is considered large in a 3 kg Chihuahua and small when dealing with a 75 kg Irish Wolfhound. This form of assessing the appropriate-sized flap that is likely to survive comes only after extensive experience in creating skin flaps.
- There are also regional variations in skin circulation. Most notable is the fact the head has an excellent blood supply compared to the lower extremities and other body regions. Longer flaps in the facial area are more likely to survive compared to a similar flap elevated on the lower extremities.
- The island arterial flap, tethered by a single artery and vein, is another example where the concept of a length-to-width ratio does not apply.
- There is an option to improve circulation to skin flaps prior to flap transfer (see Chapter 12).

ADVANCEMENT FLAPS

The single-pedicle advancement flap, bipedicle advancement flap, and V–Y advancement flap are examples of pedicle grafts moved forward into a wound without lateral movement. The single-pedicle advancement flap (sliding flap) is probably the most common local flap employed in veterinary medicine because of its simple design and lack of a secondary defect requiring closure (Fig. 11-3). Paired single-pedicle advancement flaps can be employed to close

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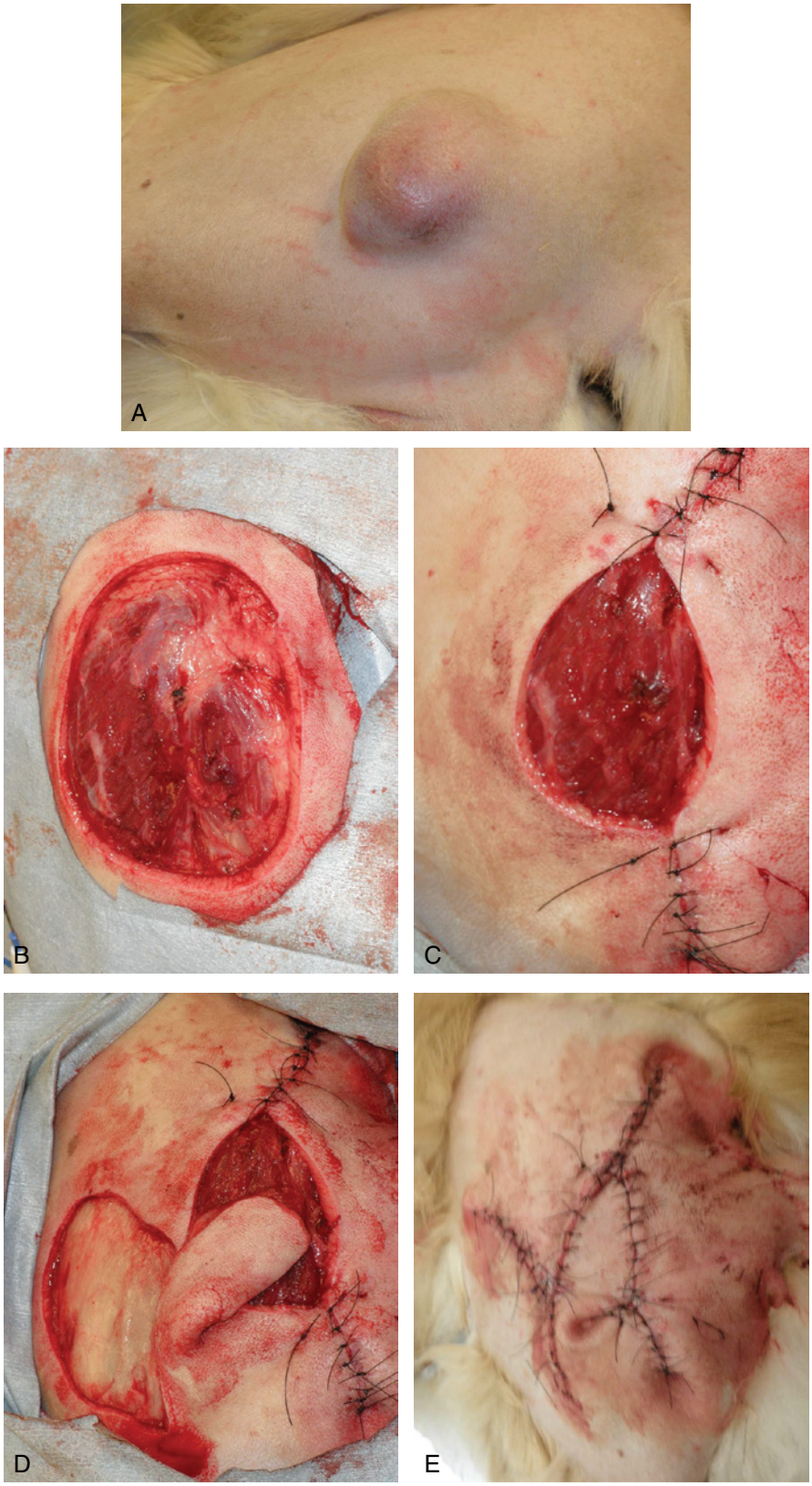


FIG. 11-1 (A) Mast cell tumor resection. Resection of the underlying musculofascial layer and a minimum 2 cm circular border of skin was performed to resect this growth. (B) Resection of a mast cell tumor involving the left caudolateral thigh. This area is particularly prone to dehiscence. Skin tension is best assessed with the patient standing, with the muscles under tension. Assessing skin tension in this area, when the muscles are relaxed, results in inaccurate assessment of skin tension. Under these circumstances, the incision may be under considerably more tension when the patient stands postoperatively, with a higher probability of wound dehiscence. (C) There is sufficient loose skin to close a portion of the proximal and distal portions of the surgical defect. Note that this results in a smaller surgical defect: a smaller transposition flap can be used to close the remaining defect. (D) A 90° transposition flap, developed from the looser skin of the anterior thigh, was secured to the remaining oval defect, completing the closure (E).

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FIG. 11-2 The fallacy of "length-to-width" ratios. Research in pigs and dogs compared the survival areas of skin flaps of the same length but with variable widths. In dogs, flaps were raised based on the same subdermal plexus circulation supplying the base of each flap. The results were surprising. Each flap had the same relative lengths of survival. In this illustration, the darkened end of the flaps represents tissue necrosis secondary to ischemia. Perfusion pressure through the subdermal plexus could not sustain the terminal portion of each flap. Creating a wider subdermal plexus flap does not improve survival.

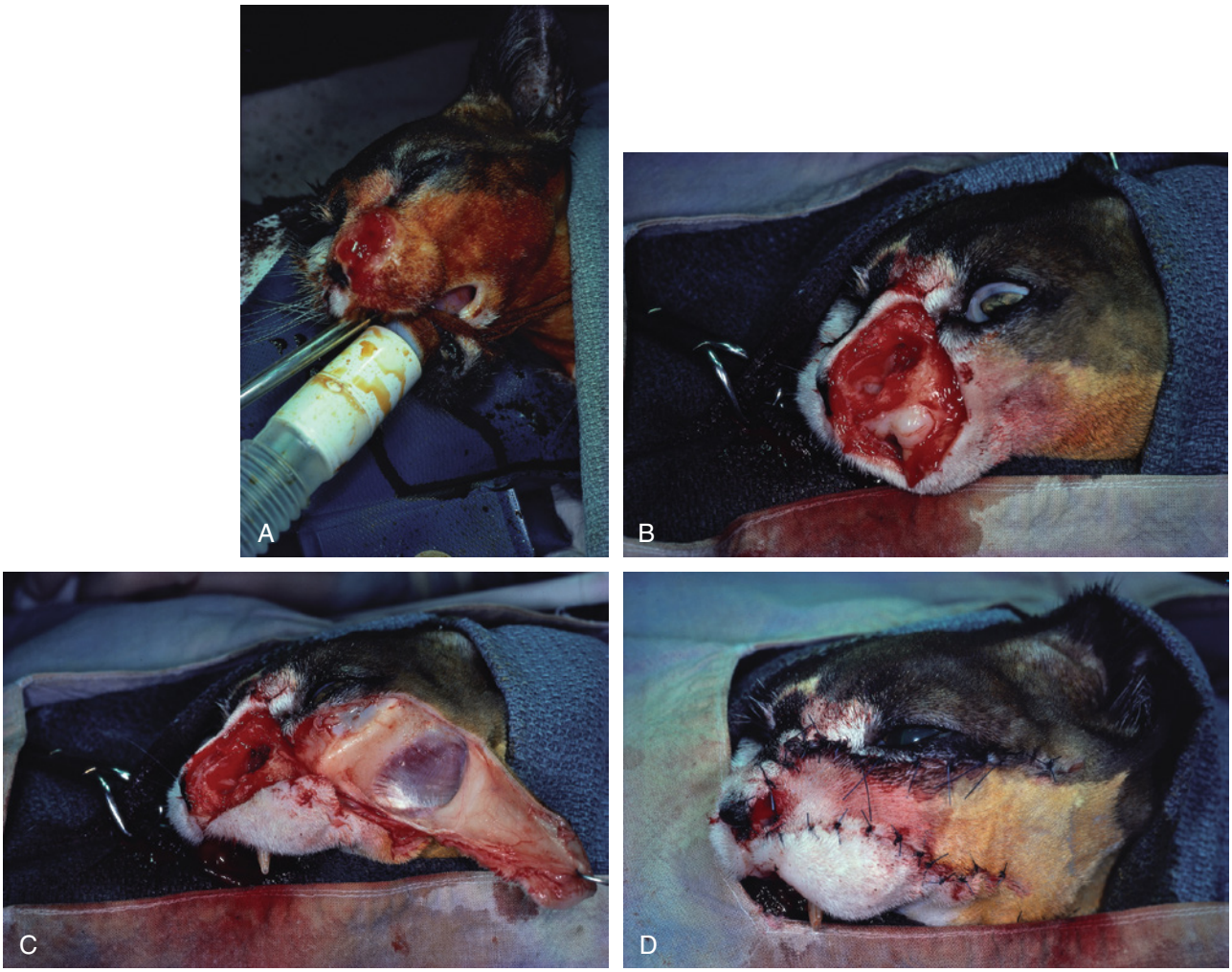


FIG. 11-3 (A) Squamous cell carcinoma involving the left nasal planum and adjacent skin. (B) Wide resection of the mass, including underlying bone. (C) Closure of lower gingival–labial mucosal defect. Staged elevation of a single-pedicle advancement flap below the platysma muscle layer. (D) Closure of this wound, with the advancement flap, underscores the considerable cutaneous elastic advancement present in most feline patients.

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FIG. 11-4 (A) Bipedicle advancement flap used to cover a large skin defect overlying the calcaneus. A Schroeder-Thomas splint was used to immobilize the tarsal area until incisional healing was complete. (B) A release incision is a bipedicle advancement flap by design. Note that the flap provides durable full-thickness skin coverage over this potentially problematic bony prominence. The exposed lateral (donor area) and medial granulation beds quickly healed by second intention.

square or rectangular defects, resulting in an H closure design (H-plasty) (see Plate 40). V–Y advancement is a triangular single-pedicle advancement technique primarily employed to relieve tissue tension; it has limited efficacy in wound closure.

The bipedicle advancement flap is constructed by making a skin incision parallel to the long axis of a defect, with a flap width generally equal to the width of the defect (see Plate 41). The undermined skin segment is advanced into the recipient bed. The bipedicle advancement flap has the advantage of two sources of circulation to maintain a longer flap body. The relaxing (relief or release) incision used to aid in wound closure is a bipedicle advancement flap by design (Fig. 11-4) (see Plate 23).

It must be noted that advancement flaps, despite their simple design and application, have limitations that preclude their routine use. The advancement flap primarily relies on wound coverage by *stretching* over the defect. As a result, an opposing elastic retraction occurs along the length of the flap. Excessive retraction can promote dehiscence or distortion of the distant wound margin. This must be anticipated before a single-pedicle advancement flap is employed in cases in which postoperative tension could distort neighboring structures (e.g., eyelid margins). In these areas, a transposition flap would be a better option.

The single-pedicle advancement flap primarily closes wounds by stretching over the defect. Postoperatively, the collagen fibers will exert a traction force that has the potential to distort the recipient bed. The bottom line is to use this flap with caution around areas where mild retraction of the flap could distort function. This problem is most commonly noted when a single-pedicle advancement flap is elevated perpendicular to the eyelid margin to close a problematic cutaneous eyelid defect. Consider the use of a 90° transposition flap in its place. (Also see Plate 26 for options to counter tension with skin advancement.)

ROTATING (PIVOTING) FLAPS

Rotation flaps, transposition flaps, and interpolation flaps are the three basic flaps that rotate on a pivot point (Plates 42–52). The rotation flap is a semi-circular flap that rotates into the adjacent recipient bed (Fig. 11-5) (Plate 48). Single or paired flaps can be employed to close triangular defects. As a general rule, no secondary defect is created with the rotation flap in the dog or cat.

The transposition flap is a rectangular pedicle graft commonly rotated within 90° of the wound's axis (Fig. 11-6) (Plates 42 and 43). The right-angle design can be modified to create a flap using donor skin oblique to the long axis of the defect (Plate 44). The transposition flap is the most useful of the rotating flaps (Figs 11-6–11-17).

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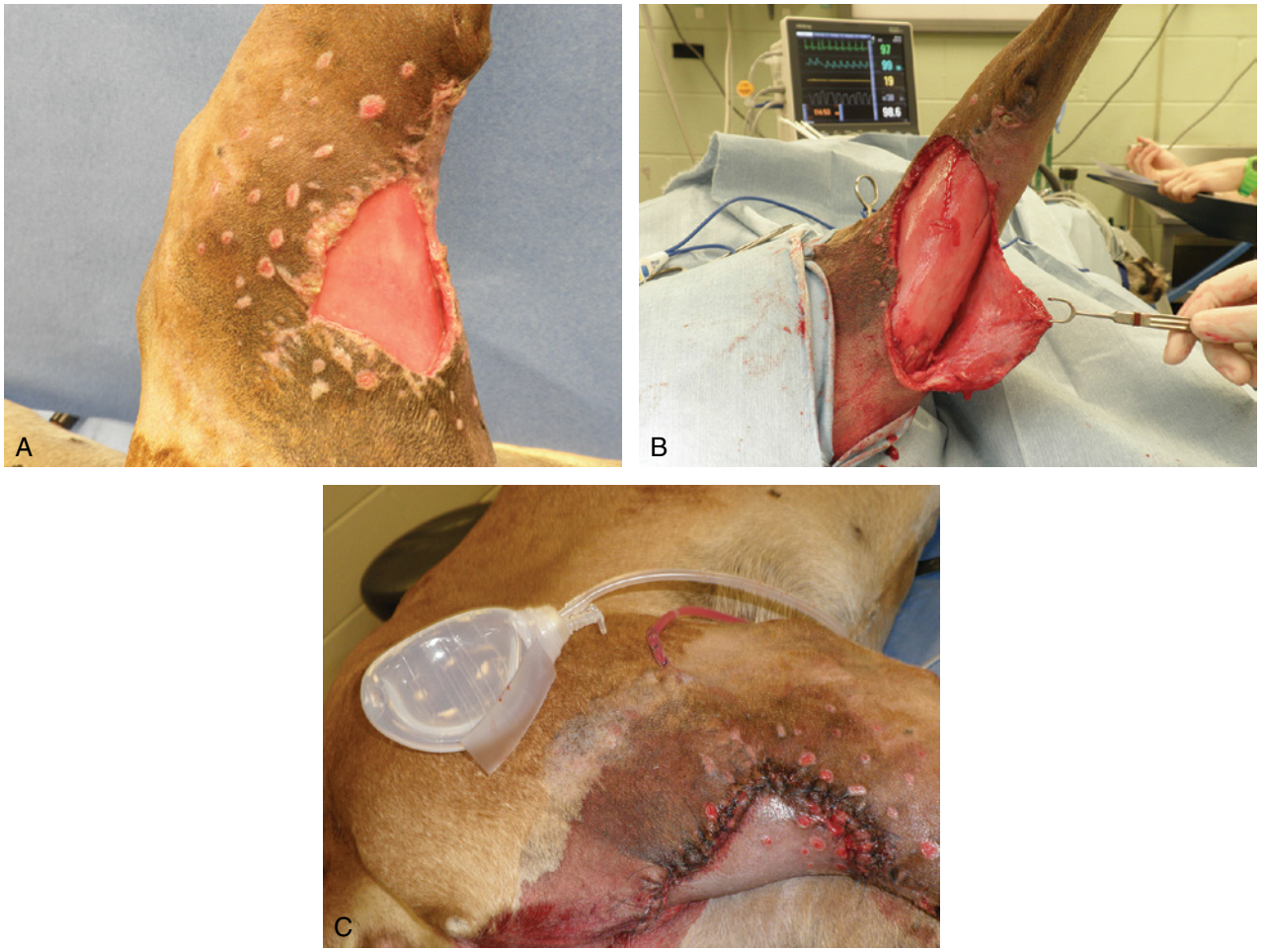


FIG. 11-5 (A) Surgical dehiscence after resection of a mast cell tumor in the popliteal region of the right hindlimb. Note the multiple release incision scars in an attempt to reduce incisional tension. This skin is best avoided for skin-flap development. (B) Elevation of a rotational flap from the proximal and medial aspects of the thigh. (C) Completion of the closure. The Jackson-Pratt drainage system is an important component of wound closure, to prevent fluid drainage between sutures and to secure the flap's dermal surface contact to the underlying wound bed.



FIG. 11-6 (A) Skin loss over the calcaneus in a Dobermann. Skin loss of this magnitude over a bony prominence is unlikely to heal by second intention without surgical intervention. (B) Sufficient circumferential skin was available to facilitate closure of this defect using a 90° transposition skin flap. The donor area closed primarily. See Figure 11-4 as an alternative option, depending on the availability of loose elastic skin.

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FIG. 11-7 (A) Cutaneous neoplasm involving the distal left tibiotarsal area (arrows). (B) Excision of the mass. (C) Rotation of a 90° transposition flap. (D) Closure of the donor and recipient beds. Developed after careful measurement, the transposition flap can be effectively employed for many of the smaller to moderate-sized defects of the limbs.

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FIG. 11-8 (A) Antecubital skin defects can be challenging to close. (B) Marking pen used to outline a 90° transposition flap parallel to the long axis of the limb. (C) Successful closure. An Elizabethan collar was used to prevent licking. Severe exercise restriction was imposed until suture removal 2 weeks later.

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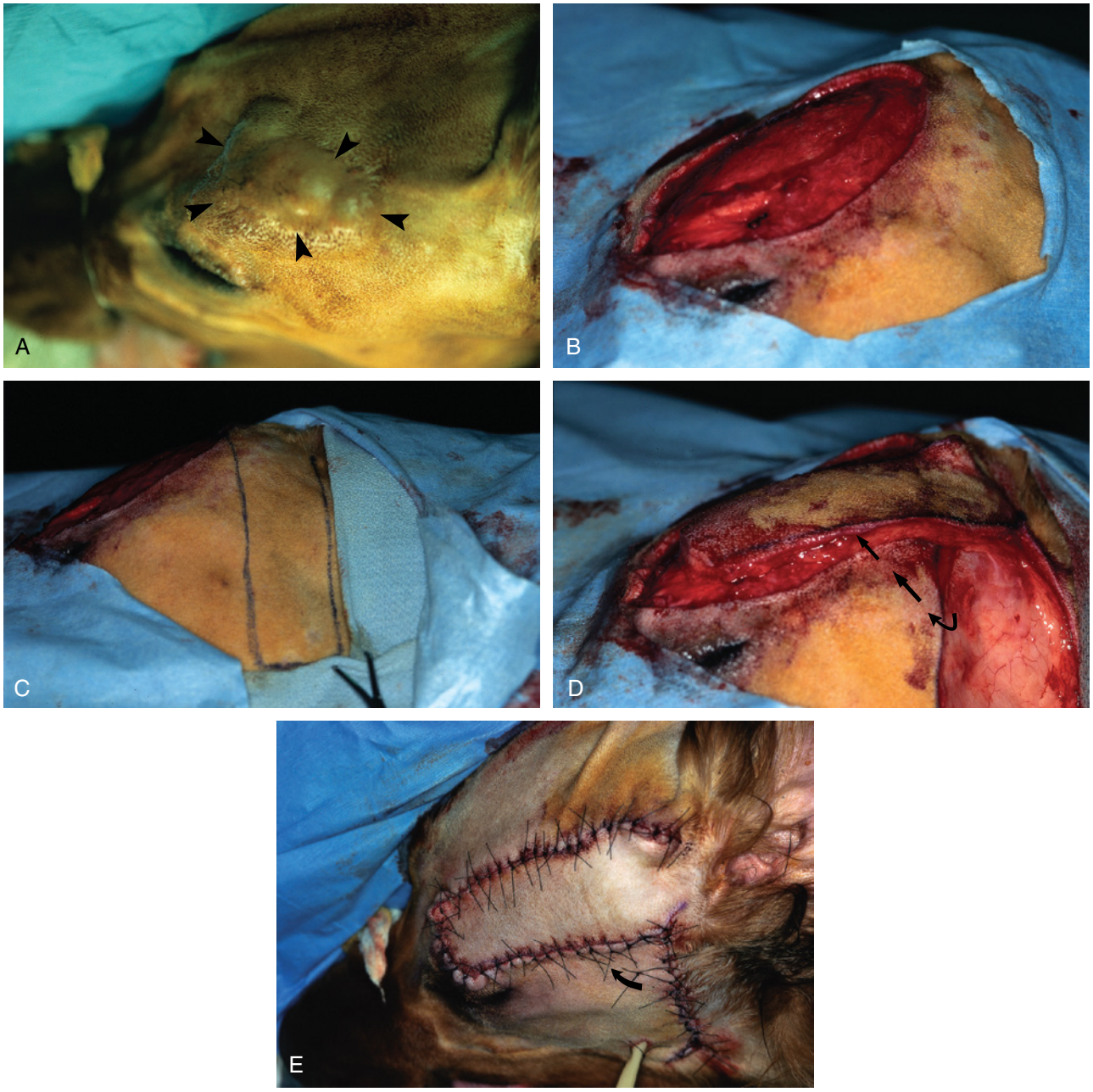


FIG. 11-9 (A) Expanding granulomatous mass (arrows) in a 1-year-old Irish setter. (B) Mass resection. (C) Outline of a 90° transposition flap along the left lateral facial area. (D) Rotating the flap into position. Based on local tissue elasticity, the skin flap could be shortened by 2 cm to help ensure complete flap survival. (E) Closure was achieved without distorting the function of the upper eyelid. Due to the surgical dead space, a drain is important to prevent seroma formation.

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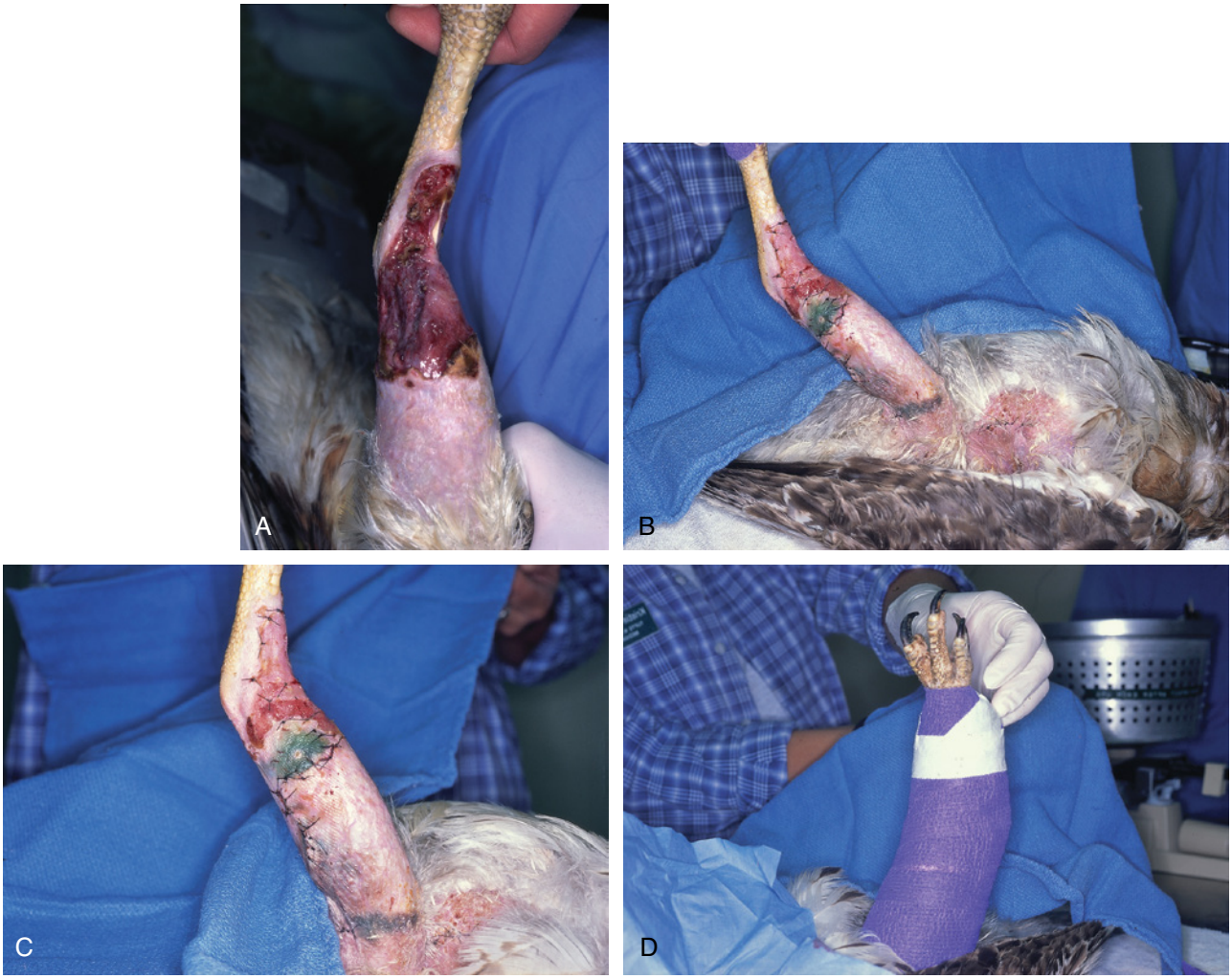


FIG. 11-10 (A) Limb wound in a red-tailed hawk. Open wound management was performed until a healthy granulation bed formed. (B) Closure of the wound was accomplished with a 90° transposition flap (upper area) and a full-thickness free graft (lower area). The free graft was harvested from the left lateral thorax. (C) Complete survival of the graft and flap. The small remaining defect healed by second intention. (D) The grafted leg was protected with a partial fiberglass cast. The rehabilitated hawk was later released. Note how flap and graft techniques are applicable to a variety of species.

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FIG. 11-11 (A) Mast cell tumor, left dorsolateral nasal area. (B) Surgical defect. (C) A 90° transposition flap is elevated perpendicular to the upper lip (arrow), taking advantage of the small area of elastic skin available in this tissue plane. (D) Successful closure of the surgical wound (see Plate 52).

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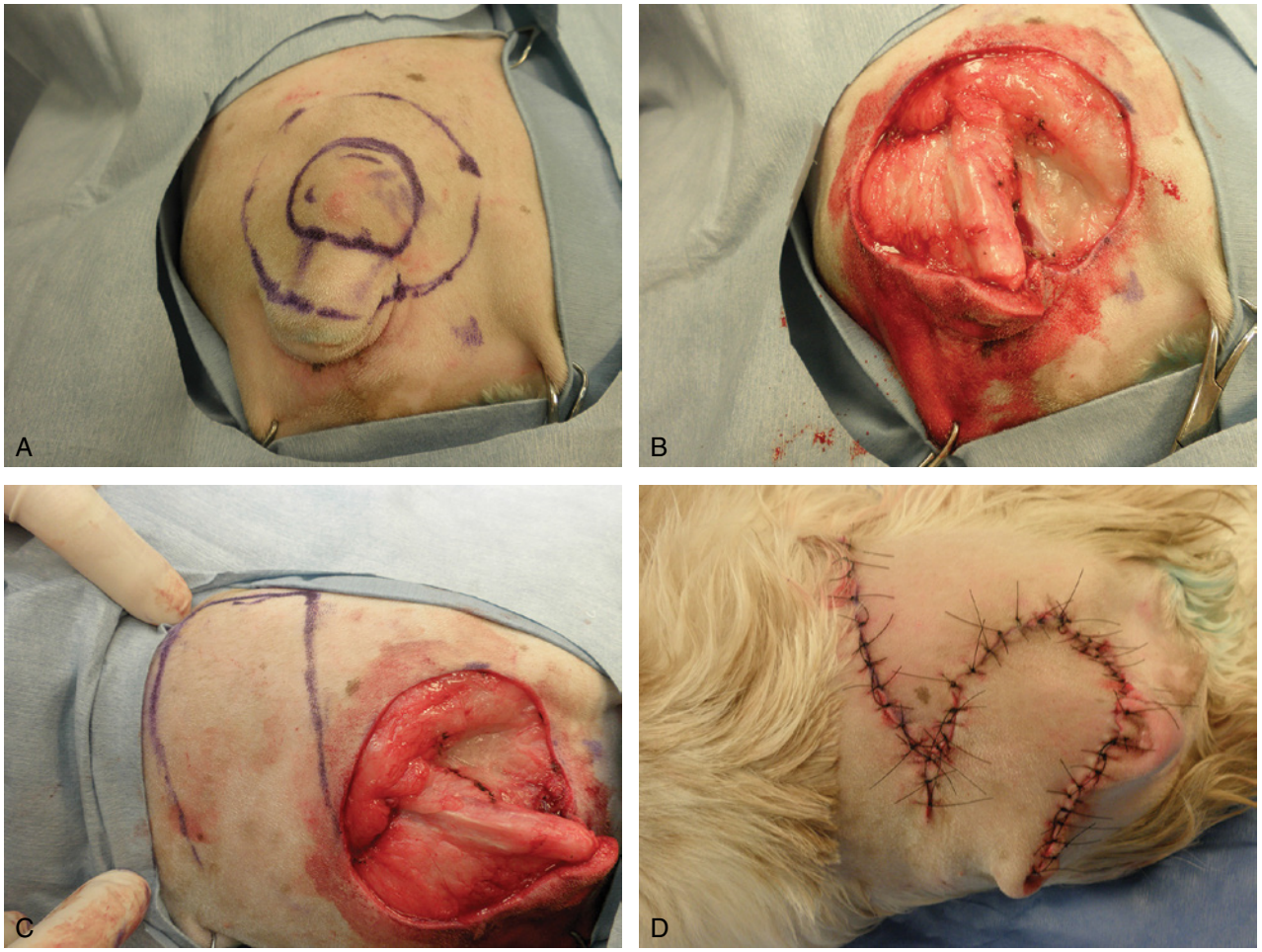


FIG. 11-12 (A) Mast cell tumor involving the dorsal tail base. A surgical gentian violet marking pen outlines the visual and palpable border of this growth (inner circle and the 2 cm border for tumor resection). (B) Resection includes resection of the subcutaneous tissue layer and adjacent muscle fascia overlying the tail. (C) Outline of the 90° transposition flap in relation to the long axis of the recipient bed (defect). (D) Rotation and closure.

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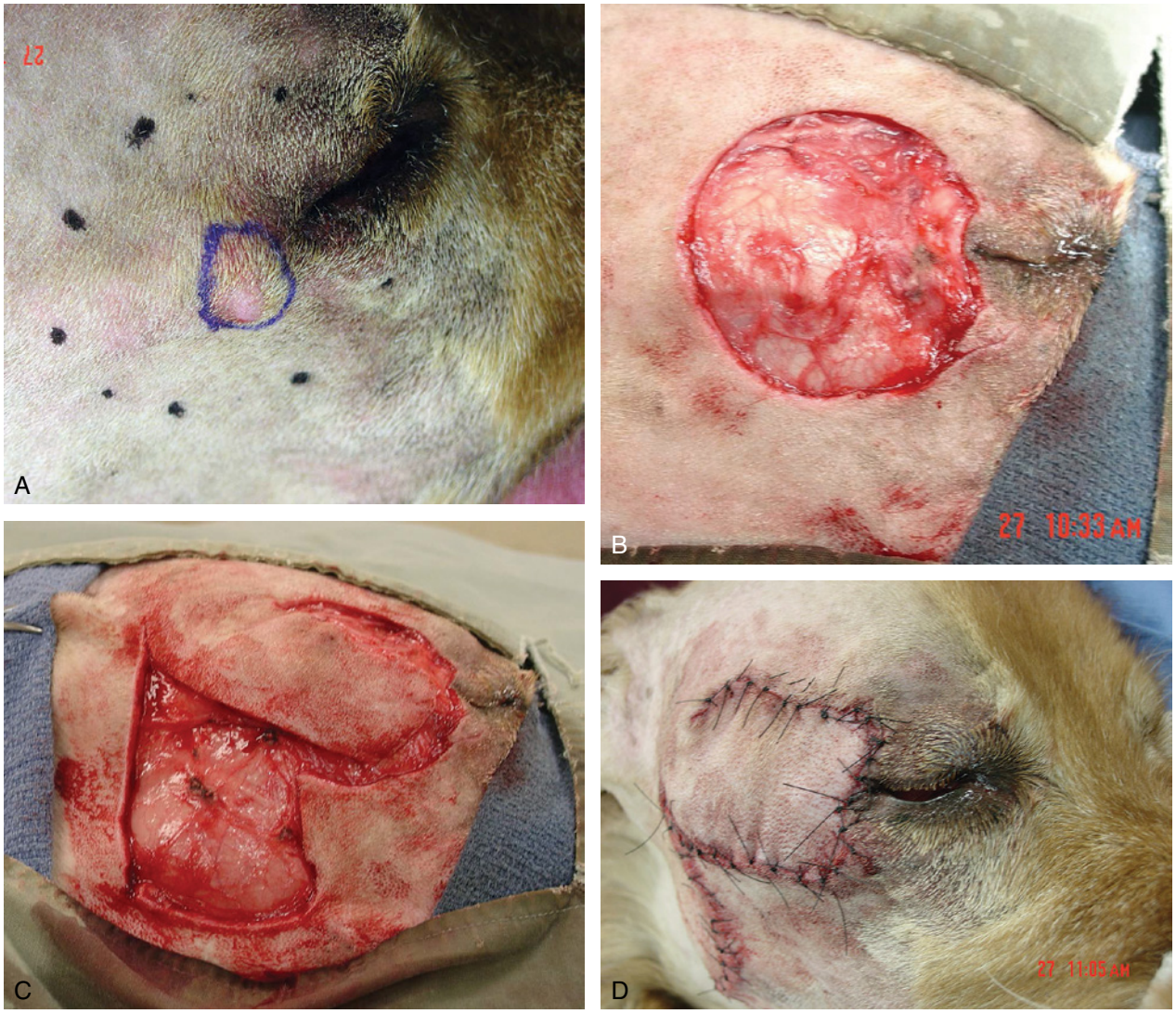


FIG. 11-13 (A) Mast cell tumor adjacent to the right lateral canthus. The blue circle is the visual outline of this tumor. The outer dotted circle represents the 2 cm halo of the tumor resection. (B, C) The surgical defect (B) is closed with a right-angle transposition skin flap. (D) Completion of the closure after removal of this grade II mast cell tumor.

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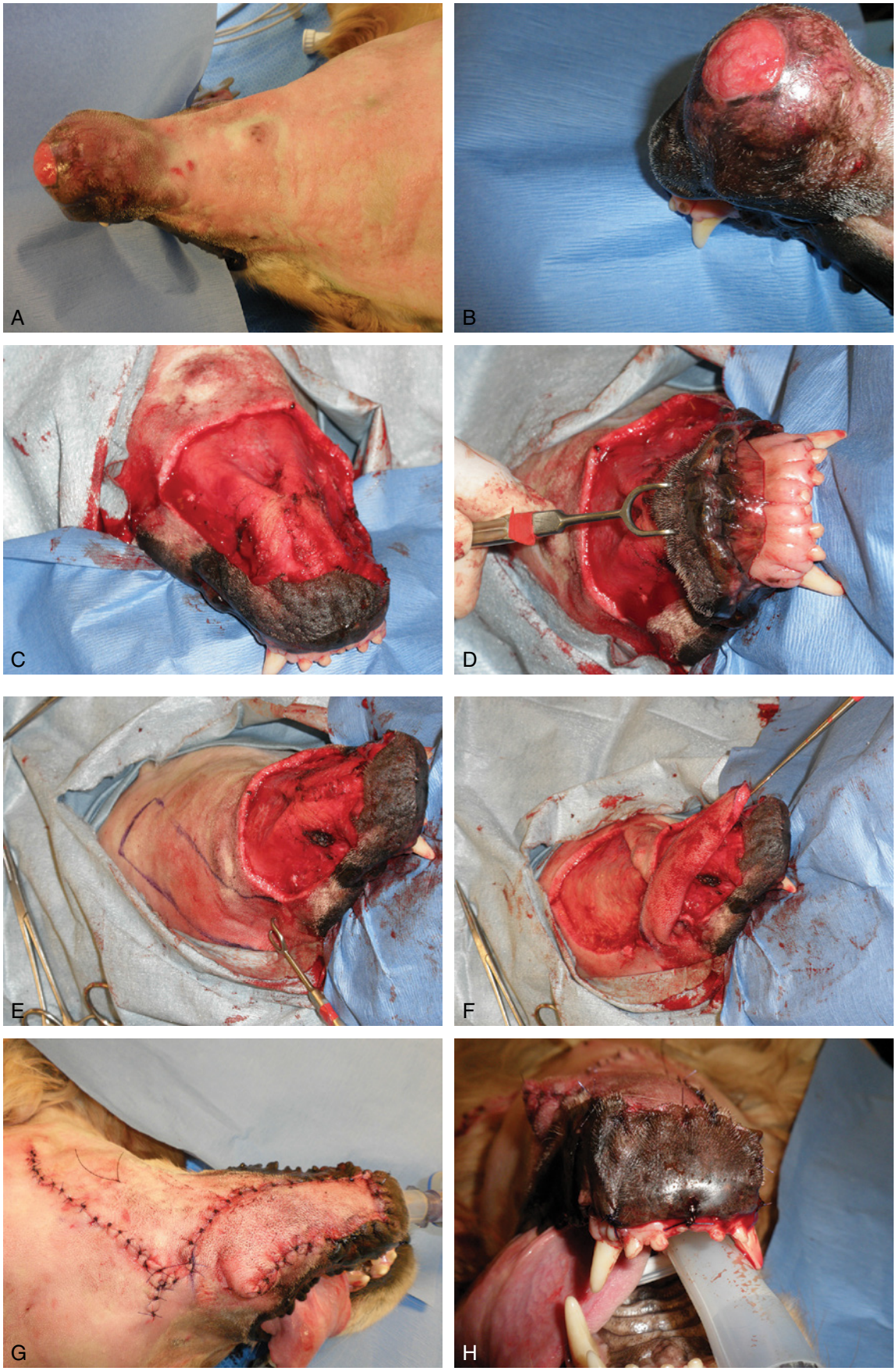


FIG. 11-14 (A) Adenoma involving the anterior mandibular skin (chin) of this geriatric golden retriever. (B) Close-up view of this expansile lesion. (C) Excision of the mass. (D) Note that the remaining labial tissue is susceptible to distortion if wound closure results in excessive traction tension, being simulated here by the skin hook. (E) Outline of the transposition flap using a surgical marking pen. (F) Flap elevation and rotation into the surgical defect. (G) Completion of the closure. (H) Rostral view of the lower lip. An absorbable suture was placed in the lip to support it postoperatively during the healing process (see Plate 50).

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FIG. 11-15 (A) Left lateral facial area skunk-bite wound resulting in extensive skin necrosis. (B) Debridement of the necrotic wound. (C) A transposition flap, developed from the lateral base of the ear, was rotated dorsally to close the upper "half" of the wound. The loose elastic lower facial tissues were used to close the ventral portion of the bite wound. (D) Completion of the wound closure and donor area of the skin flap. (E) The patient 1 week later. Swelling has declined and the patient made a complete recovery.

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FIG. 11-16 (A) Wide resection of a carcinoma involving the left orbit in a cat. (B) A local transposition flap, developed from the lateral facial skin, was combined with advancement of the remaining facial skin to close this large defect. (C) This is far simpler to accomplish compared to the common alternative, the left auricular axial pattern flap. This, in turn, reduces the surgery and anesthesia costs to the pet owner (see Plate 45).

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FIG. 11-17 (A) Soft tissue sarcoma involving the distal left hindlimb extremity of a geriatric dog. (B) Surgical defect. Options for closure would include healing by second intention, skin grafting, or the possible use of a local transposition flap. (C) Due to the limited skin available, a small transposition flap was used to close the central "third" of the surgical defect, thereby creating two smaller wounds. The skin margins of the flap can contribute to the processes of wound contraction and epithelialization. (D) The wound at 2 weeks; healing occurred approximately 2 weeks later with the protection of a reinforced bandage. (See Plate 46).

Z-plasty, a modification of the transposition flap, is discussed in Chapter 9. A modification of the transposition flap technique is exemplified by the forelimb fold flap (see Plate 49).

Wound Closure by Combining Techniques

When attempting to close larger wounds, local flaps alone or in combination with other techniques should be considered. A simple concept to consider is that a large wound can be subdivided into segments or territories. One portion of the wound may be closed with a skin flap while utilizing another closure option for the remaining area(s). There are a number of occasions where a single method of closure may not be an ideal option: Plate 45 demonstrates this concept. (See Figs 11-15 and 11-16.)

There is a practical consideration when using the transposition skin flap for closure of lower-extremity wounds. Although small transposition flaps can be developed parallel to the axis of the extremities (taking advantage of the limited loose circumferential skin), they may not be wide enough to completely close a problematic skin defect (see Fig. 9-2). However, the smaller flap can often be used to close the central portion of the wound to facilitate the healing process (Fig. 11-17) (see Plate 46).

The 90° transposition skin flap is by far the most useful flap technique available to close a variety of the small to moderate-sized problematic wounds.

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The interpolation flap is a rectangular flap rotated into a nearby, but not immediately adjacent, defect (see Plate 47). A portion of the flap must pass over the skin between the donor and recipient beds. The exposed subcutaneous surface of this flap segment is usually left open, although it may be covered temporarily with a free graft. This redundant portion of the flap is later excised once healing onto the recipient defect is complete. A second option is the use of a bridge incision, which discussed in Chapter 13, Plate 70. Interpolation flaps are uncommonly employed in veterinary medicine, although this general design is employed in tube flaps and some axial pattern flap techniques.

Think local flap first before considering more elaborate flap techniques. For example, a dorsal cranial defect can be closed by a caudal auricular axial pattern flap (CAAPF). Half the length of the CAAPF is needed simply to traverse the area between the base of the flap and the caudal border of the defect. In contrast, a smaller transposition flap developed adjacent to the pinna can cover the defect completely. The transposition flap is smaller, easier to elevate, and the time associated with skin closure is less (see Plate 45).

See Chapter 25 for additional clinical flap examples.

Suggested Reading

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Plate 40 Single-Pedicle Advancement Flap

DESCRIPTION

The single-pedicle advancement flap is the simplest of the local flaps by design. Flap width equals the width of the defect; flap length is dictated by the amount required to stretch and advance the flap into the defect without excessive tension.

SURGICAL TECHNIQUE

(A) The skin is gently grasped to assess regional skin tension. The index finger is used to push the skin toward the center of the defect to determine final flap orientation.

(B) Two slightly *diverging* skin incisions are made equal to the width of the defect in a staged fashion. The flap is carefully undermined and the skin progressively incised until the flap is sufficiently mobile to stretch over the defect.

(C) The flap is sutured into position to complete the transfer. Half-buried horizontal mattress sutures are placed in the corners of the flap to minimize circulatory compromise to the flap corners.

(D) An alternative technique is to use two single-pedicle advancement flaps, one on each side of the wound. This technique is called H-plasty based on the resulting H-shaped closure achieved.

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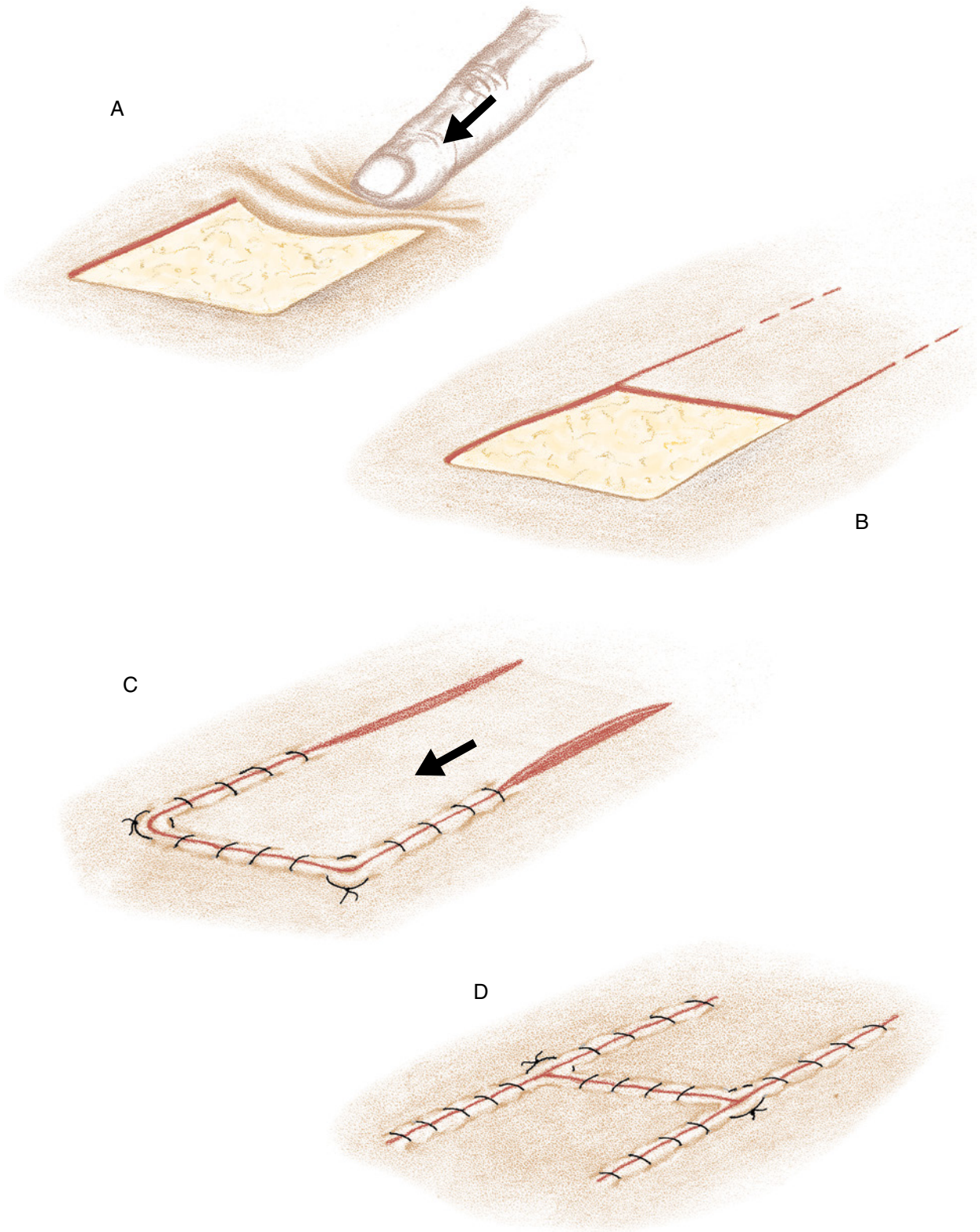
Although the single-pedicle advancement flap is a simple flap technique to master, it has significant limitations dictated by the availability of loose elastic skin immediately adjacent to the defect. The single-pedicle advancement flap does not bring additional "loose" skin to the wound site *per se*; successful closure requires the flap to stretch over the defect. There is a tendency for the advancement flap to retract due to the inherent elastic nature of the skin. This must be anticipated before it is used in areas where postoperative tension can distort neighboring structures (e.g., eyelid). Because the flap is supplied by the subdermal plexus, flap length should be kept to a minimum. H-plasty, using two shorter advancement flaps, may be advisable to avoid closure with a single long advancement flap. A disadvantage of H-plasty is the greater amount of suturing required and the formation of two "incisional intersects," which are more prone to local dehiscence.

Although the use of Burow's triangles has been advocated to prevent dog-ear formation and to improve flap mobility, they are rarely required to prevent dog-ears or puckers and are not effective in relieving tension. Only flaps created with the thicker, less elastic skin of the neck and back in the dog are likely to benefit most from their use in minimizing dog-ears. Even then, most dog-ears flatten in time without surgical removal.

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Plate 40



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Plate 41

Bipedicle Advancement Flap

DESCRIPTION

The bipedicle advancement flap is a local flap constructed with two bases or pedicles. Each pedicle is a source of circulation to the body of the flap. The circulation is derived from the subdermal plexus, unless a direct cutaneous artery is incorporated into one pedicle. The bipedicle advancement flap is constructed by making a skin incision parallel to the long axis of the wound, with the flap width generally equal to the width of the defect. The undermined flap is advanced into the recipient bed and sutured. The donor defect created is usually closed primarily.

SURGICAL TECHNIQUE

(A) Flap orientation is determined by the shape and location of the defect in relation to the availability of potential donor sites. It is generally preferable to develop bipedicle advancement flaps parallel to the long axis of the defect, taking advantage of areas where loose elastic skin prevails. Digital manipulation of the skin (arrows) is used to assess skin tension and the feasibility of using this technique.

(B) The proposed flap is drawn onto the skin with a marking pen. Flap width generally equals the width of the wound; flap length equals the length of the defect. However, avoid unusually narrow flaps that may have questionable circulation. Flap advancement (arrow) can be facilitated by curving the outer relaxing incision slightly outward so that the convex side of the incision is away from the defect. If the wound is a long-standing granulation bed, it may be necessary to excise the scar-laden inner border of the flap to improve its mobility.

(C) The flap is carefully undermined, advanced over the wound, and sutured into place (arrows).

(D) The secondary defect (donor bed) generally is closed by undermining the remaining skin border and closing the wound primarily.

COMMENTS

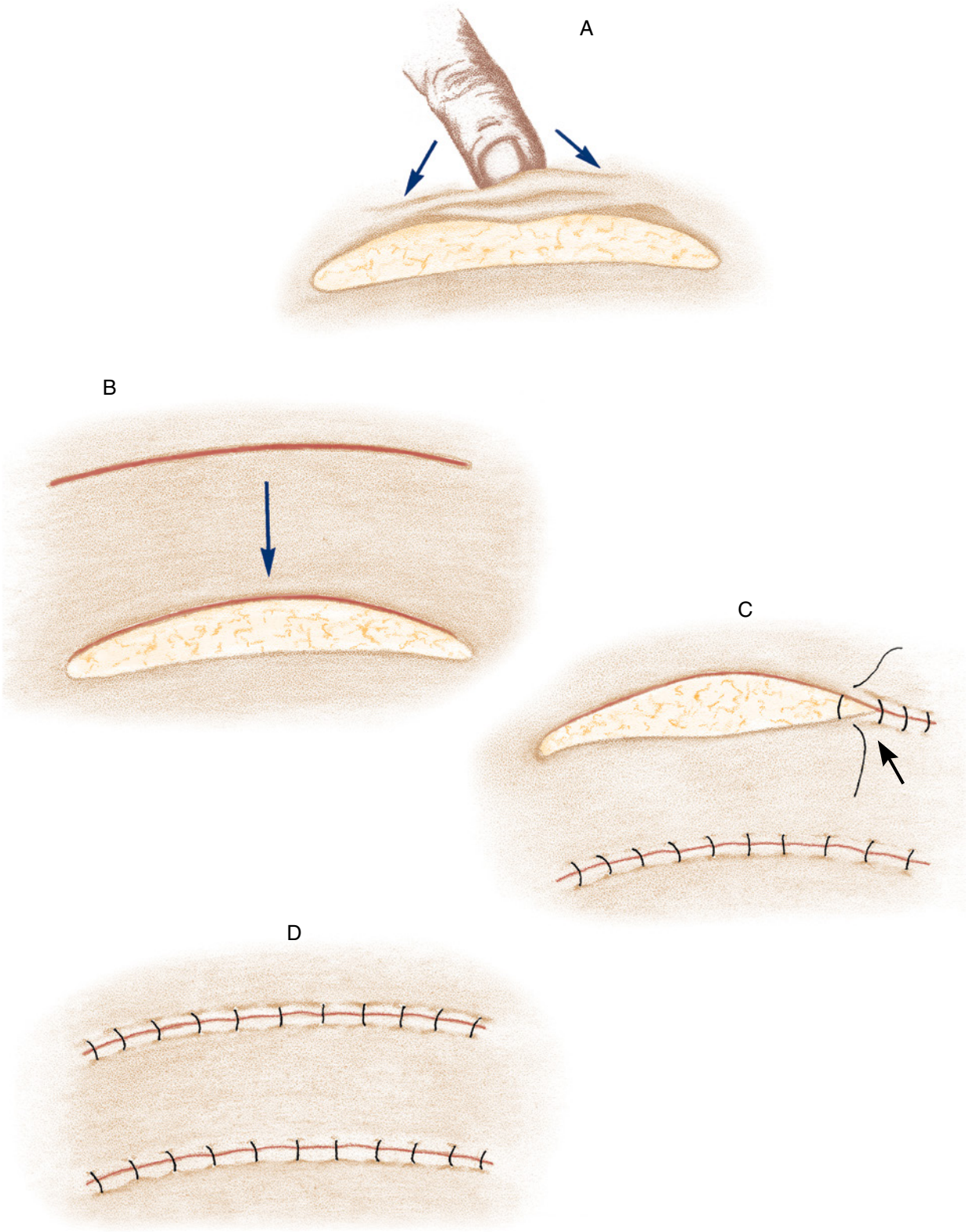
Bipedicle advancement flaps can be created on each side of a defect. Bilateral application of this flap may be advisable when the wound is too wide for unilateral application of this technique. Although bipedicle advancement flaps have two sources of circulation, the "central body" of the flap can undergo ischemic necrosis if flaps are excessively long. This may be avoided by creating flaps that are as short as possible, minimizing surgical trauma during flap elevation and transfer, and incorporating a direct cutaneous artery and vein into one pedicle when feasible. It may not be possible to close the donor site after flap transfer by undermining when there is a lack of loose elastic skin available. The area may be left open to heal by second intention, closed with a free graft, or closed with an additional local flap.

The relaxing or release incision employed to relieve tension on a closure site is a bipedicle advancement flap by design. Relaxing incisions are frequently left open to heal by second intention in those cases in which the excessive tension at the closure site is considered more important than the secondary defect created at another location. These secondary defects may be more suitable for contraction and epithelialization when they are in a body area less subject to trauma and have a better blood supply than the closure site in question. (See Plate 23 in Chapter 9.)

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Plate 41



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Plate 42 Transposition Flap (90°)

DESCRIPTION

The transposition flap is a local flap technique with a wide variety of uses. It is a rotating flap that is applicable in most body regions in the dog, cat, and other species, including birds. When it is based on the subdermal plexus as its primary source of circulation, its size is more limited than that of axial pattern flaps.

SURGICAL TECHNIQUE

(A) Local skin tension is assessed by grasping between the thumb and index finger the skin adjacent to the defect to determine the laxity and elasticity present. The elevated skin fold indicates that a transposition flap can be created parallel to this cutaneous ridge without sacrificing the ability to close the donor bed.

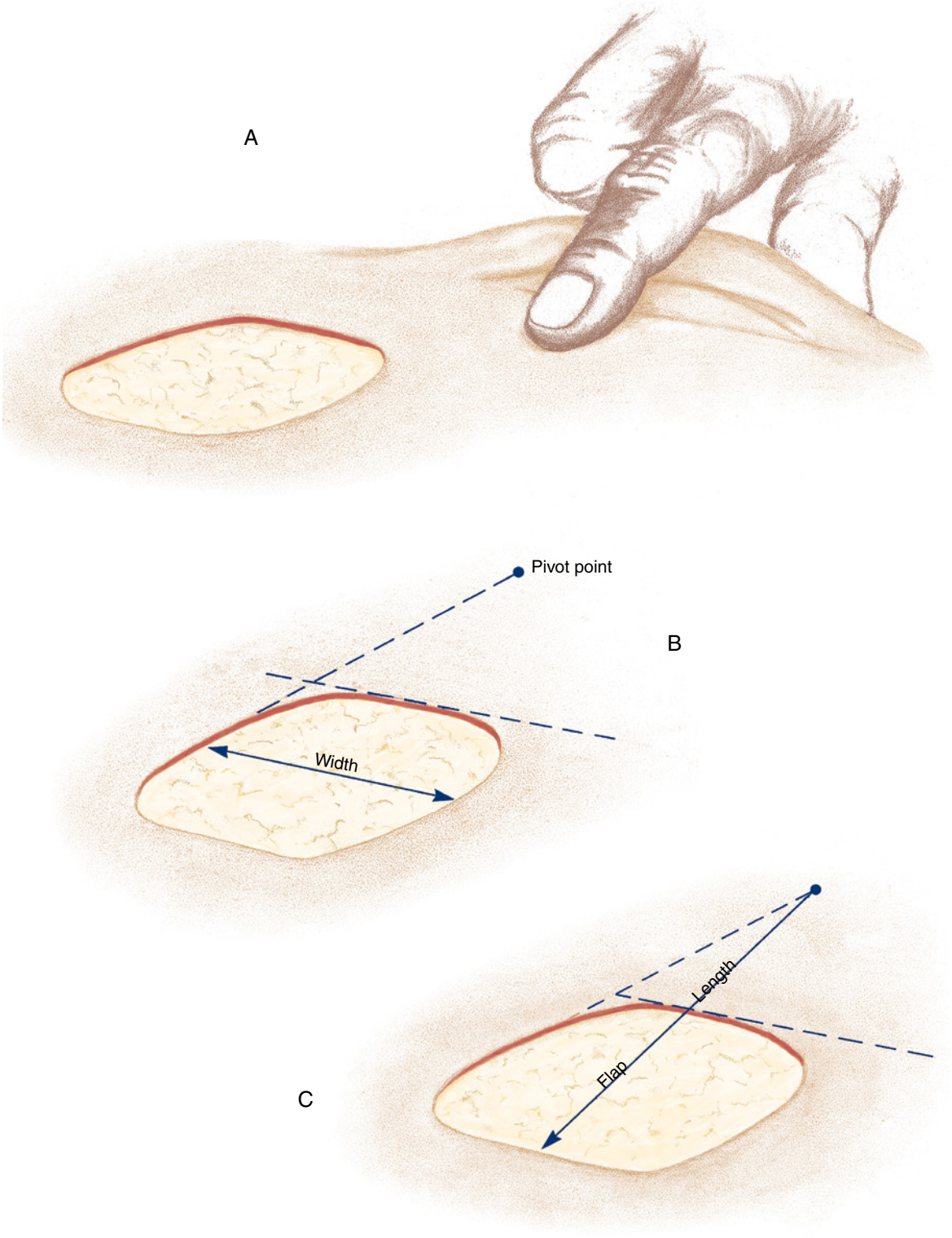
(B) The width of the flap, which equals the width of the defect, is measured and marked off along the baseline. This corresponds to the pivot point of the flap. The base or pedicle of the transposition flap is aligned along the lower border of this defect (upper dashed line). The transposition flap is developed within 90° to the long axis of the defect (lower dashed line), depending on the loose elastic skin available for wound closure.

(C) Flap length is determined by measuring from the pivot point to the most distant portion of the defect. This measurement, in turn, begins at the established baseline. Two parallel lines are drawn using the measured length dimension.

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Plate 42



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Plate 42

(Continued)

(D) The flap is drawn with a marking pen prior to incising the skin. (Note that the transposition flap shares a common border with the defect.) The skin is carefully undermined using Metzenbaum scissors. Thin triangular "tips" of skin created during the elevation of the flap are trimmed or rounded off, since they are prone to ischemic necrosis.
(E) The flap is sutured into place using a simple interrupted suture pattern.
(F) The donor bed is closed in a similar fashion. A half-buried horizontal mattress suture is used to appose the junction of the flap and donor bed closure.

COMMENTS

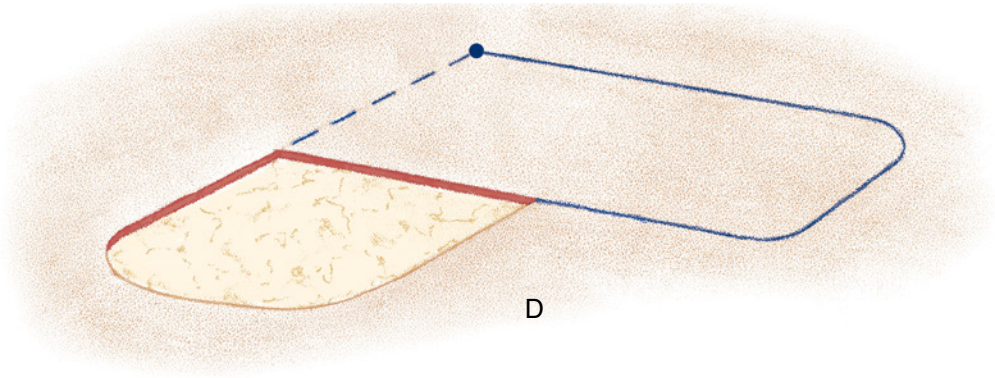
The transposition flap is a rotating flap by design and is considered by the author to be the most versatile of the local flaps for wound closure. Although transposition flaps can be pivoted up to 180° to cover a defect, loss of flap length occurs to a variable degree as it bends and kinks to extreme rotation. As a result, most transposition flaps are developed within 90° to the axis (length) of the wound. Transposition flaps bring additional skin to the defect, unlike the single-pedicle advancement flap, which relies on the stretching of elastic skin. For this reason, transposition flaps are best employed for wounds in which postoperative skin tension could cause distortion or compromise function. The transposition flap is adaptable to smaller defects of the limbs by developing the flap *parallel* to the length of the limb in order to take advantage of the limited circumferential skin laxity present in the dog and cat. While there is a certain degree of skin elasticity around wounds involving the trunk, which can compensate for small errors in flap dimension, measurements for flap development and transfer on the extremities must be precise. A 1 cm error in measurement can result in the inability to completely close the donor or recipient site.

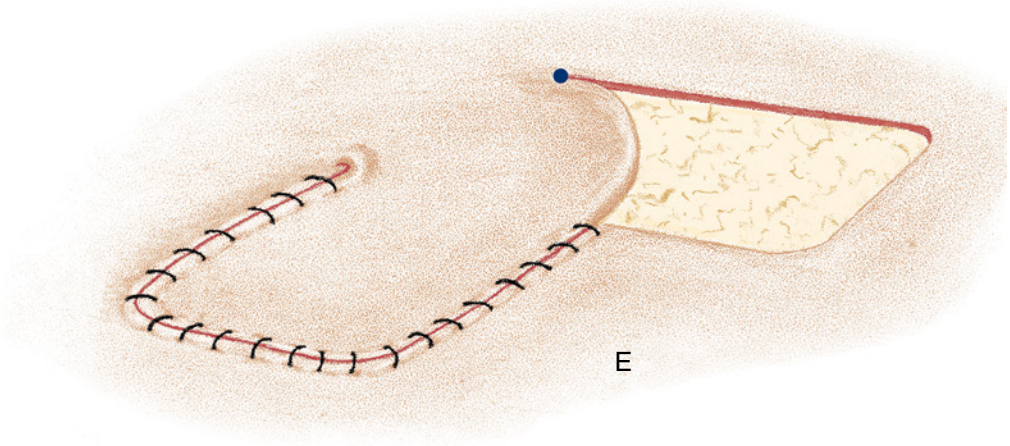
On occasion, the surgeon may note a variable amount of skin elasticity along the distant border of the cutaneous defect. *Note*: whenever possible, it is advisable to shorten the premeasured flap accordingly to improve the probability of maintaining adequate circulation to the terminal flap border.

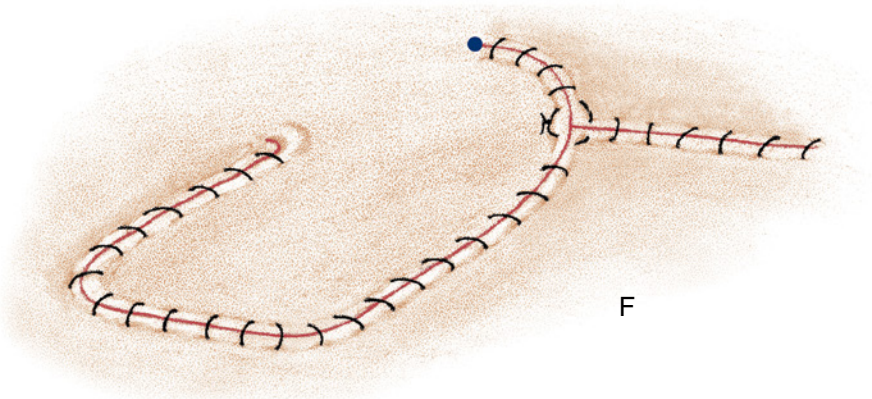
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Plate 42







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Plate 43

Transposition Flap (45°)

DESCRIPTION

The 45°-angle transposition flap is developed at a more acute angle to the axis of the defect compared to the preceding right-angle variation. Its use is more commonly associated with the closure of triangular defects.

SURGICAL TECHNIQUE

(A) Flap development is similar to the 90°-angle transposition flap. The flap is created at a 45° angle to the axis of the defect.
(B) The flap is pivoted and sutured into the prepared recipient bed.
(C) The donor site is closed primarily after undermining the bordering cutaneous tissue.

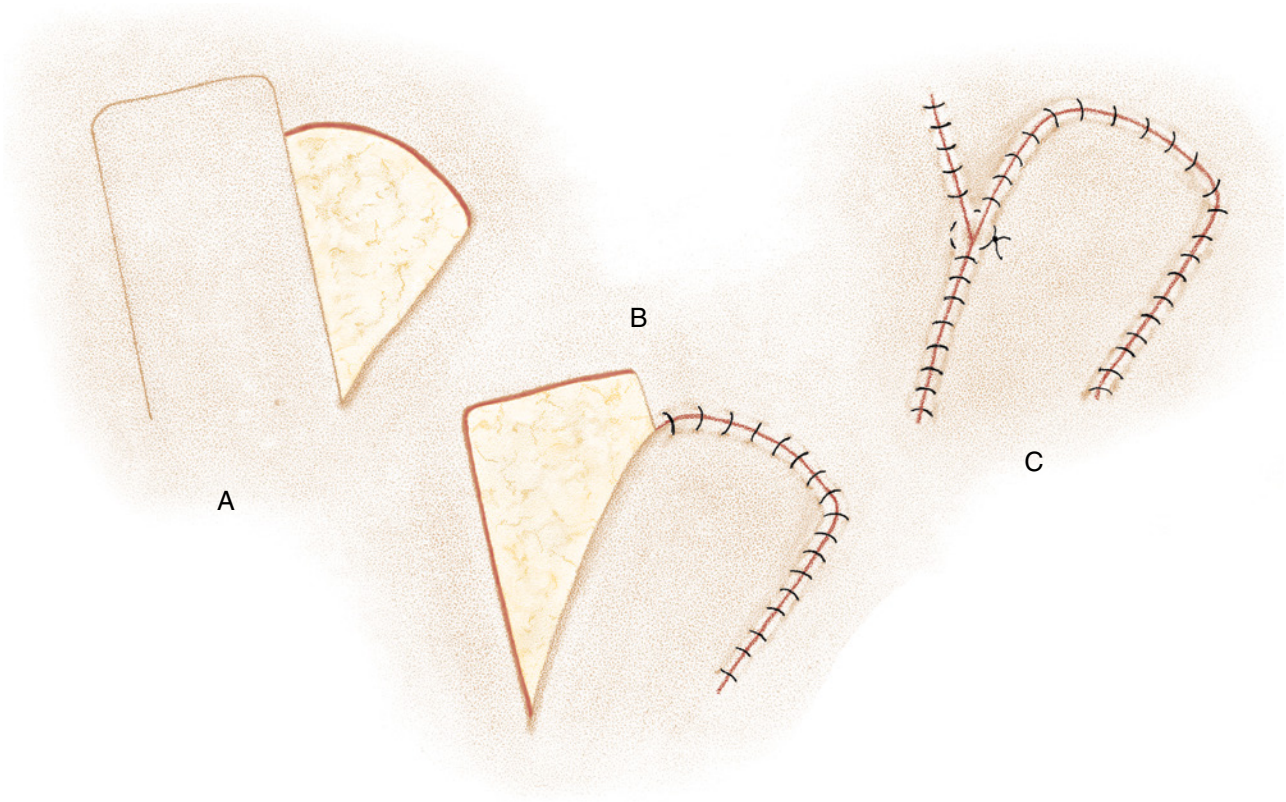
COMMENTS

The 45°-angle transposition flap variation generally is used to close triangular wounds where local skin immediately adjacent to this wound is ample to support its development. The 90°-angle transposition flap, however, has greater ability to bring additional loose skin into defects from its (slightly) more distant donor site. As a result, the 90° transposition flap is better able to close wounds that require more skin for closure or wounds in which wound tension must be avoided to prevent regional distortion and functional impairment.

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Plate 43



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Plate 44 Transposition Flap (Oblique Angle)

DESCRIPTION

As noted in Plate 42, the 90° transposition flap design is useful for a wide variety of defects. However, there are occasions where the ideal donor source of skin is more oblique to the long axis of the surgical defect. It is possible to alter the angle of the flap to take advantage of this donor area.

SURGICAL TECHNIQUE

(A) In this illustration, the available donor skin location is at a more oblique angle to the rectangular defect for flap development. The location of the flap base or pedicle is identified relative to the adjacent corner of the defect. The width of the defect is measured: from this corner the width measurement is marked on the skin where the base of the flap is established (dash line). The opposite corner of the base of the flap is the "pivot point." Measuring from the pivot point to the far corner of the defect determines the length of the flap (arrow). Two parallel lines are marked on the skin using this length measurement. A third line connects these parallel lines to complete the outline of the flap. Note the corners of the flap are slightly rounded to facilitate suturing. To facilitate flap transfer, the *lined area of skin* is resected to create a pathway for flap placement: this is a variation of the "bridge incision" technique (see Plate 65).

(B) The flap is elevated and transposed into the defect. If the flap length is excessive, a measured portion of the terminal flap can be resected.

(C) Completion of the closure and donor defect with a series of interrupted skin sutures.

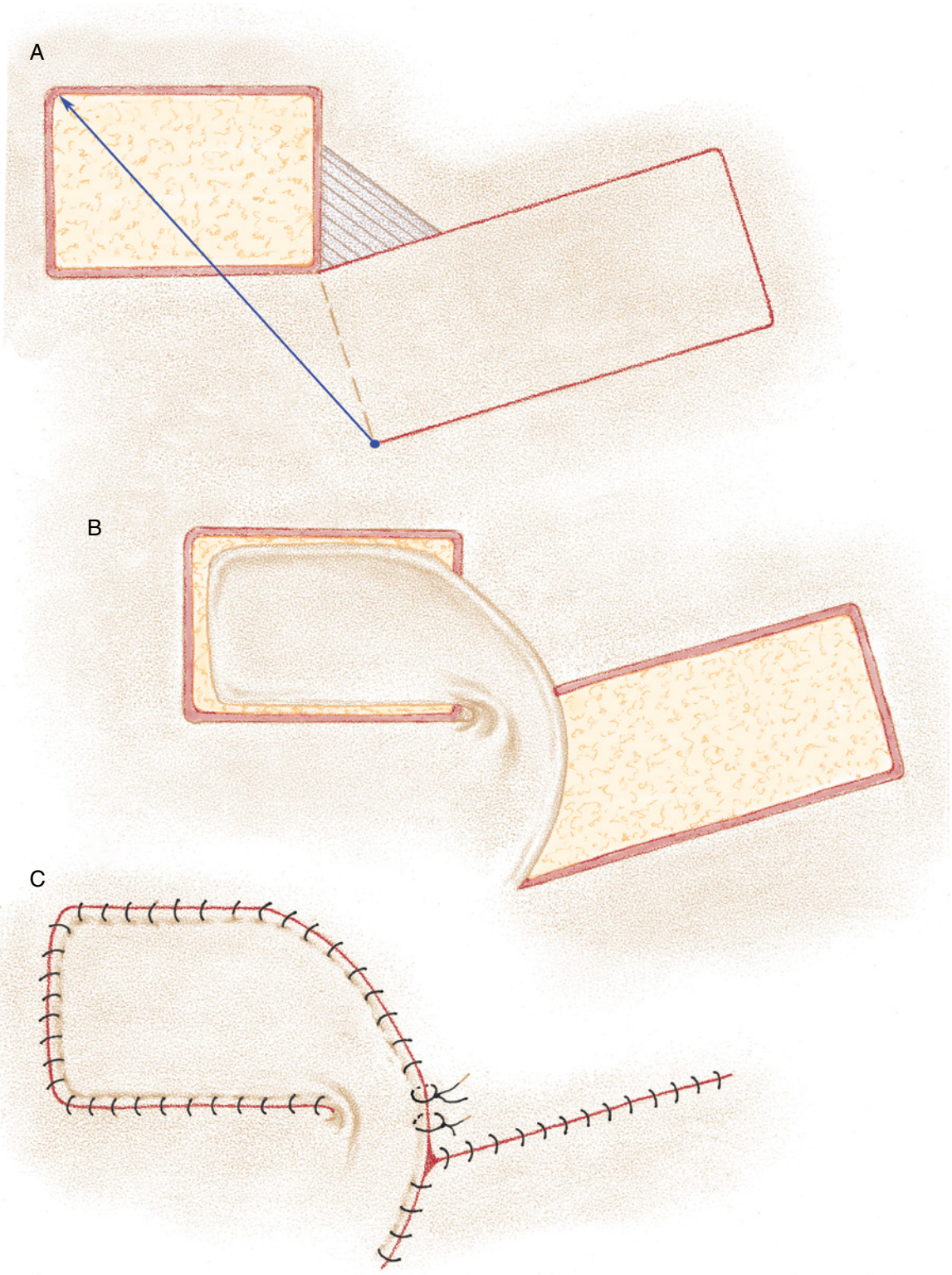
COMMENTS

Not all donor areas are ideally positioned for development of a 45° or 90° transposition flap. Transposition flaps have a tendency to shorten in length as they progressively rotate toward 180°. Careful measurement of the flap, as noted, can help the surgeon avoid a flap that is too short to cover the recipient wound bed. When in doubt, the surgeon can practice with a soft plastic foam or cloth model.

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Plate 44



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Plate 45 Local Facial Flap Options vs. Auricular Axial Pattern Flap

DESCRIPTION

Local skin flaps, alone or in combination with other simpler techniques, should be considered first over closure using more technically demanding flap/grafting procedures for the following reasons: (1) more economical, (2) less surgical trauma to the patient, and (3) less anesthesia time. This plate demonstrates the use of a local transposition flap in combination with lower facial skin advancement to close a large defect over the eye socket after wide tumor resection. The more distantly auricular axial pattern flap is noted for comparative purposes.

SURGICAL TECHNIQUE

(A) In this example, neoplasia involving the left eye will be widely excised. The auricular axial pattern flap, an option to close the large facial defect, is outlined for comparative purposes. A significant portion of this axial pattern flap is required simply to traverse the area between the donor and recipient beds. Note the transposition flap outlined adjacent to the site of tumor resection.

(B) A local transposition flap, utilizing the lateral facial skin distal to the left pinna, is elevated and rotated 90° into the surgical defect as per the guidelines noted in Plate 40.

(C) Completion of the closure. Note that the remainder of the defect and donor site are closed by simple undermining and advancement of the adjacent skin.

COMMENTS

When approaching large wounds, consider dividing the wound in sections, using, as in this example, two simple techniques to close the defect. The transposition flap closes the upper portion of the defect, easily followed by the advancement of the lower facial skin to complete the closure. Consider simpler effective methods for wound closure over more elaborate procedures when practicable. (See Figs 11-15 and 11-16.)

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Plate 45



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Plate 46 Transposition Flaps in Partial Wound Closure

DESCRIPTION

Problematic lower-extremity defects include wounds that are not healing or cannot heal by second intention in a timely fashion. Due to a lack of loose donor skin adjacent to the wound, development of a transposition flap to cover the entire wound may not be possible. Skin grafting is one option to consider. However, the author has used smaller flaps to close the central portion of a wound, thereby creating two smaller open wounds that can heal more easily by contraction and epithelialization.

SURGICAL TECHNIQUE

(A) In this example a small transposition flap is drawn onto the skin, using the limited skin residing parallel to the long axis of the tibia. Care is taken to measure the width of the flap, in order to prevent a donor defect that cannot be properly closed (see Fig. 11-17).

(B) The flap is elevated and transposed into the central third of the problematic wound, thereby creating two smaller open wounds.

(C) The flap is sutured into position, including the securing of its margins to the wound bed.

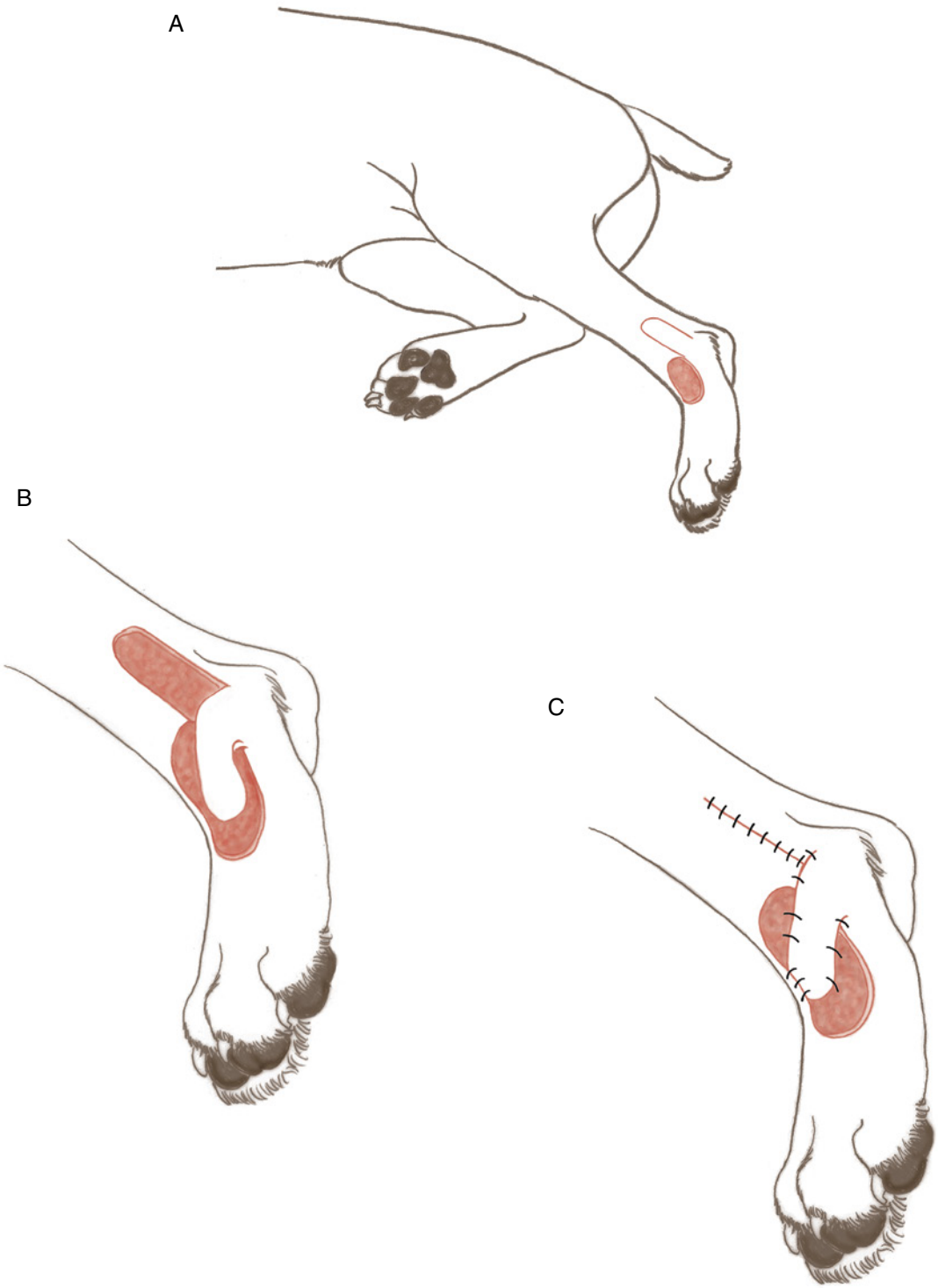
COMMENTS

By placing the skin flap in the central portion of the wound, two small, narrow wounds are thereby created. The borders of the flap facilitate contraction and epithelialization of these remaining open wounds. In this example a protective bandage (possibly reinforced with a fiberglass splint) would be used to protect the wound and immobilize movement of the tarsus. Larger wounds of the lower extremity may be best managed by using a full-thickness mesh graft. Faster healing reduces the costs associated with more prolonged open wound management.

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Plate 46



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Plate 47 Interpolation Flap

DESCRIPTION

The interpolation flap is a variation of the transposition flap, but it lacks a common border with the defect. As a result, a portion of the flap must traverse an area of skin interposed between the donor and recipient beds. The design and execution of the interpolation flap are nearly identical to those of a transposition flap. However, the length of the interpolation flap must include the additional length required to extend over the intervening skin segment.

SURGICAL TECHNIQUE

(A) Local skin tension is assessed by grasping between the thumb and index finger the skin adjacent to the defect and determining the laxity and elasticity present. The donor location is positioned to use the (loose) skin ridge grasped (dashed line).

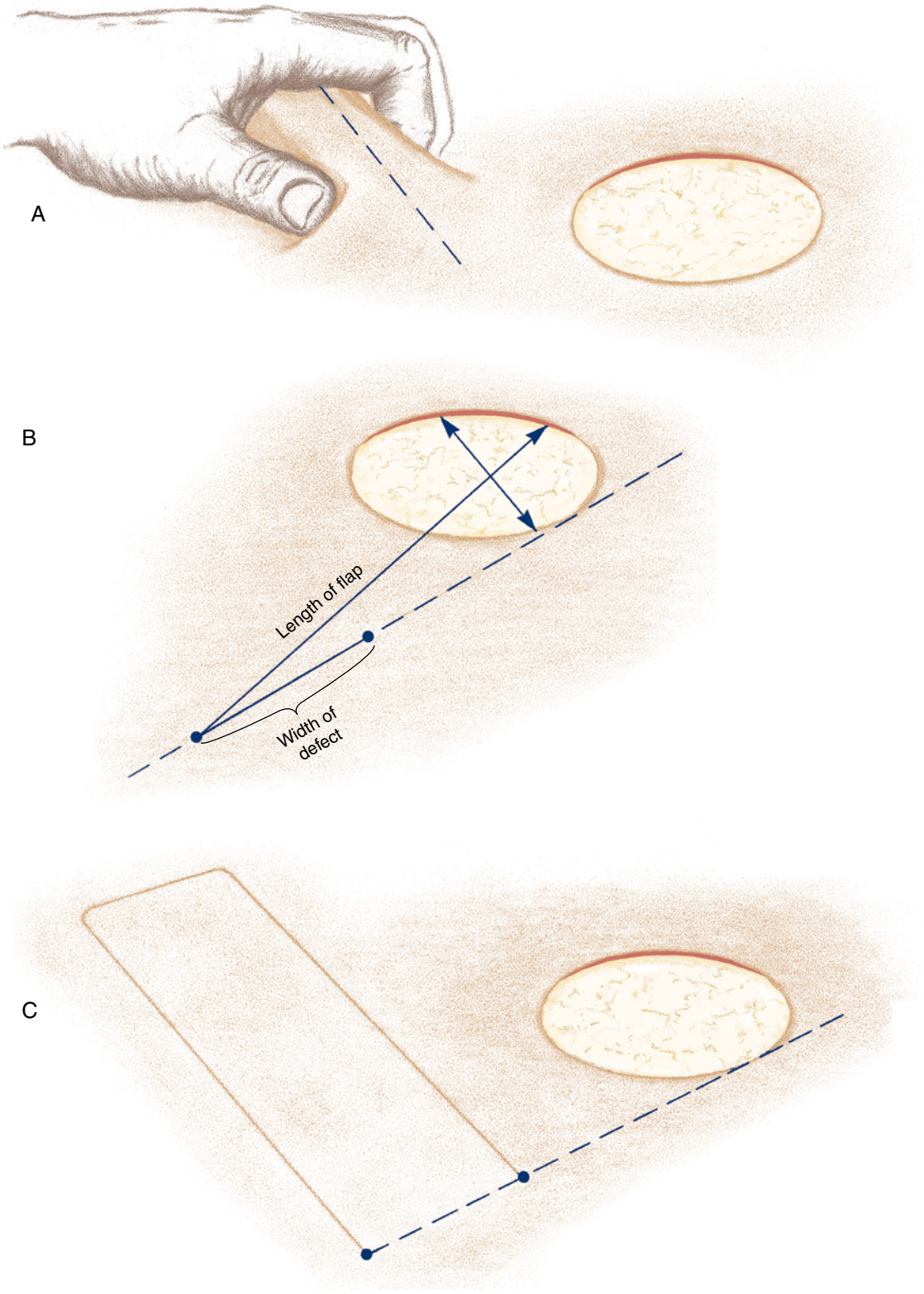
(B) The width of the flap, which equals the width of the defect (double-headed arrow), is measured and marked off at the predetermined baseline (dashed line). Note that the base of the flap is aligned with the lower border of this defect. Flap length is determined by measuring from the pivot point (distant edge of the proposed pedicle or base) to the most distant portion of the defect. (*Note*: flap length includes the additional amount required to traverse the interposing skin.) This measurement in turn is marked from the baseline.

(C) The flap is drawn with a marking pen prior to incising the skin. The two parallel lines forming the flap are equal to the length measurement in (B).

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Plate 47



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Plate 47

(Continued)

(D) The skin is then carefully undermined with Metzenbaum scissors and rotated into position. The flap is sutured into place with a simple interrupted suture pattern. The donor bed is closed in a similar fashion. A small triangular segment of skin is excised to facilitate donor bed closure.

(E) The redundant portion of the flap, overlapping the interposing skin between the donor and recipient sites, is excised in approximately 14 days, once the flap has completely healed to the wound bed. Skin incisions are sutured to complete the transfer.

COMMENTS

Like the transposition flap, the interpolation flap is a rotating flap by design. It is uncommonly used in veterinary surgery because, unlike their human counterparts, dogs and cats have a greater availability of loose skin. However, the execution of the interpolation flap technique is similar to that used for axial pattern flap coverage of distant recipient areas.

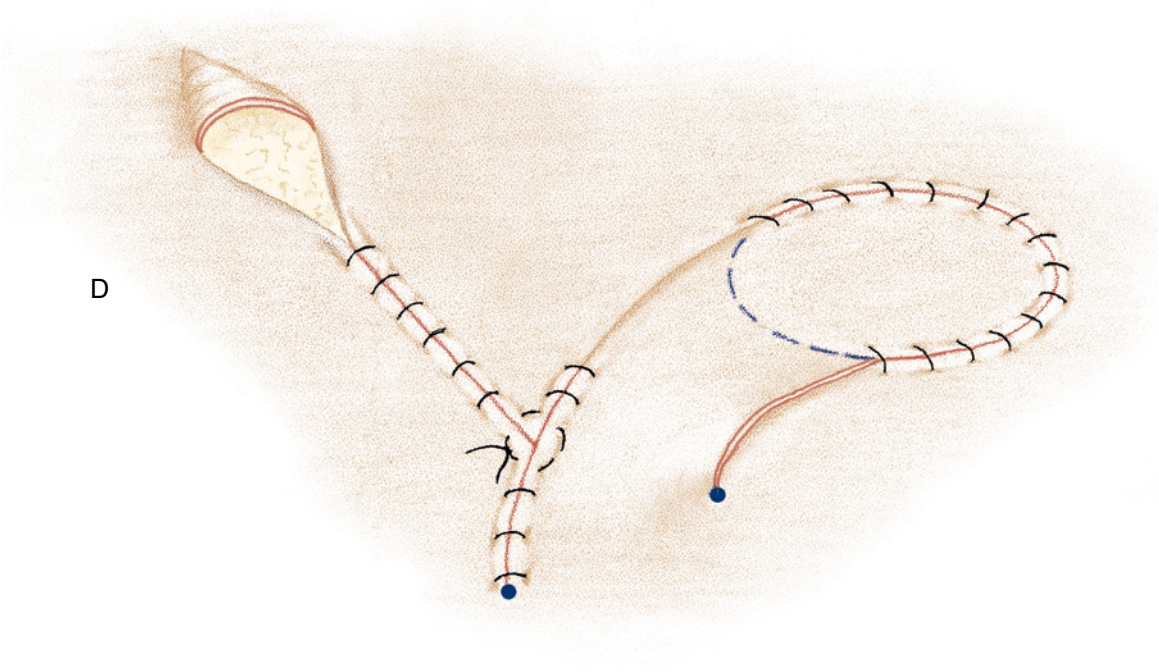
The exposed portion of the interpolation flap is subject to local infection, but a granulation surface will form on the exposed skin surface within a matter of days. The eventual excision of the redundant flap segment will control this condition. Unless the distant portion of the interpolation flap has healed over the wound with formation of collateral vascular channels to support this flap segment, severance of the pedicle could result in necrosis. Two weeks is a general clinical guideline for this maneuver.

An alternative to leaving a portion of the flap exposed would be formation of a bridge incision between the donor and recipient beds to which the flap borders are sutured (see Plate 70 in Chapter 13). Therefore, it may not be necessary to excise the redundant flap segment except for cosmetic purposes. Tubing the exposed portion of the interpolation flap or application of a split-thickness skin graft to the exposed dermal surfaces are less practical options to consider for this local flap technique.

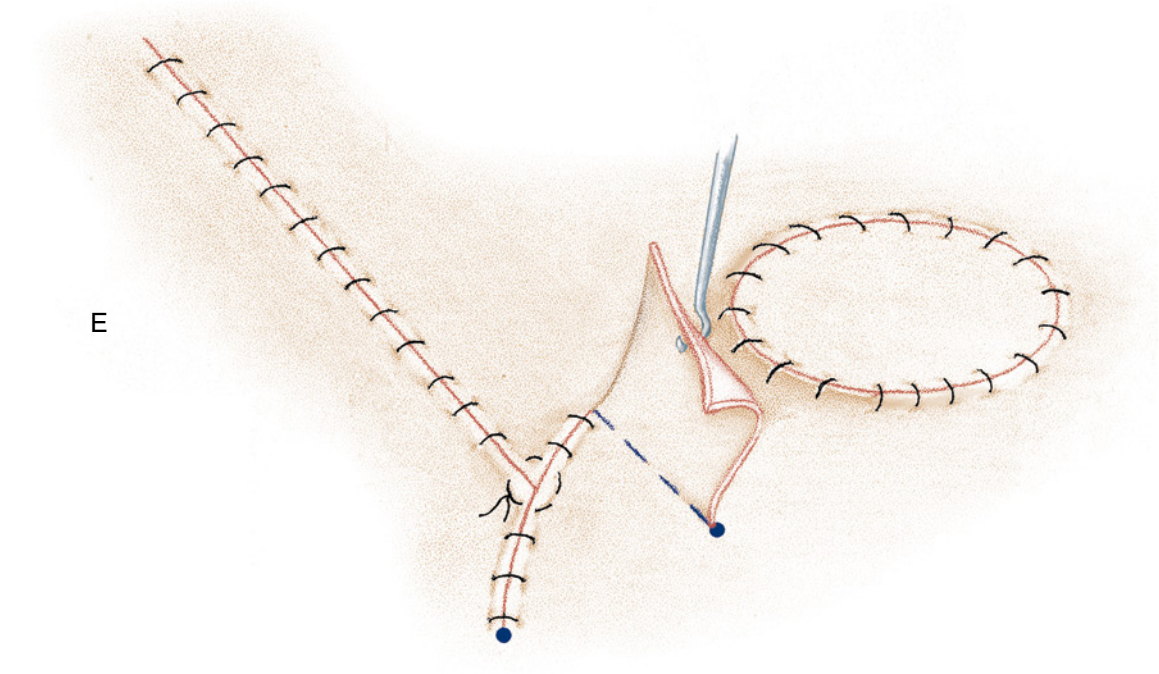
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Plate 47



D



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Plate 48 Rotation Flap

DESCRIPTION

The rotation flap is a semicircular flap most commonly used for closing triangular defects. In humans, the incision arc is four times the length required to rotate the flap into the defect. In veterinary practice, a curved incision is created in a stepwise fashion and the flap is undermined until it covers the wound without excessive tension.

SURGICAL TECHNIQUE

(A) Skin tension is assessed by grasping the adjacent skin between the thumb and index finger. The rotational flap will be positioned to take full advantage of this loose skin. A marking pen can be used to draw a circle that incorporates the triangular wound.

(B) The skin is incised over the outlined semicircle and undermined in increments until the flap rotates and stretches over the defect without undue tension.

(C) The flap is secured with a simple interrupted sutured pattern.

COMMENTS

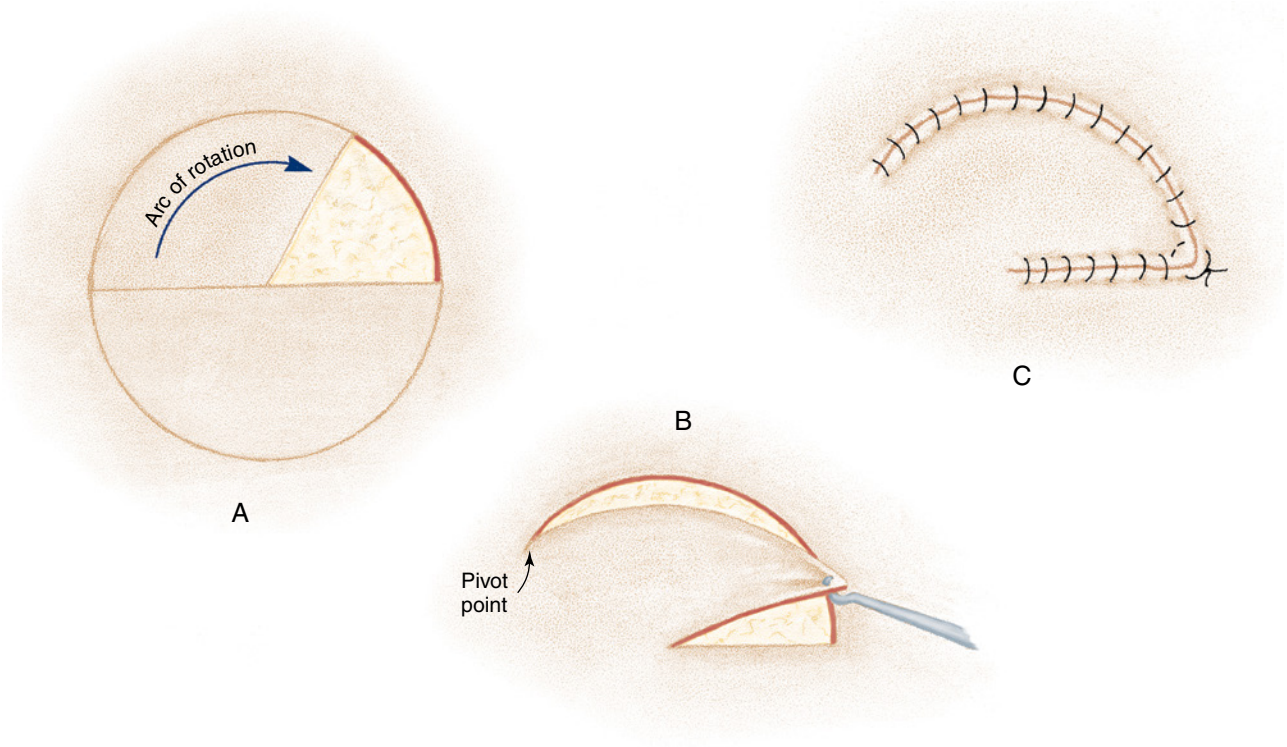
The rotation flap in design and execution combines the properties of the transposition flap and advancement flap: skin rotates and stretches to close the triangular wound without creating a secondary defect requiring a separate closure. Illustration (A) resembles a pizza with a slice removed. The stepwise perimeter incision normally will not extend beyond the horizontal line representing 180° of the imaginary circle encompassing the triangular defect in this illustration.

A variation of the rotation flap includes paired rotation flaps created on each side of a wide triangular defect (a variation of H-plasty employing two single-pedicle advancement flaps). Similarly, two rotation flaps can be employed to close rectangular areas by closing the two triangular surface areas formed by a diagonal line across opposing corners of the defect. In general, the author finds no particular advantage in the use of this technique over the transposition flap in most cases.

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Plate 48



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Plate 49 Forelimb Fold Flap

DESCRIPTION

The forelimb skin fold, loosely overlying the triceps musculature, can be elevated as a transposition flap and used to close skin wounds in the adjacent axillary area of the dog and cat.

SURGICAL TECHNIQUE

(A) The forelimb skin fold is grasped to determine the amount of skin that can be harvested as a skin flap. Manipulation of the limb will help determine the width of flap that can be elevated without creating excessive tension on closure of the donor site. Symmetrical lateral–medial skin incisions are outlined with a marking pen and reassessed before incising the prepared skin. Incisions are connected in a U fashion, proximal to the elbow.

(B) The flap is carefully undermined and elevated. An axillary wound has been prepared for flap placement.

(C) The flap is transposed and sutured into position.

(D) The donor area is sutured, completing the transfer procedure.

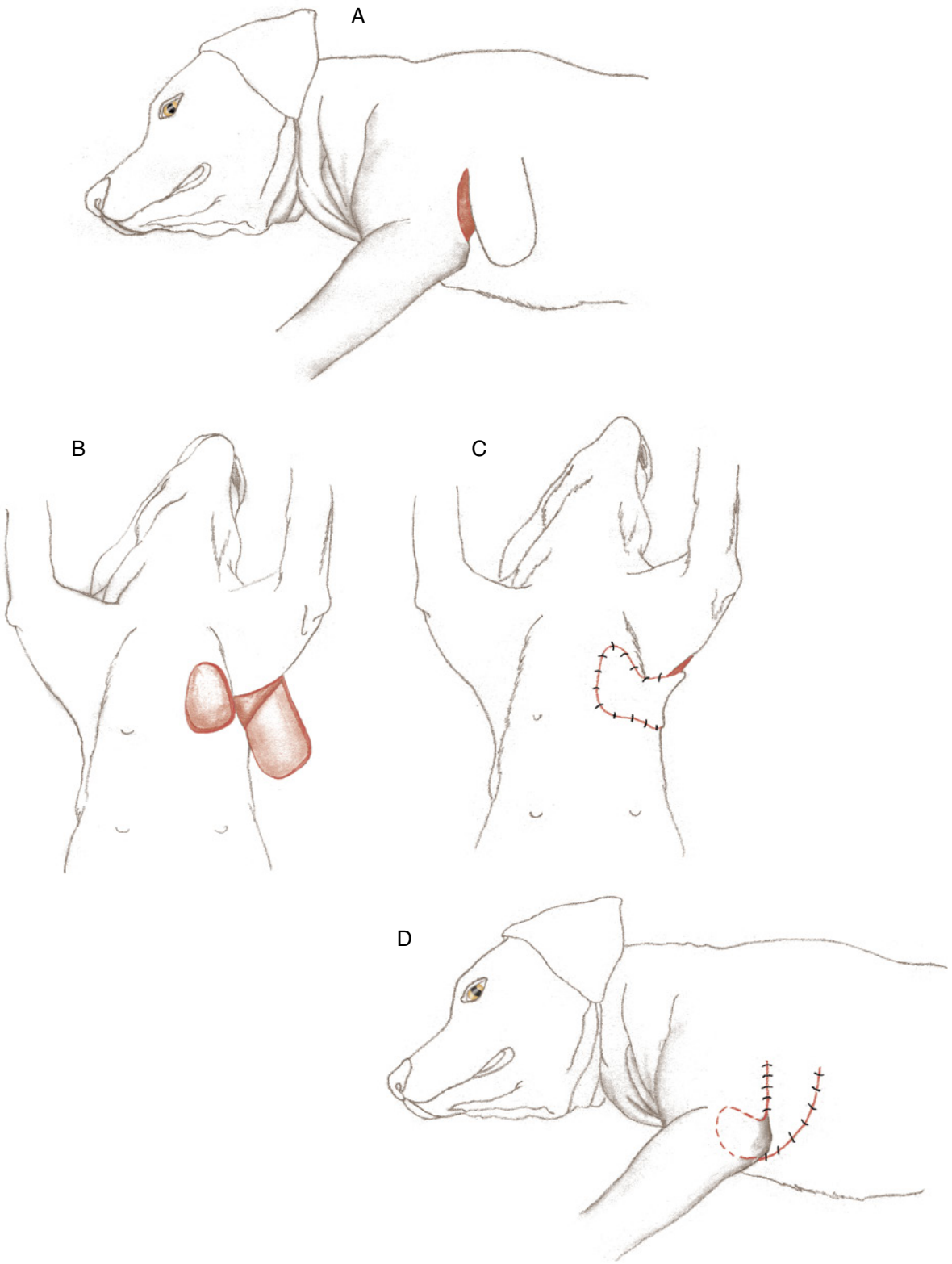
COMMENTS

Described by Hunt (1995), this transposition flap technique uses the thin, elastic skin fold of the forelimbs. Paired forelimb fold flaps can be transposed to cover larger defects that encroach on the axillary and sternal areas of the dog and cat. Flap size and length will vary with the body conformation of the individual patient.

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Plate 49



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Plate 50 Chin Flap Options

DESCRIPTION

Tumors involving the lower chin area of the dog and cat can present the surgeon with the challenge of how to close the surgical defect without causing ventral deviation of the lower labial margin. The transposition flap can provide an effective option for skin closure. Another flap alternative is the single-pedicle advancement flap.

SURGICAL TECHNIQUE

(A) Neoplasm involving the rostral chin area.
(B) Outline of the transposition skin flap.
(C) Closure of the surgical defect with a transposition skin flap.
(D) Resection of the neoplasm and the outline of the optional single-pedicle advancement flap.

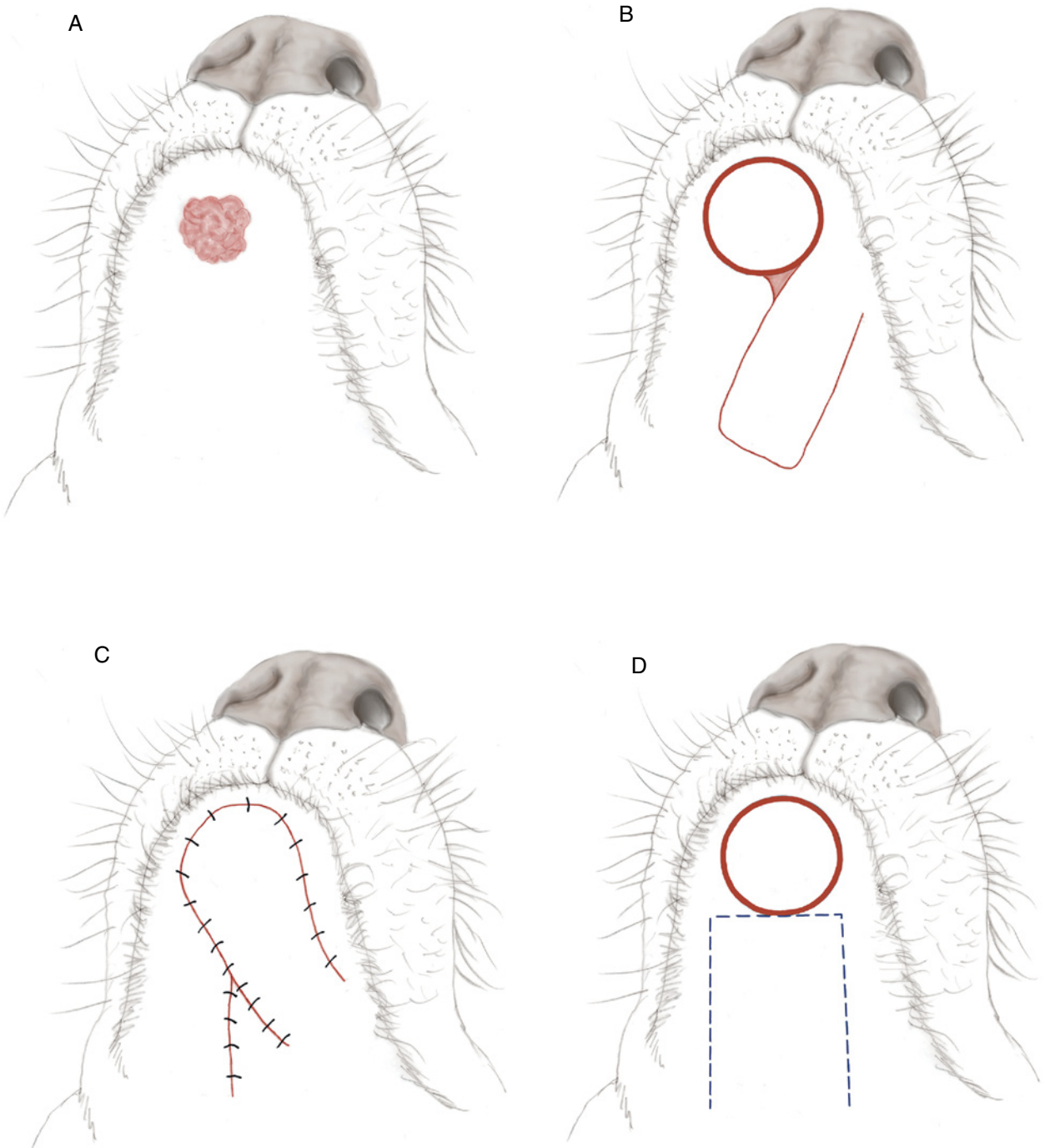
COMMENTS

The transposition flap is the most versatile flap for closure of larger defects in this area (see Fig. 11-14). Properly measured to cover the entire surgical defect, ventral deviation of the rostral labial margin can be minimized. The other flap option is the single-pedicle advancement flap (D) when loose elastic skin is available for its forward placement. However, caution is warranted with advancement flaps: they have a tendency to retract when advanced under tension. This can result in the downward retraction of the rostral lip margin. In smaller defects with the limited availability of skin, load cycling with skin hooks also can be effective in advancing the skin in this area (see Fig. 10-3).

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Plate 50



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Plate 51 Facial Fold Flap

DESCRIPTION

Skin folds represent redundant loose skin; this skin is a potential donor area for skin-flap development. Two common areas include facial folds in brachycephalic dogs and the redundant skin occasionally available dorsal to the vulva (see Plate 192).

SURGICAL TECHNIQUE

(A) Skin tumor: outline of a transposition flap designed over the adjacent facial fold.
(B) Following resection of the neoplasm, the transposition flap is elevated and rotated into the recipient bed.
(C) Closure of the recipient wound bed and donor area.

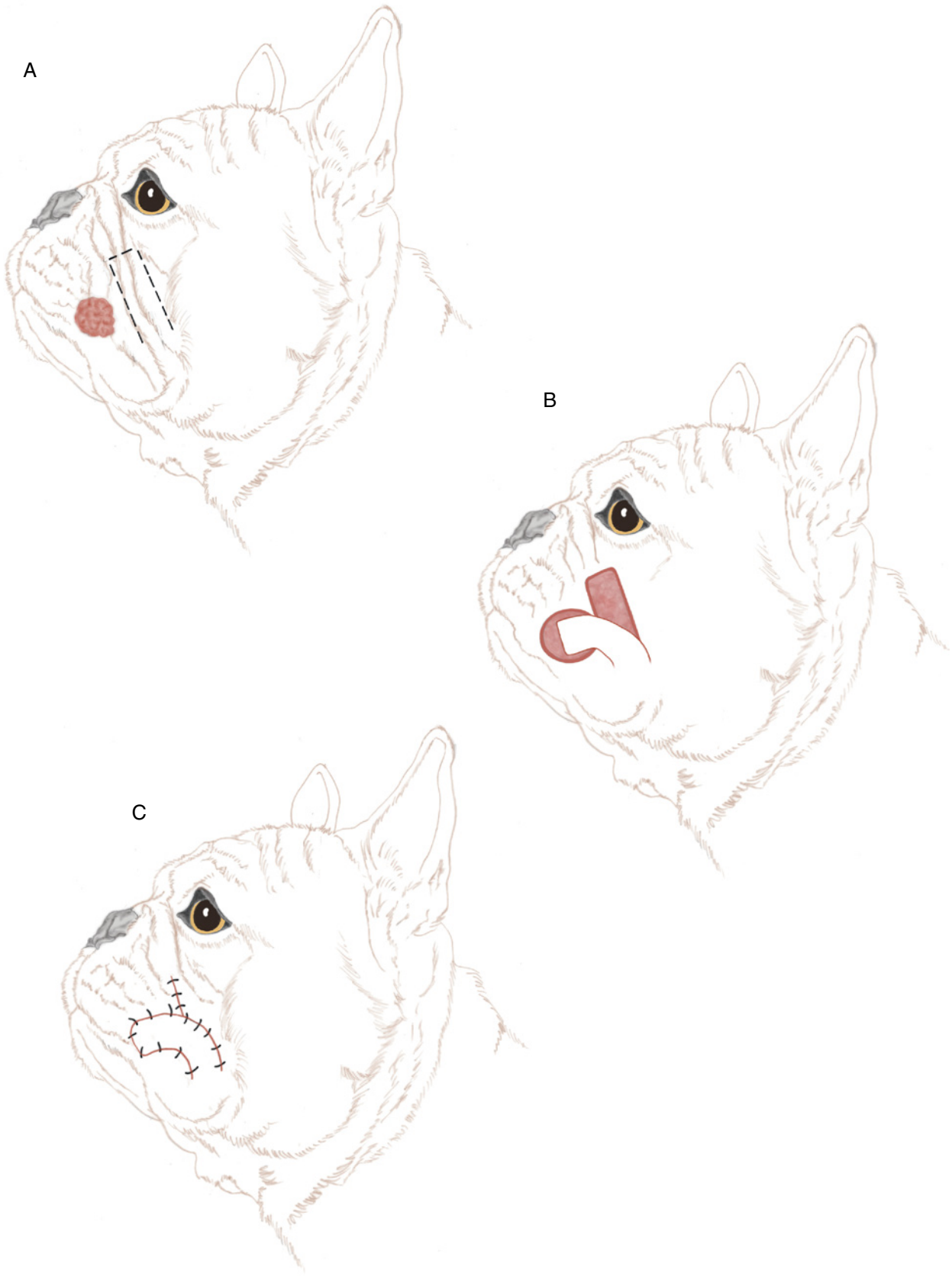
COMMENTS

Use of a major facial fold becomes a serious consideration when alternative flap options are limited. It is important to consider possible cosmetic changes in the brachycephalic dog's facial features with the pet owner when deciding whether or not to remove a portion of a skin fold in wound closure (see Chapter 15).

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Plate 51



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Plate 52 Flap Closure of Dorsal Nasal Defects

DESCRIPTION

The dorsal nasal area, caudal to the external nose, can be a challenging area for closure, based on the relative lack of skin available for closure of a skin defect following tumor resection or trauma in most dogs. Skin can be harvested as a transposition flap by designing the flap perpendicular to the long axis of the upper lip. There is sufficient skin to close the donor area following flap transfer.

SURGICAL TECHNIQUE

(A) Neoplasm overlying the dorsal nasal area. Outline of the transposition flap designed to close the surgical defect.

(B) Resection of the nasal tumor and rotation of the transposition flap.

(C) Closure of the donor and recipient beds.

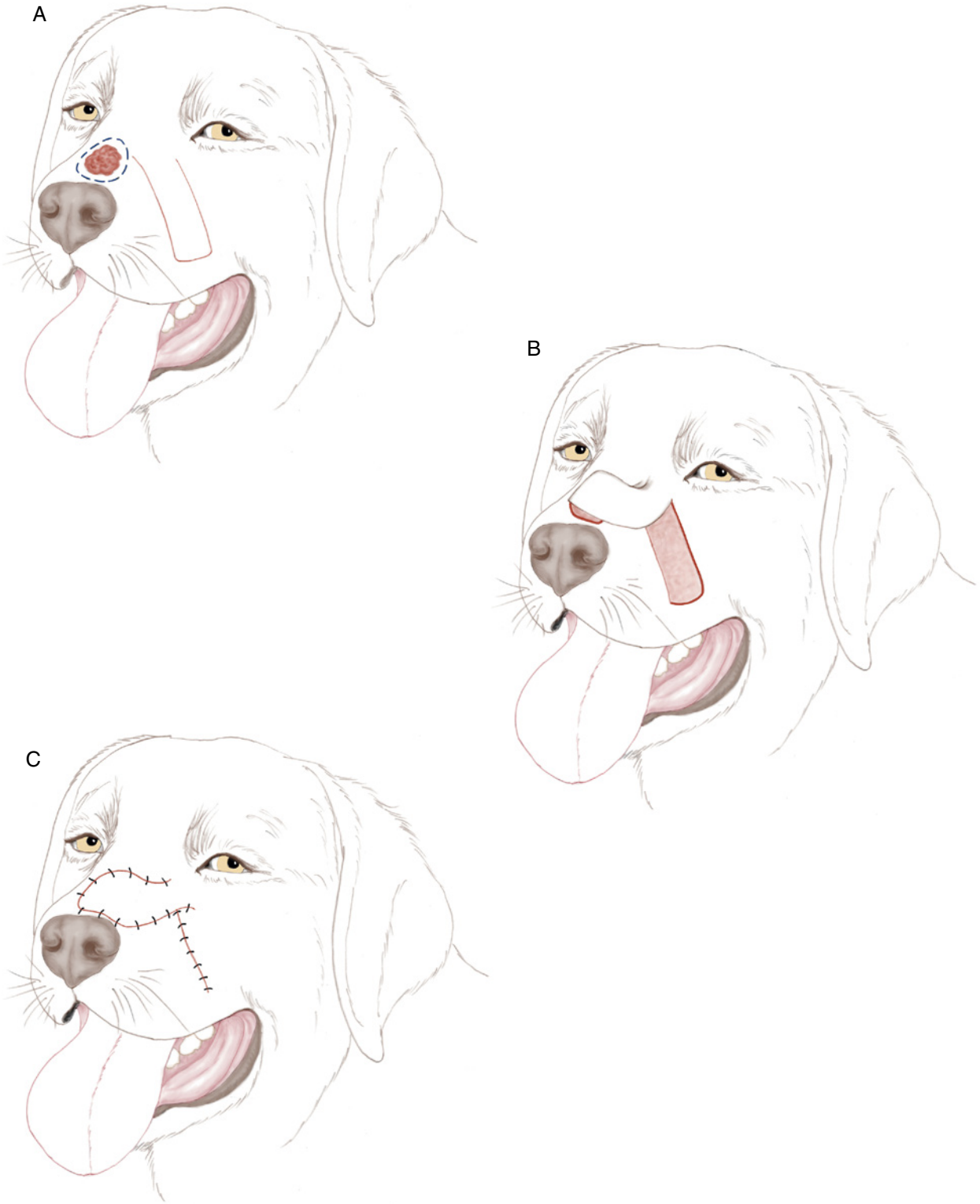
COMMENTS

The author has found this transposition flap variation quite effective in closing the dorsal nasal skin as well as the dorsal aspect of the external nose. Surgical examples include Fig. 11-11, with additional examples in Chapter 25.

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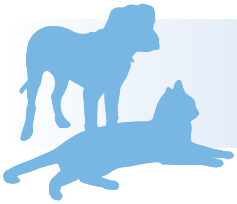
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Plate 52



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12

Distant Flap Techniques

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Indirect Flaps *442*
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DISTANT FLAPS

Distant flaps are constructed at a distant location from a skin defect. They are used almost exclusively for wounds that involve the middle to lower extremities. The skin of the lateral thorax and that of the abdomen are the most frequently used donor sites. Distant flaps are subdivided into *direct flaps* and *indirect flaps*, based on the method used to transfer the distant flap to the recipient bed.

Distant flap techniques were originally developed for use in human patients and were modified for use in the dog and cat. They provide full-thickness skin coverage for wounds and a means of successfully transplanting skin without resorting to the more exacting surgical skills and postoperative care required for successful coverage with a free graft. Like other multistage surgical procedures, they are time consuming and expensive to perform. In the case of direct flaps, there are some canine and feline (especially) patients who will not tolerate having a limb immobilized against their chest or abdomen for an extended period of time.

Over the past several years, new reconstructive surgical techniques have evolved that are simpler and more economical to perform. Axial pattern flaps and refinements in free graft transplantation have largely replaced the need for distant flaps. Nonetheless, there are occasional cases in which these procedures can be used effectively (see Fig. 18-14). Elevation of massive skin losses overlying the knee, for example, may be amenable to elevation to a lateral abdominal wall (direct) flap. In one reference (White 1999), an external fixator was used to maintain the hindlimb in a fixed position while using this direct flap technique to close a skin defect over the stifle area.

DIRECT FLAPS

Direct flaps include the single-pedicle (hinge flap) and the bipedicle (pouch flap) designs developed for using the middle to lower lateral surface of the thorax or abdomen. The affected limb is lifted and the recipient bed is sutured to the elevated flap (Fig. 12-1) (Plates 53 and 54). The pedicles are eventually divided in stages to complete the transfer in a 2–3-week time frame, provided that vascularization and healing occur between the flap and the wound bed. Direct flaps are used successfully in small animals, although cats are better anatomically suited to this technique than dogs because of their size, flexible limbs, and the ample loose elastic skin available over the trunk. However, some cats in particular poorly tolerate the immobilization of their limbs in an elevated position (see Plates 53, 54, and 55). Plate 175 demonstrates the use of a direct flap for closure of problematic pinnal defects.

Direct flaps have the disadvantage of requiring prolonged immobilization of the affected limb to ensure flap survival and healing over the wound. The author has noticed mild muscle atrophy of the limb until normal use of the leg is regained. Dermatitis secondary to skin-to-skin contact and moisture accumulation requires the veterinarian's close attention. Because multiple stages and prolonged hospitalization are required to complete the transfer, the cost to the owner is moderate. The transplanted skin assumes the same hair-growth characteristics despite its new location on the limb (Fig. 12-2).

> Today, direct flaps are considered for problematic extremity wounds in which other flap and grafting techniques are not feasible or in which their use is hampered by the wound's location and size.

INDIRECT FLAPS

Indirect flaps are almost entirely of the tubed-flap design, in which a bipedicle flap is sutured into a tube prior to its eventual transfer to the recipient bed after a delay procedure (see Plate 56). Tubing the flap prevents it from healing to the donor bed, minimizes infection, and facilitates eventual transfer to the recipient bed. Most long-tubed flaps require a 2- or 3-week "delay" to enhance their circulation before one pedicle can be severed and advanced toward the defect. Although tubed flaps can be "walked" great distances by periodically severing each pedicle alternately and advancing the freed end toward the recipient bed at 2-week intervals, it is both time consuming and impractical. Each successive step increases the likelihood of partial flap necrosis from an ineffective delay period, accidental kinking or twisting of the intact pedicle, trauma, or infection. As a result, tubed flaps are best developed close enough to the recipient bed to allow their immediate application to the wound after the initial delay period. Tubed flaps shrink or contract prior to their transfer and should be made larger than the recipient bed and longer than the length required to reach the defect: increasing the size by 25% of the exact measurements taken helps compensate for the "shrinkage factor." Like direct flaps, the color and quality of hair growth after transplantation of the flap are maintained despite its new location (Fig. 12-3).

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FIG. 12-1 (A) Pressure sore over the elbow of a Labrador. Epithelialized scar tissue and the chronic granulation tissue were resected; within days, a healthy granulation bed formed, suitable for closure. (B) Application of a single-pedicle direct flap, elevated from the lateral thorax. Although successful results were obtained, the prolonged bandaging, hospitalization, and staged transfer were costly. Today, a thoracodorsal axial pattern flap likely would be the best method to close this difficult wound. (C) By day 11, the flap has healed onto the underlying granulation surface. (D) By day 14, the pedicle was divided in stages: one half of the pedicle, 2 days apart. Following division and closure of the donor area, the incised edge was sutured to the wound border, completing the transfer. The elbow was protected with a padded bandage for an additional 2-week period. Close follow-up ensured the distant flap was not traumatized. Soft padded bedding was advised.

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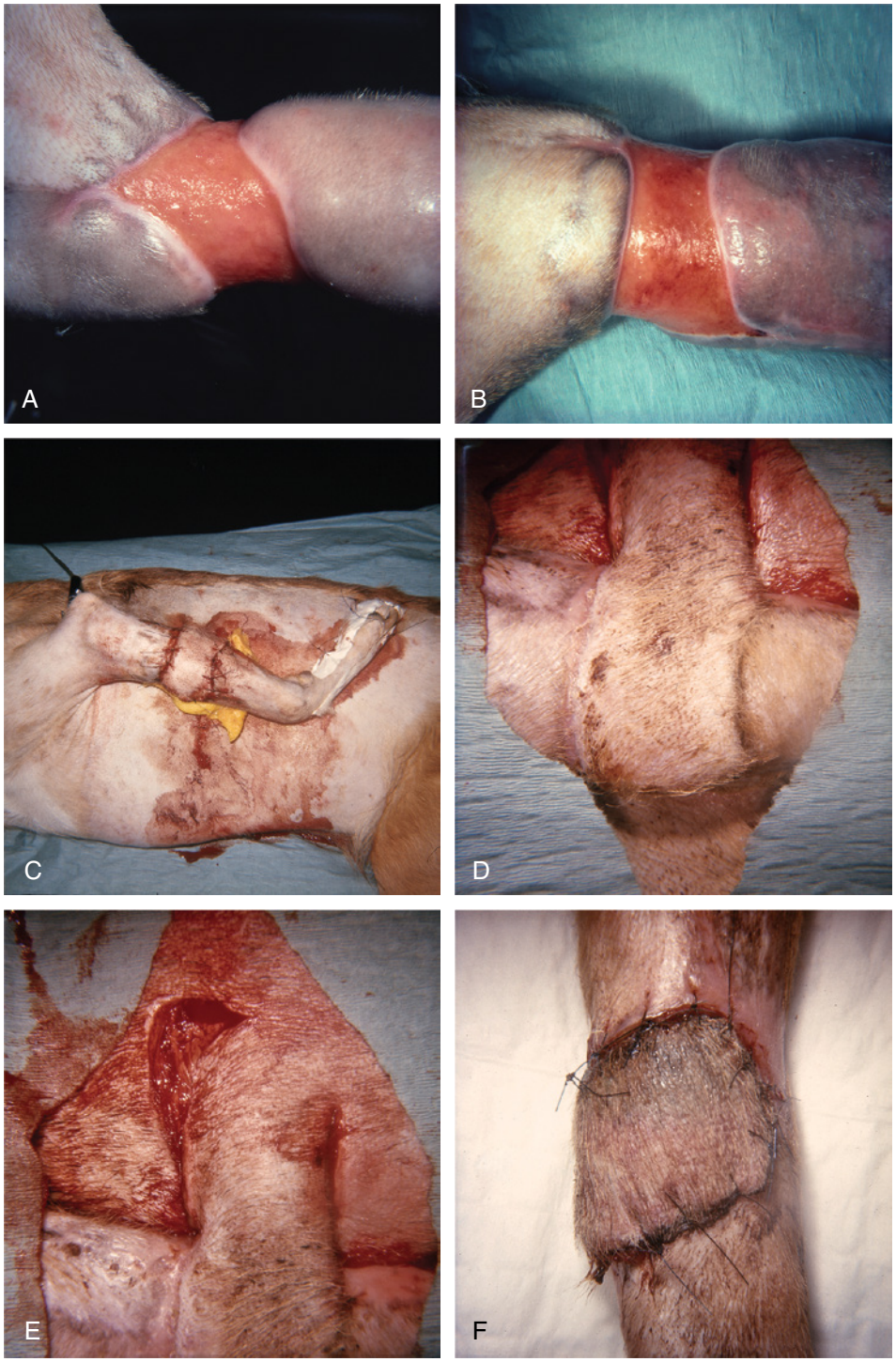


FIG. 12-2 (A, B) Circumferential degloving injury to the forelimb of a mixed-breed dog. Contracture of this chronic wound resulted in distal limb edema. Lateral (A) and medial views (B). The epithelialized border was resected prior to direct flap application. (C) Elevation of a single-pedicle direct (hinge) flap. Securing the limb to the side required an elaborate bandage, as noted in Plates 53 and 55. (D) At 2 weeks, the hinge flap has healed to the lateral half of the wound. (E) The pedicle is extended and partially divided. (F) Approximately 3 days later, the remaining half of the pedicle was divided and the remaining half of the flap was sutured to the medial side of the defect. Partial necrosis of the terminal flap occurred; second-intention healing of this site completed the closure. Today, a mesh graft would be one of the best choices for closing this wound. (Source: Pavletic MM. 1990. Skin flaps in reconstructive surgery. *Vet Clin North Am* 20:81–103. Reproduced with permission of Elsevier.)

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FIG. 12-3 (A) Forelimb defect in a mixed-breed dog, secondary to vehicular trauma. (B) Staged elevation of an (indirect) delayed tube flap developed over the left shoulder region. At week 3 the final segment of the proximal pedicle was divided. (C) The tubed flap was carefully incised over the "seam" of the tube. (D) The partially contracted tube was opened. (E) The flap was sutured into position. (F) The end of the flap necrosed: second-intention healing of this area occurred without incident. The distal tube segment of the healed flap site was resected 1 month after transfer to the recipient bed. This wound today could have been closed more easily and effectively with a mesh graft, thoracodorsal axial pattern flap, or, possibly, a brachial axial pattern flap.

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Delaying a flap is used to improve circulation to longer flaps when the surgeon is concerned over their survival if elevated and transferred in a single stage.

Prestretching to Enhance Flap Coverage

Delaying a flap is used to improve circulation to longer pedicle grafts when the surgeon is concerned over their survival if elevated and transferred in a single stage. It can be performed on subdermal plexus flaps or axial pattern flaps at the limits of their expected survival on transfer to the recipient bed. This is especially true when the terminal portion of the flap is critical to the reconstructive procedure.

There is a practical alternative to consider in order to lengthen a flap: prestretching the skin flap. The standard flap territory can be outlined with a marking pen. Skin stretchers are applied to the skin on opposing sides of the length of the flap area and it is stretched for a 48–72-hour period prior to flap elevation and transfer (see Plate 37).

THE DELAY PHENOMENON

Large flaps (without inclusion of direct cutaneous vessels) that are gradually developed in two or more stages prior to transfer are more likely to survive than pedicle grafts transplanted at the first operation. The physiologic mechanism(s) of augmenting flap survival is called the *delay phenomenon*. The improved circulation after a delay procedure can help offset the hazards of torsion and tension on flap transfer. This delay effect also may contribute to skin-flap survival with the use of tissue expanders: expanders in the latter phases of inflation create episodes of ischemia that may enhance neovascularization of the overlying skin.

Studies have focused on the microcirculatory mechanisms that account for delay and the optimal time for flap transfer. Selective division of the nerve, artery, and vein in neurovascular island flaps of rats has demonstrated that both denervation (sympathectomy) and ischemia play major roles in the delay phenomenon. Although the exact delay mechanism still is unclear, sustained vasodilation is currently believed to be the cause of improved flap survival. Delay is a two-phase response, the second phase being vasodilation of microcirculation from causes other than changes in the flap's sympathetic innervation.

Angiography and functional studies employed to examine the developing circulation within canine tubed flaps (8–10 cm long, 3–3.5 cm wide) as well as tubed flaps in rabbits have demonstrated that vessels in the subcutaneous tissue (corresponding to the subdermal plexus) increased in size and number with parallel reorientation or main vascular channels to the long axis of the flap. The longitudinal vascular arrangement in delayed flaps is most evident in loose-skinned research subjects (dog, rat, rabbit).

If ischemia and denervation are the stimuli for effective delay, tubed flaps of variable length, located in different regions of the body and on different animals, have variable circulatory efficiency. Flaps with adequate circulation do not benefit appreciably from a surgical delay compared with ischemic flaps. As a result, the variable tubed flaps employed clinically and experimentally suggest that the shorter delay period employed for short-tubed flaps (2 weeks or less) may be insufficient for long-tubed flaps with greater ischemia.

The optimal time for transfer varies among species; for example, the maximum delay effect in rabbits and swine occurs in 8–10 days, whereas rats required up to 6 weeks. Time intervals of 1, 2, and 3 weeks have been suggested as satisfactory before flap transfer in the dog. A 3-week delay is the safest interval for the dog, based on Hoffmeister's (1957, 1959) research. The author divides one half of the pedicle at 18 days; the second half is severed 3 days later to complete the delay. Long-tubed flaps may also require staged elevation to avoid an ischemic crisis from immediately tubing the bipedicle flap.

Sphygmomanometer cuffs, rubber-padded intestinal clamps, and Penrose drain tubing have been employed to "train" a tube to rely on vascular support from one pedicle by applying these compressive devices around the opposite pedicle. Compression can be applied for progressively longer periods of time until the tubed flap circulation can survive on the unclamped pedicle. As noted, delayed tube flaps have been largely abandoned for clinical usage in veterinary and human reconstructive surgery with the advent of axial pattern flaps, myocutaneous flaps, and improvements in free grafting techniques. However, deciphering this phenomenon may hold the key to selecting drugs that may mimic this physiologic response in order to salvage skin flaps with serious circulatory compromise. Although a variety of drugs have shown promise in improving survival of failing flaps, results have been inconsistent, and at times refuted by subsequent studies.

Figure. 18-14 demonstrates a combination of techniques used to reconstruct a rear paw, including (1) free grafting of pad tissue to the lateral trunk, (2) direct flap transfer of the pad grafts as a bipedicle flap, and (3) delaying the flap to ensure survival of the flap to complete reconstruction of the left rear paw.

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Suggested Reading

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Plate 53

Direct Flap: Single-Pedicle (Hinge) Flap

DESCRIPTION

The hinge flap is a single-pedicle direct flap generally used to close limb defects at or below the elbow or knee. (It is rarely used to resurface large defects involving the pinna.) The base of this pedicle graft can be positioned dorsally or ventrally on the middle to lower lateral region of the thorax or abdomen. The affected limb is elevated to the trunk and the defect positioned beneath the flap.

SURGICAL TECHNIQUE

(A) The affected limb is lifted up to the lateral surface of the trunk to determine the proper location for flap development. The width of the flap equals the dorsoventral borders of the defect, including any epithelialized wound borders that require excision. An additional 1 or 2 cm is added to this measurement to offset elastic contraction and stretching of the flap associated with limb placement. The flap is carefully drawn onto the skin of the donor site. Flap length is determined from the desired location of the flap base to the most distant edge of the defect. A cloth template is useful to determine this measurement.

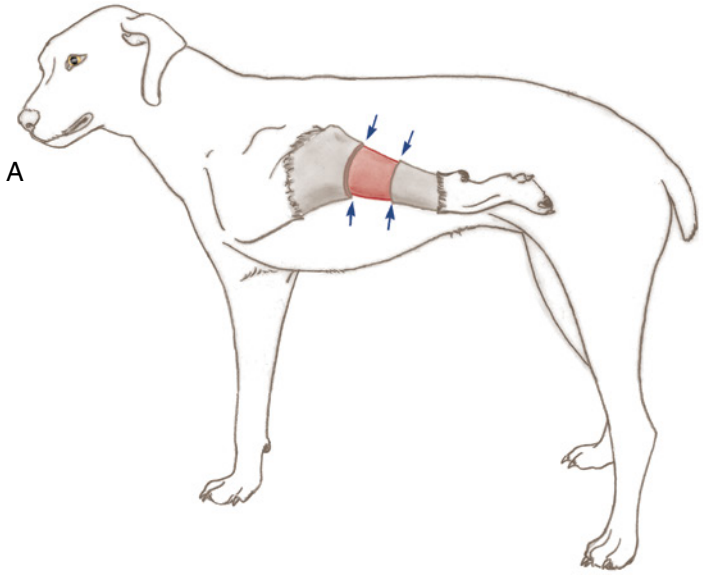
(B) The flap is incised and elevated beneath the cutaneous trunci muscle. The donor bed is partially closed. Epithelialized wound borders are excised to ensure complete flap coverage of the entire defect.

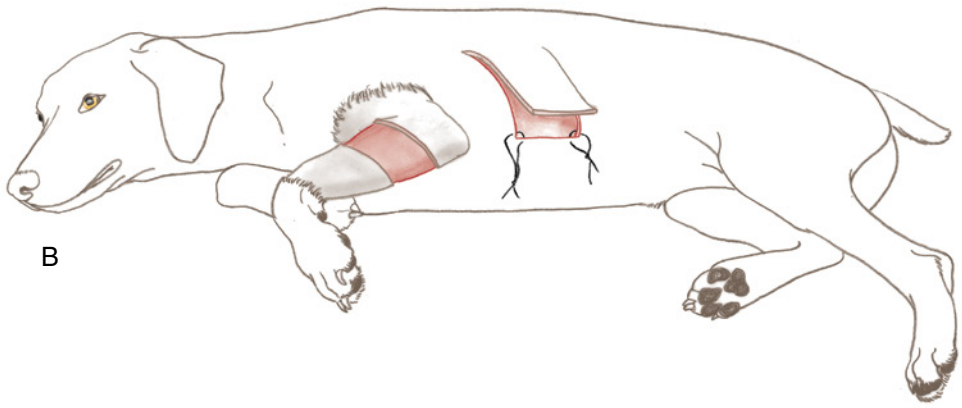
(C) The flap is sutured to the wound borders.

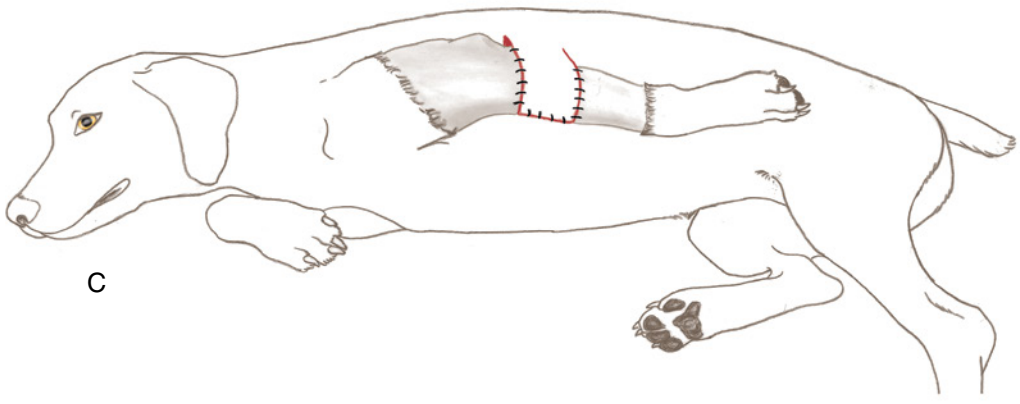
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Plate 53







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Plate 53

(Continued)

(D) To prevent shifting and slippage of the extremity from beneath the flap, elastic adhesive tape is folded over the lower extremity and continued around the circumference of the trunk. Two or three large stay or retaining sutures (size 1-0 or 2-0) are additionally placed through the skin adjacent to the defect and into the skin of the trunk to prevent the limb from shifting ventrally and placing tension on the flap pedicle. Cotton padding is placed between the limb and trunk to prevent moist dermatitis.

(E) Soft cotton padding, self-adherent gauze, and elastic adhesive tape encompass the limb and trunk. An access window may be cut into this protective wrap later for local wound care and for replacement without removing the entire bandage. Local bandage changes generally are performed every 2 or 3 days. Excitable or uncooperative patients should be sedated and restrained to avoid struggling during local wound care.

(F) The pedicle is divided in stages 10–14 days after surgery unless healing between skin edges and the underlying wound bed is incomplete. This is based on noting that the flap has healed to the underlying donor site. One half of the pedicle is divided (dotted line) followed by the remaining half 2 or 3 days later (asterisks). The freed border is sutured to the opposing wound border. Removal of a portion of the granulation bed may be necessary to facilitate closure of the donor site.

COMMENTS

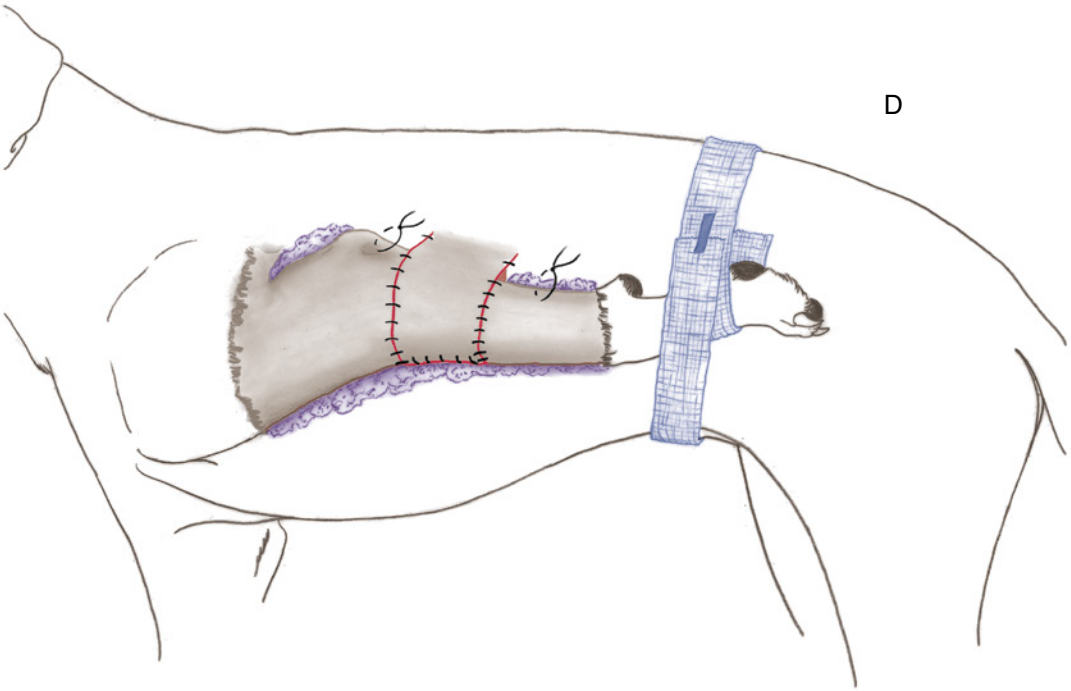
The elevated paw should be monitored for swelling, indicative of circulatory compromise; this would require properly altering the bandage support. Division of the flap pedicle can be performed more rapidly than the suggested guidelines indicate, although there is a greater likelihood of necrosis. Considering the time and cost invested in this procedure, the few extra days required for delayed pedicle division are a practical investment. Elevated limbs tend to rotate outward, making proper flap application more difficult. Carefully applied bandages can help offset this effect. Hinge flaps, like other distant flap techniques, require a wound bed with sufficient vascularity to support flap survival when the pedicle is completely divided. For example, this flap would be a poor choice to close an ischemic wound bed secondary to radiation therapy.

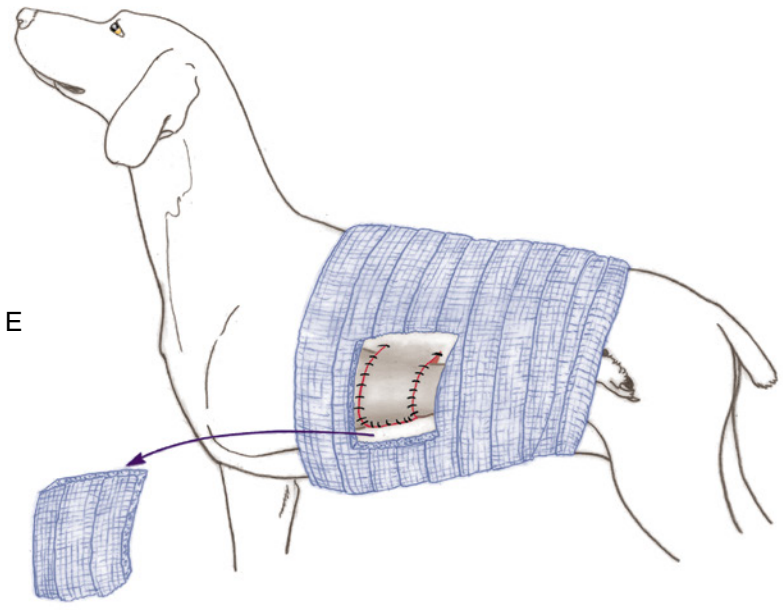
Hinge flaps are better suited for defects on the lateral surface of the limbs, although carefully designed (ventrally based) trunk flaps can be folded to cover medial defects. The single pedicle can be lengthened slightly before final division of the pedicle to cover any remaining medial defect. Long pedicle extensions are likely to suffer a degree of necrosis due to insufficient circulation. See Plate 55, Direct Flaps: Bipedicle (Pouch) Flap, to determine which of these two direct flap techniques is preferable.

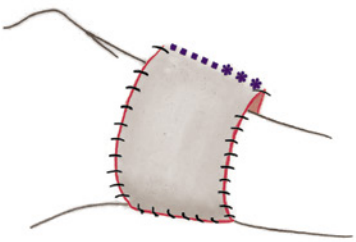
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Plate 53







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Plate 54

Direct Flap: Closure of Knee Defect

DESCRIPTION

A large skin defect involving the surface overlying the knee can be closed with a direct flap elevated from the lateral abdominal wall. This is an alternative to the caudal superficial epigastric axial pattern flap for coverage of this area.

SURGICAL TECHNIQUE

(A) Large skin defect overlying the left knee area in this example.

(B) In this patient, a lateral abdominal flap has been elevated and sutured to the lateral "half" of the skin defect. The leg has been secured with a sling to maintain the position of the left rear limb to the overlying flap. Note that cotton padding should be secured to the inner thigh skin in contact with the lateral abdominal wall. The flap area can be protected with additional bandaging.

(C) After 2 weeks, the pedicle is divided: one half of the pedicle can be incised, followed by division of the remaining half 2–3 days later. This is based on noting that the flap has healed to the underlying donor site. The donor area and remaining recipient area are sutured closed.

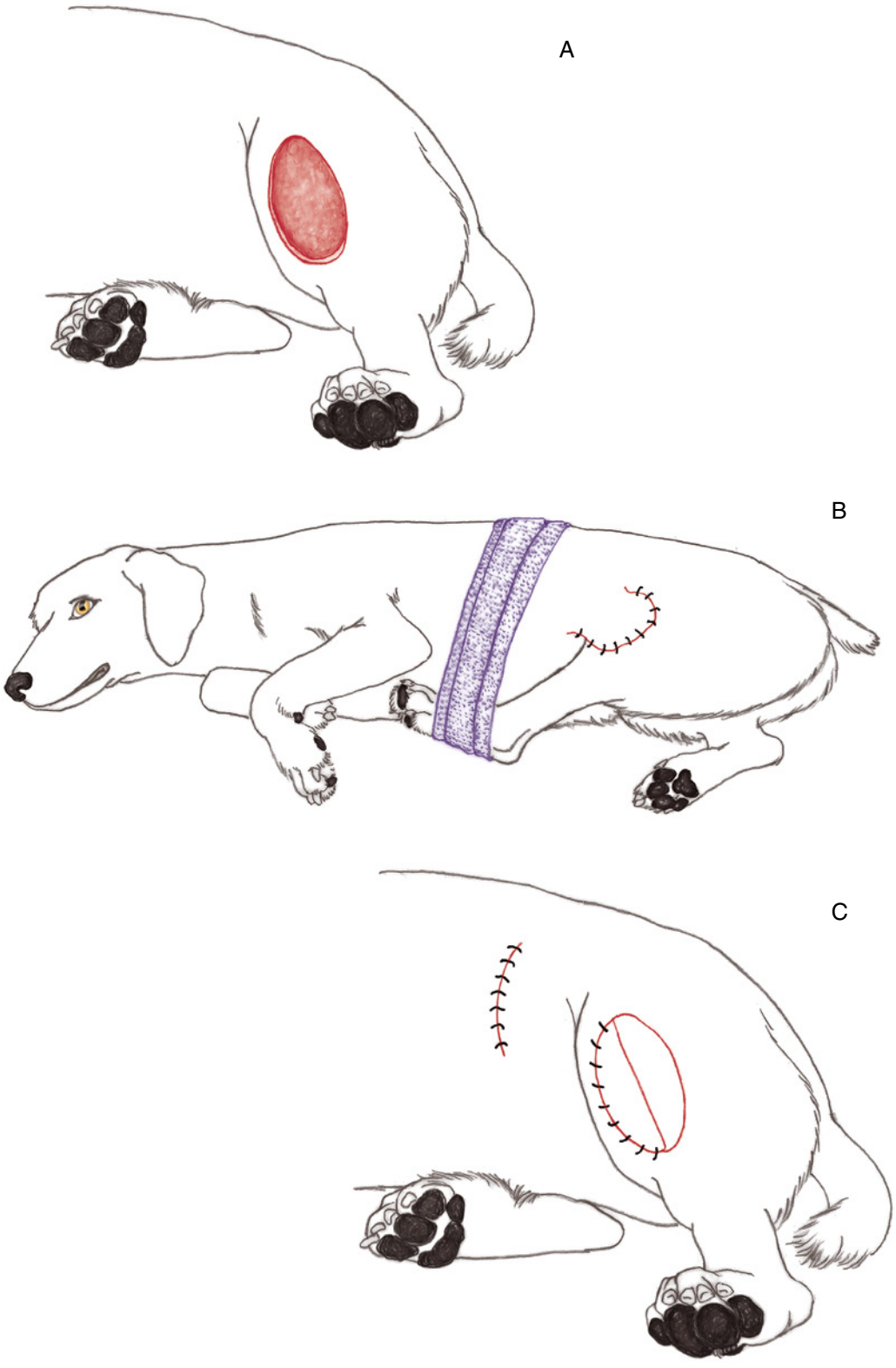
COMMENTS

The elevated paw should be monitored for swelling, indicative of circulatory compromise; this would require properly altering the bandage support. The pros and cons of using this direct flap technique should be compared to the use of the caudal superficial epigastric axial pattern flap. There may be situations where the latter technique cannot be used. Like other direct flap options, prolonged immobilization of the limb against the trunk can be challenging. Successful closure of the stifle wound requires the lateral aspect of the flap to heal to the wound surface, developing a collateral blood supply to keep the remaining flap segment viable when the pedicle is finally divided.

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Plate 54



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Plate 55

Direct Flap: Bipedicle (Pouch) Flap

DESCRIPTION

The pouch flap is a bipedicle direct flap beneath which the limb wound is positioned. Its development, location, and execution are similar to that of the hinge flap.

SURGICAL TECHNIQUE

(A) The injured limb is lifted to the lateral surface of the trunk to determine the location of flap placement. The limb is flexed to simulate the maneuver required to comfortably position the extremity defect beneath the proposed pouch flap. The affected limb and donor area are thoroughly clipped of fur.

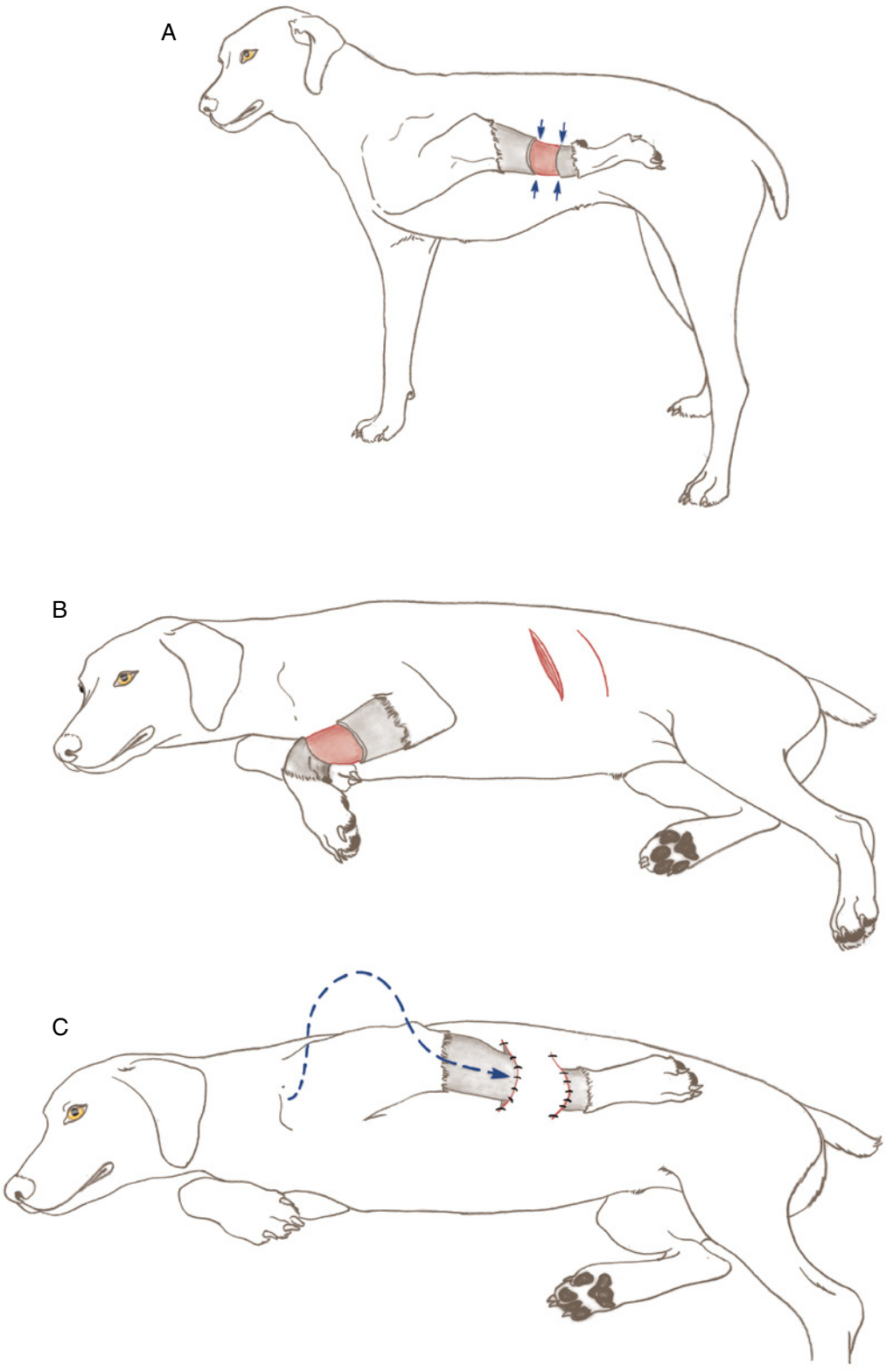
(B) The width of the flap corresponds to the dorsoventral dimension of the limb defect. It is advisable to create a flap 1 or 2 cm wider than measured to offset elastic contraction and stretching of the flap associated with limb placement. The proposed flap is carefully drawn onto the skin of the donor area. Two parallel incisions are extended in increments.

(C) The pedicle graft is undermined beneath the cutaneous trunci muscle. Sufficient room is created for limb placement beneath the flap without excessive tension, yet allowing optimum contact between the opposing surfaces. Epithelialized wound borders are excised to provide complete flap coverage. The flap is sutured to the proximal and distal borders of the limb defect. The ventral openings formed by "tenting" of the flap serve as drainage sites for the surgical area.

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Plate 55



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Plate 55

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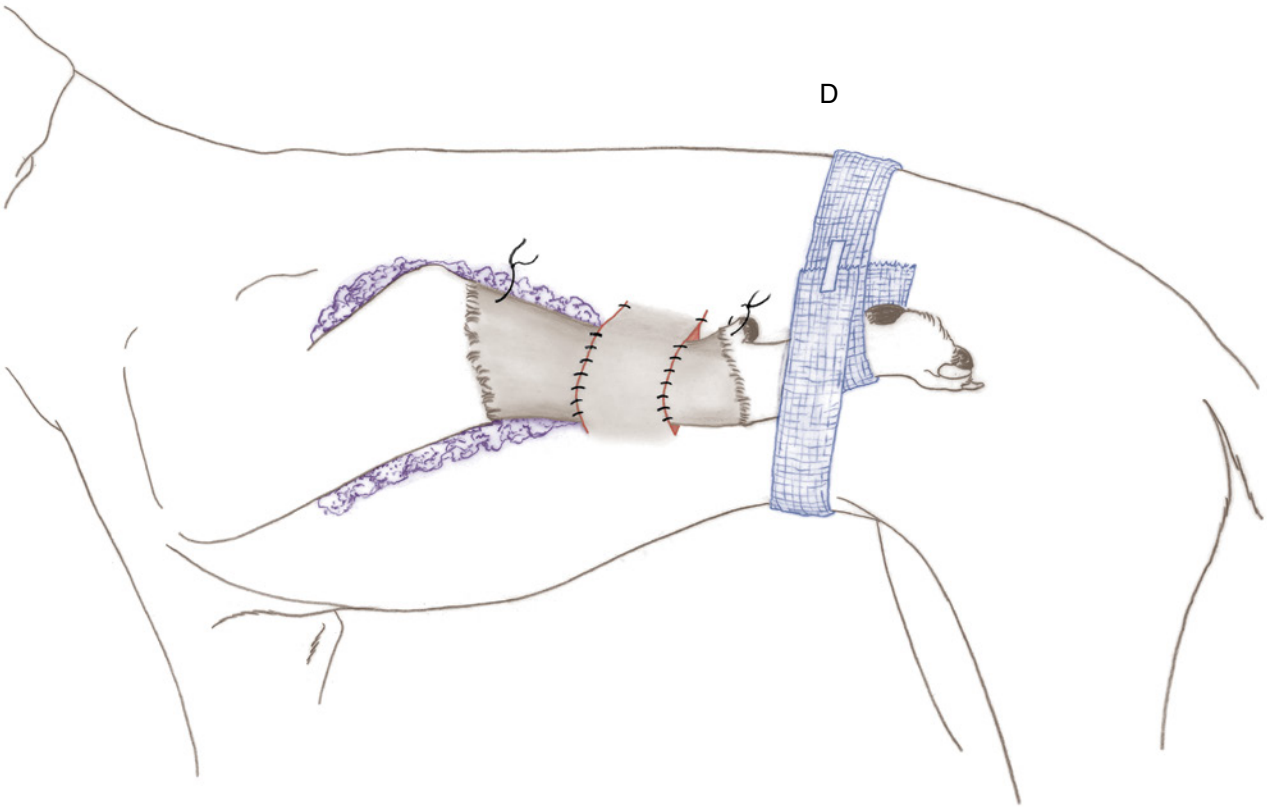
(D) To prevent shifting and slippage of the extremity from beneath the flap, elastic adhesive tape is folded over the lower extremity and continued around the circumference of the trunk. Two or three large stay or retaining sutures are additionally placed through the skin adjacent to the defect and into the skin of the trunk to prevent the limb from shifting ventrally and placing tension on the flap pedicles. Cotton padding is placed between the limb and trunk to prevent moist dermatitis.

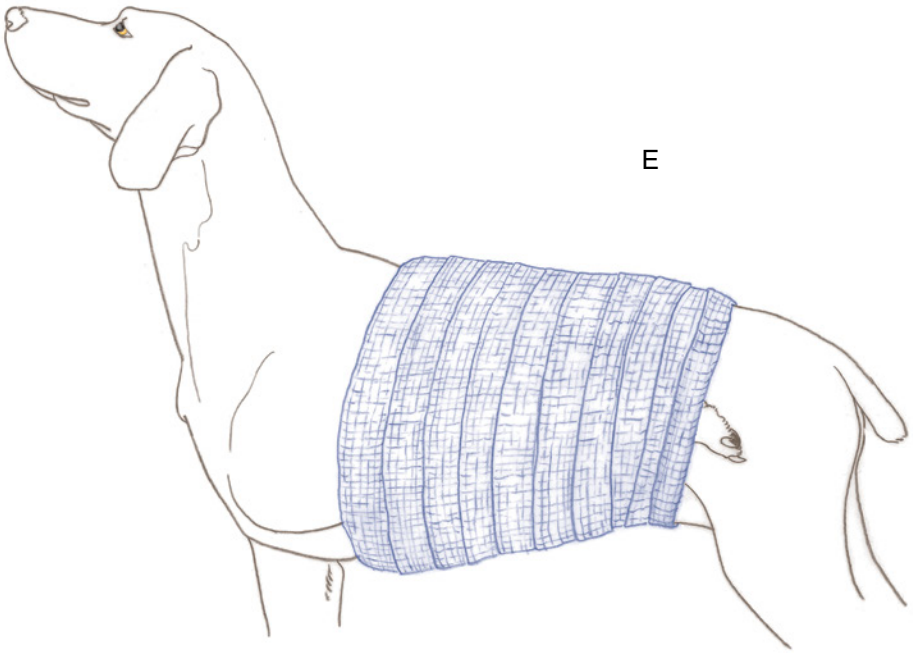
(E) Soft cotton padding, self-adherent gauze, and elastic adhesive tape encompass the limb and trunk. An access window may be cut into this protective wrap later for local wound care and replacement without necessarily removing the entire bandage (see Plate 53). Local bandage changes generally are performed every 2 or 3 days. Excitable or uncooperative patients should be sedated and restrained to avoid struggling during local wound care.

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Plate 55





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Plate 55

(Continued)

(F) Pedicles are divided into stages beginning 10–14 days after surgery unless healing between the skin edges and underlying wound bed in contact with the flap is incomplete. One half of the lower pedicle is divided (asterisks), followed by division of the second half 2 days later (dotted line). Delayed division of the upper pedicle is then repeated in similar fashion beginning 2 days after the preceding procedure (circular and oval dots). The freed edges of the flap are sutured to the opposing wound border with each division.

(G) The donor site usually is laden with granulation tissue. Excision of portions of the wound bed may be required to facilitate closure. In the event of a circumferential wound to the limb, the length of each pedicle can be extended beyond the suggested margins in (G). Each extended pedicle flap is wrapped medially to close the remaining defect. Unless circulation from the wound bed to the flap is adequate, partial necrosis of the ends of the medially placed pedicles may be noted.

COMMENTS

The elevated paw should be monitored for swelling, indicative of circulatory compromise; this would require properly altering the bandage support. The advantages and disadvantages of pouch flaps and hinge flaps are nearly identical. They are tedious, time-consuming, multistage procedures. Maintaining the limb in a fixed position is a challenge in the uncooperative patient and mild muscle atrophy can be expected on release of the limb. However, muscle mass is eventually regained with exercise.

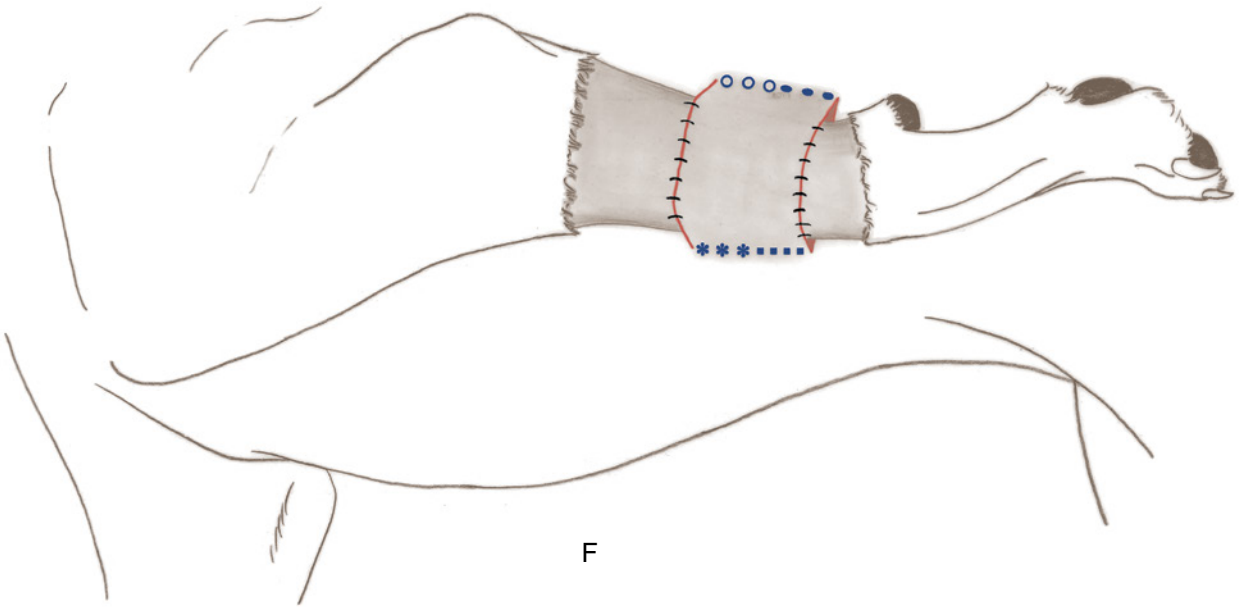
When dealing with more proximal limb defects, it may be impossible to flex the limb of the dog sufficiently to tuck the extremity into the pouch created. This maneuver is less of a problem in the cat. The hinge flap is best used when an unduly long flap is not required to cover a given defect and is more commonly used for defects that cannot be positioned beneath a bipedicle flap. Both pouch and hinge flaps are ideally suited for lateral defects of the extremities.

Elevated limbs have a natural tendency to rotate outward, which occasionally makes application to wounds more difficult. Carefully applied bandages can reduce this effect. Pouch flaps, like other distant flap techniques, require a wound bed with sufficient vascularity to support their survival after complete division of both pedicles. See Plate 53, Direct Flap: Single-Pedicle (Hinge) Flap, to determine which of these two direct flap techniques is preferable.

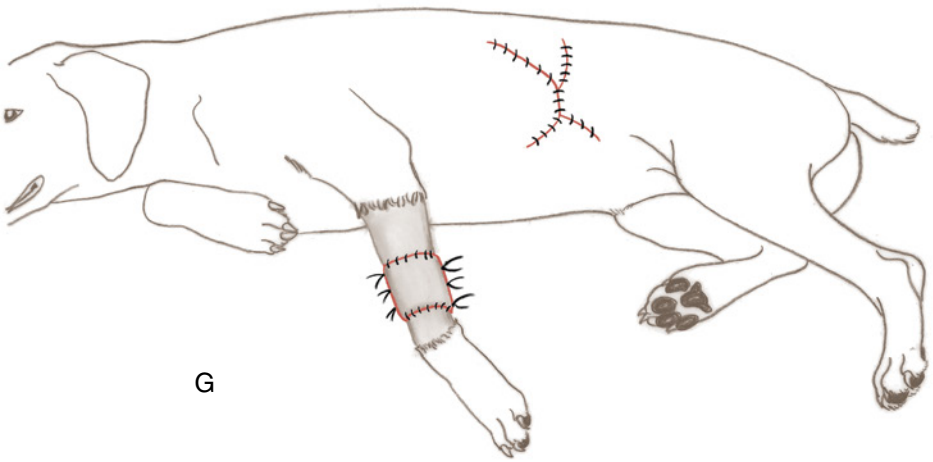
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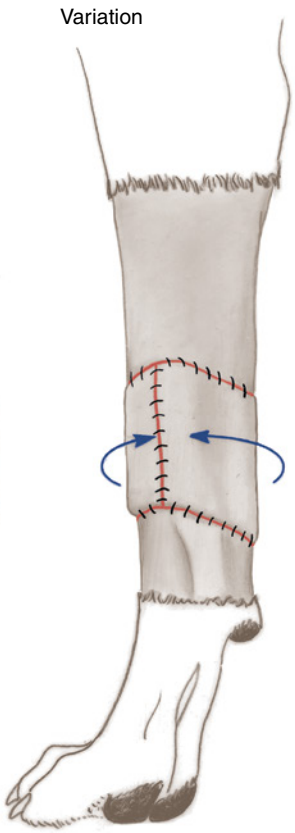
Plate 55



F



G



Variation

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Plate 56

Indirect Flap: Delayed Tube Flap

DESCRIPTION

Indirect flaps are almost entirely of the delayed tube flap design in which a bipedicle flap is sutured into a tube prior to its eventual transfer to the recipient bed. A delay period prior to transfer is used to enhance circulation to those flaps in which adequate blood flow to portions of the flap is questionable. This is particularly important for long flaps whose circulation is based on the subdermal plexus.

SURGICAL TECHNIQUE

(A) Delayed tube flaps are best developed close enough to the defect to allow their immediate application (tumbling) to the wound after the initial delay period. Loose elastic skin is required for flap development and donor bed closure. Tube flaps can be rotated up to 180° as long as care is taken to avoid excessive kinking or twisting of the transfer pedicle. Flap width equals the width of the wound: an additional 2 or 3 cm is added to this measurement to offset flap "shrinkage" secondary to fibrosis and loss of skin elasticity. Additional width should be considered to ensure no circumferential tension is present when the flap is sutured into the tube configuration. Flap length is determined by measuring from the base of the flap closest to the wound (transfer pedicle) and the length required to arc or rotate the flap into its new position. This is best determined with the use of a foam-rubber model. An additional 2 or 3 cm is also added to this measurement to offset flap shrinkage.

(B) Two parallel incisions are made based on these measurements. Alternatively, central pedicle(s) can be created temporarily to protect the central area of a long flap from necrosis. This central pedicle is divided in 1 week and the tubed flap maintained for an additional 2-week delay period.

(C) The bipedicle flap borders are sutured together, creating a tube. The donor bed is undermined and closed directly. Alternatively, one (or both) sides of the donor bed can be converted to an advancement flap to facilitate closure if necessary. The delay period for long-tube flaps is 3 weeks.

(D) The pedicle farthest from the defect is divided in two stages. On day 19, one half of the pedicle is divided and sutured back into place temporarily, with the patient under sedation with a 2% (subcutaneous) lidocaine block to the pedicle area to be divided. On day 21, the remaining half of the pedicle is divided and flap transfer can be initiated under general anesthesia. However, final severance of the remaining half of the pedicle can be postponed for a longer period of time if tube swelling or ischemia is recognized. A variation of this technique is the creation of a "pancake" extension on the end of the tube (outer dashed line) beyond the normal level where the pedicle is divided (inner dashed line). This round skin extension may be used to cover a wider defect without necessarily using the entire body of the tube flap.

(E) The recipient site is prepared for surgery prior to final division of the pedicle. Epithelialized borders are excised. The tube is incised along the original incision line, carefully dissected open, and sutured into place. Care is taken to avoid unnecessary tension, twisting, or kinking of the transfer pedicle.

(F) The redundant portion of the tube flap is usually excised when the flap has healed completely to the wound bed. The author usually divides the pedicle, in stages, no sooner than 4 weeks after transfer.

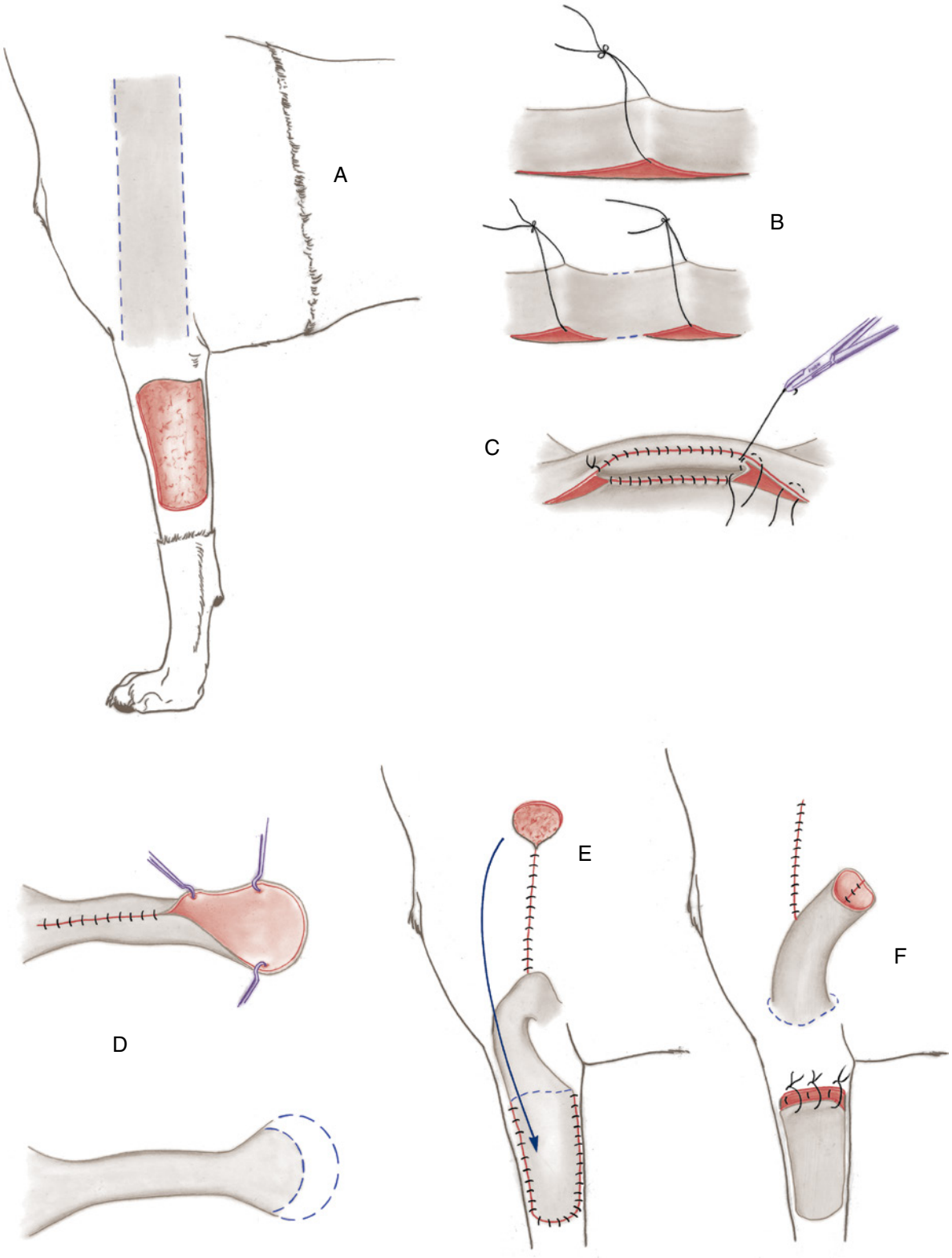
COMMENTS

Delayed tubed flaps are used to transfer skin to a distant recipient site if there is no immediate need to cover an area. They are used almost exclusively for lower-limb defects and employed only if simpler methods of skin transfer are unable to close the defect satisfactorily. In this clinical example, a brachial axial pattern flap, thoracodorsal axial pattern flap, or free graft technique would be preferable options for closure.

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Plate 56



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Plate 56

(Continued)

Tubed flaps are moved by migration in dogs and cats by one of three techniques: caterpillaring, waltzing, or tumbling. *Caterpillaring* entails moving one end of the flap close to the other; in essence, doubling the flap on itself. After a second delay procedure, the other pedicle is severed and the freed end is extended toward the defect. *Waltzing* requires the alternate movement of each pedicle in a lateral motion, whereas *tumbling* entails severing one pedicle and extending it forward, thereby advancing the flap directly toward the defect. Of the three, tumbling is the most direct method of transfer, especially when it is developed close to the defect, thus enabling immediate application of the flap to the recipient bed after a single delay period.

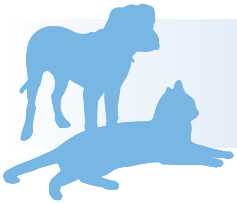
Although modifications in the basic design have been reported, the standard technique illustrated is satisfactory for most cases requiring this procedure. Removal of subcutaneous fat has been advocated to facilitate the tubing of flaps in obese human patients, but this is rarely considered necessary in the dog. Moreover, the removal of subcutaneous fat and the associated panniculus muscle can inadvertently damage the subdermal plexus and the associated vasculature, significantly compromising flap circulation. If adipose tissue might impair tubing, the flap should be designed so that it is wide enough to avoid this problem.

Each pedicle does not necessarily have the same circulatory contribution to the flap body. The "dominant" pedicle, which has greater blood perfusion, is best preserved, whereas the nondominant pedicle can be divided with less danger of distal flap necrosis after the delay procedure. Unfortunately, flap design is usually dictated primarily by the defect and available donor tissue. The final flap design is a compromise between these factors.

Tube necrosis can occur at the vascular interface between the two pedicles; this does not occur at the center of a tubed flap unless the circulatory contribution of each pedicle is equal. In general, there is no immediate need to divide the transfer pedicle after successful flap transfer. Although staged division of the tube can be instituted 10–14 days after transfer, the author generally waits a minimum of 1 month. Excluding cosmetic considerations and possible dermatitis, the tubed transfer pedicle can be retained on the patient indefinitely. It may be preserved (as a spare tire) if future regional reconstructive surgery is anticipated (e.g., local tumor recurrence). It also can be employed for additional coverage of any portion of the wound that remains uncovered, or it can be left intact to maintain flap circulation in those wounds lacking the circulation required to support pedicle graft survival (e.g., chronic radiation wounds, etc.). In these situations, a bridge incision could be used to eliminate a free-standing tube segment. Postoperatively, the tube must be protected from trauma and supported with a soft cotton bandage, depending on its position on the body. Soft cotton rolls are usually taped on each side of the tubed flap, followed by a soft cotton bandage over the area, until the flap is transferred. A bandage applied after flap transfer should place no pressure on the flap. Elizabethan collars are advisable to prevent self-mutilation.

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13

Axial Pattern Skin Flaps

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INTRODUCTION: AXIAL PATTERN FLAPS

An axial pattern flap is a pedicle graft that incorporates a direct cutaneous artery and vein into its base. The vessels extend up the length of the flap to a variable degree, the terminal branches of which supply blood to the subdermal plexus. As a result, axial pattern flaps have better perfusion compared to pedicle grafts, whose circulation is derived from the subdermal plexus alone (subdermal plexus flaps). Experimental studies and clinical trials have demonstrated that large axial pattern flaps can be safely elevated and transferred in a single stage for closure of major cutaneous defects within their general radius.

There are several axial pattern flaps that have been formally researched and designed for clinical use in the dog. They are based on the following direct cutaneous arteries: omocervical artery, thoracodorsal artery, lateral thoracic artery, superficial brachial artery, caudal superficial epigastric artery, cranial superficial epigastric artery, deep circumflex iliac artery, genicular artery, caudal auricular artery, lateral caudal (tail) artery, angularis oris artery, and superficial temporal artery. The caudal superficial epigastric artery (Figs 13-1, 13-2, and 13-3) and thoracodorsal artery (Figs 13-4, 13-5, and 13-6) have the greatest clinical promise for axial pattern development, in both the cat and dog (see Table 13-1). Other axial pattern flap techniques, such as the genicular (Fig. 13-7), cranial superficial epigastric (Fig. 13-8), and deep circumflex iliac (Fig. 13-9) (dorsal and ventral branches), are effective for a more selective group of defects based on their size and location. A variation of the ventral deep circumflex iliac, the flank fold flap (Fig. 13-10), can be useful for defects involving the caudal abdomen and inguinal area. (*Note*: the facial axial pattern flap based on the angularis oris circulation is discussed in Chapter 15, Facial Reconstruction, Plates 94 and 95.) More recent axial pattern flaps described include the feline perineal artery as well as the general outline of the regional perineal vasculature (Plates 74 and 75).

Axial pattern flaps are generally rectangular in shape (standard peninsula configuration), although they can be modified with a right-angle extension (L or hockey-stick configuration). The right-angle design enables the surgeon to cover irregular or wider defects that may not be completely covered by the standard peninsular design. Furthermore, this latter design can avoid encroachment on the other side of the patient whereby the opposite direct cutaneous vessels may be necessarily sacrificed during flap elevation.

Axial pattern flap development and transfer require careful planning. Measuring and drawing the flap on the patient's skin prior to surgery minimize errors. Alcohol-resistant marking pens are available from various companies (including VWR® markers, VWR International, LLC, Radnor, PA) are preferable when isopropyl alcohol is used for surgical preparation of the skin. Alternatively, skin staples may also be used to silhouette the outlined flap to avoid losing the markings of the predrawn flap. Because axial pattern flaps rotate into adjacent defects, guidelines for local transposition flap measurement and transfer are equally applicable to their planning.

To date, the most commonly employed axial pattern flaps include the thoracodorsal and caudal superficial epigastric variations. They are effective for a variety of defects associated with the forelimbs and hindlimbs, respectively. Plate 37 demonstrates the use of skin stretchers to lengthen axial pattern flaps when needed to reach more distant defects.

ISLAND ARTERIAL FLAPS

Island arterial flaps can be developed from axial pattern flaps by dividing the cutaneous pedicle but preserving the direct cutaneous artery and vein entering the newly created "skin island." Although island arterial flaps have considerable mobility tethered to the direct cutaneous vessels, their routine clinical use is unnecessary. One exception involves large defects that encroach on the origin of a direct cutaneous artery and vein. Under these circumstances, it is possible to rotate an island arterial flap (the base of which shares a common border with the wound) 180° over the defect (Figs. 13-8 and 13-9).

Island arterial flaps have potential for use in free flap development and transfer, using present-day microvascular surgical techniques; however, the surgical training,

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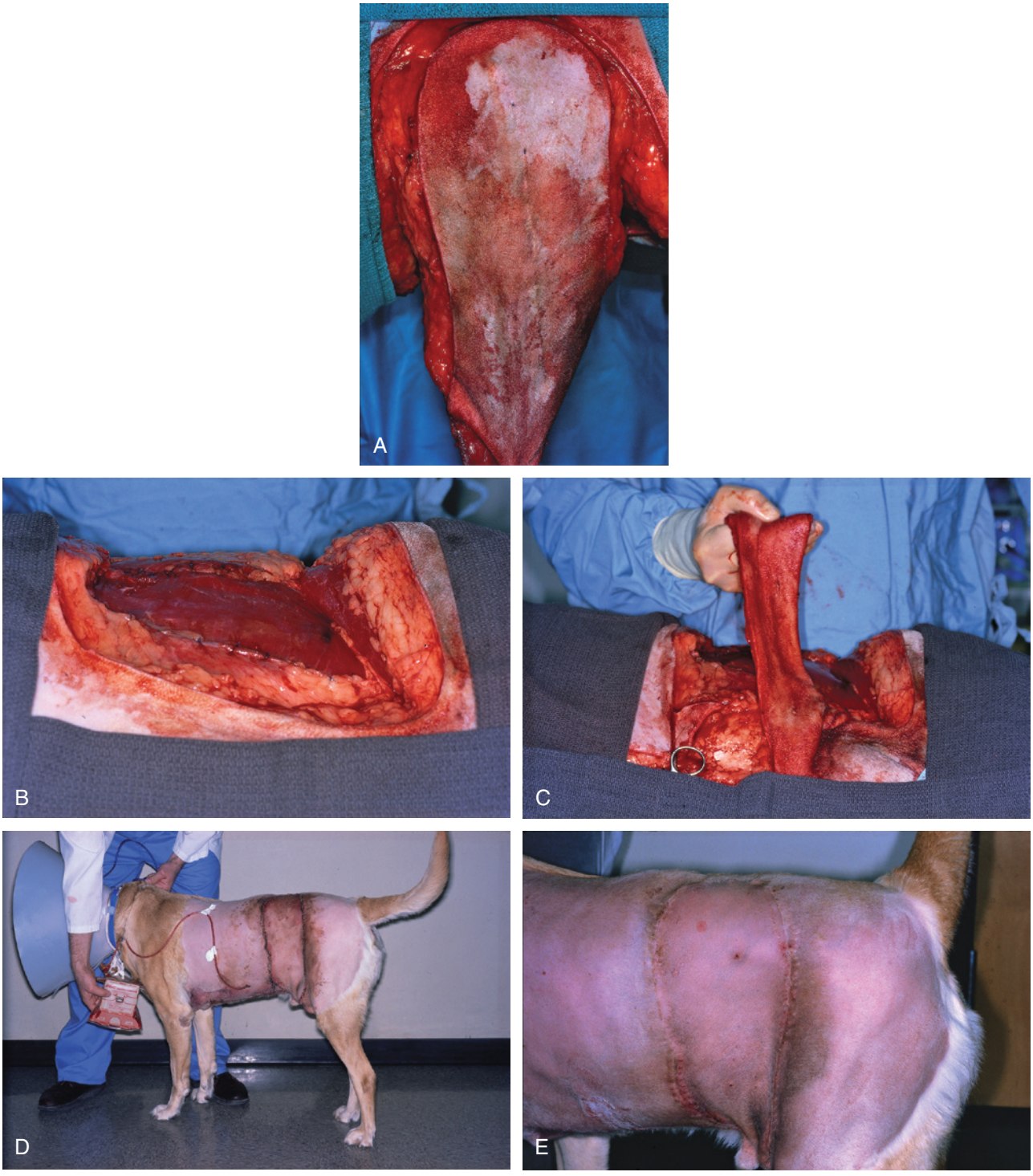


FIG. 13-1 (A) Wide resection of fibrosarcoma involving the left flank and lateral abdomen. (B) The external abdominal oblique muscle also was resected. (C) Elevation of the left caudal superficial epigastric axial pattern flap. (D) Closure of the wound. 35 W skin staples were used to secure the flap. The drain was secured to the dog's collar. Tape strips applied to the vacuum tubing were secured to the thoracic skin with staples. (E) Complete survival of the flap.

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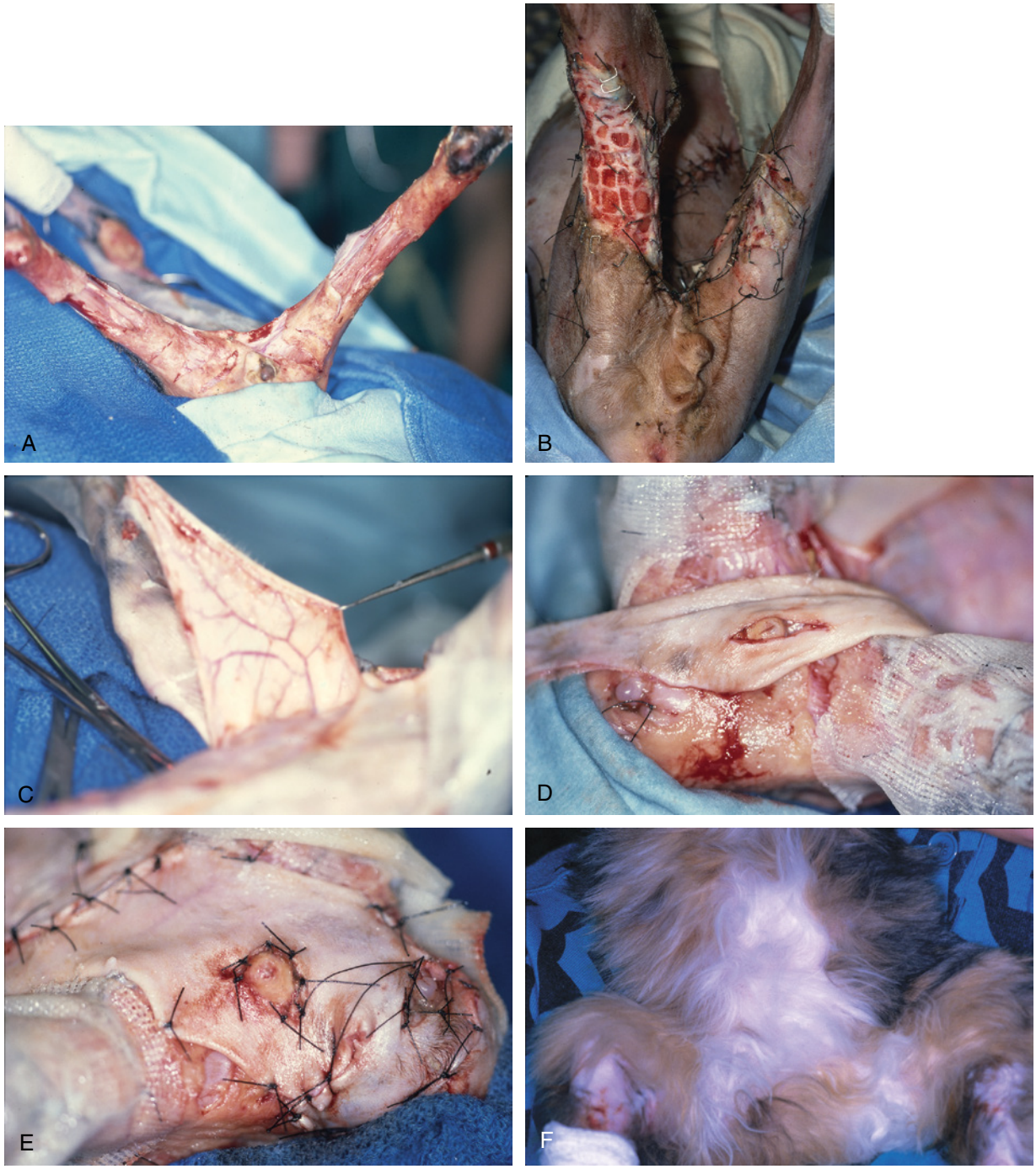


FIG. 13-2 (A, B) Extensive burn sustained by a cat. Necrotic tissue debridement was facilitated by warm saline baths in a sterilized stainless steel bucket (see Fig. 7-17). Wound closure was attempted when a healthy granulation bed formed. Contractures in the popliteal areas were released; mesh grafts were applied to the rear extremities. (C) Elevation of a caudal superficial epigastric axial pattern flap. Note branching of the epigastric vasculature. (D) A slit was created in the flap, between branches of this direct cutaneous artery and vein, to accommodate the prepuce and penis. (E) The flap was carefully fashioned around the anus and prepuce. (F) The patient a few months later, completely rehabilitated. The medical and surgical management of the wounds (flaps/grafts) and an additional operation to release a scar stricture/contracture involving the anus and right forelimb, respectively, were costly. Several years after the surgery, the patient is in excellent health.

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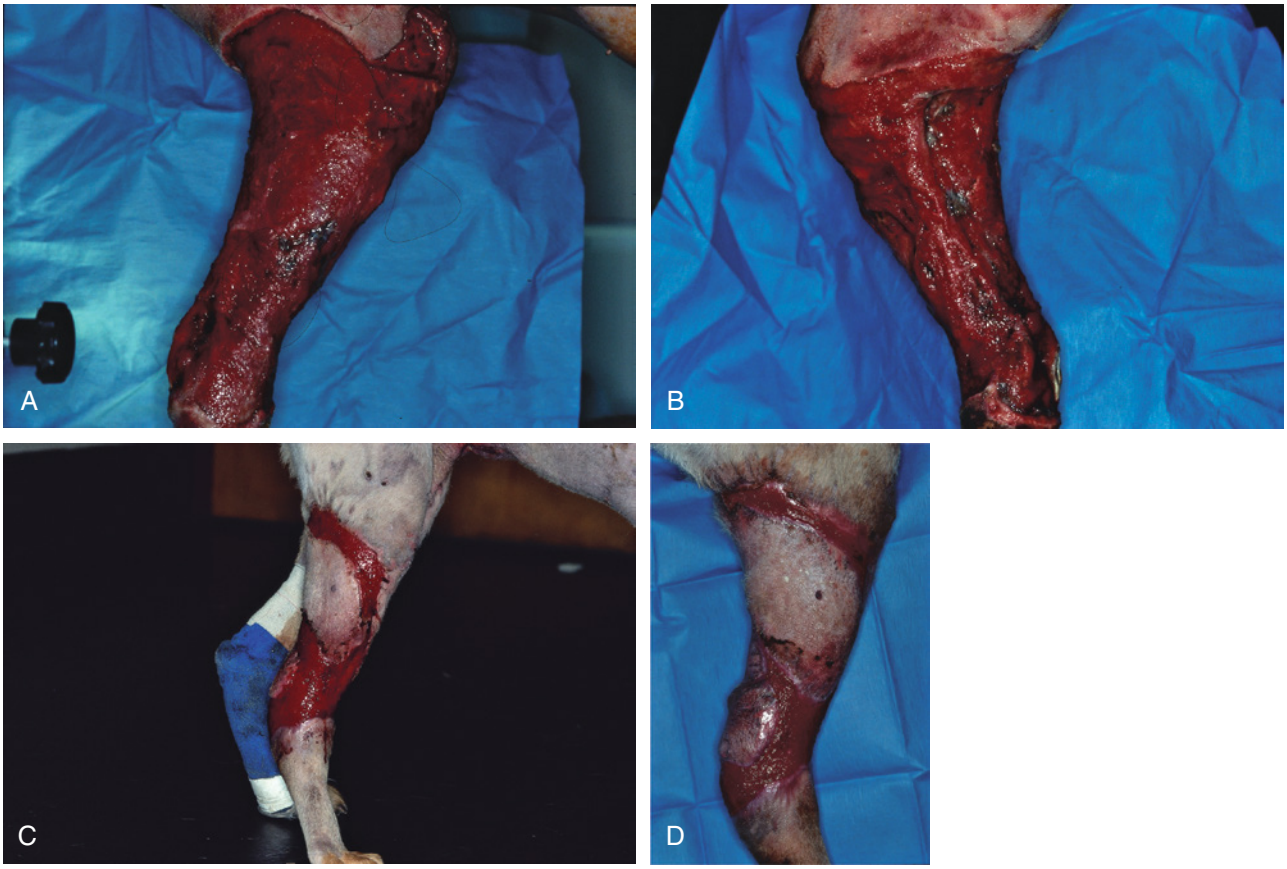


FIG. 13-3 (A, B) Massive circumferential loss of skin from the rear leg of a German shepherd, secondary to vehicular trauma. (C, D) Successful coverage with two caudal superficial epigastric axial pattern flaps in a double-helix fashion. The second flap was delayed for approximately 5 days to allow mobilization of additional abdominal skin with skin stretchers. This maneuver was needed to ensure the ventral abdominal donor site could be closed after recruitment of both flaps, which accounted for the skin of the entire ventral abdomen. Areas of exposed granulation tissue rapidly epithelialized from the borders of the flaps.

skill, equipment, and cost involved in microvascular surgery restrict such techniques to the largest academic institutions. Fortunately, most wounds can be handled more easily with the reconstructive techniques covered in this textbook.

The island arterial flaps that I have most commonly employed include the cranial superficial epigastric flap (for large defects involving the sternal area) and ventral deep circumflex iliac axial pattern flap (for problematic dorsal pelvic defects). For those interested in microvascular transplantation of free flaps, island arterial flaps can be used for this purpose.

REVERSE SAPHENOUS CONDUIT FLAPS

A variation of the axial pattern flap, the reverse saphenous conduit flap, has clinical application for wounds involving the tarsal and metatarsal areas of the dog. This flap is based over the saphenous artery and medial saphenous vein, which supply small direct cutaneous vessels to the overlying skin. On division from the femoral artery and vein, circulation flows in reverse fashion through the saphenous vessels via anastomoses with collateral vascular tributaries (Fig. 13-11).

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FIG. 13-4 (A) Nonhealing, traumatic antecubital defect in a German shepherd. (B) Tubed thoracodorsal axial pattern flap coverage of the defect. (C) Close-up view of the tubed pedicle. At the time of surgery, a tubed transfer was considered easier to position the flap, compared to a bridge incision. (D, E) Two months after transfer, the tubed pedicle was divided at both ends to complete the transfer. The dorsal end of the flap was divided first and the thoracodorsal vessels were ligated. Note the "reverse" bleeding from the cut end of the tube. (F) Completion of the tube resection.

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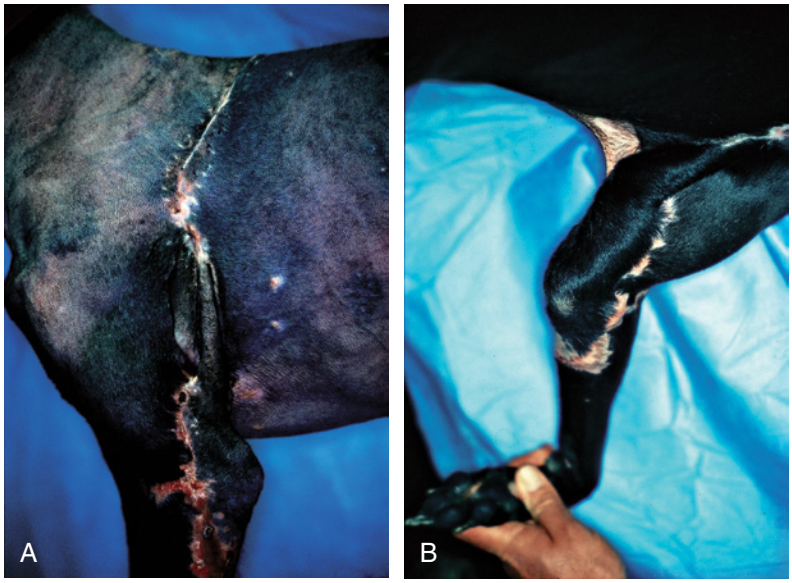


FIG. 13-5 (A) Thoracodorsal axial pattern flap used to close a massive skin loss over the elbow region, secondary to infection. A small portion of the terminal flap underwent necrosis, necessitating debridement and resuturing. Note early epithelialization of the exposed granulation bed. (B) Healing of the area was complete within 4 weeks after surgery. The flap provided a durable coverage to the elbow region of this greyhound.

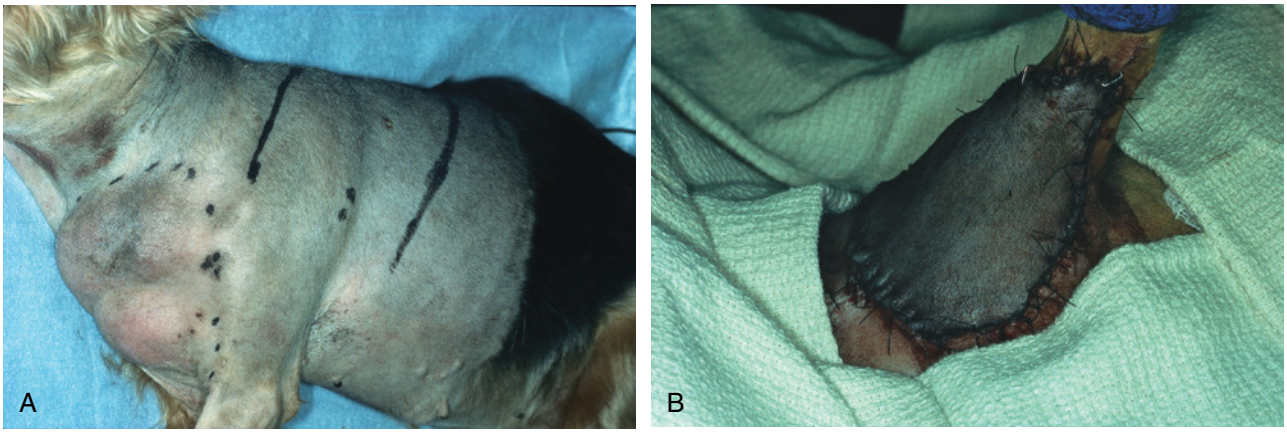


FIG. 13-6 (A) Mast cell tumor involving the left shoulder region. (B) Wide excision was followed by rotation of the adjacent thoracodorsal axial pattern flap. The patient later underwent radiation therapy and chemotherapy.

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TABLE 13-1 Summary of guidelines for axial pattern flap development.

Artery	Anatomic Landmarks	Reference Incisions	Potential Uses*
Cervical cutaneous branch of the omocervical artery	Spine of the scapula Cranial edge of the scapula (cranial shoulder depression) Dogs in lateral recumbency, skin in natural position, thoracic limb placed in relaxed extension Vessel originates at location of the prescapular lymph node	*Caudal incision*: spine of the scapula in a dorsal direction *Cranial incision*: parallel to the caudal incision equal to the distance between the scapular spine and cranial scapular edge (cranial shoulder depression) *Flap length*: variable; contralateral scapulohumeral joint	Facial defects Ear reconstruction Cervical defect Shoulder defect Axillary defects
Thoracodorsal artery	Spine of the scapula Caudal edge of the scapula (caudal shoulder depression) Dog in lateral recumbency, skin in natural position, thoracic limb in relaxed extension Vessel originates at caudal shoulder depression at a level parallel to the dorsal point of the acromion	*Cranial incision*: spine of the scapula in a dorsal direction *Caudal incision*: parallel to the cranial incision equal to the distance between the scapular spine and caudal scapular edge (caudal shoulder depression) *Flap length*: variable; can survive ventral to contralateral scapulohumeral joint	Thoracic defects Shoulder defects Forelimb defects Axillary defects
Superficial brachial artery	Flexor surface of elbow Humeral shaft Greater tubercle	*Incision lines*: flap base includes flexor surface of elbow, anterior one-third Lateral and medial incisions parallel humeral shaft Flap is progressively tapered approaching greater tubercle *Flap length*: variable; flap ends at level of greater tubercle	Antebrachial defects Elbow defects
Caudal superficial epigastric artery	Midline of abdomen Mammary teats Base of prepuce	*Medial incision*: abdominal midline. In the male dog, the base of the prepuce is included in the midline incision to preserve the adjacent epigastric vasculature *Lateral incision*: parallel to medial incision at an equal distance from the mammary teats *Flap length*: variable; may include the last four glands and adjacent skin	Flank defects Inner-thigh defects Stifle area Perineal area Preputial area
Cranial epigastric artery	Hypogastric region Abdominal midline Mammary teats Base of prepuce	*Base of flap:* location in hypogastric region *Medial incision*: abdominal midline *Lateral incision*: parallel to midline incision at an equal distance from mammary teats *Flap length*: glands 2, 3, 4; anterior to prepuce	Closure of wounds overlying sternal region
Deep circumflex iliac artery (dorsal branch)	Cranial edge of wing of ilium Great trochanter Dog in lateral recumbency, skin in natural position, pelvic limb in relaxed extension Vessel originates at a point cranioventral to wing of the ilium	*Caudal incision*: midway between edge of wing of ilium and greater trochanter *Cranial incision*: parallel to caudal incision equal to the distance between the caudal incision and cranial edge of the iliac wing *Flap length*: dorsal to contralateral flank fold	Thoracic defects Lateral abdominal wall defects Flank defects Lateral/medial thigh defects Defects over the greater trochanter
Deep circumflex iliac artery (ventral branch)	Anatomic landmarks of flap base are the same as dorsal branch of deep circumflex iliac artery Shaft of femur	*Caudal incision*: extends distally, anterior to cranial border of femoral shaft *Cranial incision*: parallel to caudal incision *Flap length*: proximal to patella	Lateral abdominal wall defects Pelvic defects Sacral defects—as an island arterial flap
Genicular artery	Patella Tibial tuberosity Greater trochanter	*Base of the flap*: 1 cm proximal to the patella and 1.5 cm distal to tibial tuberosity (laterally) *Flap borders*: extend caudodorsally parallel to the femoral shaft. Flap terminates at the base of the greater trochanter	Lateral or medial aspect of the lower limb, from the stifle to the tibiotarsal joint
Lateral caudal arteries (left and right)	Proximal third of tail length Transverse processes of vertebrae	*Incision*: dorsal or ventral midline skin incision, depending on intended flap usage; careful dissection along deep caudal fascia of the tail; vessels located lateral and slightly ventral to transverse processes, in proximal tail region; amputation of tail at third to fourth intervertebral space, preserving skin *Flap length*: proximal third of tail length	Perineum, caudodorsal trunk

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TABLE 13-1 (Continued)

Artery	Anatomic Landmarks	Reference Incisions	Potential Uses*
Caudal auricular artery	Wing of atlas Spine of the scapula	*Base of flap*: palpable depression between lateral aspect of wing of atlas and vertical ear canal; flap centered over wing of atlas *Width of flap*: central "third" of lateral cervical area over lateral aspect of wing of atlas; in cats, dorsal border close to dorsal midline *Flap length*: up to spine of scapula (survival length variability)	Facial area Dorsum of head Ear
Reverse saphenous conduit flap**	Inner thigh Tibial shaft	*Proximal incision*: central third of inner thigh at level of patella; ligate saphenous artery and vein at level of femoral artery and vein *Cranial and caudal incisions*: skin incisions extended distally in converging fashion, 0.5–1.0 cm cranial and caudal to cranial and caudal saphenous artery and medial saphenous vein; flap undermined beneath saphenous vasculature; ligate and divide peroneal artery and vein *Flap length*: variable, base of flap at level of anastomosis of cranial branches of medial and lateral saphenous veins	Defects of tarsometatarsal regions *Note:* use of flap requires intact collateral blood to lower extremity
Superficial temporal artery	Caudal edge of zygomatic arch Lateral border of caudal orbital rim	*Base of flap*: level of zygomatic arch *Width of flap*: flap approximates width of zygomatic arch *Incisions*: parallel incisions from landmarks, extending over dorsum of head toward opposing landmark, to mid-dorsal orbital rim of the opposite eye; undermine below frontalis muscle layer	Defects over dorsal nasal area, lateral facial area
Lateral thoracic artery (dog)	Axillary skin fold Deep pectoral muscle	*Base of flap*: axillary skin fold *Ventral border*: parallel to dorsal border of deep pectoral muscle *Dorsal border*: below origin thoracodorsal artery *Flap length*: terminates at/before costal arch; second teat not included	Elbow; axilla, upper extremity
Lateral thoracic artery (cat)	Axillary skin Lower thoracic skin	*Base of flap*: length of caudal border Triceps is base; lower thoracic artery at mid-point *Ventral border*: ventral midline of thorax *Dorsal border*: double distance from mid-point of base and ventral border; parallels ventral border *Caudal border*: last rib	Brachium Antebrachium Arc of rotation
Anglaris oris	Skin of the lateral facial surface caudal to oral commissure	*Base of flap*: intact oral commissure *Dorsal border*: lower border of zygomatic arch *Ventral border*: parallels lower border of mandible and parallel to dorsal margin *Flap length*: oral commissure margin to rostral margin of upper labial defect	Facial, upper lip
Branch of facial (cat)	Skin of lateral facial area caudal to oral commissure	*Base of flap*: intact oral commissure *Facial branch* = 1 cm caudal and ventral to midpoint of oral commissure (rostral edge of masseter muscle) *Ventral border*: area of ventral midline extending caudally *Dorsal border*: parallels ventral border equidistant to vessel origin. Border is 1 cm ventral to zygomatic arch *Flap length*: dorsoventral line 1 cm caudal to the caudal border of the atlas	Upper facial area

*Major defects only.
**Axial pattern flap variation.

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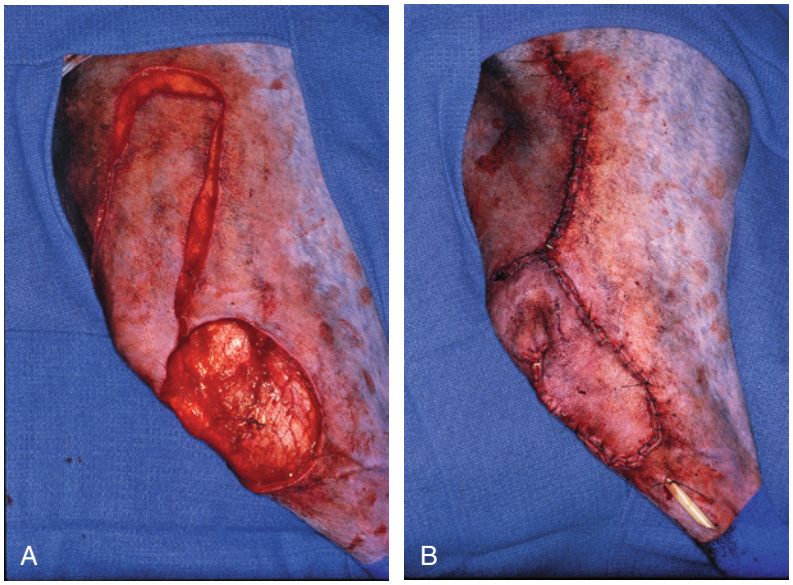


FIG. 13-7 (A) Elevation of a genicular axial pattern flap to close a skin defect secondary to sarcoma removal. (B) The flap was successfully transposed into the defect.



FIG. 13-8 (A, B) Wide mast cell tumor resection over the sternal area and closure with the cranial superficial epigastric axial pattern flap, island arterial flap variation. Today, the author would have used skin stretchers to prestretch the skin of the thorax 72 hours prior to excision to facilitate wound closure. Nonetheless, the cranial epigastric axial pattern flap can be useful for closing the more challenging skin defects in this area.

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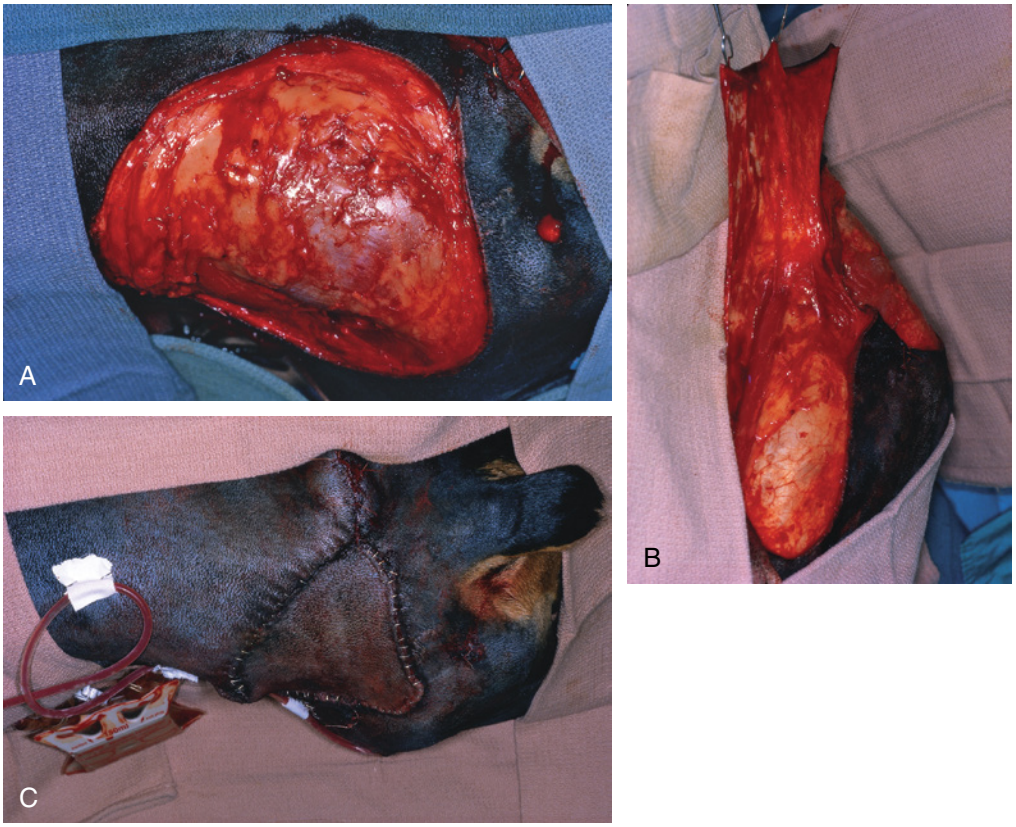


FIG. 13-9 (A) Excision of a chronic granulomatous lesion overlying the left dorsolateral pelvic region. (B) Elevation of a deep circumflex iliac axial pattern flap, island arterial flap variation, based on the ventral branch of this vessel. Note that the base of the flap shares a common border with the defect, thereby creating an island arterial flap. (C) A small dorsal portion of this skin defect was closed by direct apposition of the adjacent skin margins. The bulk of the defect was successfully closed with this flap.

SECONDARY AXIAL PATTERN FLAPS

A secondary axial pattern flap is a modification of the axial pattern flap design. Skin segments positioned over vessels or tissue containing a major artery and vein can be transferred as a unit at a later time. Once circulation is established between the dermal circulation and underlying vasculature, the elevated skin island tethered by the long vessels can be rotated into a regional defect or transferred using microvascular surgical techniques. One example of a secondary axial pattern flap includes skin segments developed over an omental pedicle that includes the epiploic vessels. Unfortunately, two-stage development and transfer is slow and comparatively expensive. It cannot be used for immediate closure of wounds, unlike the other flap and free graft techniques discussed in this book.

Secondary axial pattern flaps are rarely required. Like other less common techniques, this option should be kept in the surgeon's "data bank" for those rare, unusual wounds we might encounter.

OPTIONS TO EXTEND THE LENGTH OF AXIAL PATTERN FLAPS

When there is a significant risk of ischemic necrosis of a long axial pattern flap required to close a large wound, there are two options that may be considered to avoid this complication. They are delaying the flap (discussed in Chapter 12) or prestretching the flap (Plate 37). Of the two options, the use of skin stretchers requires 48–72 hours to safely elongate the flap, improving coverage of more distant portions of a defect. Moreover, no surgery is required in the stretching process. In comparison, delaying a flap may take as long as 3 weeks to improve circulation to the terminal end of the axial pattern flap, requiring the staged elevation and transfer of the flap. Clearly, prestretching the length of the flap prior to its surgical elevation is faster, is less expensive, and eliminates additional surgical trauma to the patient.

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FIG. 13-10 (A, B) Cat with lower abdominal wall defect: dehiscence secondary to sarcoma resection. The wound contracted and epithelialized minimally after a period of open wound management. (C, D) Closure of the defect with the left flank fold flap. The primary source of circulation to this flap is derived from the ventral branch of the deep circumflex iliac artery and vein. This technique is a variation of the axial pattern flap.

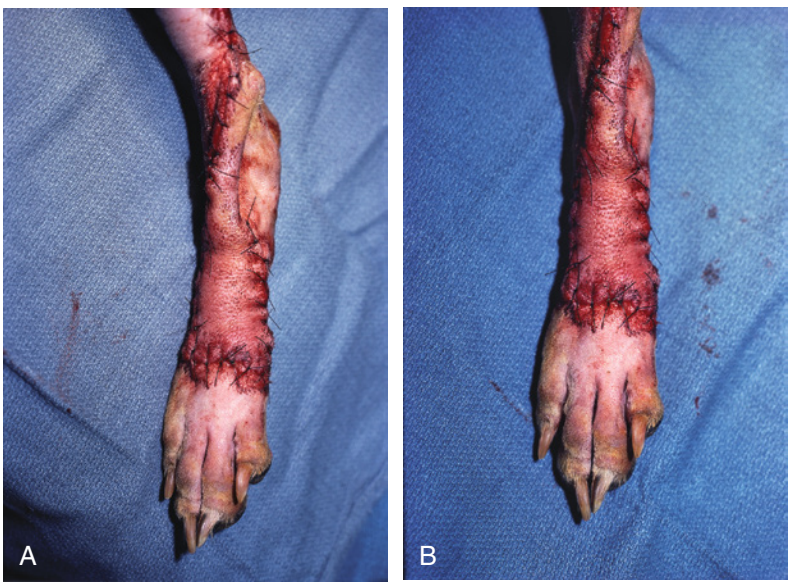


FIG. 13-11 (A, B) Example of the reverse saphenous conduit flap for closure of a metatarsal defect. The other common method of closing large defects in this area is a full-thickness mesh graft using a no. 15 scalpel blade to create the holes.

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Flap guidelines are simply that: guidelines. Use of the longest variations of *any flap* includes the risk of partial necrosis of its terminal end, secondary to ischemia. Traumatic surgical technique, improper flap elevation and transfer, infection, and insufficient postoperative care can contribute to circulatory compromise to the terminal end of the flap. In most axial pattern flaps, this usually amounts to the last few centimeters. Debridement and resuturing may be required for full-thickness skin loss. In some cases skin loss is partial thickness, with resultant survival of a portion of the dermis; resection is not necessary in these cases. If the terminal end of a longer flap is considered vital to the closure of a problematic area, a delay procedure (see Chapter 12) should be considered.

POTENTIAL POSTOPERATIVE COMPLICATIONS

As with any pedicle graft, complications have been reported in the use of axial pattern flaps including seroma formation, edema, discharge, infection, partial dehiscence, and partial necrosis of (usually the distal tip) of the flap. Complete flap necrosis is uncommon unless there is trauma or kinking of the direct cutaneous vessels. Barring any contributing health issues of the dog/cat, complete flap loss would suggest improper flap development and transfer. Most of the complications are minor, but owners should be advised that they can occur. Careful planning of the flap should include atraumatic surgical technique, preserving the blood supply, and keeping the length of the flap to the minimum required to close the wound without tension of the closure. Minimizing the physical activity of the dog and the use of the Elizabethan collar are important to protect the flap and donor area postoperatively. Closed-suction drains are effective in preventing postoperative seroma formation and drainage along the long flap margins.

Axial pattern flaps provide the surgeon with a major method of closing large skin defects. It must be kept in mind that simpler combined techniques may close a problematic wound more easily and with less surgical trauma to the patient.

PLATE CONTENTS

Other axial pattern flap variations primarily used in oral reconstructive surgery are located in Chapter 17. The plates in the current chapter cover axial pattern flaps primarily employed for major cutaneous defects. Additionally, Plates 74 and 75 discuss direct cutaneous arteries of the feline perineum, based on cadaver research (Andries et al. 2019). Plate 62 outlines the lateral thoracic artery in cats. These vessels have potential use for axial pattern flap development.

See Chapter 25 for additional clinical flap examples.

Suggested Reading

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Plate 57

Four Major Axial Pattern Flaps of the Canine Trunk

DESCRIPTION

The comparative positions of the omocervical, thoracodorsal, deep circumflex iliac (dorsal branch), and caudal superficial epigastric axial pattern flaps are illustrated.

SURGICAL CONSIDERATIONS

(A) The left side of the dog, demonstrating the relative location of the respective axial pattern flaps.

(B) The right side of the dog, showing the flap extending from the opposite side. Note the standard peninsula and right angle (L hockey-stick) variations.

(C) The position of the underlying superficial cervical branch of the omocervical artery (O), thoracodorsal artery (T), dorsal branch (DD) and ventral branch (DV) of the deep circumflex iliac artery, and the caudal superficial epigastric artery (C) are illustrated.

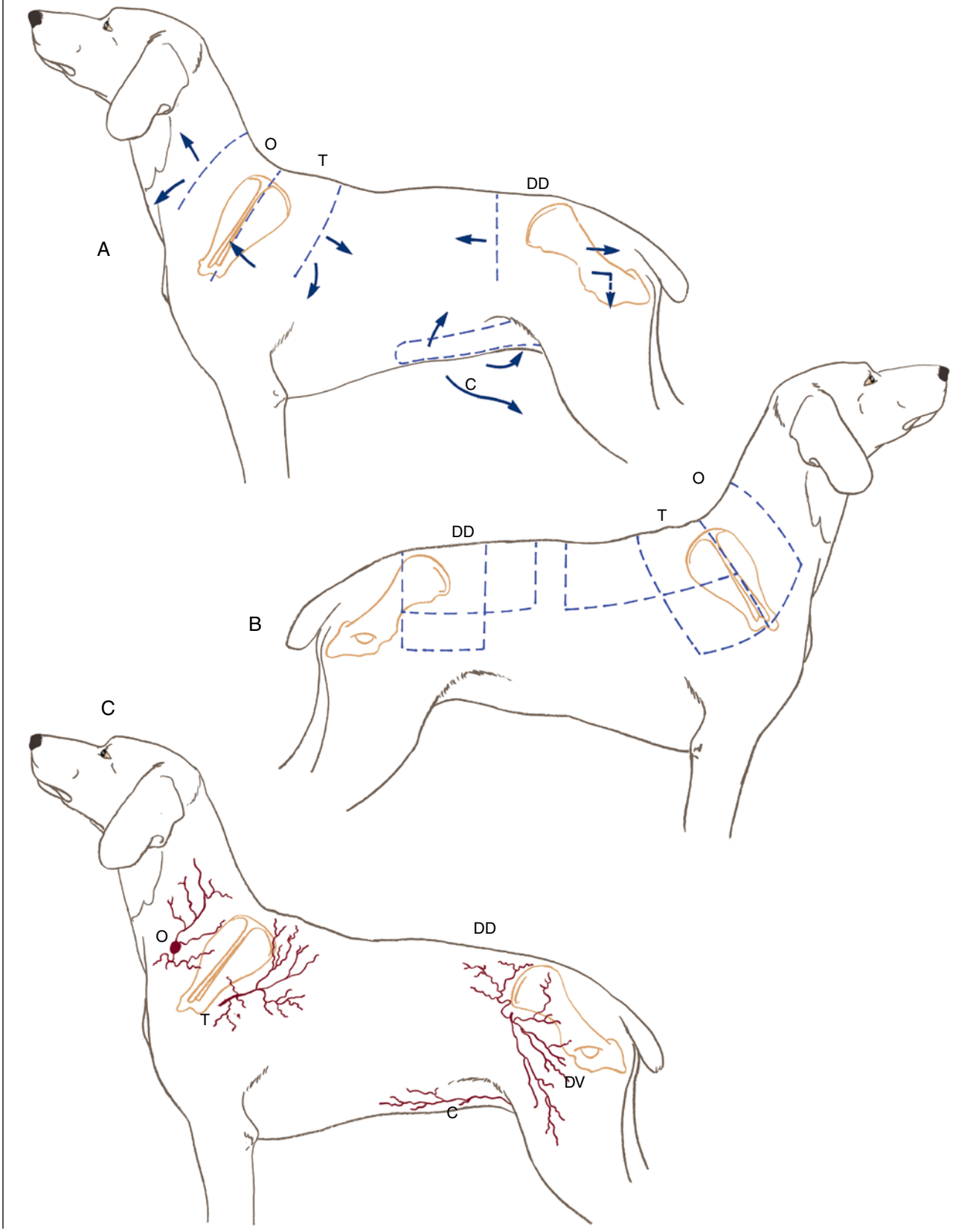
COMMENTS

Careful measurement of the defect and flap are required. Measurement tapes are ideal for this purpose. The peninsula flap design has a greater length than the right-angle design. However, the latter shape can cover a wider regional defect if the inner flap angle is sutured to itself. The advantages of each technique are discussed individually in this chapter.

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Plate 58

Skin Position and Axial Pattern Flap Development

DESCRIPTION

The proper position of the skin in relation to the underlying anatomic structures is essential to locating the direct cutaneous arteries for appropriate axial pattern flap development on the canine trunk.

SURGICAL CONSIDERATIONS

(A) Outline of the omocervical and thoracodorsal axial pattern flaps requires the skin overlying the scapula to remain in a natural position in relation to the underlying scapula. The forelimb is placed in relaxed extension. The skin over the scapula is grasped, lifted, and allowed to spontaneously retract to its natural undistended position before outlining the flap with a felt-tipped marking pen.

(B) The elevation of the deep circumflex iliac axial pattern flap similarly requires placement of the hindlimb in relaxed extension. The skin overlying the lateral pelvis is grasped, lifted, and allowed to retract into its natural position. The flap is outlined on the skin using the anatomic landmarks discussed in this chapter.

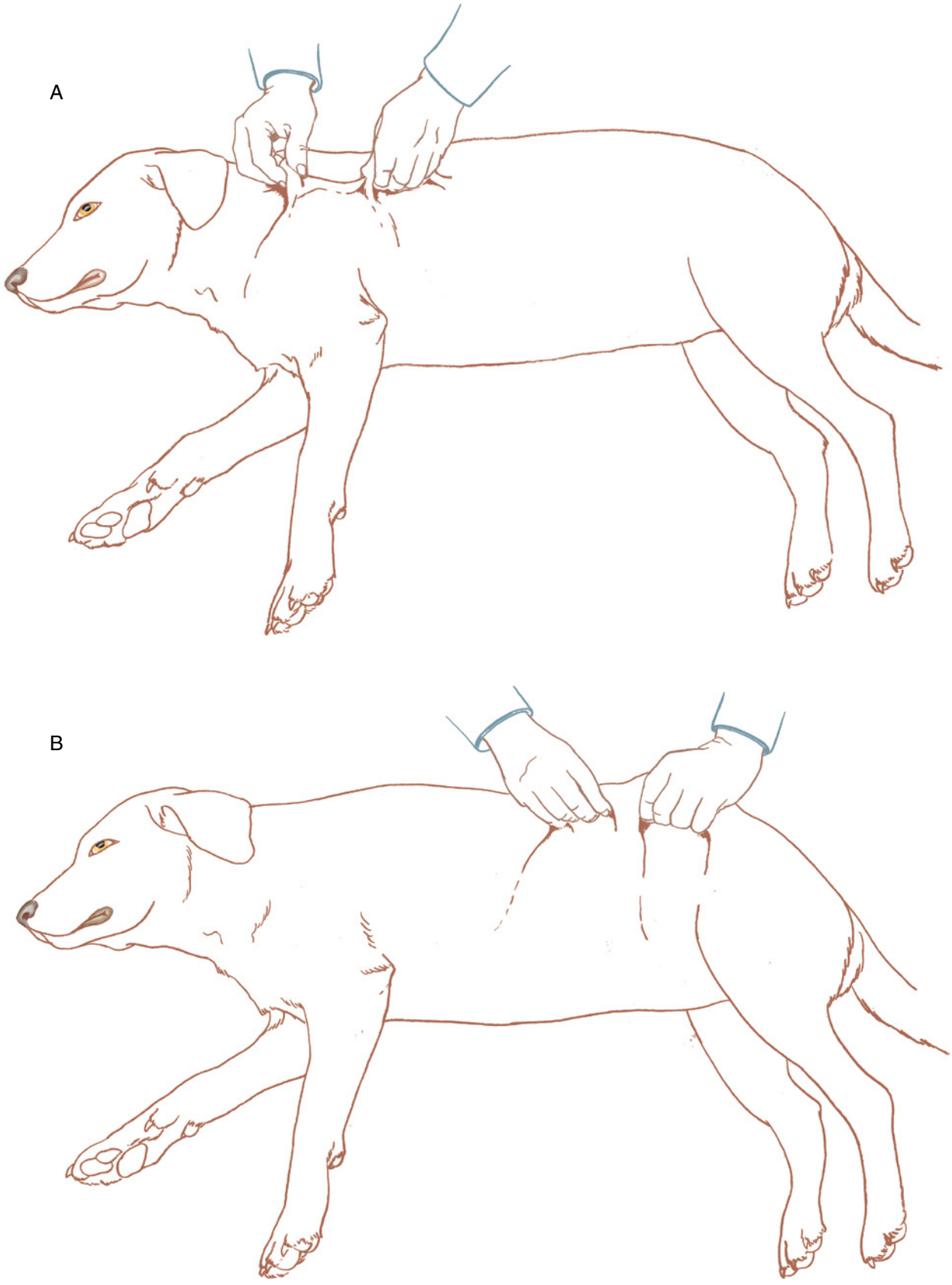
COMMENTS

The donor area must be thoroughly clipped. Cleansing the skin with isopropyl alcohol–impregnated gauze sponges will help to remove natural oils that impair use of felt-tipped marking pens. Alcohol-resistant marking pens are preferable since the flap outline is less likely to rub off during the surgical preparation of the skin (VWR markers).

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Plate 58



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Plate 59

Omocervical Axial Pattern Flap

DESCRIPTION

The omocervical axial pattern flap incorporates the superficial cervical branch of the omocervical artery and its associated vein. The vessels originate adjacent to the prescapular lymph node and arborize dorsally just cranial to the scapula.

SURGICAL TECHNIQUE

(A) The anesthetized patient is placed in lateral recumbency. The forelimb is placed in relaxed extension perpendicular to the trunk. The cervical and thoracic skin is grasped, lifted, and allowed to spontaneously retract to the normal position to ensure the loose skin is not shifted or distorted in relation to the anatomic landmarks (see Plate 58). A line is drawn over the spine of the scapula with a marking pen, forming the caudal border of the flap (arrow). The cranial shoulder depression is palpated. The cranial incision is drawn on the skin, parallel to the caudal incision site, equal to the distance from the cranial shoulder depression (prescapular lymph node) to the caudal incision line.

(B) The reference lines are extended to the dorsal midline and down the opposite side to the contralateral scapulohumeral joint (B_1). Alternatively, the right-angle (hockey-stick) design can be created as required. Note that this variation does not extend down to the contralateral scapulohumeral joint: this surface area is "converted" to the angular extension (B_2).

(C) The flap is undermined below the level of the sphincter coli superficialis muscle, beginning at the distant end of the flap. Care must be taken to avoid any trauma to the direct cutaneous vessels. Elevation of long omocervical axial pattern flaps necessitates division of the opposite omocervical direct cutaneous artery and vein.

(D) The omocervical axial pattern flap can be rotated into a variety of positions.

(E) As the flap is being sutured into the recipient bed, the donor site is closed with a subcuticular pattern followed by skin sutures or staples. Drains are employed to control dead space and reduce the likelihood of seroma formation. The arrow denotes the removal of fluid into a closed-suction drainage system.

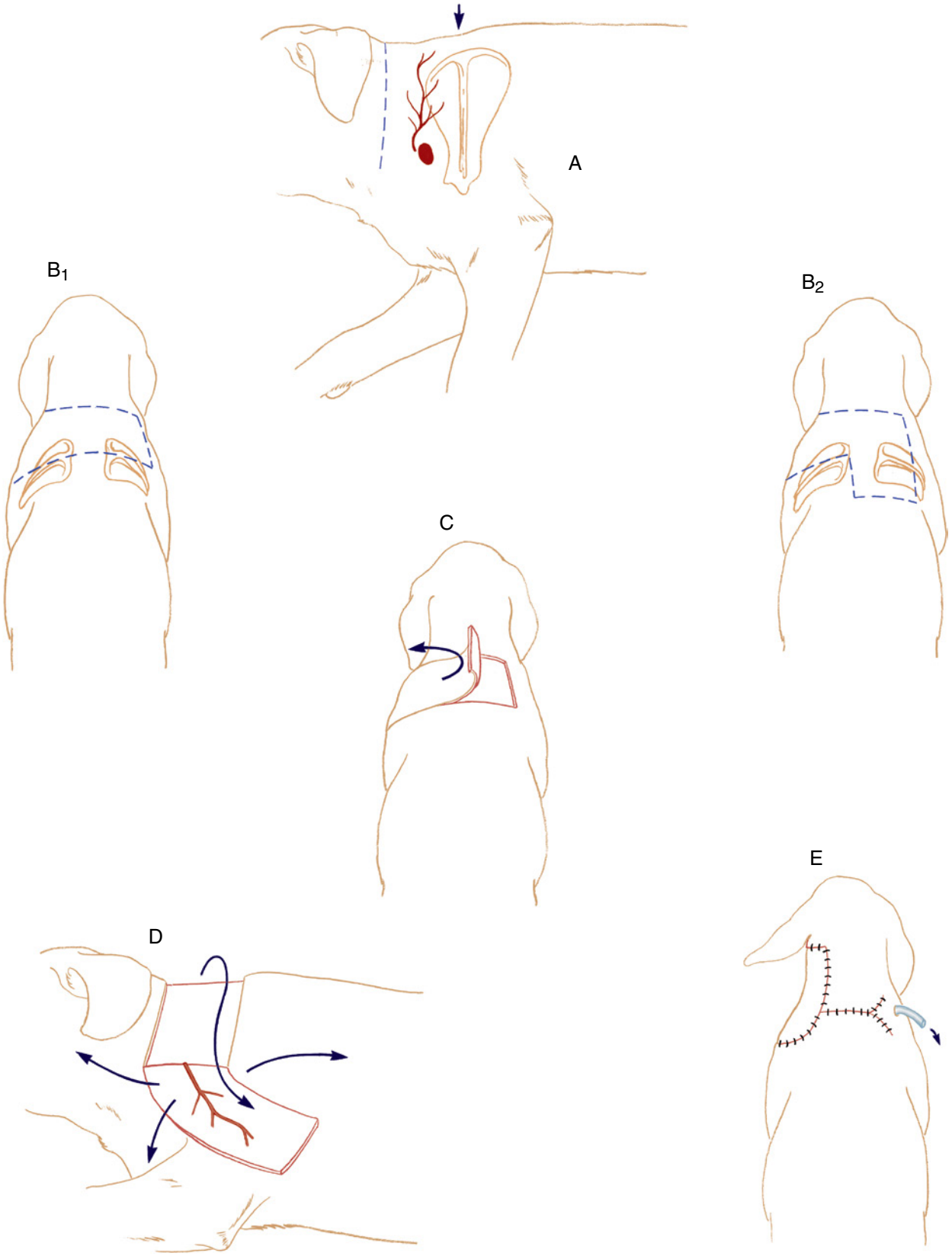
COMMENTS

The omocervical axial pattern flap has potential use for large skin defects within its arc of rotation, including wounds involving the face, head, ear, shoulder, neck, and axilla. Use of this flap also has been reported for oral reconstruction (Dundas et al. 2005). The more robust thoracodorsal axial pattern flap is preferred over the omocervical flap for the closure of defects within their mutual areas of coverage.

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Plate 59



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Plate 60

Thoracodorsal Axial Pattern Flap

DESCRIPTION

The thoracodorsal axial pattern flap is based on the cutaneous branch of the thoracodorsal artery and associated vein. The moderately sized thoracodorsal direct cutaneous artery arborizes in a dorsal direction behind the scapula.

SURGICAL TECHNIQUE

(A) With the dog in lateral recumbency, the lateral cervical and thoracic skin is grasped, lifted, and allowed to spontaneously retract to a normal position. The forelimb is placed in relaxed extension perpendicular to the trunk (see Plate 58). A felt-tipped marking pen is used to draw a line over the spine of the scapula, forming the cranial border of the flap. (The thoracodorsal vessel that originates at the caudal shoulder depression is palpated.) The caudal incision is drawn onto the skin parallel to the cranial incision, equal to the distance from the cranial incision to the caudal shoulder depression. The reference incision lines extend to the dorsal midline.

(B) The standard peninsular (B_1) or hockey-stick (L) configuration (B_2) can be created, depending on the location and size of the defect.

(C) The flap is elevated below the level of the cutaneous trunci muscle, beginning at the end of the flap. Great care must be taken to avoid injury to the thoracodorsal artery and vein: subcutaneous fat frequently obscures the ability to visualize them. The thoracodorsal flap can be pivoted into a variety of defects. The flap may be partially tubed to reach a distant defect or sutured to a bridge incision to traverse the skin interposed between the donor and recipient sites.

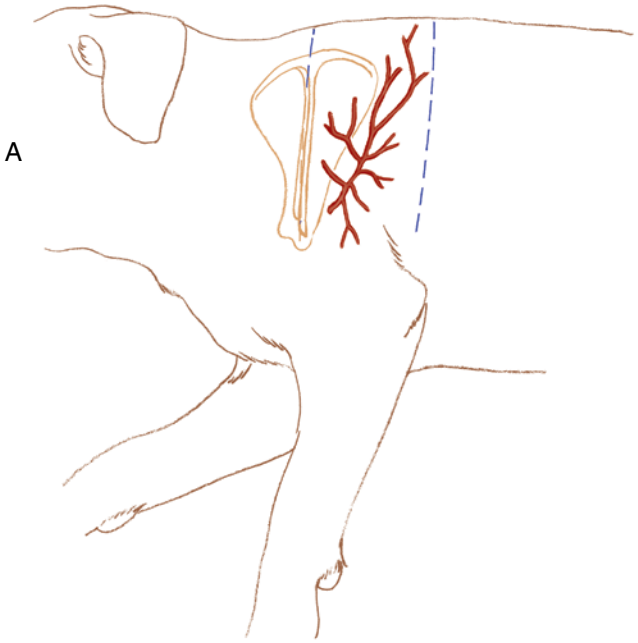
COMMENTS

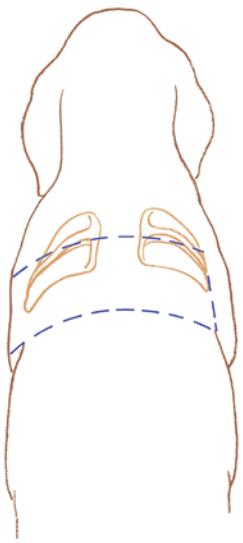
Note that the peninsular design can extend down to the contralateral scapulohumeral joint, whereas the hockey-stick variation is shortened to accommodate the angular extension. Both flap configurations, however, have similar surface areas. Thoracodorsal axial pattern flaps of considerable length can be developed to cover defects involving the shoulder, forelimb, elbow, axilla, and thorax in the dog and cat. Development of long thoracodorsal axial pattern flaps may necessitate division of the opposite cutaneous branch of the thoracodorsal artery and vein. When feasible, it is preferable to position forelimb defects for immediate flap transfer rather than repositioning the patient intraoperatively. The thoracodorsal axial pattern flap is a robust flap capable of covering a variety of defects in the dog and cat. Distal limb coverage is dependent on body conformation and limb length for the dog. In the cat, this flap can extend to the level of the carpus. Plate 37 demonstrates the use of skin stretchers to lengthen the thoracodorsal axial pattern flap.

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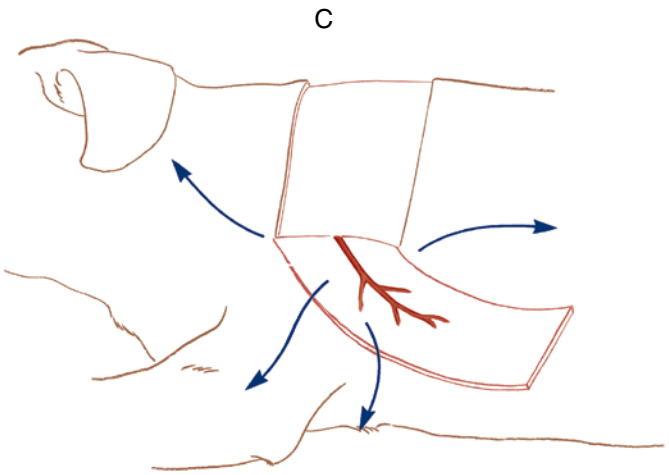
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Plate 60









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Plate 61

Lateral Thoracic Axial Pattern Flap (Dog)

DESCRIPTION

The lateral thoracic artery (LTA) arises from the caudal aspect of the axillary artery, adjacent to the cranial border of the first rib. The cutaneous branch extends in a caudal direction, supplying the cutaneous trunci muscle and overlying skin caudal to the axillary skin fold. The LTA is noted to enter the skin cranial and ventral to the origin of the thoracodorsal artery. The resultant flap has potential for closing defects involving the elbow region and other problematic wounds within its arc of rotation.

SURGICAL TECHNIQUE

(A) Outline of the LTA axial pattern flap. The *ventral margin of the flap*, caudal to the axillary skin fold, follows the palpable (dorsal) border of the *deep pectoral muscle*. This border is outlined with a marking pen. The dorsal border of the flap is drawn parallel to the outlined ventral flap border, beginning slightly ventral to the origin of the thoracodorsal artery (see Plate 60). The outlined flap inclines toward the nipple of the second mammary gland, which is not included in the body of the flap. The distal end of the flap terminates at the level of the costal arch.

(B) Elevation of the lateral thoracic axial pattern flap for closure of a defect overlying the lateral elbow region. A small segment of interposing skin (cross-hatched area) or a bridge incision can be used to facilitate flap placement on the recipient bed.

(C) The flap, sutured into place.

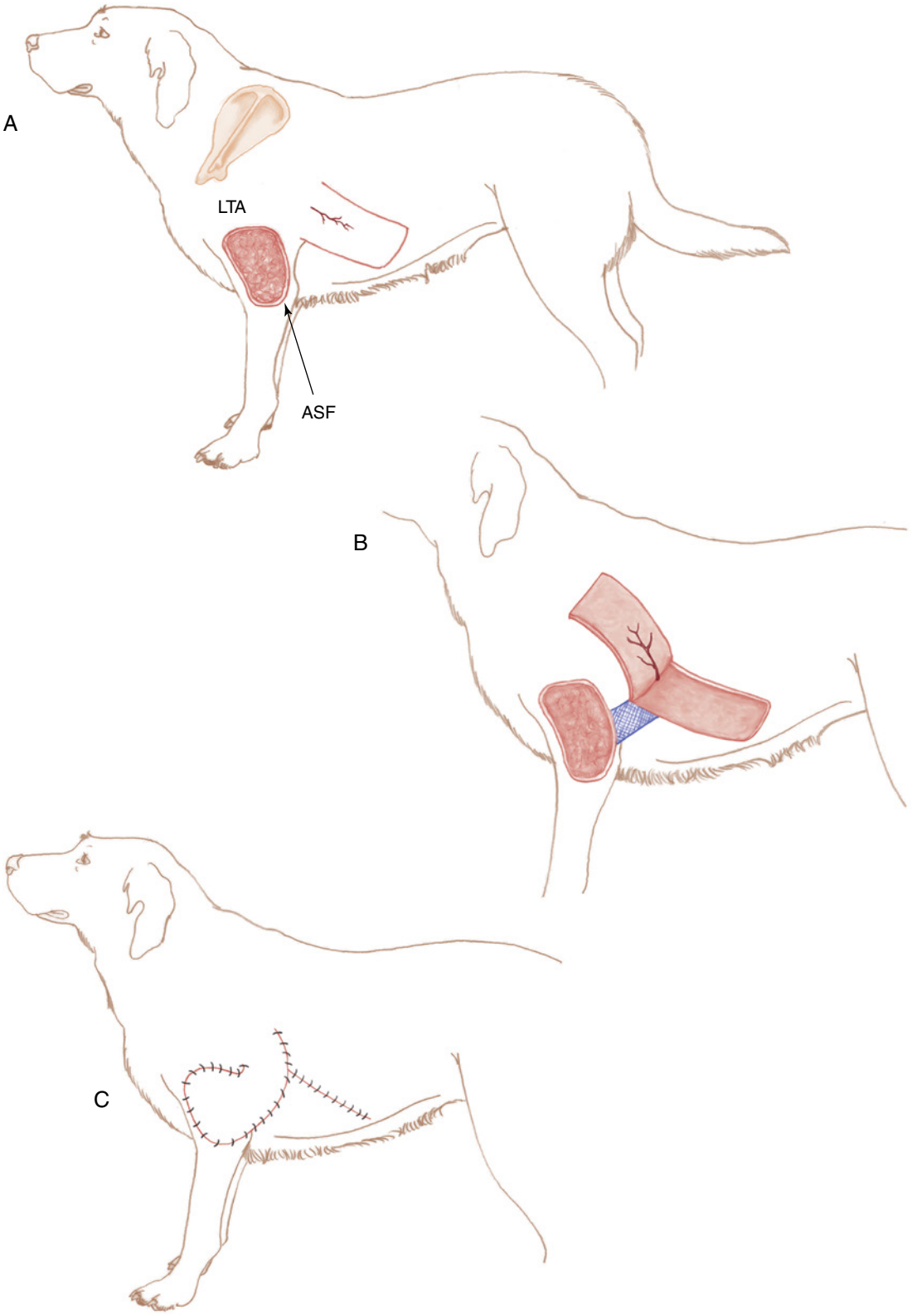
COMMENTS

The size and distribution of the lateral thoracic artery were somewhat inconsistent in the study performed by Anderson et al. (2004). This has been the author's experience in previous anatomic studies, and it should be considered when using this technique. Doppler may be useful in confirming the presence of this vessel prior to surgery. This small axial pattern flap would be useful for closure of problematic wounds in the elbow region, based on its proximity to the area. The skin is not as thick as the skin associated with the more dorsally located thoracodorsal axial pattern flap, a consideration in heavy, large-breed dogs. Failure of this flap would not preclude using the thoracodorsal axial pattern flap. In the report by Anderson et al., it was suggested that dogs with underdeveloped or ill-defined skin folds may be poor candidates for use of the lateral thoracic axial pattern flap. A study in cats (Benzioni et al. 2009) indicated that the LTA is a viable blood supply for developing this axial pattern flap, with mean flap size of 8.7 × 15.5 cm reported in the mature, average-sized cat (see Plate 62).

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Plate 61



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Plate 62

Lateral Thoracic Axial Pattern Flap (Cat)

DESCRIPTION

The flap outline differs from the canine version of the lateral thoracic axial pattern flap in dogs. It has potential use for large defects involving the brachium and antebrachium.

SURGICAL TECHNIQUE

(A) The base of the flap is represented by the caudal border of the triceps muscle. The lateral thoracic artery is located at the midpoint of the base, extending caudally to the last rib. The ventral border of the flap is the midline of the lower thorax. The dorsal border of the flap is equal to the distance from the ventral border to the midpoint of the triceps muscle border. The dorsal border parallels the ventral border to the caudal border represented by the last rib.

(B) Elevation of the flap. It can be rotated into various defects within its arc of rotation.

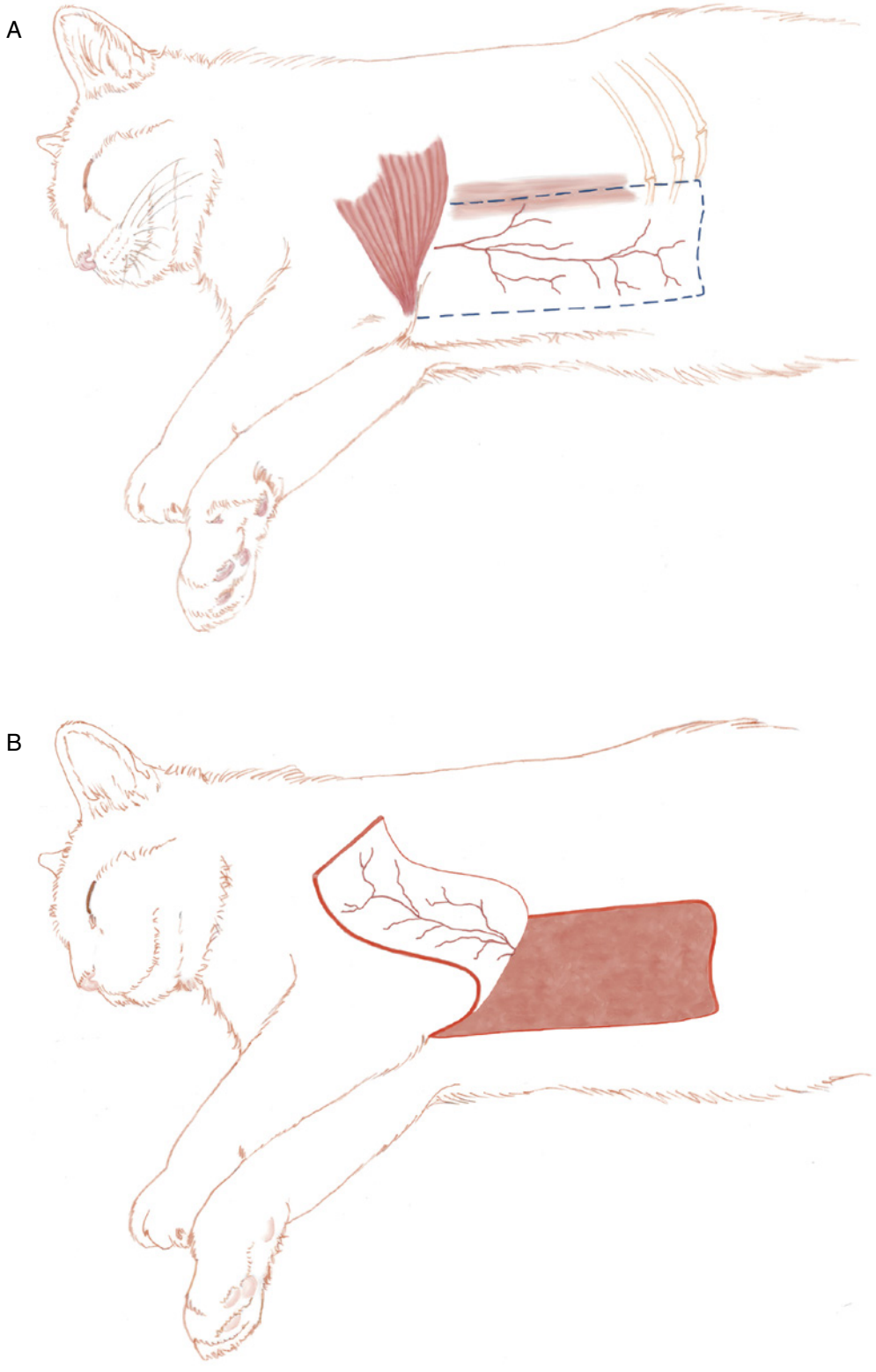
COMMENTS

This technique is based on a study in cats that indicated that the lateral thoracic artery is a viable blood supply for developing this axial pattern flap, with mean flap size of 8.7 × 15.5 cm reported in the mature, average-sized cat (see Benzioni et al. 2009). It has potential use for major skin defects within its arc of rotation, including the brachium and antebrachium. (See Plate 61 for the canine variation.)

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Plate 62



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Plate 63

Superficial Brachial Axial Pattern Flap

DESCRIPTION

The superficial brachial artery branches from the brachial artery, approximately 3 cm proximal to the elbow joint in the average-sized dog. A cutaneous branch of this vessel supplies the craniomedial antebrachium. This small, direct cutaneous artery lies medial to the cephalic vein. The axial pattern flap based over this vessel has special use for closure of antebrachial wounds.

SURGICAL TECHNIQUE

(A) The anatomic landmarks for flap outline include the elbow, humerus, and scapulohumeral joint. The anesthetized patient is placed in dorsal recumbency, with the affected forelimb supported in an elevated position. The entire limb is clipped and vacuumed.

(B) The base of the flap is centered over the anterior third of the flexor surface of the elbow. Lateral and medial incision lines are drawn proximally, parallel to the humeral shaft. However, the lines are drawn to gradually converge, tapering the flap proximally in order to facilitate closure of the donor bed. Both lines are connected at or below the proximal point of the greater tubercle. The flap is elevated from the end of the flap toward its base. Care is taken to avoid injury to the subdermal plexus, superficial brachial vasculature, and adjacent cephalic vein.

(C) The flap is rotated laterally into the adjacent defect and sutured into position.

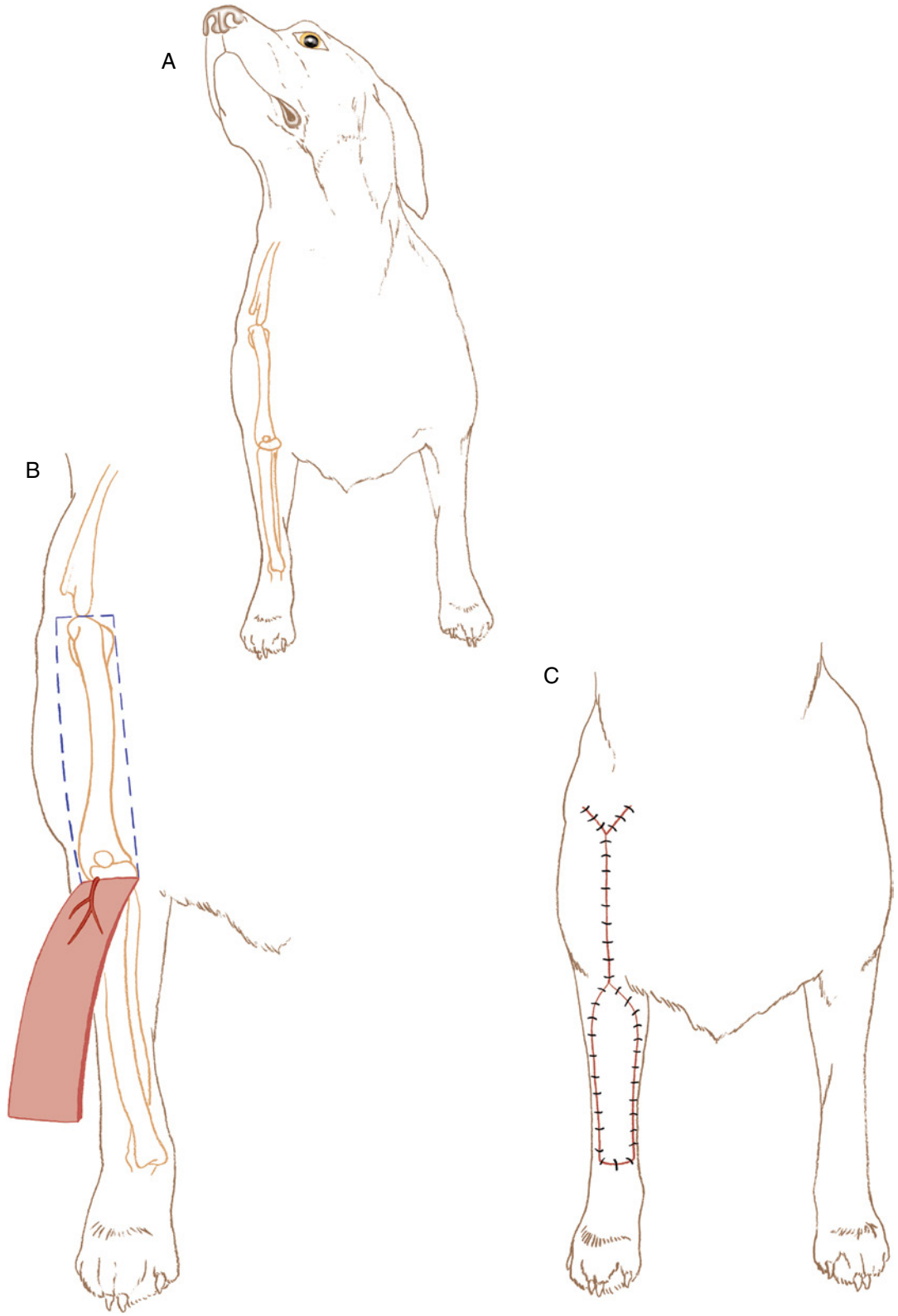
COMMENTS

Note that proximal antebrachial defects that approach the base of the superficial brachial axial pattern flap can be closed by its island flap variation. The vessel is capable of supporting an axial pattern flap of sufficient size to cover major defects involving the mid antebrachium and elbow. In general, flap length and subsequent survival preclude its use for coverage of the carpal area. Because of the small size of this vessel, meticulous surgical technique is critical in the preservation of the microcirculation to the flap. Villedieu et al. (2022) reported that partial necrosis had been noted in some flap transfers based on a review of 16 dogs. Most complications noted were managed without additional surgery.

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Plate 63



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Plate 64

Caudal Superficial Epigastric Axial Pattern Flap

DESCRIPTION

This flap includes the last three or four mammary glands (glands two through four in the cat) and is nourished by the caudal superficial epigastric vessels arising at the inguinal canal. The wider arc of rotation of this flap facilitates its placement for closure of a number of caudal trunk and pelvic extremity wounds.

SURGICAL TECHNIQUE

(A) A midline abdominal incision is drawn with a felt-tipped pen, beginning just behind the last mammary teat and continued in a cranial direction. In male dogs, the midline incision must incorporate the base of the prepuce to preserve the epigastric vasculature (inset). If a rear-limb defect requires coverage, the leg can be suspended in extension and prepared in routine fashion for the surgical transfer of the skin flap. Depending on the length required, the reference incision line is drawn between glands one and two or glands two and three and continued as the lateral incision, parallel to the medial incision line, at an equal distance from the mammary teats.

(B) The flap is undermined below the supramammarius muscle and above the aponeurosis of the external abdominal oblique muscle progressively in a caudal direction. The epimysium of the superficial pectoral muscle (closely attached to portions of the overlying skin) may be included with the flap in order to ensure the subdermal plexus is not traumatized. The caudal superficial epigastric flap can be rotated into a variety of positions when care is taken to preserve the direct cutaneous vessels from excessive kinking or twisting.

(C) This example demonstrates its use for coverage of a medial thigh defect.

COMMENTS

Wider flaps are possible if adequate skin remains to close the donor bed. Because mammary tissue is functional in its new location, ovariohysterectomy is recommended. The thin skin in some dogs will result in a flap that initially contracts on its elevation. Ovariohysterectomy can be performed through the medial incision at the time of flap elevation. The skin of the lower abdomen can be relatively thin in some dogs, and a variable degree of skin contraction of the flap width can be noted intraoperatively following elevation.

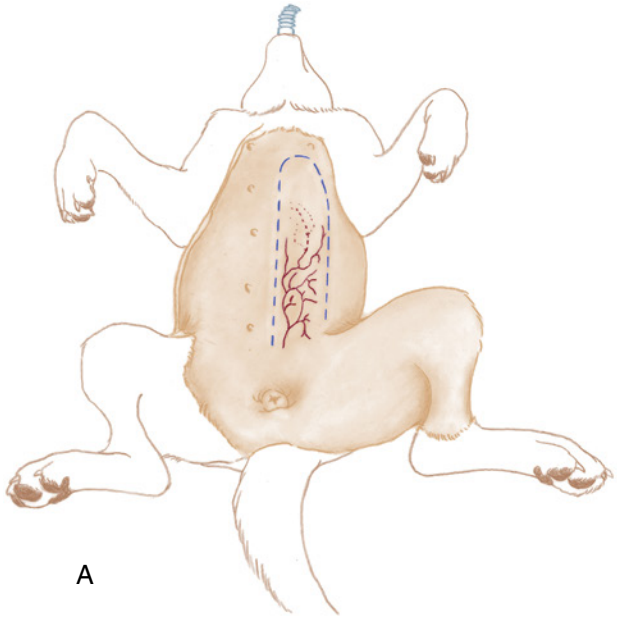
The caudal superficial epigastric axial pattern flap is a highly versatile pedicle graft for closure of major skin defects of the caudal abdomen, flank, inguinal area, prepuce, perineum, thigh, and rear limbs. Flap length and width will vary according to the patient's body conformation, the availability of loose skin, and the size required to reach/cover a given defect. Long bodies and short limbs in some dogs, for example, enable the surgeon to develop a flap of sufficient size to extend along the length of the limb. In cats, and dogs with shorter limbs in relation to body length, the caudal superficial epigastric axial pattern flap can extend to or below the level of the tibiotarsal joint. An ample amount of loose elastic skin in patients enables the surgeon to create wider flaps than the guidelines suggest for flap development.

The author has used bilateral caudal superficial epigastric axial pattern flaps for closing a large, 360° cutaneous defect of the hindlimb in a dog. This was performed in two stages approximately 1 week apart. Simultaneous elevation and transfer of these flaps would be facilitated by the use of skin stretchers preoperatively, simplifying closure of the large donor defect created (see Plate 35 and Plate 36). One case report (Mayhew and Holt 2003) elevated both flaps in a dog simultaneously for a large caudal thigh defect.

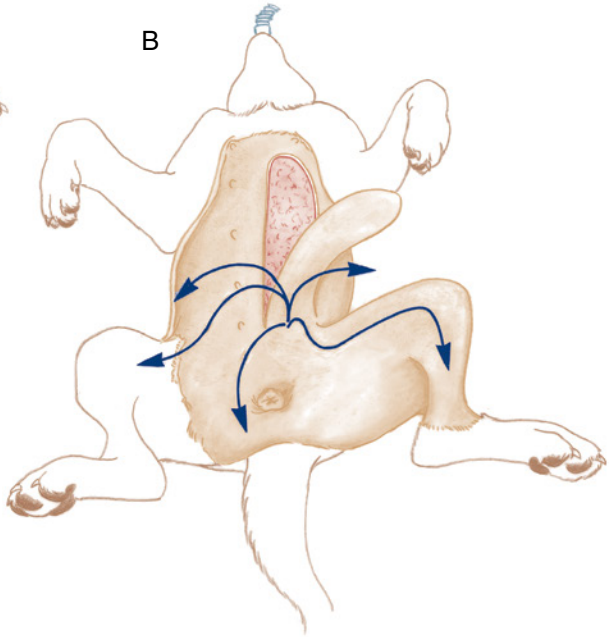
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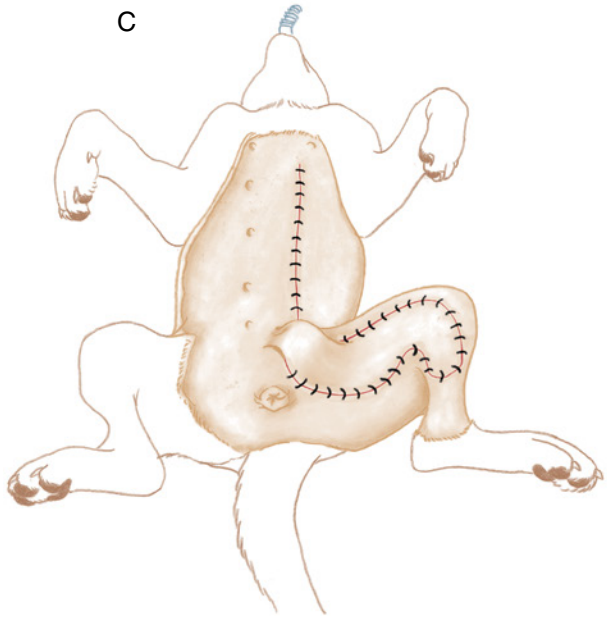
Plate 64



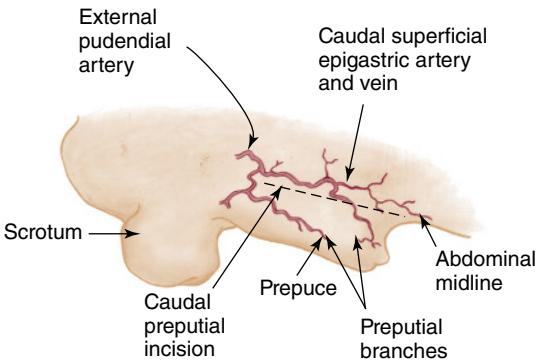
A



B



C



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Plate 65

Cranial Superficial Epigastric Axial Pattern Flap

DESCRIPTION

The cranial superficial epigastric axial pattern flap is based over the short cutaneous branches of the cranial superficial epigastric artery located in the hypogastric area caudal to the ventral border of the thoracic cage.

SURGICAL TECHNIQUE

(A_1) The flap is outlined with the patient in dorsal recumbency: a large skin defect is overlying the sternal region of this patient. Depending on the size of the patient, the base of the flap is located in the region of the cranial epigastric vessel, entering the skin lateral to the abdominal midline and a few centimeters caudal to the cartilaginous border of the ventral thorax. The midline of the abdomen serves as the central border of the flap. Like the caudal superficial axial pattern flap, the distance from the midline to the mammary teats serves as the reference of measurement for the lateral incision. The flap length includes mammary glands three, four, and possibly five. In the male, the end of the flap should be situated cranial to the prepuce due to the risk of necrosis and difficulty associated with closure of flaps extended parallel to the length of the prepuce (see inset).

(B_1) The flap is elevated in a cranial direction beneath the panniculus muscle layer, beginning at the terminal end of the outlined flap. Great care should be taken as undermining approaches the hypogastric origin of the cranial epigastric artery and vein. In this example, a peninsular flap design is employed.

(A_2) In this second variation, an island arterial flap is outlined for elevation. Note that the caudal border of the defect encroaches on the base of the flap, in essence dictating that a cranial epigastric island arterial flap is required to close this sternal wound.

(B_2) Closure of the defect after pivoting the island arterial flap into position. Additional care must be taken to avoid stretching or kinking of the cranial epigastric vessels to which this island flap is tethered.

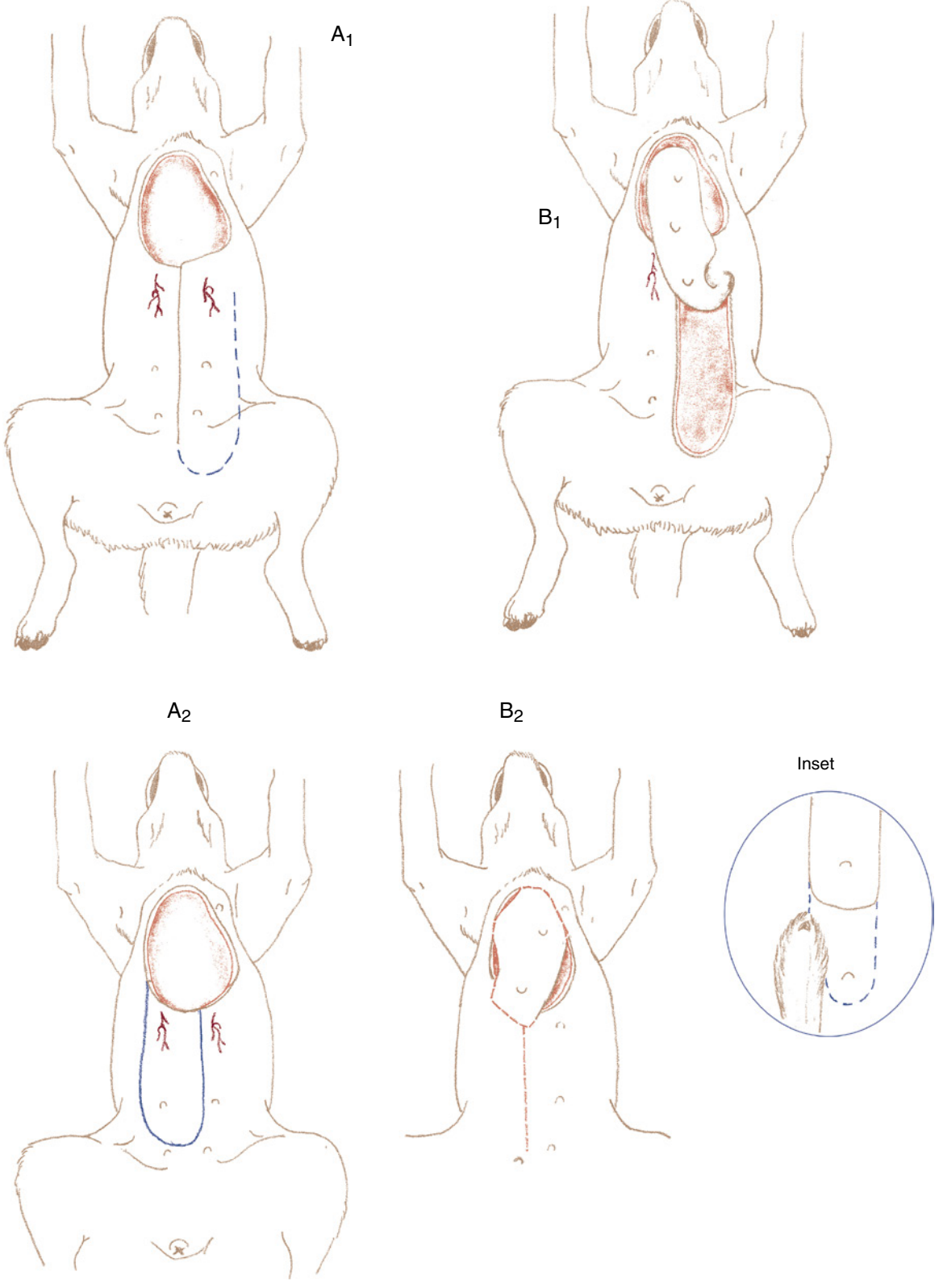
COMMENTS

The cranial epigastric artery and vein are not nearly as long as the caudal superficial epigastric vessels. As a result, the perfusion pressure of these smaller direct cutaneous arteries cannot sustain the flap dimensions of the caudal superficial epigastric axial pattern flap. Keeping the flap length as short as possible to accomplish wound closure is advisable since a variable degree of flap necrosis occasionally is noted. The location of the cranial superficial epigastric vessels is less predictable than that of the caudal superficial epigastric artery and vein. In one research subject, a second or supplemental direct cutaneous artery and vein were noted caudal to the small cranial epigastric artery. Although this flap lacks the size and versatility of the caudal superficial epigastric variation, it can be very useful for closure of large skin defects overlying the sternum. Readers should review the use of skin stretchers (see Plate 36): the author has successfully closed similar wounds in this area without the need for the cranial superficial epigastric axial pattern flap.

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Plate 65



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Plate 66

Deep Circumflex Iliac Axial Pattern Flap: Dorsal Branch

DESCRIPTION

The deep circumflex iliac artery (and paired vein) exits the lateral abdominal wall cranioventral to the wing of the ilium. It divides to form a dorsal and ventral branch. Each vessel can be used independently for axial pattern flap development.

SURGICAL TECHNIQUE

(A) With the dog in lateral recumbency, the lateral thoracic and abdominal skin is grasped, lifted, and allowed to spontaneously retract to a normal position. The hindlimb is placed in relaxed extension perpendicular to the trunk (see Plate 58). A felt-tipped marking pen is used to draw the caudal reference incision line between the cranial border of the wing of the ilium and the greater trochanter. The cranial incision is drawn parallel to the caudal reference incision line and equal to the distance between the iliac border and caudal incision line.

(B) The reference lines are extended to the dorsal midline. At this point the standard peninsular design can be created, depending on the location and size of the defect.

(C) Alternatively, the flap can be created at a right angle. Note the similar surface area in comparison to the peninsular flap design.

(D) Flaps are elevated below the level of the cutaneous trunci muscles and fascia, beginning at the distant border of the flap. The resultant flap can be rotated into a variety of defects encountered within its arc of rotation.

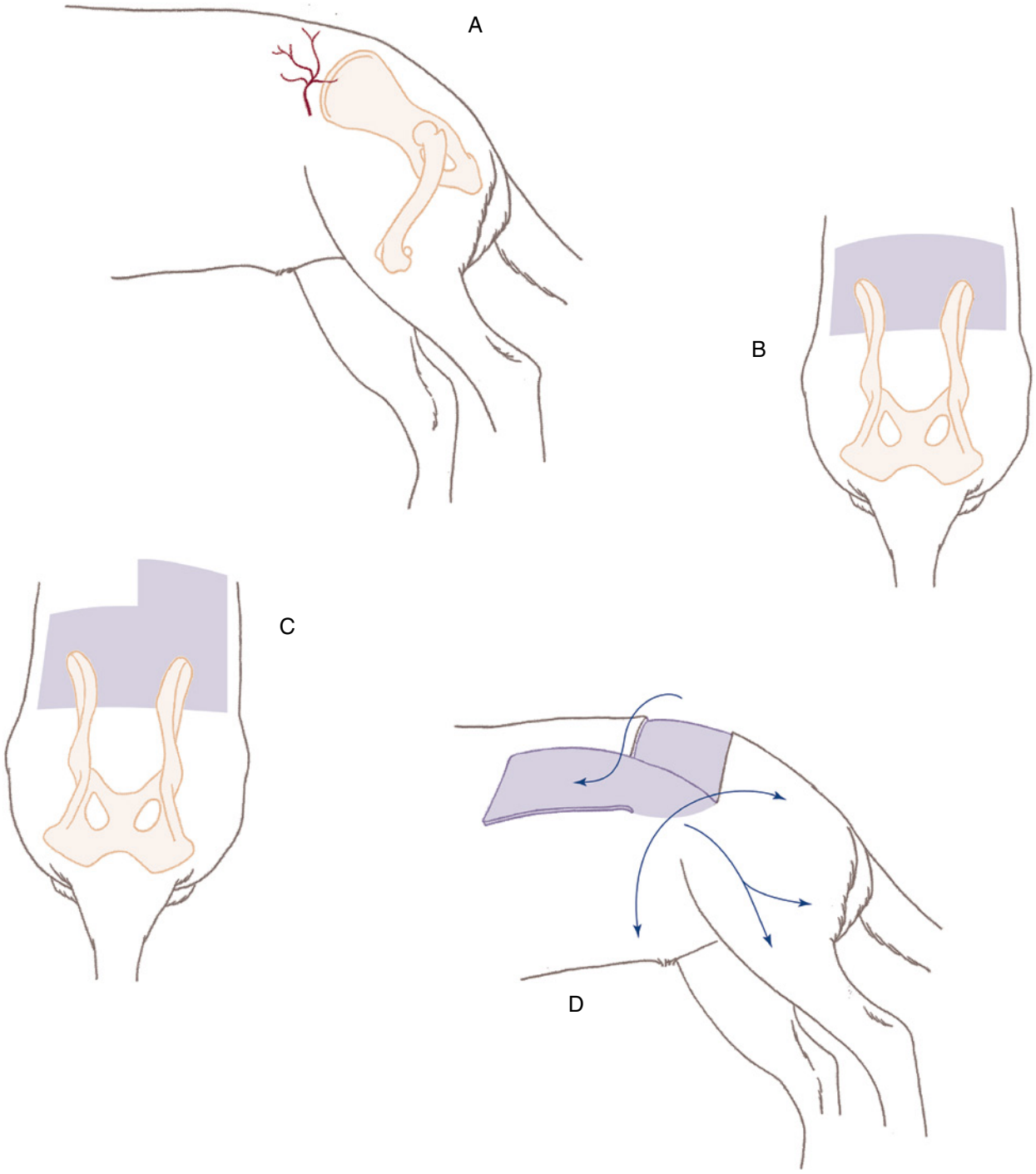
COMMENTS

The shorter dorsal branch has general application for defects involving the ipsilateral flank, lateral lumbar area, caudal thorax, lateral thigh, and pelvic area. The author finds this flap especially useful for major skin defects overlying the greater trochanter and associated lateral pelvic area.

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Plate 66



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Plate 67

Deep Circumflex Iliac Axial Pattern Flap: Ventral Branch

DESCRIPTION

The ventral branch of the deep circumflex iliac artery extends down the lateral flank and craniolateral thigh for axial pattern flap development.

SURGICAL TECHNIQUE

(A) The dog is positioned as previously discussed in Plate 66. Landmarks for establishing the width of the flap are identical. The caudal incision line is drawn from the midpoint between the wing of the ilium and greater trochanter and directed distally, cranial to the border of the femoral shaft. The cranial incision line extends from the established base point (in relation to the wing of ilium), extending down the flank/thigh region, parallel to the caudal flap border. The flap terminates above the patella by a connecting line drawn between the cranial and caudal flap borders.

(B) The deep circumflex iliac flap (ventral branch) in its peninsular or island arterial flap configurations can be used to close defects within its 180° arc of rotation.

(C) The island arterial flap is elevated, beginning at the distal border, and carefully pivoted over the preserved direct cutaneous artery and vein. It is important to fully assess skin tension and elasticity prior to surgery. Flap dimensions may require modification to ensure closure of the donor bed can be achieved without difficulty. Excessive wound tension on closure of the donor site will compromise limb function and increase the risk of dehiscence.

(D) The island arterial flap is sutured over the dorsal pelvic surface. Drainage is established to prevent seroma formation.

COMMENTS

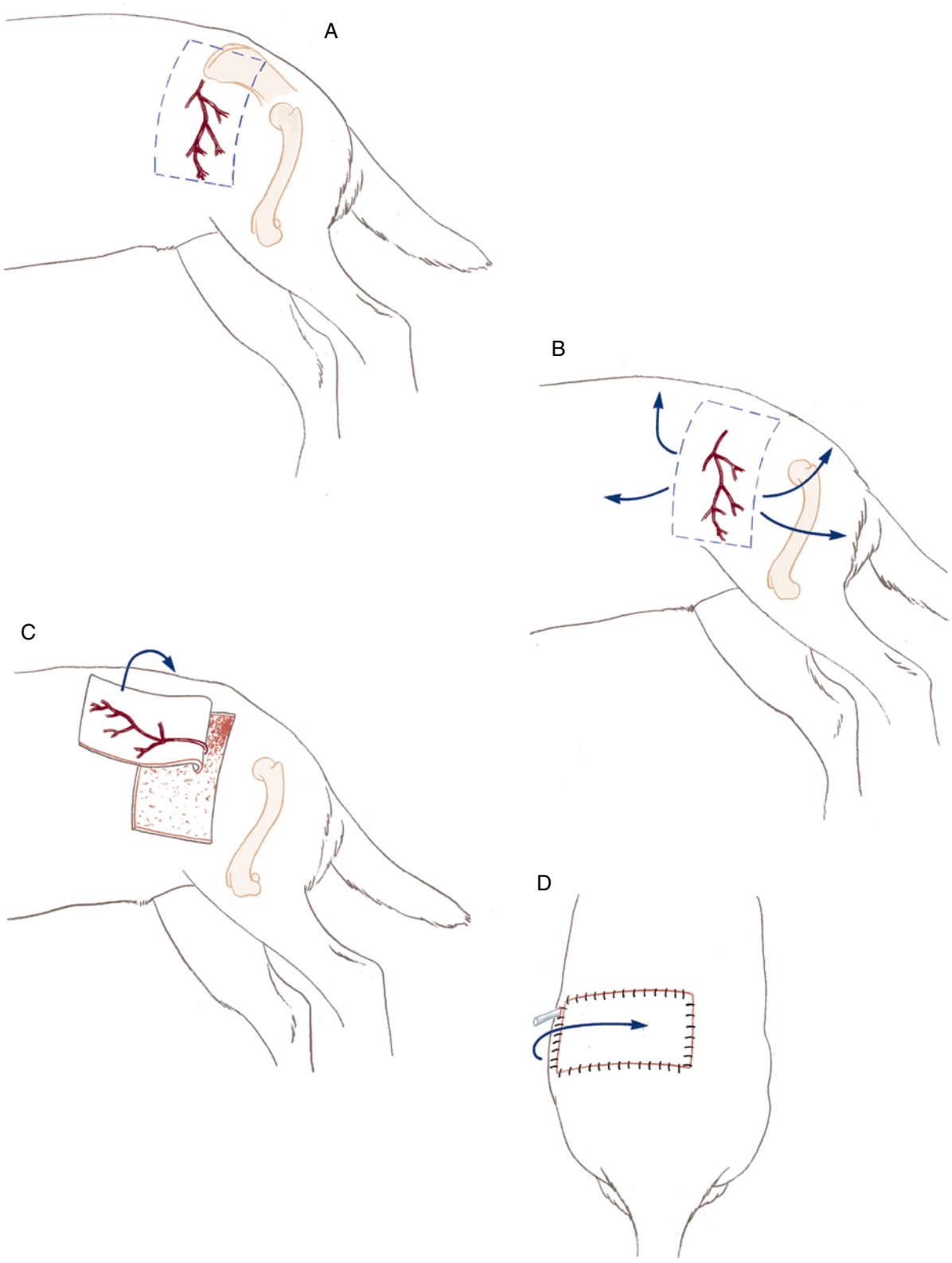
Perhaps the greatest use of the ventral flap is in the creation of an island flap for closure of major sacral and lateral pelvic skin wounds that preclude the use of the dorsal branch of the deep circumflex iliac artery for axial pattern flap development.

The hindlimb flank fold flap (Plate 68) is a variation of the ventral deep circumflex iliac axial pattern flap. The flank fold region includes the territory of this direct cutaneous artery, but the flap size is limited to the confines of the flank fold for transposition into inguinal defects.

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Plate 67



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Plate 68

Flank Fold Flap: Hindlimb

DESCRIPTION

The dog and cat have a natural fold of skin located in the flank area, dorsal and anterior to the knee. The lower branches of the ventral branch of the deep circumflex iliac artery supply this cutaneous area. It is possible to elevate and transpose this fold of skin (as reported by Hunt 1995) to cover defects in the inguinal area, especially when the caudal superficial epigastric axial pattern flap is not feasible.

SURGICAL TECHNIQUE

(A) The flank fold can be gently grasped to determine the amount of skin that can be harvested. The leg is manipulated during this maneuver to ensure that sufficient skin is present to permit closure of the donor site without undue tension. The lateral to medial (dashed line) U-shaped fold flap is drawn onto the clipped skin.

(B) A caudal inguinal defect is noted in this example. Note the relationship of this wound to the proposed flank fold flap.

(C) The flap is elevated; the small patch of skin (lined area) is resected to allow the transposition of the flap.

(D) The elastic flank fold flap is sutured into position.

(E) Lateral view of the limb, after transposition of the flap and closure of the donor site.

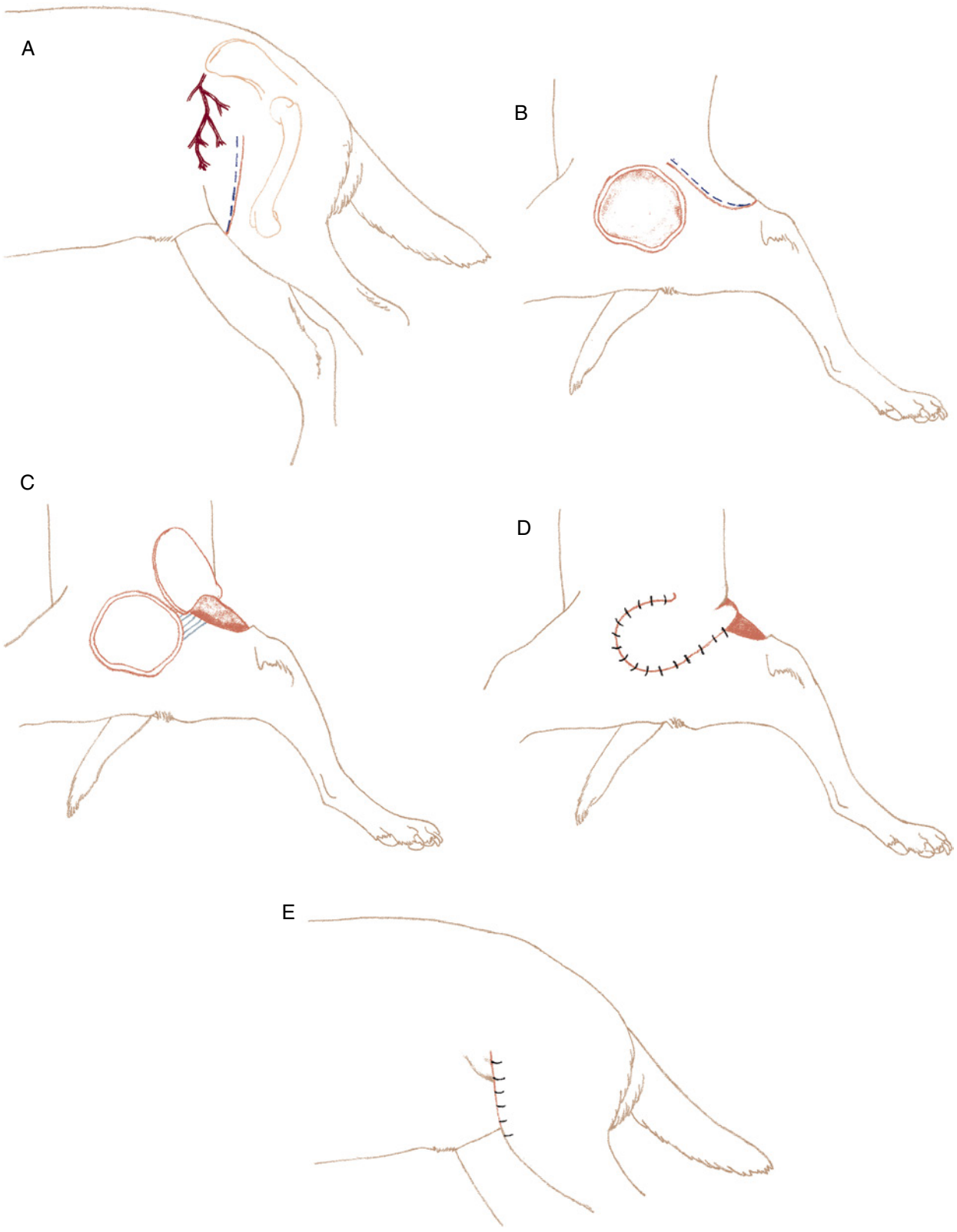
COMMENTS

This flank fold flap is a more restricted variation of the ventral deep circumflex iliac axial pattern flap. It is especially effective for closing more difficult wounds encountered in the inguinal area. This thin, elastic skin can conform readily to wounds in this area. Careful measurement of the flap is required. Excessive tension during closure of the donor site can result in restricted movement of the involved limb, risking dehiscence; open flank wounds can be quite difficult to close. (See Fig. 13-10.)

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Plate 68



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Plate 69

Genicular Axial Pattern Flap

DESCRIPTION

The genicular axial pattern flap originates over the short genicular branch of the saphenous artery and medial saphenous vein. The genicular artery extends cranially over the medial aspect of the stifle and terminates over its craniolateral surface.

SURGICAL TECHNIQUE

(A) The dog is placed in lateral recumbency and the rear limb is clipped and prepared for surgery in routine fashion. The base of the flap is marked with a felt-tipped pen at a point 1 cm proximal to the patella and 1.5 cm below the tibial tuberosity. Two lines are extended on the lateral thigh parallel to the femoral shaft to the base of the greater trochanter.

(B) The flap is carefully elevated by undermining the skin in the loose areolar fascial plane beneath the dermis.

(C) In this example, the flap is rotated into the lower-limb defect and sutured into place. The donor site is closed with a subcuticular pattern and skin sutures to minimize the risk of dehiscence.

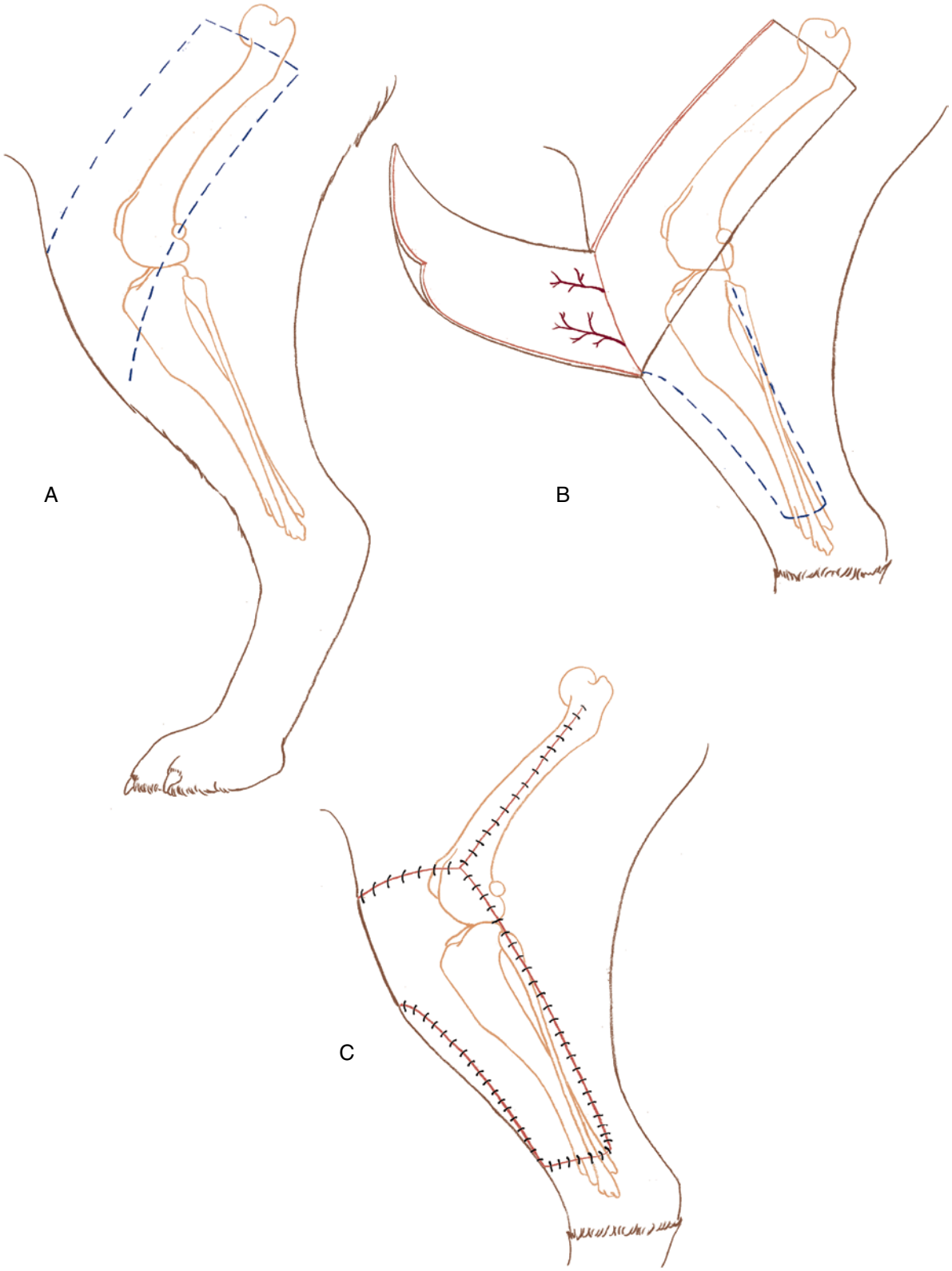
COMMENTS

The genicular artery, like the superficial brachial artery, is not a large vessel capable of supporting circulation to a large segment of skin. However, it usually is sufficient to support flaps for closure of wounds of the lateral or medial tibial regions, as well as flaps capable of extending distally to the level of the tibiotarsal joint, depending on the individual conformation of the canine patient. Keeping skin flaps as short as possible to accomplish wound closure helps ensure complete flap survival.

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Plate 69



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Plate 70

Reverse Saphenous Conduit Flap

DESCRIPTION

The reverse saphenous conduit flap incorporates branches of the saphenous artery and medial saphenous vein, which in turn supply and drain the overlying skin by means of direct cutaneous vessels. By division of vascular connections with the femoral artery and vein, blood flow is maintained in reverse by distal anastomotic connections (1) between the cranial branch of the saphenous artery and the perforating metatarsal artery by way of the medial and lateral plantar arteries; and (2) between the cranial branch of the medial saphenous vein and the cranial branch of the lateral saphenous vein, and other venous connections with the cranial and caudal branches of the medial saphenous veins distal to the tibiotarsal joint.

SURGICAL TECHNIQUE

(A) Measurements are taken to determine the flap required to reach and cover the lower-limb defect. The flap width is tapered distally, owing to the limited skin available for flap development. A skin incision is generally made across the central third of the inner thigh, at or slightly above the level of the patella.

(B) Metzenbaum scissors are used to expose the underlying saphenous artery, medial saphenous vein, and nerve (at the level of the femoral artery and vein) prior to their ligation and division. Two incisions are extended distally in convergent fashion, 0.5–1.0 cm cranial and caudal to the borders of the cranial and caudal branches of the saphenous artery and medial saphenous vein, respectively.

(C, D) The flaps are undermined beneath the saphenous vasculature. To avoid injury to the caudal branch of the saphenous artery and medial saphenous vein during progressive raising of the pedicle graft, a portion of the medial gastrocnemius muscle fascia is included with the flap. Below this point, the tibial nerve merges with the descending caudal branches of the saphenous artery and medial saphenous vein and can be preserved by meticulous dissection between these structures. Ligation and division of the peroneal (fibular) artery and vein are necessary to facilitate flap mobility. Flap elevation is completed proximal to the anastomosis between the cranial branch of the medial saphenous vein and the cranial branch of the lateral saphenous vein. The donor bed is initially closed with interrupted subcuticular sutures, then with simple interrupted skin sutures, using 3-0 suture material at the end of the transplantation. The "transfer pedicle" can be tubed to traverse the skin between the donor and recipient beds. Care is taken to ensure that the tubed pedicle is not under undue tension on extension of the tibiotarsal joint.

(E_1, E_2) A bridge incision connecting the donor and recipient beds is an optional method to traverse the skin between donor and recipient beds.

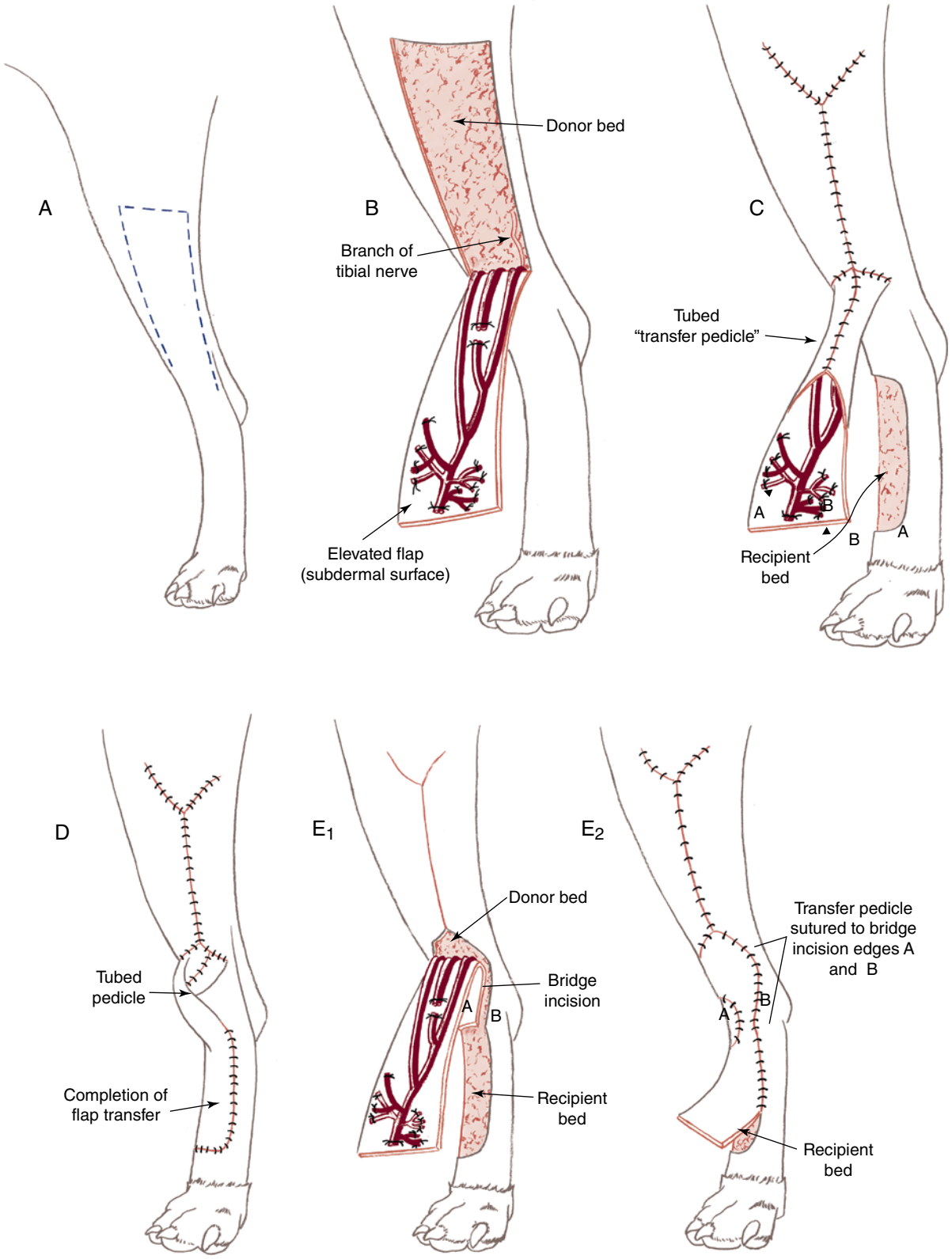
COMMENTS

Slightly longer flaps are possible, if required. The resultant flap with a distally based pedicle has potential for use in major cutaneous defects at or below the tarsus, especially wounds overlying the metatarsal surface. When the reverse saphenous conduit flap is considered for use on skin defects secondary to extensive trauma, angiography or use of a Doppler should be considered to ensure that anastomotic connections are intact and that the saphenous artery and medial saphenous vein are not the major routes of circulation to the lower limb. Based on anatomic studies, the vascular supply and general guidelines for flap development in the cat are remarkably similar to those in the dog.

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Plate 70



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Plate 71

Caudal Auricular Axial Pattern Flap

DESCRIPTION

The caudal auricular axial pattern flap incorporates the sternocleidomastoid branches of the caudal auricular artery and vein located in the palpable depression between the lateral aspect of the wing of the atlas and the vertical ear canal.

SURGICAL TECHNIQUE

(A_1) The anesthetized patient is placed in lateral recumbency. The forelimb is placed in relaxed extension, thereby positioning the scapula perpendicular to the trunk. The skin is grasped and lifted to ensure there is no distortion of the cervical skin to the underlying anatomic landmarks. The flap base is centered over the palpable lateral wing of the atlas. Two parallel lines are positioned in the central one-third of the lateral cervical profile of the dog. Wider flaps are possible. The two lines are connected to complete the outline of the flap, at the level of the scapula.

(A_2) The general outline of the flap in the cat is similar to that in the dog. The flap is centered over the lateral border (wing) of the atlas. Based on the feline anatomy, the dorsal line (border) of the flap is closer to the dorsal midline. The ventrolateral incision is positioned at the same distance measured from the dorsal line to the point of entry of the caudal auricular artery (a palpable depression at the midpoint between the base of the pinna and the lateral wing of the atlas).

(B_1) The flap is elevated in a caudal to cranial direction beneath the sphincter colli superficialis muscle layer to preserve the vascular integrity of the skin. Care is taken to preserve the auricular cutaneous vessels entering the flap between the vertical ear canal and wing of the atlas.

(B_2) The elevated flap can be rotated into a variety of positions within its arc of rotation. In this example, the flap has been rotated rostrally to close a large facial defect secondary to wide tumor resection in a cat. The flap spans any interposing skin between the donor and recipient site with a bridge incision or the flap can be partially tubed to "caterpillar" over this region. Vacuum drains are ideally suited for controlling dead space and fluid accumulation, although Penrose drains may be satisfactory.

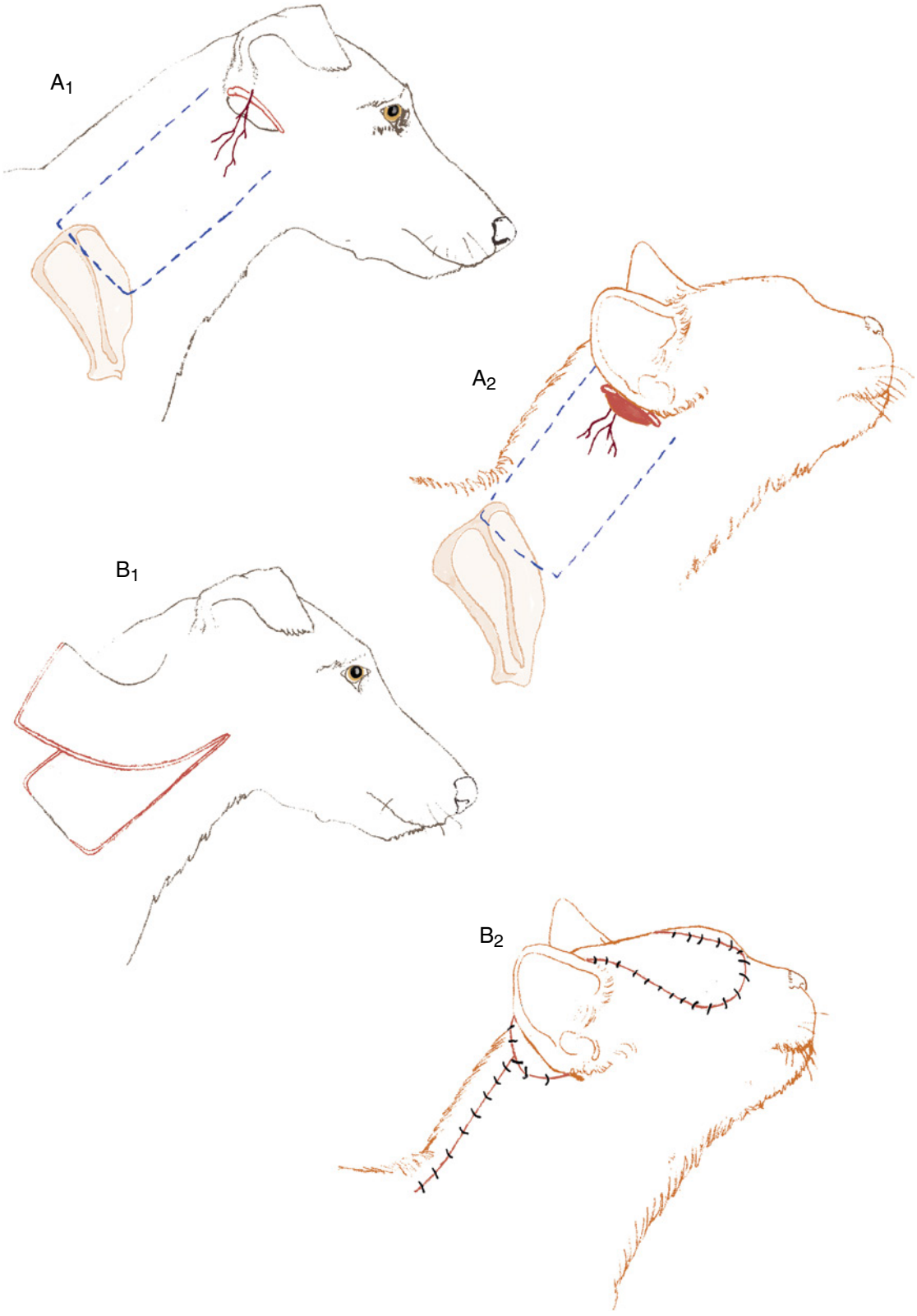
COMMENTS

Described by Smith et al. (1991), the caudal auricular axial pattern flap can be used to reconstruct the ear or the dorsum of the head, or to extend further rostrally to close defects overlying the orbital area, as illustrated in B_2. Like other flaps, keeping the flap as short as possible reduces the likelihood of partial flap necrosis that occasionally is noted when the caudal auricular axial pattern flap is extended to the cranial and mid-scapular regions. (Also see Proot et al. 2019.) In the more rostral areas of the head, the surgeon must keep in mind that simpler (local) transposition flaps, created in the lateral facial area or dorsal aspect of the head, can be used to close small to moderate defects (see Plate 45 and Fig. 11-16). Like other axial pattern flaps, a variable portion of these flaps is utilized simply to span over interposing skin in order to achieve closure of a defect. Despite this caveat, the caudal auricular axial pattern flap is a useful technique to close many of the more challenging wounds resulting from trauma or tumor resection.

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Plate 72

Superficial Temporal Axial Pattern Flap

DESCRIPTION

The cutaneous branch of the superficial temporal artery can be developed into an axial pattern flap using the skin over the temporal muscle area. The flap has potential use for facial defects within its arc of rotation. General guidelines for the dog and cat are identical.

SURGICAL TECHNIQUE

(A) General outline of the flap, dorsal view. The flap is outlined on the skin prior to incising it.

(B) Lateral view. The base of the flap is located at the level of the zygomatic arch. The width of the flap approximates the length of the zygomatic arch: the caudal orbital rim is the rostral border of the flap, and the caudal aspect of the zygomatic arch represents the caudal flap margin. Flap length, based on research by Fahie and Smith (1999), is the mid-dorsal orbital rim of the opposite eye; see (A). The flap is elevated deep to the frontalis muscle to help preserve its blood supply. The flap is elevated from the distant end of the flap toward its base.

(C) The flap rotated over the dorsal muzzle to close a large skin defect after tumor resection.

COMMENTS

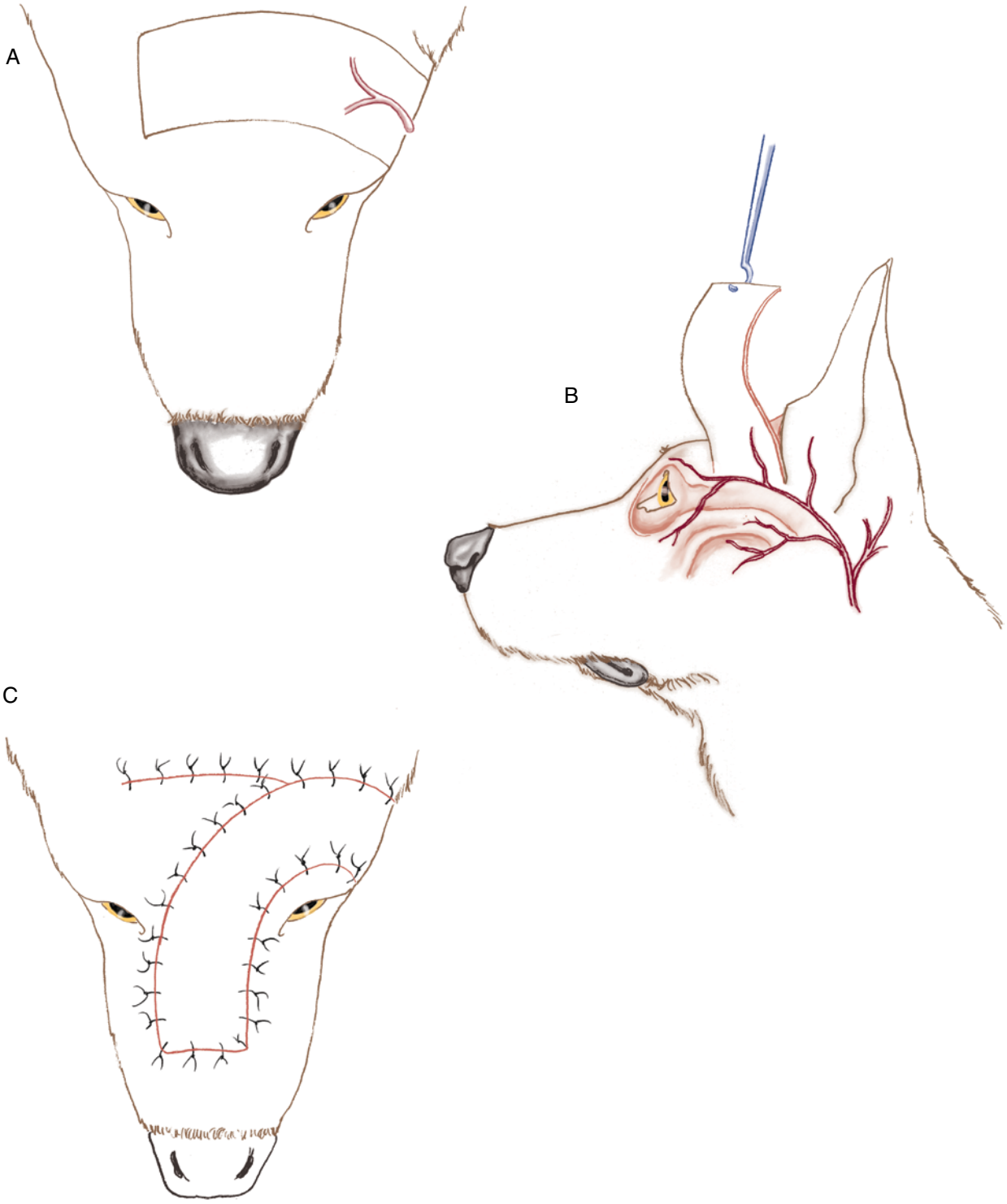
As noted, anatomic landmarks and guidelines for this flap are identical in the dog and cat. Inclusion of the frontalis muscle makes this flap somewhat of a hybrid between a myocutaneous flap and axial pattern flap. However, the muscle is included to help preserve the vasculature rather than contributing to the circulation to the overlying skin.

Use of the superficial temporal axial pattern flap may be most useful for mid-facial defects. Lateral facial defects may be closed with a simpler local flap (advancement or transposition), depending on the size and location of the wound. Care must be taken to avoid wide flaps that could compromise function of the upper eyelid(s). Skin tension in this region should be closely assessed prior to elevating this flap.

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Plate 72



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Plate 73

Lateral Caudal (Tail or Coccygeal) Axial Pattern Flap

DESCRIPTION

The caudal gluteal arteries give rise to the lateral caudal arteries, which contribute circulation to the length of the tail skin. Each vessel resides in a lateral location, ventral to the transverse processes of the caudal vertebrae in the proximal tail region; in the distal tail, the vessels course dorsal to the transverse processes. Based on these two direct cutaneous arteries and associated veins, the tail skin can serve as a source of skin for difficult wounds associated with the perineum and caudodorsal pelvic region.

SURGICAL TECHNIQUE

(A) Profile of the tail, demonstrating the caudal tail vessels and related anatomy. The dashed line illustrates the limits of the proximal one-third of the tail. In this example, the length of the flap is limited to this designated length.

(B) A dorsal midline incision is made in preparation for coverage of a dorsal pelvic defect.

(C) Dissection is directed down to the level of the deeper tail fascia. The subcutaneous tissue interface is carefully freed from this fascial plane, thereby helping to preserve the integrity of caudal tail vessels in the subcutis. On completion of the procedure, the tail proper is amputated at the caudal third or fourth intervertebral space.

(D) The flap is advanced over the caudodorsal aspect of the pelvis in this example.

(E_1) In this example, the flap can be developed with a ventral midline incision and the skin reflected dorsally; the tail is amputated. A midline incision effectively "bi-valves" the flap. Each half is supplied by its own lateral caudal artery and vein.

(E_2) In this illustration, the bi-valved flap is employed to close a perianal defect.

COMMENTS

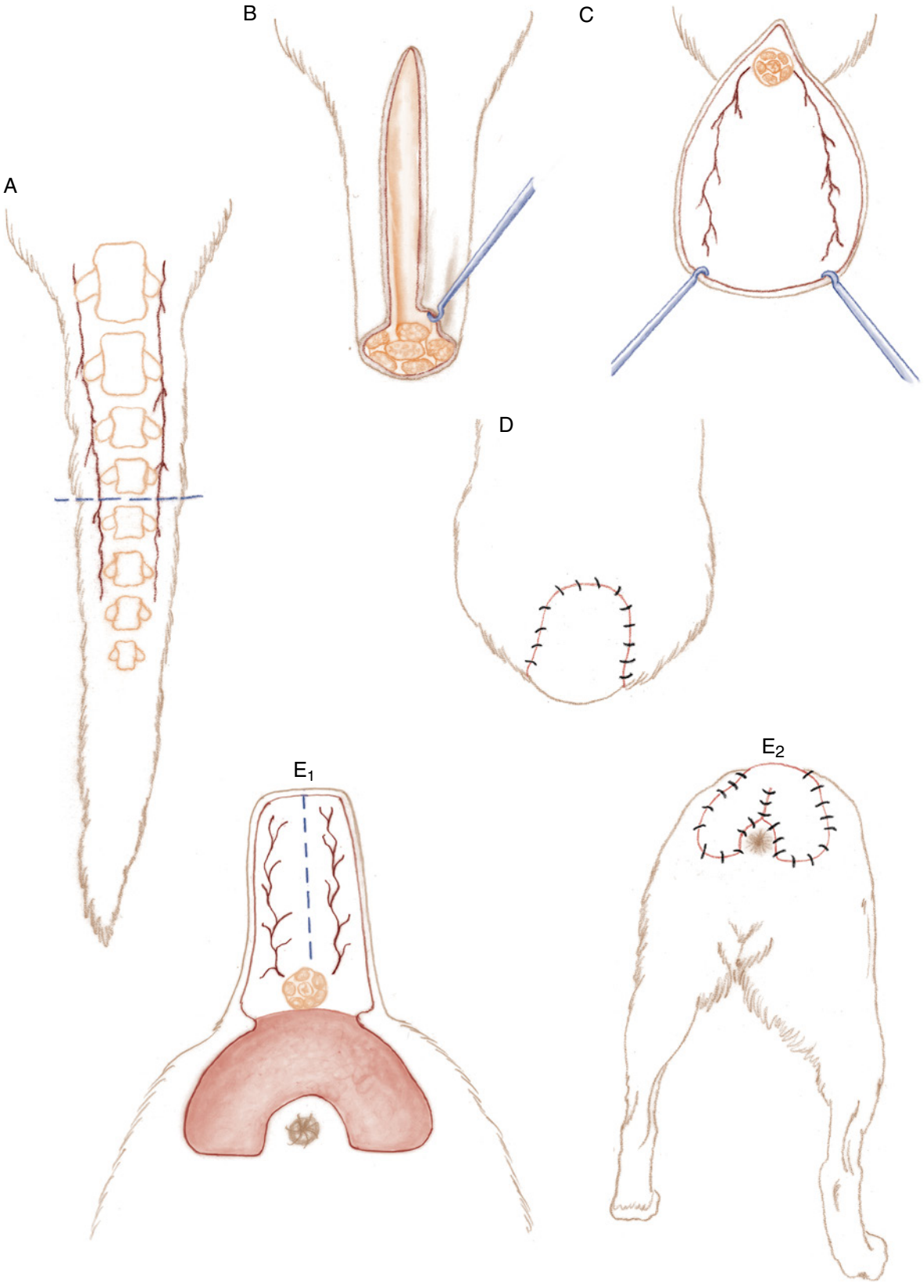
By highlighting the direct arterial blood supply to the tail, Smith et al. (1992) established an effective method of harvesting this source of skin with a greater probability of flap survival. The entire tail length potentially can be used for flap development, although the circumference of the proximal one-third of the tail is the largest source of skin. In some dogs, the proximal tail can provide a surprising amount of skin for closure of challenging wounds in the caudal pelvic area. Other flap techniques may potentially overlap the "cranial territorial limits" of this flap without the need to amputate the tail (a point of contention for some owners). Nonetheless, the lateral caudal axial pattern flap can be very useful for closing cutaneous defects within its arc of rotation, especially in those cases when disease/trauma precludes the effective use of other closure options.

As illustrated, this axial pattern flap can be elevated using a ventral incision and "bi-valved" to close a large perianal defect. However, the dorsal approach is technically easier to perform, and partially dividing the flap down the middle also will allow the surgeon to wrap the flap around the anus at the time of wound closure.

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Plate 74

Cutaneous Circulation to the Feline Perineum

DESCRIPTION

Andries et al. (2019) reported an anatomic study regarding the cutaneous circulation to the perineum of the cat, outlining the potential use of branches of the dorsal and ventral perineal arteries that could be employed as an axial pattern flap.

SURGICAL TECHNIQUE

(A) Outline of the perineal vasculature.
(B) Outline of potential axial pattern flaps.

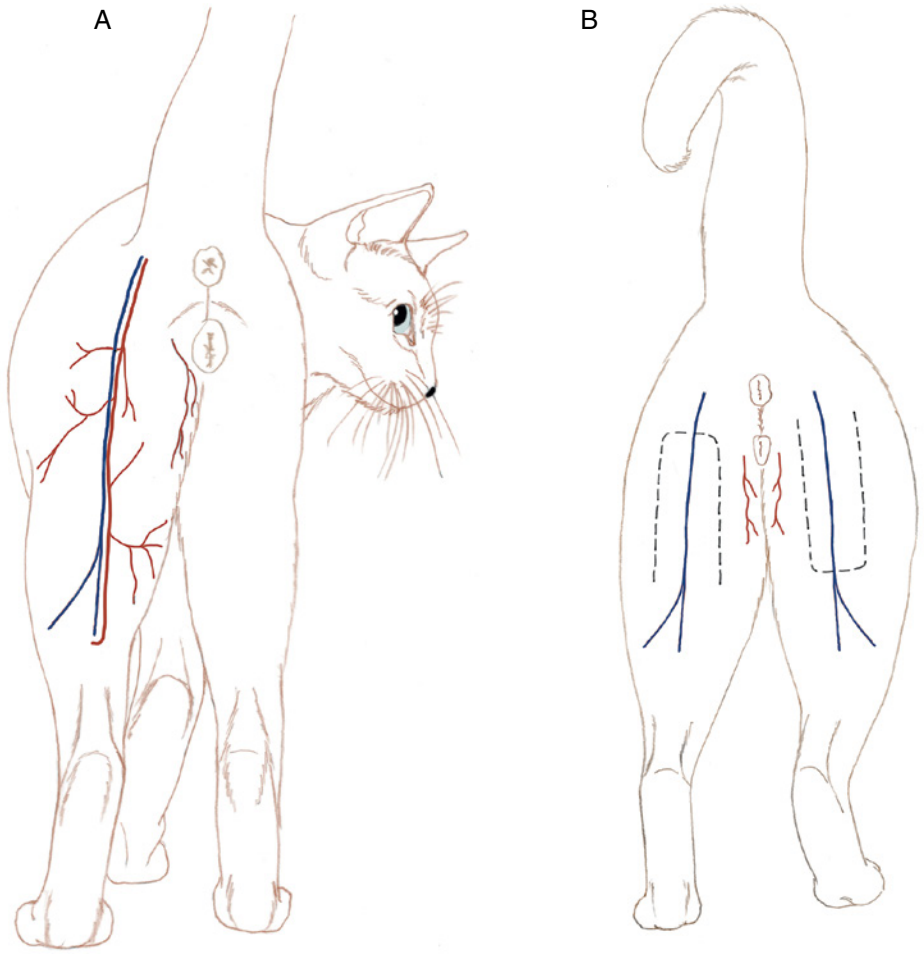
COMMENTS

The dorsal perineal artery had a prominent angiosome on the caudal thigh in cats. The artery is located in the ischiorectal fossa along the muscular furrow between the biceps femoris and semitendinosus muscles, passing sagittally toward the popliteal fossa (Andries et al. 2019). All cadavers in this study had a consistent angiosome based on the ventral perineal artery located on the caudomedial thigh. All cadavers also had a consistent angiosome from a cutaneous branch of the popliteal artery, which traveled in a distal to proximal direction starting at the popliteal fossa. This direct cutaneous blood supply has potential for axial pattern flap development.

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Plate 75

Perineal Axial Pattern Flap in Cats

DESCRIPTION

Based on a clinical case report (Murdoch and Grand 2016) and the perineal vascular study (Andries et al. 2019; Plate 74), the flap has potential use for defects within its arc of rotation.

SURGICAL TECHNIQUE

(A) Lateral tail defect. The dorsal perineal artery is located in the ischiorectal fossa along the muscular furrow between the biceps femoris and semitendinosus muscles, passing sagittally toward the popliteal fossa (Andries et al. 2019). The dashed line indicates that the base of the flap can be linked with the recipient bed to facilitate its transfer. Alternatively, the small bridge of skin between the donor and recipient beds can be resected.

(B) Elevation of the perineal flap.

(C) Closure of the donor and recipient beds.

COMMENTS

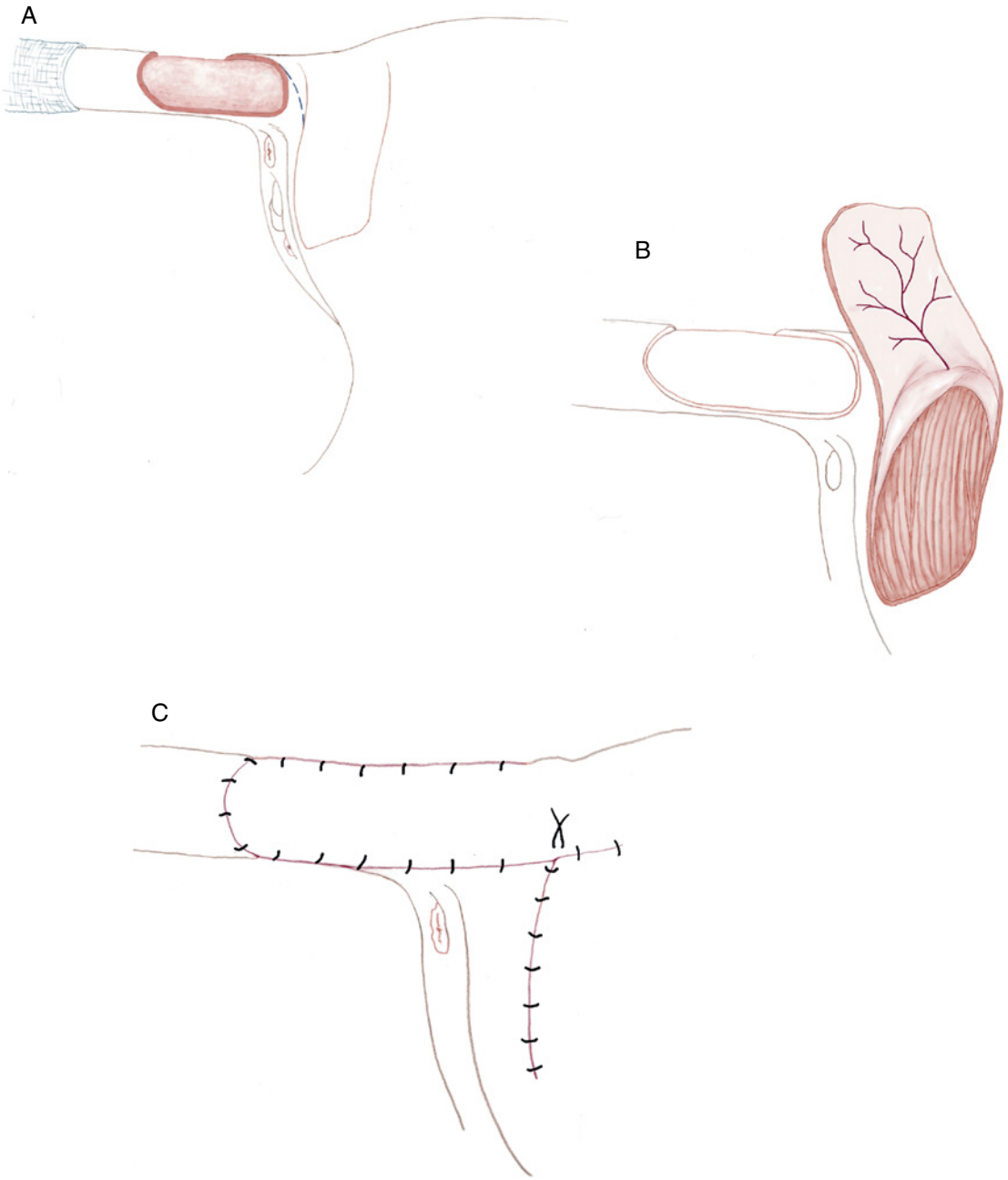
The dorsal perineal artery had a robust angiosome on the caudal thigh in cats. The development of an axial pattern flap based over the cutaneous branch of this artery was reported in a single case report (Murdoch and Grand 2016). The precise guidelines regarding the length and width of the flap are lacking in this study. Flap width would require a balance between the ability to close the donor defect under minimal tension and the measurement required to cover the width of the adjacent defect. Flap length likely would include the relative length of the dorsal cutaneous branch of the perineal artery as described by Andries et al. (2019). Keeping flaps as short as possible to close a defect without undue tension helps to improve the probability of adequate tissue perfusion from the base or pedicle of the flap.

It should be noted that the author has used local transposition flaps (subdermal plexus blood supply) closer to a tail defect in similar fashion, thereby reducing the length of flap required to reach the distant border of the defect (Figure 11-12 and see Chapter 25). Subdermal plexus flaps take advantage of using loose skin closer to the recipient bed rather than being restricted to the anatomic outline of an axial pattern flap most distant to the wound. As a result, the shorter subdermal plexus flap is likely to completely survive transfer. Nonetheless, the perineal axial pattern flap described has potential use for problematic skin defects within its arc of rotation.

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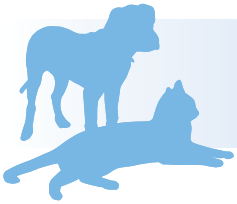
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Plate 75



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14

Free Grafts

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FREE SKIN GRAFTS

Free grafts are segments of skin completely detached from one area of the body and used to resurface another body area lacking an epithelial surface. Free grafts lack a vascular attachment on transfer to the recipient graft bed. They must survive by absorbing tissue fluid from the recipient bed by capillary action during the initial 48 hours after transplantation. During this period, capillaries from the recipient bed unite with the exposed graft plexuses to reestablish vital circulation. New capillaries later grow into the graft and the vascular channels remodel. In addition, fibrous connective tissue forms to hold the graft securely in place. Grafts assume a pink color in 48 hours if circulation is adequate. Grafts with venous obstruction have a cyanotic hue until circulation improves (Fig. 14-1).

Any accumulation of material such as pus, serum, blood, hematoma, or foreign matter between the graft and recipient bed will delay or prevent the graft. This delay often results in graft necrosis. Motion between the graft and the recipient bed has a similar effect. Fibrinolysis secondary to bacterial infection destroys the early fibrin "glue" between the graft and the bed, resulting in motion and graft necrosis. Improper contact between the graft and the recipient bed prevents proper surface-to-surface interdigitation and poor graft revascularization. This occurs if the graft is stretched over the bed like a drum skin or if an excessively large graft is applied to form graft folds that lack proper recipient bed contact. Nonviable grafts are white or black in appearance when assessed after sufficient time has progressed for their revascularization.

Grafts must contour evenly to the recipient bed to ensure direct contact for successful revascularization. The secured graft should have the ability to shift slightly when touched with the index finger after application. This makes sure the graft is applied with the correct tension. (If the graft is applied with excess tension—drum-skin effect—it will not be properly contacting the recipient bed.)

The following is my comparative guideline for determining proper graft tension: (1) flex your wrist and fingers on your left or right hand; (2) with your opposite hand, apply your index finger to the skin overlying the metatarsal surface; and (3) note the slight movement when pressing the skin with your index finger. This is how the graft should shift after securing the skin graft to the recipient bed.

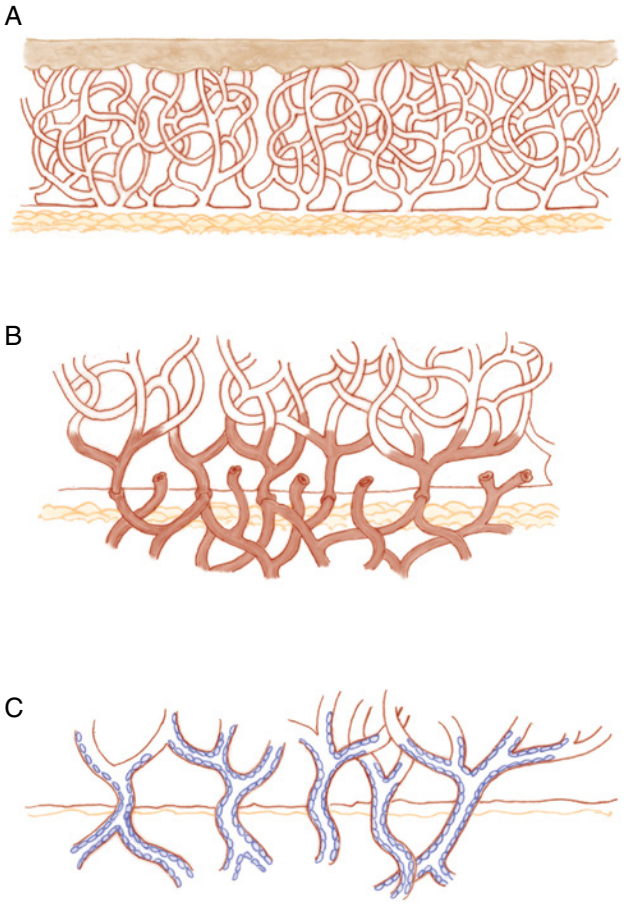


FIG. 14-1 Illustration of free graft revascularization. (A) The graft after application to a healthy granulation bed. Note that the exposed vascular channels of the deep plexus of the graft are in contact with the granulation bed surface. Vital tissue fluid from the wound surface enters the evacuated capillary system within the free graft. This plasma provides oxygen and nutrients to the graft; the graft is precariously surviving in this "tissue culture" environment. (B) Inosculation (kissing) occurs between the capillary buds and open/exposed vascular channels of the graft. Successful linkage or contact between these structures establishes blood flow into the free graft within the first 48 hours. Note that any obstruction between the recipient bed and graft, such as blood clots, pus, fluid pockets, or improper graft preparation ("defatting"), delays inosculation and graft revascularization, resulting in death of the free graft. (C) Vascular remodeling follows inosculation, with the endothelial cells from capillary ingrowth relining the entire capillary network within the graft over several days. Protection and immobilization of the graft are instrumental in allowing inosculation and vascular remodeling to occur unimpeded.

Although free skin grafts require a vascularized recipient bed for survival, granulation tissue is not necessary before a graft is applied. Healthy muscle, periosteum, and peritenon can support a skin graft. Healthy pink granulation tissue, however, is an excellent recipient bed for skin grafts. Pale, collagen-laden chronic granulation tissue has a poor vascular supply and should be

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excised to promote formation of healthy granulation tissue. Contamination and infection should be controlled, and any "epithelial cover" can be excised with a scalpel blade before graft application. Skin grafting in dogs, cats, and birds can be highly successful once the surgical details on graft harvesting, application, and bandaging are mastered. Fortunately, the learning curve is not particularly steep.

Grafting Wounds Immediately Following Trauma or Tumor Excision

There are occasions where a surgical wound cannot be closed without the use of a skin graft (especially the mid to lower extremities). One question is whether to graft over the surgical defect or delay grafting until a granulation bed forms days later. One study (Tong and Simpson 2012) suggested grafting can be performed successfully immediately after a surgical procedure (e.g., tumor removal, resection of diseased skin, etc.). However, what the paper (and the reviewers) failed to address is the fact that many of the grafts had partial-thickness necrosis: this would suggest the wound bed circulation was less than ideal to support complete graft survival. A subsequent paper (Bonaventura and Ganjei 2021) compared single-session graft application following tumor resection versus delayed full-thickness graft application following a delay, thereby allowing a granulation bed to form. Results from this study indicated that there were no significant differences in the percentage of graft survival and successful outcome.

Another issue is cost. Failure of the graft will require a second attempt at grafting the area. This can double the cost of the skin grafting procedure, with the financial burden either written off by the hospital or passed on to the pet owner. Unless the surgical bed is considered to be clearly suitable for free grafting (healthy muscle surface, minimal surgical trauma, etc.), waiting a few days for a healthy granulation bed may be a wiser and more economical option. The surgeon also should determine if tension-relieving techniques or local flaps may be better options than immediate graft application.

Antibiotics and Skin Grafting

All granulation beds are contaminated with bacteria. Surgeons have their preference for whether to use topical and systemic antibiotics in skin grafting procedures. Surgeons occasionally culture the granulation bed prior to skin grafting to ensure appropriate treatment can be instituted prior to graft application. (The author does not routinely culture wound beds before grafting in most clinical cases.) In humans, group A beta-hemolytic streptococci (*Streptococcus pyogenes*) are the biggest culprit for graft dissolution. Topical and systemic penicillin can be used to control this organism prior to grafting. Other organisms, including *Pseudomonas* sp. and *Klebsiella*, occasionally are problematic for graft survival.

The following is the author's method: once a healthy granulation bed is obtained, apply a heavy layer of silver sulfadiazine or triple antibiotic ointment over the recipient bed, followed by a nonadherent dressing and protective bandage. This should take place 24–48 hours prior to grafting. The author places patients on a broad-spectrum systemic antibiotic (usually cefazolin) perioperatively, followed by its continuation during hospitalization. Patients are discharged on an oral broad-spectrum antibiotic postoperatively for 1 week.

At the time of surgery, cover the recipient bed with sterile gauze when fur is clipped. The skin is prepared for surgery in standard fashion. The recipient wound bed is cleansed with gauze swabs and chlorhexidine/saline (or lactated Ringer's solution) in a 1 : 40 dilution. Povidone–iodine and saline (1 part povidone–iodine to 9 parts saline) also may be used.

After transfer to the recipient bed, cover the graft with a layer of triple antibiotic ointment, followed by a nonadherent dressing and protective bandage wrap (see Bandaging Technique for Skin Grafts, later in this chapter).

CLASSIFICATION OF FREE GRAFTS

Free grafts can be classified according to the source of the graft, the graft thickness, and the graft shape or design. Although autogenous grafts are used for permanent free graft coverage in small animals, allografts (homografts) and xenografts (heterografts) can be used as temporary biological dressings until an autogenous graft can be successfully applied. Free grafts can be harvested as full- or split-thickness skin grafts. Split-thickness grafts are harvested with razor blades, graft knives, or a power dermatome. Graft knives and razors are difficult to master and rarely harvest the quantities of split-thickness skin grafts required for larger skin wounds that occasionally justify their use. Uniform thickness and adequate harvesting of split-thickness grafts require the use of the more expensive gas- or electric-powered dermatomes.

Grafts usually are applied immediately after harvesting. Under unusual clinical circumstances, the harvested skin can be temporarily refrigerated until application can be completed.

Selecting the Donor Area for Graft Harvesting

Clearly, most skin areas could be used as a potential donor site for skin graft harvesting. In general, thicker dermal skin has greater durability. Body areas with the greatest hair growth are normally selected. Secondary considerations include the direction, length, and color of the hair growth at the donor site. When available, the ample and easily accessible lateral thoracic and lateral abdominal skin is the most suitable area to harvest skin grafts. This location makes it a particularly useful donor area for grafting problematic lower-extremity wounds.

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GRAFT THICKNESS

Graft thickness varies according to the amount of dermis included with the overlying epidermis. The donor bed of a split-thickness graft bed (harvested with a dermatome) can be excised and closed, or it may be left to heal by adnexal regeneration and epithelialization. Thin split-thickness grafts "take" more readily than full-thickness grafts, but they lack durability and proper hair growth, and they are more susceptible to secondary graft contraction. Full-thickness grafts are generally preferred for these reasons. From the author's experience, properly prepared full-thickness grafts can achieve survival rates comparable to thinner grafts in the dog and cat. Free grafts can be applied as a sheet over the entire recipient bed or they can be cut into various shapes or patterns.

The full-thickness hand/scalpel mesh graft is a highly effective technique for closing defects involving the lower extremities (see Plate 83).

PARTIAL-COVERAGE GRAFTS

Punch grafts, strip grafts, stamp grafts, mesh grafts, and pinch grafts are commonly used as partial-coverage grafts to increase the total recipient surface area that a small graft harvest can cover. Other terms employed for pinch grafts include Reverdin's graft, island graft, pin graft, and the older name "seed graft." Punch grafts are distinguished from pinch grafts by the uniform harvesting of the grafts using a biopsy punch.

Although these grafts can vary in thickness, they are frequently full-thickness grafts. With these grafts, open spaces between the graft margins allow for drainage until the granulation tissue bed is covered by the advancing sheet of epithelial cells originating from the graft. For this reason, partial-coverage grafts are useful for recipient beds with low-grade infections. Small grafts also conform to irregular recipient beds and are simple to apply. Widely placed graft segments unfortunately can produce an epithelialized surface that lacks the functional and cosmetic results achieved with the more complete coverage of full-thickness grafts. The author prefers to use full-thickness mesh grafts to close most moderate-sized wounds of the lower extremities and to use punch grafts for smaller wounds that are not located over areas where durability is essential (Figs 14-2 and 14-3).

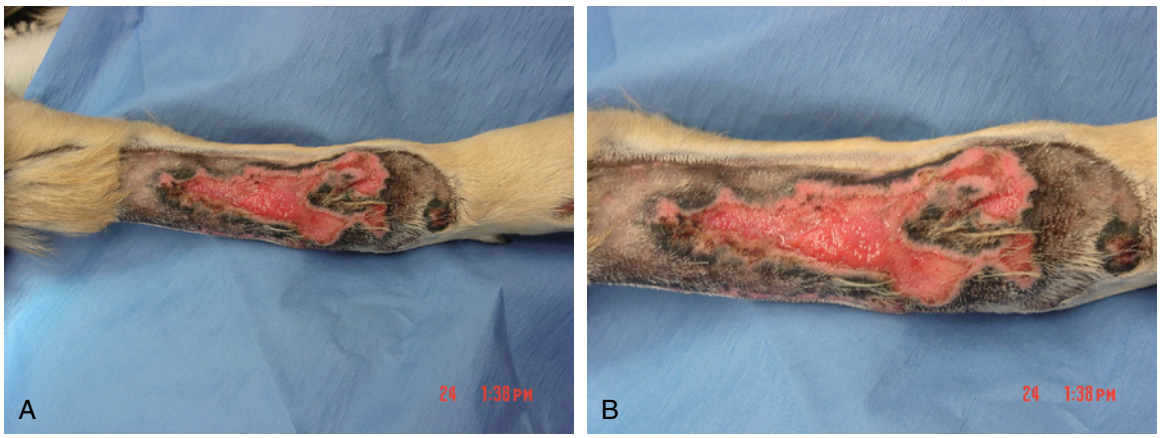


FIG. 14-2 (A) Chronic, fibrotic forelimb wound of several months' duration. Multiple topical wound-healing stimulants and dressings were used in an attempt to promote second-intention healing, to no avail. (B) Close-up view of the wound: note the perimeter of old epithelial coverage. (C) A 4 mm disposable skin biopsy punch (Sklar Tru-Punch™, Sklar Instruments, West Chester, PA) was used to create holes in the thick granulation bed approximately 1 cm apart. Small iris scissors can be used to trim off the core of granulation tissue. Cotton swabs or topical compression with moistened sponges are used to control bleeding. A syringe and a 20-gauge needle can be used to flush clotted blood from the holes with sterile saline prior to graft insertion. (D) A 6 mm biopsy punch was used to harvest skin plugs in the healthy skin more proximal to the wound. A single 3-0 nylon suture is used to close each donor hole. The punch grafts are kept between two moistened sponges prior to their insertion. The plugs are inserted, followed by the application of a nonadherent Adaptic pad (Johnson & Johnson) with a layer of triple antibiotic ointment applied over its surface. The Adaptic pad is stapled to the skin peripheral to the wound to prevent slippage beneath the outer protective bandage. The patient was discharged the same day. (E) Recheck 5 days later. The wound has dramatically decreased in size as a result of wound contraction and epithelialization. The author has occasionally seen this phenomenon of rapid epithelialization and wound contraction after the use of punch grafts to promote epithelial coverage to lower-extremity wounds, and calls the phenomenon *punch graft induction*. (F) Complete closure at a 2-week recheck. Prolonged use of an Elizabethan collar is advisable to prevent the patient from licking at the healed wound.

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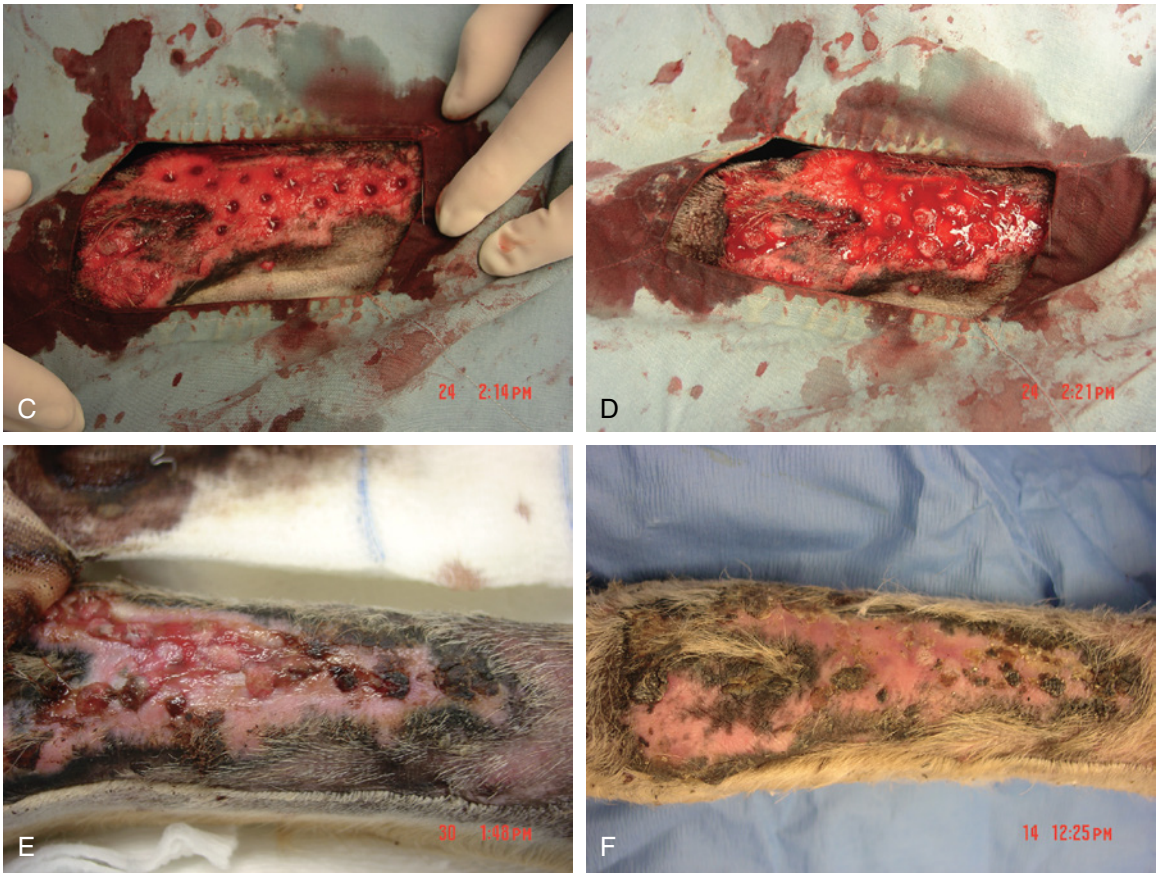


FIG. 14-2 (Continued)



FIG. 14-3 Pinch graft application. This technique is used for thinner granulation beds. A no. 15 blade is used to make a small pocket for insertion of a small pinch graft.

In general, split-thickness mesh grafts are used for extensive body defects or when donor skin is somewhat limited. Large burn wounds are potential candidates for split-thickness mesh grafts.

Full-thickness grafts, meshed with a scalpel blade, are practical and effective in providing a more durable skin coverage in small animals than are punch and strip grafts (Fig. 14-4). Hair growth from full-thickness skin grafts is fair, but does not achieve the density provided by a skin flap (Figs 14-2–14-8).

A novel method of covering large surface areas with autologous epithelial cells is the RECELL system (AVITA Medical), in which a harvested segment of skin is processed into an autologous skin-cell suspension that is sprayed onto a vascularized wound surface. It could be combined with a vascularized dermal substitute. There is one case in the veterinary literature (Dawson et al. 2021) employing RECELL in a dog with large full-thickness skin defects to epithelialize the dorsal cutaneous defect (see Chapter 2, Artificial Skin and Skin Substitutes).

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FIG. 14-4 (A) Miniature pinscher with a large circumferential skin defect of the left forelimb, secondary to vehicular trauma. (B) A template of the wound is created using the absorbent paper liner from a package of sterile surgical gloves. The paper is applied to the wound surface, leaving an outline of the moist wound surface. The paper is trimmed and placed over the lateral trunk area, with care taken to help ensure that a reasonable hair-growth pattern of the extremity is maintained. (C) The harvested graft is placed on a 4-inch roll of autoclaved Vetrap (3M), exposing the subcutaneous surface of the skin. 35 W skin staples (sutures are also acceptable) are used to position the graft onto the Vetrap. This greatly simplifies the removal of the subcutaneous tissues down to the dermal surface. (D, E) Saline is applied to the graft periodically to prevent desiccation. On completion of the "defatting" process, a no. 15 blade is used to create a series of 1 cm stab incisions in a staggered row configuration. On completion, the "hand mesh graft" is positioned over the viable granulation bed.

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FIG. 14-5 (A, B) Continuation of patient in Fig. 14-4. Graft application to the wound bed. Skin staples greatly facilitate graft application. Uniform tension is applied to the graft to ensure it conforms to the wound bed without excessive tension; the stab incisions are allowed to gap slightly open to facilitate drainage from beneath the graft. The graft should directly contact the irregularities of the recipient wound bed. The graft slightly overlaps the adjacent skin bordering the wound bed; staples are used to secure the graft. Staples are also used to secure the graft to itself where the graft completes the circumference of the lower-extremity defect. (C) Triple antibiotic ointment is applied liberally to 3 × 8-inch Adaptic dressings. Each dressing is spiraled around the graft in a flat, uniform fashion. Staples are used to secure dressings to each other as well as to the skin bordering the grafted area. (D) Sterile 4 × 8-inch surgical sponges are opened and spiraled over the Adaptic dressing (two layers). (E) This can be followed by two or more layers of 4-inch wide cast padding (Specialist Cast Padding, BSN Medical) secured with roll gauze to form a firm bandage. (F) Elastikon (Johnson & Johnson) forms the tertiary wrap. Note that the tape overlaps the skin above the bandage for added security. Tongue depressors are added to the Elastikon with 1-inch surgical tape for added bandage rigidity.

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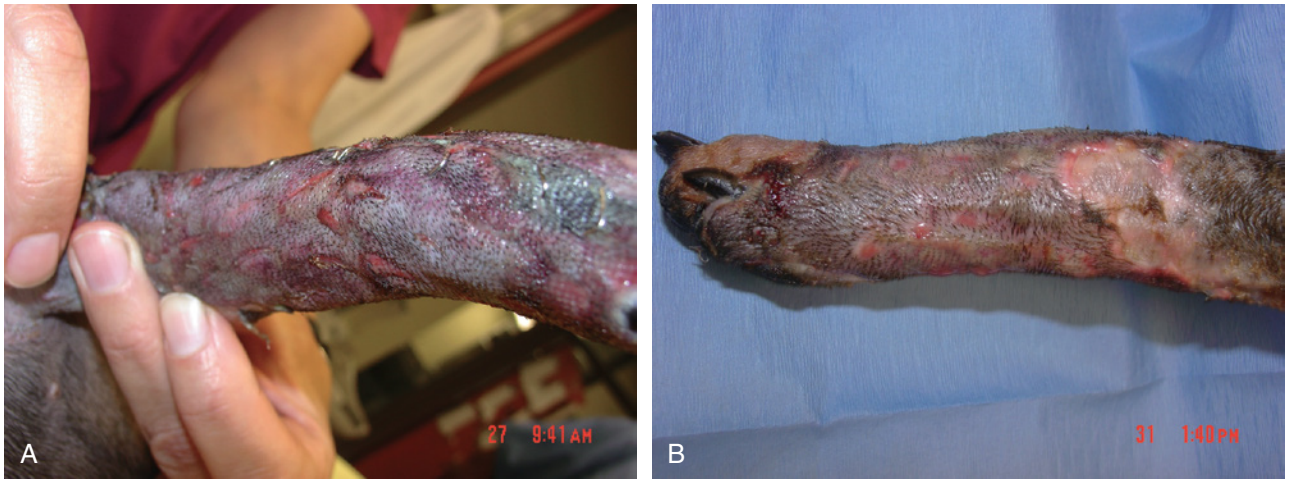


FIG. 14-6 (A, B) Continuation of the patient in Figs. 14-4 and 14-5. The graft at 1 week (lateral and medial views), with complete survival or "take."

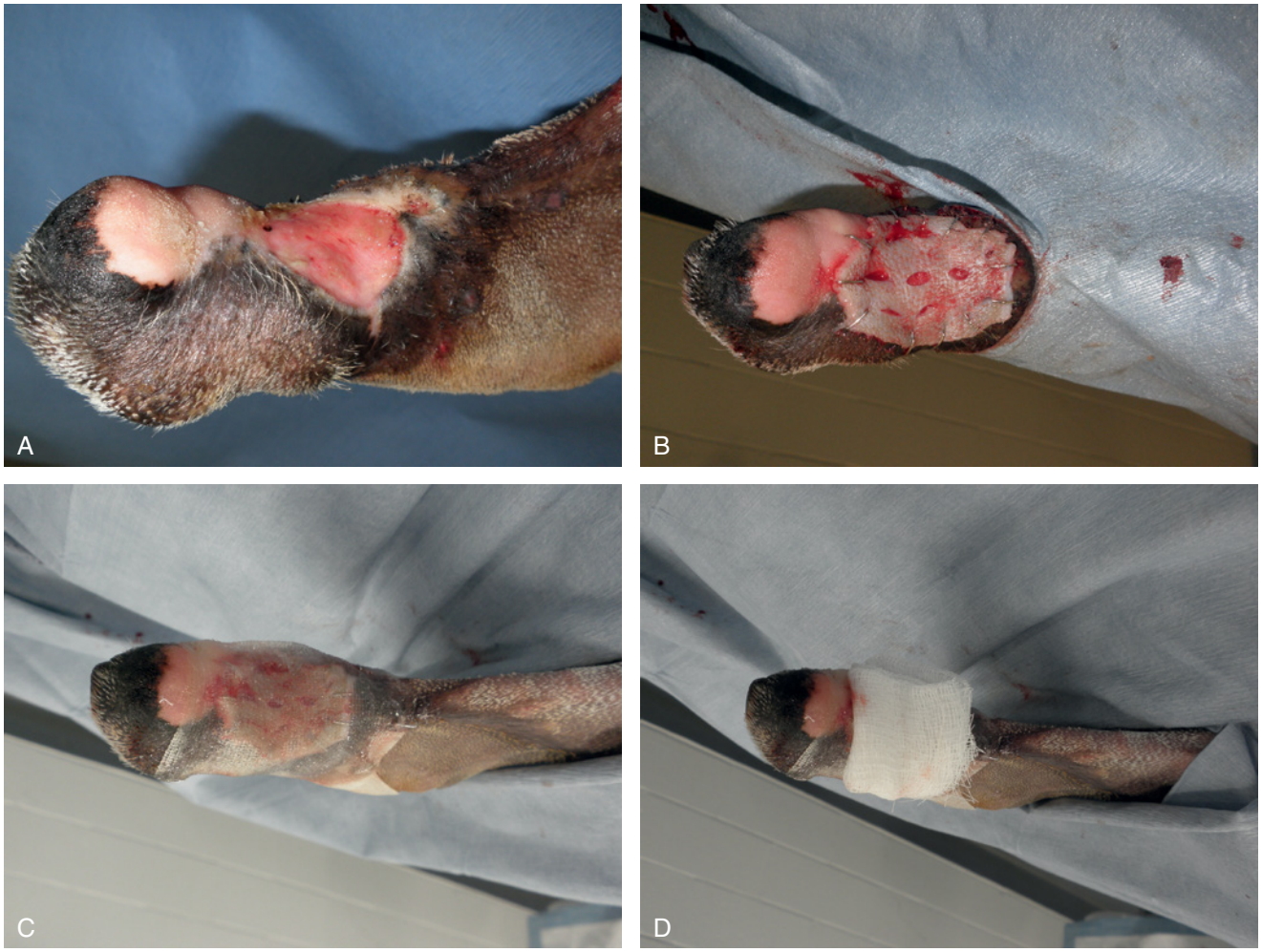


FIG. 14-7 (A) Traumatic wound with loss of the digits. Chronic open wound on the dorsal metatarsal area. (B) Full-thickness mesh graft application secured with skin staples. (C) Application of nonadherent dressing secured to the skin with surgical staples. (D) Placement of a sterile gauze sponge pad to compress the underlying depressed graft bed prior to bandage placement. This facilitated immobilization of the graft by pressing the graft into the wound depression. (E) Placement of a firm protective bandage of layered cast padding and self-adherent gauze. (F) Tongue depressors were taped together at an angle to help immobilize the tarsal joint. (G) Bandage change, day 5. Graft take is evident. Note that the border of the graft overlapping the cutaneous perimeter is necrotic. This thin band of devitalized skin will peel off with removal of the skin staples. Overlapping the graft will help ensure complete graft coverage of the recipient bed.

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FIG. 14-7 (Continued)

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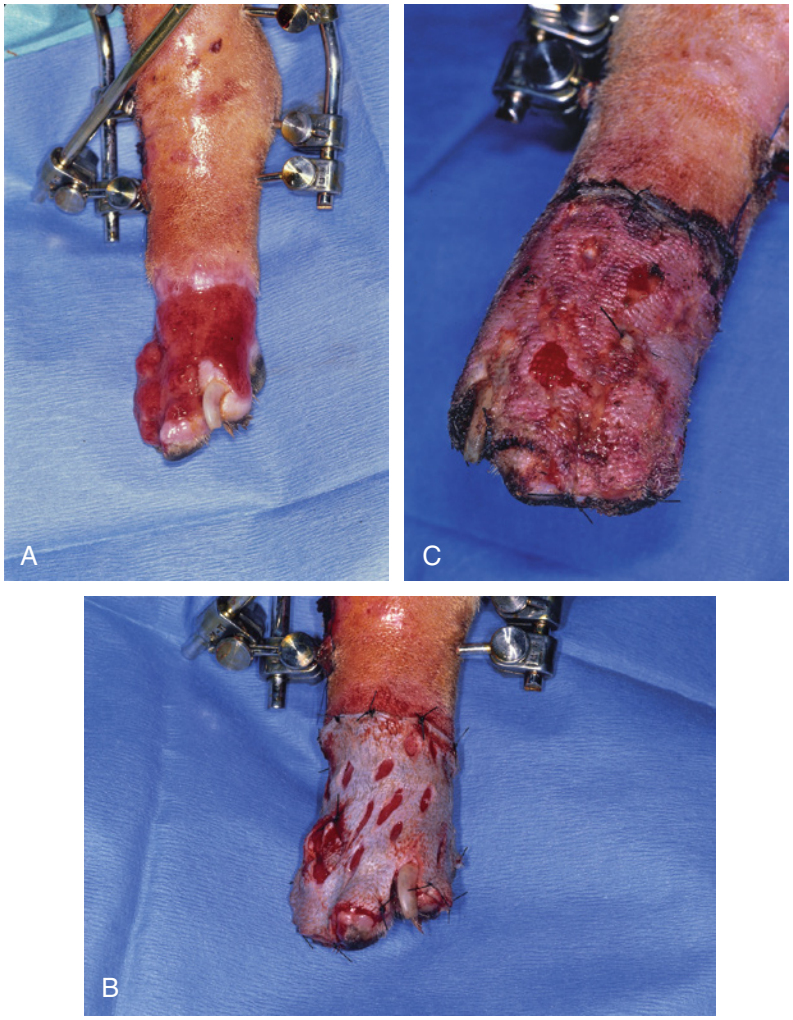


FIG. 14-8 (A, B) Hand mesh graft application to the lower extremity of a dog. External fixators used in fracture repair provide an additional "security anchor" for the graft bandage. (C) Approximately 5 days after graft application. Grafts that survive have a pink to lavender hue at the time of initial revascularization. Full-thickness mesh grafts are among the most useful techniques for closure of distal-extremity defects.

DERMATOMES

There are several dermatomes available commercially for human use. The Brown Electric dermatome has been the most commonly used unit in veterinary practice. The author has used the Zimmer Electric Dermatome (Zimmer Biomet, Warsaw, IN) and has found this instrument to be superior in its ability to harvest split-thickness skin grafts in the dog and horse (Figs 14-9 and 14-10). Although uncommonly used on a routine basis, large practices may find this instrument worthwhile to have on hand.

Punch, pinch, and strip grafts are primarily used to facilitate epithelialization of problematic wounds. They lack the durability achieved with sheet grafts and mesh grafts, which cover the majority of the wound with full-thickness skin.

Punch graft "induction": there have been several cases over the years in which punch graft placement dramatically induced the processes of wound contraction and epithelialization in chronic open-extremity wounds (see Fig. 14-2). Epithelialization from the perimeter of the wound quickly expands toward the center of the wound, oftentimes more so than the epithelial contributions of the punch grafts themselves. The cause of this dramatic healing process remains unclear. Grafts may enhance the release of cytokines to promote epithelialization or possibly serve as anchors for more effective myofibroblastic contraction.

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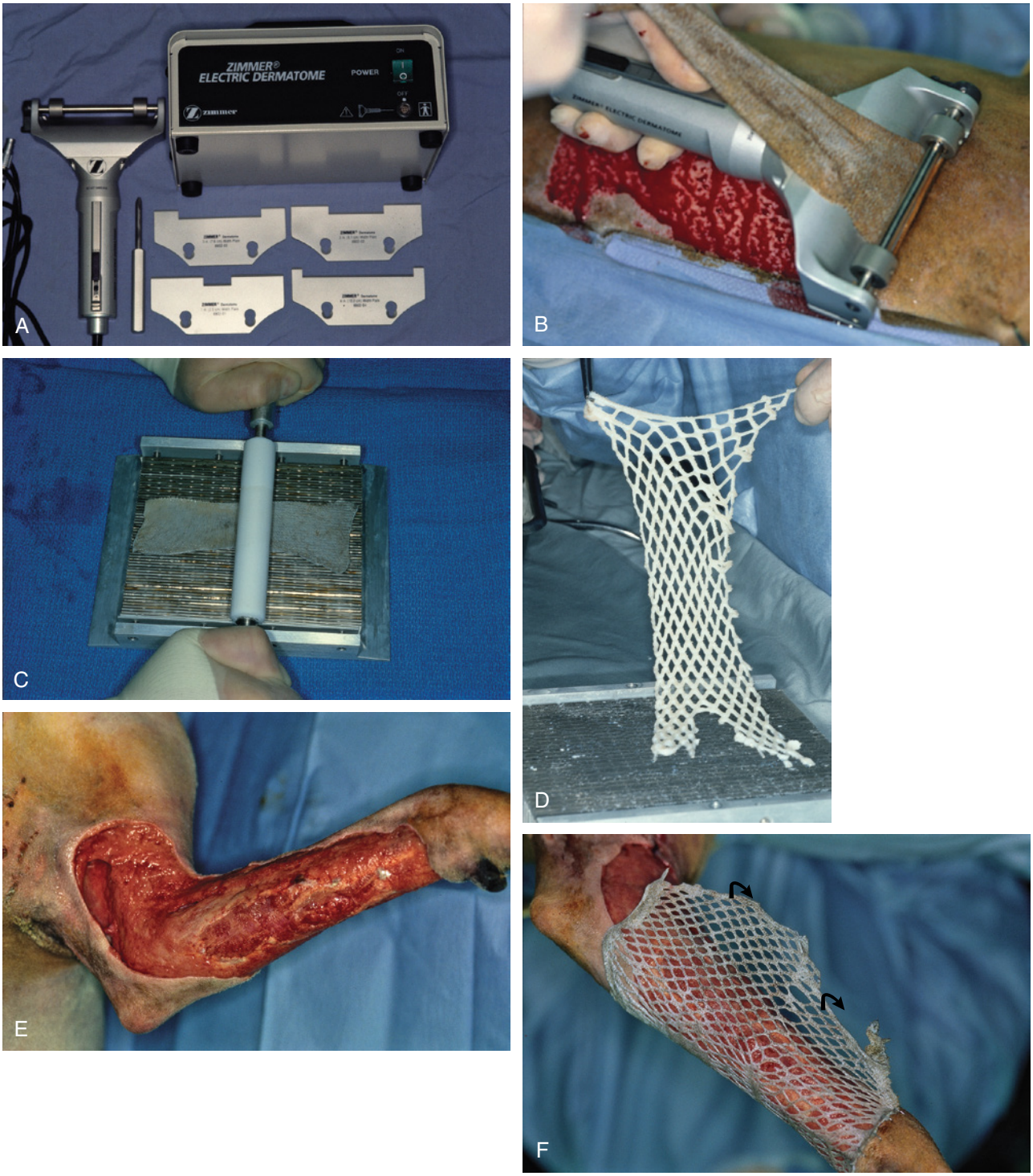


FIG. 14-9 (A) The Zimmer Dermatome is an excellent unit for harvesting split-thickness skin grafts. (B) The width of the graft harvested is determined by which base plate is selected. Each plate has a slot that determines the amount of skin exposed to the dermatome blade. (C) The Padgett Mesh Graft Expansion Unit (3 : 1 ratio; Padgett Instruments, Kansas City, MO). The Teflon roller compresses the graft into the staggered blades. (D) The meshed skin graft elevated from the Padgett Expansion Unit. (E, F) The graft can be expanded (stretched) up to three times the original surface area of the graft, depending on the desired coverage.

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FIG. 14-10 (A) Shiba inu with burn of several months' duration. (B) Mesh graft placement secured with skin staples. Placement of 2-0 nylon suture loops around the perimeter of the grafted area. (C) Tie-over dressing technique. A nonadherent dressing impregnated with triple antibiotic ointment followed by a bulky layer of sterile gauze sponges trimmed to conform to the grafted area. Umbilical tape was used to secure the dressing through the suture loops in a crisscross fashion. (D) Successful graft take is noted (photo at 1 week).

PRESERVATION BY REFRIGERATION

In veterinary medicine there is little need to refrigerate harvested skin: in most cases grafts are harvested and applied directly to the wound in one surgical procedure. If there is extra skin and the possible need for additional grafting, short-term refrigeration can be used to preserve the tissue (Fig. 14-11). In the event of a need to abort the grafting procedure, the skin can be refrigerated and reapplied at a later time in a more stable patient. In humans, excisional defects may be complicated by excessive bleeding or the graft may be necessarily delayed if the recipient bed is considered unsuitable for successful grafting. Careful planning can minimize these intraoperative errors.

Storage of grafts may reduce the phase of plasmatic imbibition by the production of anaerobic metabolites that stimulate early vascularization of the graft. This may be a benefit in those areas in which immobilization is problematic. In one limited study in horses, meshed skin grafts were refrigerated in a tissue culture medium composed of a balanced electrolyte solution with amino acids, vitamins, and dextrose (McCoy's 5A Medium, Flow Laboratories, Inc., McLean, VA). Grafts were rolled in moistened gauze and placed in a sterile plastic container with 1–1.5 ml of McCoy's Medium per cm^2 of skin graft tissue; air was included in the container to support cellular metabolism. Grafts were refrigerated at 4 °C. Graft acceptance was good to excellent up to the 3-week limit of the study. For humans, successful graft storage has been reported up to 6–8 weeks. McCoy's 5A Medium contains phenol red as an indication of catabolite production. A color change of cherry red to orange-yellow is an

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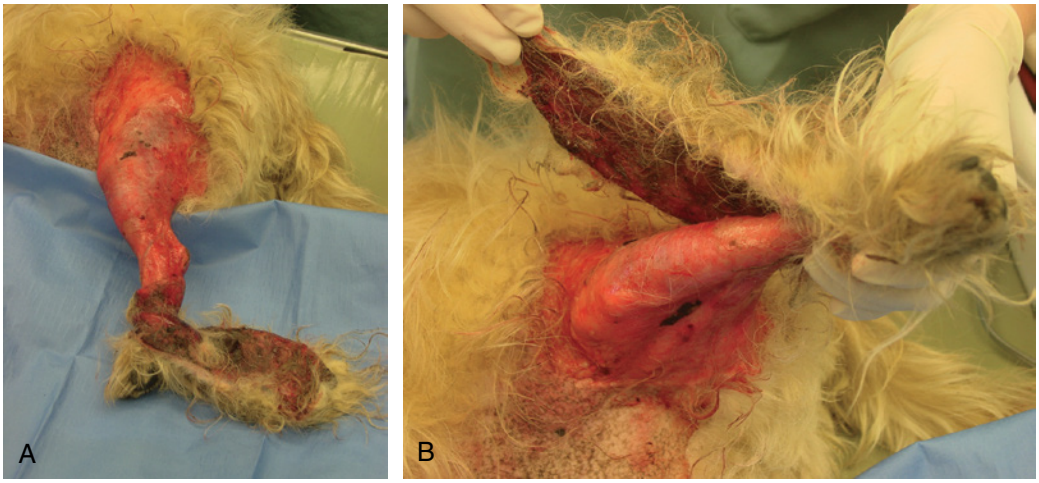


FIG. 14-11 (A, B) Fresh avulsion wound involving the rear leg of a small dog, as a result of a dog fight. This specific type of injury is occasionally referred to as a *degloving injury*, in which the skin is circumferentially avulsed or pulled distally in the fashion of removing a glove. Although this skin theoretically could be prepared (even preserved) and grafted back to the leg, it is best to discard this contaminated and traumatized tissue. The wound should be prepared for surgical closure using a freshly harvested skin graft. In this case, one or two caudal superficial epigastric axial pattern flap(s) also is an option (with or without the addition of a skin graft).

indication of catabolite build-up, necessitating replacement of half the medium volume; complete change of the medium may have an adverse effect on graft survival.

In small animal surgery, careful preparation of the patient and recipient bed can eliminate the need for graft storage and the costs incurred with graft preparation/refrigeration.

INTRAOPERATIVE CONSIDERATIONS

Strict aseptic technique is mandatory. The harvested graft must be kept moistened at all times with sterile saline or lactated Ringer's solution. Unless immediately applied, harvested skin is placed in moistened gauze pads and secured to the surgery table cover with forceps to ensure the sponge is not accidentally used and discarded. To save time, an assistant can close large donor sites while the surgeon prepares and applies the harvested graft to the recipient site. Skin staples are normally employed to secure free grafts; sutures are usually reserved to secure a graft in a problematic area. Skin staples can be effectively used to secure the dressing around the graft and to help secure layers of gauze as needed.

BANDAGING TECHNIQUE FOR SKIN GRAFTS

Few bandages require more exact application than a bandage used to secure and immobilize a body region after application of a free graft. Most skin grafts are performed on the extremities. All three layers of a bandage are essential for a successful "take." Components of the bandage include the following (see Fig. 14-5):

1. *Ointment*. An antibiotic ointment (oil base) is applied to a nonadherent dressing uniformly. The ointment protects the graft from desiccation and helps to reduce bacterial proliferation. (The author normally prefers triple antibiotic ointment.)
2. *Nonadherent dressing*. The dressing overlaps the entire graft. It is applied evenly over the grafted surface, without wrinkles or folds. The nonadherent (or more properly called *low-adherent*) dressing helps prevent the bandage from sticking to the graft area during subsequent bandage changes. Skin staples or "tacking" sutures can be used to prevent shifting of the dressing. (The author prefers Adaptic.)
3. *Absorptive/padding layer*. Sterile 4 × 4-inch gauze sponges are unfolded to 4 × 8-inch lengths. Usually two sponges are spiraled around the circumference of the extremity to cover the dressing. Sterile self-adherent gauze is used to secure the pads around the extremity (or body part grafted). Layers of nonsterilized cast padding normally are used in conjunction with layers of roll gauze for the bulk of the bandage. This layering process is repeated until a thick, firm secondary layer of gauze and cotton is created to immobilize the graft against the recipient bed and discourage motion. The bandage is extended above the adjacent joint in the process of application.
4. *Elastic wrap*. An outer elastic wrap is applied to the bandage. Adhesive elastic is used to secure the

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bandage to the fur and skin to prevent slippage. (The author prefers Elastikon, although a combination of Vetrap and Elastikon also can be used effectively.)

5. *Additional immobilization*. Slings, Mason metasplints, spicas, Schroeder-Thomas splints, tongue depressors, plywood coaptation splints, or reinforcement rods are used if additional rigidity or immobilization is necessary. Skin grafts applied over, or adjacent to, a joint surface usually require additional support or immobilization. A spica bandage/splint may be advisable for grafts applied to the proximal portions of the limb to avoid slippage and help restrict regional motion. Cats are quite adept at "flicking" bandages off their extremities, but cannot remove spica-style bandages (Figs 14-12 and 14-13). Tie-over dressings can be effective in immobilizing grafts, especially in difficult areas (inner thighs, upper limbs, etc.).
6. *Postoperative care*. Bandages may be changed as early as 48 hours after graft application. However, it is safer to wait for a minimum of 3 days to ensure the critical 48-hour period of the graft revascularization is not disturbed. Patients should be sedated and restrained during bandage changes to avoid accidental trauma to the graft site. General anesthesia is recommended for excitable/aggressive patients. Care must be taken not to pull or lift the graft from the underlying wound bed during dressing removal. In most cases, adherence of the topical dressing is the result of dried blood binding exposed areas of the granulation bed to the interstices of the dressing. These areas can be softened with warm saline and "unbuttoned" with gentle traction applied to the dressing. If the dressing is particularly tenacious, the dressing may be left on the graft followed by the addition of topical ointment *on top of this dressing*, before reapplication of the secondary and tertiary bandage layers. As noted in chapter 4, vacuum-assisted closure (VAC) style devices (see Plate 1) also have been used to secure skin grafts. The frequency of bandage changes varies with the patient and graft techniques used. Unless infection is a concern, bandage changes can be timed for every 3–4 days after the initial change. Once healing is complete, bandaging can be discontinued (normally by 2 weeks after mesh graft application). However, the author has protected grafts up to 1 month, usually in conjunction with prolonged use of Elizabethan collars, in active patients with a propensity to lick or chew at themselves.
7. *Cage/run confinement*. Dogs and cats are confined to their cages. They are kept on a leash when taken outdoors to urinate and defecate. Minimal activity is essential to graft survival, especially in the first 48-hour period of graft revascularization. Minor soiling of the outer bandage does not necessitate a complete bandage change, as the heavy padding and the outer wrap usually limit the depth of contamination. However, bandages should not be allowed to get soaked with water or urine. A plastic bag can be applied temporarily to the bandaged foot when the dog is exposed to wet surfaces. It must be remembered that motion can result in bandage materials rubbing on the graft site. This has been recognized as a cause of graft failure in active patients.

With cooperative patients and compliant pet owners, the patient can be discharged from the hospital after the first bandage change. Again, the key factor is minimizing activity and local motion to ensure graft survival.

Viable grafts assume a pink to lavender hue depending on the state of vascularization. Dead skin assumes a white or black color. Early signs of superficial graft necrosis are discouraging, but not always catastrophic, because hair follicles and cutaneous adnexa in the deep portion of the graft may survive and may serve as a source for wound epithelialization.

Cats are notorious for flipping bandages off their extremities, especially the forelimbs. Hyperactive dogs are also a concern. To prevent bandage/splint loss, strips of Elastikon elastic adhesive tape encompass the trunk and are applied to the bandage/splint (spica splint fashion). This method is highly effective in preventing its removal by the patient (see Figs 14-12 and 14-13).

Vacuum-Assisted Closure: an Alternative Method to Secure Free Grafts

VAC can be used to manage open wounds in preparation for wound closure and to facilitate development of a granulation bed. The system can be used to firmly immobilize the graft to a wound bed, especially in areas where bandaging may be challenging. The details of using the VAC system are discussed in Chapter 4. Like bandage immobilization of skin grafts, failures also have been noted using VAC.

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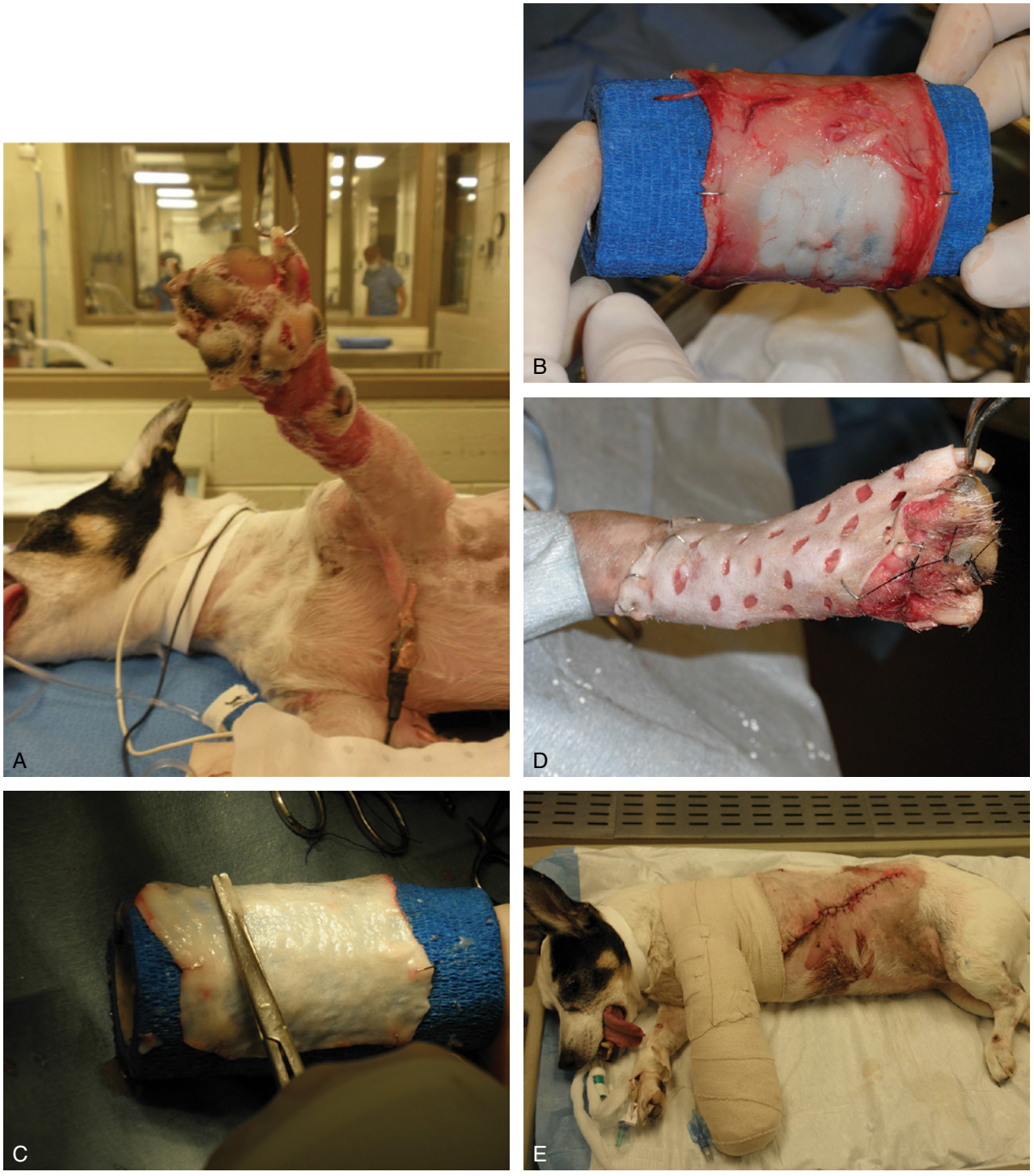


FIG. 14-12 (A) Extensive skin loss involving the circumference of the left forelimb in a Jack Russell terrier. (B) The graft, secured with staples to an autoclaved Vetrap roll. Note the difference between the "defatted" area compared to the intact subcutaneous fatty layer. (C) Removal of the subcutaneous fatty layer from the graft. Sharp, curved Metzenbaum scissors are necessary for exposing the dermis, essential to graft revascularization. (D) The meshed graft is applied over the circumferential defect. The border of the graft slightly overlaps the margins of the wound, facilitating securing of the graft with skin staples. (E) Elastikon bands are applied around the thorax: both ends of these bands are secured to the bandage immobilizing the left forelimb. The incision denotes the donor area of the lateral thorax and abdomen where the full-thickness mesh graft was harvested.

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FIG. 14-13 (A) Skin defect involving greater than half the circumference of the left forelimb in a terrier cross. A healthy granulation is prepared for graft application. (B) The full-thickness graft was harvested from the left lateral thoracic area. The graft was stretched and secured to the autoclaved Vetrap with skin staples. After removal of the subcutaneous fat with curved Metzenbaum scissors, a no. 15 blade was used to create staggered holes along the length of the free graft. (C) Mesh graft application using skin staples to secure the graft to the recipient wound bed. (D) After application of a reinforced bandage to immobilize the graft, Elastikon bands were applied around the thorax: both ends of the band were secured to the outer bandage. This is technique is useful for overactive patients, especially when the grafted area is close to the elbow region. (E) Close-up view of the Elastikon bands passing around the thorax. This spica splint design is highly effective in preventing displacement of the bandage.

PLATE CONTENTS

The plates describe the various grafting techniques discussed in this chapter. Mesh grafts (using a scalpel blade) remain the most useful option for covering problematic lower-extremity wounds. Punch grafting is the simplest option for closing smaller problematic wounds where second-intention healing has stalled, despite the best medical efforts to resolve this delay in healing. Punch grafts usually are employed for those smaller lower-extremity granulation wounds where durability of the resultant epithelialized scar is not an issue. Fortunately, the dermatome is rarely required: its use is a consideration for the largest defects in which the other reconstructive surgery options cannot completely close the wound.

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Plate 76

Punch Grafts

DESCRIPTION

Punch grafts are small, circular full-thickness grafts used to seed a granulation bed with "epithelial islands." Suitable numbers are used to reepithelialize the interposing granulation surface. A biopsy punch can be used to harvest tissue and create holes in a thick granulation bed.

SURGICAL TECHNIQUE

(A) Fur is clipped sufficiently close to leave a short stubble that serves as an "angle guide" for plug harvesting. Adson-Brown forceps and a biopsy punch (6–10 mm) are used to harvest skin graft plugs. The punch is angled parallel to the hair shafts. Scissors are used to lift and cut the skin plug from its subcutaneous attachments. Subcutaneous fat is trimmed from the base of each plug (inset). Harvested grafts are then placed between sponges moistened with sterile saline or lactated Ringer's solution. Donor beds are closed with individual sutures.

(B) A smaller biopsy punch (approximately 2 mm smaller) is used to cut circular holes into the thickened granulation bed to compensate for graft contraction on harvesting and to allow grafts to fit more snuggly into each hole. Grafts are spaced about 1–2 cm apart. Rows are staggered using the same guidelines. Forceps and fine-tipped sharp-sharp scissors are used to remove the plug of granulation tissue. Sterilized cotton swabs are inserted (for 5 minutes minimum) into the individual granulation holes created to control hemorrhage.

(C) Harvested grafts are inserted into the granulation bed level to its surface. A sterile nonadherent dressing, antibiotic ointment, and firm cotton bandage are applied to the area to secure the grafts into their new position and immobilize the area. The bandage is changed 3–5 days postoperatively and every 2 or 3 days thereafter until epithelialization is complete.

COMMENTS

The punch graft technique is a modification of one technique designed for "correction" of male-pattern baldness. Unlike humans, however, the purpose of punch grafts for animals is to promote wound epithelialization and not hair growth. The technique is simple to execute and is easily performed on an outpatient basis. Punch grafts are forgiving: partial loss of punch grafts can be remedied with a second set with minimal surgical time or skin required. Grafts can be harvested with a local lidocaine block and patient sedation.

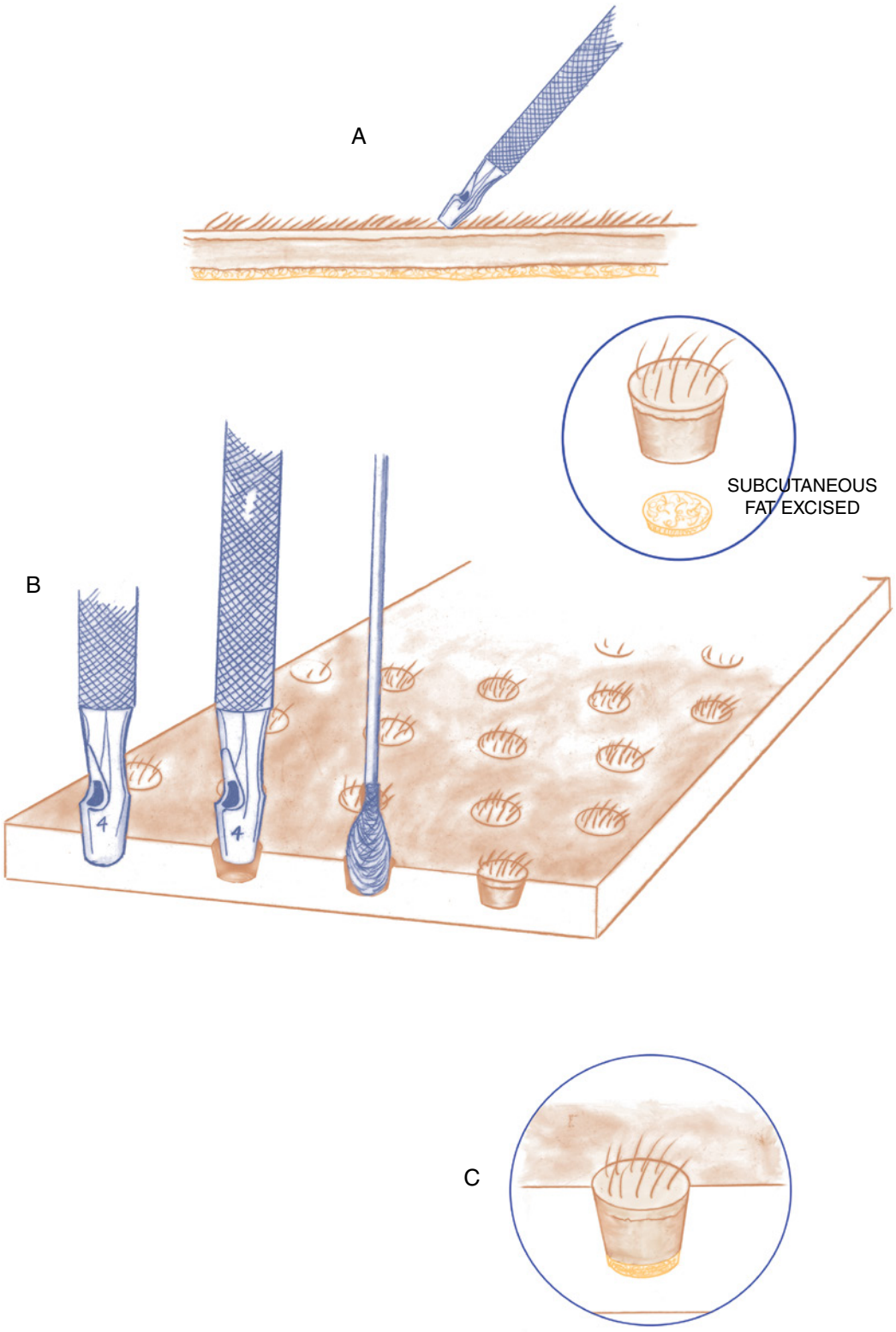
Punch grafts are more applicable to thicker granulation beds that allow firm seating of the graft plugs. Moreover, graft insertion facilitates revascularization by exposing the base and sides of the plugs to the capillary bed of the recipient site. In thin granulation beds, harvested plugs are inserted into pockets created with a no. 15 scalpel blade, as described in Plate 77. Holes are created beginning at the lower border of the wound so that bleeding does not obscure the area as additional grafts are applied.

The author has seen punch grafts accelerate epithelialization of chronic open wounds of the lower extremity (see Fig. 14-2). The major disadvantages of punch grafts include poor cosmetic results and an epithelialized wound surface that lacks the durability of flap or full-thickness graft coverage of the entire wound. They are best used for smaller wounds located in areas *not* subject to excessive wear or external trauma. In large wounds, the harvesting and insertion of multiple punch grafts are tedious. Under these circumstances, mesh grafts are comparatively easy to perform and provide a more suitable outcome.

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Plate 76



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Plate 77

Pinch Grafts

DESCRIPTION

Pinch grafts (Reverdin's graft, island grafts, seed grafts, pin grafts) are a variation of the punch graft technique, although the method of harvesting the skin segments differs. Pinch grafts are inserted into angular pockets in the granulation bed formed with a no. 15 scalpel blade.

SURGICAL TECHNIQUE

(A) The skin is prepared for surgery in routine fashion. A hypodermic needle or curved suture needle is grasped with a needle holder. The needle is inserted into the skin and elevated. The "tented" skin segment is harvested with a scalpel blade (dotted line). Donor areas are closed with skin sutures. Subcutaneous fat is excised before wrapping the skin segments in gauze sponges, moistened with sterile saline or lactated Ringer's solution.

(B) A no. 15 scalpel blade is angled 30–45 degrees and stabbed into the granulation bed. Digital compression is used to control bleeding.

(C) The small grafts are inserted into the angular slits followed by application of a snug bandage (previously described under punch grafts).

COMMENTS

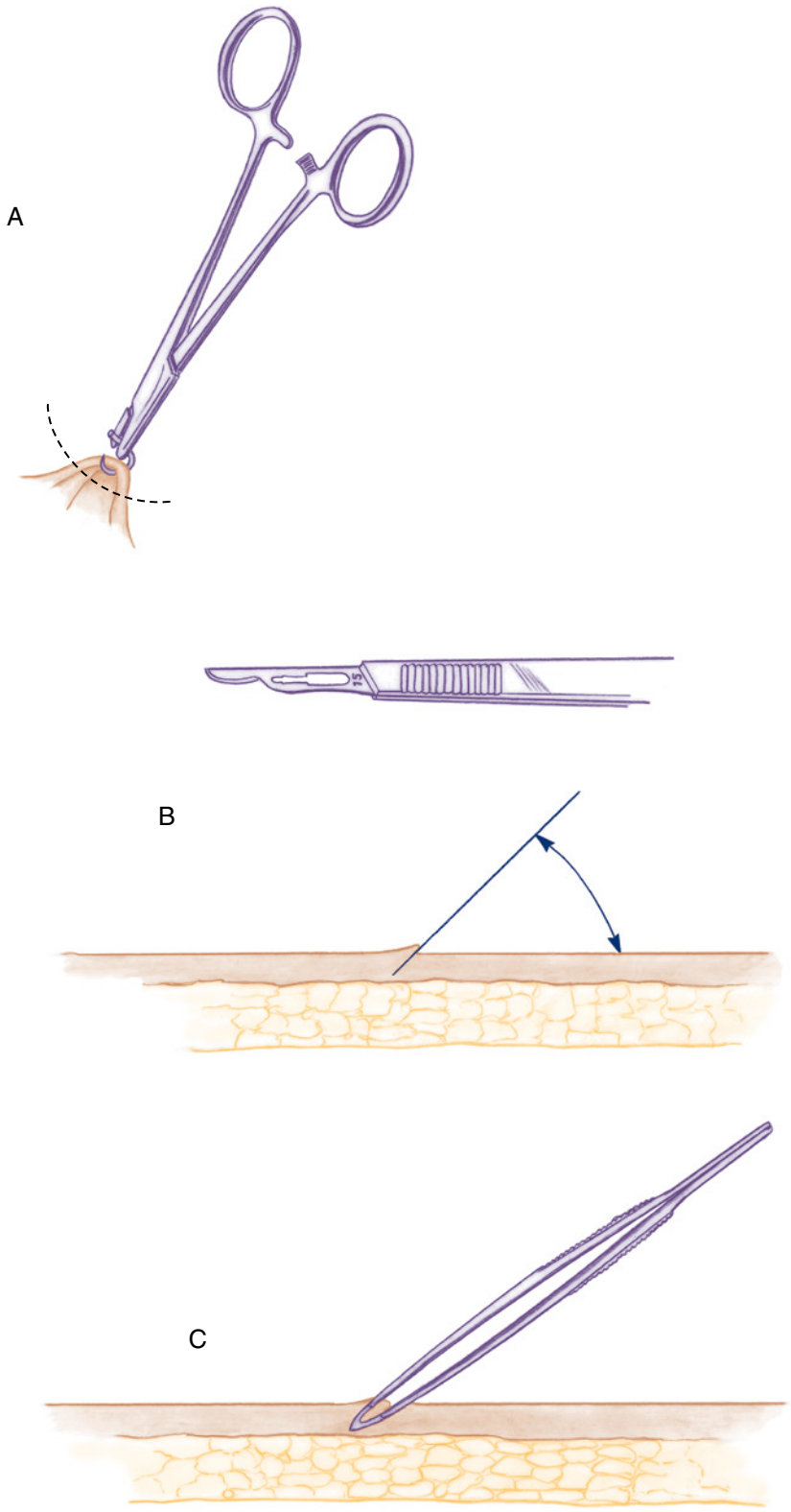
Stab incisions in the granulation bed are begun at the most dependent position to prevent hemorrhage from obscuring the entire surgical field. The incision is directed ventrally/distally to create a "gravity-proof" pocket for the grafts. Hemorrhage must be controlled prior to insertion of the graft, otherwise the graft can float out with active bleeding. The depth of the stab incision is adjusted by the angle of blade insertion. Shallow granulation beds require a narrow angle, whereas a thicker bed may allow an angle up to 45 degrees.

Pinch grafts have the same general advantages and disadvantages as punch grafts, although harvesting is less uniform than with the latter technique.

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Plate 77



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Plate 78

Strip Grafts

DESCRIPTION

Strip grafts are a variation of the punch graft technique. Narrow strips of harvested skin are placed in parallel grooves or furrows cut into the granulation surface. They are most commonly employed to cover longer wounds.

SURGICAL TECHNIQUE

(A) A rectangular segment of skin is harvested equal to the length (long axis) of the defect. The width of skin harvested is estimated by the number of strips required, the width of the skin strips, and the space between each strip on their application to a recipient bed. All subcutaneous tissue is excised from the harvested skin graft. The harvested graft is divided into strips 3–5 mm wide. If necessary, wider strips can be developed.

(B) A no. 11 or 15 scalpel blade is used to cut furrows into the recipient granulation bed, approximately 2 mm deep and wide enough to accommodate the graft strips. Furrows or graft rows can be spaced 10–15 mm apart. Strips of gauze or umbilical tape are compressed into these grooves to control hemorrhage for 5 minutes. Grafts are laid into the depression formed on removal of the gauze strips. A single suture can be placed on each end of the strip grafts. Alternatively, the surgeon can rely on the bandage alone to secure the grafts into the granulation furrows.

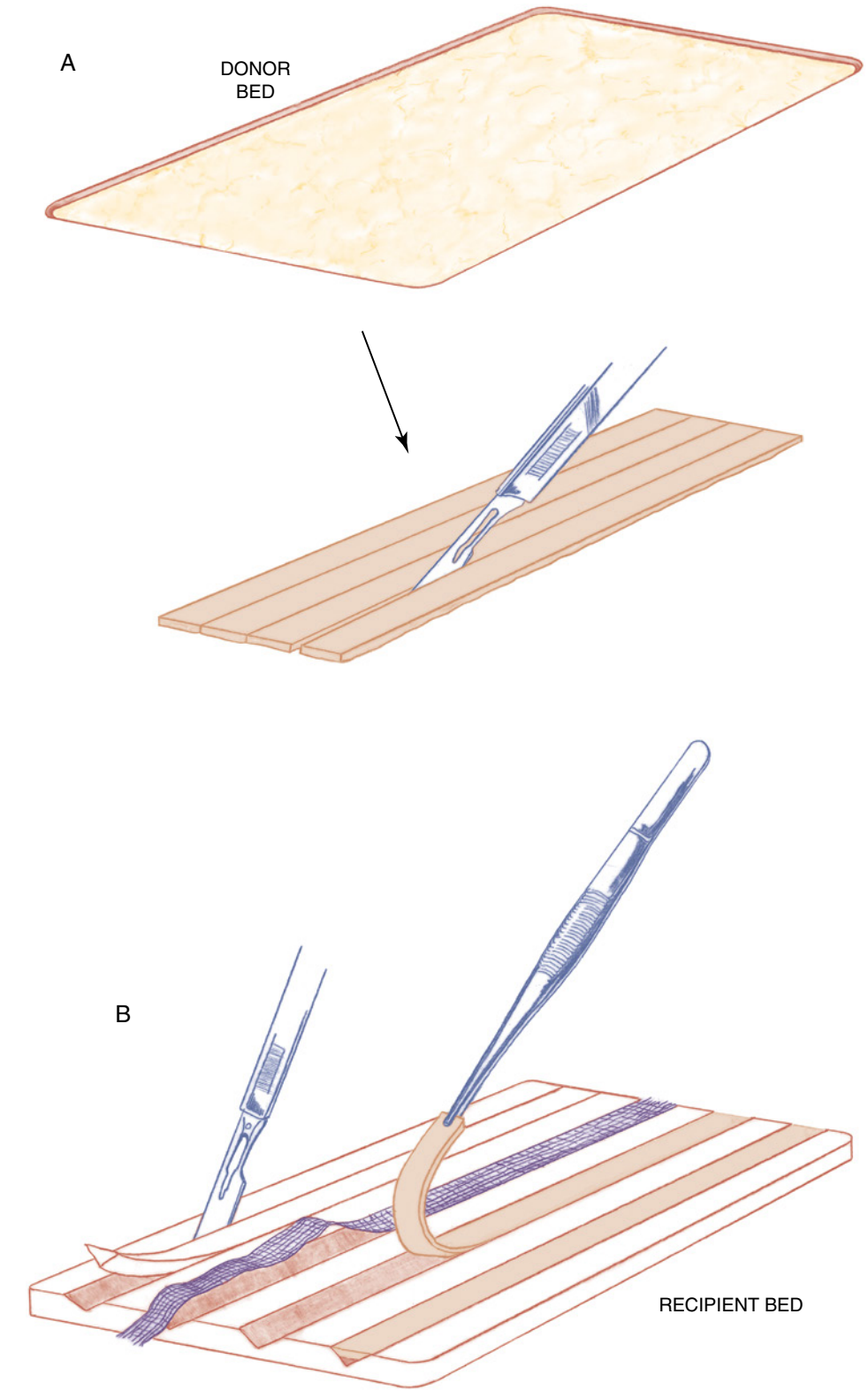
COMMENTS

Strip grafts, like punch and pinch grafts, are primarily employed to promote epithelialization of the wound. Their advantages and disadvantages are similar to those described for punch and pinch grafts. Strip grafts may be more applicable to long, narrow wounds involving the extremities, although the selection among these three grafting techniques is largely the preference of the surgeon.

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Plate 78



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Plate 79

Stamp Grafts

DESCRIPTION

Stamp grafts are yet another method of providing coverage to wounds by placing "postage-stamp" segments of skin over a wound bed. Their borders serve as sources of epithelium for the exposed granulation surface between each stamp graft. When placed approximately 1 cm apart, stamp grafts serve the purpose of wound coverage; when placed at greater distances apart, they act more as skin islands to reepithelialize larger granulation beds.

SURGICAL TECHNIQUE

(A) Split-thickness or prepared full-thickness grafts (free of subcutaneous tissue) are cut into postage-stamp-sized segments. Size can be somewhat varied.

(B) Grafts are laid onto the wound surface. Stamp grafts are commonly placed approximately 1 cm apart. Fine sutures can be placed in each corner to maintain the flaps' position until the fibrin "glue" forms between the wound bed and overlying graft. A nonadherent dressing and protective wrap are used to restrict motion.

(C) Alternatively, the surgeon can resect a thin portion of a wound bed to recess the graft, thereby reducing the likelihood of surface motion. This more tedious technique will necessitate control of hemorrhage before graft application. It is rarely required.

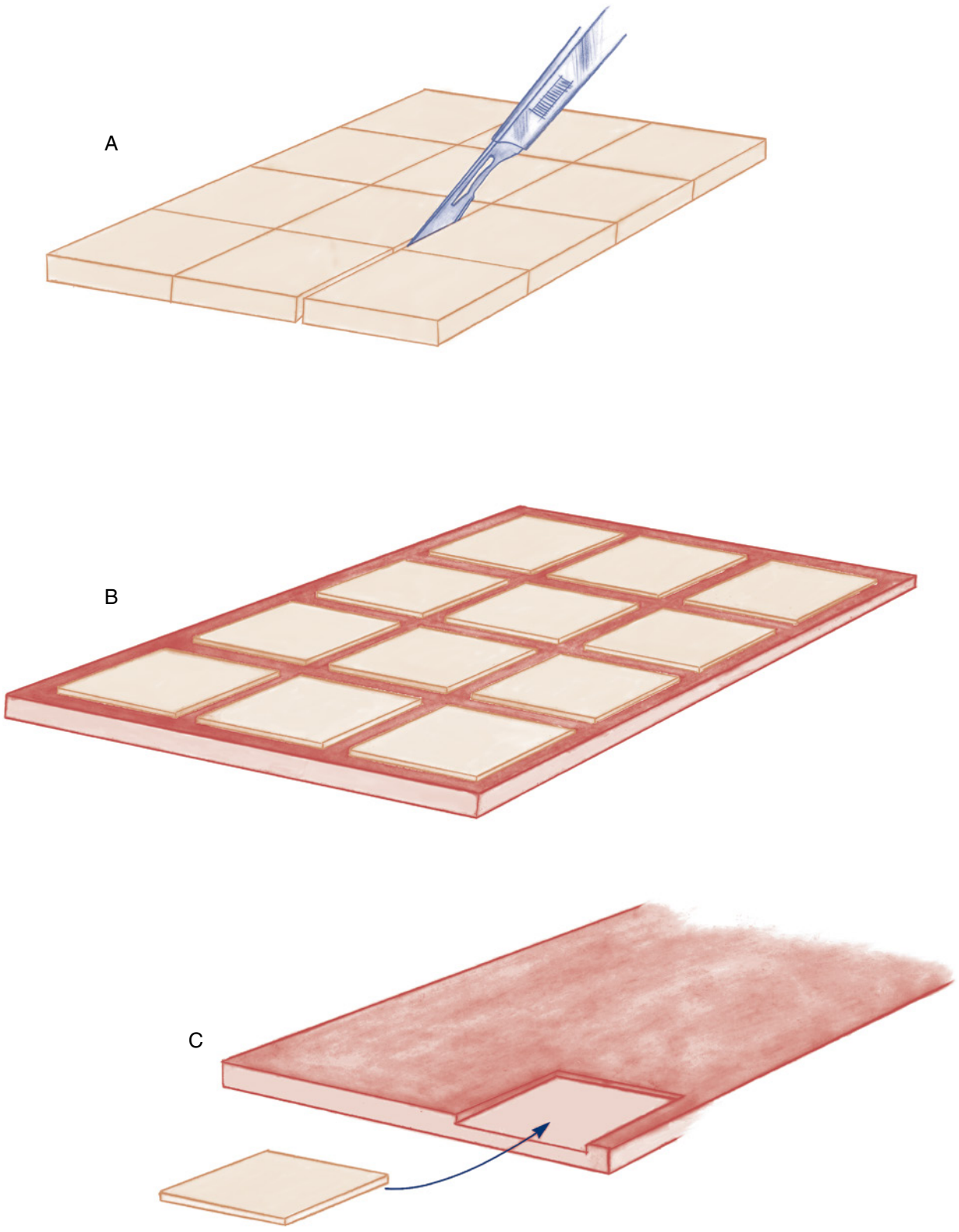
COMMENTS

Stamp grafts are yet another method of applying free grafts to wound beds. Drainage is provided by spacing them apart. They technically combine the advantages of the simpler punch, pinch, and strip grafting techniques with the greater coverage afforded by sheet and mesh grafting. It is the author's opinion that they have no significant advantages over mesh grafts and lack the simplicity of the punch, pinch, and strip techniques. Securing multiple small grafts to the granulation bed is more problematic than mesh grafting techniques. Cosmetic results vary with their thickness and proximity of placement.

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Sheet Grafts

DESCRIPTION

Sheet grafts are used to completely cover a recipient bed with a uniform layer of skin. Skin thickness can be varied according to the individual needs of the patient. When possible, full-thickness skin grafts are usually selected for their durability and hair growth. The vascular wound bed must be free of debris, epithelial coverage, and infection prior to graft application.

SURGICAL TECHNIQUE (FULL-THICKNESS GRAFTS)

(A) Using sterile paper (from a surgical glove package) or gauze, a template is made of the recipient bed by pressing the material onto the wound. When the material is lifted off the bed, it has the moistened impression of the defect. The template is positioned on the selected donor site and is oriented to match the hair growth at the recipient area. A marking pen can be used to outline the template onto the donor site, about 1 cm outside its border to ensure adequate wound coverage. In general, a rectangular segment embracing these dimensions is removed to facilitate closure of the donor defect. Redundant (excessive overlapping) skin is excised during graft application.

(B) The graft is removed and the donor area closed. The graft is "defatted" by removing all subcutaneous tissue, including any panniculus muscle, by using Metzenbaum scissors. Initial fat removal can be achieved by securing the harvested skin (dermal surface) up to a 4-inch roll of autoclaved Vetrap with skin staples (see Fig. 14-4). The graft also may be draped over the index finger, advancing Metzenbaum scissors across the graft for close fat excision from the dermis.

Some surgeons try to defat the graft with a scalpel blade during its harvest. The blade is used to cut the hypodermis from the dermis, rather than simply undermining the skin. A Zimmer Dermatome also could be set to remove a thick split-thickness skin graft to avoid the need to defat the graft.

The defatted dermal surface exposed assumes a cobblestone appearance after scissors resection of the hypodermal tissues. Hair follicles (appearing as dark flecks) can be seen within the dermis. When held to a light source, the resultant graft appears opaque. Grafts are periodically immersed in a bowl of sterile saline or lactated Ringer's solution to keep the graft moist, rinse off fragments of subcutaneous fat, and visualize strands of attached subcutaneous tissue requiring removal. It is useful to have a second bowl of saline for a final graft rinse before its placement onto the recipient bed.

(C) The graft is laid over the wound, enabling it to contact the irregular surface of the vascular recipient bed. One or more stab incisions can be made in the graft to promote drainage. The graft overlays the edges of the wound slightly to ensure complete wound coverage. Simple interrupted sutures or skin staples are used to secure the graft border to the underlying skin overlapped. The graft is carefully bandaged.

COMMENTS

Although grafts prepared in this fashion are considered full-thickness grafts, in reality they vary in thickness depending on the amount of dermis inadvertently removed during the removal of the subcutaneous tissues. Hair growth varies with the number of surviving hair follicles. Hair growth normally is sparser compared to the skin prior to surgical preparation. The graft must be kept moist at all times during the procedure by periodically bathing the graft with cool, sterile saline or lactated Ringer's solution. Skin grafts must not be applied too loosely or too tightly. The graft must contact the wound bed uniformly. Properly applied, the graft has the mobility of the skin over the back of your hand when manipulated with your index finger. Surviving grafts initially assume a pink to lavender hue. As circulation improves, skin color becomes normal and hair growth resumes.

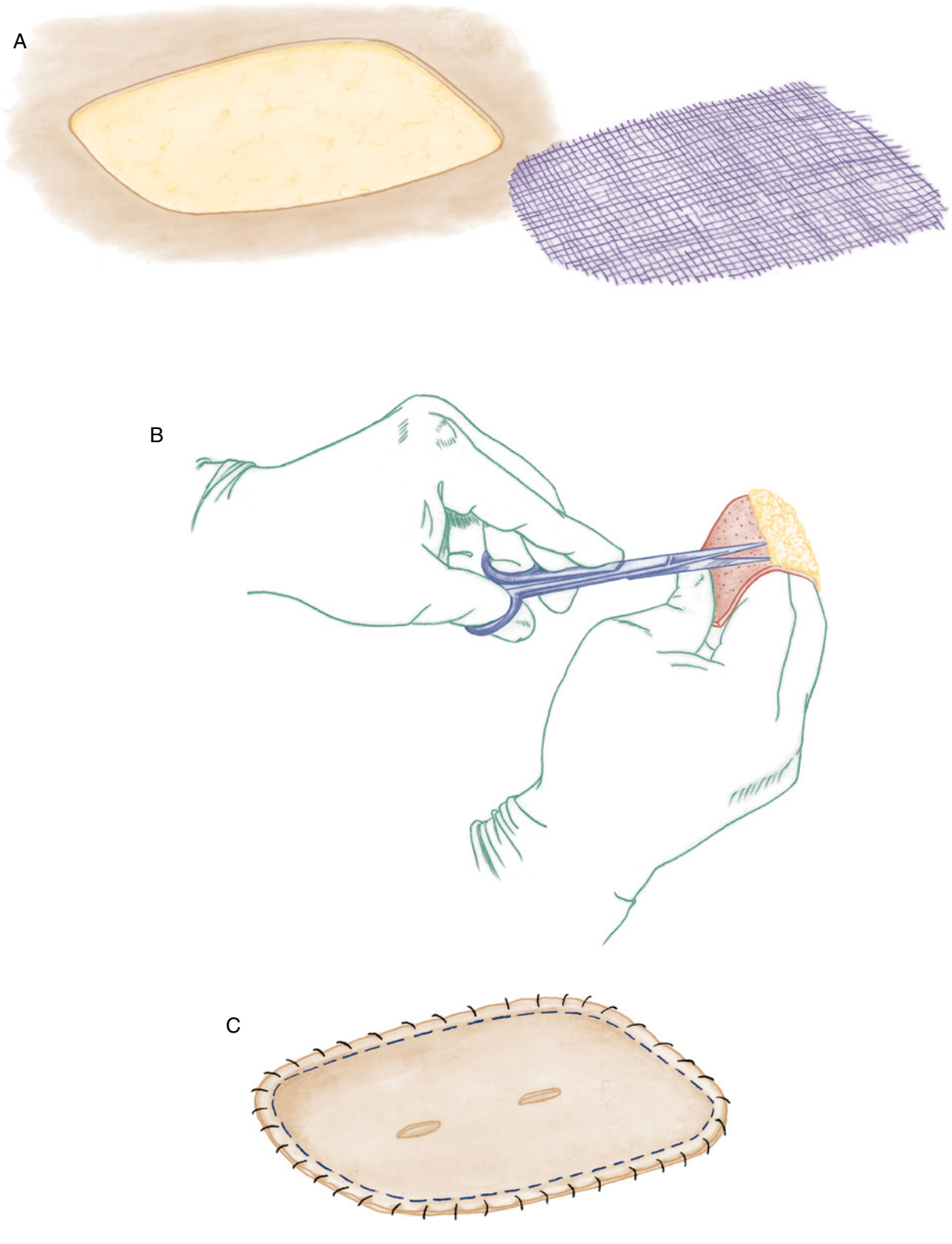
Overlapping the free graft border ensures complete wound coverage and keeps the skin border from curling underneath, which would prevent survival of the border line. However, it is not absolutely necessary to overlap the graft borders, especially in those cases where there is limited graft for wound coverage. With a successful "take," the overlapped skin border sloughs and will peel off during suture removal 7–10 days later.

The author favors mesh grafts over sheet grafts because of their superior drainage. The multiple slits help prevent fluid accumulation; drain holes rapidly close by epithelialization upon a successful graft "take."

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Plate 81 Dermatome: Split-Thickness Skin Graft Harvesting

DESCRIPTION

There are several dermatomes available commercially for harvesting split-thickness grafts. The original Brown Electric Dermatome has been replaced by the newly redesigned Zimmer Dermatome.

SURGICAL TECHNIQUE

The surgeon must be familiar with the components and setting adjustments of any dermatome prior to surgery. Practice in its use can be obtained on fresh cadaver specimens. The width of the graft is adjusted on the dermatome. Graft thickness can be adjusted to between 0.015 and 0.030 inches depending on the thickness of the donor skin and the graft thickness desired. The author usually selects a graft 0.015 inches (0.38 mm) thick.

Basic preparation and use of the newer Zimmer Dermatome are similar to that of the Brown Dermatome. There is a single dial to easily set the depth (thickness) of the graft cut. Exchangeable base plates vary the exposure of the skin to the oscillating blade to control the width of the graft harvested.

The dermatome is ideally suited to harvesting skin from a long, flat surface. Selection of a donor site(s) is a matter of availability. In general, it is preferable to select a suitable donor site in a location or locations that are easily accessible and that do not require the intraoperative repositioning of the patient.

Sterile saline or lactated Ringer's solution can be injected beneath the skin to facilitate graft harvesting over irregular areas (e.g., ribcage). Sufficient fluid is injected to elevate the skin from the underlying structures that impede advancement of the dermatome or alter the angle of the oscillating blade.

Sterilized mineral oil (or a thin layer of a light topical ointment) is applied over the donor area to facilitate smooth advancement of the dermatome. A sterile water-soluble lubricant also can be substituted for mineral oil, although the author prefers an oil-based lubricant.

Two towel clamps are placed ahead and two behind the path of the dermatome. Traction on the towel clamps by an assistant tightens the donor skin, facilitating the harvesting of the split-thickness graft. The blade is angled and pressed firmly onto the skin surface as the dermatome is engaged. The dermatome is advanced forward on its base. The graft is grasped with forceps as it emerges from the unit. The graft harvest can be terminated by angling the dermatome upward to cut the graft free of the donor site. The graft is kept moistened with sterile saline or lactated Ringer's solution during its application to the recipient bed.

COMMENTS

The Zimmer Dermatome is easy to use and cuts the skin of the dog remarkably well. It is superior to the Brown Dermatome. Graft knives are difficult to use in animals and have inconsistent results. Injection razors and safety razors can be modified to harvest small segments of skin, but the harvest is unrewarding for the larger wounds for which split-thickness grafts are most applicable. Long segments can be difficult to obtain from cats and small dogs. The relatively firm, flat surface of the epaxial muscles lateral to the dorsal spinous process and lateral thigh are among the best areas for harvesting long strips of skin. The skin is thicker over the back and more amenable to split-thickness skin graft harvesting. The lateral surface of the upper extremities also can be used. The flexible abdominal wall can be a difficult area from which to harvest skin with a dermatome. The ribs also limit the effective ability to harvest a graft from the lateral thorax despite injection of saline subcutaneously.

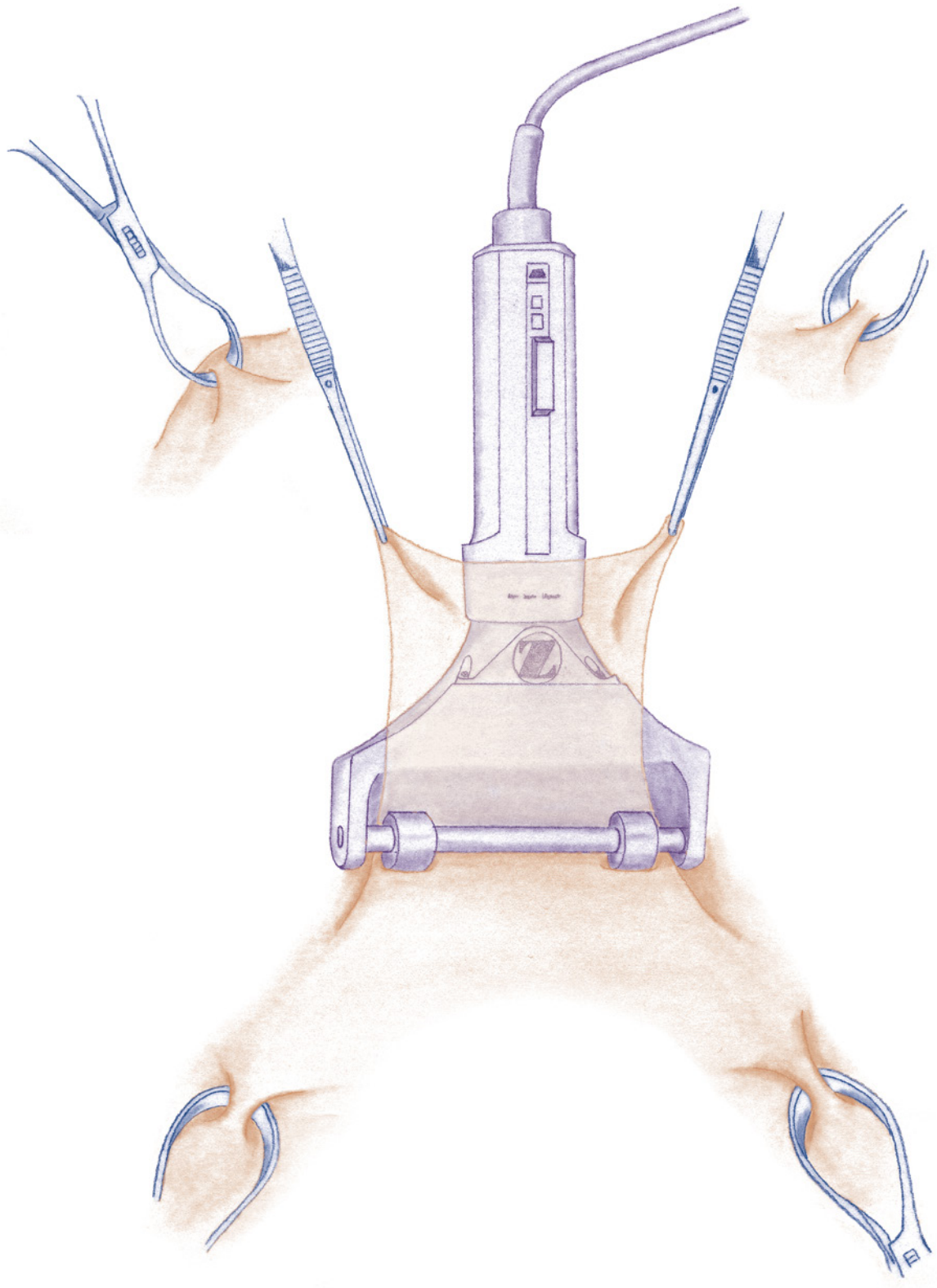
Thin split-thickness grafts have sparse hair growth and less durability than thicker grafts. Their primary clinical advantage in veterinary medicine resides in their ability to cover large wounds without sacrificing skin from the donor area. The partial-thickness defect created can reepithelialize within 3 weeks. It is possible to harvest additional thin split-thickness grafts from the same donor site on healing.

Full-thickness grafts, properly prepared and applied, have a survival rate comparable to split-thickness grafts, with the added advantage of durability and better hair growth. When a graft is required, smaller to moderate-sized defects usually are closed with full-thickness grafts; large defects can be closed with split-thickness grafts.

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Plate 82

Mesh Grafts (with Expansion Units)

DESCRIPTION

Harvested split-thickness grafts can be converted to a diamond on an "expandable steel" configuration using special mesh graft-expansion devices (Padgett Instruments). The uniform coverage provided by machine mesh grafts is ideally suited for large surface wounds, wounds with irregular surface contours, or in the presence of a low-grade infection for which postoperative drainage is critical to graft survival.

SURGICAL TECHNIQUE

(A) A split-thickness graft or appropriately prepared full-thickness graft is positioned on the mesh graft-expansion unit, dermal surface down. The Teflon rolling pin is rolled over the cutting bed with steady, firm, uniform pressure. The staggered cutting blades must completely cut through the entire thickness of the graft. Repeated application and roller compression are required to ensure the graft is completely cut; the blades must be kept sharp for optimal effectiveness.

(B) The graft is lifted off the expansion unit with forceps. Restrictive graft borders are cut off with scissors. The graft is applied over the wound bed, overlapping the wound borders when possible. Individual sutures or staples are used to secure the graft to the skin bordering the wound. Mesh grafts placed on the central regions of a large wound can be carefully secured to the granulation bed with a few sutures. Care is taken to limit bleeding during this maneuver. The graft is kept moist with sterile saline or lactated Ringer's solution during the entire procedure. The wound is covered with a sterile bandage.

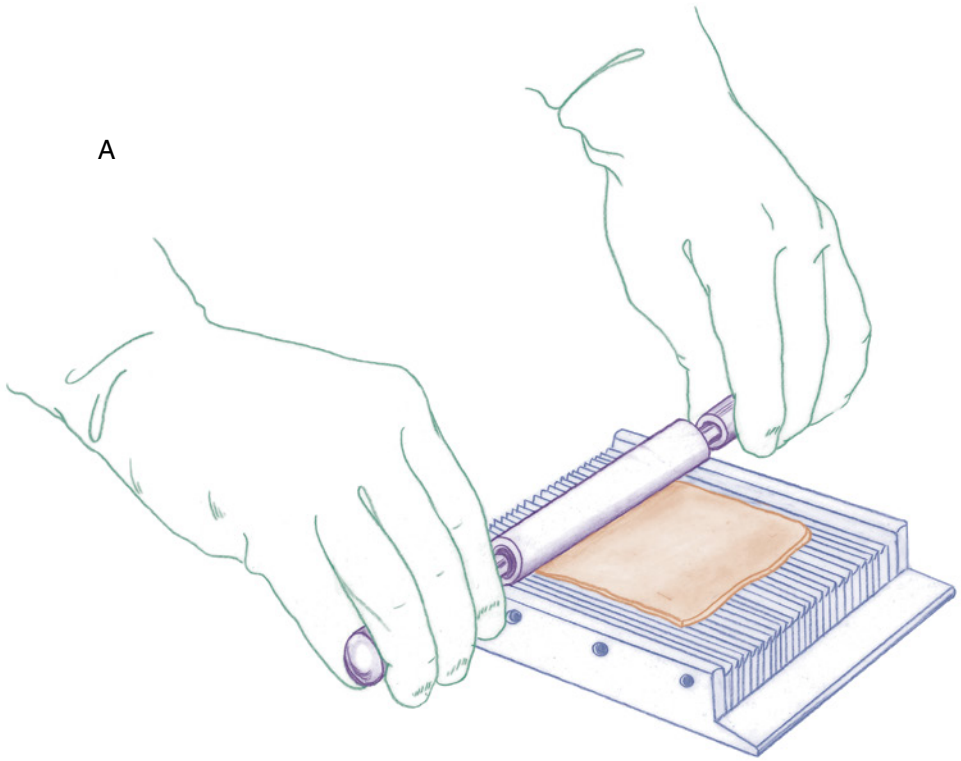
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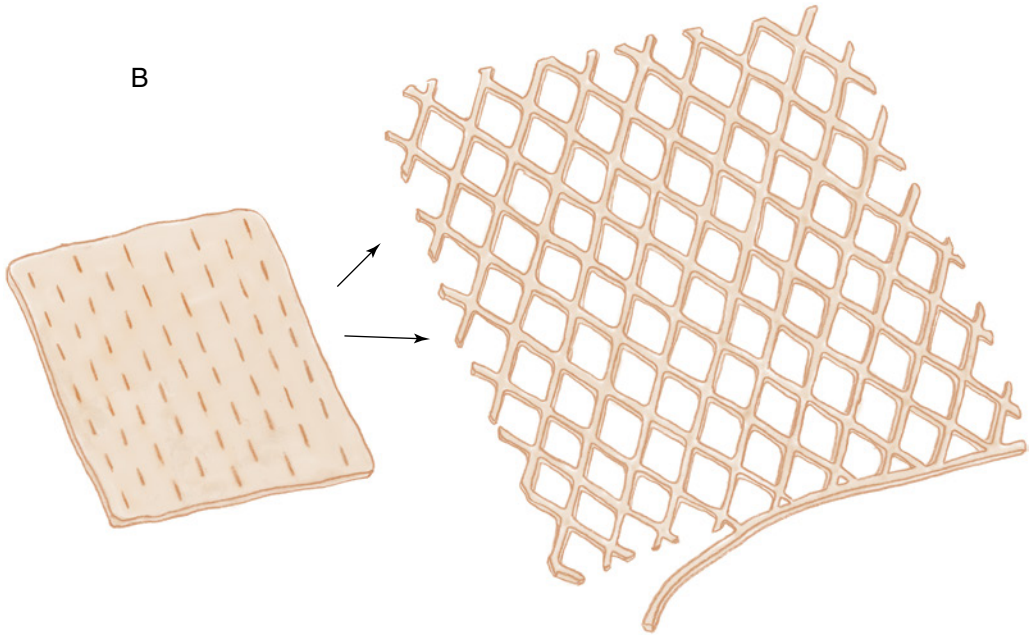
Graft expansion using mesh graft-expansion units provides a uniform means of increasing the surface area of skin grafts. (There are mesh graft-expansion units other than the unit illustrated.) Graft expansion is largely in the lateral direction in relation to the instrument. In small animal surgery, these grafts are primarily employed for large surface area defects with limited donor sites. For this reason, a dermatome is frequently employed to harvest split-thickness skin grafts, thus enabling the donor areas to reepithelialize without the complete loss of skin. However, full-thickness grafts can be meshed when the surgeon wishes to maximize graft coverage and provide optimum drainage. The malleable diamond or expandable steel design is ideally suited for wound beds with irregular surfaces and wounds with a low-grade infection for which optimal drainage can prevent pus or discharge accumulation beneath the graft. Although there are expansion units (Mesh Graft II Dermatome, Zimmer Biomet) that vary the mesh expansion ratio (3 : 1, 6 : 1, 9 : 1), the 3 : 1 ratio is selected as the most useful design for sufficient coverage to promote prompt epithelialization. Mesh grafts do not require maximum expansion unless optimum coverage is required. Because of the cost and infrequent need for a dermatome and mesh graft-expansion unit, most practitioners will not elect to purchase these surgical devices. Animals requiring expansion grafts are best referred to a local surgical referral practice or institution equipped with these specialized instruments.

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Plate 82





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Plate 83

Mesh Grafts (with Scalpel Blades)

DESCRIPTION

Multiple small (1 cm) incisions can be used to improve drainage beneath a graft and obtain limited expansion of its surface area for wider wound coverage. Hand meshing is generally used with full-thickness grafts.

SURGICAL TECHNIQUES

(A) See Plate 80, Sheet Grafts, for the technique of graft preparation. The prepared graft is laid on a firm, sterilized flat surface. The author uses the bottom of a stainless steel surgical tray. Sharp no. 15 scalpel blades are used to create small parallel incisions approximately 1 cm long and less than 2 cm apart over the length of the graft. Subsequent parallel rows of drain holes are alternately staggered in similar fashion, less than 2 cm apart. The graft is stretched between the thumb and index finger to facilitate this procedure.

(B) The graft is sutured into place. Suturing or stapling one side of the graft enables the surgeon to slightly stretch the graft with the appropriate tension as the opposite side is secured. This is repeated for the remaining sides and opposing corners. The author generally overlaps the graft borders slightly, as described in Plate 80. A bandage is applied to secure the graft.

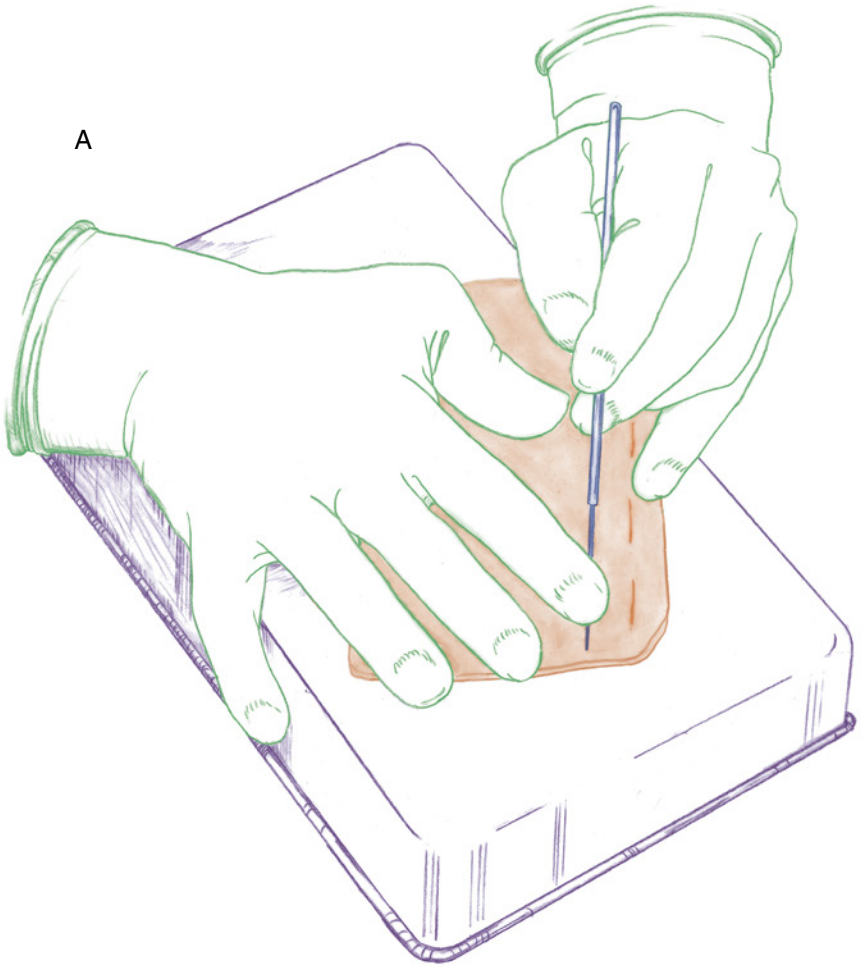
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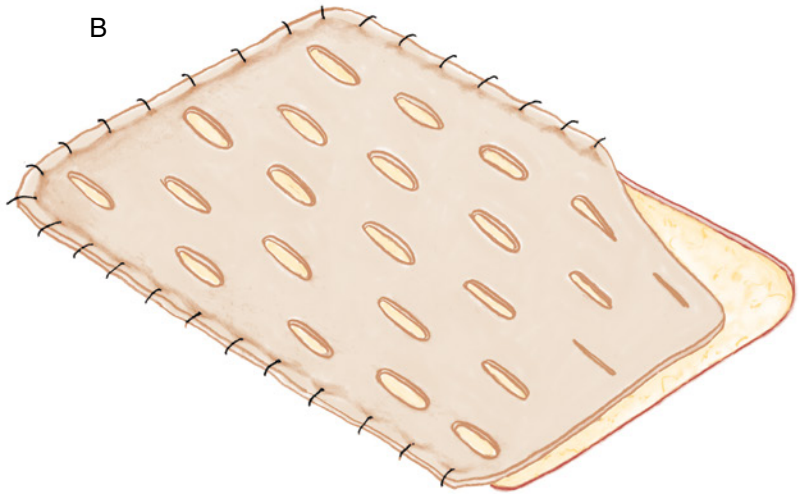
Hand mesh grafts expand in one direction, but are not as expansible as grafts that have been meshed mechanically. Hand meshing is primarily employed to maximize drainage. The graft is stretched slightly to enable the slit to gape open a few millimeters. With a successful "take," these holes contract and epithelialize rapidly, frequently within a week after application. The author prefers full-thickness mesh grafts over other free grafting techniques for moderate-sized defects involving lower extremities. As noted in Fig. 14-4, harvested grafts can be secured to autoclaved Vetrap to remove the subcutaneous fat. Stab incisions are easily performed by pushing the no. 15 scalpel blade through the graft and into the underlying Vetrap.

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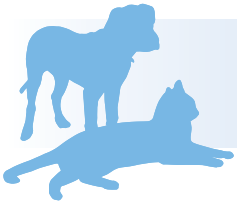
Plate 83





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15

Facial Reconstruction

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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INTRODUCTION: FACIAL RECONSTRUCTIVE SURGERY

There are a variety of defects of the lips, cheek, and planum nasale encountered in the dog and cat. Defects resulting from trauma, chronic inflammation/infection, wide tumor resection, and congenital disorders are particularly challenging to the veterinarian faced with restoration of function of the oral cavity and achieving satisfactory cosmetic results for the concerned owner. Lip fold pyoderma is a common condition in cocker spaniels and other breeds with large upper lips overlapping the lower lips (Fig. 15-1). Chronic skin fold pyoderma, unresponsive to medical management, is a candidate for surgical resection (Fig. 15-2). Avulsion wounds are one of the more common wounds encountered in cats and dogs secondary to bite wounds (Fig. 15-3), vehicular trauma, or falling from a height (Figs 15-4, 15-5, and 15-6). With major upper labial avulsion wounds that involve the external nose (Fig. 15-6), failure to properly realign each nasal meatus can result in stricture formation (Fig. 15-7).

Dogs are graced with large upper labial and buccal surfaces, which facilitate closure of moderate-sized defects. Cats, with their more refined facial conformation, lack the fullness and elasticity of the canine lips and cheeks. Although dogs generally present with a greater number of wounds and oral neoplasms of the lips and cheeks, the techniques discussed in this chapter are also applicable to the cat.

Selection of the most appropriate method of closure is based on the size and location of the defect, the donor tissues available for closure, and the inherent tissue elasticity unique to the species, breed, and individual patient. Skin defects of the face are generally closed with skin flaps (see Chapters 11 and 13). One novel closure noted in the literature used a pinnal flap to close an extensive facial burn in a dog (Swainson et al. 1998). The pinna as a composite flap has been used to close an adjacent defect (Price et al. 2021). Anatomic differences between breeds also can affect the method of closure. For example, the cocker spaniel's large lips and cheeks are more amenable to simpler closure techniques, whereas a collie's longer facial conformation may require a more elaborate restorative procedure.

Restoration of function is the primary goal of the veterinarian. Although our patients have no interest in the cosmetic outcome, most owners do have a variable degree of concern about their pets' appearance, especially as it pertains to the face. Most clients readily accept cosmetic imperfections when the potential outcome is discussed prior to surgery. Most cases involving wide tumor resection and single-stage reconstruction result in very acceptable cosmetic results, especially when the surgeon and client recognize the notable improvement in appearance compared to the injury or disease process being corrected (Fig. 15-8).

The large adjacent donor areas of skin and mucosa facilitate wound closure without resorting to the multistage reconstructive procedures used in human plastic surgery (Figs 15-9 and 15-10). Dense fur growth helps to cover scars and mask deficits. Unlike the flatter, completely exposed, hairless human face, the elongated muzzle of the dog and cat essentially divides the facial area into halves and makes any facial asymmetry less obvious to the human eye.



FIG. 15-1 (A) Lip fold pyoderma (labial fold intertrigo), secondary to chronic exposure of the lower labial skin to the overlapping upper labial tissues. (B) Elliptical excision of the inflamed segment. The tissue may be removed with a scalpel blade with electrocautery to control the multiple bleeders normally associated with removal of this chronic inflammatory tissue. A surgical laser also may be used. It is recommended that both intradermal sutures and skin sutures are used together; healing may be delayed based on the location of the surgical incisions.

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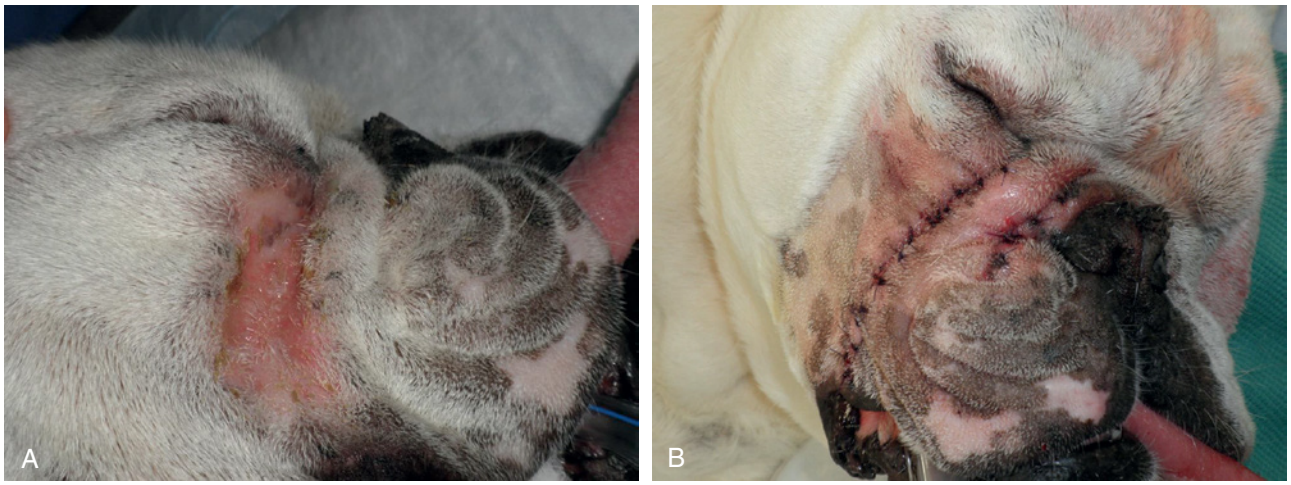


FIG. 15-2 (A) Chronic right facial fold pyoderma in an English bulldog. (B) Resection of the pyoderma tissues, including a smaller rostral depression. The left side of the dog's face was normal.

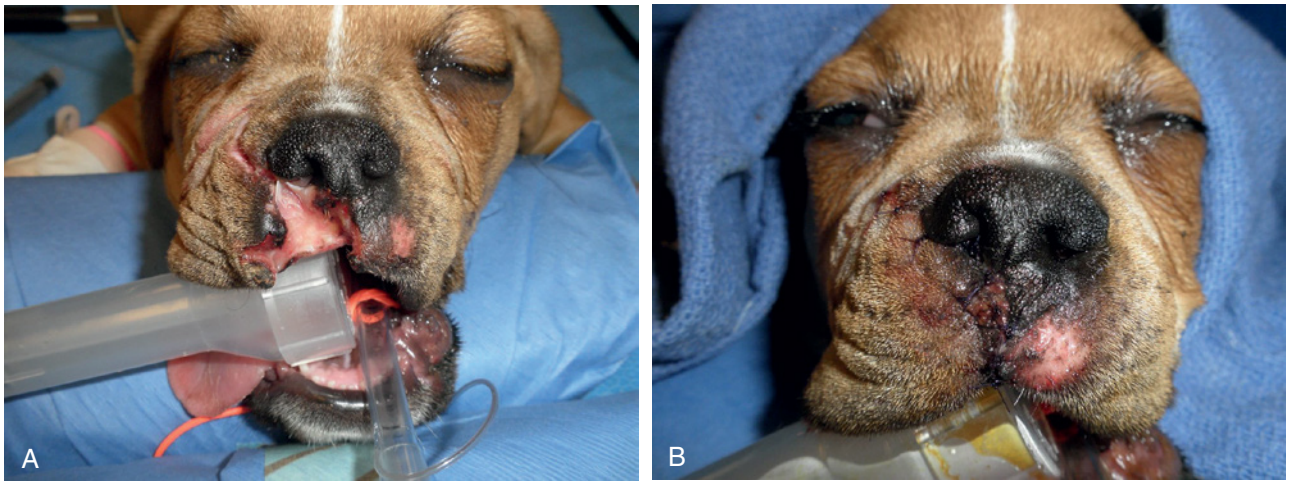


FIG. 15-3 (A) Bite wound avulsion of the rostral lip. The lacerated tissue was viable and required minimal debridement. The pigment nasal tissue served as a guideline for restoration of the nasal sulcus followed by the remaining lower labial border. (B) The wound was closed in three layers, using the opposite intact labial area as a guideline for tissue realignment.

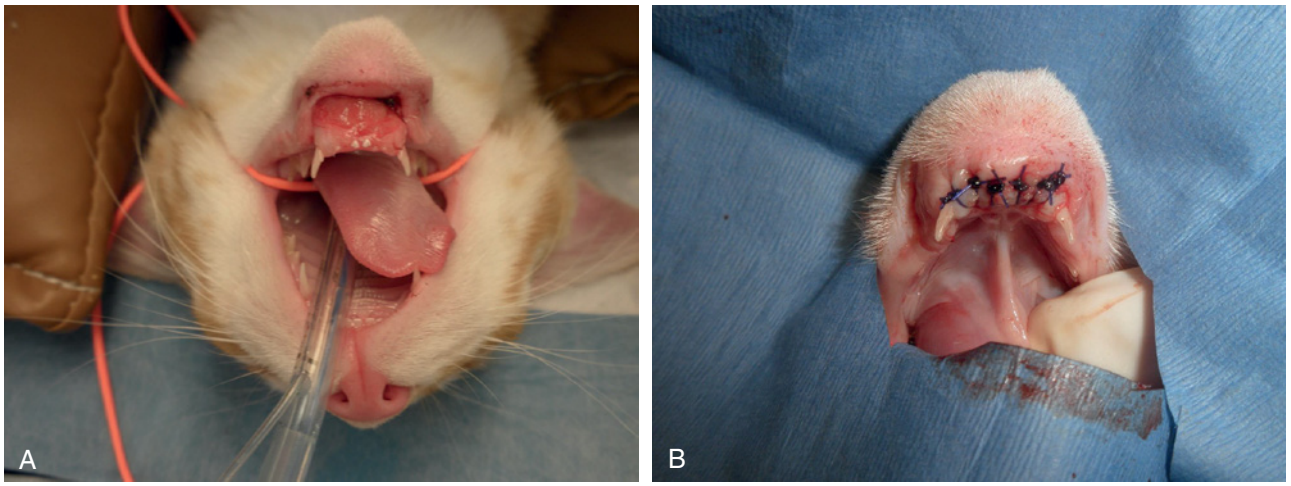


FIG. 15-4 (A) a 4-month-old cat with lower lip avulsion. The symphysis was intact. (B) Closure using sutures inserted deep to the level of the periosteum to gain purchase during closure.

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FIG. 15-5 (A) Lower labial avulsion in a stray cat. This wound is several days old. The cat also had lacerations and a partial avulsion of the tongue. (B) Close-up view. Debridement and lavage were needed to prepare this wound for closure. (C) A 22-gauge wire is suitable for realigning and stabilizing a separated mandibular symphysis. The author prefers to twist the wire ventrally, to avoid lingual laceration. Three to four wire twists are used to stabilize the wire; removal is easily performed under sedation. (D) Completion of the closure (see Plate 85). (Source: Pavletic MM. 1990. Reconstructive surgery of the lips and cheek. *Vet Clin North Am* 20:201–226. Reproduced with permission of Elsevier.)

Anatomic Considerations

A basic understanding of the anatomy of the lips and oral cavity is essential to understanding the techniques discussed in this chapter. The lips (labia oris) form the anterior and most of the lateral boundaries of the vestibule. The upper and lower lips (labia maxillaria et mandibularia) join caudally at acute angles, forming the commissures of the lips (commissurae labiorum). A deep, straight cleft, the philtrum, marks the union of the halves of the upper lips rostrally. The mucosal surface of the upper lip has a larger surface area compared with the lower lip, which tapers in width anteriorly. The lower lip has a firm attachment to the gum between the lower canine and first premolar (interdental space). This interdental attachment maintains the position of the lower lip and prevents it from sagging. When lower labial reconstruction surgery is undertaken, this tissue attachment must be substituted with appropriately placed sutures.

The lips and cheeks have two epithelial surfaces: the outer skin and the inner mucosa. Between these two surfaces are two thin muscles, the outer orbicularis oris and the inner buccinator. Other facial muscles insert at this level, including the levator nasolabialis, caninus, levator labii maxillaris, platysma, zygomaticus, and sphincter colli profundus-pars palpebralis. The cheeks (buccae), which form the lateral walls of the vestibular cavity, are morphologically similar to the lips with which they are continuous.

A rich arterial and venous network supplies the skin, mucosa, and fibroelastic tissue of the lips and cheeks. The facial artery divides to form the superior labial artery, inferior labial artery, and angularis oris artery. The infraorbital artery contributes circulation to the upper lip

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FIG. 15-6 (A) Upper labial avulsion. (B) Closure is comparatively easy: gravity helps maintain tissue alignment, whereas gravity has a tendency to pull lower labial avulsion closures apart (see Plate 84). (C) Massive avulsion of the upper labial and nasal tissues. (D) The incisive foramina (arrows) can be used to loop two absorbable sutures through the palate and into the septal tissues to stabilize the nasal area. These stabilizing sutures are tied in the oral cavity. The mucosal laceration is then closed, completing the procedure (see Plate 84).



FIG. 15-7 (A, B) Older patient with a history of facial trauma in the past. The attending doctor was confused about this labial anomaly. This dog sustained an upper labial and nasal avulsion injury that remained untreated. Scarring obstructed the nostrils; the small opening became the new stoma for nasal breathing. The external nose, lacking any soft tissue support, could be flexed excessively in a dorsal and lateral direction.

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FIG. 15-8 Resection of a labial neoplasm. The surgeon elected to close the wound by apposing the adjacent muzzle skin to the remaining mucosa. Cosmetic results are poor; patient function was adequate, although leakage of oral contents occasionally was noted. A buccal rotational flap (Plate 90) could have resulted in improved cosmetic results and reduced the loss of oral contents from the labial defect.

and cheek. The posterior, middle, and anterior mental arteries supplement circulation to the anterior aspect of the lower lip. Because of this tremendous collateral circulation, the larger flaps developed for labial and buccal defects have a high probability of survival when care is taken to incorporate one or two branches of these vessels into the flap base.

The parotid duct opens into the buccal cavity opposite the caudal margin of the fourth upper premolar or shearing tooth. On occasion, it is necessary to excise this area during tumor removal. Although the duct may be ligated, it can easily be preserved by relocating the duct through a small mucosal incision, spatulating its end and securing it to its new position with 4-0 or 5-0 absorbable sutures, using a simple interrupted pattern. In cases of severe upper labial/nasal avulsion, sutures are used to reattach soft tissues and ensure the nasal passages are properly realigned. Upward septal and vomer avulsion will result in significant lateral instability of the nasal region. The paired palatine fissures can be useful in stabilizing the avulsed septum and vomer by serving as a natural

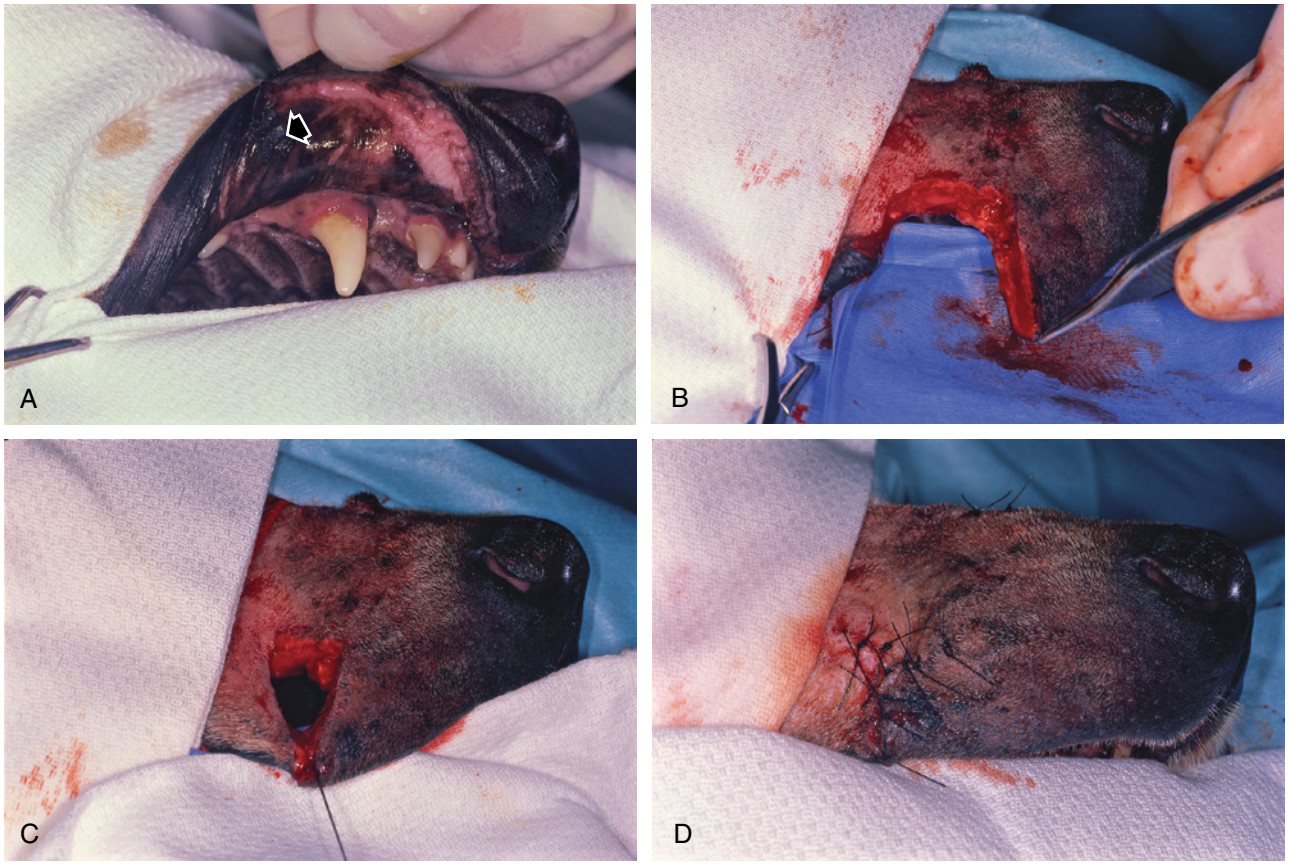


FIG. 15-9 (A) Upper labial melanoma (arrow). (B) Full-thickness rectangular resection (see Plate 87). (C) Initial apposition of the labial border. (D) Closure of the mucosa was followed by skin closure.

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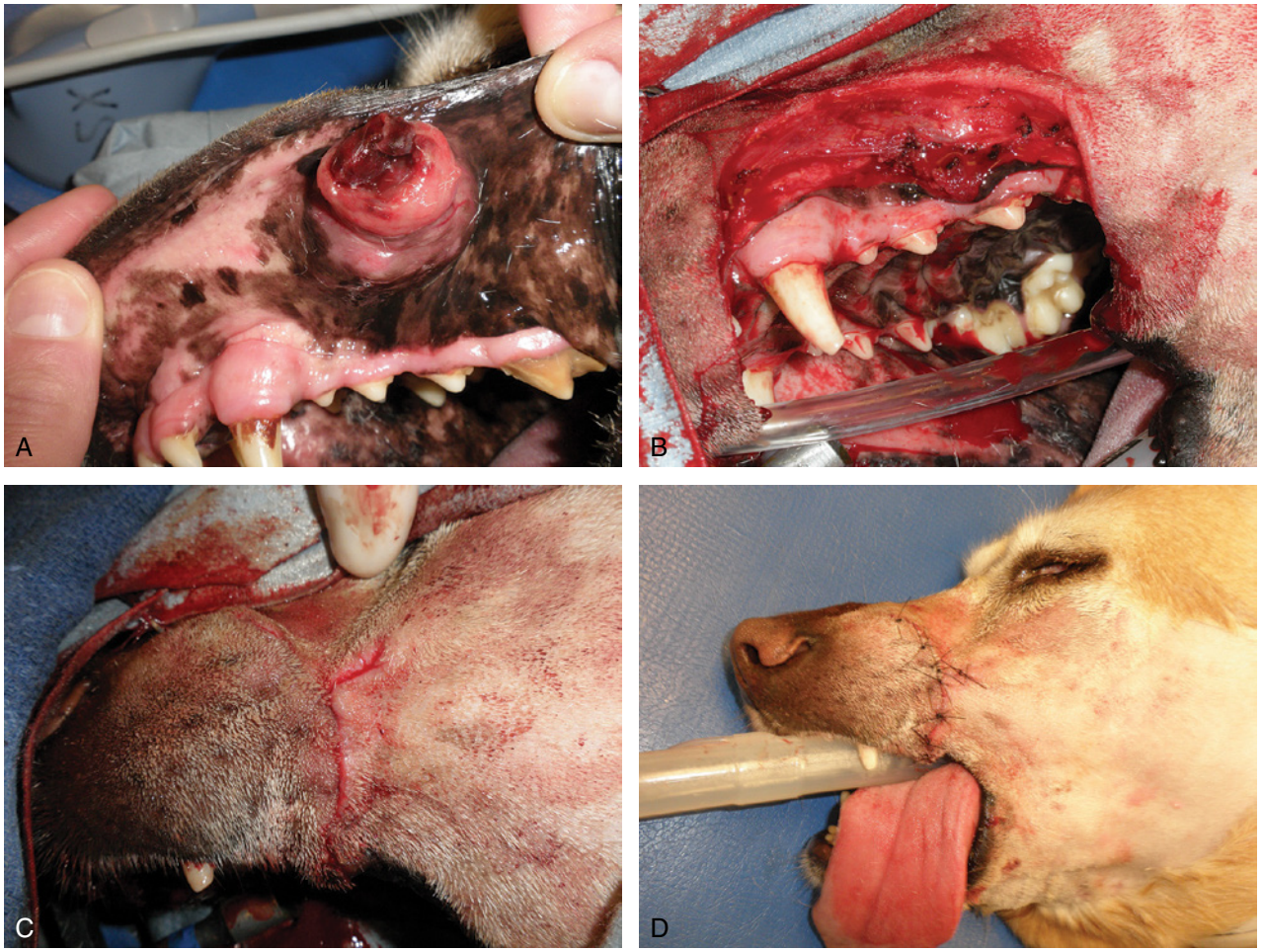


FIG. 15-10 (A) Labial carcinoma involving the left upper lip. (B) Wide resection (>2 cm margins) of this neoplasm. (C) Apposition of the rostral and caudal labial margins after closure of the mucosal margins with absorbable interrupted sutures. (D) In this patient, the skin incision closed in a linear fashion (see Plate 87).

opening to insert stabilizing sutures. Two suture loops can be preplaced from the oral side of one fissure, into the septum/vomer, and back out of the opposing foramen. The absorbable sutures can be tied within the oral cavity to improve stability. This is followed by suture apposition of the mucosal tear (Fig. 15-6).

Veterinarians should note that skin flaps can be used as substitutes for large oral mucosal defects. The ample loose skin in the facial/cervical area permits the development of advancement and transposition flaps, discussed in Chapter 11 (Figs 15-11 and 15-12).

Use of skin for replacement of oral mucosa is reserved for the largest defects in which other reconstructive techniques in this chapter are not viable options.

Labial Closure Options

As noted, small to moderate defects of the upper or lower lip often can be closed by simple apposition techniques (Plates 86 and 87). Larger labial defects can be closed by labial advancement (Figs 15-13 and 15-14) or rotation of the oral commissure and buccal mucosa (Fig. 15-15). The rostral upper lip may be reconstructed by single or bilateral labial advancement flaps (Fig. 15-16), a single labial pivot flap (Figs 15-17 and 15-18), or bilateral labial pivot flaps (Fig. 15-19).

The dorsal–ventral width of the upper and lower lip (to a lesser degree) does allow for resection of the dorsal (upper portion) of the upper lip and the ventral (lower) portion of the lower lip without necessarily sacrificing the entire segment. The labial lift-up (Plate 91) and labial

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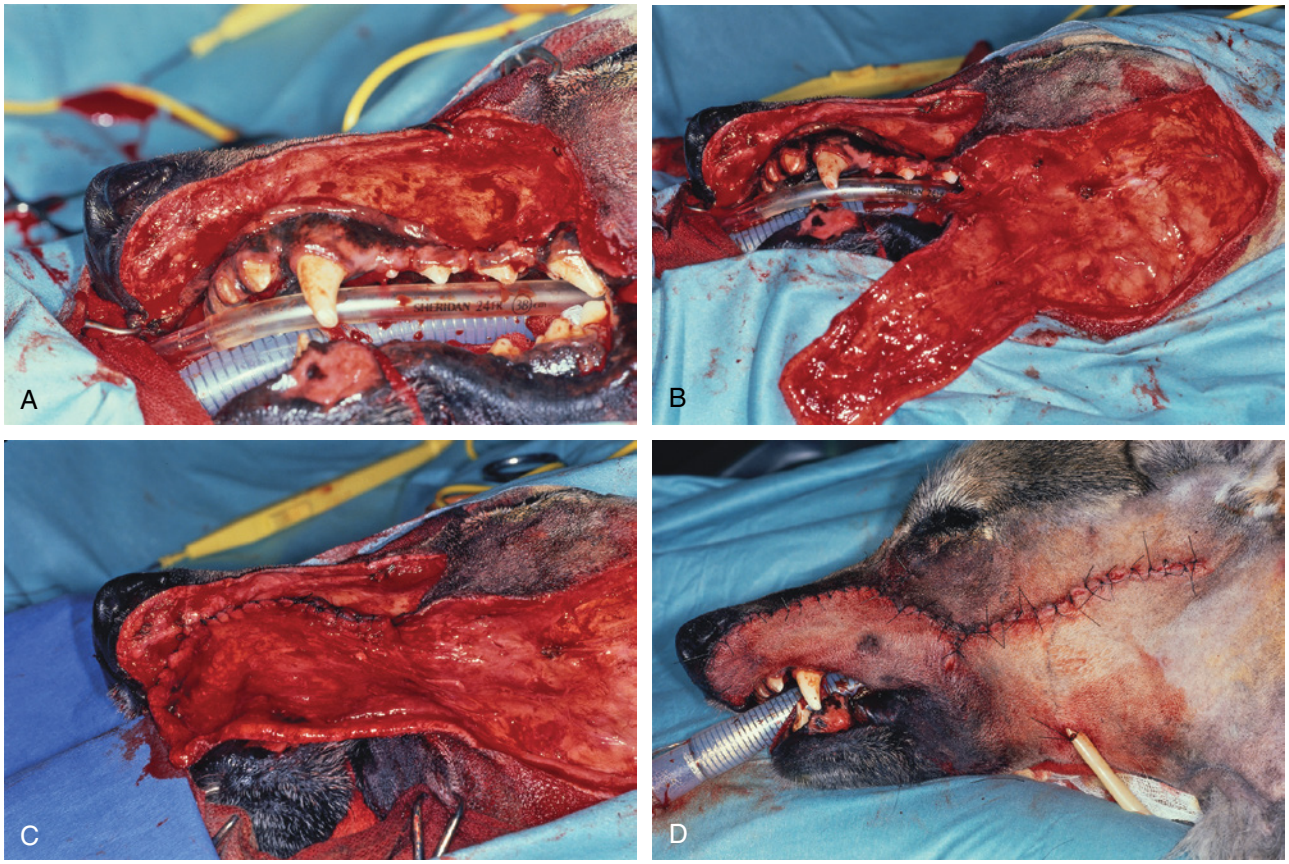


FIG. 15-11 (A) Reconstruction of the upper lip after removal of a soft tissue sarcoma. (B) Elevation of a skin flap, with the flap base aligned with the viable oral commissure. Flap length is measured from the base of the flap to the remaining rostral labial border. Flap width equals the combined width of the labial mucosa and outer cutaneous defect. (C) The dorsal border of the flap is sutured to the mucosal defect. The skin flap is then folded lengthwise, with the lower flap border sutured to the upper limits of the cutaneous defect. (D) Immediate postoperative view. Postoperative swelling and gravitational pull improved subsequent coverage of the partially exposed left upper canine (see Plate 94).

pull-down (Plate 92) techniques are useful for resection of diseased tissue with more limited labial involvement (Figs 15-20 and 15-21). Provided that the goal of complete surgical margins is achieved, the integrity of the remaining labial margin simplifies the closure with satisfactory cosmetic results.

Miscellaneous Labial and Facial Procedures

Labial Avulsion

As noted, labial avulsion cases in dogs and cats can be the result of vehicular trauma, bite wounds, or a fall from an elevated position (Figs 15-4, 15-5, and 15-6). In one study (Saverino and Reiter 2018), dog bites were the primary cause of lip avulsion in dogs whereas vehicular trauma was more common in the cat. Upper labial avulsion was more common in dogs; lower labial avulsion was more common in cats. Closure is normally accomplished by suture approximation along the margin of the avulsion. Dehiscence was a common short-term complication (Plates 84 and 85).

Cleft Lip (Cheiloschisis, "Harelip")

Cleft lip is a congenital defect that may be the result of either a recessive or an irregular dominant trait. It can be unilateral or bilateral (Fig. 15-22). Hormonal, nutritional, and mechanical factors also may play a role in its formation. Cleft lip is reported to be more common in

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FIG. 15-12 (A, B) Wide resection of squamous cell carcinoma involving the upper lip, cheek, adjacent dental arcade, and maxilla of a dachshund. (C, D) Closure of the mucosal defect was accomplished with oral commissure reformation, followed by inverse tube flap closure of the mucosal defect. The dorsal border of the flap was sutured to the hard palate; the ventral border was sutured to the gingival border of the mandible. Skin was advanced over the area to complete the closure. (E, F) Labial and frontal view of the dachshund at suture removal. Functional and cosmetic results were excellent. The skin flap replaced the massive mucosal defect. (This elaborate reconstructive surgical technique is discussed in Plate 93.)

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FIG. 15-13 (A) Stray golden retriever with a rostral labial defect. The owner reported that food and water would run out of the labial defect. (B) Elevation of the labial advancement flap. (C) Forward advancement with a skin hook. (D) Suture closure of the mucosal, musculofascial, and cutaneous layers. (E) Note the small area of dehiscence at the time of suture removal, secondary to the dog rubbing his nose; a longer Elizabethan collar would have been advisable (Source: Pavletic MM. 1990. Reconstructive surgery of the lips and cheek. *Vet Clin North Am* 20:201–226. Reproduced with permission of Elsevier.) (See Plate 88.)

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FIG. 15-14 (A) Mycobacterial granuloma. (B) Resection and closure with a labial advancement flap. (C) Postoperative tension deviates the rostral lip to the right side. The more limited tissues available make this technique more challenging in the cat. (D) One month later, the tension has relaxed (by mechanical creep and stress relaxation of the skin, fascia, and mucosa) and the facial area has assumed a more normal position (see Plate 88).

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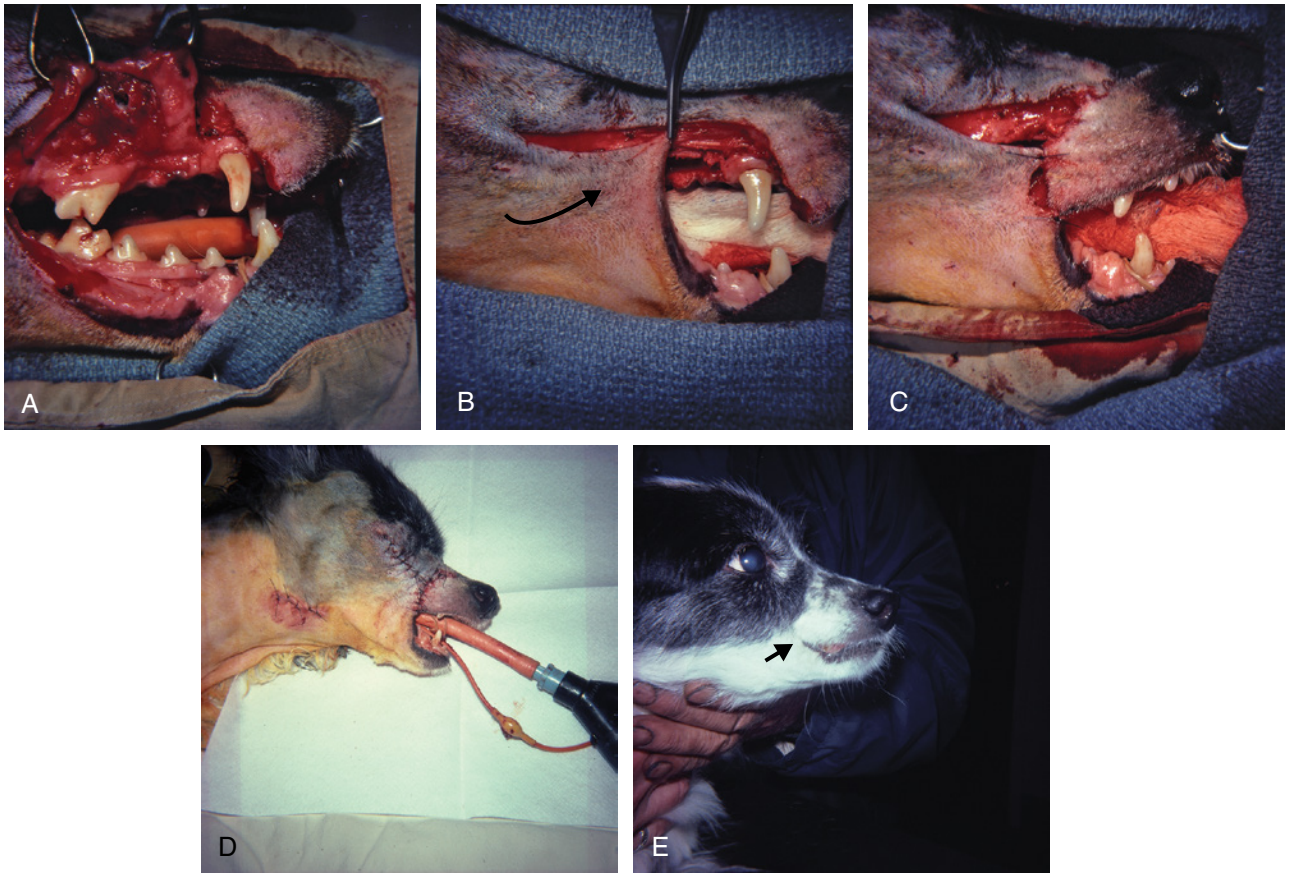


FIG. 15-15 (A) Wide labial excision of a diffuse squamous cell carcinoma, involving the upper lip and adjacent gingiva. To ensure complete removal, the involved dental arcade and adjacent hard palate were excised with the involved labial tissue. (B, C) With two-thirds of the upper lip resected, the cheek is rotated rostrally (arrow). A portion of the labial border is resected for apposition to the remaining rostral labial segment. The mucosal border of the rotated check is sutured to the palatal border and rostral mucosa of the rostral lip segment. This is followed by closure of the middle fascial layer and then by skin sutures. The jaw was manipulated intraoperatively to ensure that a reasonable range of motion was preserved during closure. (D) Completion of closure. Lymph node biopsy was negative for metastatic disease. (E) The patient had no recurrence 1 year after follow-up. Note the new oral commissure is advanced forward using this technique (arrow) (see Plate 90).

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FIG. 15-16 (A) Diffuse mast cell tumor, rostral labial area. (B) Wide resection of the rostral lip, using a carbon dioxide laser. (C) Closure by simple bilateral advancement of the left and right lip segments, beginning with apposition of the mucosal surfaces. (D) Closure of the skin margins, completing the closure (see Plate 88).

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FIG. 15-17 (A) Labial mast cell tumor (grade II) resection. (B) Excision with a carbon dioxide laser. (C) Demonstration of one option, labial pivot flap (see Plate 97). This technique requires partial resection of the labial border. (D, E) This small pivot flap was better suited to closure of the surgical defect, still maintaining symmetry with the opposing half of the rostral labial area. This patient underwent subsequent radiation therapy.

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FIG. 15-18 (A) Mast cell tumor involving the rostral right half of the upper lip. (B) Aggressive resection of mast cell tumor with a carbon dioxide laser. (C) Right labial pivot flap, rotated into the surgical defect. Absorbable sutures are used to appose the mucosal borders. (D) The labial border is resected to match the left cutaneous labial margin. (E) Completion of the closure. (F) The patient at 3 weeks. Right labial tension causes slight shifting of the rostral lip. Over the next few weeks, tissue planes relaxed by mechanical creep and stress relaxation. (G) Angular view of the reconstructed area with reasonable cosmetic results (see Plate 97).

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FIG. 15-19 (A) Diffuse mast cell tumor involving the rostral lip and lower nasal area dorsal to the premaxilla. (B) Carbon dioxide laser division of the lateral labial margins. (C) Laser division of soft tissues associated with the premaxilla. (D) Complete resection of the mast cell tumor. (E) Bilateral pivot flap closure: the labial mucosa is secured to the gingiva. (F) The labial margins are divided by 2 cm, separating the mucosa and cutaneous margins for separate suture apposition. (G) The labial mucosal borders are secured with interrupted 3-0 absorbable sutures, followed by closure of the cutaneous surfaces completing the reconstruction of the rostral lip. In this patient, the bilateral pivot flaps recreate a natural symmetrical curvature of the rostral lip and philtrum. In some patients, preserving the pigmented labial margins, with their incorporation into the skin closure, can provide a central pigmented strip to help replicate the resected philtrum. (H) Placement of the resected labial tumor adjacent to the reconstructed lip for comparison (see Plate 98).

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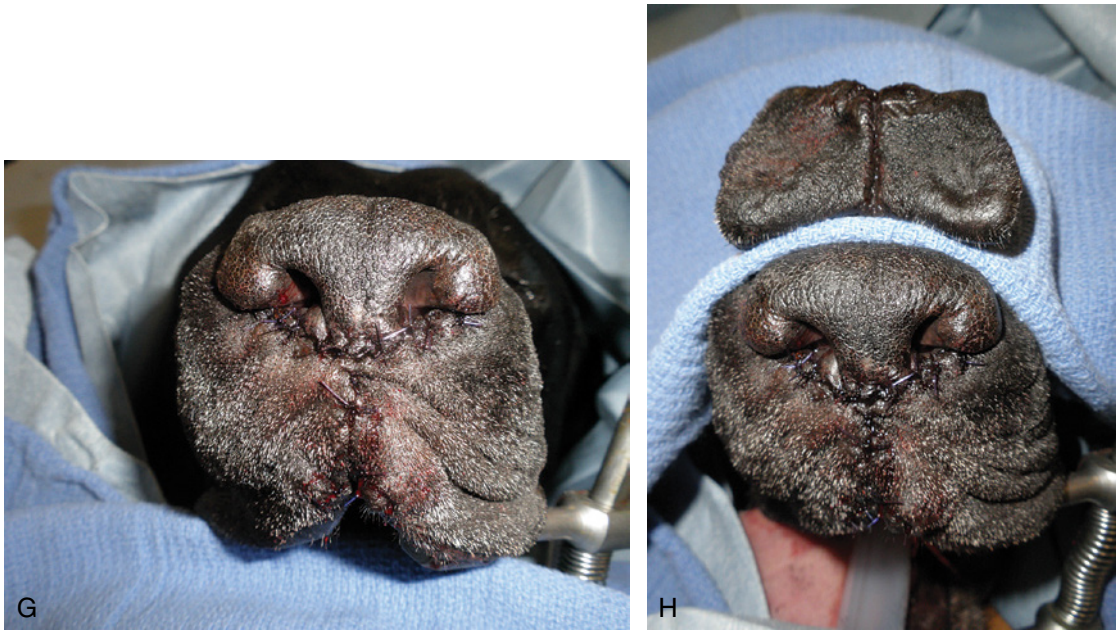


FIG. 15-19 (Continued)

brachycephalic dogs, although the author has seen it in a number of breeds. It is less commonly seen in cats (Fig. 15-23). Cleft lip (primary palate) also may be seen in conjunction with cleft palate (secondary palate) (see Chapter 17). Cleft lip usually is unilateral; bilateral cleft lip is less common. Unilateral cleft lip repair is facilitated by using the opposite half of the nose as a visual guideline for tissue realignment (Fig. 15-24).

Textbooks vary on the ideal time to consider repair. Because cleft lip patients can eat and drink without difficulty, the author prefers to wait until the patient is 5–6 months of age (Figs 15-25 and 15-26). At this age, tissues are better developed and sutures are less likely to "cut out." Owners should be made aware of the fact that most dogs will have a slight deviation of the external nose toward the side of the cleft lip. The upper lip on the affected side may be somewhat underdeveloped when compared to the opposite side. These cosmetic imperfections are less noticeable compared to the presenting labial defect; with successful closure, owners are generally quite pleased with the overall surgical result (Plate 96).

The author does not routinely perform this procedure with every mandibulectomy performed. It may be more useful in large-breed dogs that have greater lingual length and mass. Oral commissure advancement can be performed at a later date for those dogs with persistent overexposure.

Oral Commissure Advancement (Commissurorraphy)

Loss of a significant portion of the mandible, secondary to tumor resection or trauma, can result in loss of lateral lingual support, causing a tendency for the patient's tongue to slip or loll to the side (Fig. 15-27). The tongue slides to the corner of the mouth, displacing the buccal area caudally. Dogs usually adapt to this problem by learning to retract and lift their tongue to a variable degree. In some patients, prolonged exposure of the tongue can dry its epithelial surface, necessitating periodic application of water. Drooling and the spillage of water and food during mastication also may be noted after hemimandibulectomy. It is best to discuss these potential complications with the owner prior to surgery.

The angles of the mouth (angularis oris) where the upper and lower lips join are called the oral commissures. Resection of the labial border of the oral commissure and a variable portion of the upper and lower labial borders will allow the surgeon to suture the incised mucosal and cutaneous surfaces together. This creates a forward extension of the cheek as the oral commissure is advanced rostrally. In essence, a "sling effect" is created to support the tongue within the mouth. The length required to support the tongue is estimated at the time of surgery, which may be one-half to two-thirds the length of the lower labial border (Plate 99).

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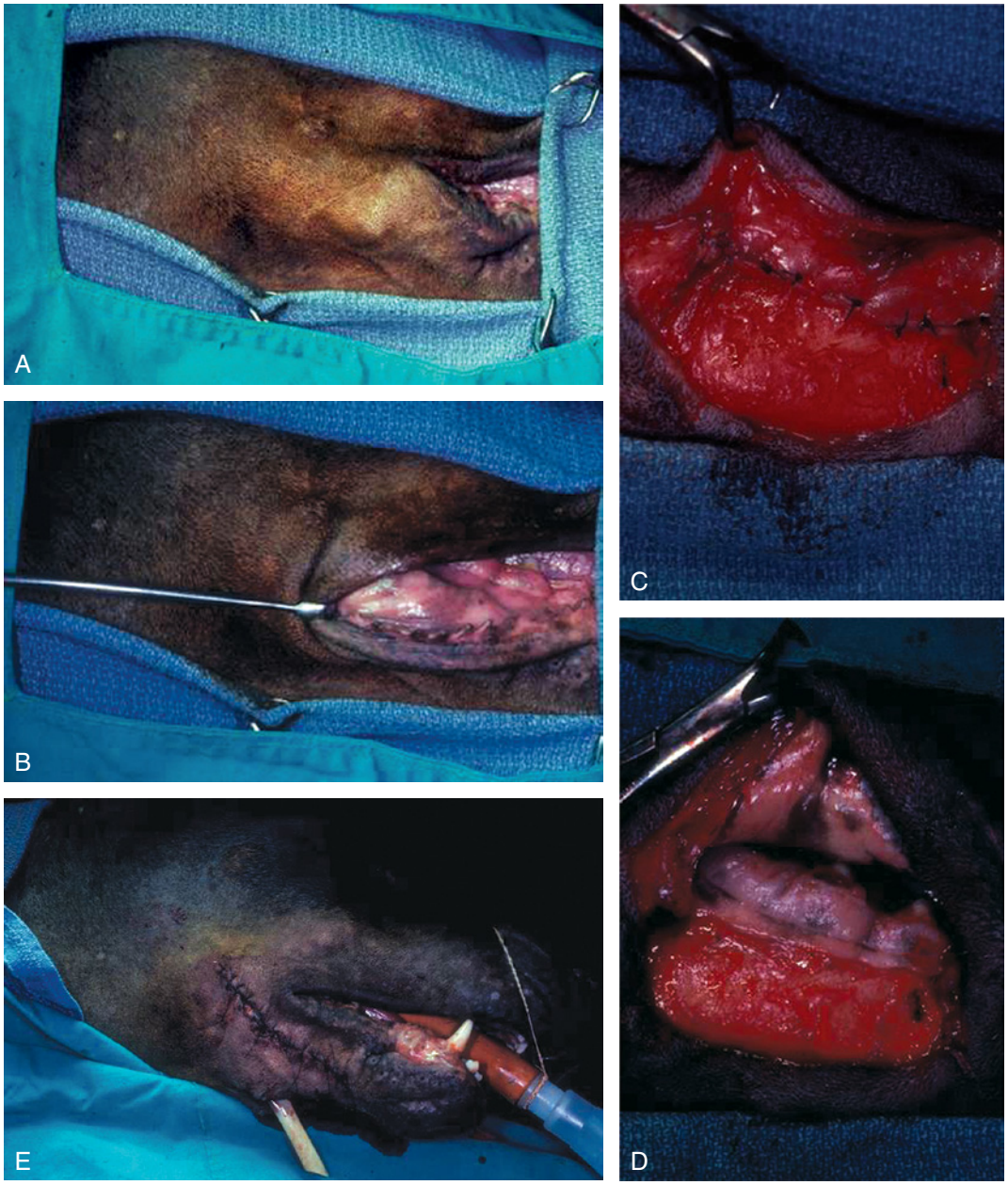


FIG. 15-20 (A, B) Older Dobermann with an expansile granuloma involving the right lower lip. A spay hook is used to retract the oral commissure, exposing the granuloma beneath the labial mucosa. (C, D) A full-thickness labial incision is used to elevate the upper half of the lower lip, allowing for complete resection of the foreign-body granuloma. Closure of mucosa by suturing the labial border to the thin mucosal band preserved along the gingival border. (E) Completion of the skin closure. The labial pull-down technique preserves its function with a reasonably normal cosmetic result (see Plate 91).

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FIG. 15-21 (A) Mast cell tumor involving the left facial area and dorsal portion of the upper lip. (B) Wide, deep resection of the mast cell tumor, including the upper portion of the lip. The lower half of the lip is a bipedicle compound labial flap. Note how labial "pull down" gives access to the maxilla and lateral nasal cavity. (C) The labial mucosa is sutured to the gingiva with absorbable sutures. (D) A 90° transposition flap was required to close a portion of the surgical defect. (E) The patient 3 weeks later. The labial pull-down technique can be combined with partial maxillectomy for more aggressive tumors in this area (Plate 92).

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Premaxilla (Incisive Bone) Loss/Resection

Traumatic loss of the premaxilla or incisive bone can be the result of trauma in conjunction with loss of the external nose and rostral labial area (Fig. 15-28). Resection of this bone is commonly performed in removal of neoplasms confined to this area. Although uncommon, loss of the rostral labial tissue and external nose can be seen secondary to trauma or a disease process. In these cases, resection of the premaxilla may be required to facilitate reconstruction of the labial defect. Following removal, bilateral full-thickness labial advancement flaps are better able to more effectively span the remaining rostral facial defect (Fig. 15-29).



FIG. 15-22 Bilateral cleft lip in a newborn puppy. A complete physical examination is required to check the patient for other congenital anomalies.

Brachycephalic Facial Fold Surgery

Facial fold surgery in brachycephalic dogs has been advocated for two reasons: (1) fur overlying the ridge (top) of a large skin fold that causes ventromedial corneal irritation/ulceration (keratitis) and (2) chronic face fold pyoderma (chronic intertriginous infection) involving the crease or trough of a skin fold. One or two skin folds may be noted overlying the muzzle of a given brachycephalic patient. Face folds may uniformly span the width of the face or partially dissipate at the mid-muzzle area.

There are veterinary articles describing complete removal of the facial fold for these two conditions. Unfortunately, this can negatively alter the normal appearance of the patient. Partial resection of the face fold can correct these two face fold problems while still maintaining the classic facial features of the patient. In chronic pyodermas, the skin surface underlying the crease or trough also requires removal to alleviate this problem (see Plate 100). This technique variation of the author preserves the face fold ("rope") and eliminates this area of intertrigo (Figs 15-30 and 15-31).

Nasocutaneous Fistulas

Loss of the nasal bone and the overlying skin can be seen secondary to trauma, infection, radiation therapy, or tumor resection. It must be kept in mind that skin overlying small nasal bone defects has its dermis exposed to the nasal cavity. In smaller defects, the nasal mucosa is

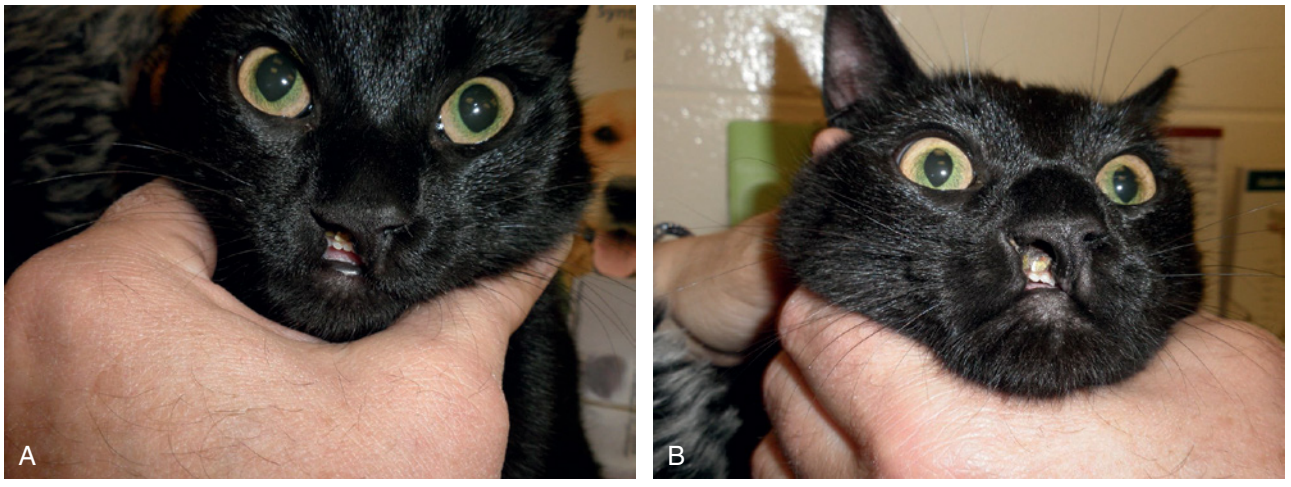


FIG. 15-23 (A) Cleft lip in a cat, frontal view. (B) Upper angular view demonstrating the magnitude of the defect. Cleft lip is far less common in cats compared to dogs.

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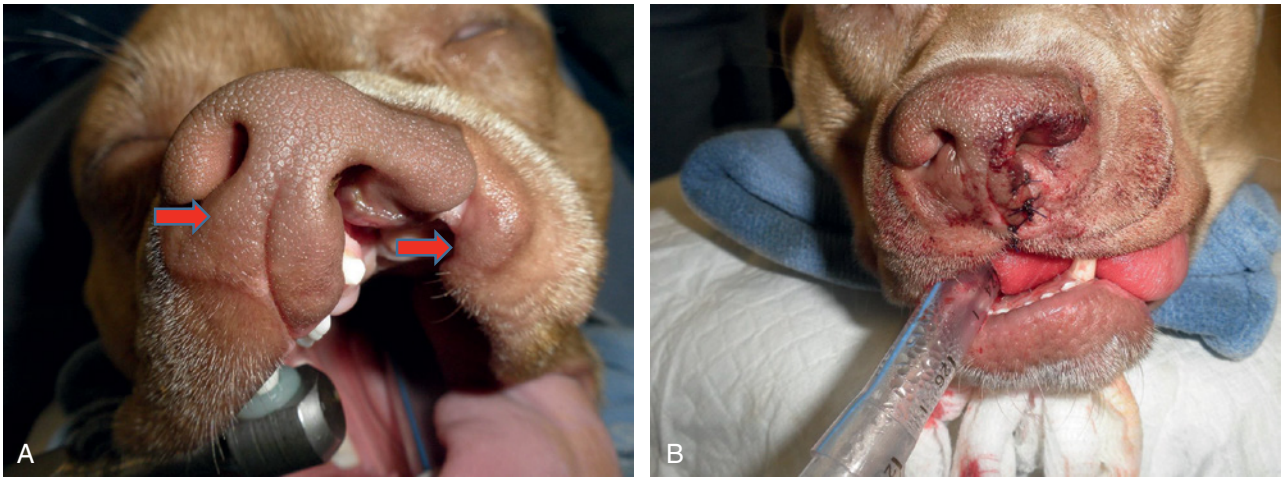


FIG. 15-24 (A) Cleft lip in a mature retriever. Note that the pigmented sulcus of the right intact nostril serves as a guideline for approximation of the opposing side (arrows). (B) Completion of the closure. Only simple alignment and apposition are required.

capable of migrating over the adjacent dermal surface. Reepithelialization of the dermis is important in the protection of the skin overlying the bone defect. Failure in this process results in chronic exposure of this dermal surface to the contaminants of the nasal cavity. Chronic inflammation and bacterial proliferation can result in cutaneous necrosis, creating a nasocutaneous fistula.

Subsequent attempts at closing the fistula with skin alone result in the eventual loss of the skin. The author developed the use of full-thickness flaps of the upper lip to close nasocutaneous fistulas (Plate 101). The labial mucosa becomes the protective barrier to the overlying musculofascial layer and skin, essential in resolving the fistula (Figs 15-32, 15-33 and 15-34).

Full-Thickness Lower Labial Flap

Although rarely needed from the author's experience, the lower lip can be elevated as a full-thickness labial flap. The basic blood supply is similar to the upper lip. The thickness of the lower lip tapers rostrally. The caudal half of the lower lip is wide enough to be used as flap to reconstruct a problematic defect involving the caudal area of the upper lip (Plate 102).

Cheilopexy for Drooling

In certain breeds (St. Bernards, Great Pyrenees, etc.) the overabundance of everted lower lip, rostral to the oral commissures, can impair normal retention of saliva (Fig. 15-35). Excessive drooling may result in moist dermatitis of the lower labial skin. When the dog shakes its head, many owners find long strands of saliva being distributed over their furniture and house guests to be rather distasteful.

Cheilopexy is a surgical technique designed to lift and support the lower labial border by surgically attaching a portion of the everted lower lip to the mucosa of the upper lip. This technique is reportedly effective in reducing excessive drool. In patients with nonunion mandibular fractures, cheilopexy can create a supportive sling to the affected side (see Plate 103).

> Cheilopexy is not a commonly performed procedure in veterinary practice. Most owners familiar with these breeds simply accept drooling as a part of pet ownership. Owners also may be unaware of cheilopexy as an option to control this problem.

Plate Contents

Each plate is specific in the use of a particular technique for closure/correction of a given area of the face. When considering closure of rostral defects of the upper lip, the reader should review the plates specific to closure of surgical wounds in this area: there are several options to restore function.

See Chapter 25 for additional clinical flap examples.

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FIG. 15-25 (A) Cleft lip in a 6-month-old Bernese mountain dog. The author normally recommends repairing cleft lips around 5–6 months of age because the tissues are better able to retain sutures without tearing. (B) Close-up view. (C) Intraoperative view of the defect. (D) Preplacement of sutures after creating the required surgical incisions to close the oronasal defect. (E) Completion of the closure (see Plate 96). (F) View of the patient at suture removal. Note that the nose tends to tilt toward the side of the original defect in cleft lip patients. This is due to loss of normal tissue support. As in this case, you may also note the upper lip on the involved side is somewhat shorter dorsoventrally when compared to the opposite side.

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FIG. 15-26 (A) Unilateral cleft lip in an orange tabby. This opening frequently became impacted with food when the cat ate from its food bowl. (B) Unlike in the dog, labial advancement (arrow) of the right upper lip was required to reduce incisional tension. (C) Vertical mattress sutures (arrow) are important for maintaining approximation of the apposed rostral labial margins in the cat. Interrupted sutures were used to close the dorsal margin of the labial advancement flap. (D) Closure approximately 2 weeks later. Key in closure of this challenging cleft lip was to minimize tension with the right labial advancement flap and the use of vertical mattress sutures as noted.

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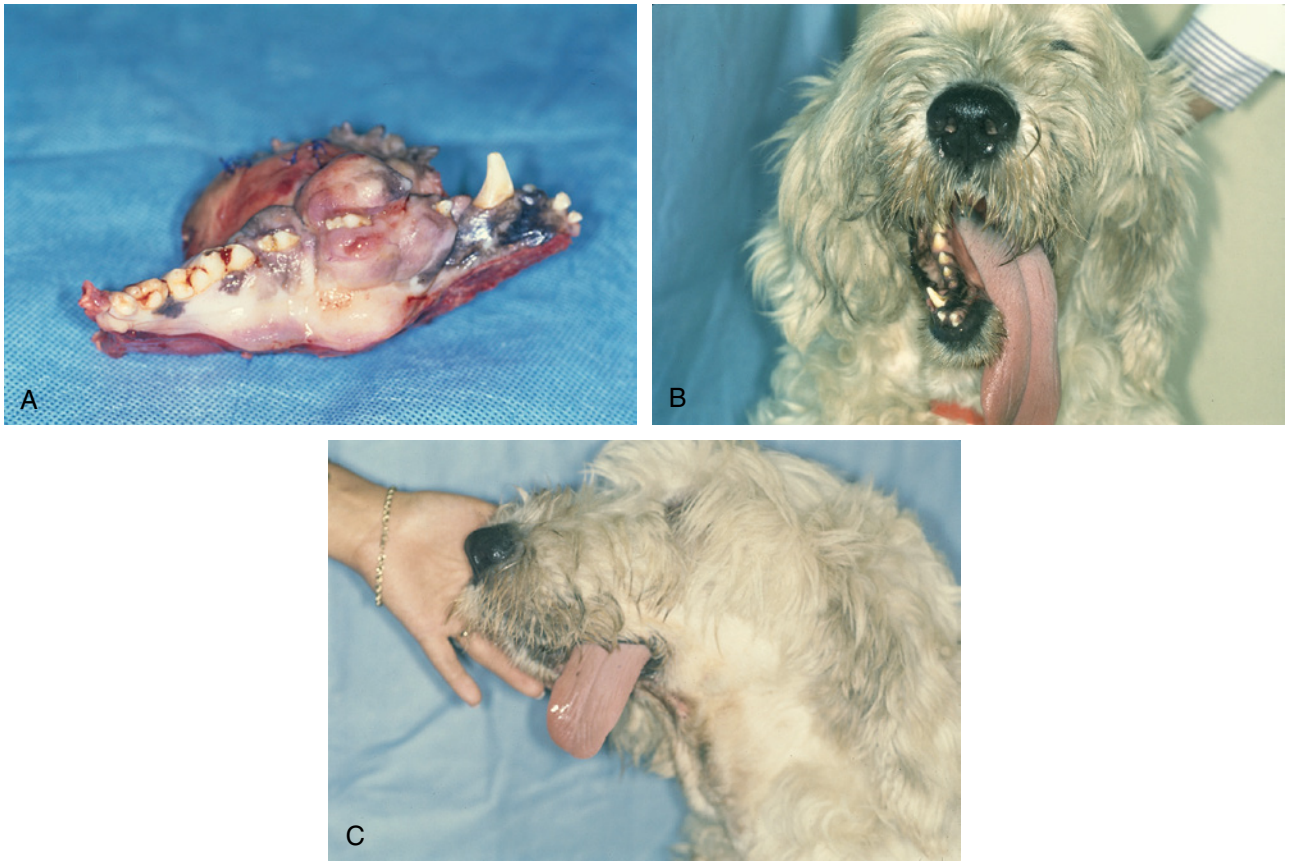


FIG. 15-27 (A) Hemimandibulectomy for osteosarcoma in an old English sheepdog. (B, C) Front and side views of the dog. Without support from the left mandible, the tongue deviates laterally. The mass of the tongue displaces the oral commissure caudally. Most dogs will learn to retract their tongue to a variable degree; problematic cases may benefit from oral commissure advancement (see Plate 99).

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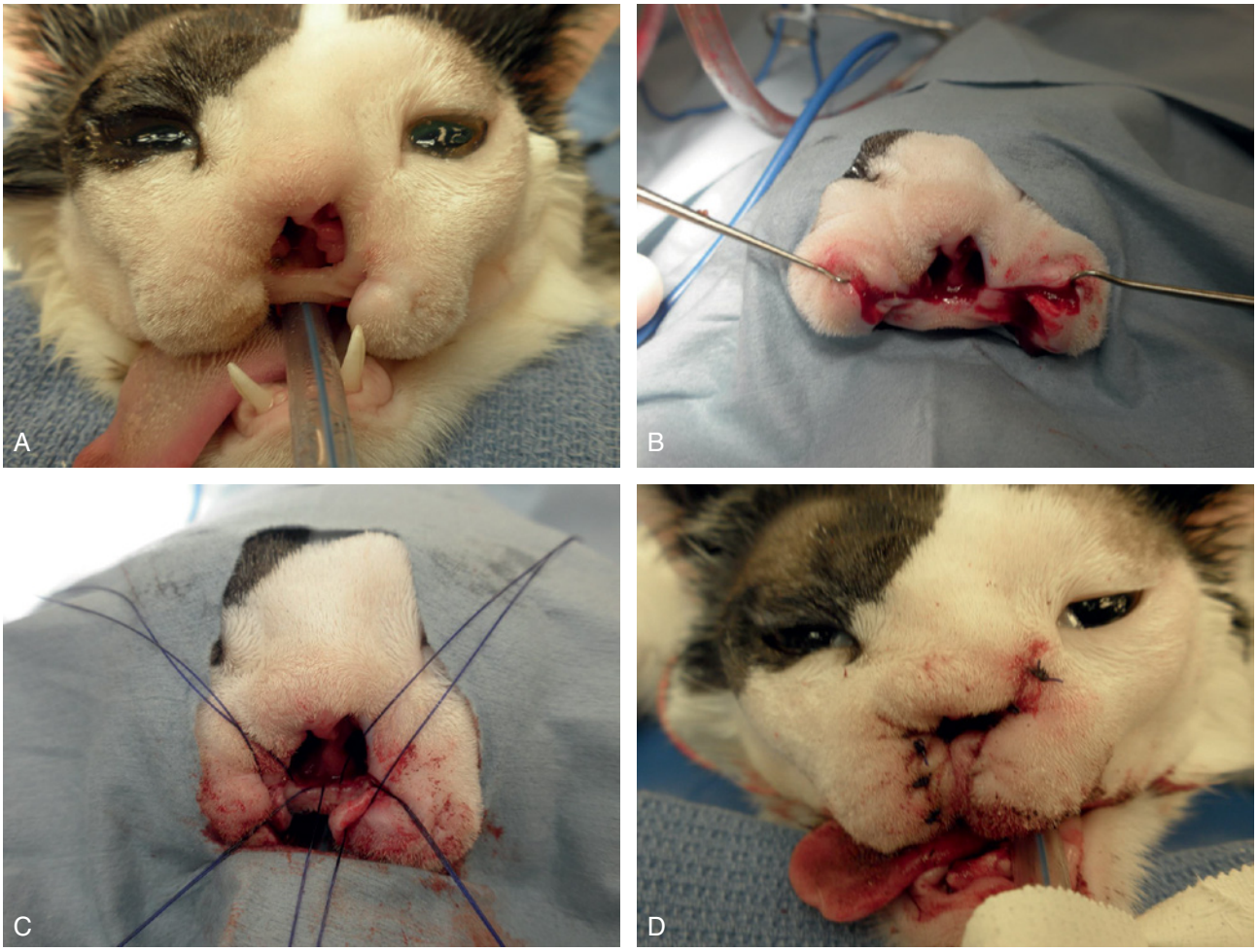


FIG. 15-28 (A) Adopted stray cat with traumatic loss of the rostral lip, nose, and incisive bone. (B) Development of bilateral rostral labial advancement flaps. (C) Preplacement of the sutures aligning the exposed rostral palatal margin to the dorsal margins of each flap. (D) Following closure of the dorsal margin of the defect, the end of each flap was approximated with mucosal interrupted sutures followed by the use of three vertical mattress sutures to align the cutaneous margins. As noted, vertical mattress sutures are preferred to offset tension and increase the direct apposition of their respective dermal surfaces.

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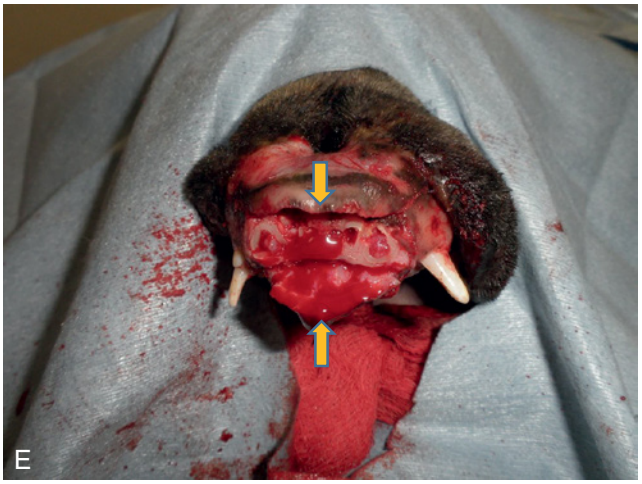
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FIG. 15-29 (A) Complete loss of the upper labial area and external nose secondary to infection as a puppy. There was complete stenosis of the nasal opening, forcing the dog to breathe through its mouth. (B) The rostral facial skin was elevated dorsally: the flap of skin is retracted with a skin hook. A Hall drill was used to open the nasal cavity. The skin flap was divided in the middle (yellow line), allowing each half to be sutured along the lateral sides of the nasal opening. (C) The flap margins were sutured to the internal nasal mucosa bordering the bony defect created to expose the left and right nasal cavities. (D) The dog, 1 month later. This staged procedure was to ensure the new nasal opening did not stricture. The dog at this time was breathing easily. (E) A Microaire reciprocating bone saw was used to resect the incisive bone rostral to the canine teeth. Shortening the muzzle facilitated advancement of the left labial flap. Note the preserved gingival and palatal margin (arrows). (F) Elevation of the left and right upper labial advancement flaps. The rostral half of the right upper lip was lost secondary to the original infection. The left labial advancement flap was used to cover the majority of the rostral labial defect. (G) The left upper labial advancement flap's mucosal margin was sutured to the hard palate margin; the upper cutaneous margin was secured to the preserved gingival margin. The end of this flap was apposed to the truncated right labial advancement flap. The arrow denotes the direction of the left upper labial advancement flap. (H) Angular view of the closure, primarily from the left upper labial advancement flap. The dog made a complete recovery.

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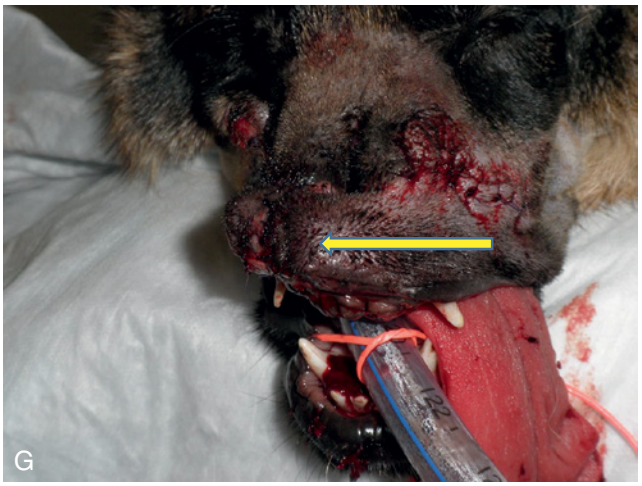




FIG. 15-29 (Continued)

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FIG. 15-30 (A) Pekinese with a history of corneal ulceration secondary to facial fold irritation. (B) Dorsal traction of the facial skin highlighting the facial fold after removal of the fur. (C) Resection of half the upper ridge of the skin fold was performed. This preserved the cosmetic appearance of the dog while removing the ridge that was irritating the corneas. The underlying cleft of the fold was not removed, unlike dogs with chronic pyoderma of this area. (D) Closure using 4-0 absorbable sutures and a simple interrupted pattern.

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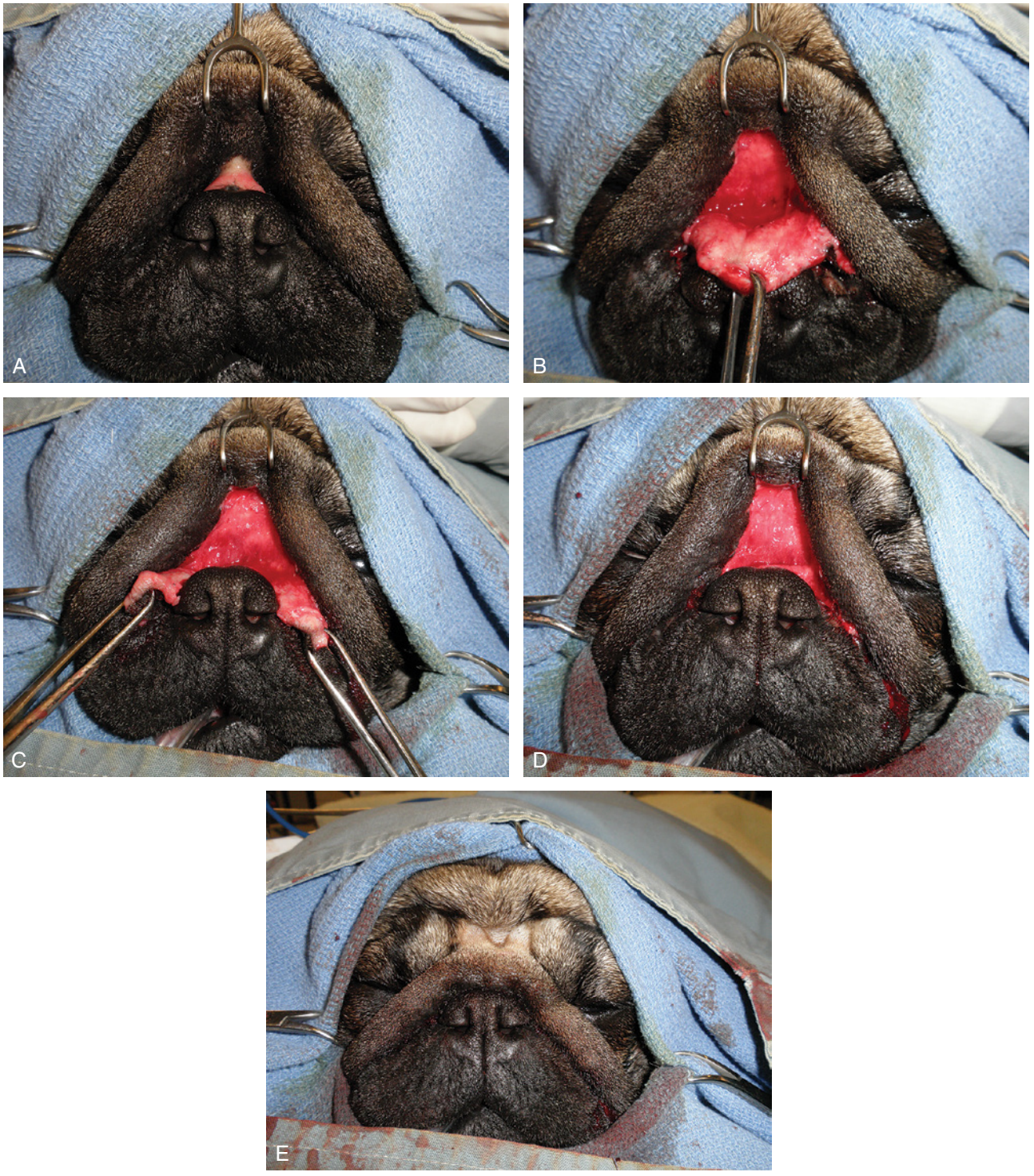


FIG. 15-31 (A) Facial fold pyoderma with severe excoriation of the skin beneath the major facial fold. (B) The initial incision is created at the junction of the diseased skin segment and the healthy cutaneous border. Deep dissection is used to elevate the diseased dermal surface. (C) In this case, the rostral cutaneous border is incised and the central portion of the diseased segment is split. This facilitates subsequent resection of the remaining diseased fold segment. (D) Completion of the resection. The healthy skin borders are reapposed. (E) Completion of the closure retaining the skin fold and natural facial conformation of the patient (see Plate 100).

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FIG. 15-32 (A) Right lateral view of a facial fistula and the flap remnant. (B) The labial flap was rotated dorsally and sutured to the cutaneous perimeter of the fistula. A portion of the labial margin was excised, allowing for the apposition of the rostral margin of the flap. (C) Completion of the first reconstructive surgical procedure. (D) Photograph 1 week postoperatively. (E) Progressive breakdown of the skin surrounding the right labial flap, 5½ months after the initial closure. The skin destruction is associated with the dermal surface of the remaining skin overlying the nasal cavity. The right labial flap remains viable and intact (arrow). (F) Debridement of the skin around the fistula was performed up to the level of the underlying bony perimeter. The right full-thickness labial flap was shifted dorsally to close the defect associated with the right medial canthus to complete the reconstruction. Note that the pigmented labial border was resected prior to suture closure. The rostral portion of the left lip was then sutured to the prepared margin of the labial flap. (See Plate 101.) Source: Pavletic MM. 2021. Full-thickness labial flaps to reconstruct facial defects in four dogs. *Vet Surg* 50:1338-1349. Reproduced with permission of Veterinary Surgery.

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FIG. 15-33 (A) A neutered male 34 kg border collie that presented with a dorsolateral facial defect extending into the nasal cavity. Approximately 5 months prior to presentation, a subcutaneous myxosarcoma (grade 1) resection was performed at a nearby hospital. The tumor resection included the removal of facial skin and the underlying maxillary bone, exposing the nasal cavity. The skin closure broke down: two attempts at closing the nasocutaneous fistula with skin flaps had failed. (B) Resection of the fibrotic skin back to the level of the bony margin encompassing the fistula. This is an important step for establishing a viable wound border for placement of the labial flap. (C) Excision of 3 cm of the pigmented labial border (arrow), providing an incised surface for suture placement. (D) The thin band of skin between the donor and recipient beds was excised (white arrow) for proper positioning of the labial flap. Yellow line denotes location of a mucosal incision: this incision will be sutured to the ventral margin of the defect. (E) Trial placement of the right full-thickness labial flap. A gauze template of the prospective flap can be used intraoperatively to ensure proper flap development prior to incising the tissues. Note that the pigmented labial border is excised. (F) The island of mucosa of the flap was sutured to the perimeter of the defect. This was followed by closure of the skin. The right rostral lip as sutured in two layers (mucosa, skin) to the rostral margin of the flap to complete the closure (arrow). (See Plate 101.) Source: Pavletic MM. 2021. Full-thickness labial flaps to reconstruct facial defects in four dogs. *Vet Surg* 50:1338-1349. Reproduced with permission of Veterinary Surgery.

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FIG. 15-34 (A) Chronic nasocutaneous fistula with bone necrosis secondary to radiation therapy. (B) Radiation ulceration, frontal view. Note the close proximity to the right medial canthus. (C) Wide debridement of the oronasal fistula to healthy bone. (D) Elevation of the right upper labial flap. The thin band of skin interposed between the fistula and flap (arrow) requires resection prior to transposing the flap. The yellow line denotes the mucosal incision required for positioning of the "mucosal island" to replace the nasal mucosa. (E) Placement of the labial flap. A no. 15 scalpel blade is used to resect the pigmented labial border in preparation for closure of the donor and recipient areas. (F) Closure of the nasocutaneous fistula and donor labial defect (mucosa and skin). (G) Healing approximately 6 weeks later. (H) Rostral view. Note the white fur in the field of radiation. (See Plate 101.)

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FIG. 15-34 (Continued)

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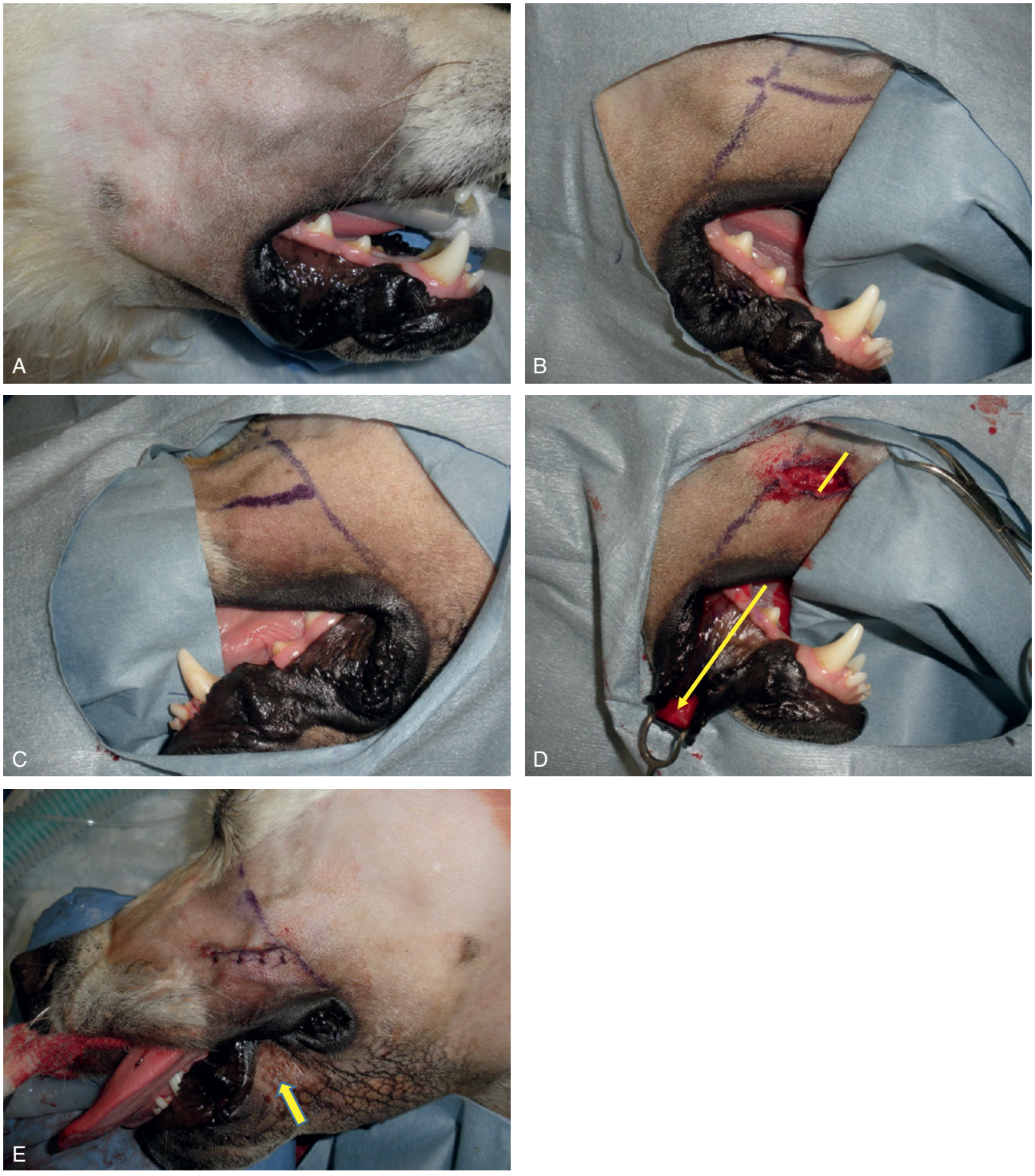


FIG. 15-35 (A) Golden retriever with history of chronic drooling. (B) Right facial area outlined with a surgical marking pen. Vertical line is the oral commissure to the medial canthus. The short perpendicular line denotes the location for the full-thickness upper labial incision. (C) Outline of the left facial area. (D) Note the lower labial mucosal incision and full-thickness upper labial incision. Allis forceps or a skin hook is used to draw the lower labial incision to the upper mucosal incision. Both mucosal surfaces are sutured together followed by closure of the skin. The yellow arrow denotes the passage of the forceps or skin hook. (E) Completion of the surgery, left side. Note the upward displacement of the lower lip (arrow), thus restoring the lower labial "trough" to contain saliva. Note the chronic dermatitis of the lower neck secondary to the drooling. See Plate 103.

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Plate 84

Repair of Upper Lip Avulsion

DESCRIPTION

Avulsion of the upper lip is less common than lower labial avulsion injuries. The gingival border is pulled free of the upper incisors. Exposure of the dorsal surface of the incisive bone is noted when the nasal cartilage is grasped and gently lifted. The wound may not be readily apparent on initial presentation, as the weight of the nose returns the gingival border to its approximated anatomic position. On rare occasions, the nasal cartilage can be avulsed with portions of the upper lip.

SURGICAL TECHNIQUE

(A) After judicious debridement and copious pressure lavage, the lip is positioned in its appropriate position.

(B) Absorbable horizontal mattress (3-0) sutures are looped around the intact incisors by driving the needle as close to the incisive bone as possible. Small holes can be driven into the border of the maxilla if teeth are missing, using a K-wire or a 1/16-inch Steinmann pin to permit passage of the suture material (see Plate 85).

(C) Sutures are tied to complete the closure.

COMMENTS

The causes of upper lip avulsion are identical to those for lower labial avulsion injuries. On impact, the nose is driven caudally and dorsally, resulting in separation of the gingival border. Suturing the lip back into position stabilizes the nasal cartilage and prevents it from being displaced by normal activities of the dog or cat. Avulsion of the nasal cartilage requires the preplacement of sutures in order to realign the left and right nostrils. As previously discussed, more severe avulsions, including the nasal septum, may require stabilizing sutures passed through the paired palatine fissures prior to closure of the remaining soft tissue margins (see Fig. 15-6).

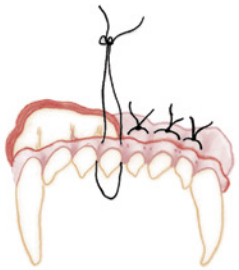
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Plate 84



A



B



C

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Plate 85

Repair of Lower Labial Avulsion

DESCRIPTION

Avulsion wounds of the lip most commonly occur along the gingival border of the lower incisors, although they may extend caudally to involve the adjacent premolar and molar regions. Lower labial avulsion is most commonly seen in cats, with the patient presenting with the lip and lower chin hanging beneath the mandible.

SURGICAL TECHNIQUE

(A) After judicious debridement and copious pressure lavage with sterile saline, the lip is gently grasped with skin hooks or Adson-Brown thumb forceps and elevated to the level of the incisor teeth.

(B) With little or no soft tissue to which the lip can be sutured, horizontal mattress sutures are looped around the intact incisors by driving the needle as close to the mandible as possible.

(C) If teeth are missing, small holes can be driven into the border of the mandible, using a K-wire or a 1/16-inch Steinmann pin to permit passage of the suture material.

(D) Absorbable or nonabsorbable 3-0 suture material may be used. A Penrose drain can be inserted through a cutaneous stab incision to manage dead space. Drains are usually removed by the third day.

COMMENTS

Because of the excellent collateral circulation to the lips, massive tissue sloughing is uncommon. Major skin loss generally requires closure with a local skin flap.

From the author's experience, lower labial avulsions are more common in cats. They are usually the result of the animal being struck from the rear by a vehicle, driving the head downward and forward into the pavement, or falling face forward from an elevated position. Although these injuries are rather gruesome to behold, they are not particularly difficult to close.

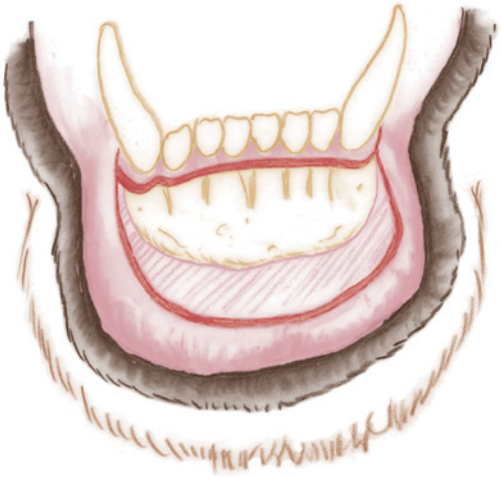
Symphyseal fractures may be seen in conjunction with lower labial avulsion wounds. Bone-reduction forceps can stabilize the fracture, allowing cerclage wire (22-gauge) stabilization of the realigned mandibles before suture repair of the avulsion wound. The upper and lower dental arcades are apposed to ensure proper occlusion.

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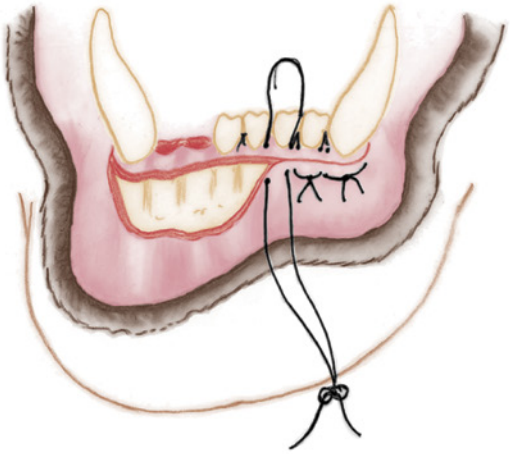
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Plate 85

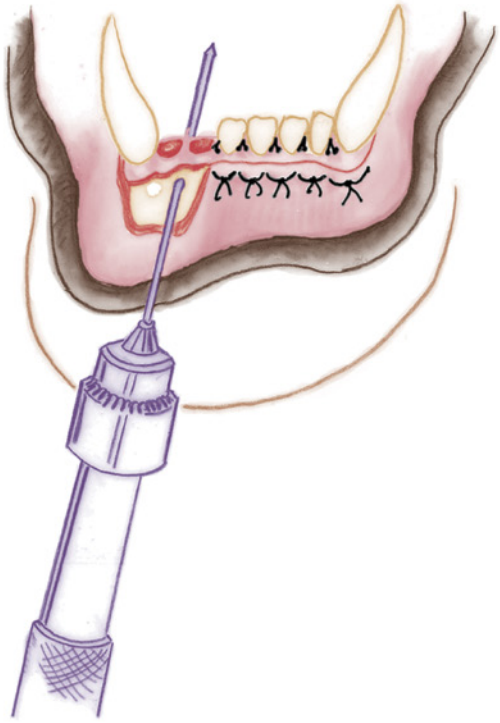
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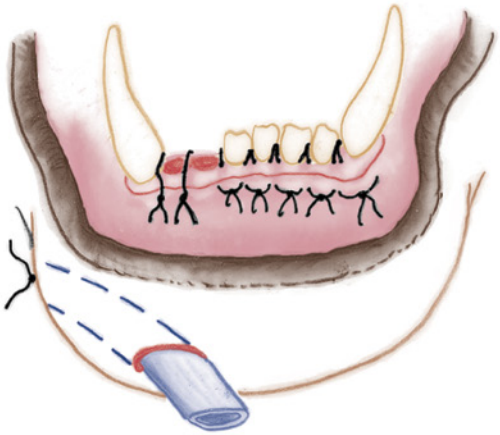
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Plate 86

Wedge Resection Technique

DESCRIPTION

Wedge resection entails full-thickness excision of a lip segment. The remaining labial borders are apposed directly without the use of release/relaxing incisions to facilitate tissue apposition.

SURGICAL TECHNIQUE

(A) The size and location of the excision are determined with particular attention to obtaining adequate surgical margins in the resection of the neoplasm. A scalpel blade is used to incise through the entire thickness of the lip.

(B) The labial margins are accurately aligned with the first suture to avoid creation of an offset (stair-step) defect.

(C) Simple interrupted absorbable (3-0) sutures are placed in the submucosal layer to realign the mucosal surface.

(D) Additional sutures are used to realign subcutaneous tissues and fascia if necessary, prior to closure of the skin using 3-0 nonabsorbable suture material. Note the forward advancement of the oral commissure (arrow).

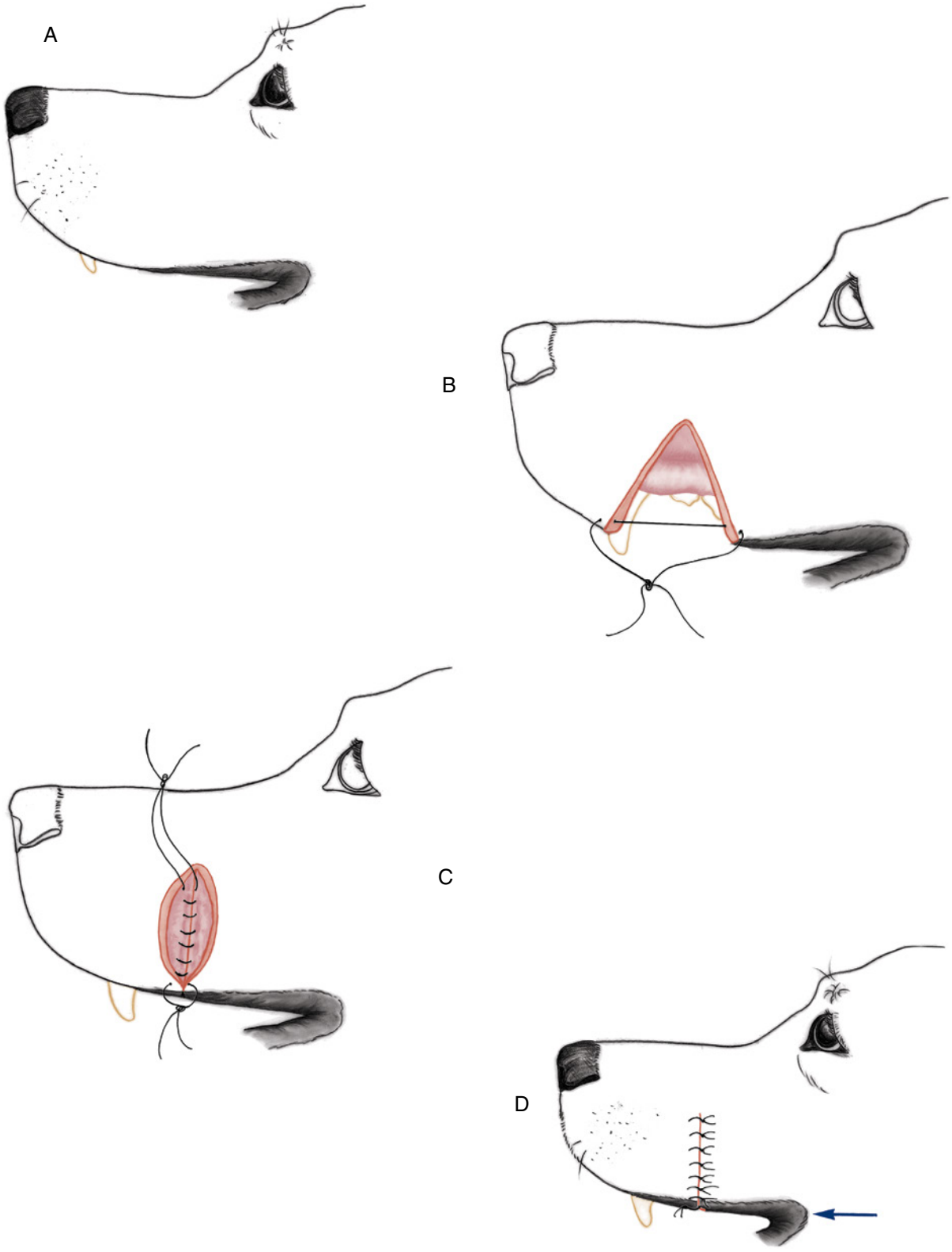
COMMENTS

Wedge resection is easy to perform, especially in the dog. Irregular defects or lacerations can be debrided and closed in this fashion. However, the surgeon should consider rectangular excision (see Plate 87) to ensure that adequate tissue margins are obtained with malignant tumor excision. The mouth should be manipulated intraoperatively to make sure that a normal range of motion is maintained without excessive tension on the incision.

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Plate 86



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Plate 87

Rectangular Resection Technique

DESCRIPTION

Rectangular resection entails full-thickness excision of a lip segment. The remaining labial borders are closed in a Y fashion, unlike the linear closure achieved with a wedge resection.

SURGICAL TECHNIQUE

(A) The margins of the excision are determined with particular attention to obtaining adequate surgical margins when a neoplasm is removed. A scalpel blade is used to incise through the entire thickness of the lip.

(B) Labial margins are accurately aligned with the first suture to avoid creation of an offset (stair-step) defect.

(C) The surgeon may note the oral commissure advance forward during the closure.

(D) Simple interrupted absorbable (3-0) sutures are placed in the submucosa to realign the mucosal surfaces, beginning in the upper corners of the defect. Closure progresses ventrally, resulting in a Y closure.

(E) Additional sutures are used to realign subcutaneous tissues and fascia as necessary, prior to closure of the skin using 3-0 nonabsorbable sutures.

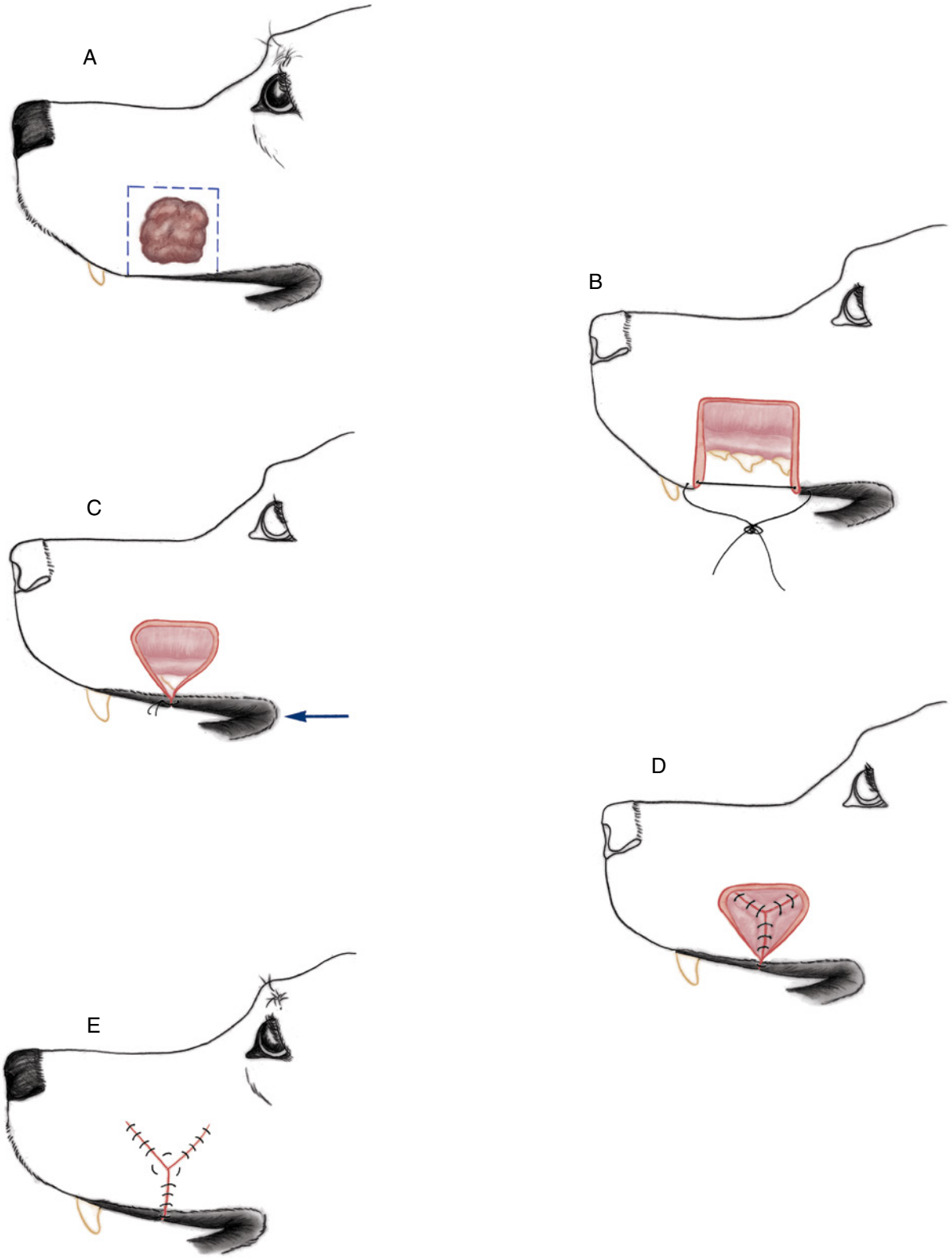
COMMENTS

Rectangular resection is easily performed in the dog and has no distinct disadvantage when compared to wedge resection. Wider surgical margins can be obtained around malignant tumors. The mouth should be manipulated intraoperatively to ensure that a normal range of motion is maintained without excessive tension on the incision. This technique can be combined with partial maxillectomy. Under these circumstances, the upper mucosal margin is sutured to the palatal tissue to complete the closure of the oronasal defect.

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Plate 87



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Plate 88 Full-Thickness Labial Advancement Technique (Upper Lip)

DESCRIPTION

The labial advancement flap entails complete elevation of the entire thickness of the upper lip to maximize its advancement into rostral labial defects. The superior labial artery and vein help to ensure an adequate blood supply is present during this surgical maneuver.

SURGICAL TECHNIQUE

(A) This is an example of full-thickness rectangular excision of a malignant neoplasm of the upper lip.

(B) The upper lip is incised down to the mucosa. The scalpel blade is redirected slightly to leave a 5 mm strip of mucosa along the gingival border. (The mucosal strip is better able to hold sutures than the gum.) The length of the full-thickness labial advancement flap varies with the size and location of the defect, as well as the flap length required to stretch over the wound without excessive tension.

(C) Any tension bands of tissue palpated as the flap is stretched must be carefully divided at the base of the flap to avoid compromise to the blood supply. As the flap is advanced (large arrow), note the rostral advancement of the oral commissure (small arrow).

(D) A small, wedge-shaped area can be trimmed off the rostral border of this "composite" flap to better conform the flap to the curvature of the opposing labial margin. As noted in (C), the oral commissure will advance rostrally as the flap is advanced into the labial defect.

(E) The mucosal surface is initially closed with 3-0 absorbable sutures in a simple interrupted pattern.

(F) The skin is closed in similar fashion with 3-0 nonabsorbable sutures. Tension sutures may be used in any area under moderate tension, if necessary. The jaw should be manipulated during closure to ensure mobility is maintained without excessive tension placed on the surgical margins.

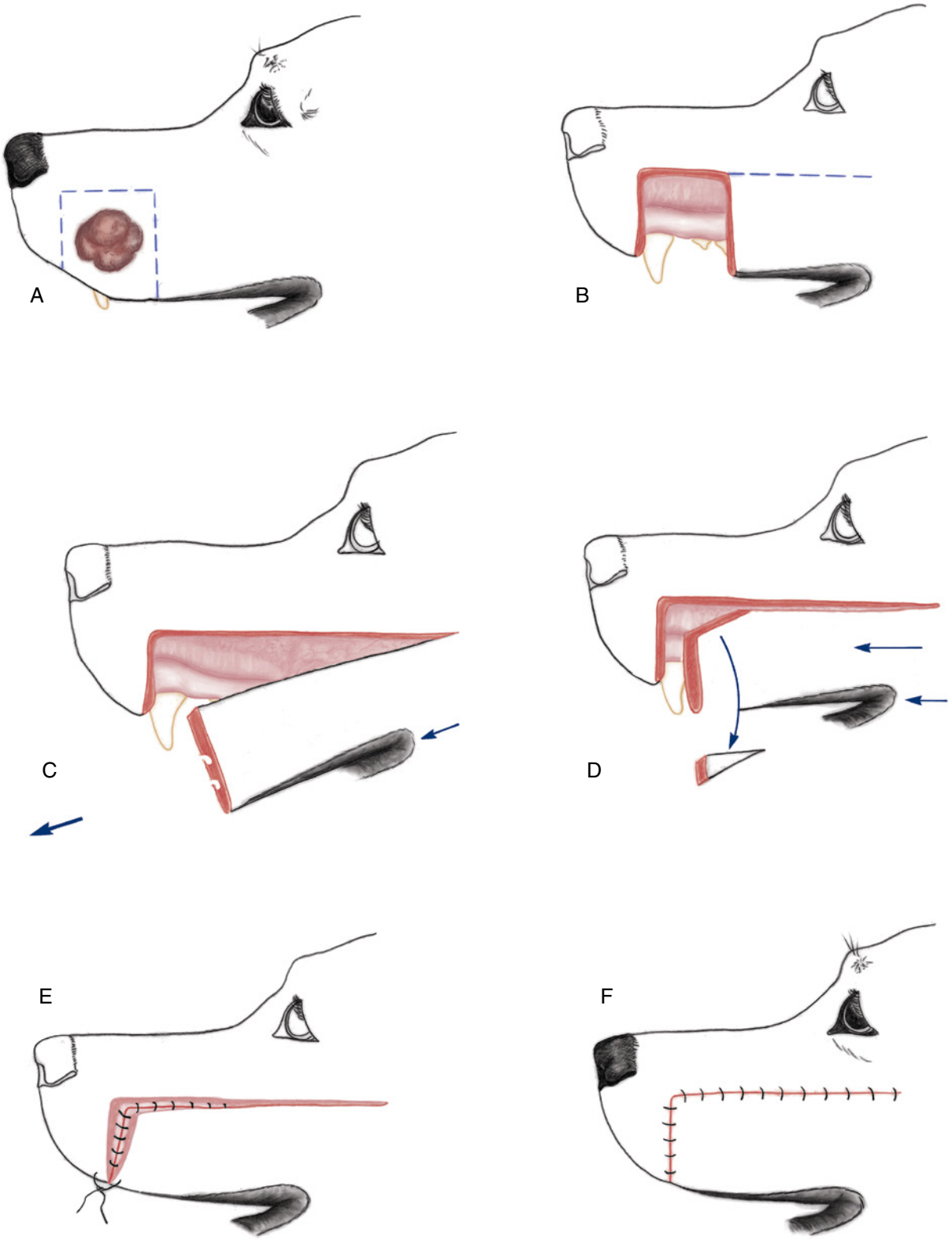
COMMENTS

The labial advancement flap is ideal for defects involving the rostral one-third of the upper lip. It can be combined with partial maxillectomy if a neoplasm extends beyond the labial tissue. Elastic retraction of the flap can cause unilateral distortion of the nasal planum. However, this deviation usually subsides over the next 2 or 3 weeks as swelling recedes and the soft tissues stretch under tension. An Elizabethan collar is advisable until suture removal because a number of patients will attempt to paw or rub at their face during the first postoperative week. This flap design can be used for closure of nasocutaneous fistulas and defects of the palate (see Plates 101 and 128).

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Plate 88



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Plate 89 Full-Thickness Labial Advancement Technique (Lower Lip)

DESCRIPTION

Lower labial advancement entails mobilization of the lower lip to close rostral labial defects. The inferior labial artery and vein help to ensure that an adequate blood supply is present during this surgical maneuver. The lower lip is easier to mobilize and advance compared to the upper lip, with the mucosa/submucosa being the major restricting tissue layer. As a result, a long skin incision is not required to maximize rostral advancement of the lip.

SURGICAL TECHNIQUE

(A) This is an example of full-thickness labial excision of a malignant neoplasm.

(B) When feasible, the mucosa of the lower lip is incised 5 mm from the gingival border in a staged fashion. A skin incision of variable length is created as the lower lip is advanced forward.

(C) Rostral traction on the lower lip (arrow) helps determine the length of the incision required to advance the mucosa and skin into the rostral defect.

(D) The mucosal incision is closed initially with 3-0 absorbable sutures. Offset placement of these sutures (by taking a suture bite along the gingival reflection rostral to the labial mucosa) can facilitate forward advancement of the lip into the defect. Sutures are used to recreate the labial attachment at the interdental space located between the lower canine and first premolar teeth to offset the tendency of the lip to sag.

(E) A ¼-inch Penrose drain is used to control dead space prior to closure of the skin with nonabsorbable (3-0) sutures. In most cases, the drain is removed by day 3.

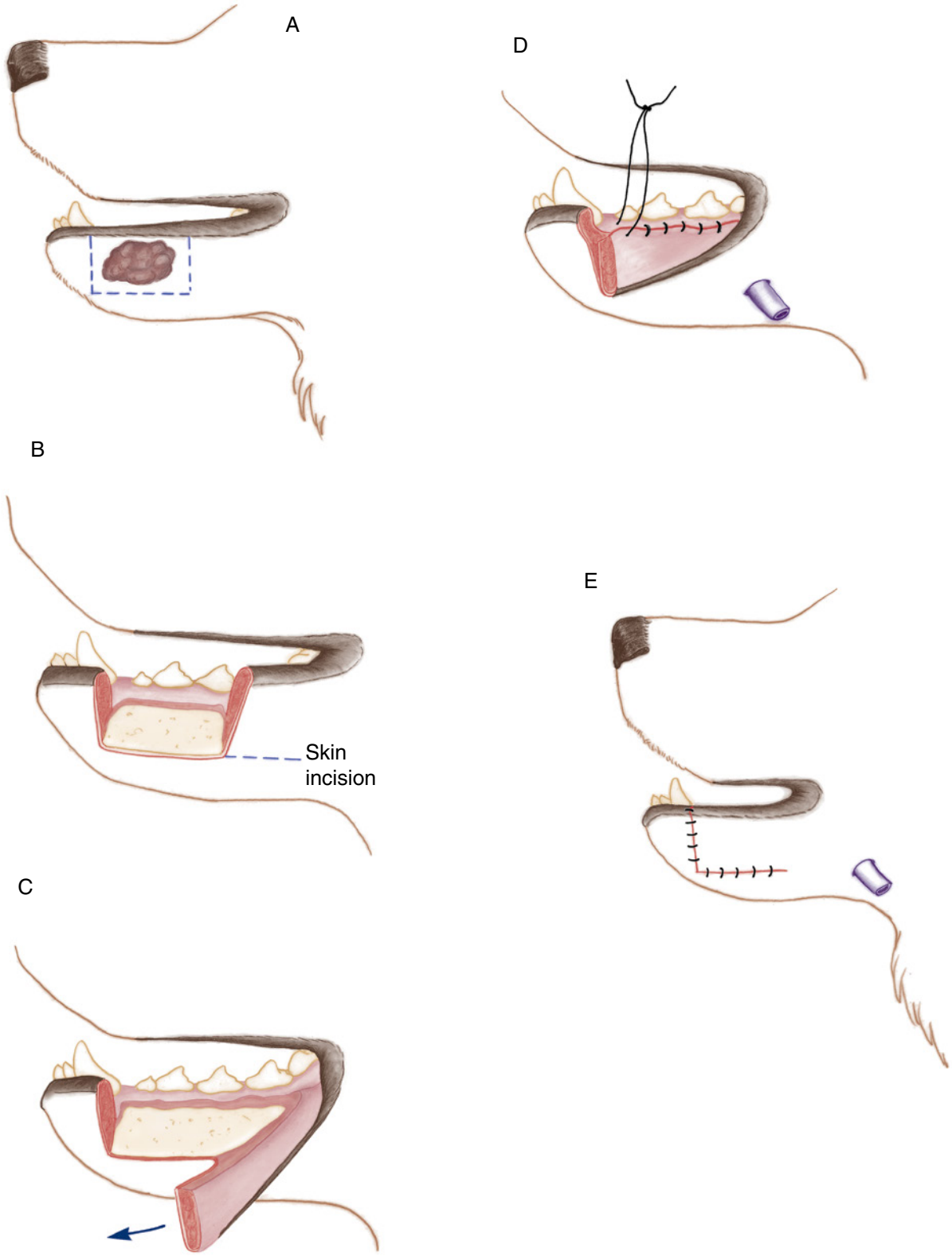
COMMENTS

Compared with upper labial advancement flaps, lower labial advancement flaps require less dissection. The skin, mucosa, and interposing tissue of the lower lip are not as closely joined compared to those of the upper lip; the inner elasticity of the skin of the lower lip enables the surgeon to advance it rostrally, without creating a long skin incision comparable to the length made in the mucosal surface. As noted, care must be taken to recreate the interdental attachment to prevent drooping of the lower lip. The lateral surface of the mandible is completely exposed during this procedure in the event that adjunctive surgery is required on this structure. Plate 102 demonstrates the use of this technique as a transposition flap.

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Plate 89



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Plate 90

Buccal Rotation Technique

DESCRIPTION

The buccal rotation technique was developed for reconstruction of large upper lip defects in which insufficient tissues are present for effective use of the labial advancement technique

SURGICAL TECHNIQUE

(A) This is an example of full-thickness labial excision of a malignant neoplasm. When possible, preserving a durable 5 mm mucosal margin along the gingival border is useful for suture closure of the defect.

(B) After removal of a major portion of the upper lip, wound closure is assessed by grasping and rotating the cheek margin by 90°. The caudal margin of the upper lip and oral commissure is rotated into the labial defect (arrow).

(C) A portion of the labial border is excised of sufficient length for apposition to the rostral labial margin. The elevated caudal labial margin is then aligned with the rostral border of the defect.

(D) Opposing gingival and labial surfaces are apposed with 3-0 absorbable sutures with an interrupted pattern. The oral commissure will notably advance in a rostral direction (arrow).

(E) Skin is apposed with simple interrupted sutures. Areas under tension are apposed with vertical mattress sutures. In this example, a half-buried horizontal mattress suture is used on the upper corner of the flap.

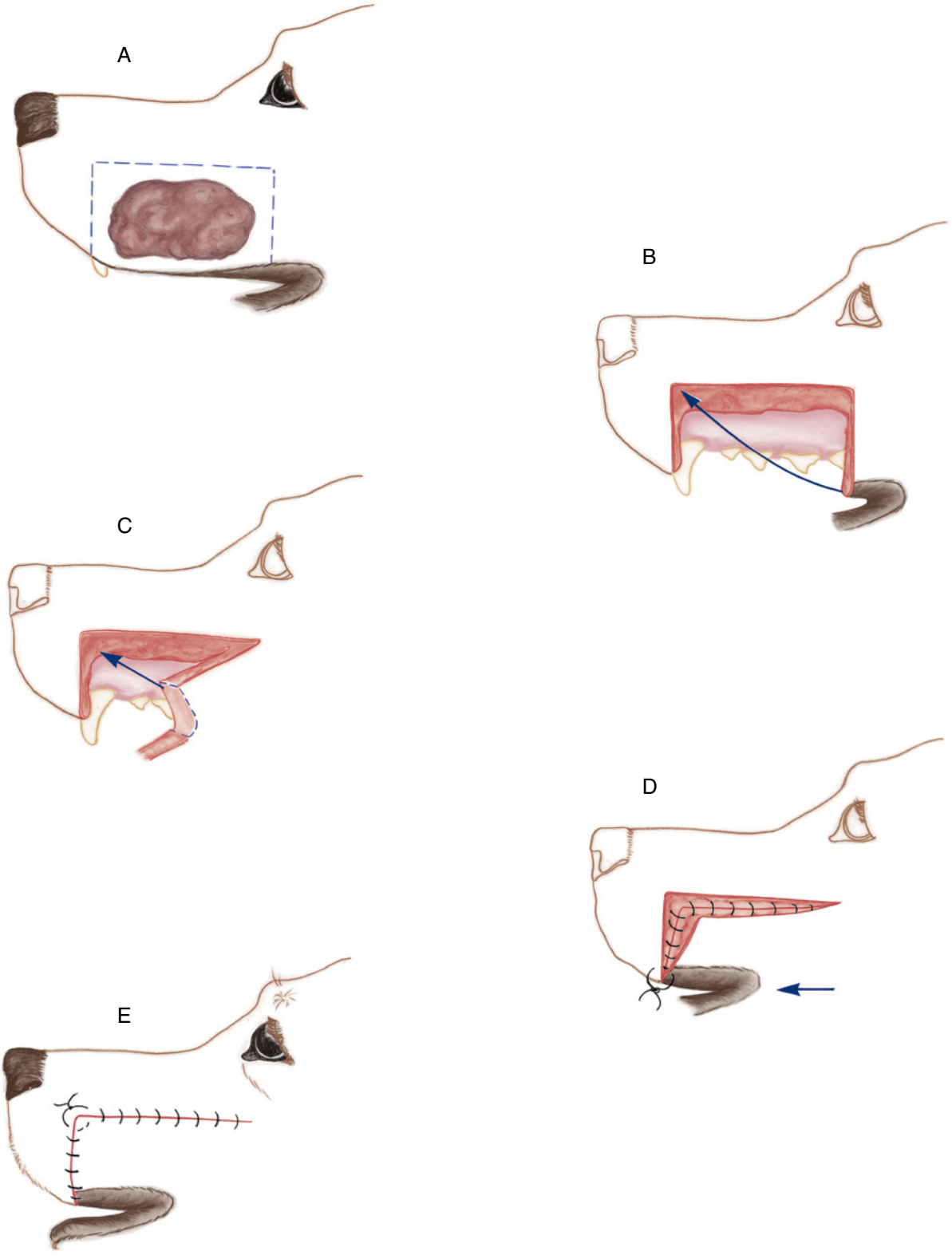
COMMENTS

The buccal rotation technique is employed for reconstruction of large upper labial defects. The oral commissure advances rostrally during this surgical maneuver. However, the facial asymmetry created is not readily noticeable except by the more discriminating observer. This procedure also can be combined with simultaneous excision of the regional dental arcade and maxilla for more extensive neoplastic processes. Although it is possible to enlarge the advanced oral commissure by incising and suturing the corresponding skin and mucosal edges, there is no practical, functional benefit to this surgical maneuver. In the execution of this design, the flap is a rotational flap (see Plate 48) rather than a transposition flap (see Plates 42–44). However, a reported variation of this flap technique is converting the buccal portion of this flap into a transposition flap design (Hildebrandt et al. 2022), thereby somewhat facilitating its mobility in a rostral direction.

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Plate 90



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Plate 91

Lower Labial Lift-Up Technique

DESCRIPTION

The lower labial lift-up technique is used to remove masses involving the gingival and ventral portions of the lower lip. The upper margin of the lower lip can be preserved with excellent cosmetic results.

SURGICAL TECHNIQUE

(A) The lip is incised parallel to the labial border above the mass.

(B) The bipedicle labial flap created is lifted dorsally. The diseased tissue is excised. The flap is elevated dorsally (arrows).

(C) After removal of the mass, the mucosal margins are reapposed with simple interrupted absorbable sutures.

(D) The skin is closed with simple interrupted sutures. A Penrose drain may be employed to control dead space.

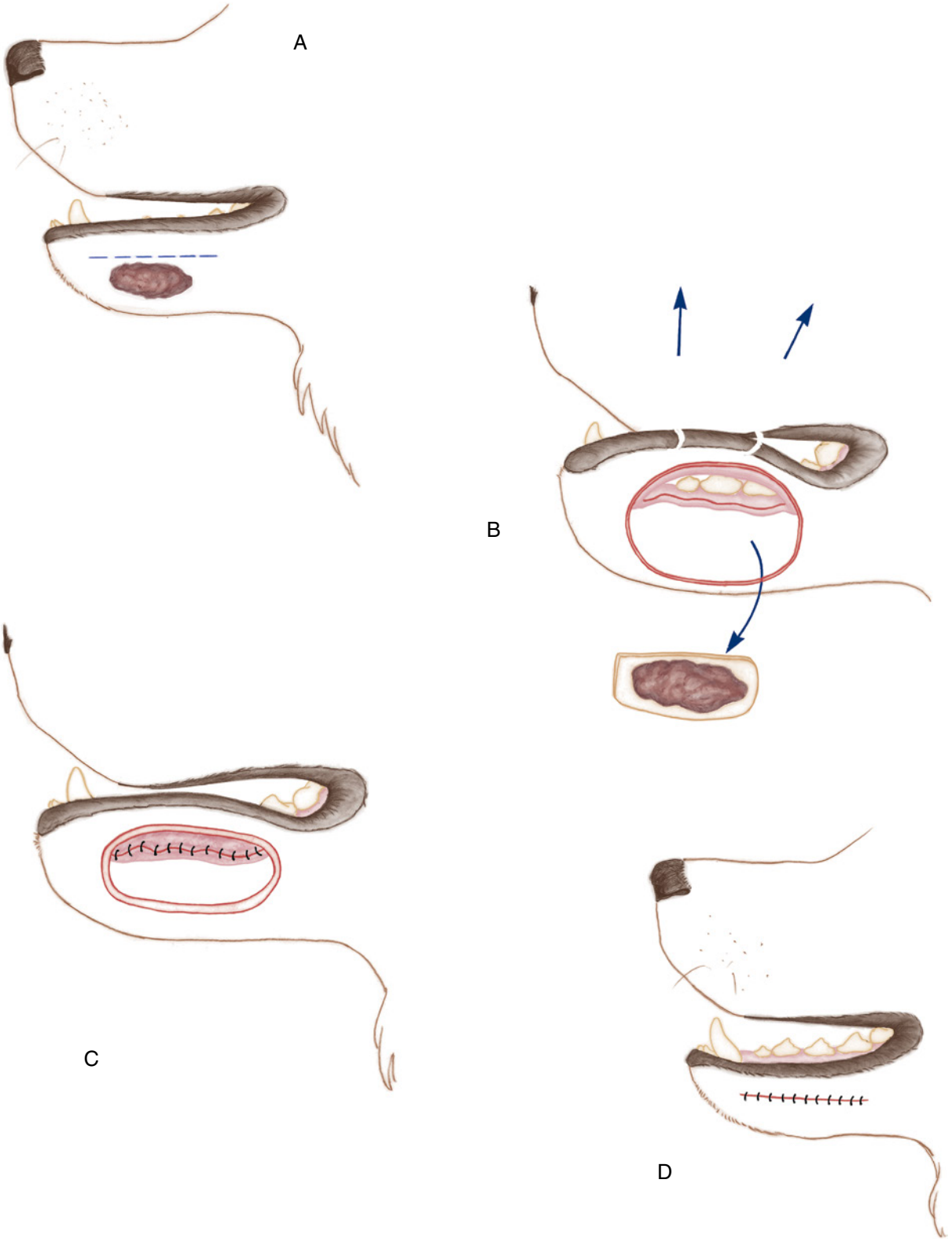
COMMENTS

This technique enables the surgeon to preserve the normal labial border for optimal cosmetic results. Caution must be exercised to ensure adequate tissue margins are obtained when malignant tumors are excised.

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Plate 91



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Plate 92

Upper Labial Pull-Down Technique

DESCRIPTION

Tumors of the lateral maxilla, gingiva, and adjacent bone occasionally extend into the dorsal portion of the upper lip. Removal of a portion of the dorsal lip may be necessary. Similarly, to obtain additional exposure to this area, a full-thickness labial incision can be made parallel to the gingival area, thereby allowing the surgeon to retract or pull-down the upper lip.

SURGICAL TECHNIQUE

(A,B) Full-thickness excision of a dorsal labial lesion (dashed lines).

(C) Downward traction of the upper lip (pull-down) facilitating the surgical exposure of the area. Note that removal of the dental arcade, maxilla, and adjacent skull may be necessary to obtain margins around infiltrative neoplasms.

(D) The labial mucosa is sutured to the adjacent oral mucosal border after resection of the lesion. The labial mucosa can be sutured to the palatal tissue when tumor extension requires resection of the adjacent facial bone and hard palate.

(E) The skin is closed with a simple interrupted suture pattern. A drain may be inserted to control dead space, if necessary.

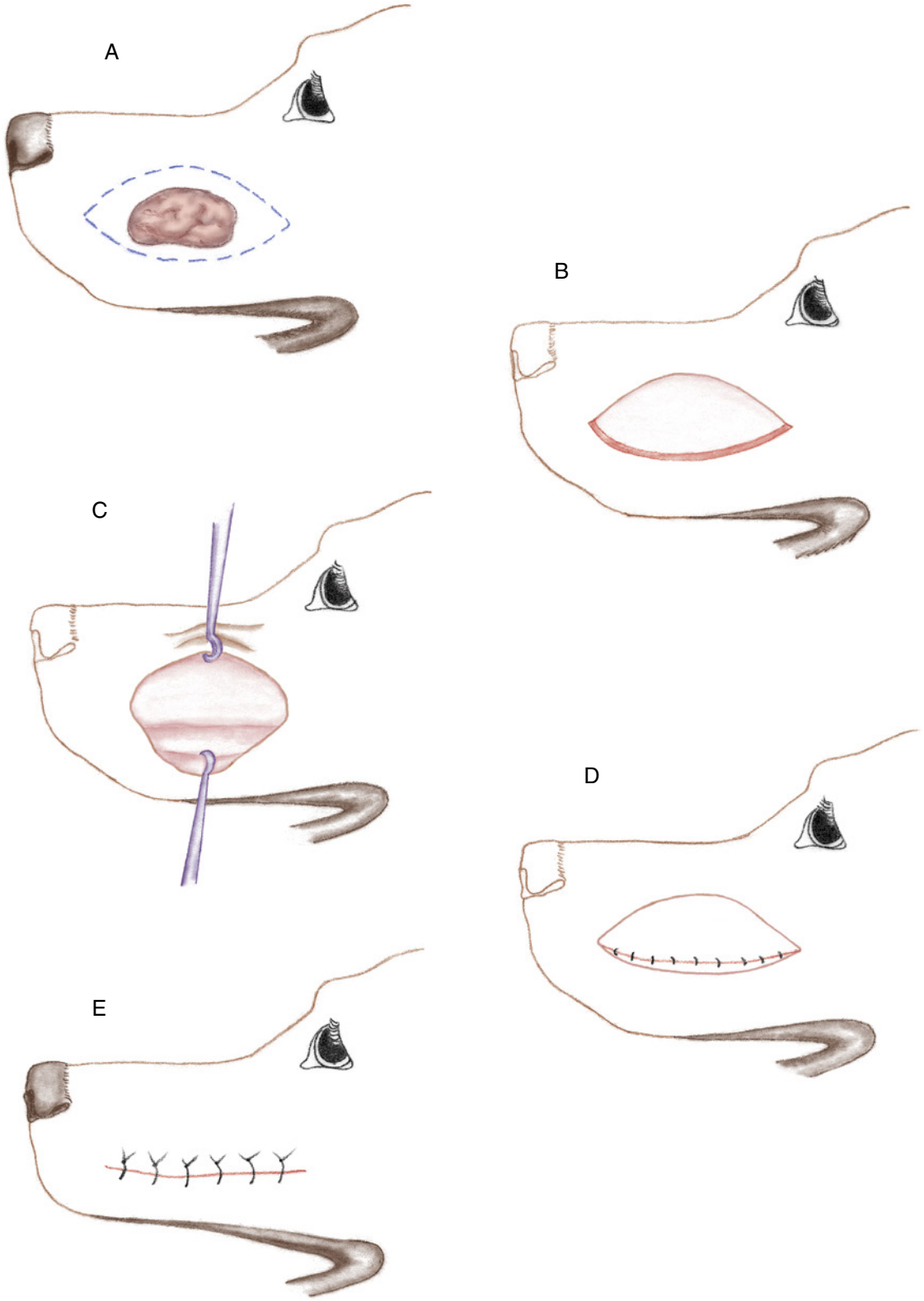
COMMENTS

This technique permits the surgeon to preserve the labial margin and the majority of the upper lip. Caution is warranted to ensure that adequate tissue margins are obtained when resecting neoplasms. This procedure also can be combined with simultaneous excision of the regional dental arcade and maxilla for more extensive neoplastic processes.

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Plate 92



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Plate 93

Labial/Buccal Reconstruction with Inverse Tubed Skin Flap

DESCRIPTION

Occasionally there is insufficient skin and/or mucosa available for closure of the lips or cheeks. This occurs with the removal of wider diffuse neoplasms, extensive facial trauma, and in those cases in which cancer recurrence necessitates removal of additional tissue. Local transposition flaps are particularly useful to close the cutaneous surface; they also can be used to replace major mucosal defects involving the oral cavity.

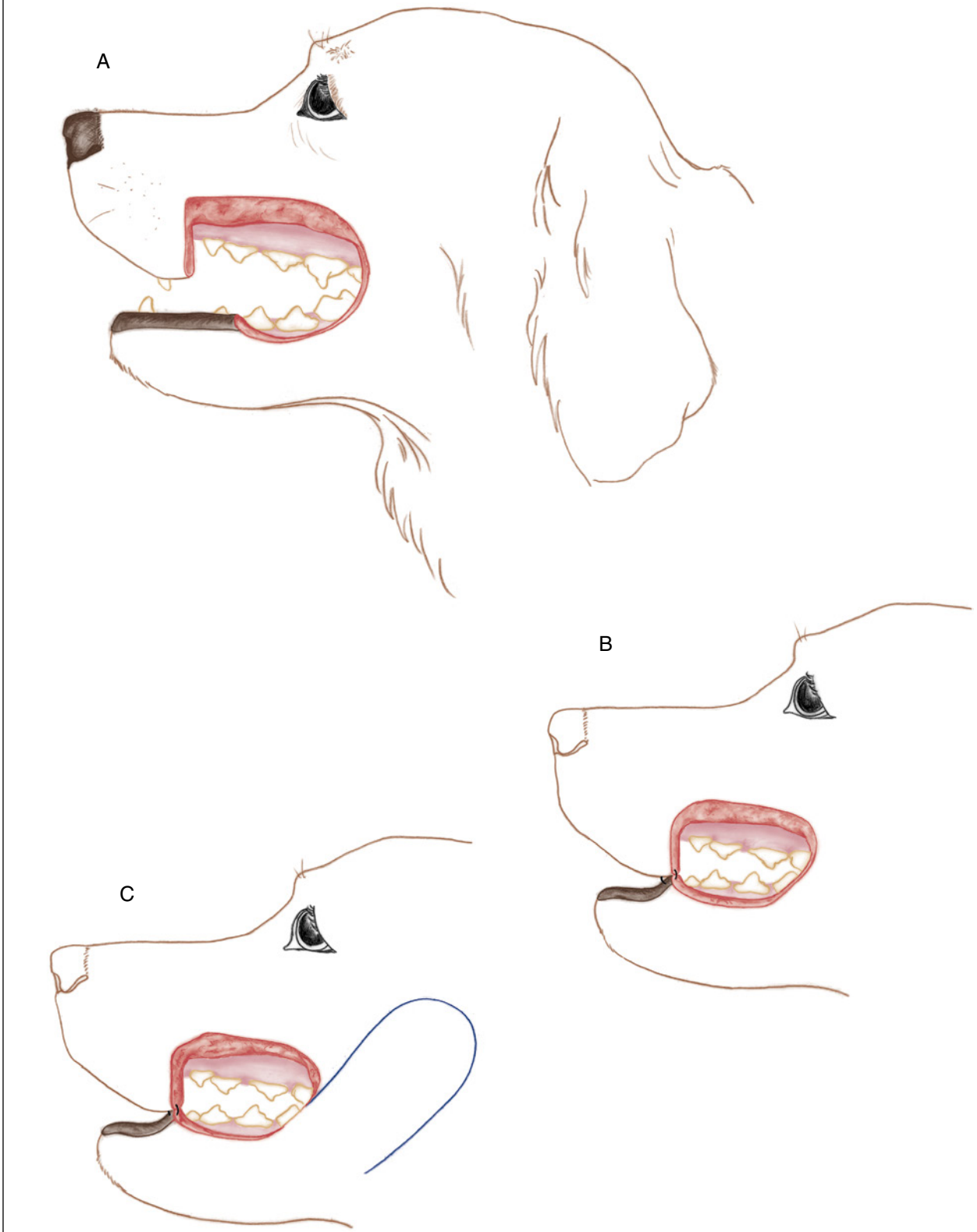
SURGICAL TECHNIQUE

(A) This is an example of full-thickness buccal and upper labial defect after tumor resection.
(B) Partial closure of the defect is achieved by apposing the remaining borders of the upper and lower lip.
(C) A local transposition flap is carefully measured for use in replacing the remaining mucosal defect.

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Plate 93



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Plate 93

(Continued)

(D_1, D_2) A portion of the transposition flap is partially tubed in inverse fashion to pass the body of the flap into the oral cavity for replacement of large mucosal defects of the cheek, lip, and adjacent palate (D_1). Simple interrupted (3-0) absorbable sutures are used to secure the skin flap to the remaining mucosal borders (D_2).

(E) The skin is advanced over the transposition flap and inverse tube segment, completing the closure. Note the narrow opening of the epithelial lined skin tube (arrow). If necessary, this short tubed segment can be excised when healing is complete and neovascularization to the flap is reasonably ensured; that is, 4–6 weeks postoperatively.

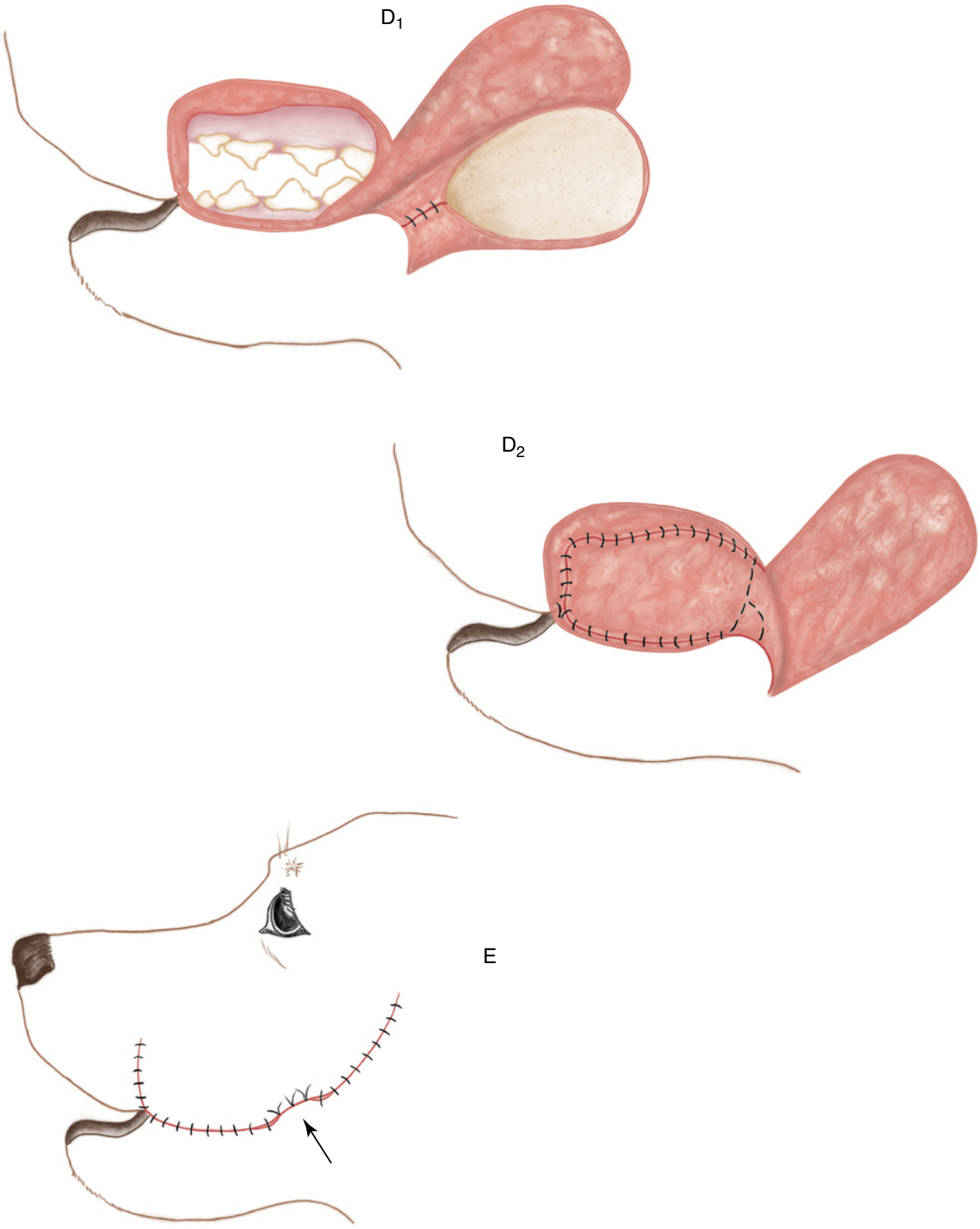
COMMENTS

Small gaps in the mucosal surface can heal by second intention, with the exposed dermal or muscular surface serving as a vascular scaffold for the advancing epithelium. Large mucosal defects are unlikely to heal by second intention without causing significant contraction, scarring, and distortion of the overlying tissues. A skin flap can be used as a satisfactory substitute for the mucosal lining. Skin flaps also have been used successfully by the author to close oronasal fistulas when insufficient mucosa is available. This technique also can be used for closure of defects after wide tumor resection that includes partial maxillectomy (see Fig. 15-12).

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Plate 94

Skin Flap for Upper Labial and Buccal Replacement (Facial [Angularis Oris] Axial Pattern Flap)

DESCRIPTION

Occasionally major segments of the upper lip and adjacent cheek require resection for diffuse neoplasms. The author was first to report on the use of cutaneous axial pattern flaps to reconstruct the skin and mucosal surfaces simultaneously. Yates et al. (2007) better defined the blood supply to this flap technique and created anatomic guidelines for flap development based on this study. Subsequent reports have noted its efficacy in closure of large defects of the hard palate (see Chapter 17).

SURGICAL TECHNIQUE

(A) Wide resection of this neoplasm required excision of 75% of the upper lip and adjacent cheek.

(B) Standard guidelines for transposition flap development are used. In this example, the width of the flap ideally should be twice the width of the lip excised, since "half" of the flap is required to replace the mucosal defect. The flap will be elevated and advanced into the upper labial defect (arrow).

Defined guidelines for outlining the flap are as follows: the dorsal border of the outlined flap parallels the ventral border of the zygomatic arch, and the ventral outlined border of the flap parallels the lower border of the mandible. The base of the flap incorporates the oral commissure and the adjacent upper/lower labial margins. Branches of the angularis oris vessels and interconnecting cutaneous vasculature of the labial vessels supply the base of this flap. Take care to preserve these vessels at the approach to the base of this flap during undermining. Flap length is determined by the measured distance from the base of the flap to the rostral facial defect. Flap length is normally within the defined limits of this flap design, using the vertical ear canal as the anatomic landmark as a general guideline for flap length.

(C) The upper border of the replacement flap is sutured to the remaining borders of the mucosa with 3-0 absorbable suture material, using a simple interrupted pattern. The flap is then folded along its length as it is elevated and sutured to the dorsal cutaneous margin (arrows).

(D) The skin flap is folded onto itself and sutured to the remaining cutaneous borders with 3-0 nonabsorbable suture material. A Penrose drain may be inserted prior to completion of the closure.

COMMENTS

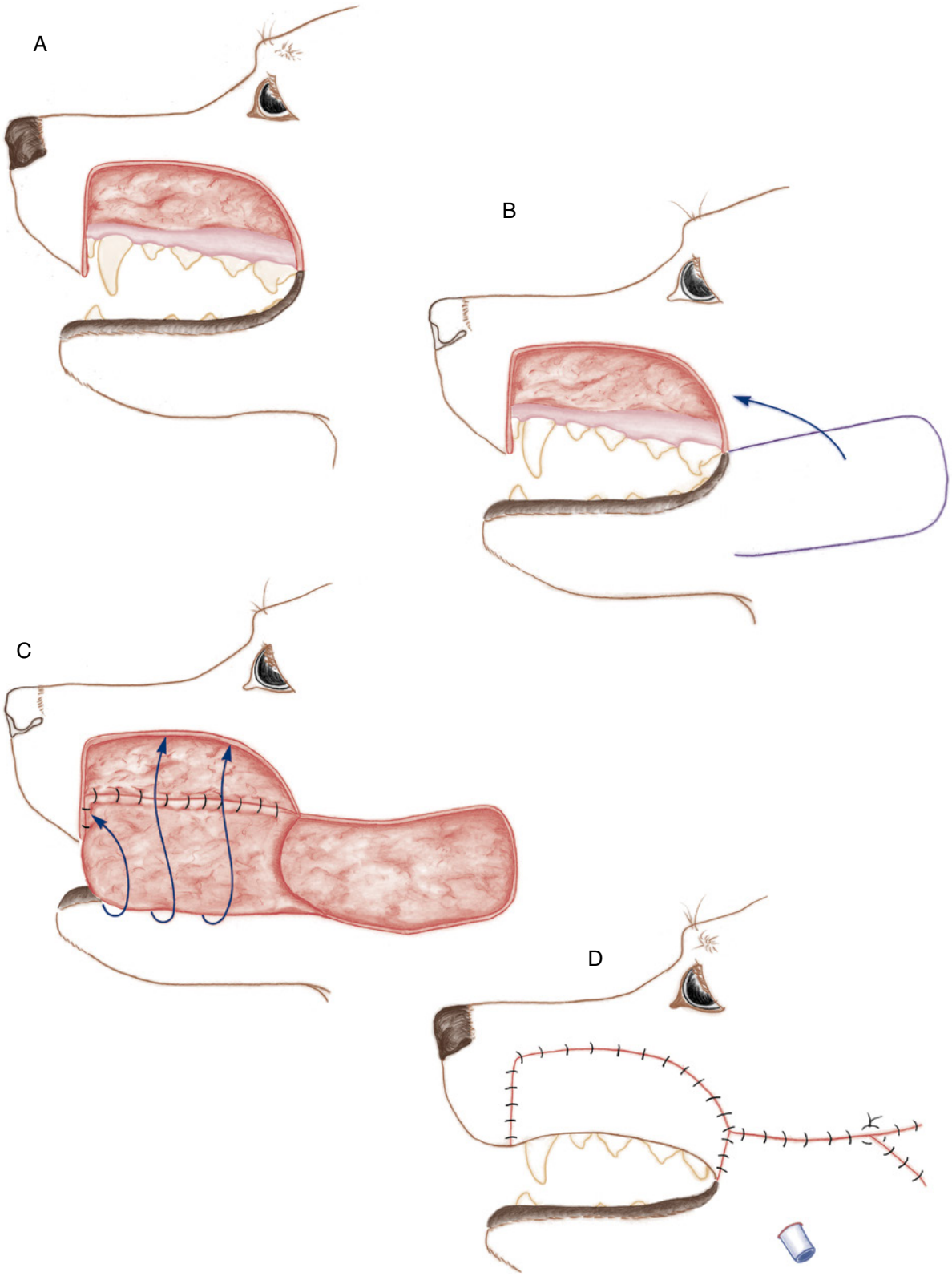
Skin flap replacement of the lip and upper cheek is employed when the surgical defect is too large for the other techniques discussed in this chapter. It can be combined with partial maxillectomy when more extensive tumors are encountered. Flap dimensions can be tailored to the defect based on the general guidelines provided. The skin serves as an adequate replacement for oral mucosa, although use of mucosa is preferable whenever possible. The flap also may be used to close large cutaneous facial defects within its arc of rotation. Yates et al. (2007) confirmed the efficacy of this technique for canine facial reconstruction, identifying the rich vasculature entering the base of this flap, including the angularis oris artery and branches of the superior and inferior labial arteries arising from the facial artery. The terminal end of the flap has collateral support from branches of the transverse facial artery and masseteric artery; these branches are sacrificed during elevation of this flap.

By definition, this skin flap qualifies as an axial pattern flap based on branches of the facial artery (facial axial pattern flap). (See Fig. 15-11).

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Plate 94



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Plate 95

Feline Facial Axial Pattern Flap

DESCRIPTION

A cutaneous branch of the facial artery supplies the area of the angularis oris and lateral facial skin. Like the canine facial axial pattern flap in Plate 94, a lateral facial flap can be elevated for closure of large skin defects within its arc of rotation.

SURGICAL TECHNIQUE

(A) The origin of the facial branch is l cm caudal and ventral to the midpoint of the oral commissure (at the rostral edge of the masseter muscle insertion on the mandible). The base of the flap is located in a dorsoventral line at the rostral edge of the masseter muscle. The ventral flap border is located along the area of the ventral midline, extending caudally. The dorsal border parallels the outlined ventral border, equal to the distance from the vessel's origin. The dorsal border is 1 cm ventral to the zygomatic arch. The flap length is 1 cm caudal to the caudal border of the atlas. A line is drawn, connecting the dorsal and ventral margins.

(B) In this illustration, the flap is elevated for transfer.

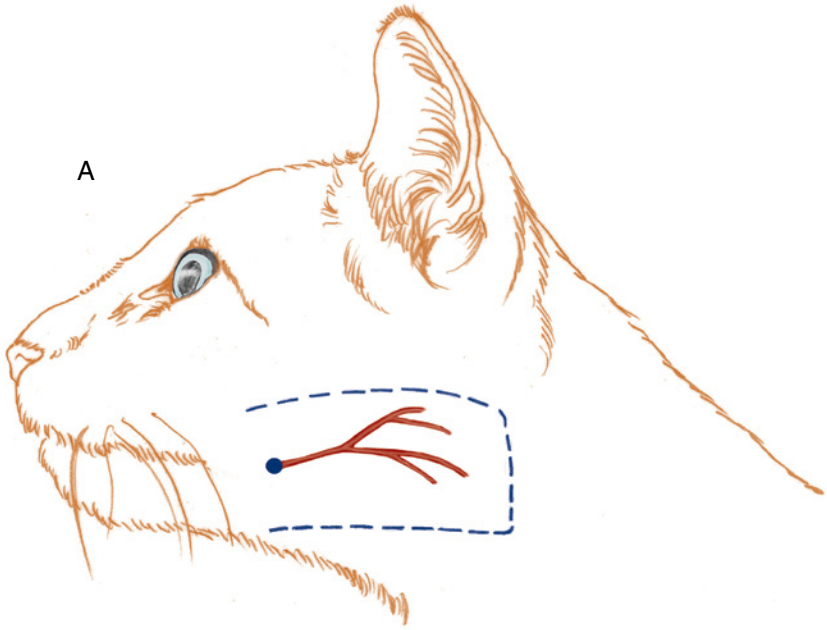
COMMENTS

As noted in Plate 45, the use of this flap and the auricular axial pattern flap for facial/head reconstruction must be compared to using a simpler local transposition flap that could be developed closer to the defect.

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Plate 95





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Plate 96

Cleft Lip Repair (Primary Cleft, Cheiloschisis, Harelip)

DESCRIPTION

A cleft rostral to the incisive foramina and involving the lip is termed *cleft lip*. Cleft lip can vary in depth and severity. Most cases are unilateral. Cosmetic results in the dog depend on accurate tissue apposition in order to maintain facial symmetry, normal pigmentation, and a normal hair growth pattern comparable to the opposite side.

SURGICAL TECHNIQUE

(A) Unilateral cleft palate in a Boston terrier. The opposite half of the nose and the lip serve as anatomic guidelines.

(B) Reflection of lips demonstrating oronasal communication. Malaligned incisors are occasionally present and may require extraction to facilitate closure. A mucosal incision is created (dashed line); 3-0 to 4-0 absorbable sutures are preplaced. When tied, the linear incision is folded in half to close the oronasal communication (arrow).

(C) On closure of the oral cavity from the nasal cavity, the epithelial borders of the labial/nasal cleft are excised.

(D) The labial mucosal surfaces are sutured with 3-0 or 4-0 absorbable sutures. The intermediate layer is closed with buried interrupted sutures in similar fashion. Accurate alignment of the labial border is completed by suturing the mucocutaneous junction, followed by the remaining cutaneous surface, with simple interrupted nonabsorbable sutures. Vertical mattress sutures may be alternated with simple interrupted sutures to offset regional tissue tension.

COMMENTS

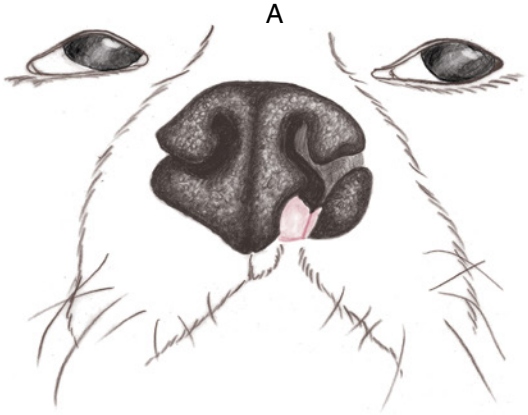
A properly aligned closure will maintain the symmetric curve of each lip, a straight philtrum, and the anatomic relationship of the nasal planum. Atraumatic surgical technique is mandatory for a proper repair. It is the author's experience that the more complex Z-plasty procedures and flap techniques employed in the human (and occasionally noted in the veterinary literature) are completely unnecessary in the dog. The opposite intact rostral labial area serves as a template for alignment and closure of the cleft. There are different cosmetic considerations and anatomic variations between the face of the human and the dog that obviate the necessity of more complicated closure options in most cases. (See Figs 15-23 through 15-26).

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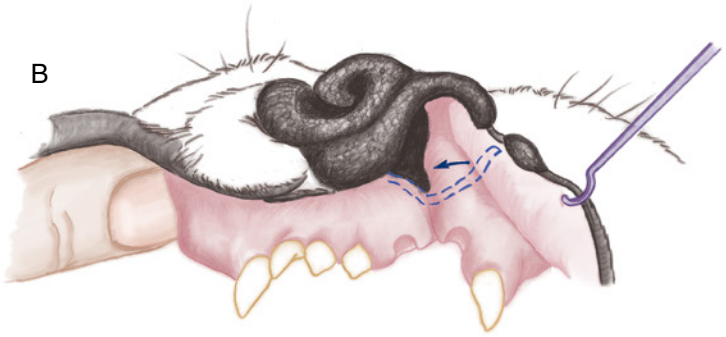
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Plate 96

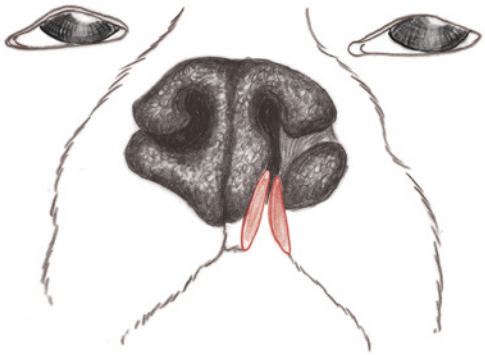
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Plate 97

Unilateral Rostral Labial Pivot Flaps

DESCRIPTION

With resection of the rostral half of the upper lip, closure can be accomplished with a labial advancement flap or the rostral labial pivot flap described in this plate (see Figs 15-17 and 15-18). Selection is determined by regional tissue tension and which technique can more easily restore function with the best cosmetic results.

SURGICAL TECHNIQUE

(A) Neoplasm involving the rostral labial area.
(B) Full-thickness resection is performed.
(C) Following full-thickness resection of the lesion, the lip is rotated and the proper position is determined. The pigmented labial margin in alignment of the philtrum is resected. (Alternatively, the pigmented border can be divided along its margin if its retention would better match regional tissue color.)
(D) The opposing mucosal borders are initially sutured, using 3-0 (slowly absorbable) sutures in a simple interrupted fashion. This is followed by apposition of the cutaneous borders.

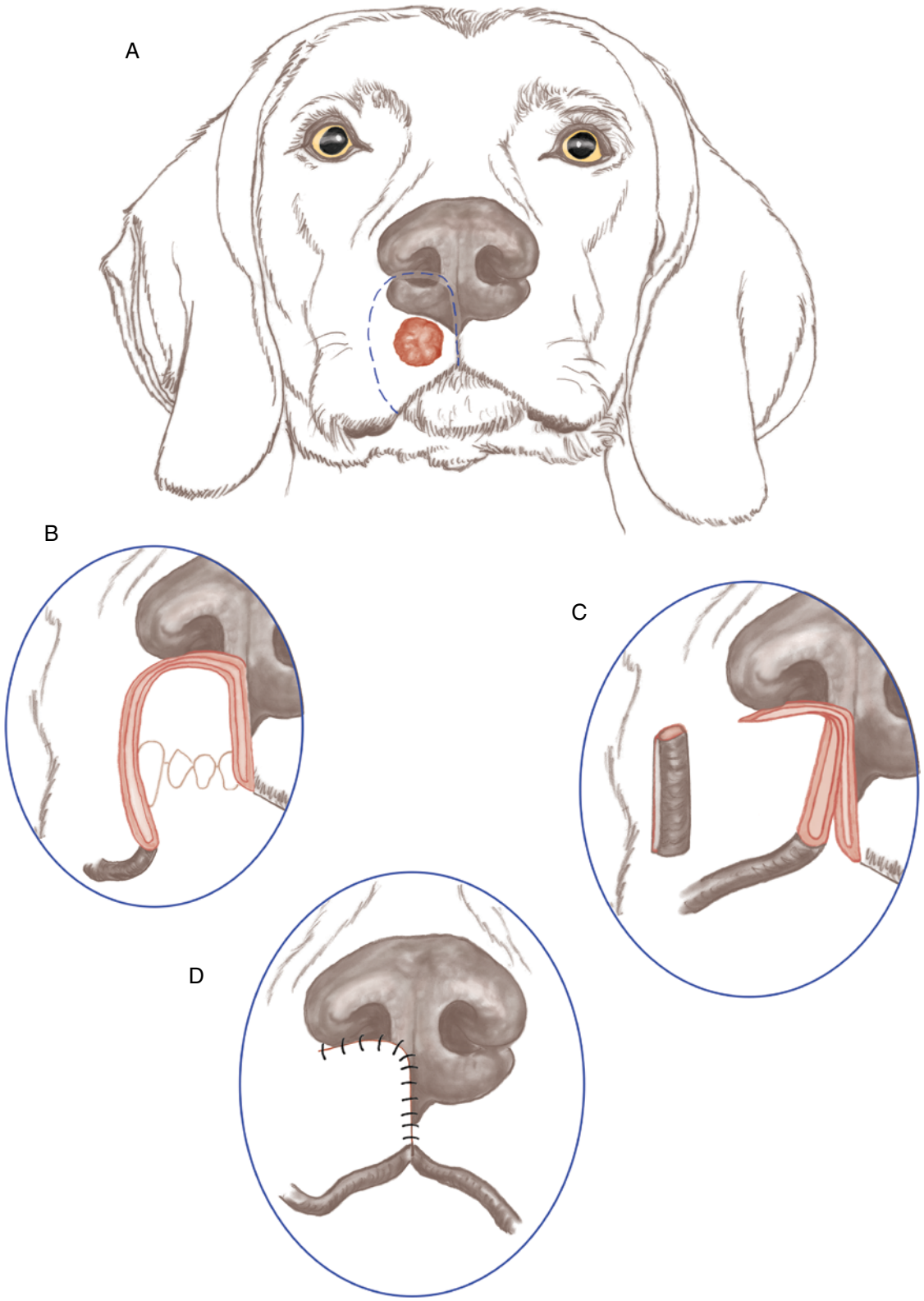
COMMENTS

Cosmetic results are surprisingly good, in large part because this technique results in a more natural curvature of the rostral labial border, matching the opposite half of the intact lip. Like other facial and oral procedures, an appropriate-sized Elizabethan collar should be used to minimize pawing or rubbing at the surgical area postoperatively.

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Plate 97



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Plate 98

Bilateral Rostral Labial Pivot Flaps

DESCRIPTION

With resection of the rostral portion of the upper lip, closure can be accomplished with labial advancement flap(s) or the rostral labial pivot flap(s) described in this plate (see Fig. 15-19). Selection is determined by regional tissue tension and which technique can more easily restore function with reasonable cosmetic results.

SURGICAL TECHNIQUE

(A) Neoplasm involving the rostral labial area.
(B) Following full-thickness resection, the lower margins are rotated dorsally (arrows).
(C) The opposing labial borders are resected in preparation for closure (dashed lines). The length resected will approximate the original length of the rostral lip.
(D) Mucosal borders are sutured, using 3-0 (slowly absorbable) sutures in a simple interrupted fashion. The dorsal labial mucosal border is sutured to the mucosa reflecting off the gingiva, followed by apposition of the opposing labial mucosal margins.
(E) Completion of the closure.

COMMENTS

A single pivot flap (Plate 97) can be used for unilateral defects encroaching on the midline of the upper lip or bilaterally for centrally located defects as noted in this plate.

Like other facial and oral procedures, an appropriate-sized Elizabethan collar should be used to minimize pawing or rubbing at the surgical area postoperatively.

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Plate 98

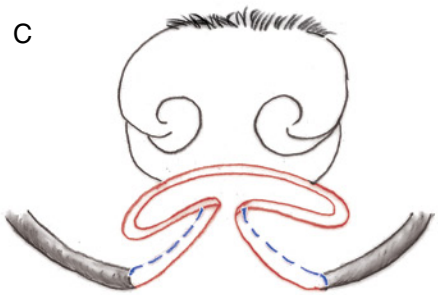
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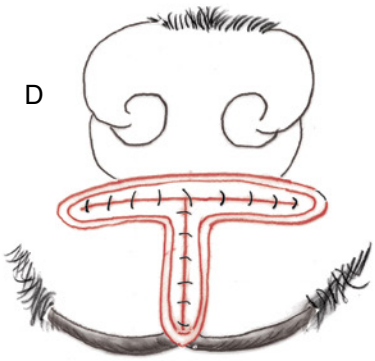
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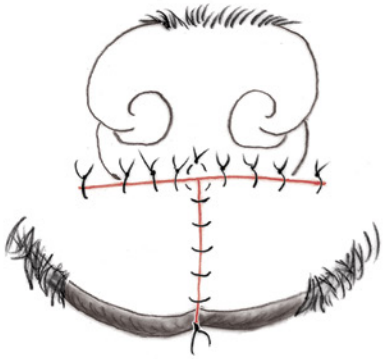
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D



E



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Plate 99

Oral Commissure Advancement (Commissurorraphy) Technique

DESCRIPTION

Oral commissure advancement is occasionally used to maintain the position of the tongue after hemimandibulectomy. It can be performed at the time of hemimandibulectomy or postoperatively as an elective surgery for those patients that would truly benefit from this procedure. It also is occasionally performed *unilaterally* or *bilaterally*, often in older patients with nonunion mandibular fractures secondary to advanced dental disease or trauma.

SURGICAL TECHNIQUE

(A) After hemimandibulectomy, the length and mass of the tongue have caused it to persistently shift out of the oral cavity. The patient may not have adapted to maintaining their tongue primarily in their mouth.

(B) Partial resection of the upper and lower labial margins, including the oral commissure. General guidelines for the length of the excision can be determined by the length of the tongue relative to the length of the labial borders. In general, the caudal one-half to two-thirds of the upper and lower margins may be resected to create adequate lateral support for the tongue. The base of the lingual frenulum (intermandibular attachment) also can be used as a simple anatomic landmark for the length required for commissure advancement to support the tongue.

(C) Closure is accomplished by suturing the upper and lower labial mucosal margins with 3-0 (slowly absorbable) sutures in a simple interrupted pattern.

(D) The skin is closed similarly, using a simple interrupted pattern.

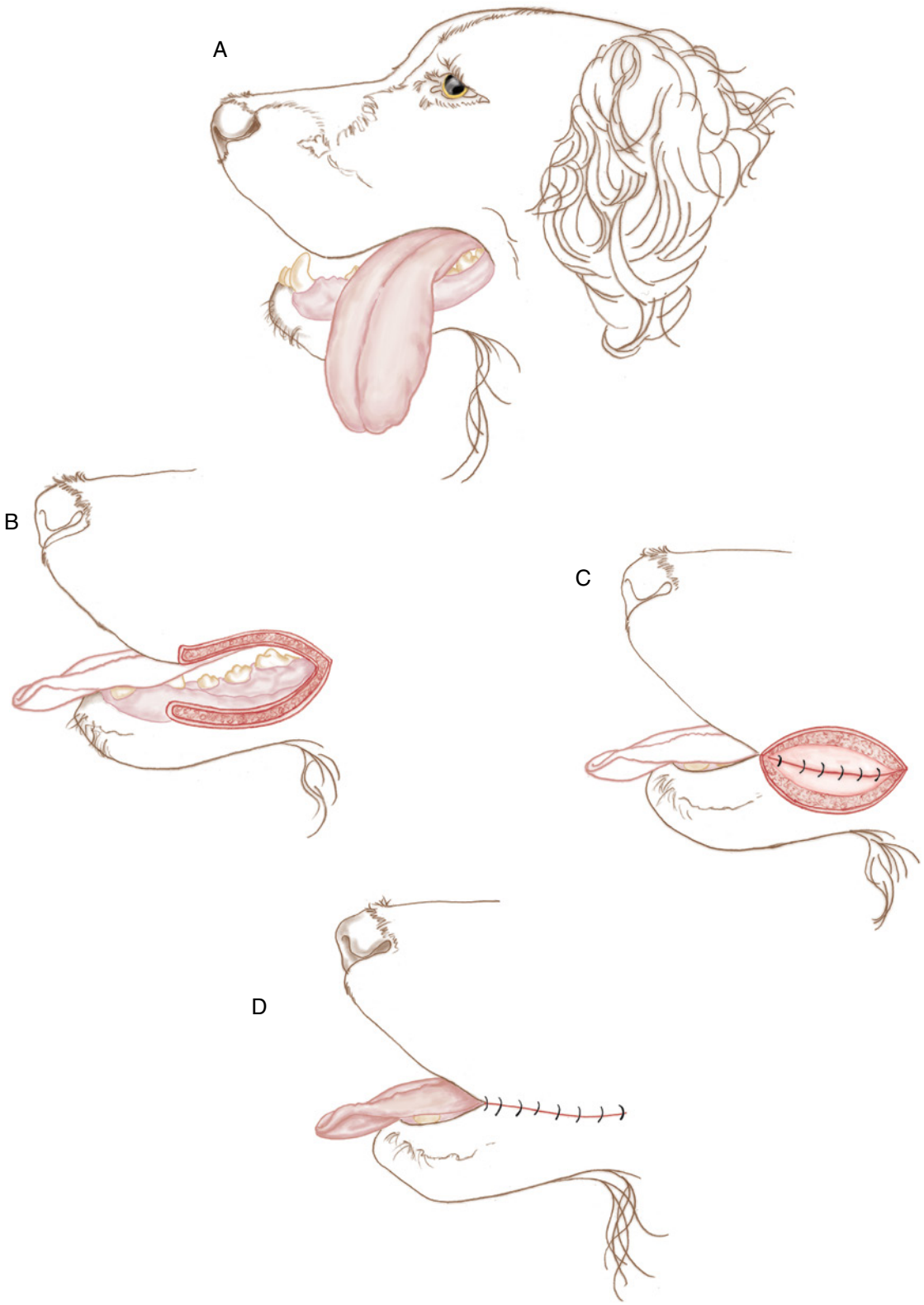
COMMENTS

The dog has the remarkable ability to vary the position of the oral commissure: commissure retraction ("canine smiling") can stretch and expose the length of the upper and lower lips to a surprising degree. The decision on whether or not to include this procedure at the time of hemimandibulectomy is based on the preference of the surgeon. It may be most useful in large dogs, where the overall size of the tongue may predispose them to lingual deviation. As noted, it also is used in older dogs that may have mandibular instability secondary to nonunion mandibular fractures. In the case of bilateral mandibular fractures, oral commissure advancement creates a supportive sling. This improves the comfort of the pet, their cosmetic appearance, and enables the patient to eat and drink more effectively.

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Plate 99



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Plate 100

Brachycephalic Facial Fold Correction

DESCRIPTION

Brachycephalic dogs normally have one major facial fold; there can be a notably smaller facial fold rostral to the larger fold, adjacent to the dorsal nasal surface. The largest fold may uniformly cross the face or flatten to a variable degree over the mid-dorsal nasal surface. The rostral "trough" or "valley" of the large skin fold occasionally is the location of dermatitis (intertrigo). Surgery focuses on removal of this trough and the lower, rostral portion of the largest skin fold. (See Fig. 15-30).

There are occasions where the "ridge" of the larger skin fold and fur will rub on the patient's eyes, causing corneal irritation or ulceration. Surgical removal of a portion of the ridge can eliminate contact with the eye. This also can be accomplished by removing the rostral trough and a portion of the adjacent ridge. On incisional closure, the resultant linear scar is recessed in the trough or valley for a satisfactory functional and cosmetic outcome. (See Fig. 15-31).

SURGICAL TECHNIQUE

(A) In this example, the patient has a prominent facial fold. There is a pyoderma involving the rostral trough of this large fold of skin.

(B) Elevation of the rostral surface of the fold, exposing the infected intertriginous zone. The dashed line represents the location for surgical resection of the tissue. (*Note*: the infected skin overlying the muzzle can be fibrotic, and its resection can be problematic.) A scalpel blade may be needed to tangentially "shave" or resect the skin surface in preparation for closure. (Electrocautery is needed to control the multiple small bleeding vessels when resecting chronic inflammatory tissue.)

(C) Completion of the closure. The major fold of skin is partially preserved, maintaining the normal appearance of the dog. The scar is less conspicuous, residing in the depression between the two skin folds.

COMMENTS

Various textbook illustrations have suggested complete removal of the problematic skin fold. This has the unfortunate result of dramatically changing the facial appearance of the pet. It also is unnecessary: the reduction technique described here effectively corrects the two problems occasionally noted with prominent facial folds (intertrigo and corneal irritation) and better conceals the surgical scar.

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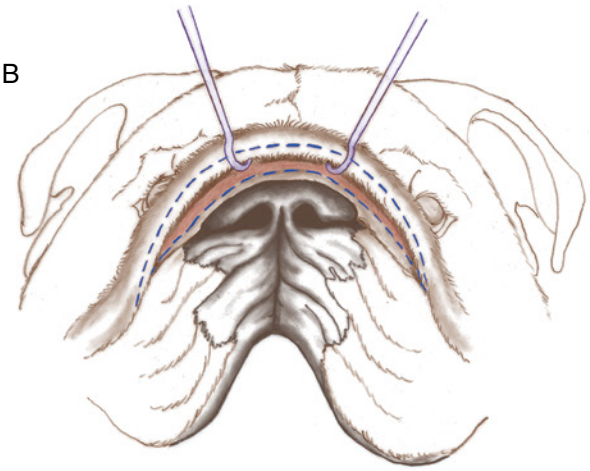
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Plate 100

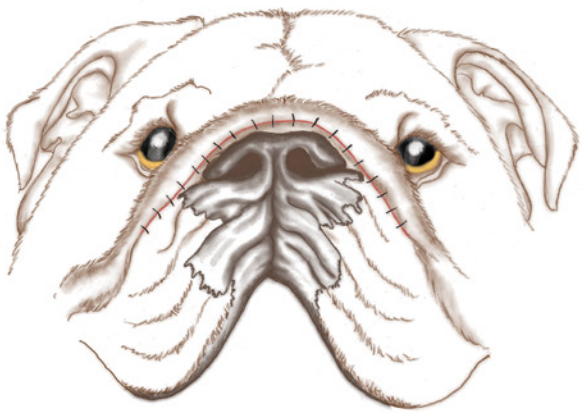
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Plate 101

Upper Labial Flap Reconstruction of Nasocutaneous Fistulas

DESCRIPTION

Loss of the nasal bone and the overlying skin can be seen secondary to trauma, infection, radiation therapy, or tumor resection. Closure of the nasal bone defect with skin alone is commonly performed successfully. Success, however, is dependent on the eventual coverage of the exposed dermis by the adjacent mucosa covering the nasal cavity. If this process fails over time, the exposed dermis is subject to chronic inflammation and bacterial proliferation that degrade the overlying skin. Repeated attempts at closure of the nasocutaneous fistula, with skin alone, is doomed to failure over time. In this situation, the full-thickness labial flap option is highly effective in resolving the nasocutaneous fistula by providing oral mucosa as a substitute for the loss of nasal mucosa. The oral mucosa forms the protective epithelial barrier needed to protect the overlying cutaneous surface from the contaminants of the nasal cavity.

SURGICAL TECHNIQUE

(A) Nasocutaneous fistula in the lateral facial area. Outline of the full-thickness labial flap.

(B) The skin and bony margin of the nasocutaneous fistula are debrided back to healthy tissue. The measured full-thickness labial flap is elevated as a transposition flap by design. The narrow segment of skin, interposed between the flap and nasocutaneous fistula, is resected. An incision is made in the flap mucosa perpendicularly, corresponding to the relative diameter of the nasocutaneous fistula. (Note that the pigmented labial border is resected.)

(C) The flap is sutured into place. Note that the rostral lip margin is advanced caudally and sutured to the adjacent margin of the flap (mucosal closure followed by skin approximation).

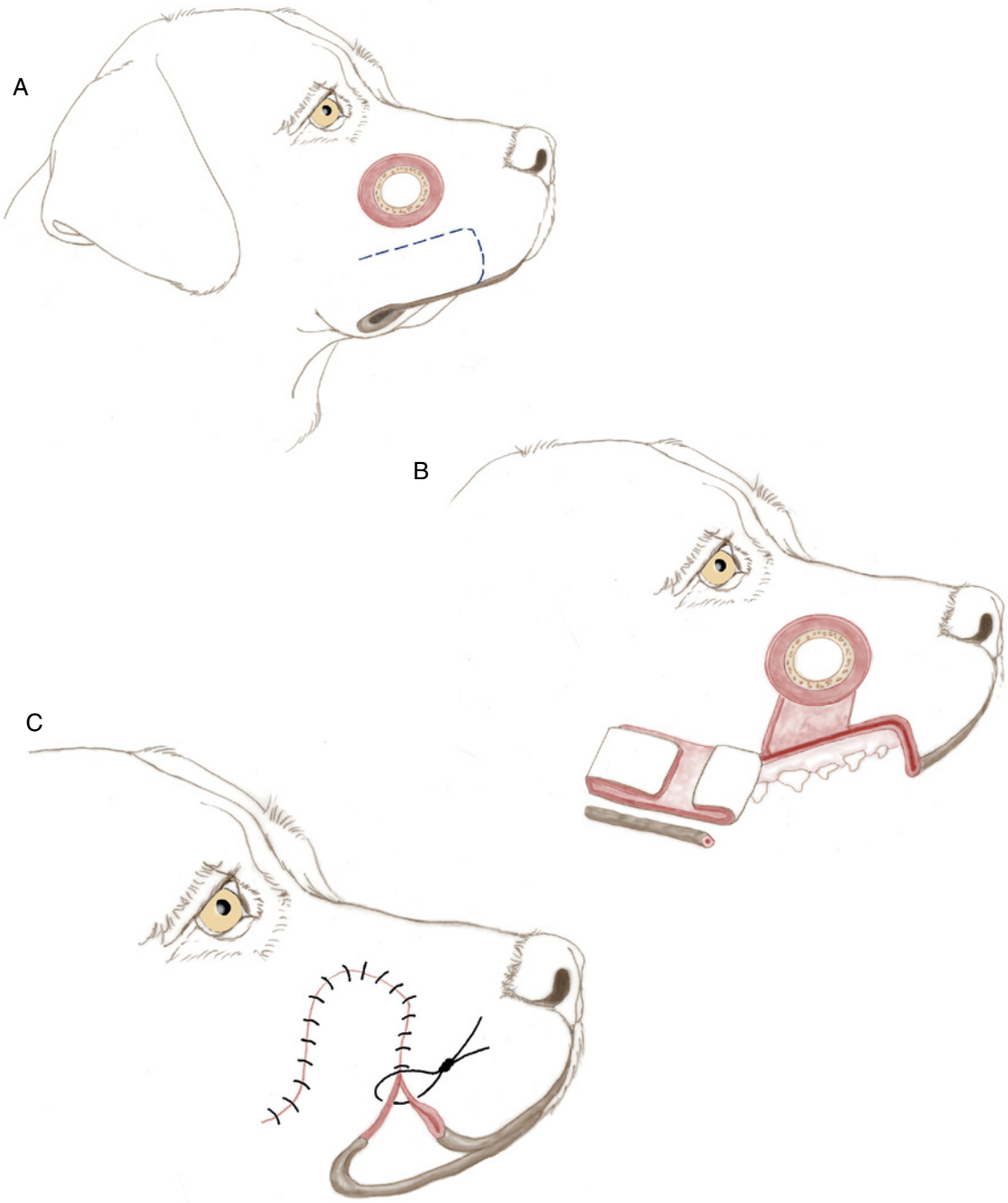
COMMENTS

There is an old adage in surgery that "no healing is complete until the epithelial, endothelial, and mesothelial surfaces are restored." In this procedure, the labial mucosa of the flap closes the intranasal mucosal defect while providing protection to the overlying musculofascial layer and skin of this pedicle graft. Results to date have been excellent in permanently closing problematic nasocutaneous fistulas. (See Figs 15-32 through 15-34).

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Plate 101



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Plate 102

Full-Thickness Lower Labial Transposition Flap

DESCRIPTION

The lower lip in the dog tapers in a rostral direction, but there is sufficient width in the caudal half of the lower lip for labial flap development. In this example, the full-thickness lower labial flap is rotated dorsally to reconstruct an adjacent upper labial defect and oral commissure area.

SURGICAL TECHNIQUE

(A) Outline of the full-thickness lower labial flap to close the outlined full-thickness upper labial resection.
(B) Elevation of the lower labial flap. Resection of the pigment labial border prior to closure (insert).
(C) Transposition of the lower labial flap into the upper labial defect (upper arrow). The donor defect is closed by elevation of the skin to the gingival margin (lower arrow).

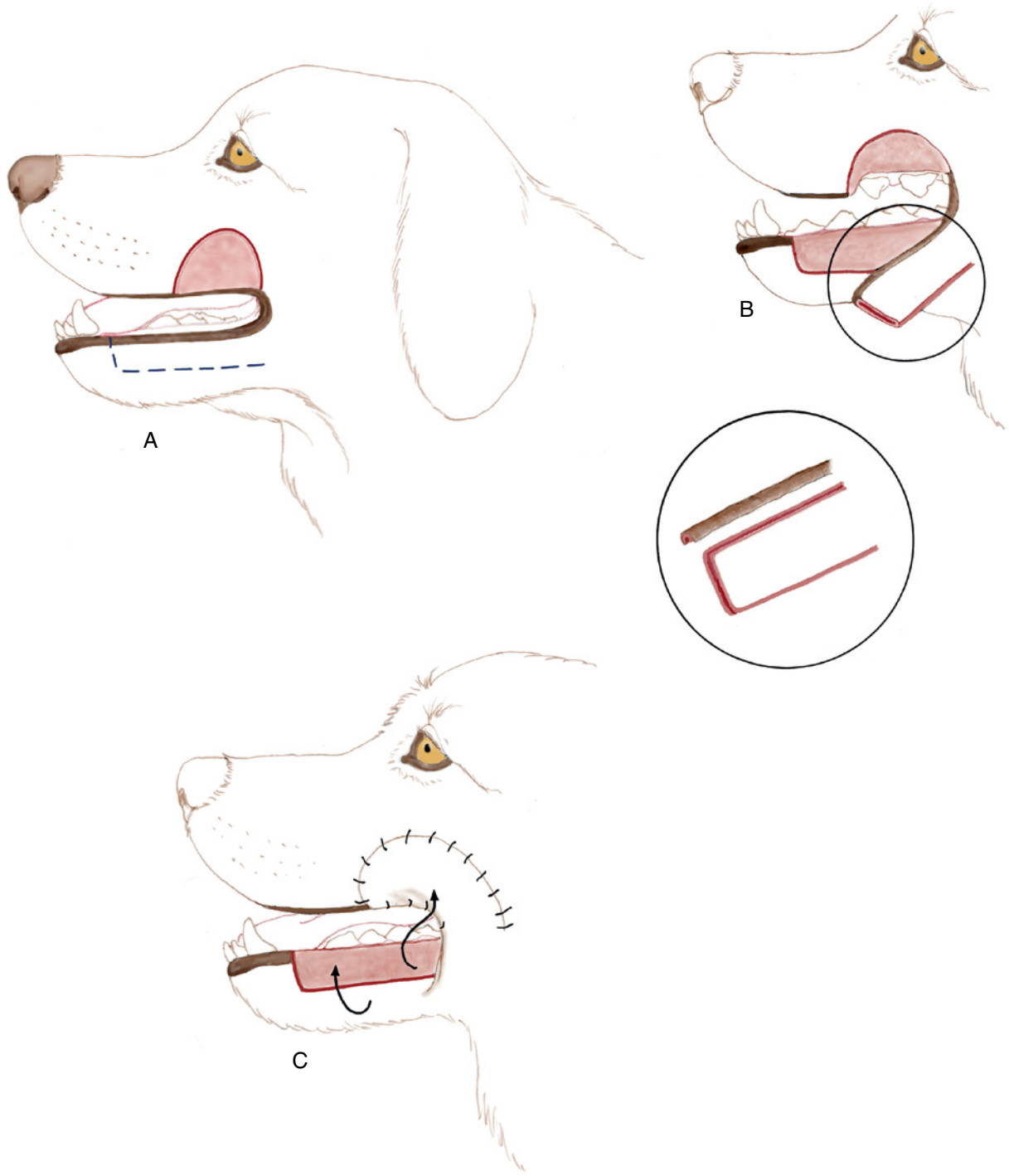
COMMENTS

This flap is uncommonly used in reconstructive surgery, although it is potentially available for that unusual facial defect if encountered.

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Plate 102



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Plate 103

Cheilopexy Technique for Drooling

DESCRIPTION

This technique, described by Stoll (1975), can be used to reduce excessive drooling in larger dogs possessing redundant labial tissue. It is a simple linear "labial pexy" of the lower labial border to the upper labial/buccal mucosal area. As a result, it lifts the lower lip, thereby creating a more effective lower labial retention barrier as saliva accumulates. In turn, the dog can swallow the saliva rather than constantly drooling on the neighboring environment.

SURGICAL TECHNIQUE

(A) The lower labial border can be assessed with the patient under anesthesia. Forceps are used to grasp the caudal aspect of the lower lip and elevate it dorsally, to get a general idea of where to create the *cheilopexy*. The mouth is opened to ensure that range of motion is reasonably preserved and excessive tension is avoided after completing the cheilopexy.

To facilitate locating the appropriate site, a line can be drawn from the medial canthus to the oral commissure (dashed line). A full-thickness labial incision is initiated immediately cranial to this guideline: the incision is 3–5 cm dorsal to the upper labial border. This incision itself is 2–4 cm long and is parallel to the labial margin. A comparable incision is made in the lower labial margin below the upper labial/buccal incision (arrow). This incision is dissected open to facilitate suturing; alternatively, a scalpel blade can be used to resect the immediate labial border. A skin hook or long-handled forceps can be used to lift the lower labial incision through the full-thickness upper labial incision.

(B) The mucosal incision of the lower lip is sutured to the labial mucosal border of the dorsal labial incision with a series of interrupted (slowly absorbable) 3-0 sutures. Large suture bites help ensure adequate security of this cheilopexy.

(C) After suturing the two mucosal incisions together, the dorsal skin incision is sutured to complete the procedure.

COMMENTS

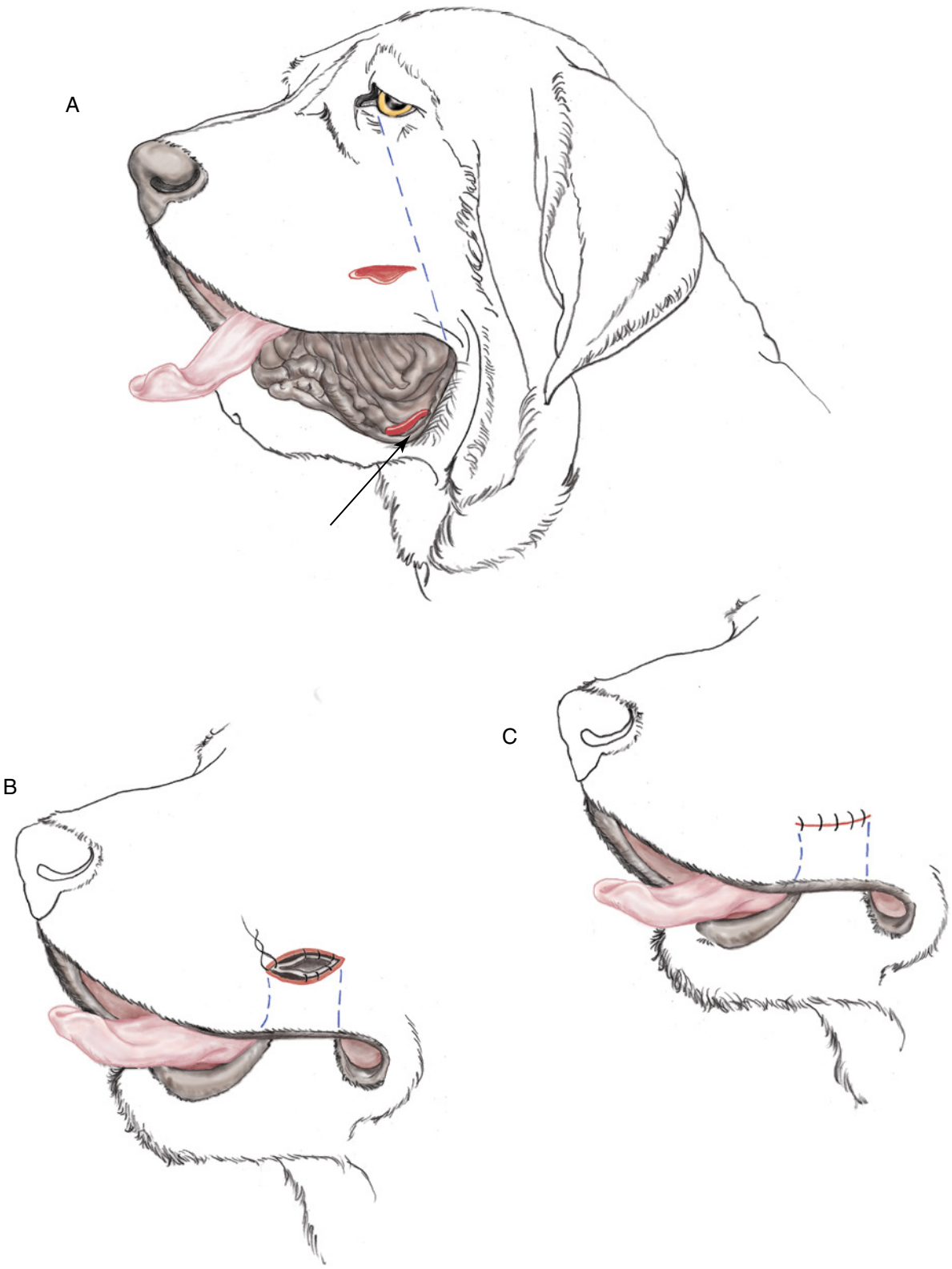
Properly positioned, this suture closure should maintain the cheilopexy until healing is complete. Only the skin sutures require removal. More elaborate mattress suture techniques are noted in the veterinary literature and also are acceptable. Postoperatively, wrinkling of the cheek may be noted, but normally flattens over time. Local dermatitis of the lower labial skin overlapped by the upper labial mucosa appears not to be a serious problem in these patients. Should there any problem with the cheilopexy, reversal of this procedure would be easy to perform.

Few owners generally elect to have this surgery performed for two reasons: many owners are not aware of this technique, and owners of these dogs generally accept the unhygienic drooling as a normal part of owning a particular breed (St. Bernard, mastiff, Newfoundland, etc.). It may be the first-time owner, unpleasantly surprised by this problem, who is more receptive to a discussion of corrective cheilopexy by the attending veterinarian. (See Figure 15-35.)

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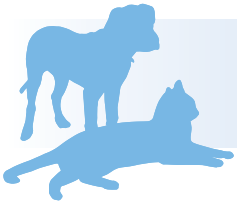
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Plate 103



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16

Myocutaneous Flaps and Muscle Flaps

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Myocutaneous Flaps *630*

Muscle Flaps *630*

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INTRODUCTION

Myocutaneous (musculocutaneous) flaps are flaps in which a skeletal muscle and the overlying skin are elevated simultaneously. In humans, the intact muscle circulation supplies blood to the skin through musculocutaneous arteries exiting the muscle surface. In dogs and cats, direct cutaneous arteries exit the muscle to supply the overlying skin.

Muscle flaps and, to a lesser degree, myocutaneous flaps have clinical potential in small animal reconstructive surgery. Several individual muscles in the dog and cat are expendable without sacrificing regional function. These same muscles could be pivoted into an adjacent defect tethered by a vascular pedicle capable of maintaining circulation to the muscle unit using basic surgical instrumentation. Muscular/fascial flaps have been advocated for perineal hernia repair, soft tissue coverage, and wound closure; and for contributing circulation to fractures, promoting bone healing, and combating infection. Muscle–tendon units can be transplanted to replace essential muscle units that have been damaged or destroyed.

Myocutaneous flaps have enjoyed considerable popularity in human reconstructive surgery because of their versatility and potential ability to transfer large skin segments in a single-stage procedure. The limited amounts of loose skin available and the limited number of direct cutaneous arteries have supported the need for myocutaneous flap transfer in humans. In contrast, the dog and cat have considerable amounts of loose skin located over the trunk and a number of direct cutaneous arteries are present for axial pattern flap development. In most cases, local flaps, axial pattern flaps, and free grafts can be used without resorting to myocutaneous flaps and the more demanding microvascular surgery occasionally used in humans to transfer them to distant locations.

MYOCUTANEOUS FLAPS

Development of a myocutaneous flap in the dog requires the presence of direct cutaneous arteries exiting the muscle surface to supply the overlying skin. Secondary myocutaneous flaps have been investigated experimentally in dogs by suturing skin onto an underlying muscle, which is later elevated and transferred to the recipient site once circulation has been established between the muscle and the skin "island." These secondary myocutaneous flaps have the major disadvantage of requiring two-stage development and transfer.

The more superficial muscles in the body are best used for myocutaneous flap development. A vascular pedicle sufficient to maintain circulation is required to facilitate rotation of a muscle into potential defects within the arc of rotation. Free flap transfer using microvascular surgical technique would enable myocutaneous flap placement to distant locations, although there are far simpler techniques to close wounds in most clinical cases.

MUSCLE FLAPS

Individual skeletal muscles can be used to repair body defects beneath the skin secondary to trauma or the surgical removal of damaged or diseased tissue. Muscle–tendon units have been transposed to treat paralysis of the extensors of the carpus (radial nerve) and tarsus (peroneal nerve). The author was the first to develop and report on the effective use of the latissimus dorsi muscle flap for thoracic wall reconstruction; it also has been used to replace the function of the triceps muscle in a dog by the author (see later in this chapter). One older study (Fujita et al. 1987) used the latissimus dorsi muscle to repair tracheal defects in experimental dogs. Other muscles have been used for hernia repair, including transversus abdominis muscle for closure of diaphragmatic hernias; external abdominal oblique muscle for abdominal hernia repair; internal obturator and superficial gluteal muscles for perineal hernia repair; temporalis muscle flap for facial defects involving the canine orbit; rectus femoris and cranial sartorius muscle flaps for trochanteric ulcers; semitendinosus muscle flaps and superficial gluteal muscle flaps for ventral perineal hernia repair and for creation of an anal sling; internal obturator and semitendinosus muscle flaps for rectal wall repair or reinforcement; and diaphragmatic muscle flaps for distal esophageal defects. Flaps composed of intercostal muscle, diaphragm, sternocephalicus muscle, and sternohyoideus and sternothyroideus muscle have been used to correct strictures and defects of the maxilla and esophagus. The canine rectus abdominis muscle flap has been described for use in the closure of prepubic tendon rupture, diaphragmatic hernia repair, and urinary bladder/urethral defects in dogs. The author has also used the sternothyroideus muscle for closure of entry and exit bullet wounds of the canine larynx (Fig. 16-1). In another case, a sternectomy was performed to remove an osteosarcoma: the author mobilized the left and right pectoral muscle and apposed their borders to close the surgical defect (Fig. 16-2). Muscle/fascia strips from the biceps femoris or deep gluteal muscle have been used as padding between the pelvis and femoral shaft after femoral head and neck ostectomy. The tibialis cranialis and

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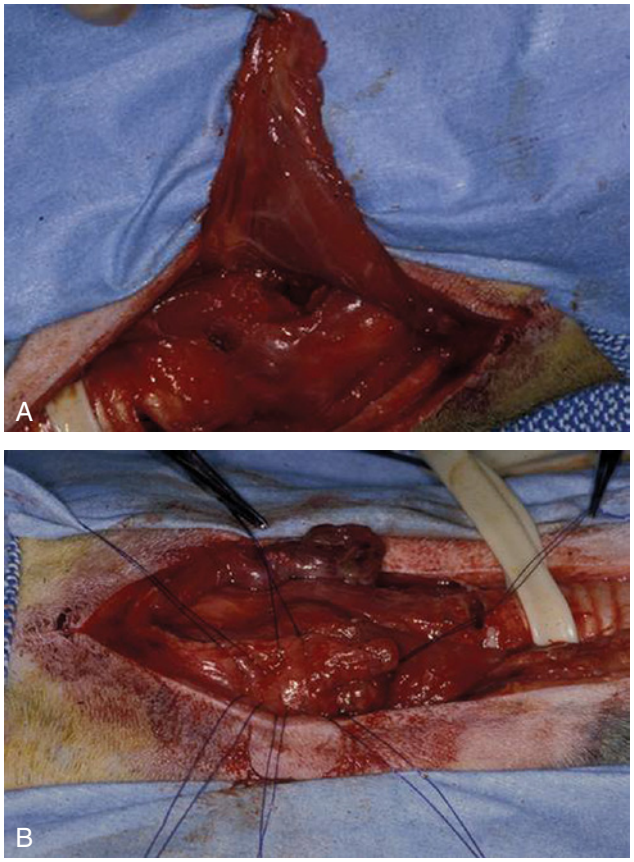


FIG. 16-1 (A) Elevation and (B) placement of the sternohyoideus muscle to close entry/entry wounds from a handgun round that struck the larynx. Although the procedure was successful, damage to the cartilage eventually resulted in partial collapse of the laryngeal opening. A permanent tracheostomy was successfully performed on this canine patient.

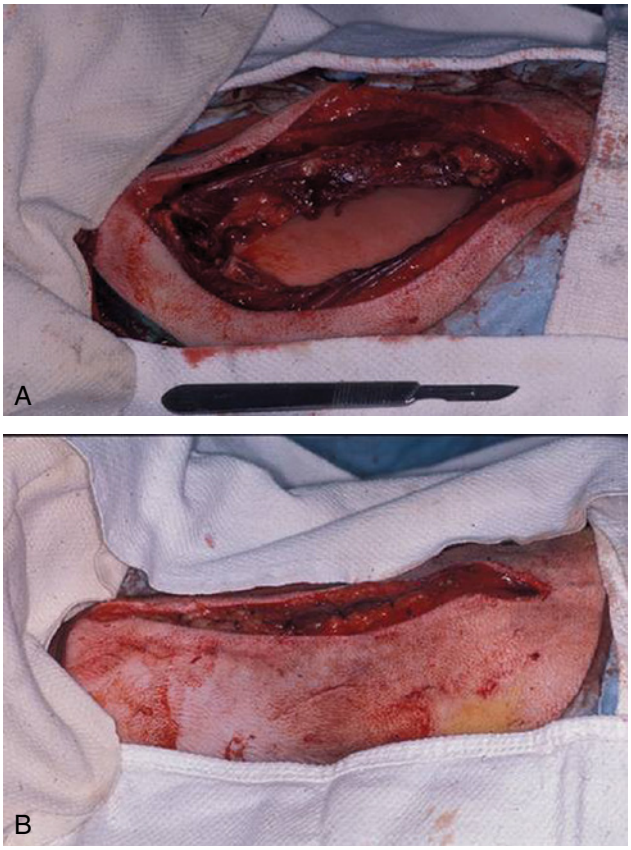


FIG. 16-2 (A) Resection of the sternum as a result of osteosarcoma. (B) The pectoral muscles were mobilized and apposed over the sternal defect successfully.

cranial border of the lateral head of the gastrocnemius can be used for defects of the crus and adjacent tibial area. Muscle flaps also can be used as a platform for free graft application. Muscles are capable of contributing additional circulation to ischemic areas that are the result of trauma, poor collateral circulation, or radiation damage. Many of the muscle flaps in the veterinary literature have limited clinical application in small animal surgery. This chapter will emphasize those techniques considered to be the most useful.

"Go-to" Muscle Flaps

The muscle flaps that the author most commonly uses involve reconstruction of the thoracic and abdominal walls, including the latissimus dorsi, external abdominal oblique, and cranial sartorius muscle flaps. The internal obturator muscle flap is highly effective for closure of perineal hernias.

Muscle Flap Circulation and Classification

Individual muscles in the body have different vascular supplies. Mathes and Nahai (1982) have developed a classification system for muscles based on their vascular anatomy. There are five major vascular patterns for muscles (Fig. 16-3).

Preservation of muscle function and bulk will depend on preservation of the blood supply as well as muscle innervation. The term *angiosome* describes a block of tissue (muscle or a given region, including bone, skin, fascia, etc.) that is supplied by a regional artery and vein (venae comitantes). Within a given muscle, there may be various angiosomes that are based on vessels supplying these specific areas. *True vascular anastomoses* within the muscle occur when a major artery connects with another without changing caliber. *Choke anastomoses* are the most common, and this term refers to areas where arteries unite by means of a plexus of two or more reduced-caliber arteries (arterioles). As the terminology denotes, blood flow is somewhat more restricted through

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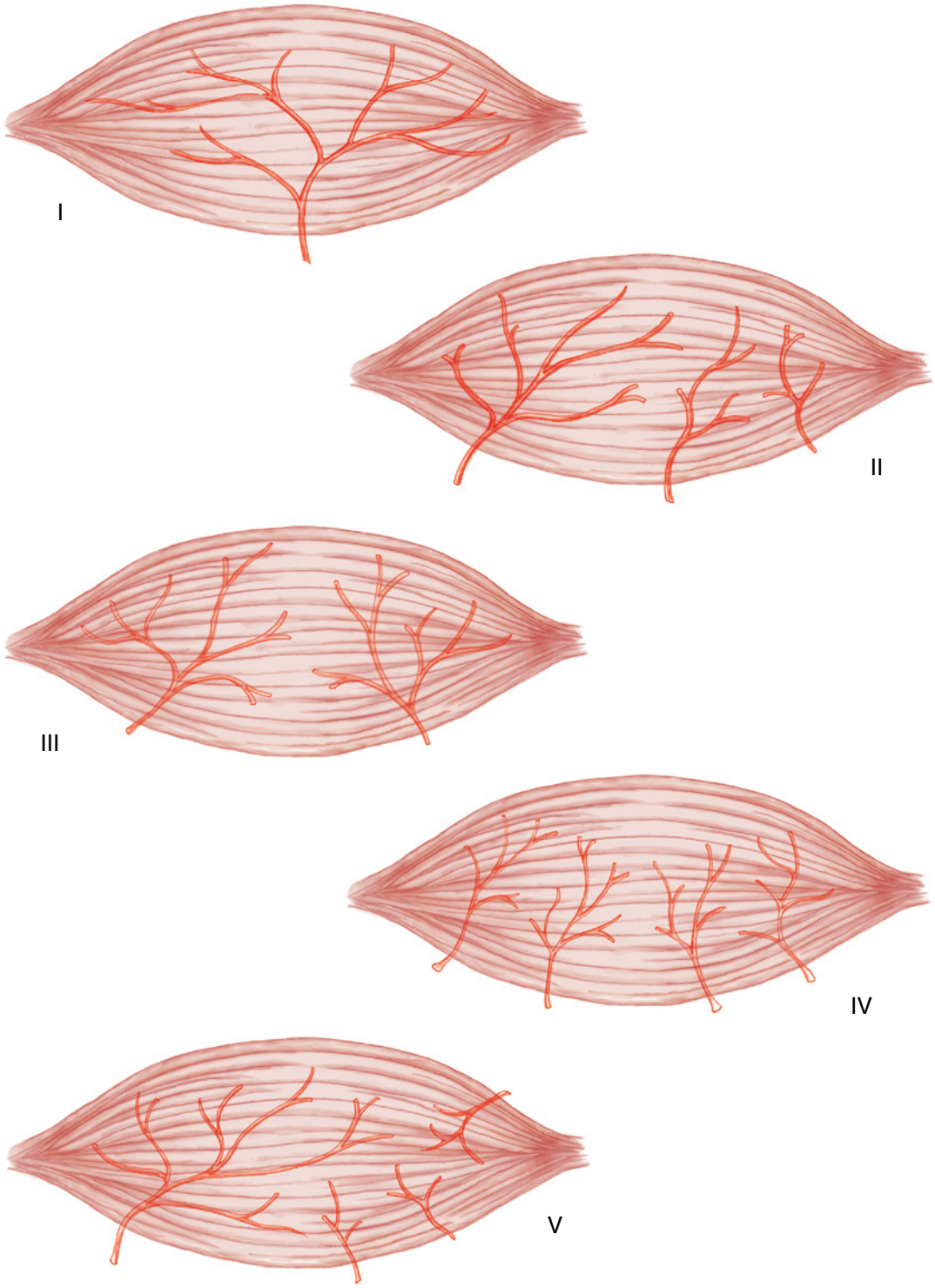


FIG. 16-3 Illustration of type I–V muscles based on their circulatory patterns. *Type I*: one vascular pedicle. Type I muscles can be elevated and pivoted on their dominant pedicle. Example: rectus femoris muscle based on the lateral circumflex femoral vessels. *Type II*: dominant vascular pedicle(s) near the origin *or* insertion of the muscle, with minor pedicle supplying the muscle belly. Type II muscles are likely to survive despite ligation of the minor pedicles during elevation of the muscle, based on the dominant vascular pedicle. Example: cranial sartorius muscle, based on the superficial circumflex iliac vessels. *Type III*: two dominant pedicles, supplying approximately half the muscle belly. Division of one vascular pedicle may or may not compromise that portion of the muscle supplied by the ligated pedicle; research is required to determine the viability of individual muscles in this category. Example: rectus femoris muscle based on the caudal gluteal artery and vein proximally and the distal caudal femoral artery distally. *Type IV*: smaller segmental vascular pedicles supplying the muscle between the origin and the insertion. Survival may be inconsistent, depending on the vascular pedicles ligated; research is required to determine the viability of individual muscles in this category. Example: caudal sartorius muscle based on a branch of the saphenous artery and medial saphenous vein. *Type V*: one dominant vascular pedicle located at the insertion of the muscle, with segmental pedicles entering near the origin. The entire muscle is expected to survive based on the dominant pedicle. Muscle survival, based on the segmental vascular pedicles alone, is questionable and would require research to determine the individual viability of a type V muscle. Example: latissimus dorsi myocutaneous flap based on the thoracodorsal artery and vein.

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choke anastomoses. For example, the angiosome adjacent to a dominant pedicle is likely to survive after ligation of its segmental blood supply via collateral circulation passing through choke anastomoses. Sacrifice of the segmental blood supply to more distant angiosomes of a muscle is more likely to result in muscle necrosis: perfusion through the more distant choke anastomoses becomes increasingly tenuous. However, for reliable clinical transfer, research is needed to confirm muscle flap survival after sacrificing selected vascular pedicles. In one feline study, delayed type IV sartorius muscle flaps had a greater survival length compared to the opposite control. Delayed transfer may have merit in those muscle flaps considered at risk of partial circulatory compromise and necrosis.

Fifteen muscle flaps for clinical use will be discussed in this chapter: the latissimus dorsi muscle, cutaneous trunci muscle, external abdominal oblique muscle, cranial sartorius muscle, caudal sartorius muscle, temporalis muscle, flexor carpi ulnaris muscle, semitendinosus muscle, transversus abdominis muscle, internal obturator muscle, superficial gluteal muscle, deep pectoral muscle, gastrocnemius muscle, rectus abdominis muscle, and sternocephalicus muscle.

Latissimus Dorsi Muscle

The latissimus dorsi muscle is a flat triangular muscle overlying the dorsal half of the lateral thoracic wall in the dog; it is the broadest of the skeletal muscles, with the exception of the cutaneous trunci muscle. It begins as a wide tendinous leaf from the superficial leaf of the lumbodorsal fascia associated with the spinous processes of the lumbar vertebrae and the last seven or eight thoracic vertebrae. It arises muscularly from the last two or three ribs. Muscle fibers converge toward the shoulder, and the cranial border of the muscle lies under the trapezius thoracis muscle, where it covers the caudal angle at the scapula. The apical end of the muscle encroaches on the dorsal border of the deep pectoral muscle, ending in an aponeurosis medially on the triceps muscle.

The thoracodorsal and lateral thoracic arteries supply the dorsal and ventral portions of the latissimus dorsi muscle. Branches of these vessels emerge from the muscle surface to supply a portion of the cutaneous trunci muscle and the skin as short, direct cutaneous arteries. The thoracodorsal artery also sends a large direct cutaneous artery to the skin dorsally caudal to the scapula. This vessel joins the skin after passing through the craniodorsal portion of the latissimus dorsi muscle, caudal to the long head of the triceps muscle.

The intercostal arteries also supply segmental branches to the dorsal portion of the latissimus dorsi muscle and overlying cutaneous trunci muscle. These branches perforate the latissimus dorsi muscle to supply the cutaneous trunci muscle and overlying skin as the proximal lateral cutaneous branches of the intercostal arteries. The distal lateral cutaneous branches of the intercostal arteries emerge below the ventral border of the latissimus dorsi muscle to supply the regional overlying skin.

There are two variations of the latissimus dorsi muscle flap: the single-pedicle muscle flap (Fig. 16-4) and the bipedicle flap variation (Figs 16-5 and 16-6). (See Plates 106 and 107).

> The latissimus dorsi muscle flap, reported by the author for use in thoracic wall reconstruction in 1990, is the most versatile of the flap procedures in veterinary surgery. It has also been used successfully to replace the triceps muscle function in a dog (see Plate 108 and Fig. 16-7).

Cutaneous Trunci Muscle

The cutaneous trunci muscle is a derivative of the pectoralis profundus and forms a thin leaf covering most of the dorsal, lateral, and ventral walls of the abdomen in the dog. It begins in the caudal gluteal region, with muscle fibers fanning cranially and ventrally. It ends in the axilla, where it is closely associated with the underlying latissimus dorsi muscle and the caudal border of the deep pectoral muscle. The cutaneous trunci muscle causes the skin to shiver in response to external irritants over the trunk. Circulation to the cutaneous trunci muscle is from small muscular branches and direct cutaneous arteries supplying the overlying skin. Anatomic studies demonstrated that two to four short, direct, cutaneous branches of the thoracodorsal artery perforate the latissimus dorsi muscle caudal to the border of the triceps muscle and supply the cutaneous trunci and overlying skin. The subdermal plexus of the skin is closely associated with the cutaneous trunci muscles. Surgically elevating the skin and panniculus musculature together, by undermining below this muscle layer, helps preserve their circulatory relationship (Plate 105).

External Abdominal Oblique Muscle

The external abdominal oblique muscle is a long, flat muscle with fibers directed caudoventrally. It consists of costal and lumbar components. The costal component originates segmentally from the fourth or fifth rib through the thirteenth rib. The lumbar component originates in the thoracolumbar fascia along the iliocostalis muscle. Ventrally and caudally, the aponeuroses of the two components contribute to the external rectus fascia, the external inguinal ring, and the prepubic tendon. The cranial branch of the cranial abdominal artery supplies the middle zone of the lateral abdominal wall and is

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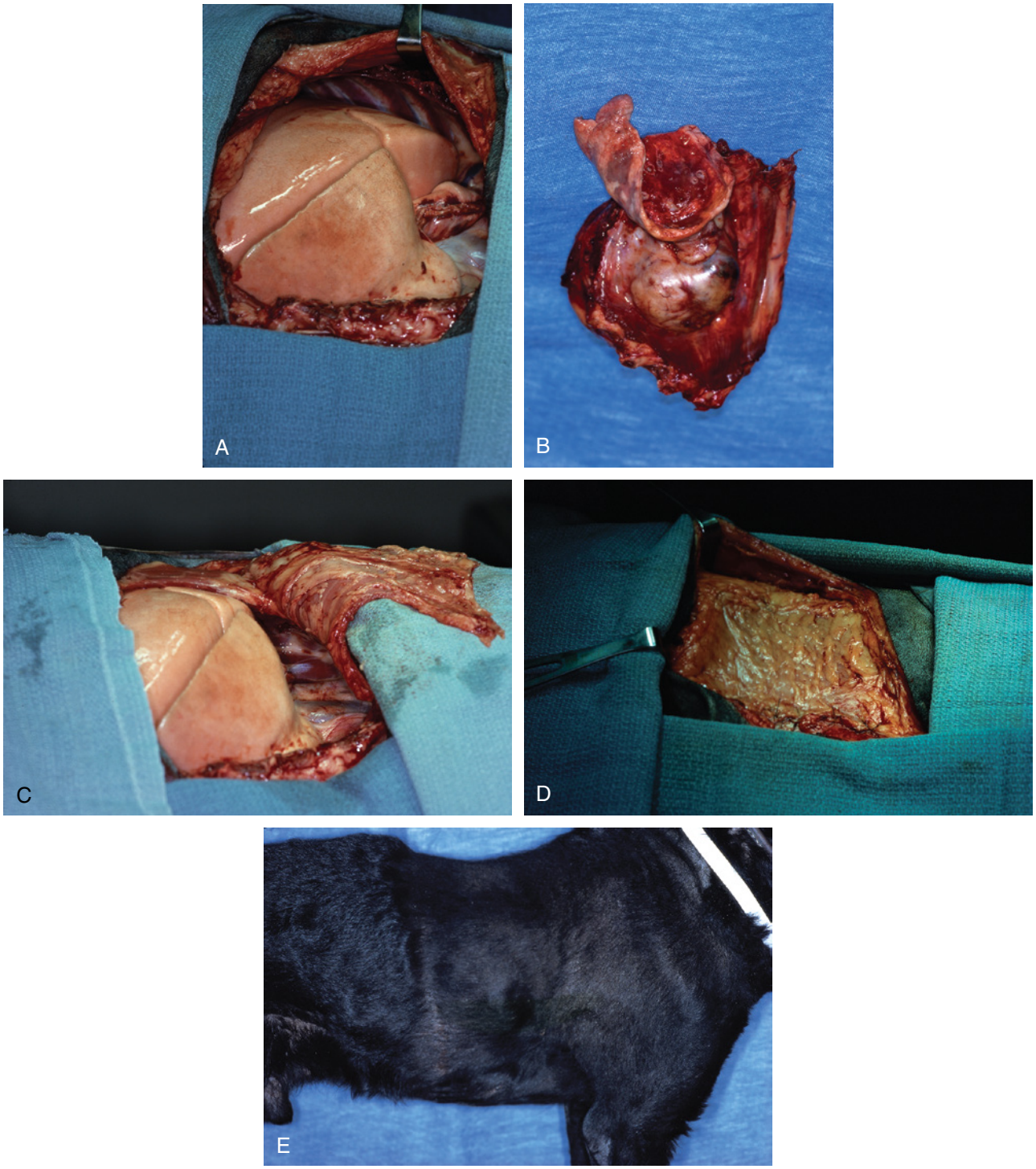


FIG. 16-4 (A, B) Resection of multiple ribs to remove a chondrosarcoma. (C) The latissimus dorsi muscle reflected backward prior to placement into the thoracic defect. (D) Marlex™ mesh (Davol, Inc., Cranston, RI) was used to span the defect prior to application of the muscle flap. The author no longer uses mesh: the muscle alone, placed under slight tension during suturing, spans large defects quite satisfactorily. (E) Postoperative view of the dog. Slight cavitation is noted, although clinically these patients have no issues breathing. Some paradoxical movement of the muscle can be noted over the first few postoperative days. (See Plate 106.)

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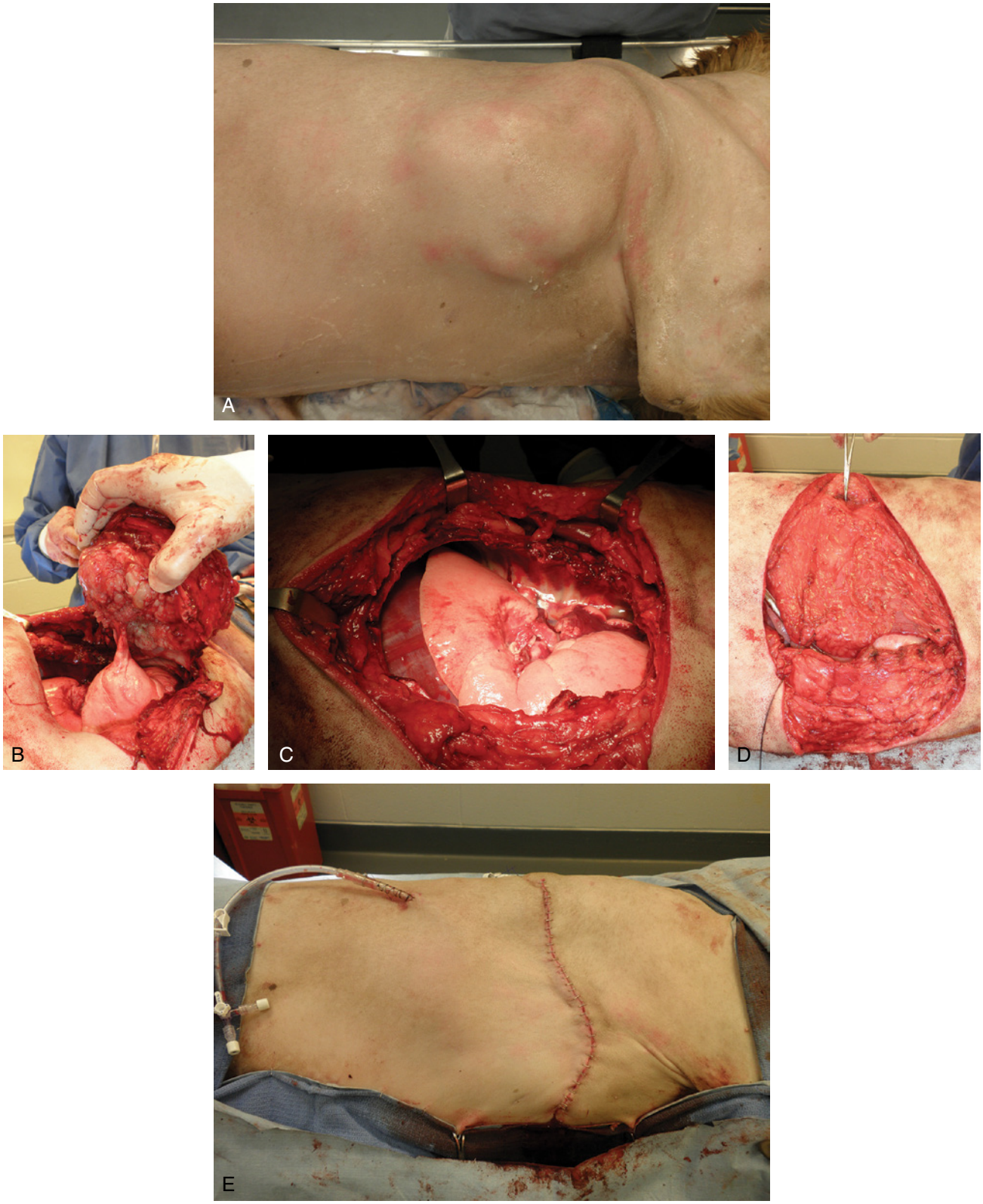


FIG. 16-5 (A) Right thoracic chondrosarcoma in a golden retriever. (B) Intraoperative resection of the involved thoracic wall segment. A thoracoabdominal stapler was used to resect the attached portion of the lung lobe. (C) The surgical defect after resection of multiple ribs. (D) The hemostat denotes the dorsal incision, allowing this bipedicle variation of the latissimus dorsi muscle flap to stretch ventrally. Nonabsorbable cruciate sutures were used to appose the muscle flap to the lower margin of the thoracic wall defect. Note the thoracostomy tube placed prior to closure. (E) Completion of the closure. The thoracostomy tube was secured with a purse-string suture and finger-trap knot. (See Plate 107.)

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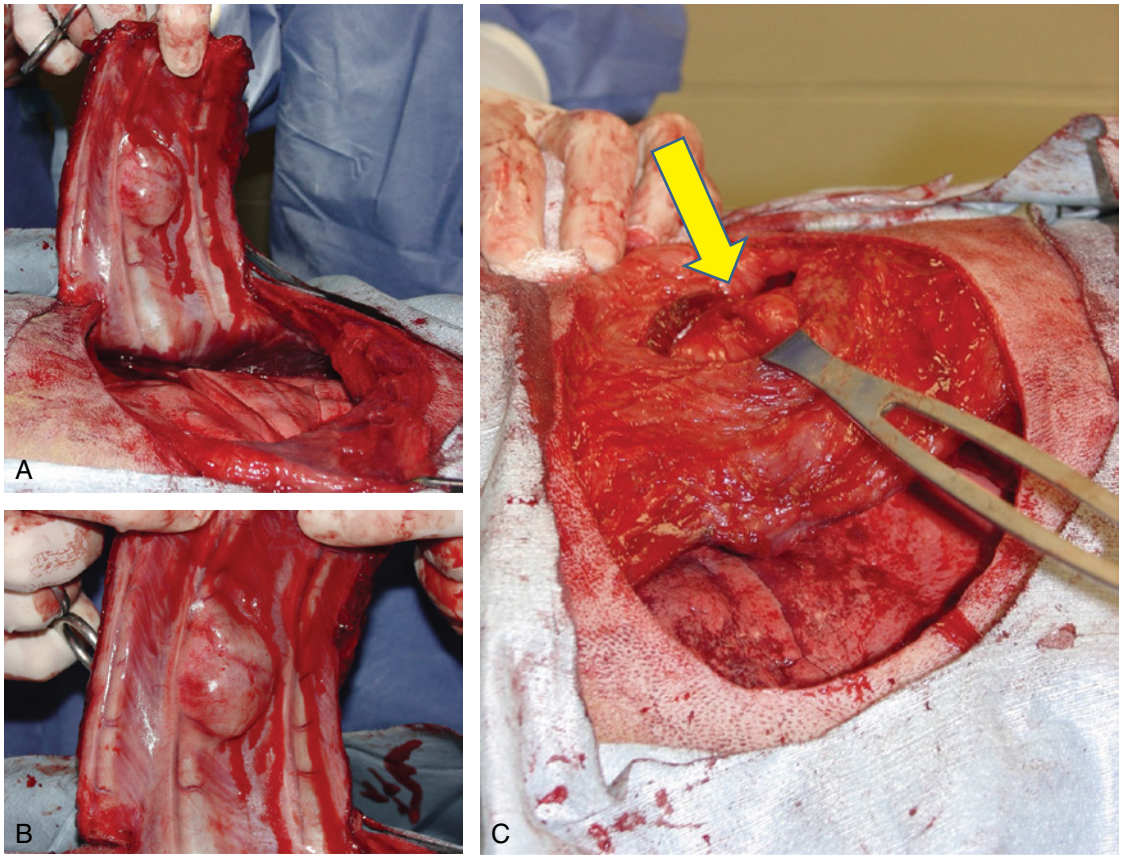


FIG. 16-6 (A) Osteosarcoma of the rib. (B) Resection of four ribs. (C) Dorsal incision (arrow) allowing the latissimus dorsi flap to extend to the lower margin of the thoracic wall defect. The bipedicle variation of the latissimus dorsi muscle flap is simpler to perform and requires less dissection compared to the single-pedicle variation. The single-pedicle variation is more mobile, allowing it to extend into defects where the bipedicle variation may not easily reach. (See Plate 107.)

accompanied by the cranial hypogastric nerve and a satellite vein. The deep branch of the deep circumflex artery anastomoses with the cranial and caudal abdominal arteries and is the main supply to the caudodorsal quarter of the abdominal wall. It, too, is accompanied by a satellite vein and is joined by the lateral cutaneous femoral nerve. This versatile muscle flap is technically easy to elevate and transfer (Fig. 16-8, Fig. 16-9, and Fig. 16-10). (See Plate 109).

Cranial Sartorius Muscle

The cranial sartorius muscle is a long, flat, straplike muscle arising on the iliac crest and lumbodorsal fascia. It extends to the medial surface of the thigh to pass into the medial femoral fascia above the patella. Vascular injections have demonstrated a single major vascular pedicle present at the proximal one-third of the muscle. This vascular pedicle is a branch of the femoral artery and vein and enters all muscle specimens along its caudal border (Fig. 16-11). (See Plate 111.)

Caudal Sartorius Muscle

The caudal sartorius muscle lies close beside the cranial belly on the medial surface of the thigh. It arises from the bony ridge between the two ventral spines of the ilium. Distally, it runs over the medial surfaces of the vastus medialis and stifle joint, where it forms an aponeurosis that blends with that of the gracilis muscle. Vascular injections have demonstrated a segmental blood supply with a dominant vascular pedicle off the saphenous artery and medial saphenous vein at the distal third of the muscle belly (Fig. 16-11). (See Plate 110.)

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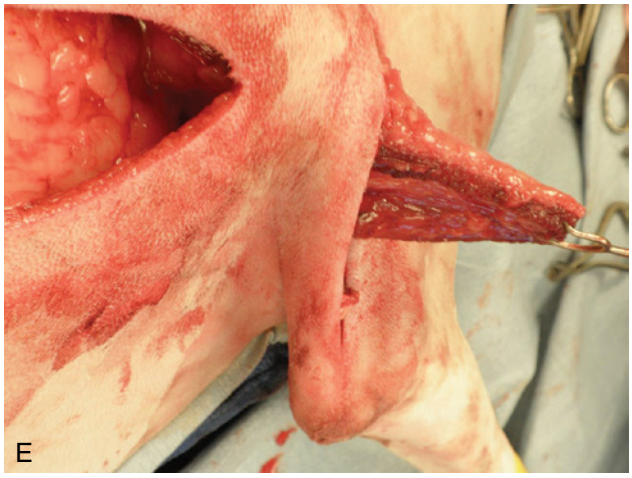
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FIG. 16-7 (A) Contracture of the right triceps muscle. The exact mechanism of this muscle atrophy is not known based on the history and final histopathology performed. (B) Preparation of the patient for surgery. Note the leg held in caudal extension. (C, D) Division of the latissimus dorsi tendon, dorsal to its attachment to the olecranon. (E) Elevation and rotation of the latissimus dorsi muscle beneath the skin between the two skin incisions. (F) Following suture placement of the latissimus dorsi muscle to the distal triceps tendon, the dorsal border of the flap is resutured, in part, to its original location. Cruciate sutures are used to increase tension along the axis of the muscle. Muscle tension is adjusted to maintain the position of the elbow joint under extension, but still allowing for the elbow to be flexed without excessive resistance intraoperatively. Note the vacuum drain inserted prior to closure of the skin incisions to control dead space. (G) The patient regained function of the leg after physical therapy. (Source: Pavletic MM, Kalis R, Tribou P et al. 2015. Triceps brachii muscle reconstruction with a latissimus dorsi muscle flap in a dog. *J Am Vet Med Assoc* 246:226–230. Reproduced with permission of the American Veterinary Medical Association.) (See Plate 108.)

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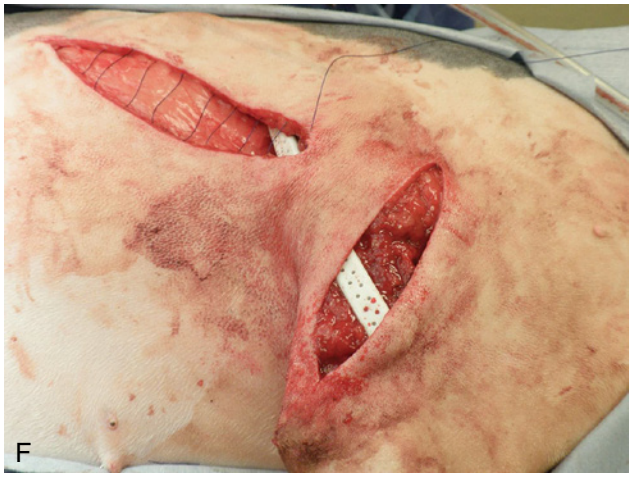




FIG. 16-7 (Continued)

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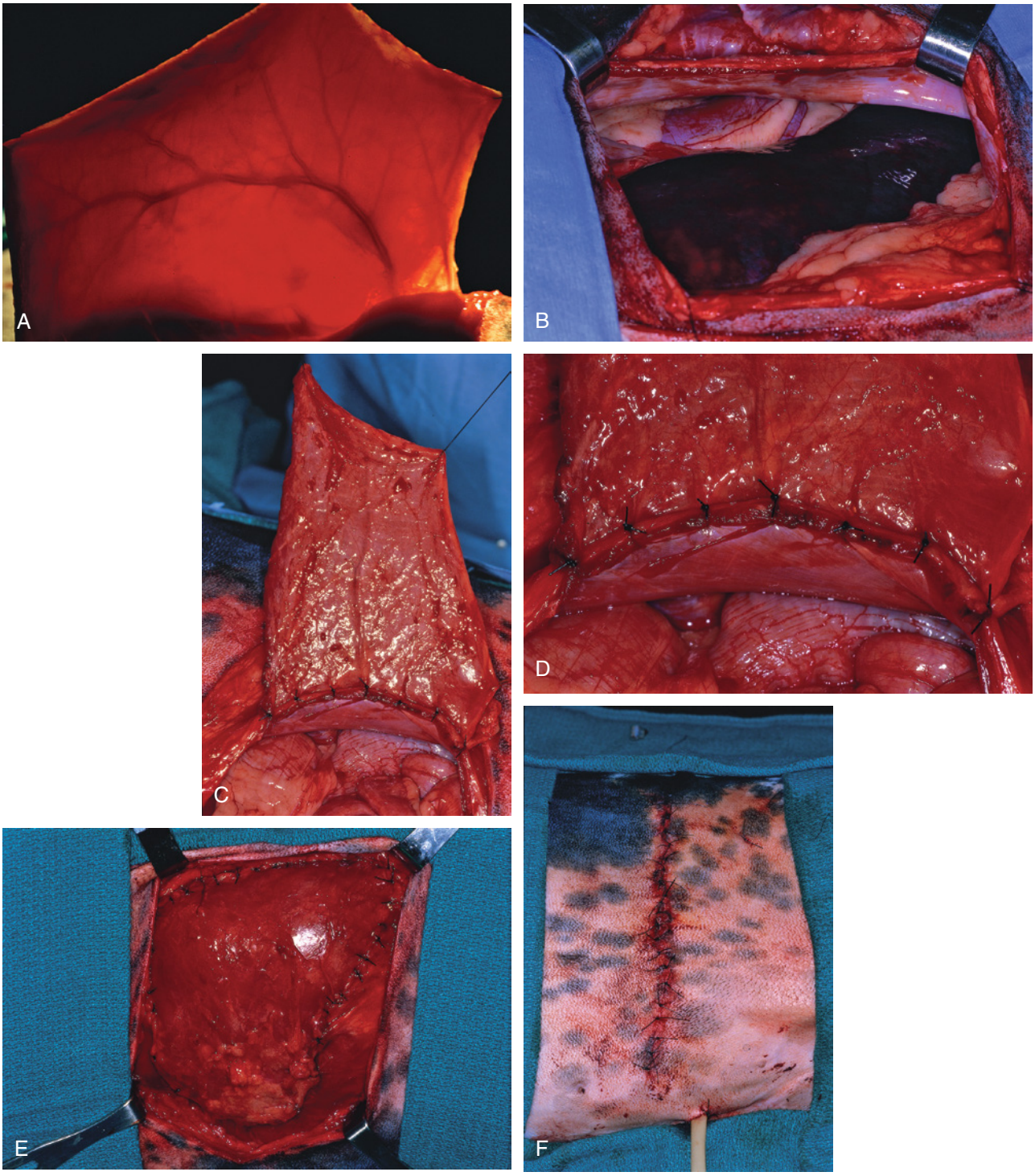


FIG. 16-8 (A) Illumination of an elevated external abdominal oblique muscle illustrating the cranial abdominal artery and vein. (B) A 10 × 10 cm defect created in the ventrolateral abdominal wall. (C) The overlapping base of the external abdominal oblique muscle flap is sutured to the dorsal border of the defect. (D) Close-up view of the sutured flap base. Care is taken not to disturb the cranial abdominal vasculature. (E) Closure is completed by suturing the remaining three sides of the muscle flap into the defect. (F) Completion of the surgery. An access incision can facilitate the caudodorsal elevation of the external abdominal oblique muscle. (See Plate 109.)

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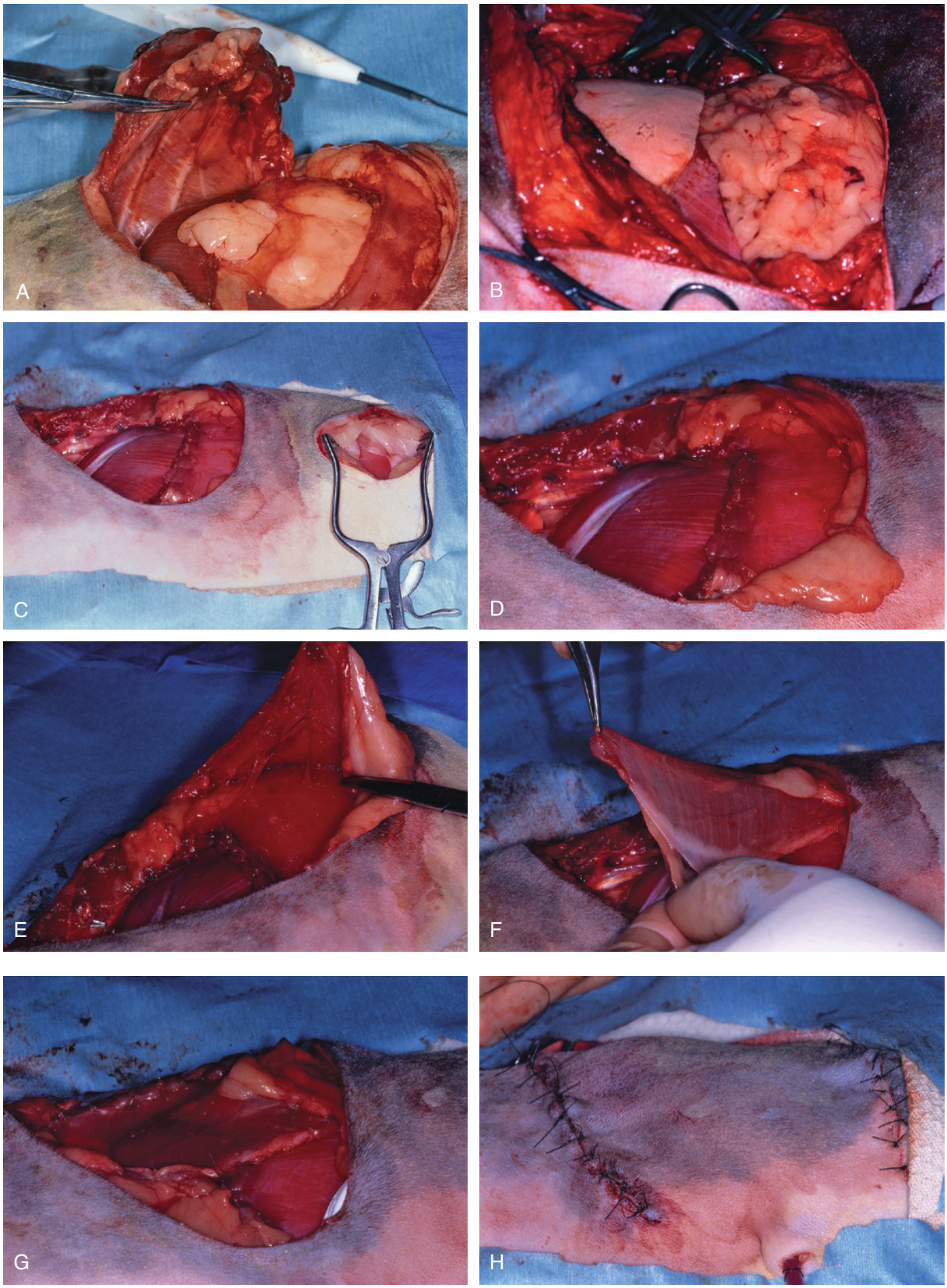


FIG. 16-9 (A) Removal of a sarcoma involving the caudal third of the thorax in a cat. (B) The large defect exposes the left caudal lung lobe and abdominal cavity. (C, D) Unlike in Figure 16-10, the diaphragm was sutured to the cranial border of the internal abdominal oblique and transversus muscle layer, thereby closing the abdominal cavity. Note the caudal access incision with the Weitlaner tissue retractor. (E) The external abdominal oblique muscle separates from the underlying internal abdominal oblique with minimal dissection. (F) The muscle is pivoted into the surgical site. (G) The muscle is sutured to the remaining thoracic wall and adjacent soft tissues. (H) Completion of the surgery. The patient made a complete recovery. (See Plate 109.)

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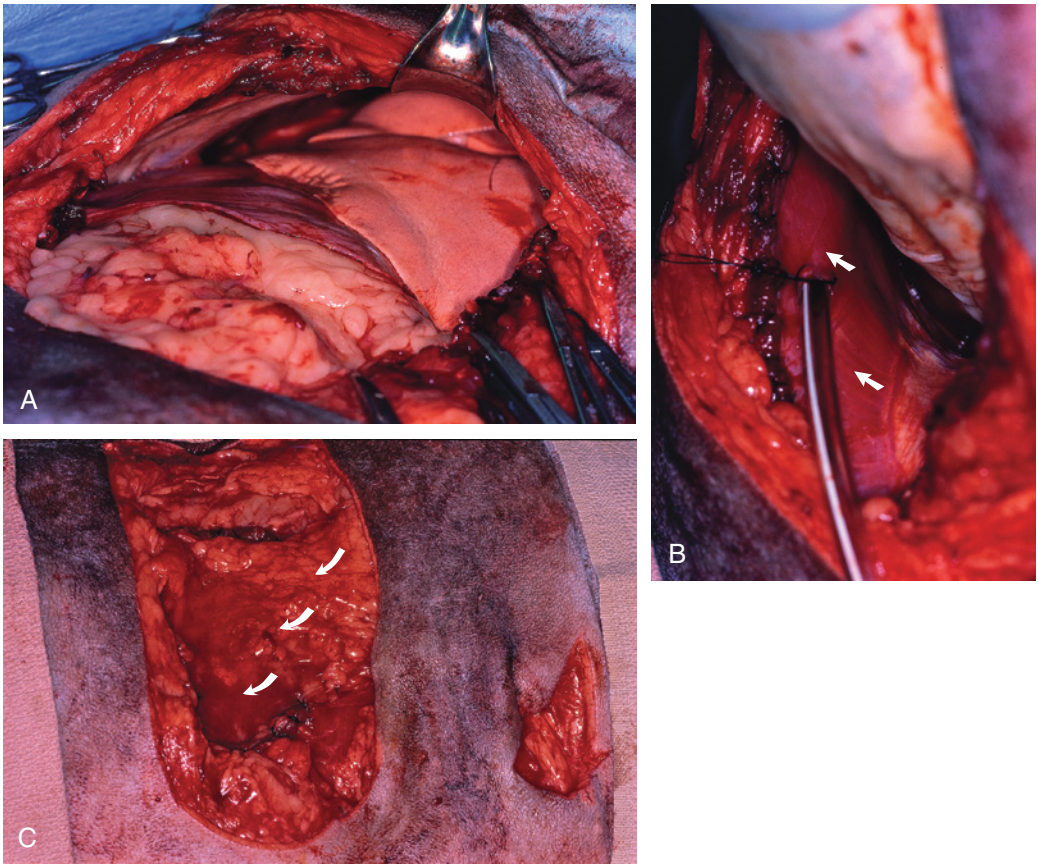


FIG. 16-10 (A) Resection of sarcoma involving the left lateral thorax and abdomen. (B) Diaphragm advancement to close the thorax. (C) Forward rotation (arrows) of the external abdominal oblique muscle to close the lateral abdominal wall defect, without the need for synthetic mesh. Note the caudal cutaneous access incision to facilitate muscle flap elevation. (See Plate 109.)

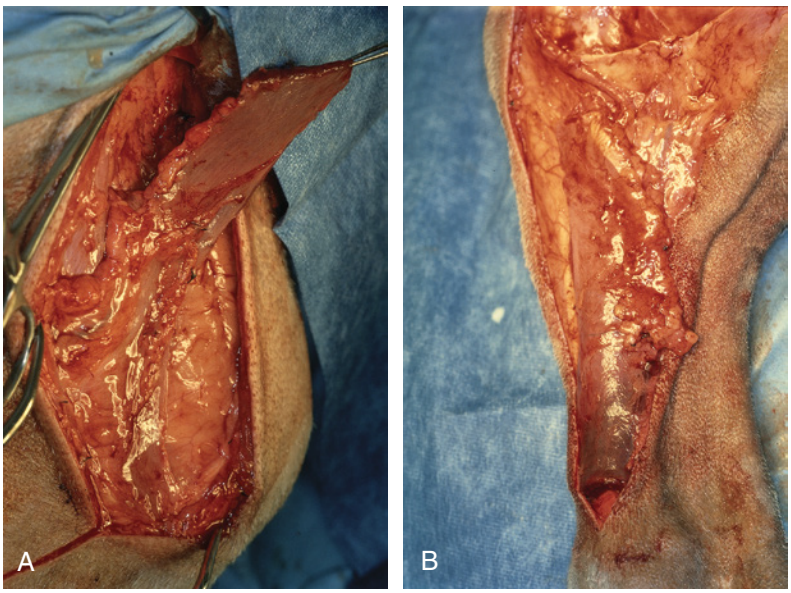


FIG. 16-11 (A) Elevation of the cranial sartorius muscle. (B) Elevation of the caudal sartorius muscle. (See Plates 110 and 111.)

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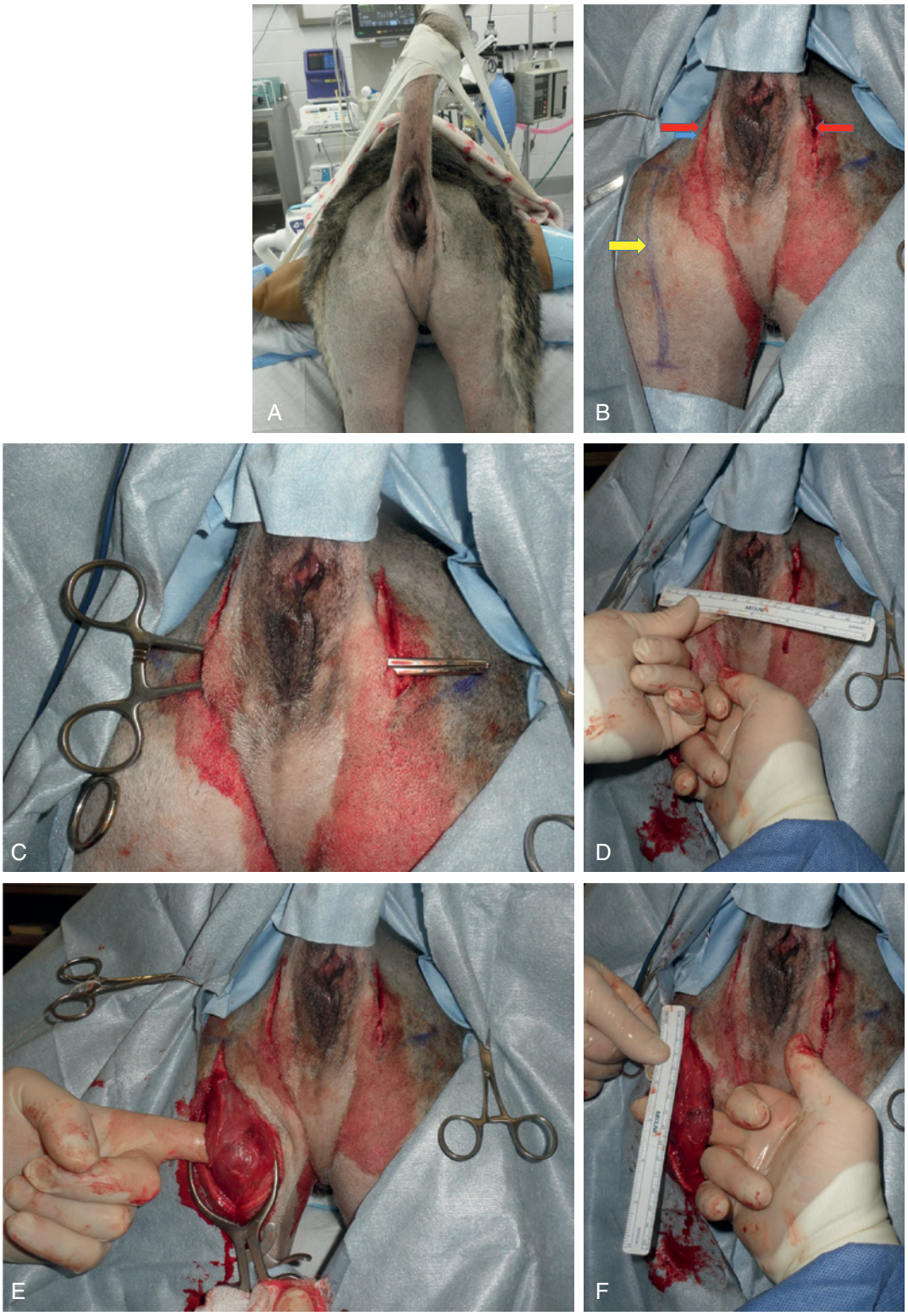


FIG. 16-12 (A) German shepherd police dog: bilateral perineal hernias had been repaired by the referring surgeon. Following surgical correction, a ventral perineal hernia subsequently formed and the dog was referred to Angell Animal Medical Center. (B) Following surgical preparation, two incisions (red arrows) were created lateral to the anal sphincter areas. A surgical marker (yellow arrow) was drawn onto the skin overlying the left semitendinosus muscle. (C) Blunt dissection ventral to the rectum to create a passage for the semitendinosus muscle flap. (D) Measurement from the left ischial tuberosity to the right ischial tuberosity. This measurement served as a guideline for the length of the left semitendinosus muscle flap to harvest. (E) Dissection along the lateral border of the left semitendinosus muscle. (F) Once fully elevated, the left semitendinosus muscle was measured based on the measurement in (D). (G) A cruciate stay suture was placed on the end of the muscle flap, facilitating its elevation and passage to the level of the right ischial tuberosity. It is important to note that the incised semitendinosus muscle contracts to a variable degree: creating a muscle a few centimeters longer than the intraoperative measurements is advisable. (H) The end of the muscle was sutured to the fascia at the level of the right ischial tuberosity. The incisions were subsequently closed with a series of interrupted sutures. The dog made a full recovery and had normal bowel movements following the muscle transfer. (See Plate 114.)

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FIG. 16-12 (Continued)

Miscellaneous Muscle Flap Techniques

The temporalis muscle flap (orbital defects), flexor carpi ulnaris (carpal defects), semitendinosus muscle (upper hindlimb and perineal defects) (Fig. 16-12), and transversus abdominis muscle (large diaphragmatic defects) are less commonly used in wound repair due to their location and the relative infrequency of problematic wounds in their arc of rotation. Nonetheless, these techniques can be useful for those occasional defects in which wound healing and closure are particularly challenging. Over the years the author has found the internal obturator muscle flap invaluable for perineal hernia repairs, but has not found a need for use of the superficial gluteal muscle. Although rarely, the sternohyoideus muscle has been used by the author as a tissue patch for the cervical esophagus and larynx (see Fig. 16-1). The author has not found the opportunity or need for the deep pectoral muscle or gastrocnemius muscle; based on his surgical experience over the past 40 years, they are options to keep in mind for those occasional "outlier" cases we see as veterinarians.

Plate Contents

Each of the 15 plates illustrates a variety of muscle flaps available for reconstructive surgery. Their clinical application is discussed with each plate.

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Plate 104 Latissimus Dorsi Myocutaneous Flap

DESCRIPTION

The latissimus dorsi myocutaneous flap simultaneously transfers both muscle and skin to close a variety of defects within its arc of rotation.

SURGICAL TECHNIQUE

(A) Under general anesthesia, the patient's thorax is completely clipped and prepared for surgery. The dog is placed in lateral recumbency with the skin in its natural undistorted position relative to the underlying body mass. The forelimb is placed in relaxed extension, perpendicular to the trunk. The dorsal flap border (A) is drawn with a marking pen from a point ventral to the acromion (1), caudal to the border of the triceps muscle (below the origin of the thoracodorsal direct cutaneous artery) (2), and extending to the level of the head to the 13th rib (3). The ventral border of the flap (B) extends from the forelimb skin fold caudal to the lower triceps muscle's border (the lower third of the length of the humerus) (4), and extends caudodorsally to the 13th rib, parallel to the first line (5). The caudodorsal border (C) of the flap is drawn by using the level of the 13th rib border to join the dorsal and ventral flap lines.

(B) The ventral skin flap border is incised initially, and the isolated ventral border of the latissimus dorsi muscle is elevated. The skin flap incision is extended, and a latissimus dorsi muscle flap of a width equal to that of the overlying skin is elevated. As the muscle is elevated from the thoracic wall, the proximal lateral intercostal vessels are isolated, ligated, and divided below the latissimus dorsi muscle to complete the flap elevation. In this example, a bridge incision is created between the donor and recipient beds to facilitate transfer of the flap without partial tube formation.

(C) The flap is sutured into position. Penrose drains or closed suction units are used to obliterate dead space at the donor and recipient sites.

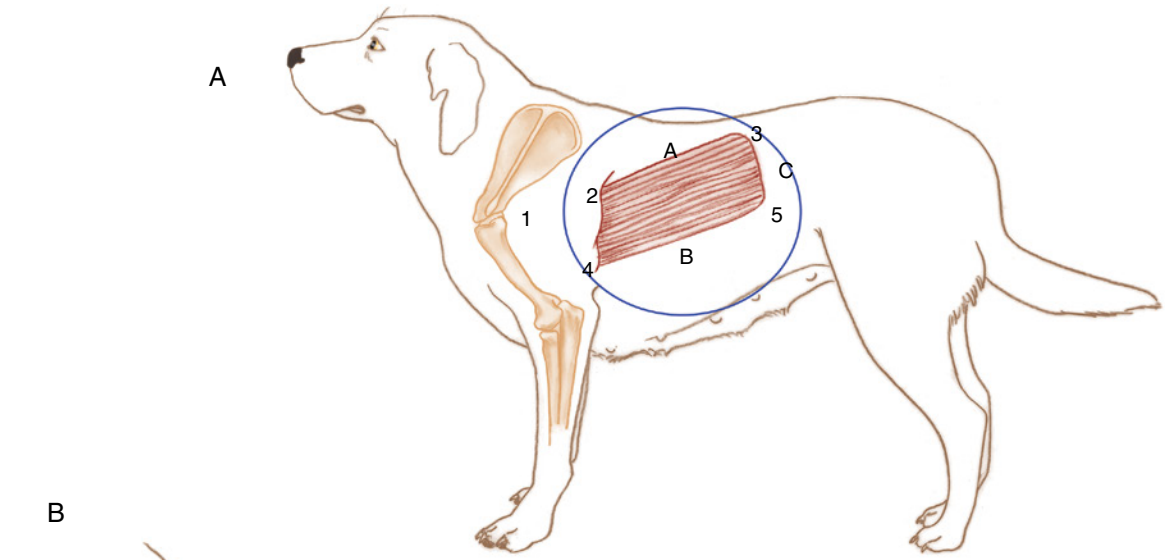
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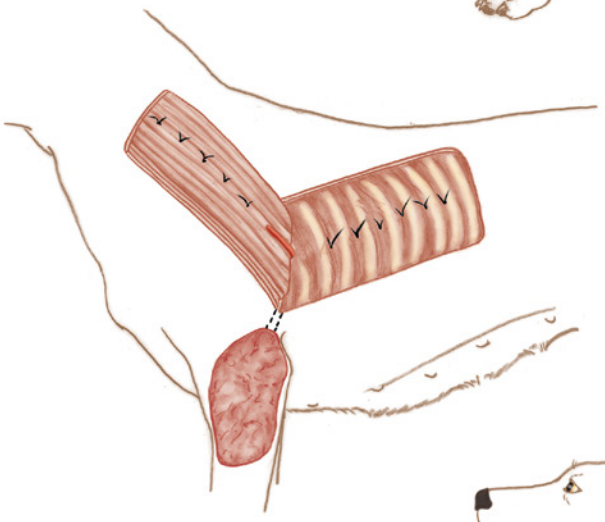
Careful preoperative measurements are necessary to ensure that the flap will satisfactorily cover the defect. Note that the length of the flap decreases the more the flap is rotated. Although the latissimus dorsi myocutaneous flap is thicker, less pliable, and less elastic than the adjacent cutaneous trunci myocutaneous flap and adjacent thoracodorsal axial pattern flap, it is capable of extending down the forelimb to a variable degree, depending on the patient's body conformation. The thoracodorsal axial pattern flap and cutaneous trunci myocutaneous flaps are better suited for skin defects, whereas the latissimus dorsi myocutaneous flap, with its greater bulk, is better suited for thoracic wall defects in which the simultaneous reconstruction of the chest with muscle and skin is highly desirable.

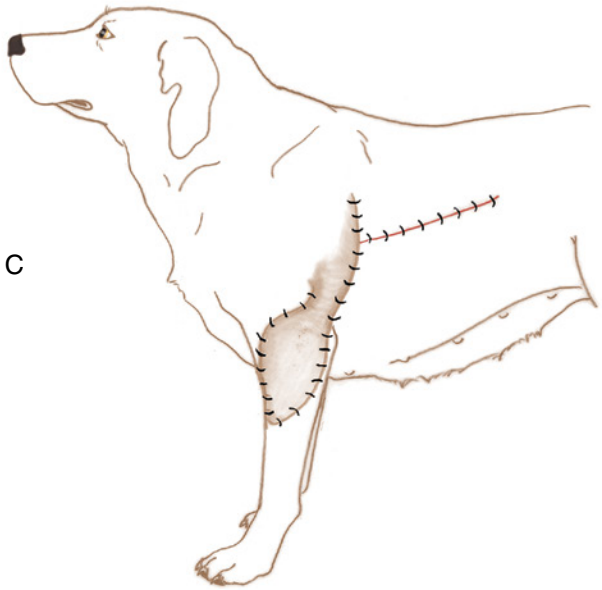
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Plate 104







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Plate 105 Cutaneous Trunci Myocutaneous Flap

DESCRIPTION

The cutaneous trunci myocutaneous flap is similar in shape and design to the latissimus dorsi myocutaneous flap. It is thinner than its counterpart and has slightly greater mobility within its arc of rotation.

SURGICAL TECHNIQUE

(A) The general outline for elevation of the cutaneous trunci myocutaneous flap is identical to that for the latissimus dorsi myocutaneous flap (see Plate 104). However, elevation of this flap is confined to the loose areolar fascial plane beneath the cutaneous trunci muscle.

(B) The skin is incised down to the level of the cutaneous trunci muscle, in a fashion similar to elevation of the latissimus dorsi myocutaneous flap. Branches of the proximal lateral intercostal direct cutaneous arteries (and veins) exiting the surface of the latissimus dorsi muscle require ligation and division during flap elevation. A bridge incision is used in this example to facilitate placement of the myocutaneous flap (dashed lines).

(C) Penrose drains or closed suction units are used at the donor and recipient sites to obliterate dead space during flap transfer and recipient bed closure.

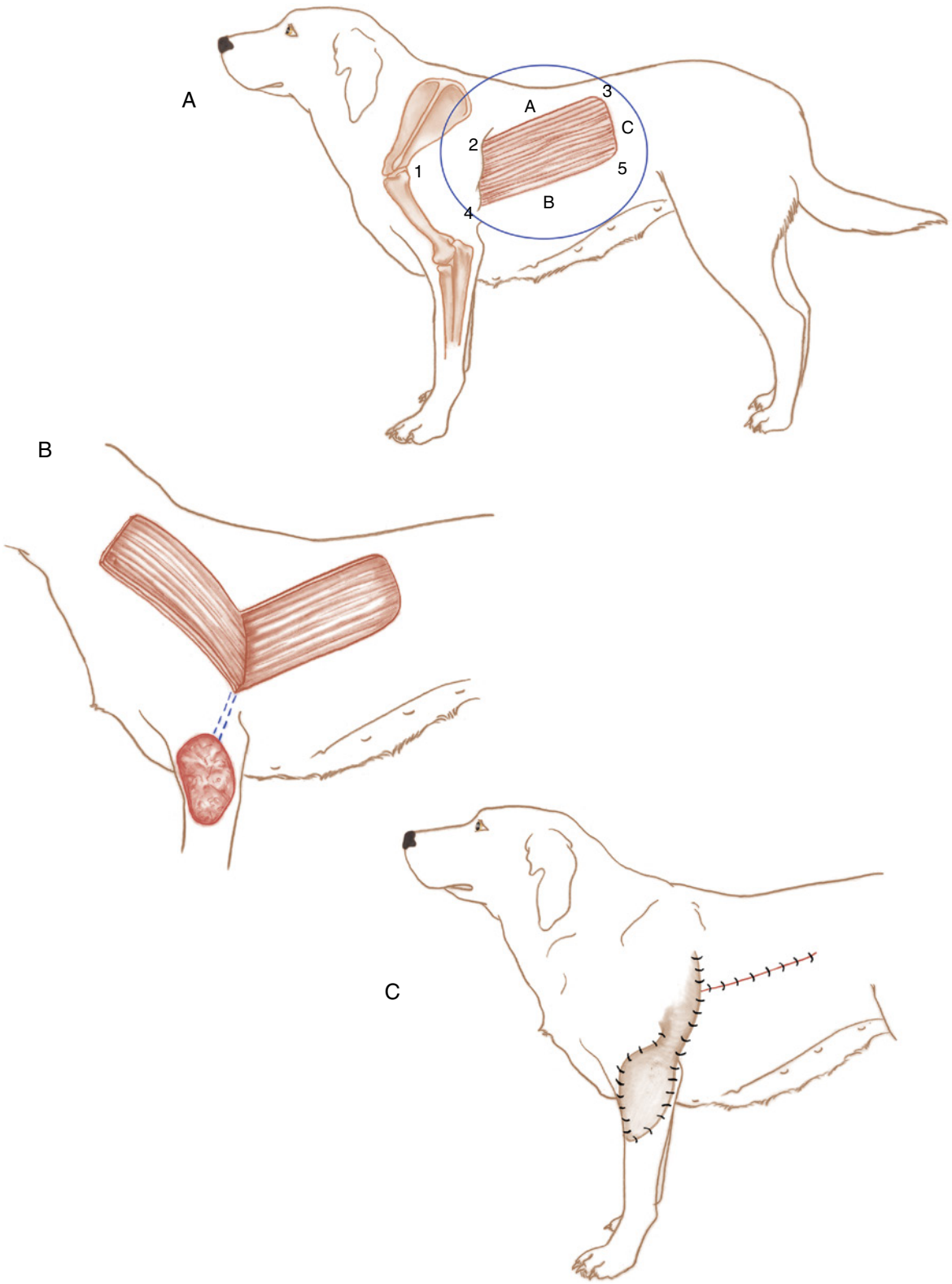
COMMENTS

Careful preoperative measurement is necessary to ensure that the flap will satisfactorily cover the defect. Note that the flap length is reduced the more the flap is rotated. Although flap size and coverage are similar to those of the thoracodorsal axial pattern flap, the author has safely developed longer thoracodorsal axial pattern flaps in the dog when necessary. Clinical experience, size of the flap required to cover the skin defect, and the ease of flap transplantation should be considered when selecting a flap technique.

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Plate 105



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Plate 106

Latissimus Dorsi Muscle Flap

DESCRIPTION

The latissimus dorsi muscle is used to cover defects beneath the skin (e.g., thoracic wall) within its arc of rotation (type V muscle).

SURGICAL TECHNIQUE

(A) In this clinical example, a lower thoracic wall mass requires surgical resection.
(B) The neoplasm is resected. The skin margins are carefully retracted to expose the latissimus dorsi muscle.
(C) In this example, optional surgical mesh is sutured over the margins of the thoracic wall defect.
(D) The elevated muscle flap is pivoted and sutured over the mesh. Simple interrupted sutures or double-loop patterns (far-far-near-near, far-near-near-far) are sufficient for suturing the flap in position. A closed suction system is inserted prior to skin closure.

COMMENTS

Although a skin incision can be made over the muscle, parallel to its fibers, it is possible to expose the muscle through small skin incision(s), depending on the location of the defect being closed. In many instances, the muscle can be exposed via the surgical approach required for removal of a neoplastic condition, provided that the skin can be retracted sufficiently to expose the muscle. Handheld retractors, self-retaining retractors, or large towel clamps can facilitate muscle exposure. An additional access incision can be created if required.

Given its dominant thoracodorsal vascular supply, the muscle can be rotated into adjacent thoracic wall defects. *Important note*: in thoracic wall defects below the central body of the muscle, the terminal end of the muscle need not be detached from the terminal ribs. The dorsal and ventral muscle borders can be developed and the "bipedicle" muscle flap advanced directly into the ventral defect. This simplifies closure of the thoracic wall defect, reducing the amount of tissue dissection and operative time required to elevate the standard peninsula flap design. (See Plate 107.) The latissimus dorsi muscle has its greatest application for major thoracic wall reconstruction. The intercostal vessels entering/exiting the muscle require ligation to mobilize the muscle from the thoracic wall and overlying skin. Care must be taken to minimize trauma to the overlying skin and to preserve collateral vascular channels.

The latissimus dorsi muscle can be combined with plastic mesh, adjacent composite rib flaps, or rib grafts to add rigidity to the reconstructed chest wall after multiple rib resection. However, it has been the author's experience that mesh, bone grafts, and other implants are unnecessary. The flap, sutured to the adjacent musculofascial borders of the defect, stretches over the area. Sutured under slight tension, the flap covers thoracic wall defects in a trampoline-like fashion. Muscle edges are sutured to the adjacent muscle/fascial planes bordering the defect.

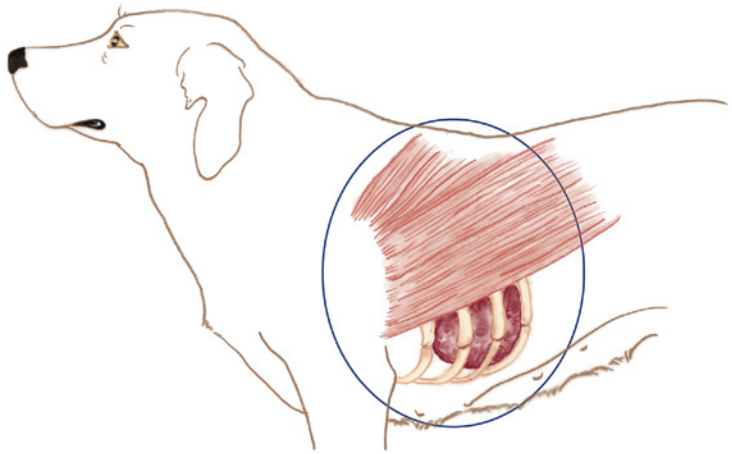
Postoperatively, a variable amount of (paradoxical) inward excursion of the flap can be seen during inspiration. It is self-limiting, with minimal motion noted, within a few days after surgery. A shallow depression or concavity can be seen at the flap site, but it is not recognizable in most patients after regrowth of the hair coat.

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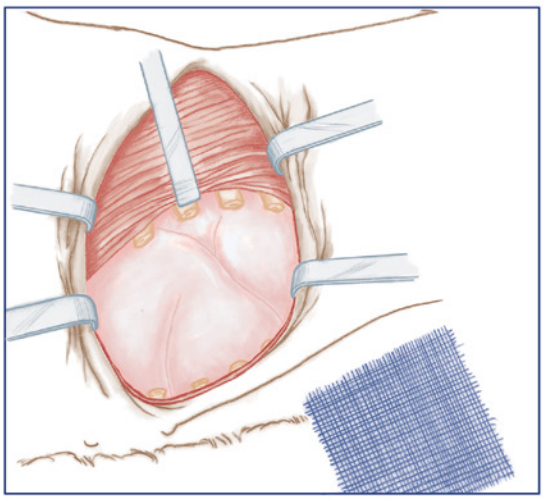
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Plate 106

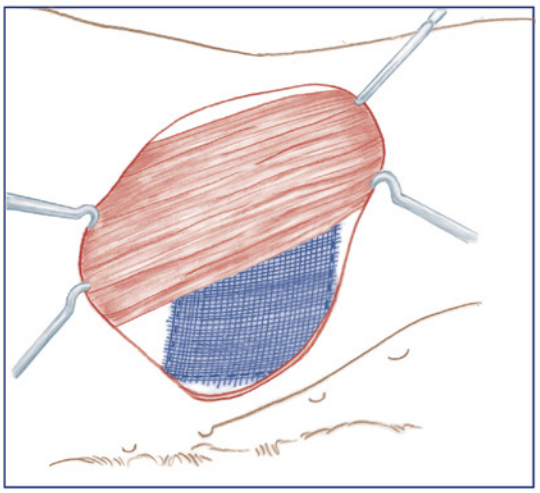
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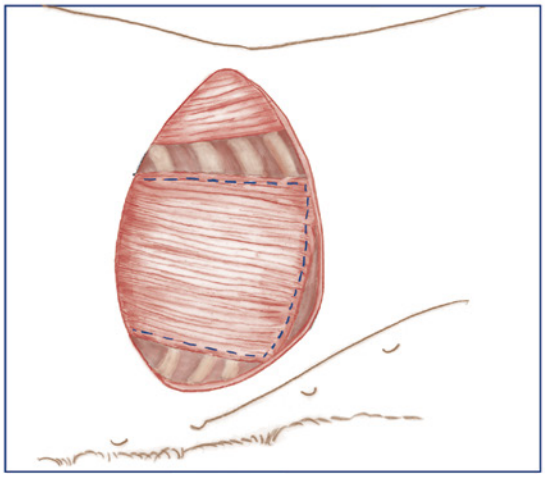
B



C



D



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Plate 107 Latissimus Dorsi Bipedicle Muscle Flap

DESCRIPTION

The author has noted that a number of thoracic wall defects, after tumor resection, do not require the complete elevation of the latissimus dorsi muscle flap for closure. A dorsal incision alone will allow the muscle to be mobilized in a ventral direction, thereby reducing the dissection required to close these challenging surgical wounds.

SURGICAL TECHNIQUE

(A) Through the same thoracotomy incision (see Plate 106), the latissimus dorsi muscle is exposed along its length after resection of the thoracic wall mass.

(B) With elevation of the ventral margin of the latissimus dorsi muscle, the intercostal vessels supplying the undersurface of the muscle are ligated and divided. The thoracic wall mass and adjacent normal tissue are excised. The dorsal incision, which parallels the lower border of the latissimus dorsi muscle, is incised. The resultant bipedicle muscle is directed ventrally, overlapping the thoracic wall defect.

(C) To facilitate muscle advancement over the lower portion of the defect, a dorsal release incision is used to form a bipedicle muscle flap.

(D) Cruciate sutures can be used to secure the dorsal and ventral muscle borders to the adjacent soft tissues to complete the closure of the thoracic wall. A thoracostomy tube and vacuum drain system are inserted prior to closure of the skin incision.

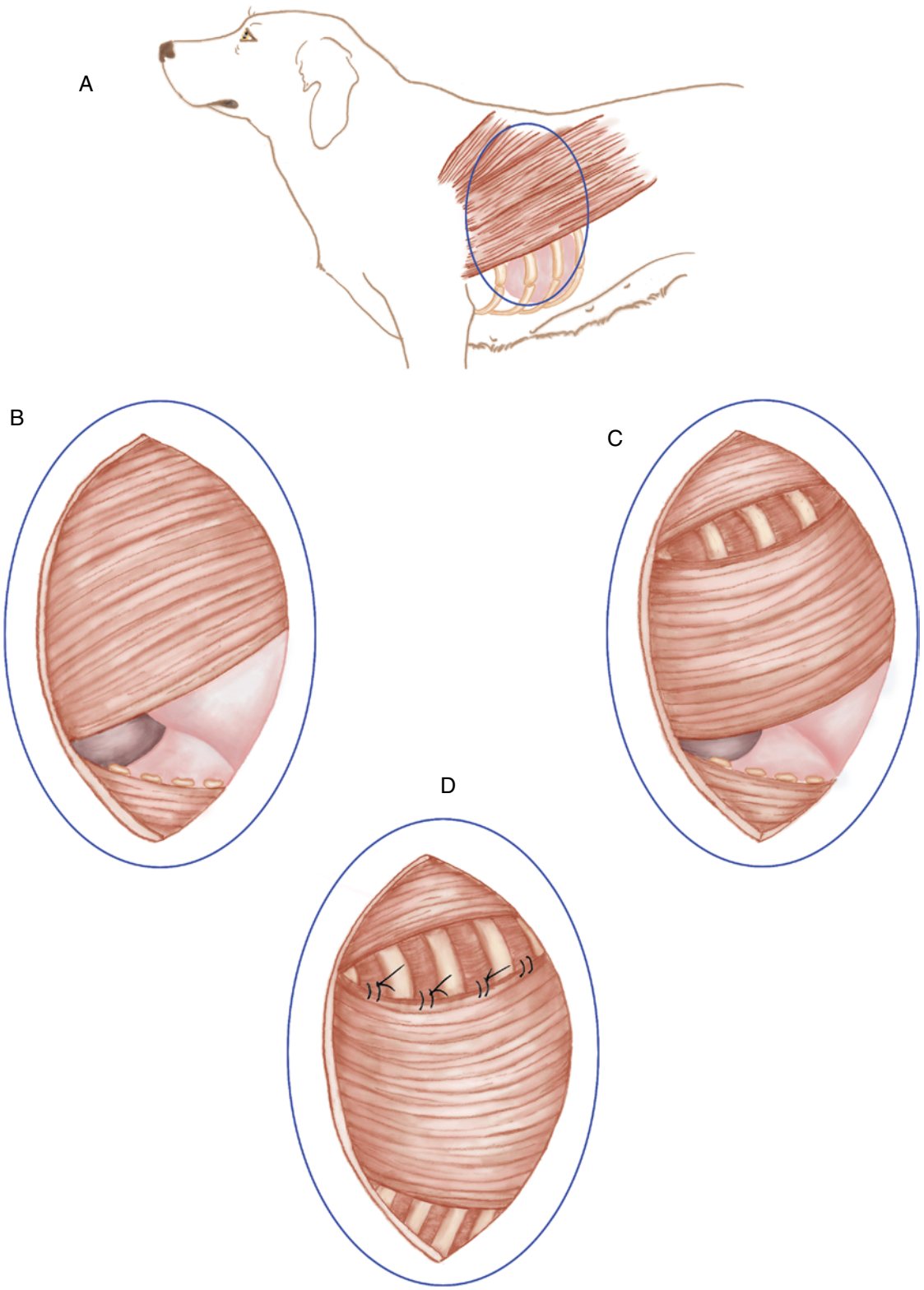
COMMENTS

This latissimus muscle flap variation eliminates the need to expose and separate the muscle attachments to the underlying rib cage. This eliminates unnecessary surgical dissection and anesthetic time. This bipedicle muscle flap variation can be attempted initially: it can be converted to the single-pedicle flap if greater mobilization is required to close the more challenging thoracic wall defects.

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Plate 107



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Plate 108

Triceps Replacement with Latissimus Dorsi Muscle

DESCRIPTION

Loss of triceps muscle function can occur secondary to neurologic injury, trauma, or potential resection for a regional neoplastic condition. Loss of this muscle unit results in the inability of the patient to bear weight on the affected forelimb. The latissimus dorsi has been successfully transplanted to the terminal triceps tendon to replace the function of this important muscle group.

SURGICAL TECHNIQUE

(A) In this clinical example, an incision is created parallel to the body of the latissimus dorsi muscle. The muscle is elevated as previously noted (Plate 106). A second incision is created over the terminal triceps muscle. The terminal tendon is severed 2–3 cm from its attachment to the olecranon.

(B) The skin between the donor and recipient incisions is undermined, allowing passage of the elevated latissimus dorsi muscle. The terminal border of the muscle can be trimmed to ensure there is a healthy margin to suture to the terminal triceps tendon unit; nonabsorbable or slowly absorbable cruciate sutures can be used to attach the latissimus dorsi muscle.

(C) Resuturing a portion of the dorsal border of the latissimus dorsi muscle to its original incised margin (cruciate sutures) is used to adjust the tension along the length of this muscle unit. Tension should be moderate with the elbow extended, yet still allow the elbow to be flexed without difficulty. As a result, contraction of the latissimus dorsi muscle should apply sufficient tension to affix the elbow in extension; relaxation will allow the elbow to flex under the influence of the biceps/brachialis muscles.

(D) A vacuum drain is inserted at the donor area and extended to the recipient area prior to closure of the skin incisions. The drain remains in place for 3–5 days unless significant drainage persists.

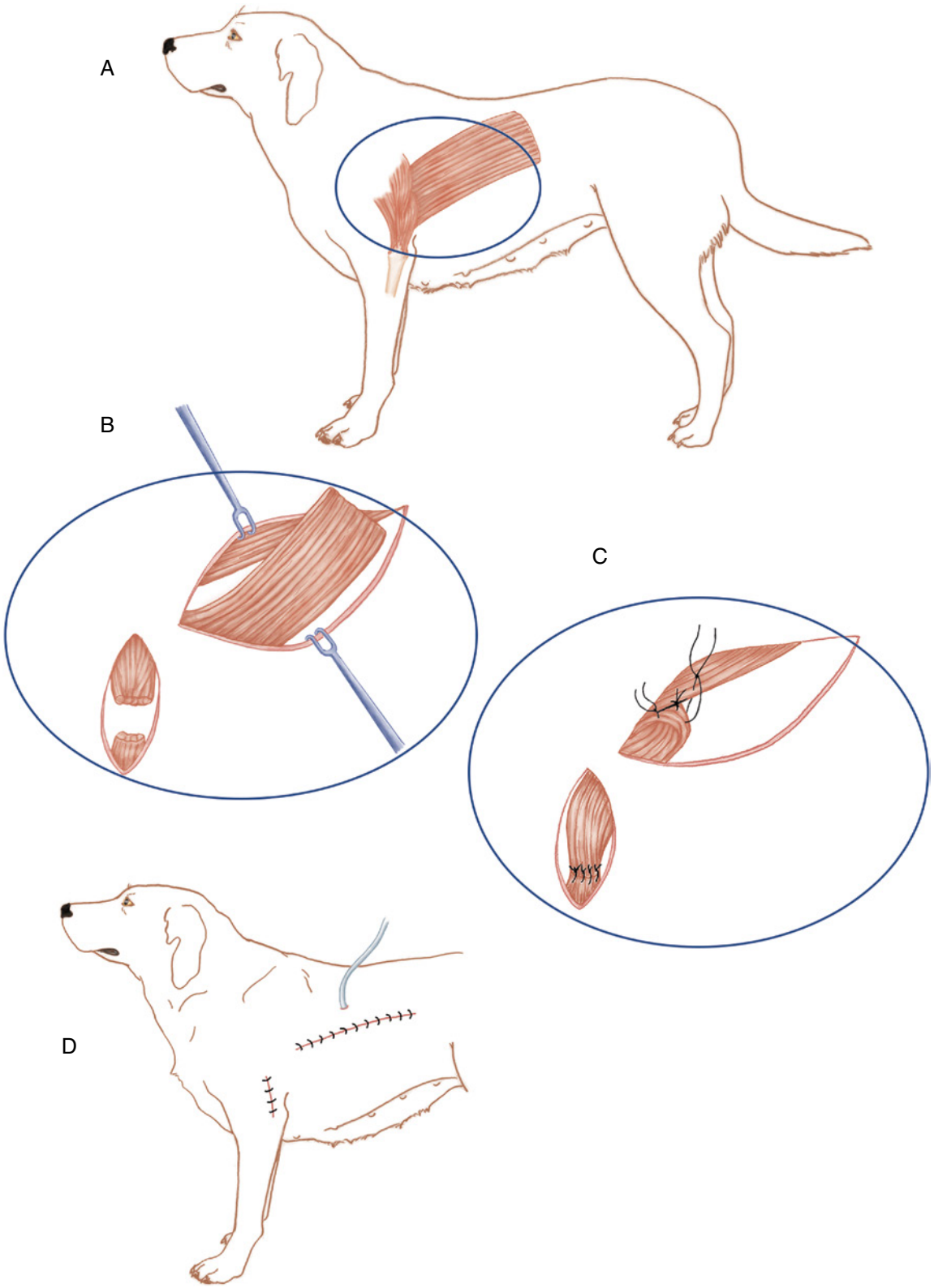
COMMENTS

Physical therapy is a significant component to the rehabilitation of the affected extremity. This includes both active and passive therapy, including the use of an underwater treadmill. (For details on the therapy required, see Pavletic et al. 2015 in Suggested Reading.)

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Plate 109 External Abdominal Oblique Muscle Flap

DESCRIPTION

The external abdominal oblique muscle flap has remarkable pliability and elasticity for closure of major abdominal and caudal thoracic wall defects (type III muscle).

SURGICAL TECHNIQUE

(A) With the patient under general anesthesia, the entire ventral and lateral abdominal wall is clipped and prepared for surgery in standard fashion. In this example, a neoplasm involves the caudal thoracic and adjacent cranial abdominal wall.

(B) In a medium dog, a paracostal skin incision is made from the level of epaxial muscles to the ventral midline, 5 cm caudal to the 13th rib. However, in this clinical example, the surgical wound serves as access to the cranial portions of the muscle, while a curved access incision, cranial and parallel to the flank, provides exposure to the caudal component. The fascial edges of the lumbar external abdominal oblique are identified and divided ventrally and caudally, leaving a 1 cm margin of fascia along the muscular edge. The lumbar external oblique is undermined, and the neurovascular pedicle, consisting of branches of the cranial abdominal artery and cranial hypogastric nerve, and a satellite vein, are identified craniodorsally, caudal to the 13th rib, and preserved. The dorsal fascial attachment is divided and the lumbar external abdominal oblique muscle severed to the level of the 13th rib. The lumbar external abdominal oblique muscular/fascial island flap, tethered by its neurovascular pedicle, is pivoted (arrow) into an adjacent thoracic or abdominal wall defect, based on preoperative measurements.

(C) The inner fascial surface of the flap is sutured to the overlapped defect with 2-0 or 3-0 monofilament, nonabsorbable suture material, using an interrupted mattress suture pattern. Care must be taken to avoid compromise to the vasculature of the muscle flap during suture insertion. Closure of this layer is important to prevent postoperative abdominal herniation.

(D) The remaining edges of the flap are subsequently sutured to the borders of the defect in a similar fashion. A simple interrupted suture pattern or a double-loop suture pattern (far-near-near-far, far-far-near-near) can be used to suture the flap borders. A closed suction unit is most appropriately used to manage dead space.

(E) The overlying skin and access incision are closed in routine fashion.

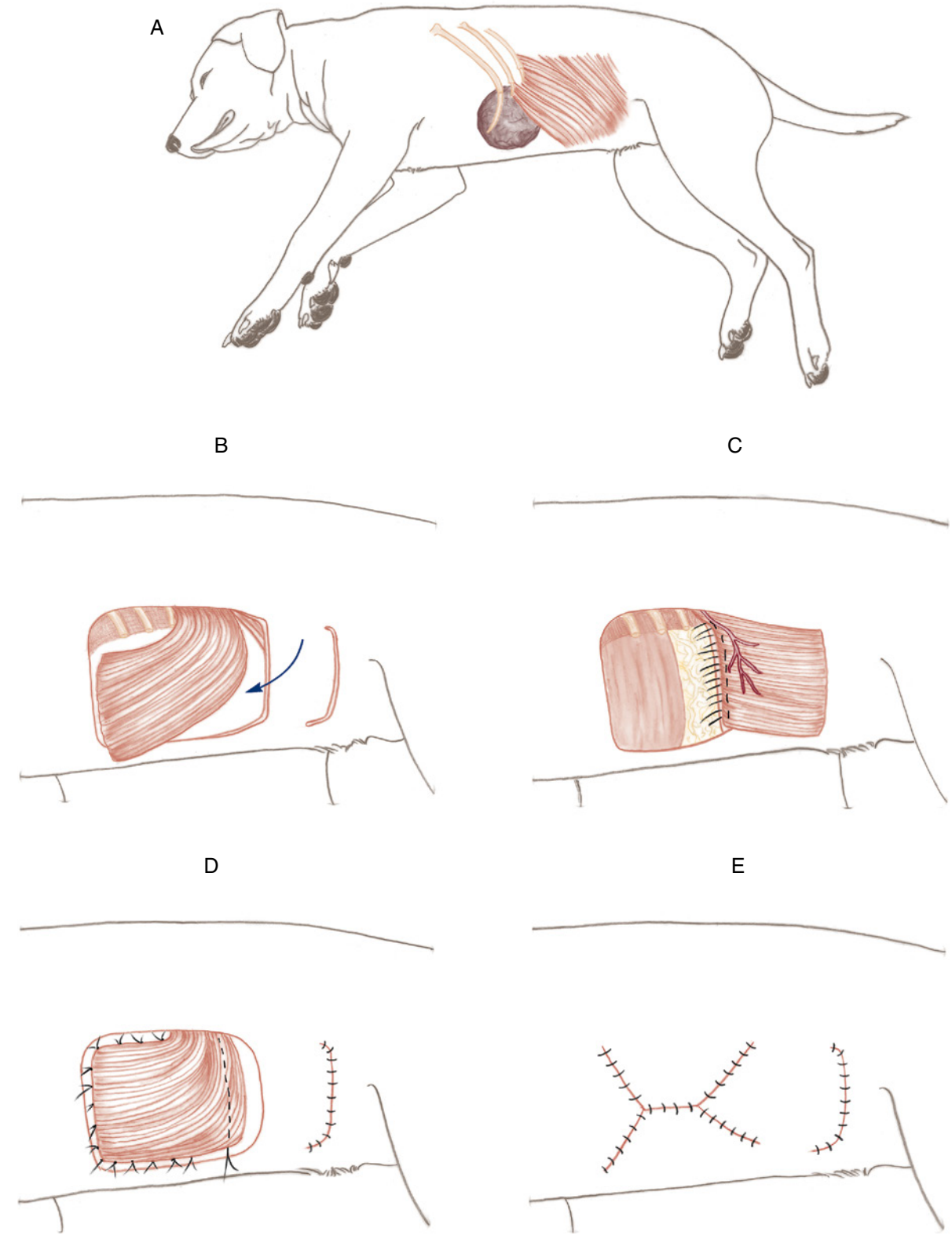
COMMENTS

The external abdominal oblique muscle, tethered by the dominant cranial abdominal arterial branches, can stretch and pivot to a considerable degree. This island muscle flap may be particularly well suited for closure of ventral abdominal wall and caudal thoracic wall defects. In the pilot study investigating its potential clinical use, the flap was capable of covering defects beyond the 10 × 10 cm full-thickness ventral abdominal wall defects created in medium-sized dogs. Loss of this muscle layer does not notably alter the abdominal silhouette. The remaining internal abdominal oblique and transversus muscles maintain the abdominal wall without the presence of the external abdominal oblique muscle layer.

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Plate 109



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Plate 110 Caudal Sartorius Muscle Flap

DESCRIPTION

The caudal sartorius muscle, tethered by a saphenous vascular pedicle, has considerable mobility and can extend as far distally as the metatarsal surface (type IV muscle).

SURGICAL TECHNIQUE

(A) Under general anesthesia, the involved rear leg is clipped and prepared for surgery in standard fashion. A skin incision is made on the medial aspect of the thigh over the length of the caudal sartorius muscle. The subcutaneous tissues are dissected to expose the underlying caudal sartorius muscle.

(B) The muscle is severed proximally, approximately 4 cm distal to its origin on the ilium. The saphenous artery and medial saphenous vein are doubly ligated and transected where they join the femoral artery and vein. Care is taken to avoid damage to the saphenous vessels in the medial tibial region and more proximally, where these vessels are intimately associated with the caudal border of the caudal sartorius muscle.

(C) The muscle can be completely mobilized by transecting its insertion near the tibial crest, leaving the saphenous artery and vein at the distal end of the caudal sartorius muscle as its sole blood supply.

(D) Tethered by the saphenous artery and medial saphenous vein, the island muscle flap can be transplanted to the distal extremity by extending the skin incision and carefully freeing up the saphenous vasculature.

(E) A closed suction unit is ideally suited to manage dead space prior to skin closure.

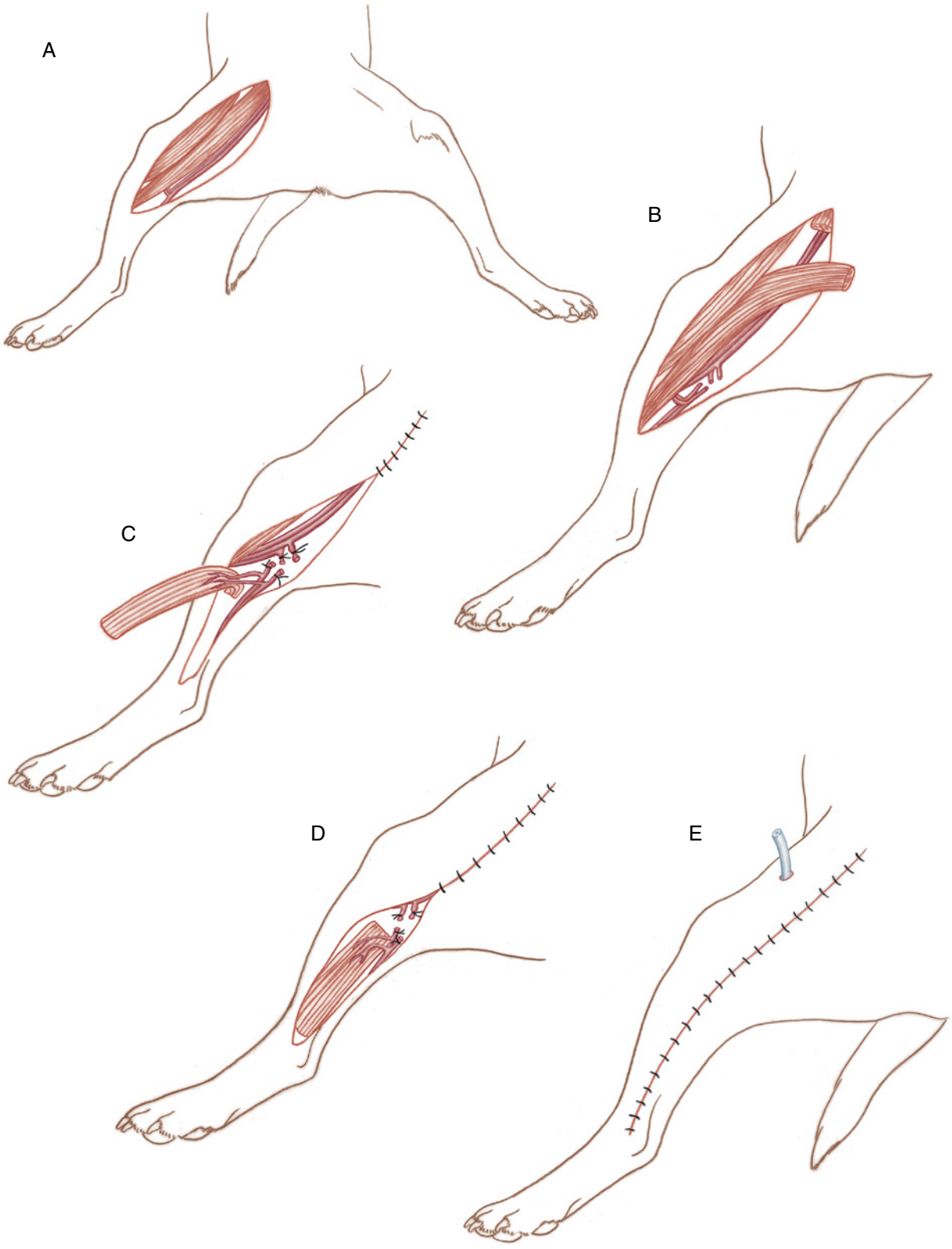
COMMENTS

The saphenous artery and medial saphenous vein maintain the caudal sartorius muscle by reversal of circulatory flow through their distal arterial and venous anastomotic connections. Fully mobilized, the caudal sartorius muscle can extend over the metatarsal surface. It has potential clinical use for distal tibial fracture repairs, where healing is impaired by osteomyelitis or poor circulation. However, it also can be used to provide soft tissue coverage to exposed structures that it is capable of reaching. A flap or free graft can be placed over this exposed caudal sartorius muscle to provide epithelial coverage, if necessary. Angiography prior to division of the saphenous artery and medial saphenous vein would be advisable before flap elevation to ensure that the saphenous artery is not the primary source of circulation to the distal extremity; extensive trauma could have compromised the cranial tibial artery and collateral sources of circulation. Division of the saphenous vasculature from a previous medial surgical approach to the tibia or from extensive trauma would preclude its effective use.

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Plate 110



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Plate 111

Cranial Sartorius Muscle Flap

DESCRIPTION

The cranial sartorius muscle, with its proximal base on the hindlimb, can rotate into caudoventral abdominal wall defects (type II muscle).

SURGICAL TECHNIQUE

(A) The patient is anesthetized and the rear limb is clipped and prepared for surgery in standard fashion. A skin incision is made on the medial aspect of the thigh, overlying the length of the cranial sartorius muscle, extending proximally to the inguinal region. The subcutaneous tissue is dissected to expose the underlying cranial sartorius muscle.

(B) Muscle borders are defined by careful sharp and blunt dissection. The muscle is severed distally at its tibial insertion and elevated from the underlying tissues to the level of the proximal vascular pedicle. Care must be taken to avoid damage to the major pedicle of the cranial sartorius entering the muscle caudally and proximally.

(C) The elevated muscle can be rotated up to 180° into adjacent defects. In this clinical example, the muscle flap was used for the repair of a chronic caudal abdominal hernia. Muscle borders are sutured to regional fascial planes bordering the wound.

(D) A closed suction unit is ideally suited to control dead space at donor and recipient sites.

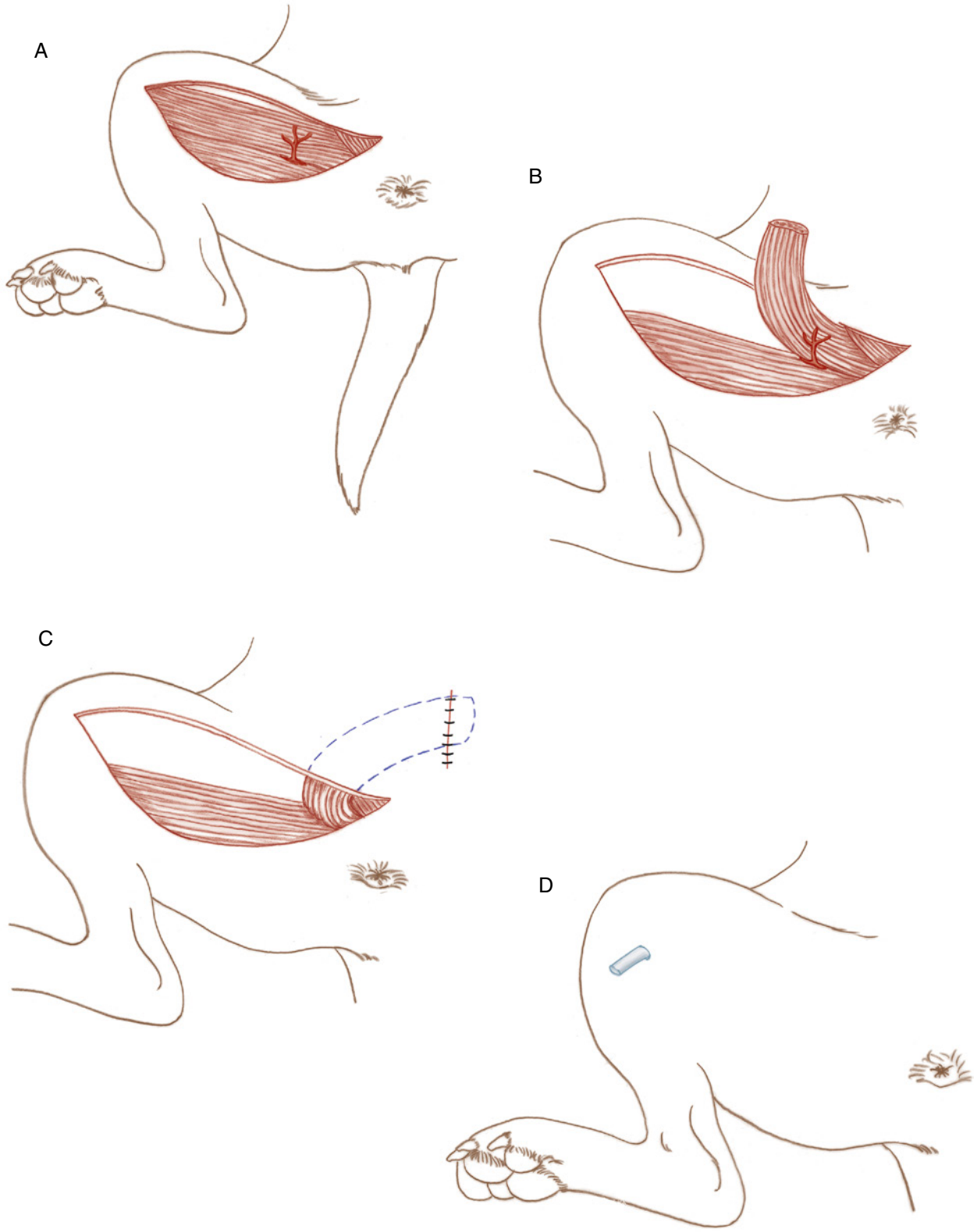
COMMENTS

Given its base and arc of rotation, the cranial sartorius muscle may have its greatest potential use for repair of prepubic tendon rupture when tissue trauma, retraction, and fibrosis preclude adequate reapposition of the tendon to the pelvis in the dog and cat. One or both cranial sartorius muscles can be mobilized if necessary. The cranial sartorius muscle may have additional use in the repair of difficult femoral hernias. Similarly, the pectineus muscle tendon can be divided to mobilize this short muscle for femoral hernia closure or reinforcement.

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Plate 112 Temporalis Muscle Flap

DESCRIPTION

The temporalis muscle flap has been described for closing orbito-nasal defects (trauma, tumor resection) and as a barrier for preventing skin from sagging into the orbit after orbital exenteration. A strong fascial sheet covers the muscle dorsally. The fan-shaped temporalis muscle resides in the temporal fossa and inserts on the mandibular coronoid process. More superficial circulation to the muscle is provided by the superficial temporal artery; the deep musculature is supplied by the caudal and rostral deep temporal arteries. The caudal deep temporal artery and rostral deep temporal artery both arise from the maxillary artery and course dorsally beneath the zygomatic arch, where they arborize in the temporal muscle. All three arteries anastomose, forming a rich vascular network within the temporal muscle (type II/III muscle).

SURGICAL TECHNIQUE

(A) In this example, orbital exenteration has been performed, with the skin incision extended caudally to expose the temporalis muscle.

(B) This illustration highlights the two muscle bundles that make up the temporalis muscle, medial to the zygomatic arch.

(C) The skin is retracted dorsally to expose the muscle; the flap is created approximately 20% wider than the width of the orbit to offset muscle contraction after elevation of the flap. The visible superficial temporal artery is identified and protected during exposure and elevation of the flap. The muscle is incised along the margin of the sagittal crest and is elevated subperiosteally from the skull with a periosteal elevator. Care is taken to preserve the deeper vascular blood supply. The sides of the flap are developed parallel to the muscle fibers. The temporalis muscle fascia can be dissected from the zygomatic arch to improve flap mobility.

(D) The flap can be rotated on its insertion and sutured into the margins of the bony/soft tissue defect. Holes may be drilled in the bony margins to facilitate suture placement.

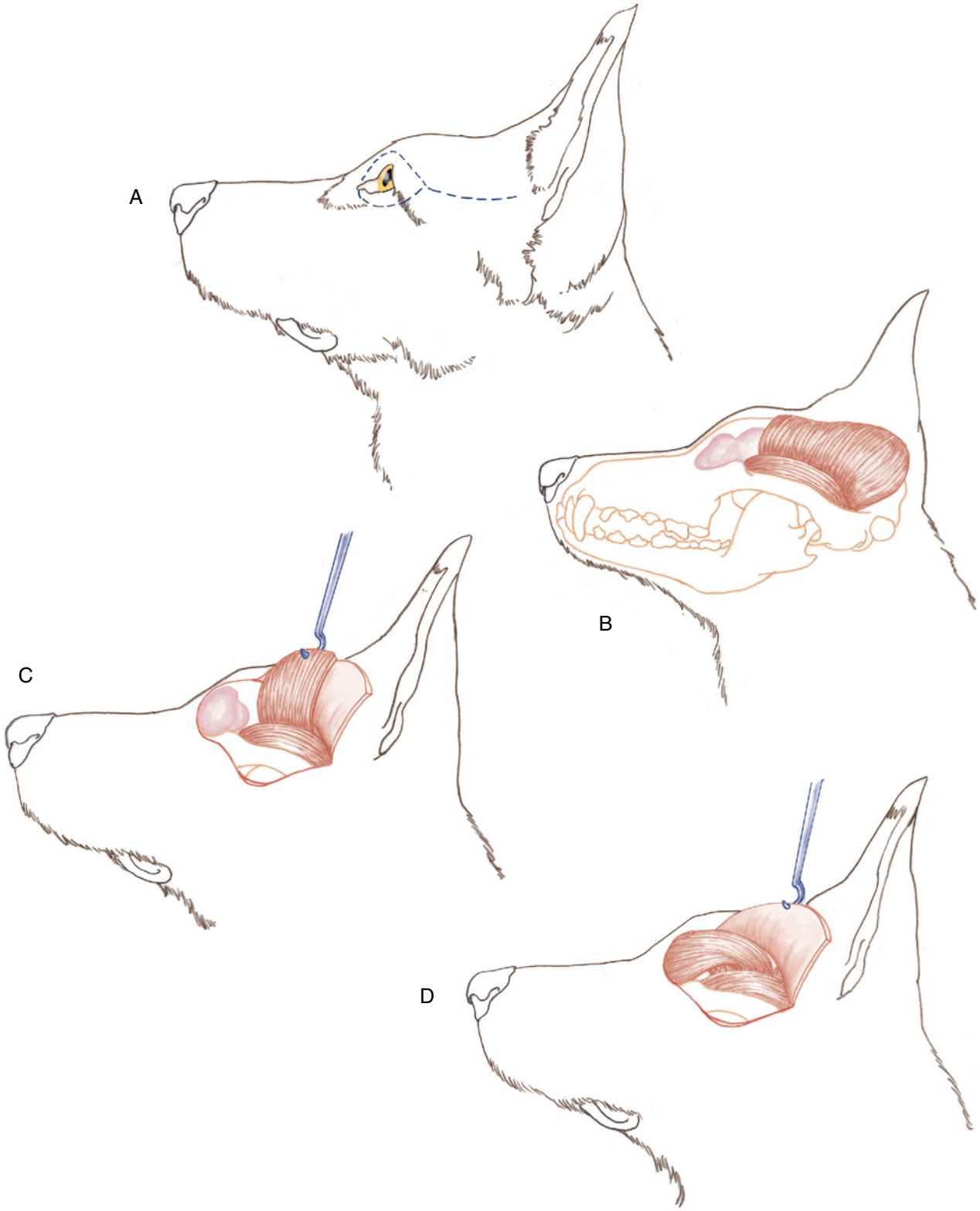
COMMENTS

In brachycephalic dogs, the temporalis muscles do not meet on the midline; this area is devoid of musculature. In dolichocephalic dogs, the left and right temporalis muscles join to form a mid-dorsal sulcus. The thickness and development of this muscle layer can vary with individual dogs. Mobilization of the temporalis muscle flap to reach the rostral margin of the orbital area can be difficult in some patients. Although this muscle flap is not routinely used, it can be helpful for problematic wounds or defects located within its arc of rotation. A dorsally based flap has been described, but division of a portion of its blood supply does risk tissue ischemia and subsequent muscle necrosis/fibrosis. This muscle flap has been used successfully to close an oronasal fistula in a dog (Cavanaugh et al. 2011).

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Plate 113 Transversus Abdominis Muscle Flap

DESCRIPTION

The more cranial portion of the transversus abdominis muscle can be elevated as a flap for closure of problematic defects of the diaphragm.

SURGICAL TECHNIQUE

(A) Anatomic outline of the diaphragm and the adjacent transversus abdominis muscle layer. A muscular branch off the phrenicoabdominal artery supplies a portion of the transversus abdominis muscle and can be incorporated into the flap during elevation. The dashed oval on the diaphragm represents the area to be replaced; the adjacent dashed line overlies the site for elevation of the transversus abdominis muscle flap.

(B) In this example, the flap is elevated in a caudal-to-cranial direction and folded forward to replace a large section of the diaphragm. The flap is secured using 2-0 or 3-0 monofilament, nonabsorbable, or slowly absorbable suture materials, depending on the size of the patient. Simple interrupted sutures can be pre-placed when closing the more problematic dorsal area of the diaphragmatic defect.

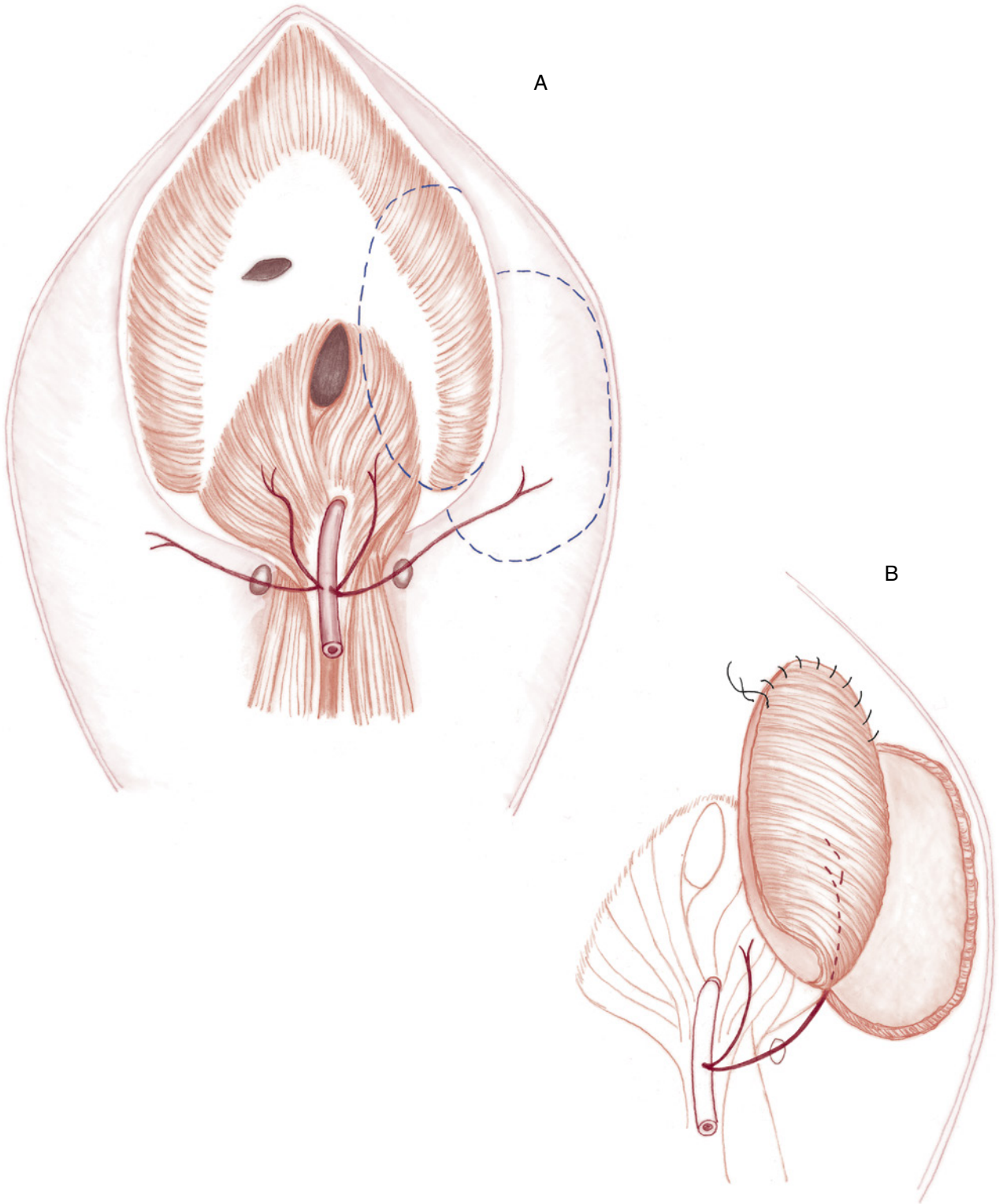
COMMENTS

This flap is uncommonly required for closure of diaphragmatic defects. The author has used it on two occasions to replace the right and left hemi-diaphragm in long-standing chronic diaphragmatic hernias in two dogs. It also can be used in those cases of neoplasia involving the diaphragm and adjacent tissue structures. Anatomic studies (unpublished, Pavletic and Trout) highlighted the muscular branches arising from the phrenicoabdominal artery. This vessel's inclusion in the flap is added assurance that muscle flap circulation is maintained. The use of the rectus abdominis muscle has been described in three dogs for smaller ventral diaphragmatic hernia repairs; use of the omentum would be a simpler alternative. The transversus abdominis muscle is an easier reconstructive technique for *major* diaphragmatic hernia repair that spares the patient the added surgical dissection associated with the rectus abdominis muscle flap. The transversus abdominis muscle has also been used as a gastrointestinal onlay flap.

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Plate 114 Semitendinosus Muscle and Myocutaneous Flaps

DESCRIPTION

The semitendinosus muscle has two dominant vascular pedicles (type III blood supply). The proximal gluteal artery supplies the upper or proximal half of the muscle, entering the proximal quarter of the muscle along its cranial border. The distal half of the muscle is supplied by the distal caudal femoral artery, entering the distal quarter of the muscle along its cranial surface. Because no controlled studies have been performed, it is not possible to determine whether the entire muscle can consistently survive on either vascular pedicle alone. The muscle halves can survive on separate vascular pedicles, but it is probable that larger portions of the muscle will survive on a single vascular pedicle. In one case report, the entire muscle and overlying skin segment survived as a myocutaneous flap based on the distal vascular pedicle for closure of a soft tissue defect of the tibial region. The proximal half of the muscle can be used for reconstructive surgical procedures involving the perineal area (ventral perineal hernia, reinforcement of the anal sphincter for incontinence, nonhealing ulcers). The lower half of the muscle can be extended distally for problematic wounds of the adjacent lower extremity. Bifurcation of the semitendinosus muscle has been reported to treat anal sphincter incontinence in two dogs (Kim et al. 2023). It is possible to develop a myocutaneous flap based on either the proximal or distal vascular pedicle (Fig. 16-12).

SURGICAL TECHNIQUE

(A_1) Outline of the proximally based semitendinosus muscle flap (left) and distally based myocutaneous flap (right) with overlying cutaneous surface (dashed lines). To expose the muscle for the proximally based muscle flap, a skin incision is made along the caudal border of the ischial tuberosity and continued distally along the caudal two-thirds to three-quarters of the length of the thigh. In this example, the muscle flap (left limb) is elevated by dividing the lower third of the muscle belly. The tendinous attachment to the ischium can be divided without compromising the circulation in order to facilitate muscle mobilization. The outline of a distally based myocutaneous flap also is illustrated (right limb).

(A_2) The dashed lines highlight the cutaneous territory of the semitendinosus myocutaneous flap based on the distal vascular pedicle. Note that the width and length of the cutaneous territory approximate the major width of the muscle belly.

(B_1) In this illustration, the elevated muscle is tunneled beneath the rectum and anus for closure of a ventral perineal hernia. The muscle is secured to the ventral aspect of the anal sphincter muscle and internal obturator muscles. Exposure of the area may be facilitated with a second incision in the opposing perineal area.

(B_2) In this example, the muscle is cupped around the external anal sphincter to improve muscle tone in a fecally incontinent patient. Note that the muscle attachment to the ischial tuberosity has been divided to improve flap mobility.

(C_1) The muscle has been divided distal to the ischial tuberosity and the cutaneous border of the overlying skin island incised.

(C_2) The myocutaneous flap is carefully elevated and rotated into a large defect below the caudal aspect of the knee, preserving the distal vascular pedicle.

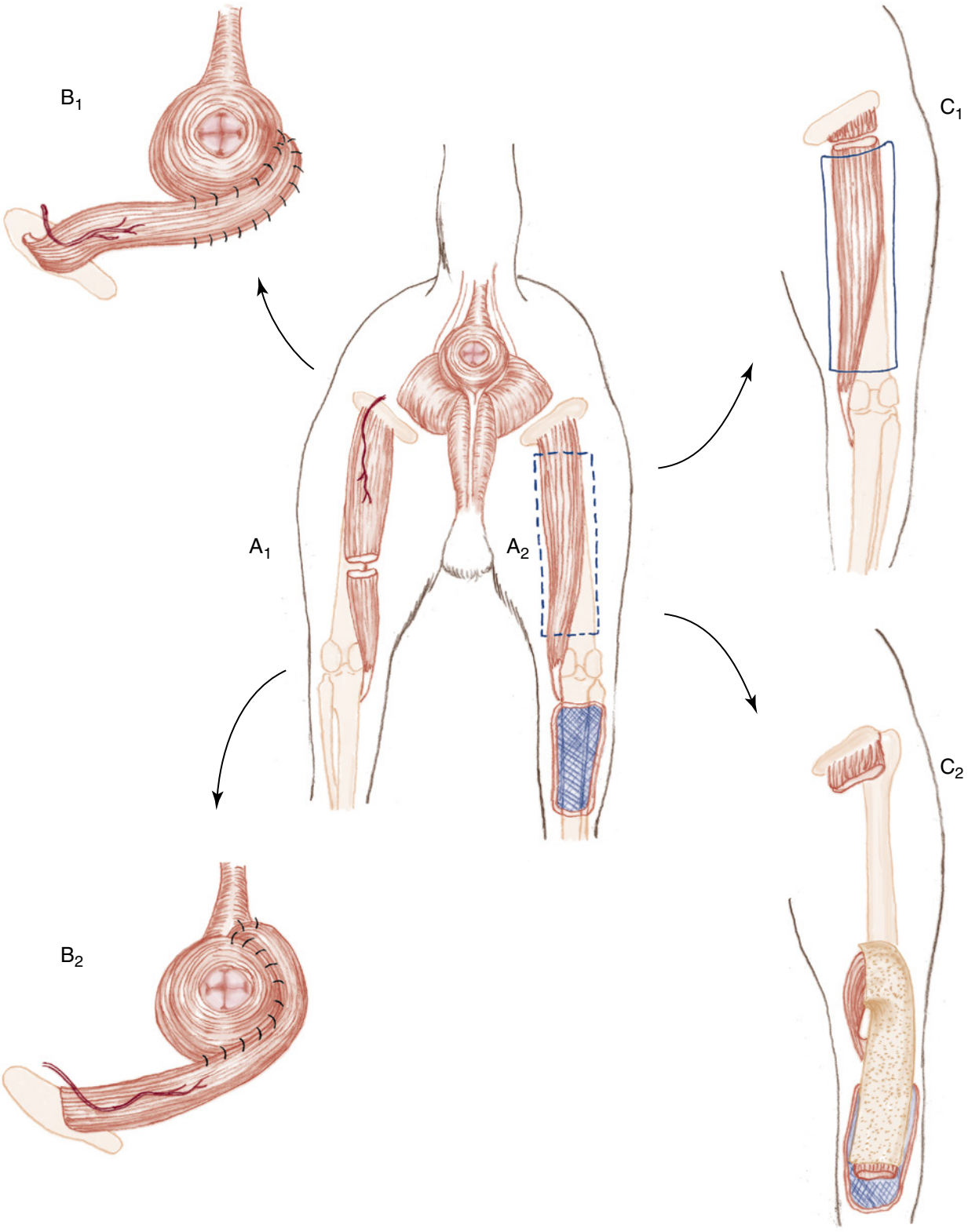
COMMENTS

As noted, additional studies are required to determine whether most of the muscle, if not its entirety, can survive on the proximal or distal vascular pedicle alone on a consistent basis. There are limited applications for the semitendinosus muscle flap and myocutaneous flap variations. However, management of problematic wounds involving the perineum and tibial region can be a challenge, and the potential accessibility of this muscle is a desirable feature. See Chapter 24 for alternative methods of managing fecal incontinence. Lastly, the superficial gluteal muscles have been used for closure of ventral perineal hernias, although one disadvantage is the need to reposition the patient intraoperatively when employing this procedure (see Plate 118). Fig. 16-12 demonstrates the step-by-step use of this muscle for successful reconstruction of a ventral perineal hernia.

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Plate 115

Flexor Carpi Ulnaris Muscle Flap

DESCRIPTION

The humeral head of the flexor carpi ulnaris is supplied by a vascular pedicle primarily from the ulnar artery and, to a lesser degree, the recurrent ulnar and deep antebrachial arteries. A caudal interosseous artery enters the distal end of the humeral head of the flexor carpi ulnaris at the deep face of this muscle, near its insertion on the accessory carpal bone. Branches of this artery run proximally and anastomose intramuscularly with the descending branches of the ulnar and deep antebrachial arteries. The caudal interosseous branch is capable of supplying circulation to a variable length of this muscle after division of the proximal blood supply. The elevated muscle can be used to cover problematic carpal, metacarpal, and distal antebrachial wounds. The muscle, in turn, can support a skin graft, if additional cutaneous coverage is required (type II muscle).

SURGICAL TECHNIQUE

(A) The skin is incised over the caudolateral aspect of the antebrachium, extending distally 1–2 cm beyond the accessory carpal bone. The underlying antebrachial and carpal fasciae are incised, exposing the ulnar head of the flexor carpi ulnaris caudally, the ulnaris lateralis laterally, and the humeral head of the flexor carpi ulnaris located between these two muscles. The distal tendon of the ulnar head is transected distally and reflected to allow complete exposure of the humeral head proximally (arrow). The borders of the humeral head are dissected and a myotomy is performed at the junction of the proximal and middle thirds of the muscle. The borders of the muscle are carefully dissected free of the adjacent tissues in a distal direction. Caution is warranted when approaching the deep surface of the distal tendon where the caudal interosseous vascular pedicle enters the muscle. The dashed line denotes the site for a potential "bridge incision."

(B) The muscle flap can be tunneled beneath interposing skin to gain access to the wound, or a bridge incision can be created to facilitate its placement into an adjacent defect, in this case a skin wound overlying the carpal area. The flap is sutured into position.

(C) In this hypothetical example, skin was shifted over the muscle flap. Alternatively, a free graft can be applied over the surface of the muscle if insufficient skin is available for closure.

COMMENTS

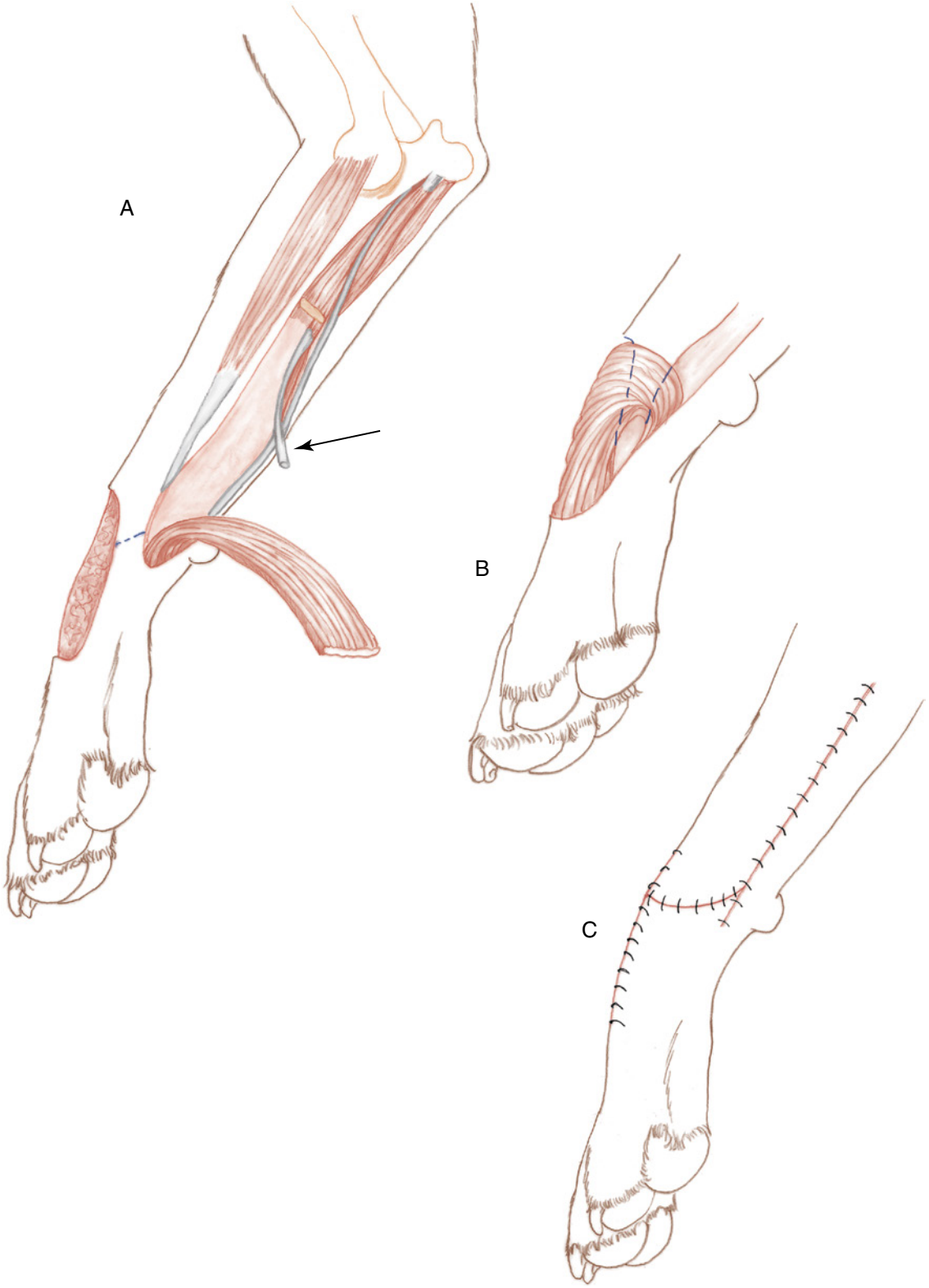
The length of muscle capable of surviving on the distal vascular pedicle alone is not known. Based on limited studies, over half is likely to survive without ischemic necrosis. This length, however, may be sufficient for most defects involving the carpal area and portions of the metacarpal area. Longer muscle flaps may be attempted, and partially excised intraoperatively if bleeding and discoloration (cyanotic appearance) are noted. Alternatively, any compromised muscle can be trimmed later during postoperative assessment of the muscle flap.

Extensive trauma involving the distal muscle and caudal interosseous blood supply may preclude use of this small muscle flap without Doppler ultrasound or angiography to assess the patency of this vital vascular pedicle. This muscle flap is infrequently needed, but can be useful for ischemic wounds secondary to radiation therapy or extensive trauma. With extensive skin loss, the viable muscular surface will serve as a vascular platform for free graft application. The graft can be applied at the time of muscle transfer or delayed until viability of the muscle is assured, usually signified by the formation of granulation tissue on its surface.

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Plate 115



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Plate 116

Cranial Tibial Muscle Flap

DESCRIPTION

The cranial tibial muscle, overlying the anterior tibial surface distal to the knee, is supplied by segmental branches of the cranial tibial artery. It has the potential to have a proximal or distal pedicle based on its circulatory pattern. The proximal-based pedicle is reported in the literature for defects within its arc of rotation (type IV muscle).

SURGICAL TECHNIQUE

(A) A skin incision is placed over the anterior tibial surface to expose the cranial tibial muscle (tibialis cranialis).

(B) The distal tendon is divided and the muscle is carefully elevated. Distal branches supplying the muscle (off the underlying cranial tibial artery) are ligated and divided.

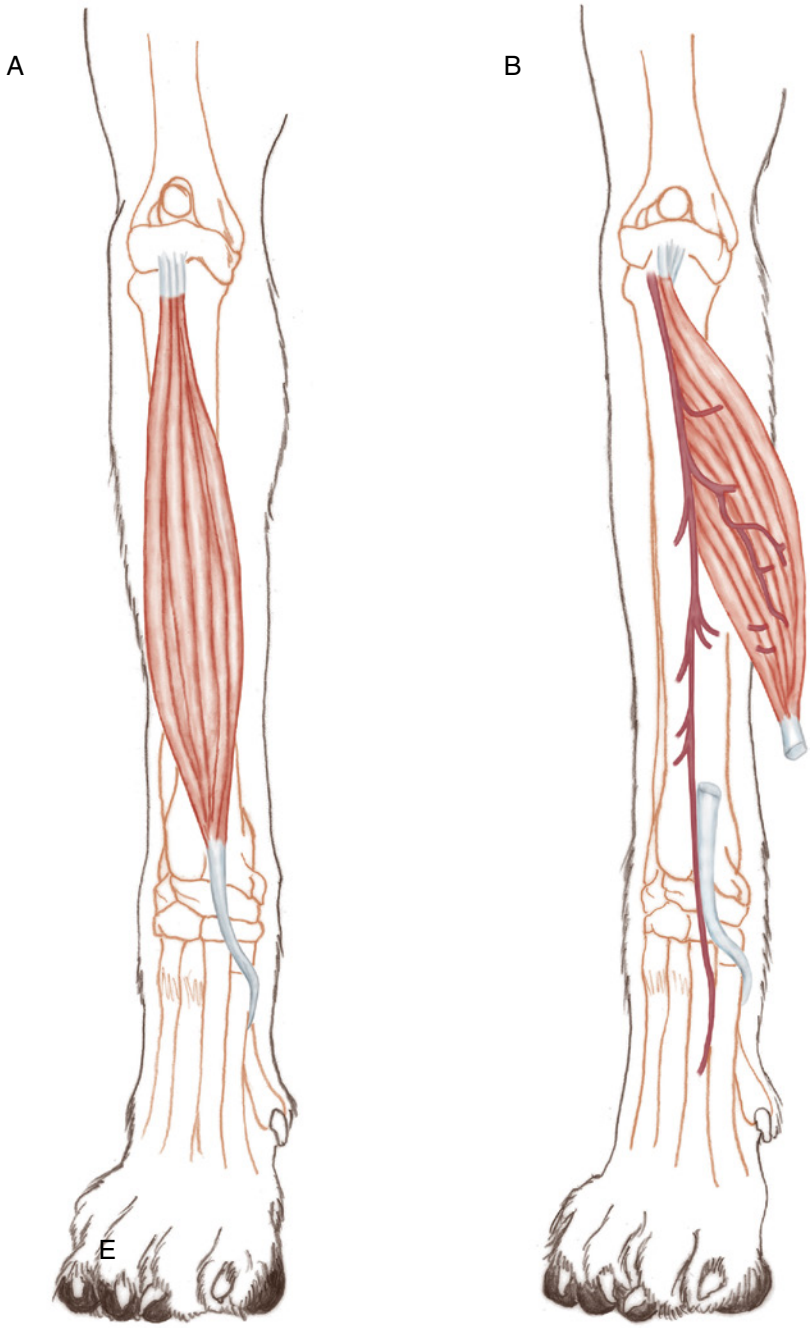
COMMENTS

The cranial tibial muscle can be used to supplement circulation to problematic wounds of the crus and serve as a vascular surface for application of a free graft. Its routine use is limited and it is rarely employed for wound closure. Nonetheless, it is one more technique for the surgeon's armamentarium.

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Plate 116



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Plate 117 Internal Obturator Muscle Flap

DESCRIPTION

The internal obturator muscles overlie each obturator foramen on the pelvic floor. The tendon of each muscle attaches to the trochanteric fossa after passing over the lesser sciatic notch. This expendable muscle contributes to the outward rotation of the hip joint. It is supplied by the small ischiadicus nerve and accompanying vessels. Complete elevation of the muscle, by dividing its tendon, has been described to fully mobilize this muscle tethered by its neurovascular pedicle. The author's variation utilizes this muscle as a simple flap to facilitate closure of perineal hernias (type I muscle). This muscle flap is routinely used by the author for most perineal hernia closures in dogs.

SURGICAL TECHNIQUE

(A) In this illustration, the internal obturator muscle can be elevated as a simple muscle flap (left). As noted in the veterinary literature, its tendinous attachment can be divided (dashed line) to improve mobility (right). The author prefers the simpler elevation of the muscle without tendon division. Using the standard approach to the perineal hernia (in this example, the left side), the internal obturator muscle is identified. An incision is created over the lower caudal border of the ischium. A Freer periosteal elevator is used to carefully undermine the dense fascia attached to the caudal border of the internal obturator muscle. This strip of fascia better supports the sutures used to secure this muscle to the external anal sphincter and sacrotuberous ligament (if needed). (*Note*: sutures are inserted *through* the body of the sacrotuberous ligament. There is a risk of entrapment of the sciatic nerve if sutures are placed around this structure.)

(B) The body of the internal obturator muscle is carefully undermined and elevated dorsally and sutured to the sacrotuberous ligament and external anal sphincter muscle. The author uses monofilament nylon sutures that are preplaced prior to tying the knots. Note that the coccygeal muscles are sutured to the upper external anal sphincter to close the dorsal portion of the hernia; the internal obturator muscle flap is used to close the ventral aspect of the hernia.

COMMENTS

The first step is to clearly identify (by sight and digital identification) all structures required for closure of perineal hernias. Sutures are preplaced and secured with a hemostat to each loop. Once complete, the sutures are sequentially tied. The author prefers monofilament nylon sutures; 2-0 suture is used for medium to large dogs; 3-0 suture material is used in small dogs. Experienced surgeons understand that the shape of the pelvis and the size of the patient influence the closure of perineal hernias. A wider pelvis makes closure more challenging because of the greater distance between the individual structures required to close perineal hernias. In some patients, the coccygeal muscle group is atrophied and there is little muscle present for hernia closure. In this case, the sacrotuberous ligament will play a more prominent role in closing the upper half of the perineal hernia. The internal obturator muscle flap alone or in combination can be used to close the comparatively rare ventral perineal hernia located below the rectum.

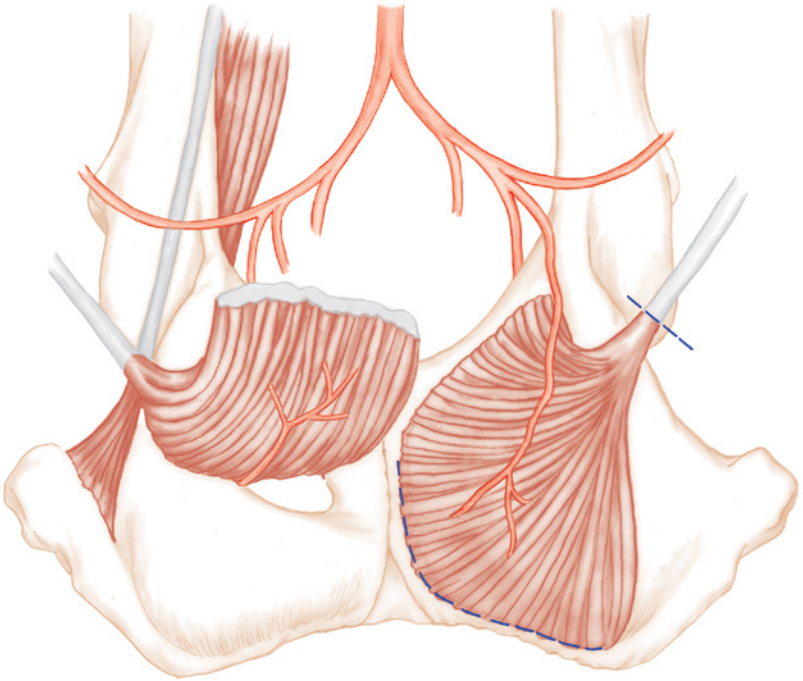
The author prefers not to remove peri-prostatic fat that is occasionally prolapsed into the hernia. This tissue is freed from any adhesions and pushed forward: when the hernia is closed, this viable fatty layer will adhere to the cranial face of the hernia repair with scar tissue for a more effective seal. For the most problematic or recurrent perineal hernia, other options include the superficial gluteal flap or the use of surgical mesh. To date, the combined use of the internal obturator muscle flap, coccygeal muscles, sacrotuberous ligament, and the external anal sphincter muscle has been highly successful in the author's hands. Neutering is recommended to reduce the risk of hernia recurrence. Bongartz et al. (2005) suggested the use of a fascia lata graft in the event the internal obturator muscle is too thin or friable for perineal hernia repair. Stoll et al. (2002) suggested the use of porcine small intestinal submucosa as an alternative. These latter techniques are normally reserved for recurrent problematic cases. See Plate 118 for use of the superficial gluteal muscle alternative.

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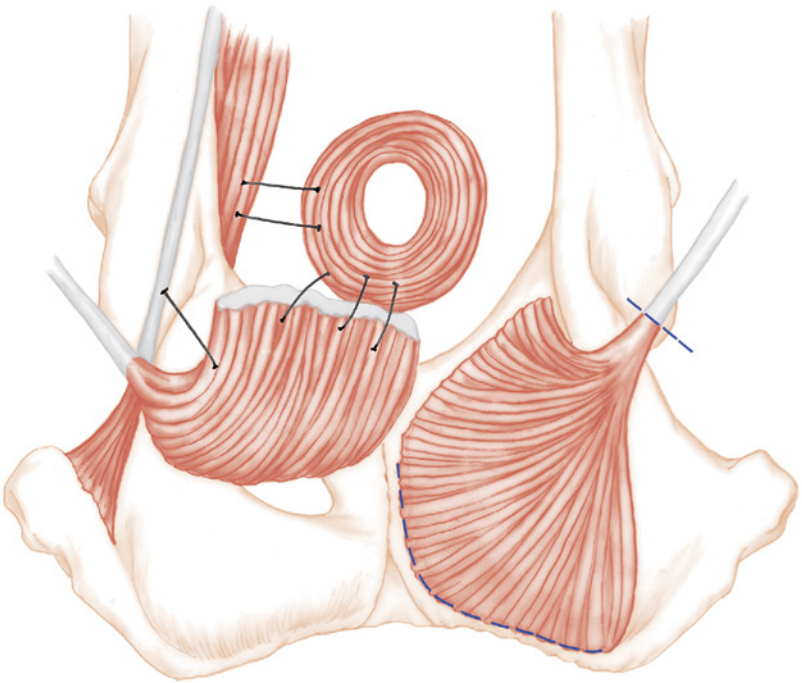
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Plate 117

A



B



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Plate 118 Superficial Gluteal Flap for Perineal Hernia Closure

DESCRIPTION

For the most problematic perineal hernias, the superficial gluteal muscle technique has been described. This accessible muscle is easily elevated from its greater trochanteric attachment and pivoted into the hernia (type II muscle).

SURGICAL TECHNIQUE

(A) Left hip region of a dog: note the attachment of the prominent superficial gluteal muscle to the greater trochanter.

(B) A curved or angular incision is used to expose the perineal hernia, with the incision extending cranially and dorsally to gain access to the greater trochanter/third trochanter and fan-shaped superficial gluteal muscle. Skin is undermined and retracted. The superficial gluteal muscle tendinous attachment to the greater trochanter is divided and the muscle elevated by careful dissection with Metzenbaum scissors.

(C) The muscle is pivoted into the perineal hernia, where it is sutured to the external anal sphincter and the dorsally located ventral-lateral sacrocaudalis muscle. The lower border of this muscle flap also can be sutured to the internal obturator muscle and sacrotuberous ligament for added security.

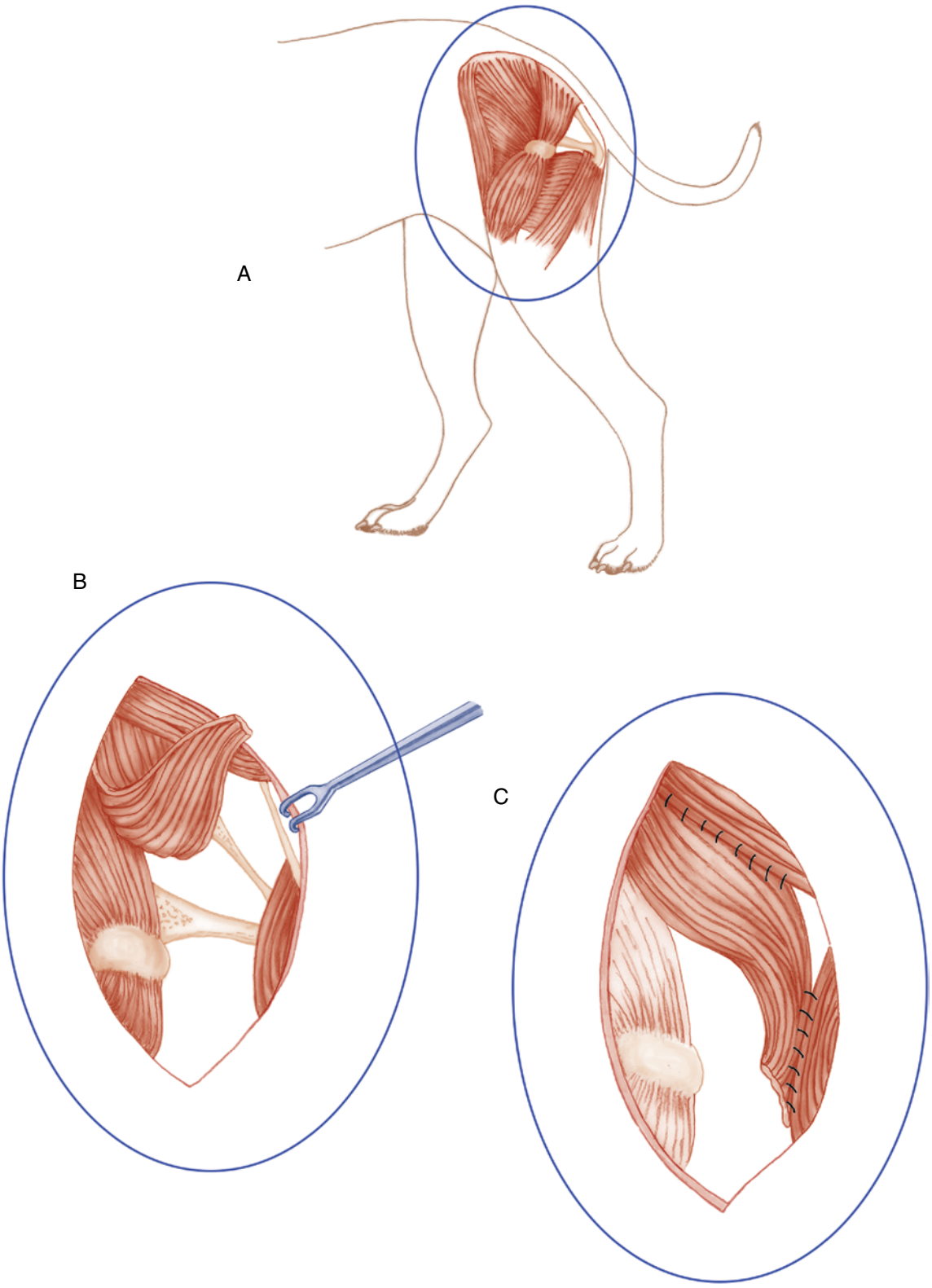
COMMENTS

The author would reserve this technique for the most problematic perineal hernias, particularly those with a history of recurrence after conventional closure. Bilateral superficial gluteal muscle flaps have been reported for the closure of ventral perineal hernias. As noted in Plate 114, the semitendinosus muscle flap is effective for ventral perineal hernia repairs and can be performed without the need for intraoperative repositioning of the patient, unlike the superficial gluteal muscle repair.

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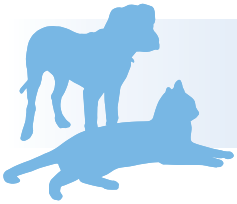
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Plate 118



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17

Oral Reconstructive Surgical Techniques

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INTRODUCTION

Defects involving the hard and soft palate (secondary palate) can be quite difficult to close successfully. The confined space of the oral and pharyngeal cavities limits visibility and surgical manipulation of the tissues. The mucosal tissues vary in thickness and durability in the oral cavity. The "suture-holding" strength of the tissues, based on relative collagen weave and content, can vary with the age and health status of the patient.

The palatal tissues are continuously exposed to motion from lingual movement, breathing, mastication, and swallowing. This movement can contribute to suture "cut-out," especially when a wound closure was performed under tension. Sutures can tear through the mucosa, causing additional inflammation and fibrosis. As a result, the inherent elasticity of the mucosal tissues declines with each subsequent surgical failure (see Chapter 6, Wound Dehiscence).

Consistently successful closure of palatal defects requires thoughtful planning before surgery. The patient must be in good health and in a state of positive protein balance. Postoperatively, the nutritional needs of the animal must be maintained to ensure that delays in healing are avoided. Tube feeding of the newborn patient may be required until the animal is old enough to be fed solid food by hand. The owner and veterinarian will need to feed a balanced canine or feline diet by altering the size and consistency of the small portions offered and by developing an appropriate feeding schedule. Water may be provided by syringe, with the head tilted slightly upward. Some patients may be able to eat and drink with little or no assistance. Difficult patients may require prolonged tube feeding. Esophagostomy or gastrostomy tubes may be a practical alternative for maintaining proper nutritional intake for prolonged periods of time. Care must be taken to watch the patient carefully for signs of aspiration pneumonia or nasal impaction from food and particulate matter. The veterinarian may need to clean the nasal cavity periodically, with cotton-tipped applicators, saline flushes, and suction, with the patient under anesthesia.

Wound closure requires meticulous atraumatic surgical technique. Suture materials must be selected that maintain their tensile strength for a prolonged period of time. A material with a small amount of elasticity is preferred in order to adjust to the variable degree of motion most oral closures are subjected to in the postoperative period. A swaged-on reverse cutting needle or a sharp taper-point needle are the author's preference, both for their ability to pass through tissues easily and their tendency to resist suture cut-out. Monofilament suture materials are preferred for their ability to glide through the mucosal tissues with minimal drag. In most cases, 3-0 is the most appropriate-sized material to select for the dog and cat. Polydioxanone is the author's suture material of choice.

Sutures should be placed beyond the 5 mm border of the wound, since collagenase activity within this healing area also can increase the possibility of suture cut-out. As a result, the author prefers to place sutures 6–8 mm from the wound border (and approximately 10 mm distance apart). Because the cut borders of oral mucosa have a tendency to curl inward ("scrolling") during suture apposition, an everting pattern is preferable to assure submucosa-to-submucosa abutment for optimal healing. The vertical mattress suture pattern is an excellent choice for its ability to resist dehiscence, evert the apposed borders, and minimally impair local microcirculation. In many cases, the author alternates vertical mattress sutures with simple interrupted sutures, since the latter pattern can help stabilize the everted wound borders during the healing process.

Slightly everting the incisional closure is important to offset the tendency of the oral mucosa to curl or scroll inward. The author prefers closure with vertical mattress sutures to evert the mucosa to ensure collagen cross-linkage to the apposed submucosal surfaces. Simple interrupted sutures are alternated with the vertical mattress sutures to both stabilize and accurately align the mucosal borders.

It must be remembered that wound closure under *minimal tension* is absolutely critical to successful surgical closure. Closure under excessive tension will defeat the best suture material and pattern placement. Although custom-fitted acrylic retainers have been used protect a palate repair from postoperative motion and trauma, the author sees no merit in their routine use. From the author's personal experience, most cleft palate repairs do not require their use or the care required to prevent food and particulate matter from accumulating between the retainer and the underlying incision. This chapter includes several techniques that can be used to close the more challenging congenital and acquired defects encountered.

Postoperative care includes curtailing patient activity for approximately 4 weeks following closure. Feeding soft food is indicated during this time period, followed by the gradual reintroduction of dry food once healing is considered complete. Patients should not be allowed to chew rawhide treats or other hard objects.

Tension is the worst enemy of primary closure of palatal defects. Suture cut-out and dehiscence are likely in this problematic area.

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This chapter emphasizes some of the more unique methods of managing problematic maxillary "holes," including cleft palate repair. Partial mandibulectomy and maxillectomy tips are discussed along with partial lingual resection (partial glossectomy).

CLEFT PALATE

Cleft palate defects can be among the most challenging surgical cases encountered in small animal practice. In the newborn puppy or kitten, palatal defects are most likely to be hereditary (Fig. 17-1). Although a number of factors (nutritional, hormonal, mechanical, toxic) have been recognized as causes of palatal defects in humans, heredity is considered a major factor in animals and has been demonstrated in canine breeding studies. As a result, it is advisable to spay/neuter dogs and cats with congenital palatal defects. Veterinarians should always examine animals with congenital defects carefully: occasionally other anomalies may be detected.



FIG. 17-1 (A) Bilateral cleft lip in a French bulldog. (B) Oral view noting a cleft palate defect.

In the human literature, there are a variety of techniques for cleft palate repair. Successful repair in humans not only requires closure of the defect for normal eating and drinking but also selecting a technique that will give the child the best possibility of speaking normally. In veterinary medicine, however, successful closure is measured by resumption of normal eating, drinking, and breathing. Except for extremely wide cleft palate defects, both the bipedicle flap (von Langenbeck) technique and mucoperiosteal flap (overlapping flap or mucoperiosteal hinge flap) techniques can be used to close most of the cases presented to the veterinarian, without resorting to the more elaborate techniques used in humans. These two procedures and their basic variations are described in detail here (Plates 120 and 121). It must be noted that both techniques, from the author's experience, work well for the narrower gaps encountered.

An extended version of the overlapping mucoperiosteal technique has been reported in the literature (Plate 122). This requires the extraction of the upper premolars 4-6 weeks before final flap elevation, allowing time for recovery of the circulation to the traumatized gingival tissues. This allows the surgeon to create a lengthened version of the overlapping flap by incorporating the gingival tissues. As a result, this longer overlapping flap has the potential to improve coverage over a wider cleft palate. Unfortunately, this requires subjecting the dog to two major surgical procedures with the loss of multiple teeth. It is the author's experience that the von Langenbeck bilateral bipedicle flaps technique is normally able to close the wider defects without the necessity of multiple tooth extractions and more than doubling the costs associated with cleft palate closure. As illustrated in Plate 121, the overlapping flap in this example was combined with using a bipedicle flap (half of the von Langenbeck technique) to improve coverage and reduce incisional tension. This is a consideration if the surgeon realizes intraoperatively that the overlapping flap is insufficient for coverage of the cleft. As such, the use of the von Langenbeck technique alone would have been preferable.

After using both procedures over the past four decades, the author believes the bipedicle flap (von Langenbeck) technique is easier to execute and currently is the preferred choice for most clefts (congenital or acquired) (Figs 17-2–17-5). Of the congenital palatal clefts, dolichocephalic dogs can be a greater challenge, based on the tapering of the muzzle rostrally, thereby resulting in narrower donor areas for cleft closure in this area (Figs 17-6 and 17-7).

There are differing opinions on the optimal time to close a congenital cleft palate in small animals. Assuming the patient is healthy, well nourished, and free of respiratory infection (secondary to possible aspiration pneumonia),

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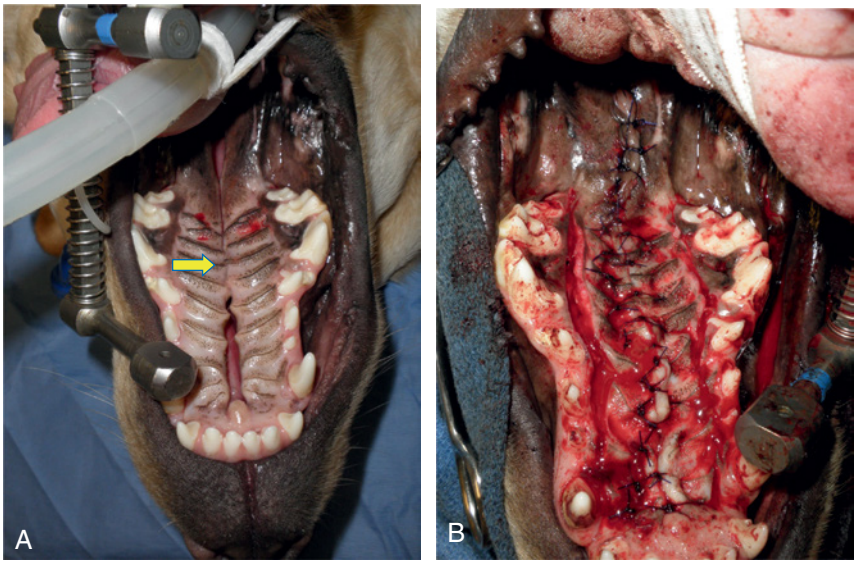


FIG. 17-2 (A) Narrow cleft palate defect. Although the caudal portion of the hard palate appears complete (arrow), a probe easily slips into the nasal cavity through this narrow cleft. (B) Closure using the Von Langenbeck technique. The mucoperiosteal flap also could be used successfully in closure of this narrow cleft palate.

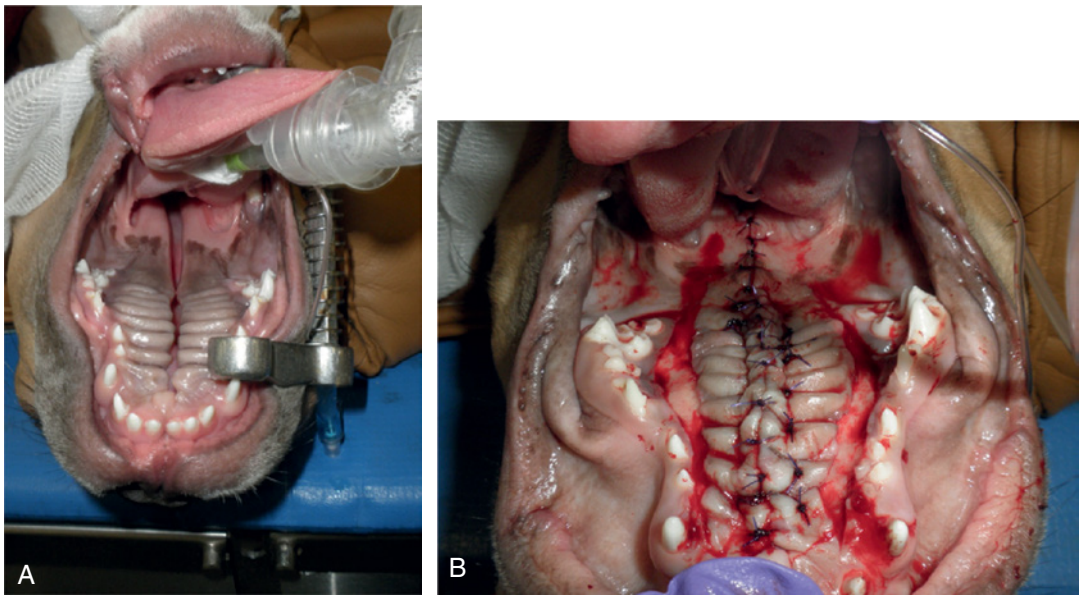


FIG. 17-3 (A) Narrow palatal defect. Either the Von Langenbeck or the "hinge flap" technique could be used successfully in this case. (B) Closure using the Von Langenbeck technique. Successful execution of this procedure requires the complete undermining and elevation of each of the bipedicle flaps prior to advancement. Closure requires the use of vertical mattress sutures (normally 3-0 polydioxanone). There is a tendency for the incision borders to shift or "stair step" with vertical mattress sutures: 4-0 polydioxanone interrupted sutures (placed between the vertical mattress sutures) ensure proper alignment of the incisional borders. Source: Pavletic MM. 2023. Surgical closure of cleft palate defects in dogs using a modification of the traditional von Langenbeck technique: 12 cases (2015–2022). *J Am Vet Med Assoc* 261:526–535. Reproduced with permission of The American Veterinary Medical Association.

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the author prefers to close the defect no earlier than 5 months of age. It must be noted that older patients have stronger tissues (greater collagen content) that are better capable of holding sutures compared to patients that are 2–3 months of age. Moreover, in many cases seen, the *relative* width of the cleft may proportionally narrow as the head of the dog matures. As a result, there is potentially more donor mucosa that can be mobilized to close the defect. Although some owners would prefer earlier closure to minimize the need to hand-feed and nurse the animal, the advantages that can be gained by delaying the closure to a later time are most significant. As long stated by the author, "the first attempt at closure is the best chance for success" in cleft palate repair.

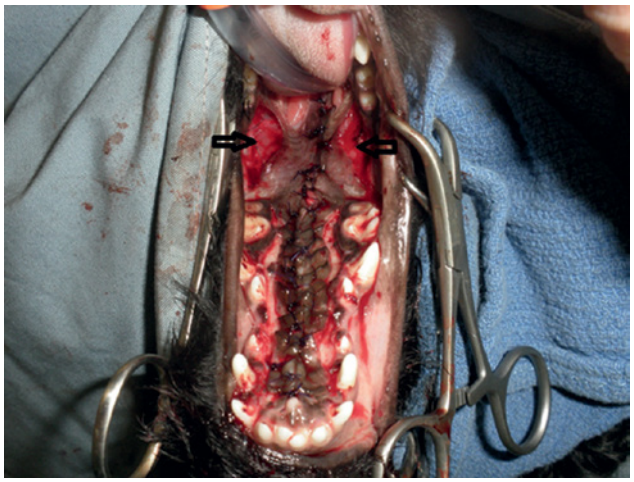


FIG. 17-4 Closure of the hard palate defect using the Von Langenbeck technique. The soft palate was closed in two layers. Note the two release incisions used to facilitate closure of the soft palate (arrows). The soft palate commonly is closed in two layers, normally using a simple interrupted suture pattern.

Cleft Palate Repair Tips

Surgeon preference for cleft palate closure can differ based on the individual's skills and experience, as well as the relative width of the defect. The author normally prefers a modified von Langenbeck technique (Pavletic 2023) in dogs. He usually waits until the dog is 5 months of age, primarily to ensure the donor palatal tissues are stronger to support suture placement. In many cases, the width of the cleft may proportionately narrow as the patient's head matures during normal development, facilitating closure.

The author typically selects 3-0 absorbable polydioxanone suture material and uses a vertical mattress pattern, ideally placed in the thicker rugal folds of the palate for added strength in the closure. To properly align the offset margins ("stair-stepping") that may occur using mattress sutures, the author normally places interrupted 4-0 polydioxanone sutures between the 3-0 mattress sutures following their placement. It is not uncommon for a small oronasal fistula to remain at the level of the incisive papilla following closure. From the author's experience this normally does not cause any clinical problems. If it does, closure can be later attempted in the mobilization of a mucoperiosteal flap or a labial flap (Plate 120).

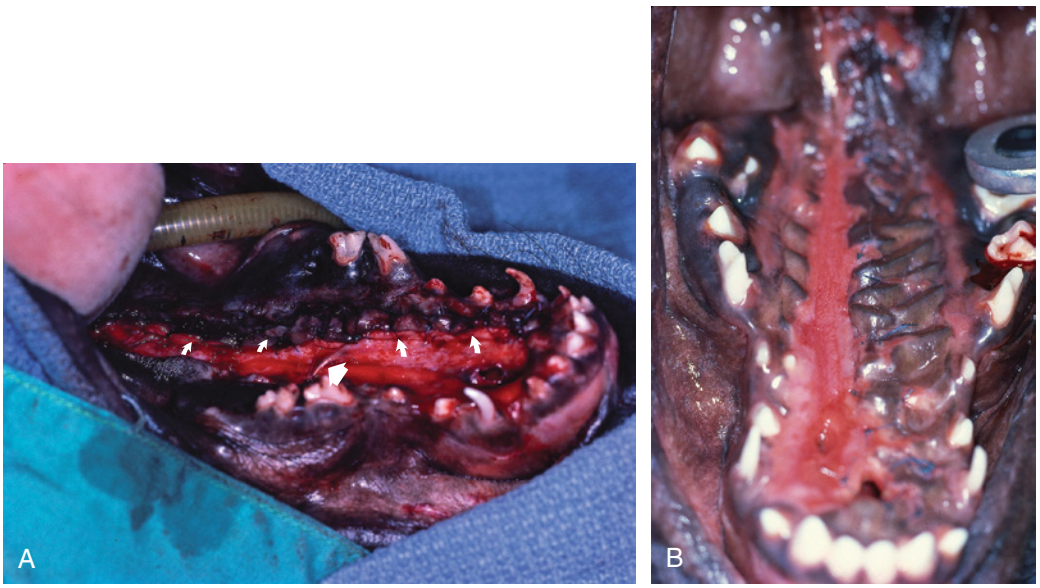


FIG. 17-5 (A) Labrador with a cleft palate closed with an overlapping or "hinge" mucoperiosteal flap. (B) Rapid epithelialization of the open wounds was noted within 10 days after surgery. (See Plate 121.)

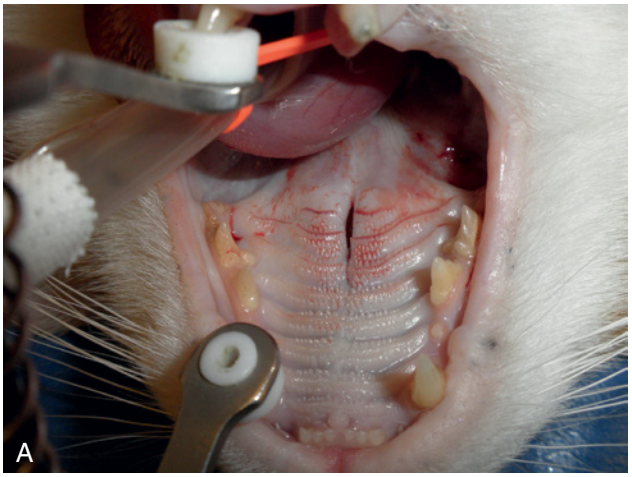
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FIG. 17-6 (A) Wide cleft of the hard palate. However, note the wide lateral donor areas to facilitate closure of the defect. (B) This Shetland sheepdog presented with a problematic defect of the cleft palate. The long, narrow length of this wide palatal defect presents a challenge, since each lateral donor area is comparatively narrow, particularly in the rostral area of the maxilla. The Von Langenbeck technique was used to close this more problematic cleft.



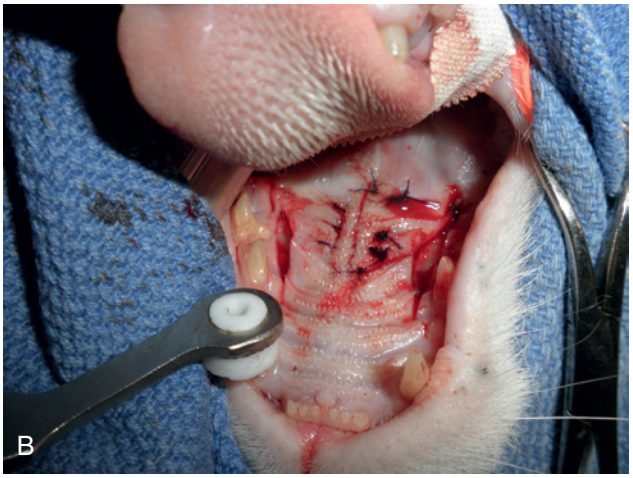


FIG. 17-7 (A) Chronic traumatic defect of the hard palate in a cat. (B) Closure using the Von Langenbeck technique with vertical mattress sutures.

Acquired palatal defects can be seen secondary to trauma. Cats that fall from a height or are struck by a vehicle can present with a split in the hard palate. Small fissures, a few millimeters wide, may seal with a blood clot and heal without surgical intervention. However, wider gaps may not heal and are best closed within a few days of the injury. This can be accomplished with placement of a 22-gauge wire around the root or base of opposite teeth in the mid-palatal region. The wire can be placed beneath the mucosal layer of the hard palate and the wire ends gently twisted together until the bone gap is approximated. The upper and lower dental arcades should be examined to ensure proper occlusion is maintained. The mobilized mucosal borders can be sutured to complete the closure. A several-day delay in repair can result in failure to compress the bony palate with a surgical wire. Under these circumstances, the use of the bipedicle (von Langenbeck) flap technique, illustrated in Plate 120, generally is successful (Fig. 17-7).

PALATAL DEFECTS/ORONASAL FISTULAS

Most holes involving the hard palate are the result of destructive neoplasms, tumor resection with secondary dehiscence of the closure, tissue necrosis secondary to radiation therapy for neoplasms, electrical heating cord injuries, persistent openings after dental extraction, or the occasional handgun/rifle round impacting the hard palate. Fistula formation also can be the result of a failure in closing cleft palate defects (Fig. 17-8). Defects adjacent to the lingual surface of the dental arcade generally are the easiest to close. Labial and buccal

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FIG. 17-8 (A) This canine patient was referred for evaluation of a problematic congenital cleft palate. Three previous attempts at closure failed, the most recent being the extended hinge flap technique noted in Plate 122. This third attempt at closure was preceded by the extraction of the left upper dental arcade. Approximately 1 month later the extended hinge flap was attempted. Most of this flap underwent necrosis, resulting in enlargement of the palatal defect. (B) The uninvolved right half of the palate was elevated as a bipedicle mucoperiosteal flap (see Plate 120). (C) The bipedicle flap was undermined and sutured to the remaining portion of the left mucoperiosteal margin of the large defect. Incomplete closure of the soft palate was also corrected. (D) Most of the large palatal defect was closed. This remaining rostral defect required closure with labial flaps facilitated by a Foley catheter anti-tension technique (see Fig. 9-24).

mucosa can be advanced or rotated into the defect after removal of the interposing teeth. The central palatal area is more problematic, especially for the larger holes in this location. Mucosal/palatal flaps can be used in many of these cases. Additionally, a full-thickness labial advancement flap created perpendicular to the facial axis can be used successfully to close many of the more challenging cases (Figs 17-9 and 17-10). There is one report on the successful use of a lingual flap for closure of an oronasal fistula in a cat. A small cartilage graft from the pinna has been used to close small oronasal fistulas in cats (Fig 17-11). The angularis oris artery has also been incorporated into a mucosal flap using the adjacent buccal and lower labial mucosa for closure of problematic palatal defects. The facial or angularis oris axial pattern flap also has been used for closure of larger palatal defects. (See Chapter 15, Plate 94.)

The author has used the upper labial full-thickness flap to reconstruct large palatal defects spanning the width of the palate, outlined in Plate 128. Figure 17-12 is an example of using this upper labial advancement flap to reconstruct the caudal hard and soft palates. The cutaneous surface faced the nasal cavity with the labial mucosal surface facing the nasal cavity. A variation of the full-thickness upper labial flap, a "superior labial musculomucosal flap" (Doyle and Degner 2019) has been developed for feline intraoral defects by its dissection and elevation from the overlying labial skin surface (Plate 129). Major reconstruction of the

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FIG. 17-9 (A) Use of a full-thickness labial flap to close a traumatic defect of the hard palate. The adjacent teeth were removed and the maxillary bone smoothed down with a Hall air drill to accommodate the labial advancement flap. The labial mucosa faces the nasal cavity; the skin surface of the flap faces the oral cavity. The labial border was trimmed and the entire flap sutured into the defect. (B) Completion of the closure. Note that the incised labial borders were sutured together, leaving a slit opening dorsally to accommodate the base of the labial flap. (C) The dog approximately 8 weeks later. The linear labial defect obscured by hair growth can be closed by carefully incising the cutaneous base of the flap and suturing the borders to the adjacent labial defect. Alternatively the area may be left alone if no dermatitis has been noted. (See Plate 125.)

soft and hard palate can be problematic, and cases must be carefully assessed to ensure successful long-term benefits for the patient (Plate 130). Small oronasal fistulas rostral to the soft palate can be closed with a partial-thickness advancement flap of the soft palate (Plate 131).

> The author has used skin flaps for closure of oral and labial defects for several years. Although dermatitis may be noted from exposing the skin to the moist oral environment, clinically the dogs and cats have done well.

MANDIBULECTOMY AND MAXILLECTOMY

When performing basic mandibulectomy and maxillectomy surgeries, we are not reconstructing the lost bone segments, although this has been attempted for segmental mandibulectomies. Following resection of the diseased/damaged tissues, the focus is in closing the defect. In maxillectomies, there is a special need to separate the oral and nasal cavities in order to preserve normal eating and breathing of the patient. Surprisingly, cosmetic results are normally acceptable depending on the location and extent of the tissues resected. Most dogs fare reasonably well with most resections.

Mandibulectomy and maxillectomy are almost exclusively used for the removal of neoplasms. Plates 132 and 133 outline the basic variations of both surgical procedures. In most cases, the adjacent labial and buccal mucosa can be undermined and advanced over the defects. Technically, mandibulectomies and maxillectomies are easier to perform in the rostral half of the oral cavity. Maxillectomies in the caudal portion of the oral cavity can be more challenging based on the more

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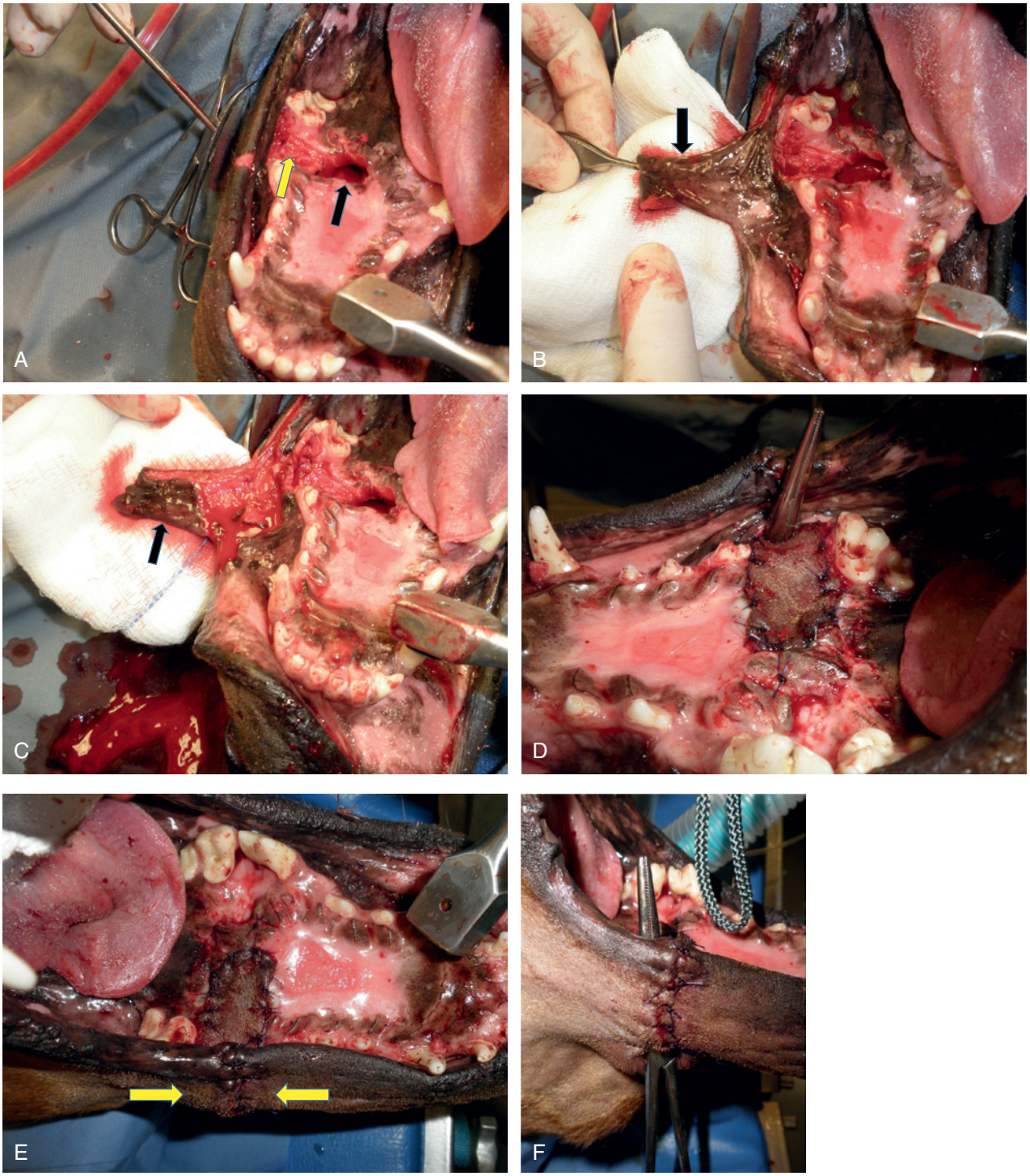


FIG. 17-10 (A) Oronasal fistula secondary to radiation therapy (black arrow). The yellow area points to the removal of the carnassial tooth and mucosa. A Hall Air Drill was used to lower and flatten the bone to accommodate a labial flap. (B) Elevation of a full-thickness labial flap (see Plate 125). The labial border will be resected (arrow) in preparation for its placement over the orocutaneous fistula. (C) Full-thickness labial advancement flap (arrow). The island of mucosa will face the nasal cavity. (D) The labial flap secured to the debrided margins of the oronasal fistula with the mucosal surface facing the nasal cavity. (E) The rostral and caudal margins of the left upper lip are approximated (arrows). (F) The hemostat highlights the slit opening where the base of the flap passes medial to the outer labial defect closure. This gap is normally left intact, although it could be closed once healing is complete, waiting 2 months to ensure collateral circulation of the flap fully develops. (See Plate 125.)

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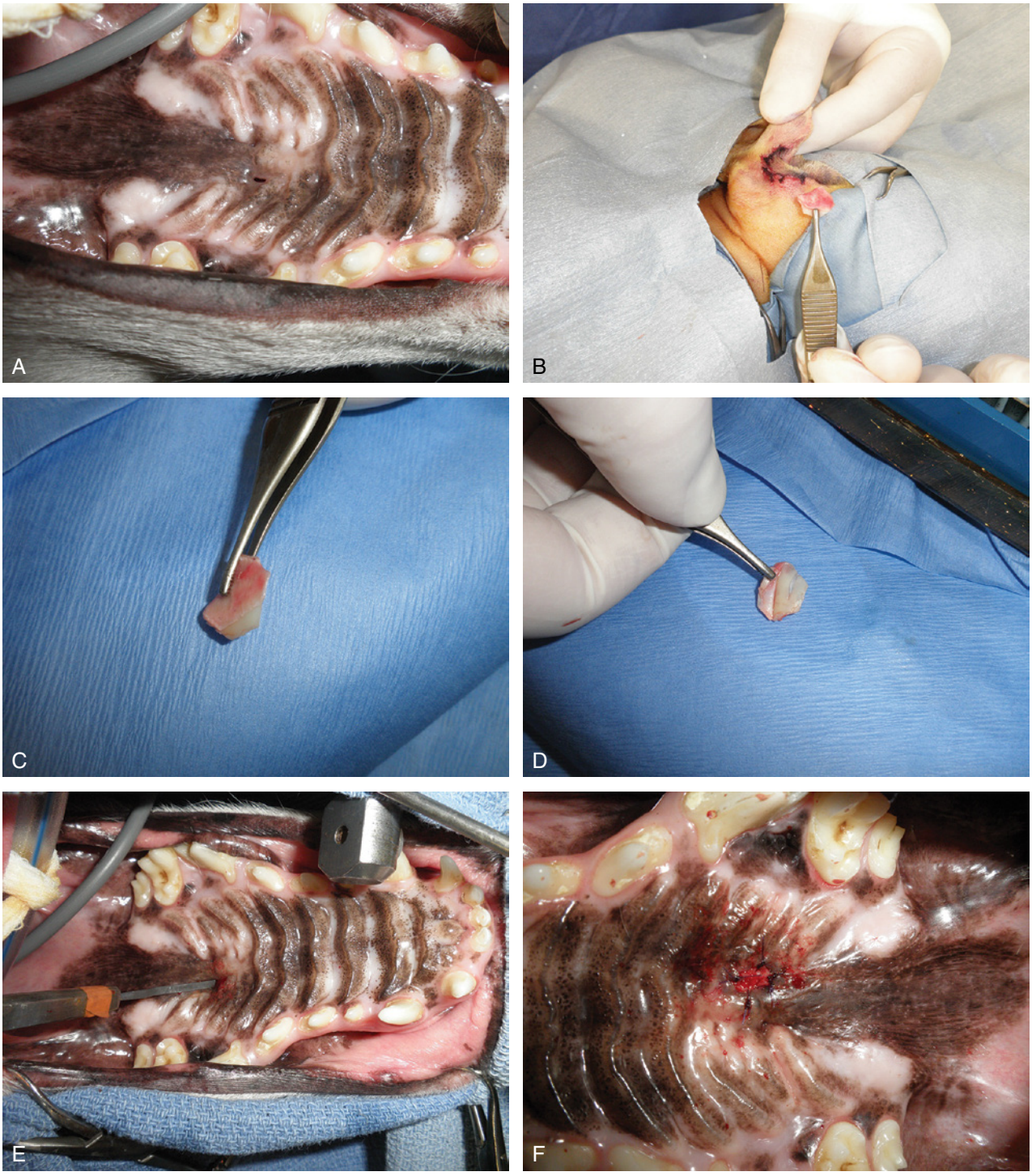


FIG. 17-11 (A) Chronic oronasal fistula secondary to traumatic palatal defect. (B) A wafer of pinnal cartilage was resected from the margin of the right pinna. A small flap of the lateral pinnal area was reflected to expose the cartilage. In this photograph, the flap has been sutured back. (C) The harvested graft. Iris scissors can be used to contour the graft prior to its insertion. (D) In this example the lateral and medial cartilage surfaces were separated, creating a thinner wafer of cartilage. (E) A no. 11 scalpel blade was used to excise the epithelial margin of the fistula. A small elevator was then used to free the mucosa from the underlying bone. Both steps are important for the preparation of a freshened wound bed for graft placement. The cartilage scaffold, covered with granulation tissue, forms a vascular platform for epithelial cell migration. (F) The cartilage wafer was trimmed with a 3 mm border to overlap the circumferential margins of the defect. Four absorbable (4-0) sutures were used to secure the graft to the prepared margins of the fistula. It is important to place a suture into the graft prior to tucking it into the defect, in order to avoid dropping the cartilage into the nasal cavity. The graft successfully closed this defect. (See Plate 126.)

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FIG. 17-12 (A) Diffuse squamous cell carcinoma involving the hard and soft palatal tissues. (B) Reconstruction with a full-thickness labial advancement flap. (C) The labial defect created by the loss of the upper lip was replaced with a local skin flap pivoted into the area. It is advisable to consult with an oncologist to determine the best method(s) to prevent recurrence of oral neoplasms when complete surgical margins are in question.

restrictive exposure to the area; an assistant can retract the oral commissure caudally. Alternatively the oral commissure can be temporarily incised to improve exposure. Tumors primarily confined to the level of the dental arcade are technically easier to resect and achieve wider surgical margins. As neoplasms extend to the mid-palatal area, complete resection and closure become more challenging. With large maxillectomy defects, the flaps discussed earlier are options for reconstruction of the area, as noted. The omocervical axial pattern flap also has been reported (Dundas et al. 2005) for maxillectomy closure.

Mandibulectomy: Basic Nomenclature Pertaining to the Area Excised

- *Rim excision*: resection of the involved dental arcade in a semi-lunar shape, retaining the lower mandibular margin
  - Tumor primarily located in gingival area
  - Excision is semi-lunar in appearance
- *Unilateral rostral mandibulectomy*: resection of the unilateral three incisors, canine tooth, and first/second premolars
  - Small tumor not associated with mandibular symphysis
  - Preservation of the caudal portion of the symphysis, when possible, will maintain the integrity of the mandible and allow the dog to eat normally
- *Bilateral rostral mandibulectomy*: resection may be rostral or caudal to the canine teeth and may extend further caudally into the premolars
  - Tumor location influences extent of this bilateral resection
  - Preservation of the caudal portion of the symphysis, when possible, will maintain the integrity of the mandible and allow the dog to eat normally

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- *Total unilateral mandibulectomy*: division of the symphysis and resection of the entire unilateral mandible including the vertical ramus
  - Extensive unilateral neoplasms
  - In tumors involving a portion of the opposite mandible rostrally, a "one-and-one-half" mandibulectomy can be performed in dogs
- *Subtotal unilateral mandibulectomy*: tumors involving the body of the mandible without invasion of the vertical ramus
  - The mandible is divided rostral to the junction with the vertical ramus and includes half of the symphysis
- *Segmental mandibulectomy*: resection of a segment of the mandible between the vertical ramus and caudal to the second premolar
  - Smaller growths that are not likely infiltrating rostral and caudal to the excision
  - Note that loss of the innervation to the remaining rostral premolars will result in devitalization of these teeth
- *Caudal mandibulectomy*: resection primarily limited to the vertical ramus of the mandible with a variable portion of the caudal body of the mandible
  - Tumors limited to the caudal extent of the mandible
  - *Note*: partial resection of the vertical ramus has been performed when scarring between the vertical ramus and zygomatic arch restricts the dog from opening its mouth. This can be secondary to trauma or scarring secondary to local radiation therapy. Surgery also may require resection of the zygomatic arch

Maxillectomy: Basic Nomenclature Pertaining to the Area Excised

- *Incisivectomy*: tumors restricted to the incisive bone
  - Small neoplasms or trauma limited to incisive bone rostral to canine teeth
- *Unilateral rostral maxillectomy*: resection of a portion of the incisive bone and rostral maxillary bone on one side of the skull
- *Bilateral rostral maxillectomy*: resection of the entire incisive bone and rostral portion of the maxillary bone bilaterally
  - Resection normally at the level of the first and second premolars
- *Central unilateral maxillectomy*: resection of a variable portion of the lateral maxilla based on surgical margins required for removal of the neoplasm
- *Unilateral caudal maxillectomy*: resection of the caudal region of the maxilla

The major intraoperative complication in maxillectomy, and mandibulectomy to a lesser degree, is the control of hemorrhage. The surgeon must be familiar with the location of the major vessels in the region. Postoperatively the most common problem is dehiscence. In unilateral total or subtotal mandibulectomies, the tongue will lose the lateral support provided by the mandible and dental arcade, resulting in the tongue lolling out of the mouth. Drooling may be noted with the loss of this barrier provided by the mandible. Oral commissure advancement, occasionally called "commissurorraphy" (Plate 99), can help reduce lateral deviation of the tongue. With complete loss of the symphysis, each mandible can move independently. "Drift" of the mandible may be noted and is more commonly seen with unilateral total and subtotal mandibulectomies. On occasion, the upper and lower dental arcades may not align and the teeth can periodically strike each other, creating a clicking sound. Dogs will normally adapt to this condition.

In maxillectomies, dehiscence results in oronasal fistula formation; this usually necessitates additional surgery to resolve this condition. Atraumatic surgical technique with preservation of the blood supply is essential to successful surgical closures. Dehiscence is much more likely when surgeons attempt to close oral defects under tension. Improper suture placement and pattern also can contribute to incisional dehiscence (see Fig. 6-32).

The author strongly recommends the use of vertical mattress sutures to evert opposing mucosal borders to increase the surface area of contact for proper healing; mattress sutures eliminate the tendency for mucosal margins to curl or scroll inward. Lastly, interrupted absorbable sutures can be placed between vertical mattress sutures to properly align margins. Careful planning and execution are essential for a successful outcome.

Other complications associated with these major oral procedures can include infection, salivary duct injury, subcutaneous emphysema, pain, lingual dysfunction/deviation, lateral sublingual edema, prehension difficulties, and reluctance to eat.

Prior to any major procedure for tumor resection, a biopsy is considered essential in determining the practical feasibility of surgery and the potential need for adjunctive treatments. Oftentimes the surgeon is dealing with a geriatric patient: the overall health of the patient is an important factor to consider before advising major oral surgery. Histopathologic examination of the neoplasm is critical in determining the surgical margins needed and whether adjunctive therapies (radiation therapy, chemotherapy) are important to prevent or blunt tumor recurrence. Consultation with an oncologist is critical to establishing prognosis for the patient and long-term patient care beyond the surgery.

Owner concerns include the possible complications associated with surgery, the long-term prognosis, the quality of life of their pet, the cosmetic outcome expected, and the cost of the surgical procedure (not always in this order). Beyond surgery and anesthesia, owners commonly share concerns about the potential side effects of radiation therapy and chemotherapy for their geriatric pets, including the additional costs incurred with these adjunctive treatments. Some of these concerns can be related to their personal experiences or the challenges they have seen with family members or friends who have undergone

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cancer therapies. In the more challenging cases, it is helpful to include an oncologist in the examination room discussion to discuss clinical staging of their pet and answer the myriad of questions that commonly arise.

As with other malignancies, thoracic radiographs (three-view) are important to help rule out metastatic disease. Computed tomography (CT) is considered more effective in assessing the lungs for early pulmonary metastasis. Examination of the lymph nodes can be facilitated with microscopic examination of needle aspirates or excisional biopsy. CT is normally preferred over radiographs of the mandible/maxilla for planning surgery. For smaller lesions, detailed dental radiographs and cone-beam CT are very effective in determining the extent of the oral lesions. Three-dimensional CT reconstruction and the use of three-dimensional models can be invaluable to assess the extent of the disease process in large tumors and a proper surgical plan. For those patients likely to receive radiation treatment, a "bite block" can be created at the time of CT of the head.

Plates 132 and 133 overview the common locations for partial mandibulectomies and maxillectomies. Major mandibulectomy and maxillectomy procedures are best handled by boarded surgeons and dentists who have advanced training and experience in these challenging cases.

GLOSSECTOMY

The tongue is a remarkably complex organ that plays a major role in food and water consumption. Taste buds on the dorsal surface of the tongue are used to detect sour, sweet, and salty tastes. The tongue is primarily composed of skeletal muscle. The muscular layers are discussed in anatomy textbooks in great detail. The precise movements of the tongue are important in lapping water, food prehension, and mastication. It plays a major role in the oral and pharyngeal phases of swallowing.

Resection of a portion of the tongue is referred to as glossectomy (Figs 17-13 and 17-14). Glossectomy can be classified according to the location or level of the amputation. *Partial glossectomy* refers to resection of a variable amount of the free or mobile portion of the tongue, usually rostral to the frenulum (Figs 17-15



FIG. 17-13 Lingual plasmacytoma. Resection on the dorsal surface of the tongue and the underlying portion of the tongue is simple to perform, followed by closure with interrupted absorbable sutures.

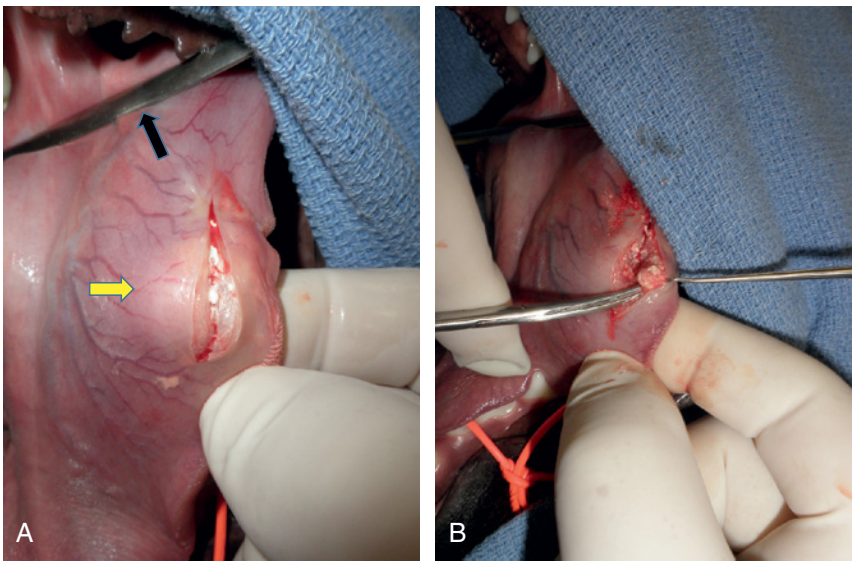
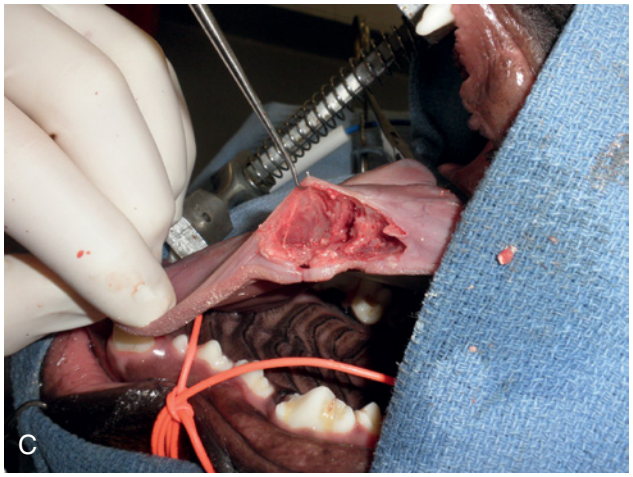


FIG. 17-14 (A) Calcinosis circumscripta (yellow arrow) involving the tongue in a mixed-breed dog, ventral lingual surface. Doyen intestinal clamps (black arrow) applied across the tongue are useful in reducing hemorrhage and facilitating positioning of the tongue. (B) Removal of the contents of the encapsulated area. (C) Removal of the lesion. The pocket was lavaged and suctioned prior to closure. (D) Closure with interrupted 3-0 polydioxanone sutures.

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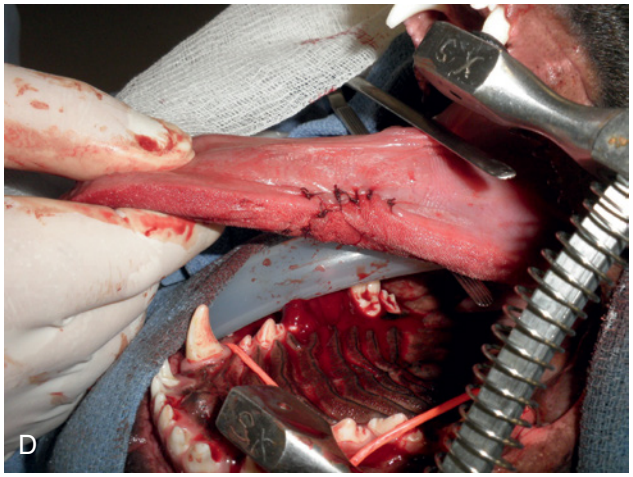
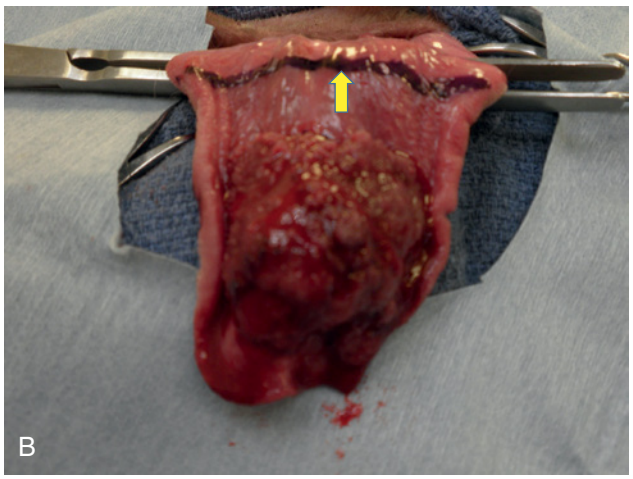


FIG. 17-14 (Continued)





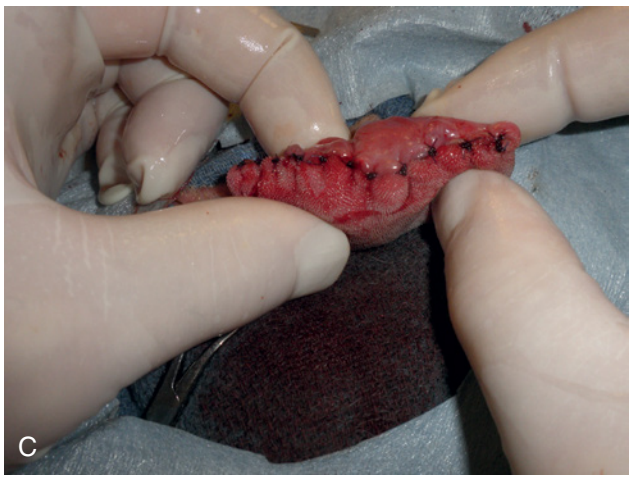


FIG. 17-15 (A) Lingual carcinoma, rostral 25% of the tongue, ventral surface. (B) Placement of a Doyen intestinal clamp is effective in reducing hemorrhage and maintaining the tongue in a forward position. A surgical marker was used to denote the line of amputation (arrow). (C) Simple linear closure with a series of interrupted absorbable sutures. Prior to closure, electrocautery is used to seal small vessels. The dog ate and drank normally postoperatively.

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and 17-16). *Subtotal glossectomy* includes removal of the entire free portion of the tongue and a portion of the more caudal muscles. *Near total* refers to removal of >75% of the tongue, whereas *total glossectomy* refers to complete resection of the tongue. In most cases, surgeons are performing partial glossectomies. Advanced neoplasia or (rarely) major trauma would likely dictate subtotal glossectomy depending on the circumstances of the individual patient if it is in the best interest of the pet. In most cases, surgeons are dealing with partial glossectomies for smaller neoplasms.

There is no reconstructive surgery per se for replacement of the tongue. However, there are closure options that may be considered to preserve lingual function and optimize the length of the tongue to facilitate normal eating and drinking (Fig. 17-17) (see Plate 134). The author has performed only two subtotal glossectomies in dogs. As noted in the veterinary literature, the dogs over time adapted to eating and drinking. Dogs can learn to drink water like a horse, by inserting their muzzle into a deep water bowl or bucket to suck water into their mouth. Esophagostomy or gastrostomy tubes may be required to feed the dogs after major glossectomy. Over time the dogs may adapt to eating dog food with little assistance. Others may require hand-feeding. In one report, the owners formed "meatballs" of canned dog food and chilled them in a freezer. The firm meatballs were subsequently tossed to the dog to catch and swallow.

Drooling saliva after subtotal glossectomy is a common problem since the tongue plays a significant role in the normal process of retaining and swallowing saliva. Dogs may require an absorbent cloth bib to collect overflow. It is important for the pet owner to completely understand the care required following this major procedure.

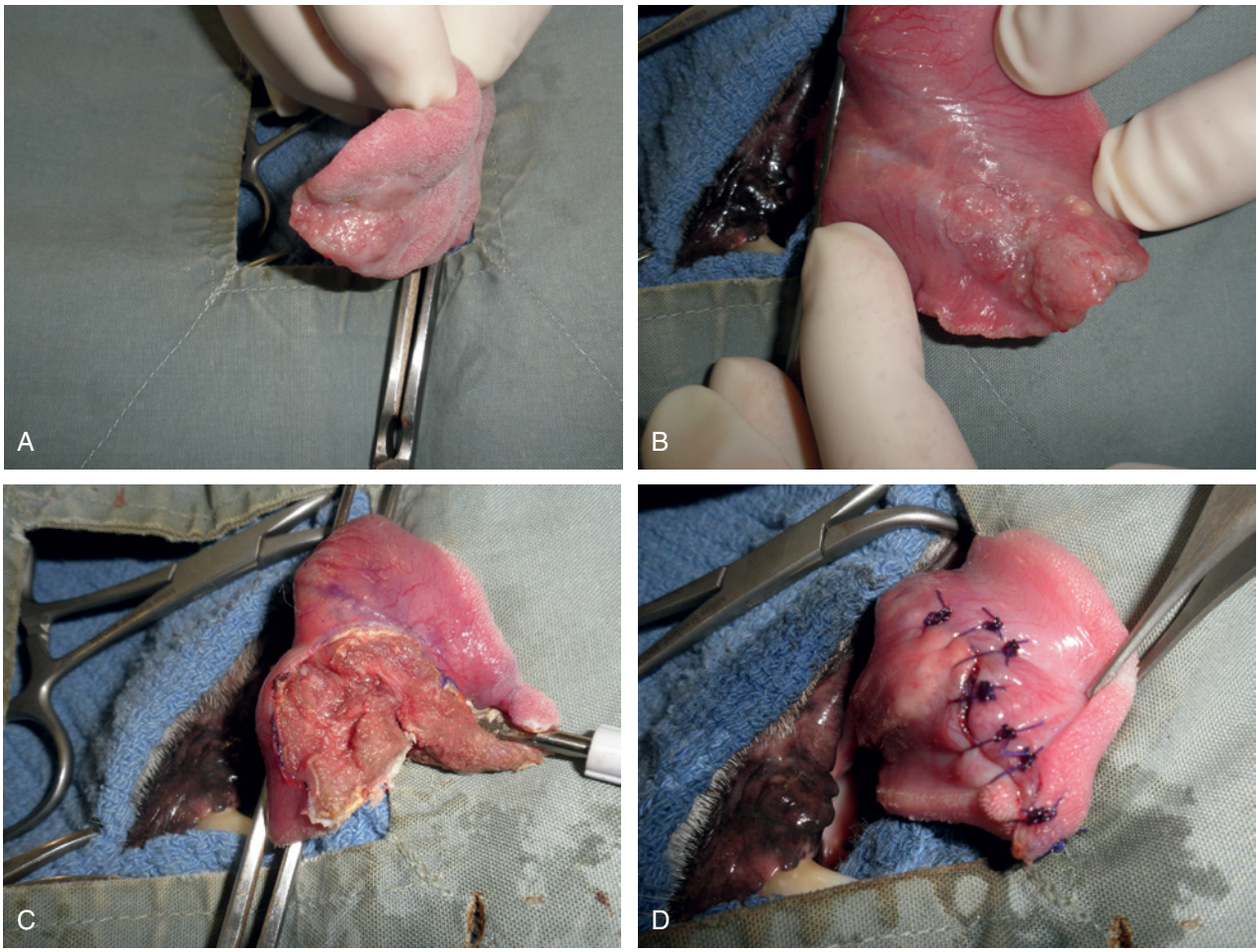


FIG. 17-16 (A) Squamous cell carcinoma involving the tip of the tongue in a dog, dorsal surface. (B) Close-up view, ventral surface. (C) Resection of the carcinoma using Doyen forceps to control bleeding and immobilize the tongue to facilitate surgical resection and closure. Electrocautery was used to control small bleeders. (D) Closure with a series of interrupted 3-0 polydioxanone sutures. The dog ate and drank normally postoperatively. (See Plate 134.)

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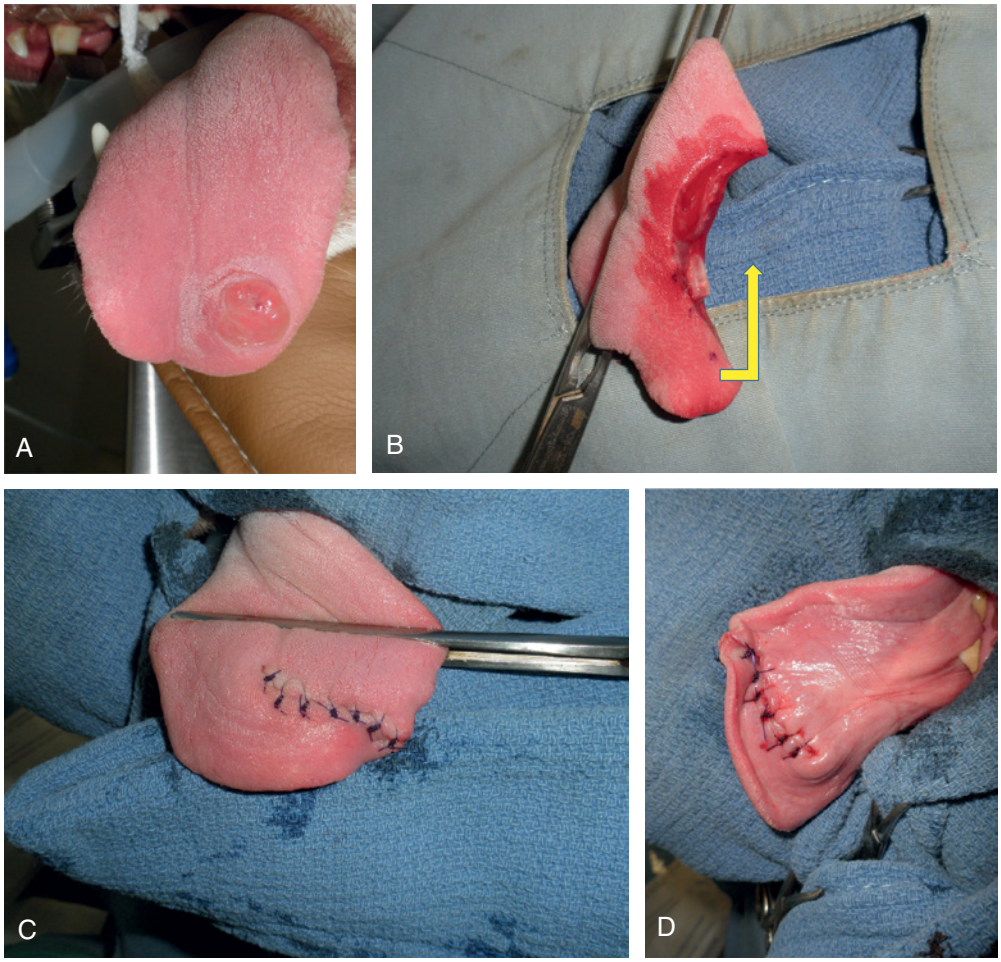


FIG. 17-17 (A) Carcinoma involving the tip of the tongue. (B) Resection of the growth. Placement of Doyen forceps rostral to the surgical area. The lingual flap created from the opposing side of the tongue is rotated into the defect (arrow). (C) Closure of the dorsal surface with absorbable interrupted sutures. (D) Closure of the ventral surface of the tongue. This procedure successfully lengthened the tongue. Postoperatively the dog ate and drank water normally. (See Plate 134.)

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Plate 119 Mucosal Flaps

DESCRIPTION

Upper labial and buccal mucosa can be used to close defects of the hard palate. Flaps of mucosa can be advanced or transposed to close oronasal fistulas. One of the more common fistulas occurs after canine tooth extraction.

SURGICAL TECHNIQUE

(A) Example of a chronic oronasal fistula after removal of the right upper canine in a dog.

(B) The alveolus of the canine tooth often is infected. Osteomyelitis is commonly associated with long-standing cases, as a result of food, water, and debris entering this recess. Although the alveolus can be curetted to remove debris and tissues lining the socket, a small osteotome and mallet can be used to resect the entire area, including the gingiva (circular line), in order to ensure healthy tissues remain before closure with a mucosal advancement flap, outlined in the adjacent upper labial mucosa.

(C) The delicate mucosal flap is carefully undermined and advanced over the defect. Because the width of the flap tends to contract on elevation, the author recommends the flap be wider (by 25–30%) than the width of the defect being covered. Generally, 3-0 monofilament absorbable suture materials are used to secure the flap to the adjacent tissues.

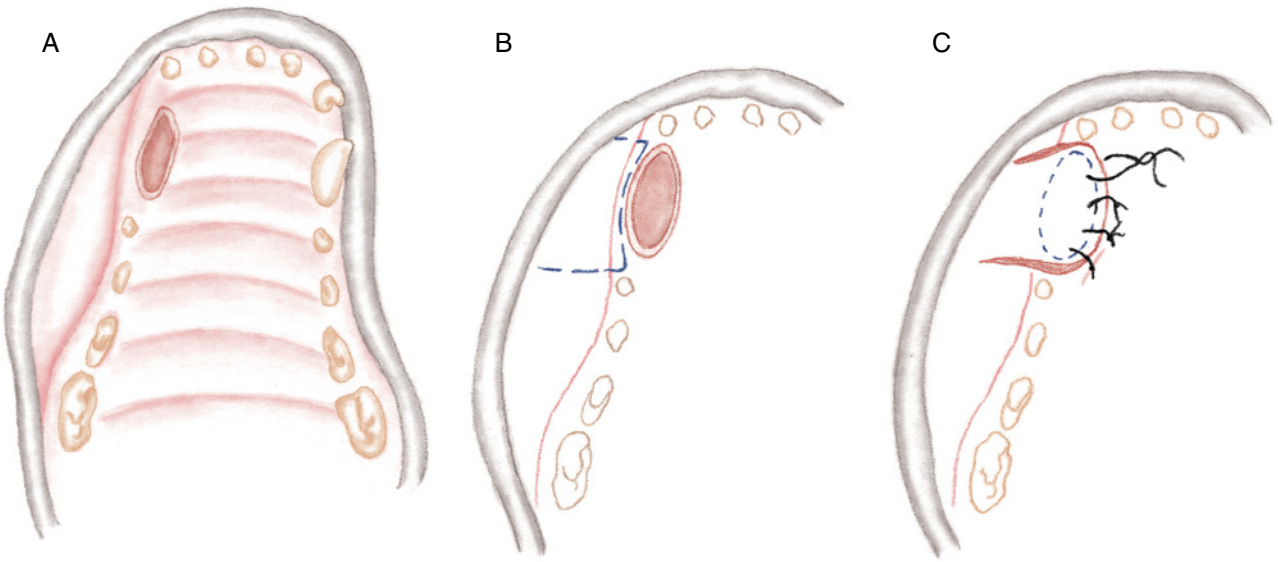
COMMENTS

In chronic fistulas, it is important to excise the exposed bone/alveolus to ensure only healthy bone remains prior to flap closure. Mucosal advancement flaps are remarkably simple to perform, although the slightly more difficult 90° transposition flap also can be used successfully. It is important to emphasize the need to make the flaps wider than the defect to ensure closure is achieved under minimal tension.

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Plate 119



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Plate 120

Palatoplasty: Bipedicle Advancement Technique (von Langenbeck Palatoplasty)

DESCRIPTION

A classic method of closing cleft palates is the use of bilateral, bipedicle advancement flaps, using the available mucosal tissues of the hard and soft palates. The major palatine artery and vein are incorporated in these bipedicle flaps to ensure adequate circulation is present during this surgical maneuver. Von Langenbeck first published this technique for cleft palate repair for humans in 1861. The author, with small modifications of the original technique, has found this palatoplasty procedure highly effective in closing both narrow and wide cleft palate defects.

SURGICAL TECHNIQUE

(A) Cleft palate, extending from the hard to soft palate. Closure is attempted after 16 weeks of age, provided that the patient is healthy and well nourished. Note the relationship of the major palatine artery with the dental arcade. The nasal cavity should be inspected for impacted food or debris, using cotton-tipped applicators, prior to preparing the mouth for surgery using povidone–iodine swabs.

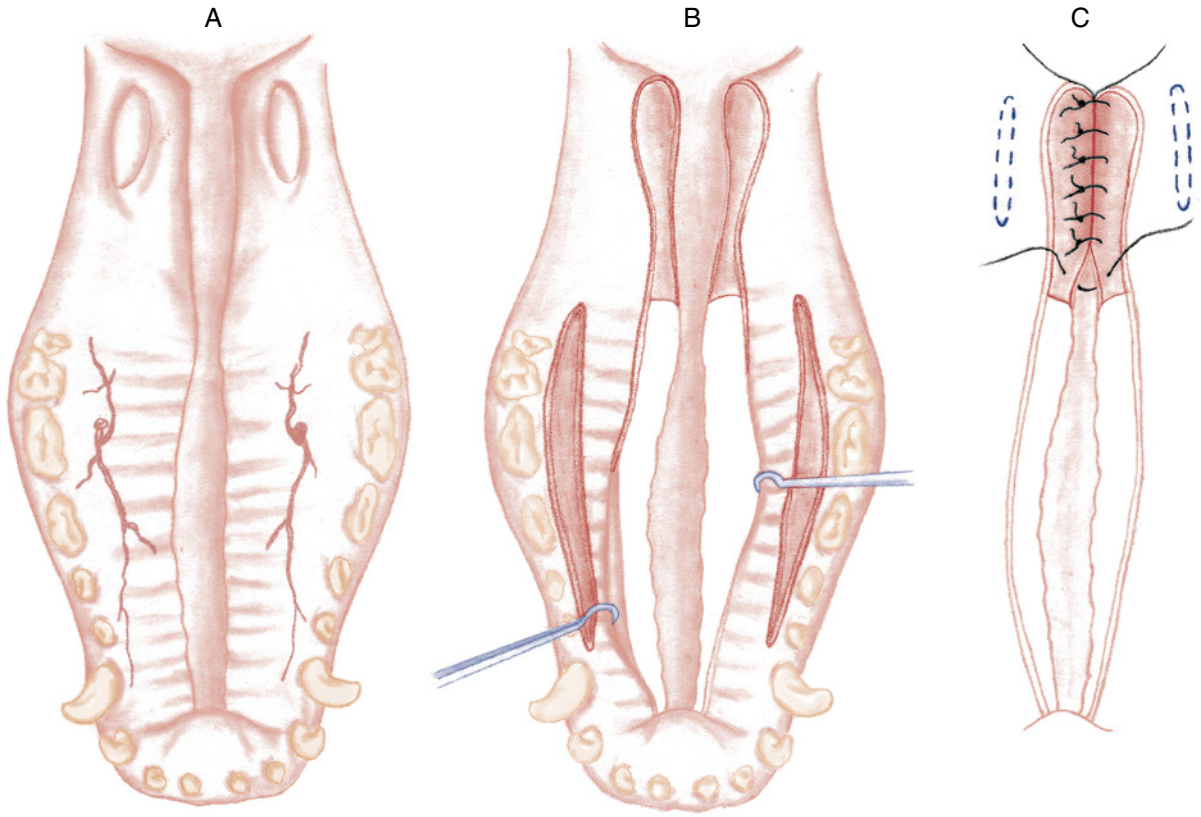
(B) Two incisions are made along the lingual surface of the left and right dental arcades, creating two bipedicle flaps on their elevation. A small, flat, periosteal elevator is used to separate the palatal tissue from the underlying bone. Care is taken to avoid injury or division of the major palatine artery. In this example, a scalpel blade was used to resect the epithelial borders from the soft palate defect.

(C) The nasopharyngeal mucosal surface of the soft palate is apposed with slowly absorbed simple interrupted sutures. Suture bites should be approximately 8–10 mm from the defect (mucosal border). Prior to closing the oropharyngeal mucosal surface of the soft palate, release/relaxing incisions can be made (if necessary) in the mucosa, medial to the tonsillar crypts (dashed lines).

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Plate 120



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Plate 120

(Continued)

(D) Closure of the oropharyngeal mucosal surface of the soft palate. Vertical mattress sutures can be alternated with a simple interrupted pattern in the presence of tension. Placement of the sutures into the palatal ridges (rugae) will improve suture purchase in the closure, reducing the risk of suture pull-out.

(E) Closure of the hard palate defect with alternating simple interrupted and vertical mattress sutures. Slowly absorbable monofilament suture material, which maintains its tensile strength for a prolonged period, should be selected (suture size 3-0). Any small eversion gaps remaining can be meticulously apposed with 4-0 simple interrupted sutures.

(F) Completion of the closure. The secondary defects created by the flap advancement will rapidly epithelialize within 2 weeks.

COMMENTS

This bipedicle palatoplasty technique can work quite well in the dog and cat, without resorting to more elaborate techniques that are reported in the human literature. Preservation of the major palatine artery is critical to complete flap survival. Meticulous, atraumatic suture technique is essential to successful closure of these challenging defects. It is not uncommon for a small rostral defect to form at the rostral tip of the hard palate closure, caudal to the upper incisors (see Figs 17-1–17-6). In general, these small defects cause no particular problem to the patient.

The vertical mattress suture is an effective tension pattern: eversion of the opposing flap borders is important to ensure that collagen can link the two connective tissue surfaces of each flap together. Inversion of the wound borders may result in failure, since the inward deviation of both epithelial borders will preclude healing. As noted earlier, placement of the sutures into the palatal ridges (rugae) will improve suture purchase in the closure, reducing the risk of suture pull-out. The interrupted pattern does give accurate edge-to-edge apposition and limits mild incisional "gaping" associated with the vertical mattress suture pattern used in this area. The author prefers suture placement 8–10 mm from the border of the defect for optimal holding power. Unlike other reports, the author does not believe a two-layer closure is feasible in many patients, nor is it necessary. A single-layer closure is quite satisfactory, provided that suture placement is precise.

Plastic plates or "retainers" have been advocated to protect the closure during the healing processes. These hard acrylic plates are wired to the dental arcade. While they may be useful in the most challenging cases, the author has not found them to be necessary. Unfortunately, food and debris can accumulate between the plate and surgical site, possibly serving as a source of infection. In most cases, failure in cleft palate closure is the result of wound closure under excessive tension in an otherwise healthy patient.

Owners, with the assistance of their veterinarian, can tube-feed patients until they are old enough to eat small pieces of solid food (balanced diet) by hand. It is useful to consult with a veterinary nutritionist should any dietary questions or problems arise. Patients should be watched closely for signs of aspiration pneumonia and treated accordingly.

The author prefers to operate on the patient no earlier than 4–5 months of age, when the tissues are better able to support suture placement. Moreover, as the patient grows and matures, the *relative* width of the palatal defect may decrease, making closure easier.

Postoperatively, animals are fed small "balls" of canned dog food the day following surgery: dogs readily swallow them whole effortlessly when fed by hand. They drink water in a normal fashion. An Elizabethan collar is advisable, especially in the days following surgery: many patients will attempt to paw at their face, likely because of the abnormal sensation in the mouth after tissue advancement.

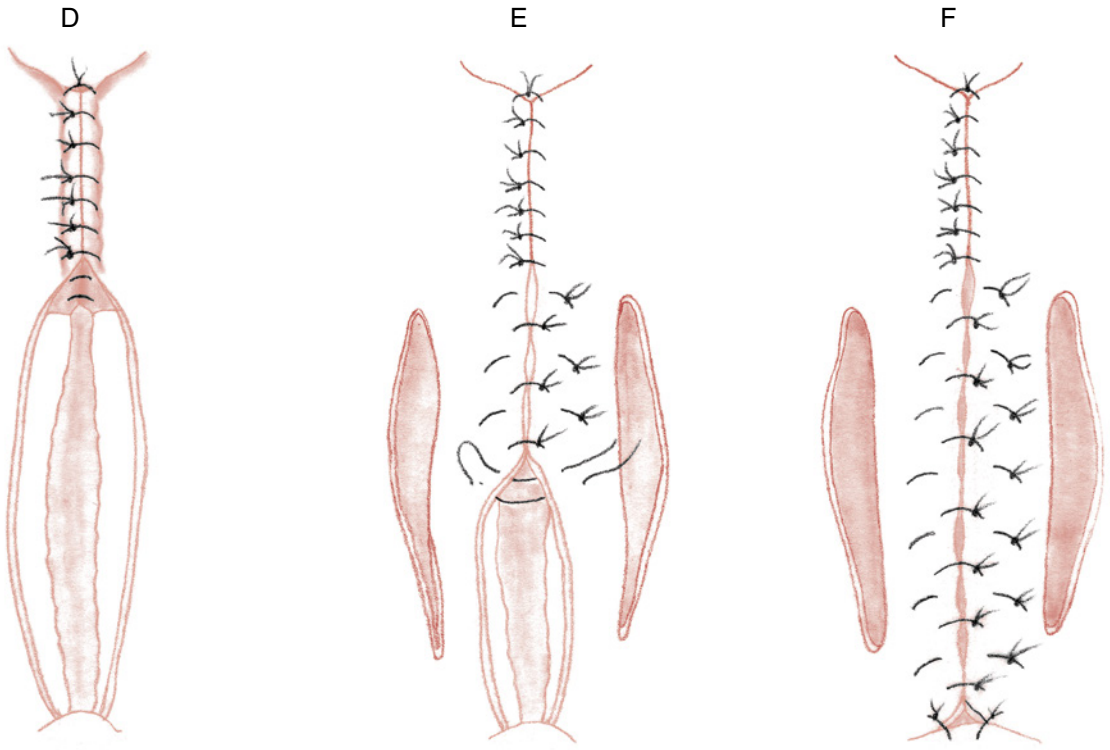
Most cases of wound dehiscence are noted within 5 days after surgery. If the patient is doing well 72 hours after surgery, the author normally will discharge the patient and reexamine them 1 week later. Like many procedures, the surgeon's best opportunity to successfully close a palatal defect is the first surgery. Therefore, the patient must be well nourished, in a state of positive protein balance, and healthy.

Which technique to select for closure of a cleft palate largely is a matter of preference. Over the past 20 years, the author has found that the von Langenbeck technique works especially. Well for the wider palatal defects.

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Plate 120



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Plate 121

Cleft Palate Repair: Overlapping (Mucoperiosteal) Flap with Unilateral Bipedicle Flap

DESCRIPTION

The overlapping flap technique (also called the hinge flap or mucoperiosteal flap) is an alternative method for closing defects of the hard palate. A medially based hinge flap is folded over the palatal defect, with the oral epithelial surface facing the exposed nasal cavity. The border of the flap is sutured beneath the opposing palatal tissue border (vest-over-pants suture technique). In this example, the opposing donor area also is elevated as a bipedicle flap (see Plate 122) for additional coverage of the cleft, improving the overlap closure while reducing incisional tension.

SURGICAL TECHNIQUE

(A) The dashed line represents the outline of the mucoperiosteal flap. Care is taken to preserve the major palatine artery.

(B_1) After incising the palatal tissue with a no. 15 scalpel blade, a small periosteal elevator is used to carefully elevate the flap, leaving the palatine vasculature intact.

(B_2) A cross-sectional view of the elevated flap. Note the pedicle is continuous with the nasal mucosal/periosteal surface lining the bone of the hard palate.

(C_1) The palatal tissues on the opposing side of the defect are prepared as a bipedicle advancement flap while preserving the major palatine artery and vein.

(C_2) Cross-sectional view of the mucoperiosteal flap and bipedicle flap, prior to suture placement.

(D_1) The mucoperiosteal flap is folded over the cleft, and the edge of the flap is tucked beneath the border of the opposing bipedicle flap. Absorbable, 3-0 polydioxanone sutures are used in this patient, using a mattress pattern (or vest-over-pants).

(D_2) A cross-sectional view of D_1.

(E) Completion of the hard palate closure. The soft palate is closed in a conventional two-layer closure, discussed in Plate 120. Note in this example that two mucosal release incisions were made to reduce tension on closure of the soft palate defect.

COMMENTS

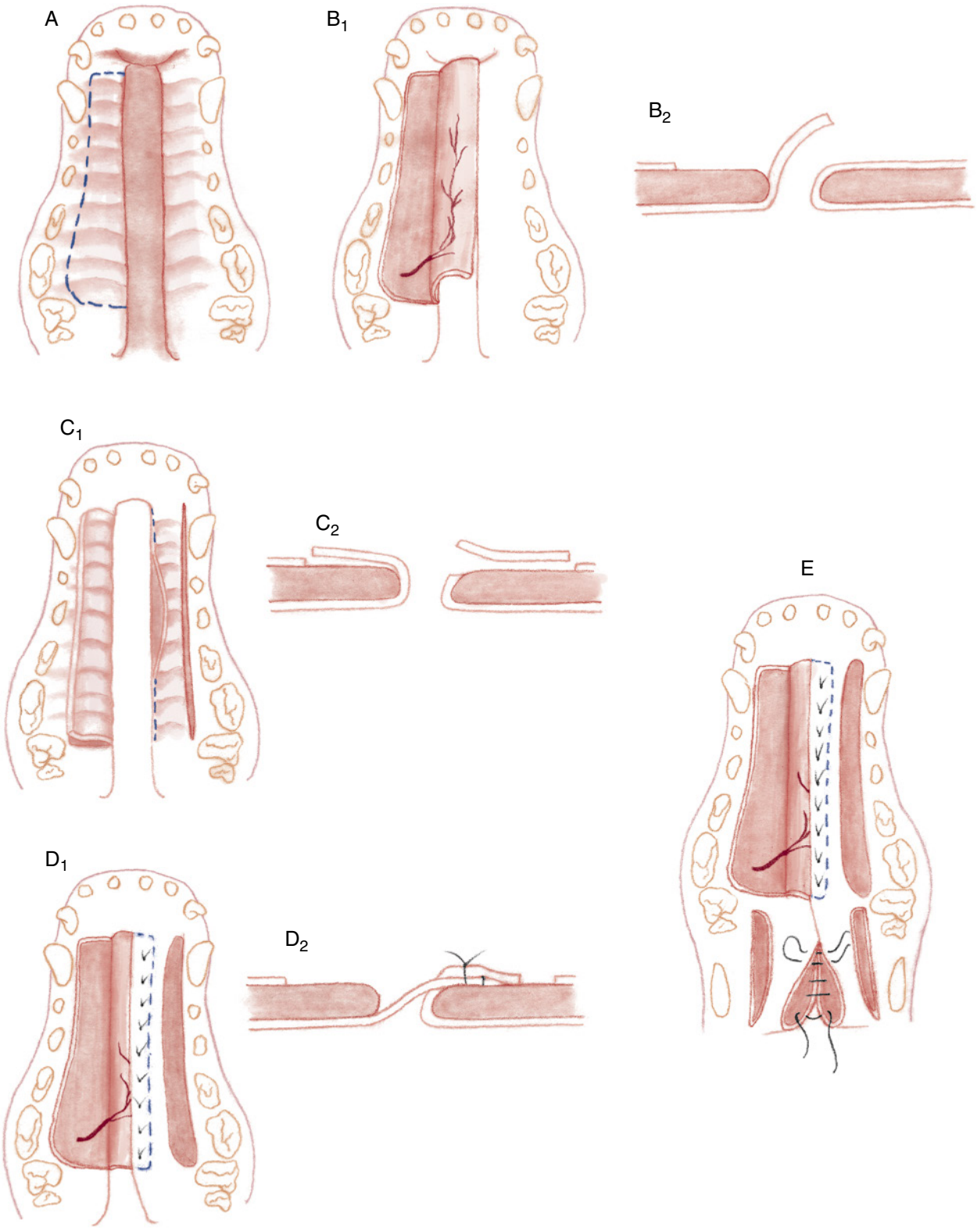
The overlapping flap technique (without the opposing bipedicle flap) is normally effective for narrower cleft palate defects. When using this technique, the author has found that combining this flap with the bipedicle flap can improve coverage for wider palatal defects. Doing so also reduces incisional tension and can improve coverage of the overlapping flap margin tucked beneath its surface. Currently the author prefers the von Langenbeck technique (two bipedicle advancement flaps) for closing wider cleft palate defects (see Plate 120).

See the comments in Plate 120 pertaining to patient care.

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Plate 121



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Plate 122 Extended Overlapping Flap Technique

DESCRIPTION

This technique was reported to create a longer overlapping (hinge flap) of the hard palate to close a wider cleft palate defect. It requires the extraction of a portion of the upper dental arcade followed by a 4–6-week delay. The gingiva is elevated with the overlapping flap to enhance its length.

SURGICAL TECHNIQUE

(A) Extraction of the premolars with closure of gingival tissues. This area is allowed to heal for 4–6 weeks, allowing time for the circulation to recover from the surgical trauma.

(B) Outline of the extended overlapping flap. The lateral incision incorporates the gingiva, thereby extending the length of the flap by several millimeters. The arrow denotes the arc of rotation of the elevated flap. The mucosal border on the opposite side of the cleft is elevated, allowing insertion of the flap margin.

(C) The flap is rotated and inserted beneath the elevated medial border of the hard palate mucosa on the opposite side of the cleft. Horizontal mattress sutures (vest-over-pants) are used to secure both margins using 3-0 polydioxanone. The soft palate defect is closed in two layers.

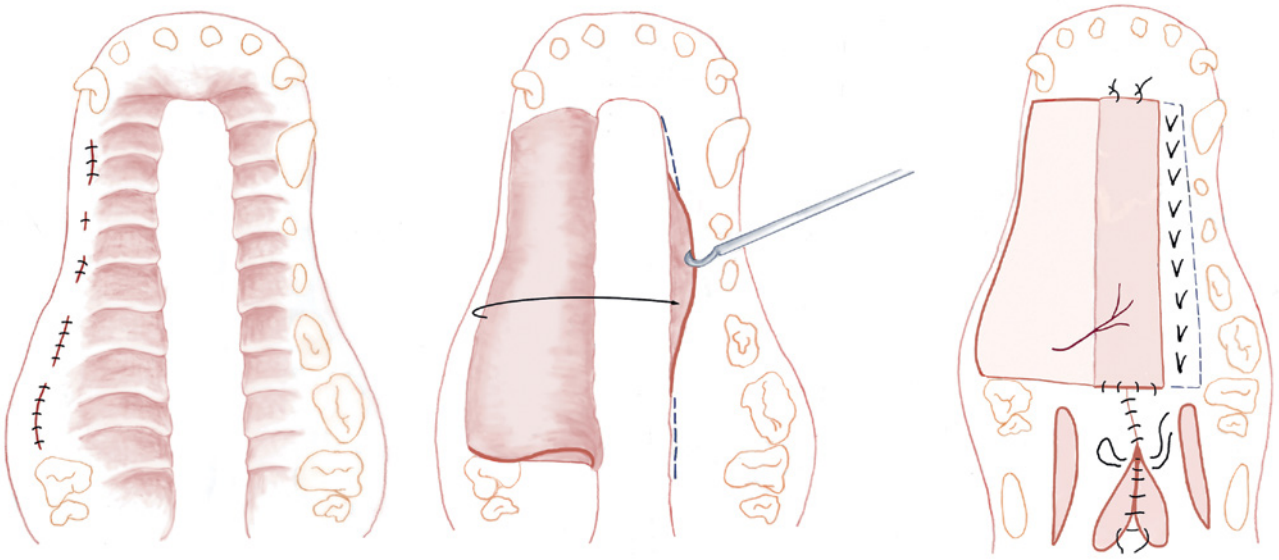
COMMENTS

This technique unfortunately requires the removal of normal teeth. Outside the loss of useful teeth and the transient discomfort of the dog, the cost to the owners is considerably increased. While the goal is to close a wider cleft, by enhancing the overlapping flap's length, it is the author's contention that the von Langenbeck technique (Plate 120) can close most of the wider cleft palate defects more effectively without the need to extract any teeth. Nonetheless, there may be an occasion when this flap option may be a serious consideration. Lastly, the traditional overlapping flap could be combined with a contralateral bipedicle flap (half of the von Langenbeck technique), thereby reducing closure tension and enhancing coverage (Plate 121).

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Plate 122



A B C

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Plate 123 Palatine Mucosal Flap

DESCRIPTION

The left and right palatine arteries course rostrally to supply circulation to a significant area of the mucosa covering the bony palate. In select cases, a mucosal transposition flap, incorporating the major palatine artery, can be used to close small to moderate-sized oronasal fistulas within its effective arc of rotation.

SURGICAL TECHNIQUE

(A) The palatine artery originates caudal and medial to the third premolar. The flap outlined in this example (dashed line) comprises two parallel incisions, one along the lingual border of the dental arcade and the second along the midline of the palate. The flap width in this illustration is sufficient to overlap the (width) borders of the oronasal fistula. The flap length is determined in the fashion noted in Plate 41, Transposition Flap (90°). The shaded area of mucosa, interposed between the donor and recipient sites, is resected to accommodate the palatine flap.

(B) Elevation of the flap. Care must be taken to avoid dividing or traumatizing the palatine artery and vein.

(C) Suturing of the palatine flap. It is highly desirable to have the flap overlap the bony border of the oronasal fistula. The ridge of bone helps to support the suture line, reducing the possibility of wound dehiscence. The donor area is not closed. The exposed viable bone and periosteum will support epithelial cell migration from the adjacent mucosal borders.

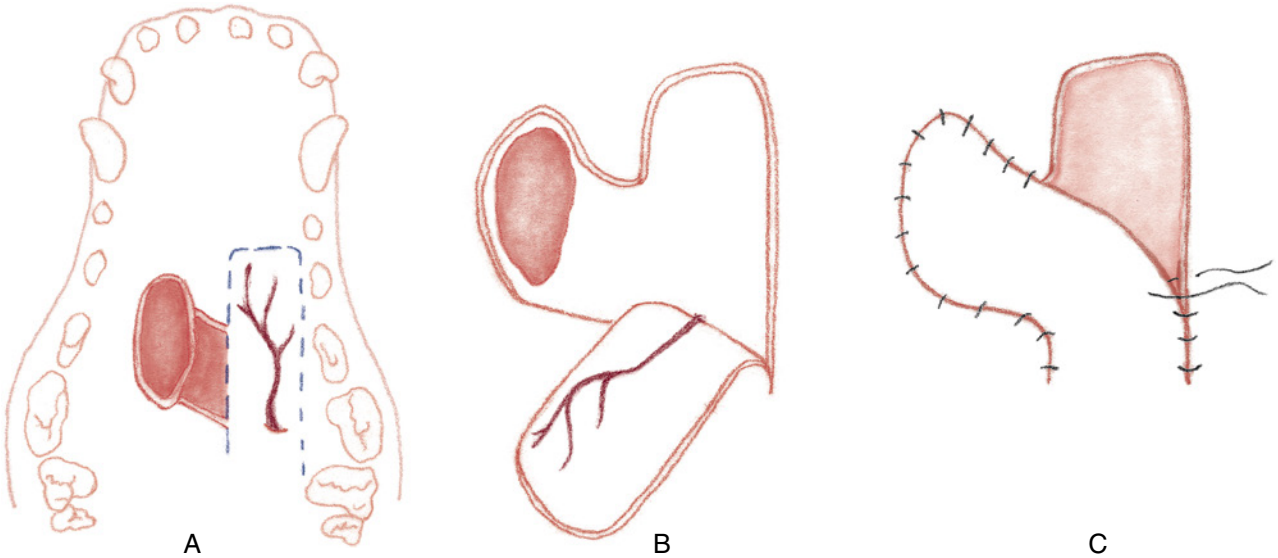
COMMENTS

Like axial pattern flaps, inclusion of an artery and vein helps ensure an adequate circulation for complete survival of the flap. However, like skin flaps, smaller mucosal flaps of the hard and soft palate can be created without the need for major vessels. Effective use of the palatine flap depends on (1) preserving the integrity of the major palatine artery and vein and (2) a small to moderate-sized defect located within the flap's effective arc of rotation. Keep in mind that the palatal tissue is not particularly elastic: its stiffness makes it more difficult to manipulate when compared to skin.

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Plate 123



A B C

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Plate 124 Soft Palate/Pharyngeal Mucosal Flaps

DESCRIPTION

Significant defects of the soft palate can result in problems associated with drinking and eating. Food and water can enter the nasopharynx and nasal cavity. Direct approximation may not be possible as a result of the width of the defect. In these cases, flaps can be employed from the adjacent palatal and pharyngeal mucosa. One clinical example is illustrated.

SURGICAL TECHNIQUE

(A) This illustration demonstrates a congenital defect of the soft palate.

(B) The outline of a mucosal flap uses a portion of the soft palate. Flap dimensions should be approximately 10–20% wider and longer than the dimensions of the defect in order to offset elastic contraction of the flap and slight shortening associated with unfolding of the flap. The mucosal border of the opposing side of the palatal defect is excised in preparation for flap application. Alternatively, the middle edge of this area can be "split" or divided with a no. 15 scalpel blade. This latter option separates the oropharyngeal and nasopharyngeal surfaces, preserving a few additional millimeters of mucosa.

(C) The flap borders are incised and the body of the flap, composed of oropharyngeal mucosa, is reflected. Note that the base or pedicle of this mucosal flap derives its circulation from the capillary network located along one border of this congenital defect. Care must be taken to minimize trauma to this delicate flap. Fine-tipped iris scissors and small skin hooks are useful for elevation of this flap. Absorbable sutures (3-0 or 4-0) are used to suture this *oropharyngeal* mucosal flap to the opposing *nasopharyngeal* mucosal border.

(D) Outline of a pharyngeal mucosal flap. See Plate 42, Transposition Flap (90°), for details on determining dimensions of this mucosal flap.

(E) The mucosal transposition flap is rotated into the oropharyngeal defect of the soft palate and secured with 3-0 or 4-0 absorbable sutures. The donor area is closed in a similar fashion, unless excessive tension precludes proper apposition.

COMMENTS

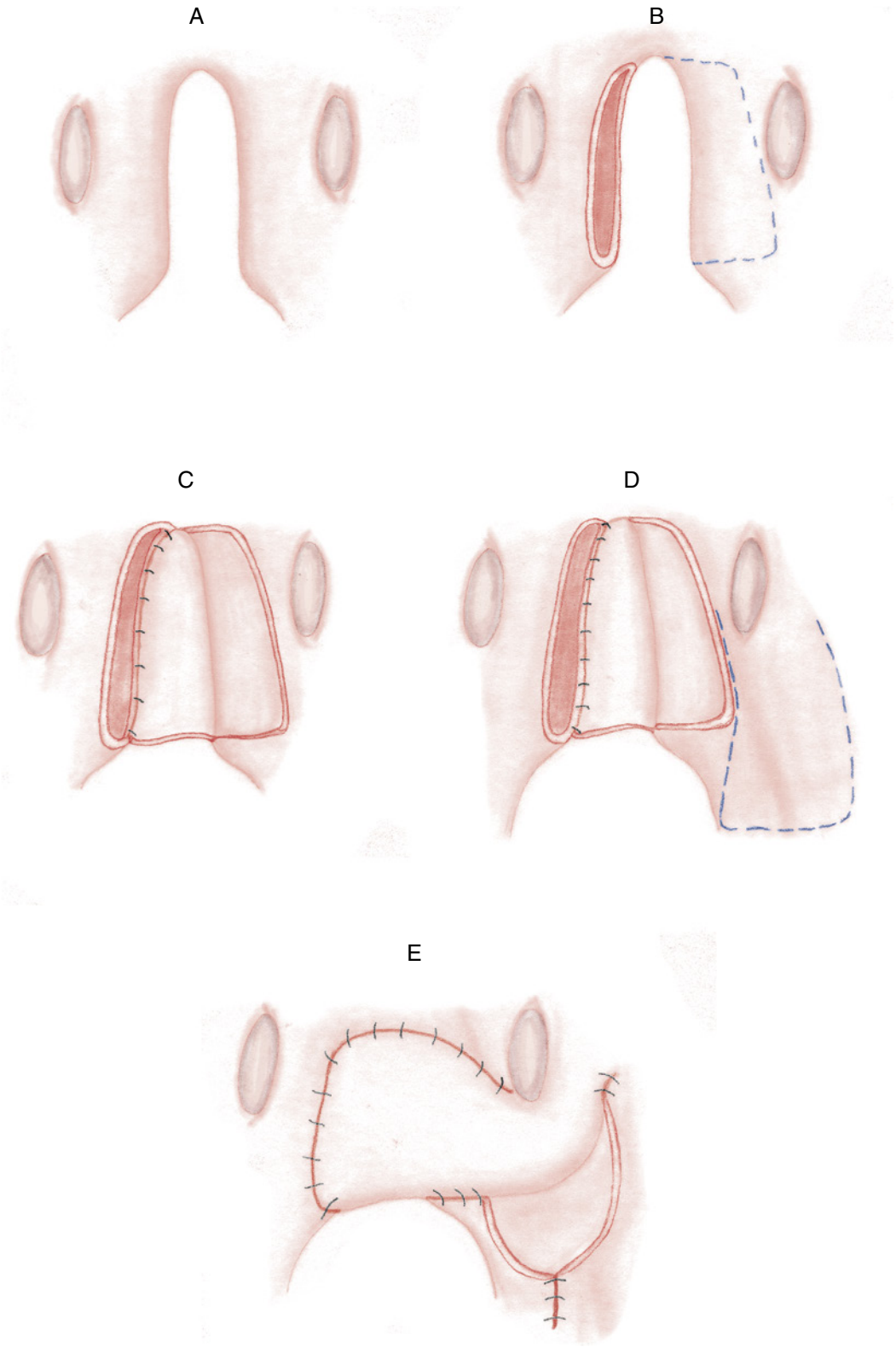
Most cases of these uncommon soft palate defects are presented to the veterinarian in young adult dogs. Clinical signs are more subtle than in cleft palate patients, who have notable eating difficulties as kittens or puppies. Thoracic radiographs may be advisable to rule out aspiration pneumonia prior to surgery.

Meticulous dissection and atraumatic surgical technique are essential to successful closure of this congenital defect. Tension on the closure sites should be kept to a minimum. Postoperatively, the patient is given soft food for 2–4 weeks. Exercise is kept to a minimum during this time. Reexamination of the area will require light anesthesia. Owners should be informed that closure of this and other oral defects can be difficult; dehiscence of a portion of the closure site can occur in this dynamic body region.

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Plate 124



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Plate 125

Full-Thickness Labial Flap Closure of Oronasal Fistulas

DESCRIPTION

On occasion, insufficient labial mucosa, buccal mucosa, and palatal tissue are available for closure of oronasal fistulas. Cats, in particular, lack the ample mucosal surfaces for the simple advancement closure techniques employed with dogs. A full-thickness labial advancement flap can be created perpendicular to the length of the upper lip for direct advancement into oronasal fistulas.

SURGICAL TECHNIQUE

(A) This is an example of an oronasal fistula in a cat.

(B) The width of the defect is measured rostrocaudally. The width of the flap equals this measurement. However, the author recommends making the flap 1–2 cm wider to offset elastic contraction of the flap and reduce the likelihood of incisional tension. Two full-thickness labial incisions are made and the labial border is excised. The dental arcade and gingival tissue between the oronasal fistula and base of the flap also are excised. The pigmented labial border is resected (arrow).

(C) On removal of the teeth and gingiva, the flap is advanced into the oronasal fistula (arrow). Inset: If additional length is required, the labial border is preserved; it is then undermined and reflected upward (curved arrow). This "unfolded" full-thickness labial flap is advanced over the oronasal defect.

(D) Absorbable sutures (3-0, 4-0) are employed to secure the flap into place.

(E) A notched defect is noted in the lip of the cat. See Comments.

COMMENTS

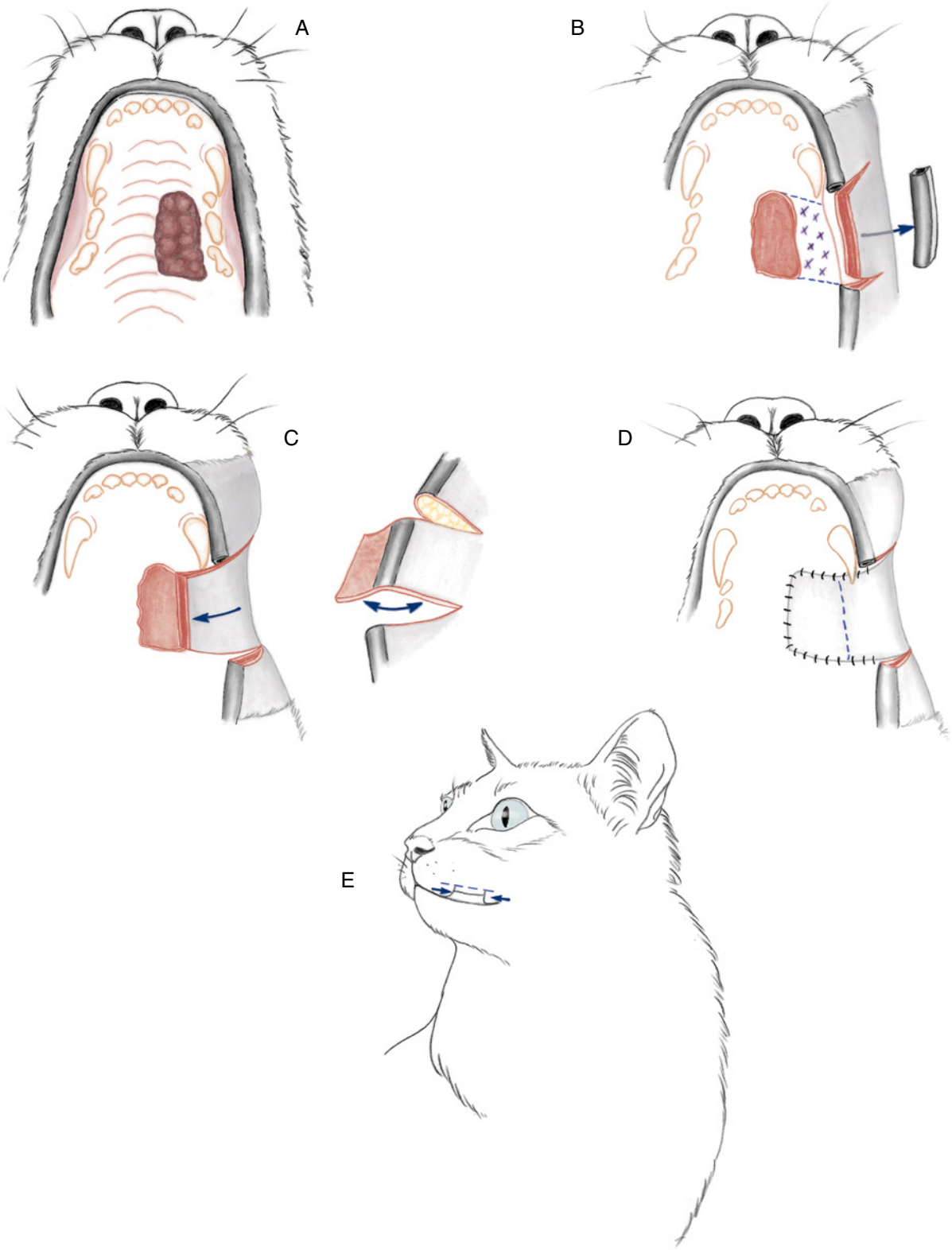
This technique results in creating a labial "notch" due to the sacrifice of a segment to close an oronasal fistula. *Note:* the incised labial margins can be reapposed over the flap to reestablish continuity to the upper lip if sufficient labial tissue is present (E, arrows). A slit or linear opening, dorsal to the apposed labial margins, remains to accommodate the flap's base or pedicle (see Figs 17-9 and 17-10).

At a later date, when healing of the flap is complete, the cutaneous pedicle can be carefully incised and the edge sutured to the apposed cranial and caudal labial mucosal borders to complete the closure (dashed line in E). The author has found this to be unnecessary, since this small healed opening creates no significant cosmetic or functional problem. Hair regrowth may obscure any labial defect to achieve satisfactory cosmetic results without further surgery. This technique has been used successfully in dogs and cats.

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Plate 126 Cartilage Grafts for Palatal Fistulas

DESCRIPTION

Reported by Cox et al. (2007), a small cartilage graft, taken from the base of the pinna, can be used to patch small feline palatal defects; it has been successfully used both in humans and in experimental dogs. The cartilage forms a tissue scaffold or platform for granulation tissue migration and subsequent epithelialization over the developed granulation surface.

SURGICAL TECHNIQUE

(A_1, A_2) Example of the area from which to harvest a flat piece of the conchal cartilage (scapha of the pinna) (arrow); the circular graft is harvested a few millimeters larger than the measured oral defect. (A_2) illustrates the oral defect of the caudal hard palate.

(B_1) A small periosteal elevator is used to create a pocket for the cartilage graft, between the bone and overlying soft tissue of the hard palate.

(B_2) A small rostral and caudal incision can be used to facilitate placement of the cartilage graft.

(B_3) Insertion of the cartilage graft, folding the cartilage into the small pocket created around the circumference of the defect.

(B_4) Normally two to four sutures using 4-0 absorbable suture material (taper-point needles) can be used to secure one suture into the graft *prior to* positioning the graft into its final position: this can prevent accidental loss of the graft should it fall into the underlying nasal cavity.

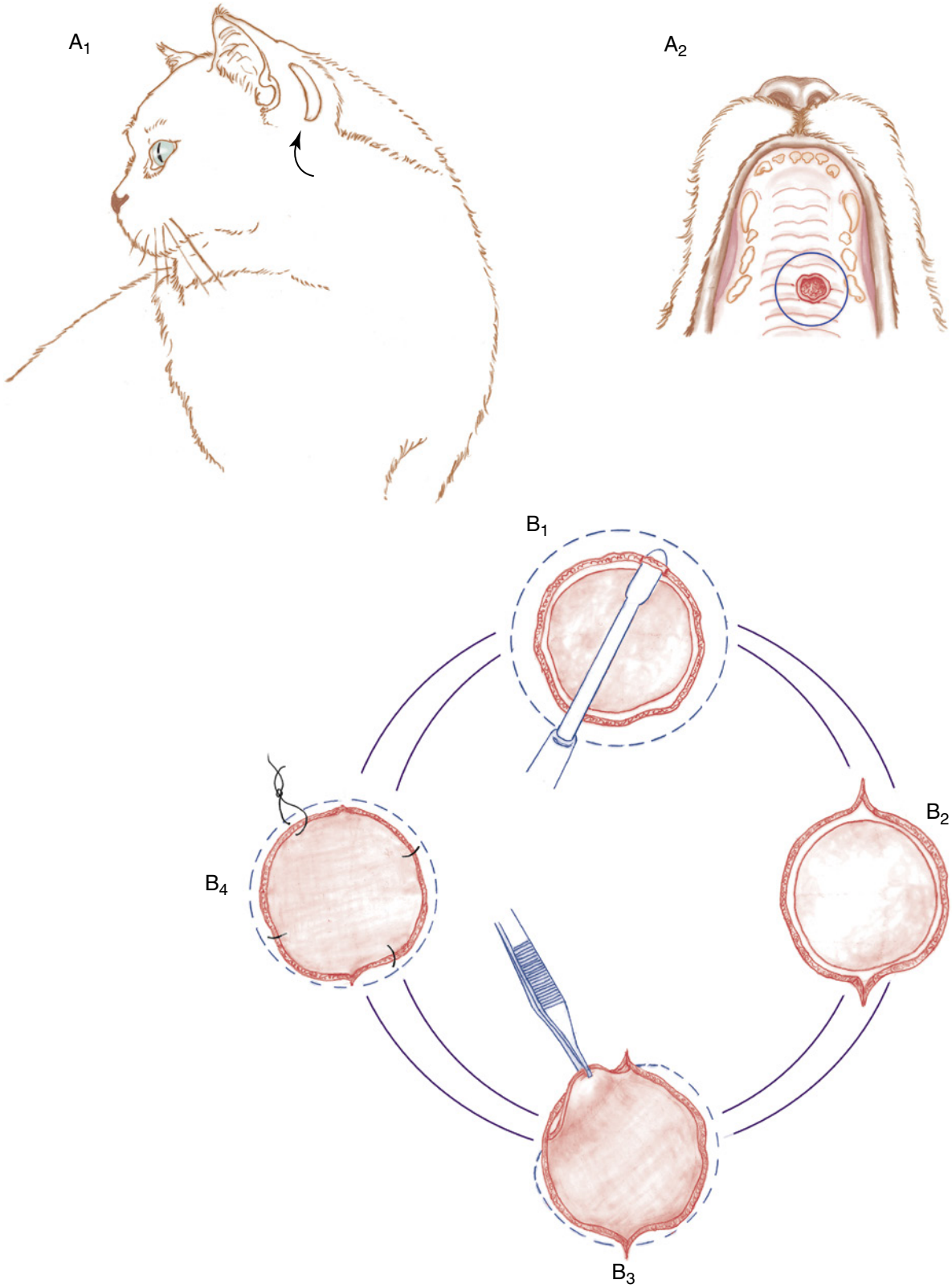
COMMENTS

Cartilage also can be harvested from the lateral ear canal (performing a lateral ear canal resection), although the curvature of this tissue makes it more problematic to make it lie flat during its insertion into the defect. The author prefers the lower caudal base of the pinna. This technique may be useful for small fistulous tracts (less than 1.5 cm) without the need to resort to more aggressive attempts at surgical closure; it is unknown if larger defects can be closed with this technique. (The author reserves its use to the smaller defects that are <5 mm, in which he has had good success.) In one case study, the cartilage graft failed but closure with a second graft was successful. Placement of an avascular segment of cartilage into a contaminated environment does run the risk of dissolution of this tissue. Soft food is advisable during the healing process for 2–4 weeks.

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Plate 126



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Plate 127 Angularis Oris Mucosal Flap

DESCRIPTION

The angularis oris artery arises from the facial artery and courses superficially from the cranial border of the masseter muscle to the ipsilateral commissure of the mouth. The pulse of the angularis oris artery can be felt by inserting the index finger into the mouth, caudal to the oral commissure. The facial artery also gives rise to the superior and inferior labial arteries, supplying the upper and lower labial tissues, respectively. Bryant et al. (2003) have described the use of a mucosal flap, based over the angularis oris vessels, for the closure of problematic palatal defects.

SURGICAL TECHNIQUE

(A) Territory of the angularis oris mucosal flap. Inset: With the dog in lateral recumbency, a skin incision is created from the margin of the oral commissure caudally to the level of the rostral margin of the masseter muscle. The skin margins are retracted, exposing the angularis oris artery and vein. (A light source can be inserted into the oral cavity to "candle" or illuminate the vessels. A pencil Doppler probe also may be useful for locating this artery.) Two parallel incisions created dorsal and ventral to the angularis oris vessels extend through the exposed subcutaneous tissue and buccal mucosa, forming the margins of the flap (dashed lines). These incisions are extended to the caudal extent of the buccal pouch, at the level to which the angularis oris vessels extend below the cranioventral border of the masseter muscle. This mucosal flap includes the buccal mucosa to the level of the oral commissure. The flap may be "islandized" by incising the buccal mucosal base of the flap caudal to the entry of the angularis oris vessels and carefully dissecting the connective tissue to mobilize this island flap.

(B) In this illustration, the flap is being used to close a problematic palatal defect. A simple interrupted suture pattern with slowly absorbable sutures is used to appose the flap margins to the defect. The donor defect is closed by suturing the mucosal defect, followed by the overlying skin incision.

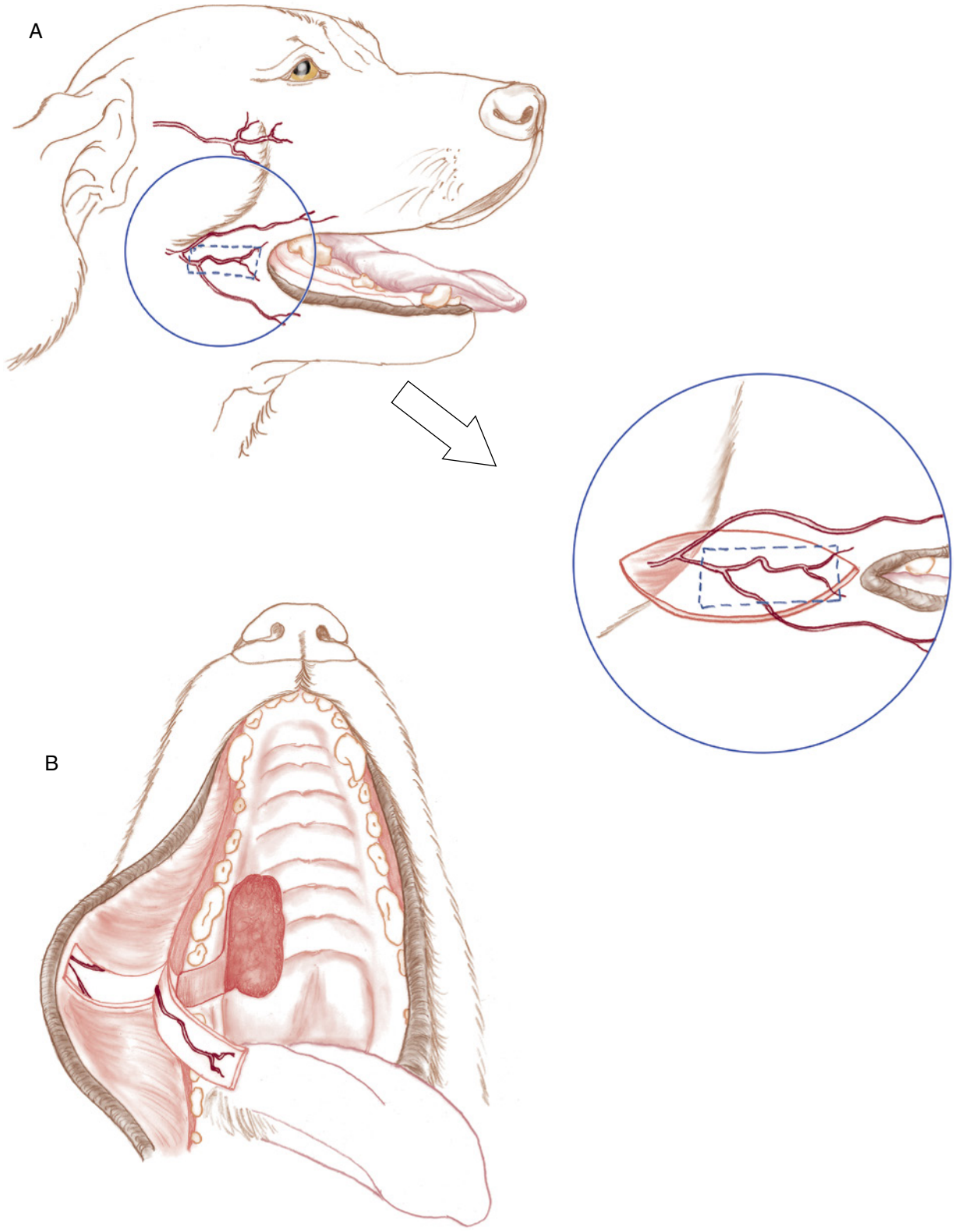
COMMENTS

This procedure was reported in two dogs. The flap has the potential of extending rostrally to the distal gingival margin of the ipsilateral canine tooth or across the palate to the contralateral dental arcade. This technique is one more option for the surgeon to consider, based on the size and location of the oral defect.

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Plate 127



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Plate 128

Full-Thickness Upper Labial Flap for Major Palatal Defects

DESCRIPTION

The versatile full-thickness upper labial flap can be used to reconstruct major defects of the hard/soft palate area (see Plate 88).

SURGICAL TECHNIQUE

(A) Outline of oral tumor resection encompassing the central palate. The right upper premolars in line with the defect are extracted in this example.

(B) Standard elevation of the full-thickness upper labial flap as outlined in Plate 88. In this example, a large segment of the hard palate has been resected secondary to a diffuse neoplasm. Following premolar extraction, a Hall air drill can be used to smooth the bone to accommodate the thickness of the labial flap. The pigment labial border is resected to allow suture placement to the margin of the palatal defect. A linear mucosal incision is carefully created: this outlines the margin required for overlapping the palatal defect.

(C) The proximal edge of the mucosa (closest to the base of the flap) is sutured to the adjacent oral defect. The margins of the flap are sutured to the margins of the palatal defect.

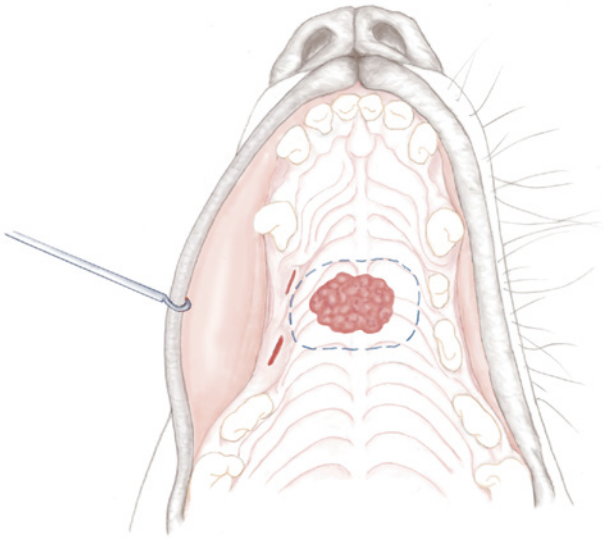
COMMENTS

The resultant labial defect can be reconstructed with a transposition skin flap at the time of labial flap placement. Figure 17-12 is a clinical example of this technique. The cutaneous surface faces the oral cavity, although it is possible to fold the labial flap with the skin facing the nasal cavity. Oral exposure of skin, from the author's experience, creates no clinical issue for the dog. This flap simultaneously replaces the nasal mucosal and oral mucosal defects of this palatal defect.

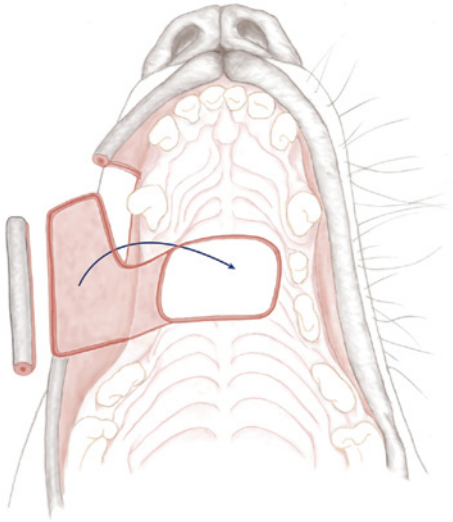
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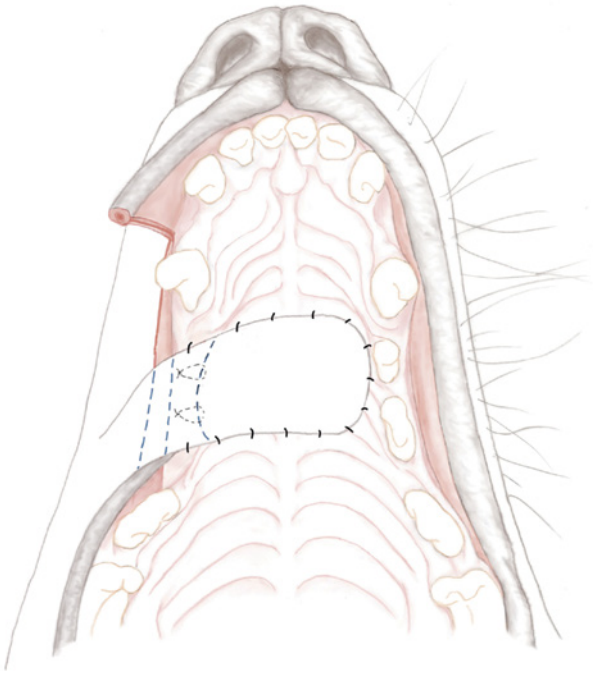
Plate 128



A



B



C

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Plate 129

Feline Superior Labial Musculomucosal Flap

DESCRIPTION

The feline superior labial musculomucosal flap is a variation of the upper full-thickness labial flap based on the superior labial vessels. The mucosa and overlying muscular layer are dissected from the cutaneous surface, creating a compound labial flap devoid of a cutaneous surface. Similarly, a flap can be developed over the inferior labial vasculature.

SURGICAL TECHNIQUE

Outline of the upper labial musculomucosal flaps in the cat (outline on cat's left upper lip). A flap potentially can be designed for the lower lip and cheek area (outline on cat's right lip/cheek).

COMMENTS

Reported by Canever and Degner (2021), this compound flap comprising the labial mucosa and muscular layer is a viable flap for closure of adjacent palatal defects in the cat. The labial vasculature provides circulation to each flap outlined. It offers an additional option for closure of problematic oronasal fistulas within its arc of rotation. This technique also has potential promise for use in dogs based on the similar soft tissue and vascular anatomy of the upper and lower lips (Doyle and Degner 2019).

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Plate 129



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Plate 130

Bilateral Myomucosal Advancement Flaps of the Upper Lip

DESCRIPTION

For large defects of the hard palate and adjacent soft palate, myomucosal flaps of the upper lip can be advanced bilaterally to span the wide defect.

SURGICAL TECHNIQUE

(A) View of a wide palatal defect spanning the medial margins of the dental arcades. The teeth have been extracted and the maxillary margins have been partially removed in preparation for the advancement of the left and right myomucosal advancement flaps. Bilateral mucosal flaps with a portion of the underlying muscle/fascia are created approximately 25% wider than the palatal defect to offset tissue contraction; this will reduce the risk of tension during closure.

(B) The elevated flaps have been advanced and sutured over the palatal defect (H-plasty design).

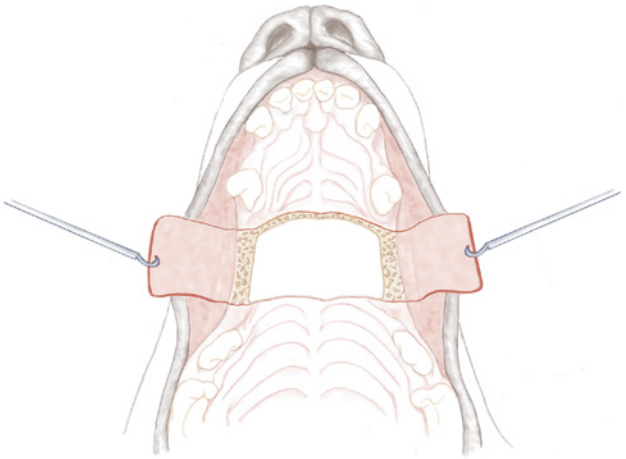
COMMENTS

This technique is a variation of other myomucosal flaps of the upper lip used to close palatal defects. It has special application for wide palatal defects secondary to tumor resection. Healing is also contingent on nasal mucosa eventually reepithelializing the undersurface of the paired flaps.

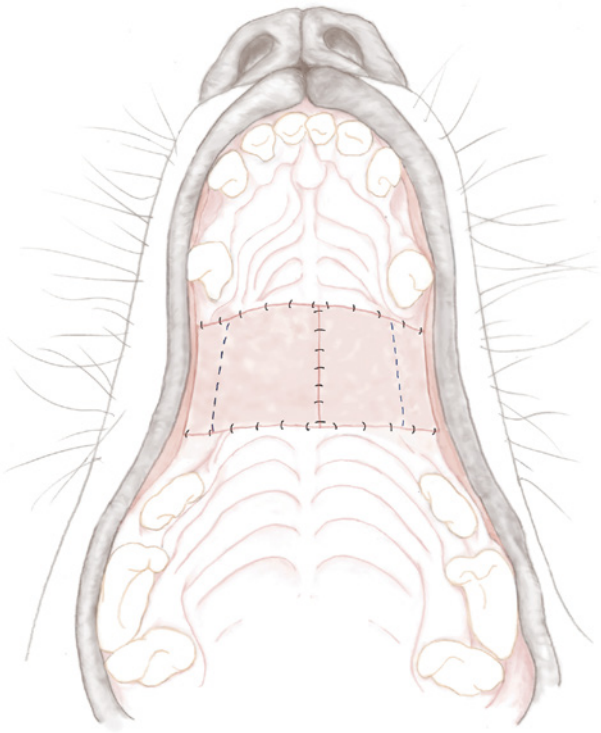
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Plate 130



A



B

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Plate 131 Soft Palate Split-Thickness Mucosal Flap

DESCRIPTION

Small oronasal fistulas, at the junction of the hard and soft palate, may be closed by elevating the oropharyngeal mucosa as a single-pedicle advancement flap.

SURGICAL TECHNIQUE

(A) Outline of the single-pedicle advancement flap. The oronasal fistula borders are debrided.

(B) The flap is elevated at the level of the mid-thickness of the soft palate, advanced, and sutured to the healthy debrided margins around the perimeter of the fistula.

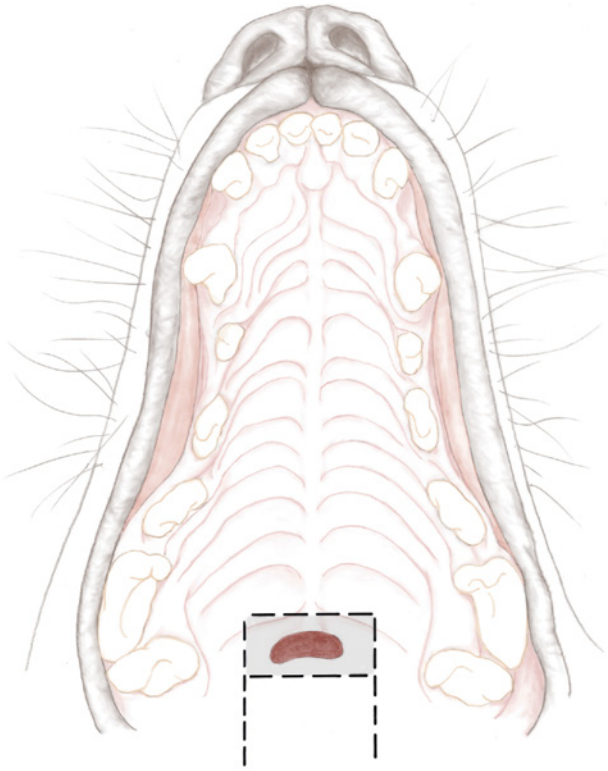
COMMENTS

Oronasal fistulas limited to this location are relatively uncommon. Nonetheless, this simple flap technique fits this specific defect and is worth keeping in mind.

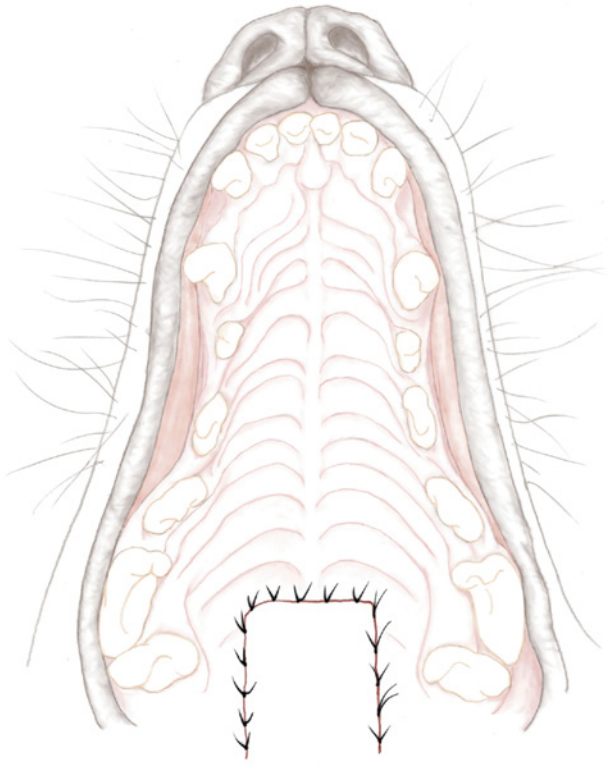
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Plate 131



A



B

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Plate 132

Partial Mandibulectomy Options

DESCRIPTION

Illustrations of common anatomic landmarks for mandibulectomy procedures.

SURGICAL TECHNIQUE

(A) Lateral profile of the mandible with the dental arcade. The lower lines/arrows denote common points of mandible excision for unilateral rostral, mid-segmental, and subtotal mandibulectomies in the dog. Variable portions of the dental arcade require resection with the segment of mandible removed.

(B) Examples of mandibulectomy options. Rostral mandibulectomy cut angles can be varied to obtain surgical margins during local tumor resection. In these three examples, an important goal, exclusive of complete tumor resection, is preserving a caudal portion of the mandibular symphysis when possible. Preservation will allow the mandible to continue functioning as a single unit, allowing the dog to eat normally.

(C) The semi-lunar or "rim" resection (shaded area) of the dorsal margin of the mandible can be effective for tumors limited to the gingival margin. The depth of the excision can be extended ventrally to the level of the mandibular canal. The dense ventral margin of the mandible preserved maintains the integrity of the mandible. Mucosa is elevated bilaterally and advanced over the defect. The dog is maintained on soft food postoperatively; no hard food products (hard biscuits, rawhide, etc.) and hard toys are permitted.

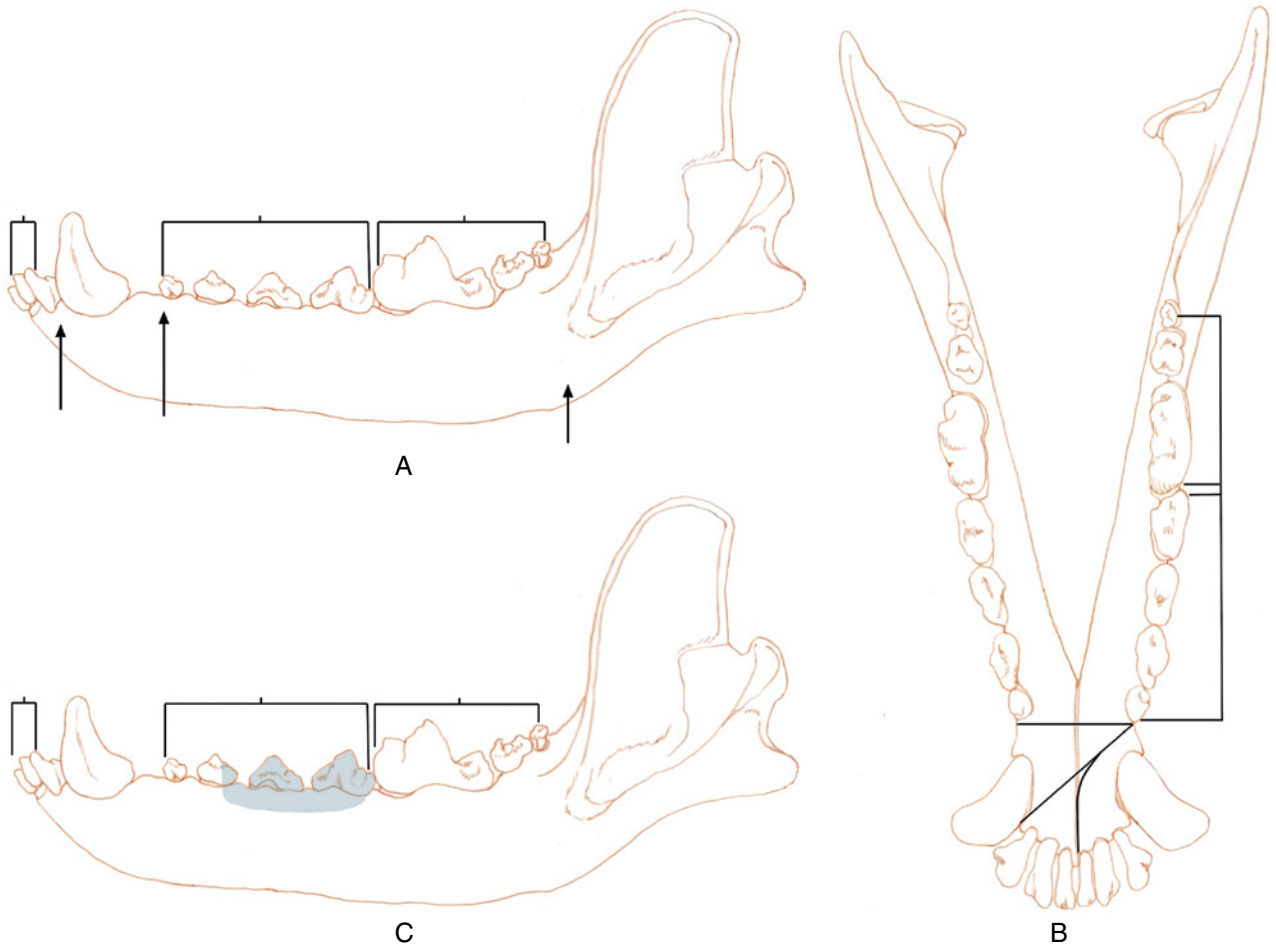
COMMENTS

Most partial mandibulectomies are not particularly difficult with the proper instrumentation. Sagittal saws, Hall drills, and MicroAire® reciprocating saws (MicroAire, Charlottesville, VA; author's preference) can be used to divide the dense bone of the mandible. Like other oncology patients, biopsy of the tumor, radiographic imaging, and staging of the dog are performed prior to mandibulectomy. Excised areas are submitted to assess the tumor and surgical margins.

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Plate 132



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Plate 133

Partial Maxillectomy Options

DESCRIPTION

Common anatomic landmarks for partial maxillectomy are illustrated.

SURGIAL TECHNIQUE

(A) Lateral view of the maxilla. This illustrates common options for partial maxillectomy in the dog, including incisivectomy (A), bilateral or unilateral rostral maxillectomy(A/B), and the areas of central and caudal maxillectomy (C/D). The depth of the maxillectomy (C/D) is dependent on the tumor and margins required to excise the mass completely.

(B) Ventral view of the maxilla with general partial maxillectomy areas commonly resected in the dog. This includes the area of the central/caudal maxillectomy (C/D); the bilateral rostral maxillectomy (A/B) includes the incisive bone (A) (incisivectomy).

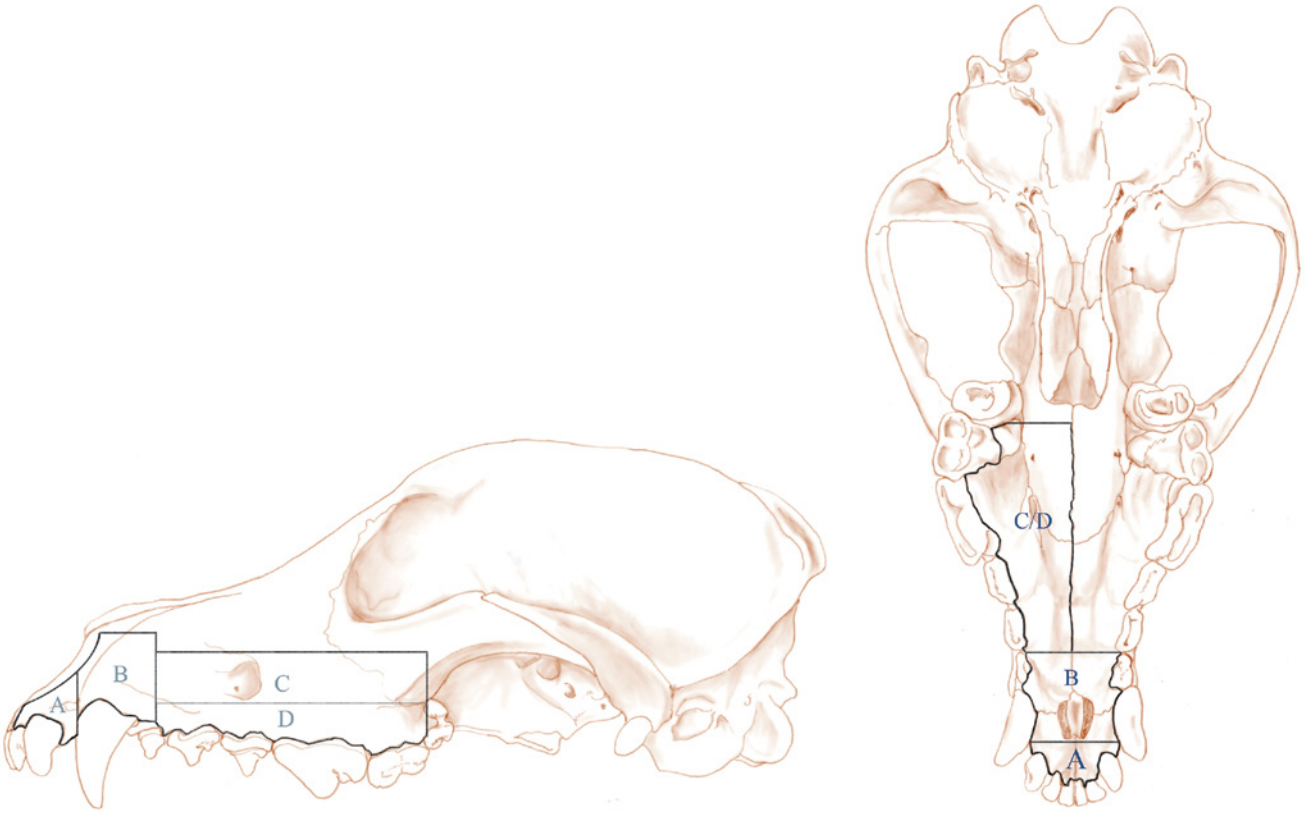
COMMENTS

Partial maxillectomy is generally a more demanding surgical procedure compared to partial mandibulectomy. With the exception of incisivectomy, partial maxillectomy requires removal of a variable portion of the bone encasing the nasal cavity. Postoperative dehiscence can result in problematic oronasal fistula formation. The most challenging maxillectomies include those central and caudal maxillectomy procedures extending to the mid-palatal area. Partial maxillectomies that are adjacent to a single dental arcade are technically easier to perform, relying on mobilization of the labial and buccal mucosa. Other techniques in this chapter are options for more problematic closures.

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Plate 133



A B

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Plate 134 Partial Glossectomy

DESCRIPTION

Partial glossectomy rostral to the frenulum is normally tolerated well by dogs. Surgical resection of the smaller growths on the dorsal and lateral margins of the tongue also is tolerated with normal lingual function maintained.

SURGICAL TECHNIQUE

(A) Example of a lingual carcinoma involving the rostral portion of the tongue.
(B) Resection of the neoplasm, dashed line. Note the placement of a Doyen intestinal clamp caudal to the surgical area.
(C) The dashed area is resected: note that the opposing side of the tongue forms a flap outline to facilitate closure of the defect. Inset: Example of a partial glossectomy involving the dorsolateral lingual surface and a portion of the underlying musculature.
(D) The full-thickness lingual flap created is folded into the defect and sutured using absorbable sutures (dorsal view).
(E) Closure of the ventral lingual surface.

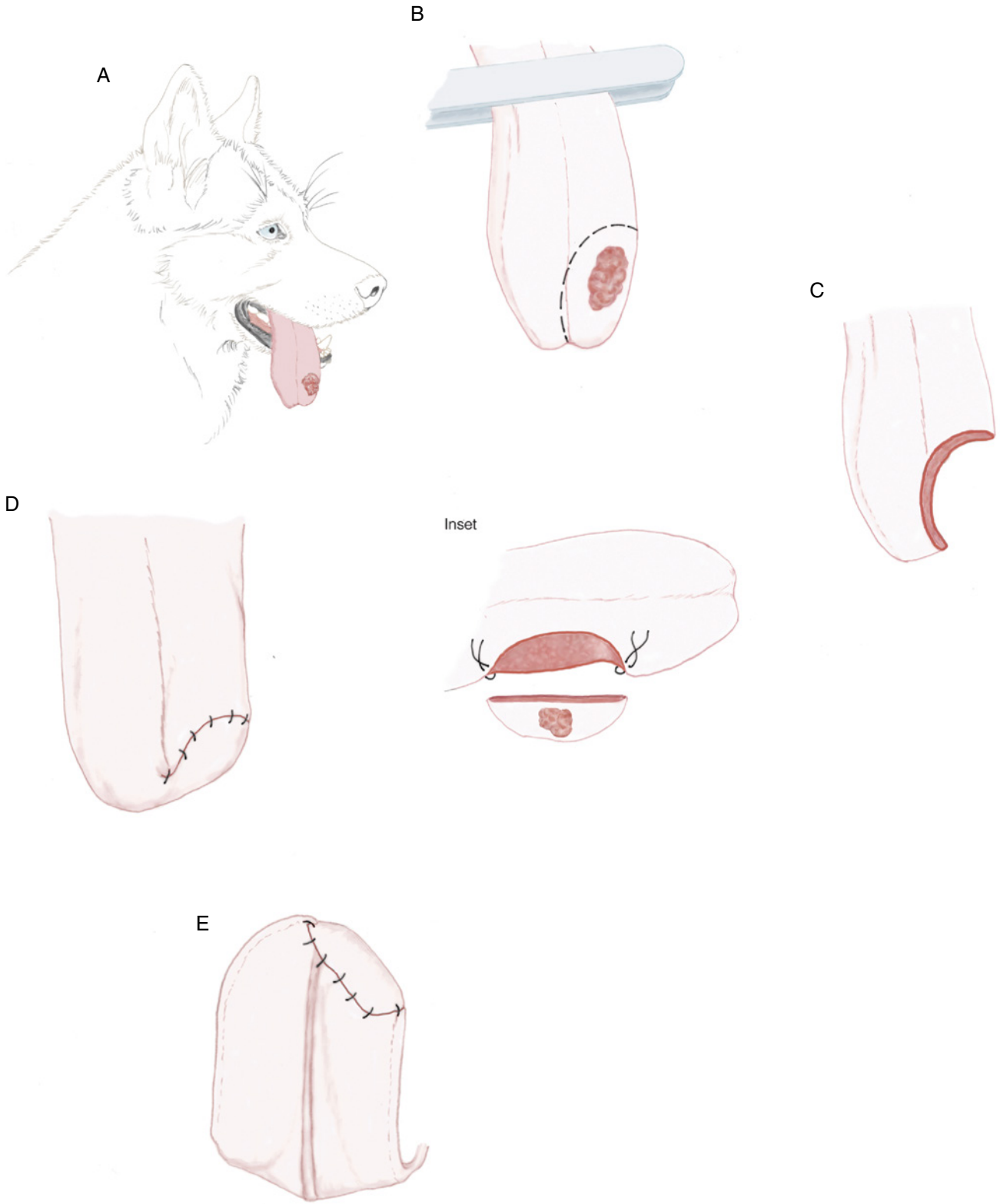
COMMENTS

A single Doyen intestinal forceps, placed across the tongue caudal to the surgical area, reduces bleeding; the forceps also facilitate exposure of the tongue. In this example, the small lingual flap preserves a portion of the length of the tongue that otherwise would be lost if the entire lingual tip required excision. As noted, the Inset illustration demonstrates a partial glossectomy that can be performed for more superficial lingual masses. See Figure 17-17.

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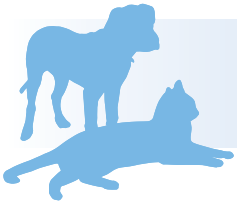
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Plate 134



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18

Foot Pad Reconstruction

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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INTRODUCTION

The foot pads of the dog include the digital pads, metacarpal pads, and metatarsal pads. They are capable of supporting the weight of the dog over a variety of surfaces. The epidermis of the pads is 1800 μm thick, considerably greater than the 25–40 μm thickness of the hairy skin.

The epidermis of the digital pads is elevated in a series of conical papillae. Secondary conical papillae are noted within each conical structure. This conical papillary surface provides a tough "anti-slip" surface for weight bearing, whereas the underlying pad cushion serves as a shock absorber. Composed of subcutaneous adipose tissue and collagenous and elastic fibers, the resilient pad cushion has the ability to compress, expand, and conform during activity on uniform or irregular surfaces. No other cutaneous surface can substitute completely for this highly specialized pad structure.

The center of gravity in the dog is located immediately behind the shoulder girdle, resulting in a greater force-to-body-weight ratio on the front pads. The maximum vertical force on the front pads approximates the body weight of the dog, whereas the vertical force on the hindlimbs is 0.8 times the body weight. Longitudinal pad force is 10 times less than vertical force. The front pad contact times can be as much as 1.5 times greater than those of the corresponding hindlimb pads.

The metacarpal and metatarsal foot pads are the most important for weight bearing. Complete loss of the digits secondary to disease or trauma would still enable preservation of limb function as long as the "meta-pad" is preserved. To date, options for metacarpal and metatarsal pad replacement have focused on transposing or advancing digital pads to areas where their placement will provide a durable, weight-bearing surface. Careful dissection of the phalanges via a palmar or plantar incision enables the surgeon to replace metacarpal or metatarsal pad defects (resulting from injury, tumor excision, or abnormal weight bearing secondary to neurologic and musculoskeletal injuries) with one or more digital pads. One or two digital pads can be employed to reconstruct the entire metacarpal or metatarsal pad in large dogs. In some dogs, a single digital pad may be sufficient, depending on its surface area. With complete loss of the digits, it is possible to advance and rotate the surviving metacarpal or metatarsal pad over the end of the exposed metacarpal or metatarsal bones. This will better position the "meta-pad" for optimal impact with the ground during ambulation.

Complete loss of all foot pads of the forelimb or hindlimb in the dog is considerably more serious, since no adjacent pad tissues are available for coverage. Skin, as a pad substitute, generally lacks the durability to withstand the daily physical abuse normally sustained by foot pads in all but the smallest veterinary patients. In cats, successful skin coverage of the foot requires restricting the cat to a more sedentary existence in the house, ideally on soft surfaces to minimize trauma to the cutaneous transplant. In large dogs, amputation of the involved limb has been performed when there was no viable option for pad replacement (Fig. 18-1). In providing a durable pad surface to the affected limb devoid of foot pads in large dogs, two potential options exist: microvascular transfer of a digital pad from another foot, or free grafting of digital pad tissue from another foot. The accessory carpal pads also may be a donor source for pad grafting. However, the use of the accessory pad depends on its surface area and relative thickness. Each technique has potential advantages and disadvantages.

PAD LACERATION AND LESION EXCISION

The thick corneal pad is susceptible to abrasive and shearing forces during ambulation. The feet also are exposed to sharp objects that may result in penetrating wounds, lacerations, or shearing wounds.

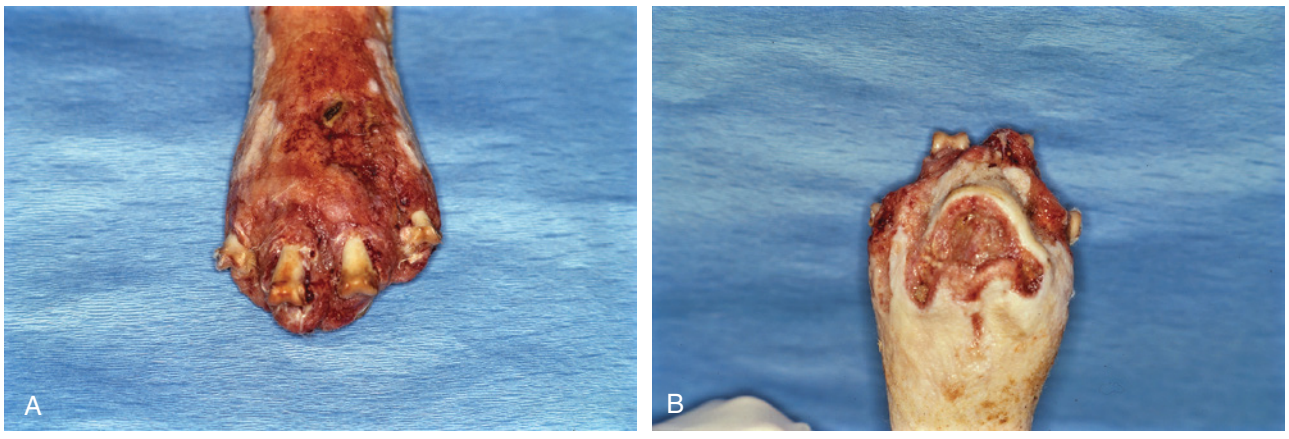


FIG. 18-1 (A) Extensive vehicular trauma to a canine paw. Complete loss of all digital pads. (B) Note loss of the metatarsal pad. A primary option for foot salvage under these circumstances is pad grafting.

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Freshly lacerated wounds can be lavaged, debrided, and closed primarily. Grossly contaminated or infected wounds may require open wound management for a variable period of time prior to closure. Foot pads have relatively poor "suture-holding power." Sutures can pull out of the dermal–corneal tissues during ambulation. The displacement of the underlying pad cushion can further stress any suture line. As a result, 2-0 sized suture materials, employing vertical mattress sutures with large "bites" of pad tissue, are best employed to appose pad lacerations in medium to large canine patients. A heavily padded foot bandage, protected with a fiberglass splint that envelopes the lower paw surface, is advisable to blunt impact and minimize digital cushion spread beneath the incision in order to prevent wound dehiscence. It is strongly advisable to protect the healing pad for approximately 3 weeks to help ensure proper healing. In general, sutures can be removed in about 2 weeks, barring healing complications (Fig. 18-2). The author commonly uses absorbable poliglecaprone to reduce the need for routine suture removal; a minimum of five throws is required to secure the knot.

On occasion, extensive damage or loss of flexor tendon support of the digits can result in abnormal weight bearing (Fig. 18-3). Foot pad ulceration may be noted, especially in the larger, active dog. Successful fusion podoplasty has been reported under these circumstances. Similarly, this technique can be used for severe interdigital pyoderma cases unresponsive to therapy. This technique entails removal of all skin folds between the digits and the metatarsal/metacarpal pad of the affected limbs, followed by suture apposition of the bordering pad edges.

Tumors, Cysts, and Granulomas of the Paws

There are a number of neoplasms involving the paws in dogs and cats (Fig. 18-4). Retained foreign bodies (glass, metal, plant material) in the pads or interdigital areas are often associated with an intermittent draining tract (Figs 18-5 and 18-6). A large number of growths involving the paws are actually benign conditions where local resection can be performed. Osteomyelitis may



FIG. 18-2 (A) Circumferential skin loss of the hind paw in a young Dalmatian, secondary to vehicular trauma. Note partial avulsion of the metacarpal pad. (B) Close-up view of the foot. Only a portion of one digital pad survived. (C) A full-thickness mesh graft was used to resurface the circumferential skin defect. The displaced metacarpal pad was sutured into its original position. Restoration of a functional limb was achieved.

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FIG. 18-3 (A, B) Traumatic loss of the flexor tendons and overlying skin. The area was successfully grafted to resolve the defect. Note the upward deviation of the digits. Future management includes the use of a protective bootie when the dog walks on hard surfaces to prevent abrasion of the caudal aspect of the tilted digital pads. (See Fig. 3-14.)



FIG. 18-4 (A) Loss of toe nail with associated swelling secondary to squamous cell carcinoma. (B) Preparation for amputation using autoclaved Vetrap as a temporary tourniquet. Gelpi retractors were used to facilitate exposure. (C) Preservation of the interdigital web provides support to the digits on closure. The author recommends protecting the paw with a heavily padded bandage for a minimum of 3 weeks, with bandage changes every 4–5 days to minimize the risk of dehiscence.

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FIG. 18-5 (A) Interdigital granuloma with small site of drainage. (B) Interdigital granuloma with small site of drainage. (C) Granuloma resection: note the plant material.



FIG. 18-6 (A) Interdigital granuloma in a 2-year-old Irish setter. Resection of the granuloma and involved web is required to resolve this condition. (B) Closure of the remaining interdigital web. A protective bandage was used to protect the paw over a 3-week period. The ingrowth of hair follicles was considered the cause of this granulomatous lesion.

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FIG. 18-7 (A) Follicular ingrowth resulting in this expansile granuloma in a mixed-breed dog. (B) Dissection and removal of the granulomatous mass. The yellow elastic wrap served as a temporary tourniquet. Prior to closure, the tourniquet was removed and bleeding vessels were controlled with electrocautery. (C) Closure of the surgical incision. (D) Note the redundant interdigital web ballooning up. The skin, stretched by the expansile mass, decreased over time. A bandage was applied to protect the paw for 3 weeks.

involve the phalanges or metacarpal/metatarsal bones. Radiographs are invaluable for diagnosing these problematic conditions.

In many cases granulomas may be associated with the dermal sebaceous glands or hair follicles. Inward deviation of hair follicles can result in granulomas by stimulating a foreign-body reaction such as fibroadnexal hamartomas (Fig. 18-7). In many cases, local resection is possible without elaborate reconstructive surgery (Fig. 18-8). Laser therapy has been used to control smaller lesions. Needle aspirates can be useful to determine the possible cause of a lesion prior to surgery. For problematic cases, a biopsy (and culture) are advisable before embarking on a major surgical procedure.

Swelling associated with the third phalanx secondary to squamous cell carcinoma, malignant melanoma, or sarcomas can be mistaken for a nail-bed infection. Radiographs are important to assess the third phalanx for bone destruction secondary to neoplasia. As noted, aspirates and biopsy samples can be used to confirm neoplasia in equivocal cases.

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FIG. 18-8 (A, B) Feline paw with encapsulated cyst. The intact cyst was easily dissected from the paw. (C) Closure was followed by a protective bandage for 3 weeks.

It must be noted that the interdigital web is important in stabilizing the digits during ambulation: resection of the entire toe web can be performed, but the unsupported digit can deviate outward and cause discomfort to the patient during ambulation (Fig. 18-9).

DIGITAL PAD TRANSFER

Digital pads tethered on a vascularized cutaneous pedicle can be transplanted, within their arc of rotation, to defects on weight-bearing surfaces. This is most useful when portions of the metatarsal or metacarpal pads are lost. Similarly, abnormal weight bearing as a result of limb trauma may require positioning a digital pad over an ulcerated area.

A ventral incision for removal of the first and second phalanges is preferable to a dorsal incision, thus enabling immediate placement of the flap into its new position. The veterinary surgeon will find that pads heal more slowly than other skin closures. Partial dehiscence may be noted, but the sutures can easily be replaced. A heavily padded bandage with external support is required to promote healing in this weight-bearing area (Fig. 18-10).

In the example in Fig. 18-11, the complete metatarsal pad was resected with the malignant melanoma. Although two pads (digits 2 and 5) can be used to replace a large metatarsal or metacarpal pad, this Labrador had large digital pads. As a result, a single digital pad was used to reconstruct the excised metatarsal pad.

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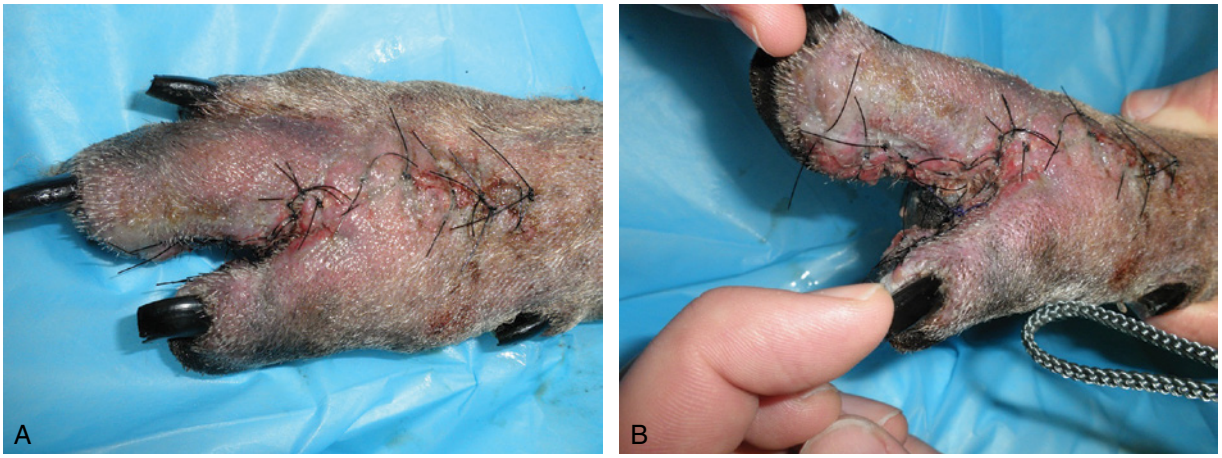


FIG. 18-9 (A, B) Amputation of the third digit and surgical closure. Without the presence of the supporting toe web, the second digit is easily splayed apart, causing discomfort to the dog. Apposition of the opposing skin surfaces of digits 2 and 4 can eliminate this problem.

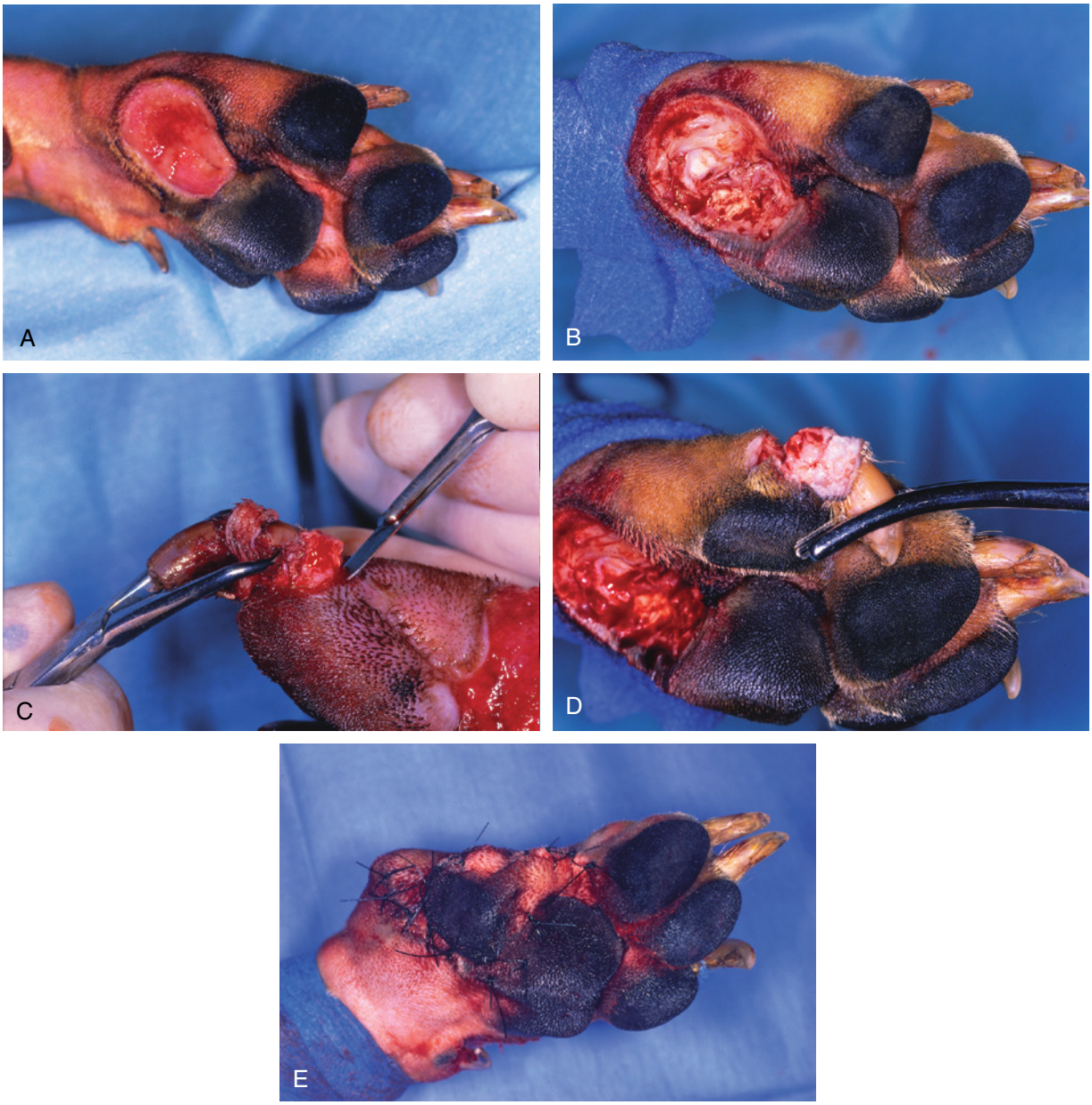


FIG. 18-10 (A) Chronic ulcer secondary to trauma. Abnormal weight bearing contributed to metatarsal pad ulceration. (B) Debridement of the ulcer. (C, D) Resection of the entire third phalanx. (E) Application of the digital pad after surgical removal of the phalanges.

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FIG. 18-11 (A) Melanoma involving the metatarsal pad in a retriever. (B) Complete metatarsal pad resection (with complete margins) followed by reconstruction with the fifth digital pad. A large digital pad may be sufficient to replace the metacarpal or metatarsal pads. (C) The patient 3 weeks postoperatively. A protective bandage is required for a minimum of 3 weeks. A protective paw bootie is advisable when the patient is ambulating on hard, abrasive surfaces. (See Plate 137.)

METACARPAL/METATARSAL PAD TRANSFER

Loss of the digital pads from trauma or disease may require repositioning of the metacarpal or metatarsal pad to provide a durable weight-bearing surface to the limb. The destroyed digits are amputated, and a portion of the distal metacarpal/metatarsal bones may be resected to permit proper metacarpal/metatarsal pad positioning over the resultant stump. This procedure can result in a fully functional limb despite the loss of all digits (Figs 18-12 and 18-13).

Contrary to the early veterinary literature, dogs can have a reasonably functional limb with loss of multiple digits. The key to foot salvage is to preserve the metacarpal and metatarsal pads of the damaged or diseased paw.

ACCESSORY CARPAL PAD

The small accessory carpal pad has been used to cover the stump of the front limb, when amputation was necessary, at the level of the proximal metacarpal area. Depending on the amputation site, the pad and mobile skin can be advanced, rotated into position, or incorporated into a transposition skin flap to cover the terminal end of the extremity. Significant shortening of the limb limits use of the extremity in ambulation, but may assist the animal in balance or rising from a resting position. The accessory pad varies in its thickness and consistency. In some dogs the pad is little more than a small, thickened knob; in other dogs the accessory pad is a small pad with the consistency of a normal digital pad. It is a potential source of pad tissue for grafting purposes, depending on its size and consistency. A recent paper reported the use of the accessory pad for grafting in a dog (Kim and Yoon 2020).

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FIG. 18-12 (A) Loss of digits of the hind paw secondary to immune-mediated vasculitis (see Fig. 6-19). (B) Resection of the granulation bed. (C) The distal ends of the exposed metacarpal bones were resected. The central digits normally require partial resection. (D, E) Advancement of the metacarpal pad over the terminal stump. A functional limb was obtained. (F) The pad at suture removal. (See Plate 138.)

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FIG. 18-13 (A) Traumatic loss of the digits. (B) Cranial view of the paw. The metatarsal pad was viable (arrow). (C) Surgical resection of the granulation bed, exposing the metatarsal bones. The exposed cartilage and terminal end of digits 3 and 4 were resected with bone cutting forceps. (D) Closure with a series of interrupted sutures.

PAD GRAFTING

Complete traumatic loss of all pads of a foot presents a significant problem to a dog: amputation may be necessary. However, freshly severed digital and metacarpal/metatarsal pads have the potential to be grafted onto the limb. Pad grafting options are summarized in Plates 139 and 140.

The two-stage procedure noted in Plate 139 is technically demanding (Fig. 18-14). The pad is preserved on a temporary vascular recipient site while the wound is being prepared for later flap transfer. This technique has the main advantage of providing a thick subcutaneous layer to replace the pad cushion; this cannot be achieved by direct pad application to a granulation bed. However, small pad grafts (Plate 140) have the potential advantage of preserving remaining toe pads by taking small segments without necessarily sacrificing a digit for harvesting a larger single-pad graft. Grafts are ideally placed on surviving elements of the metacarpal/metatarsal pad cushion.

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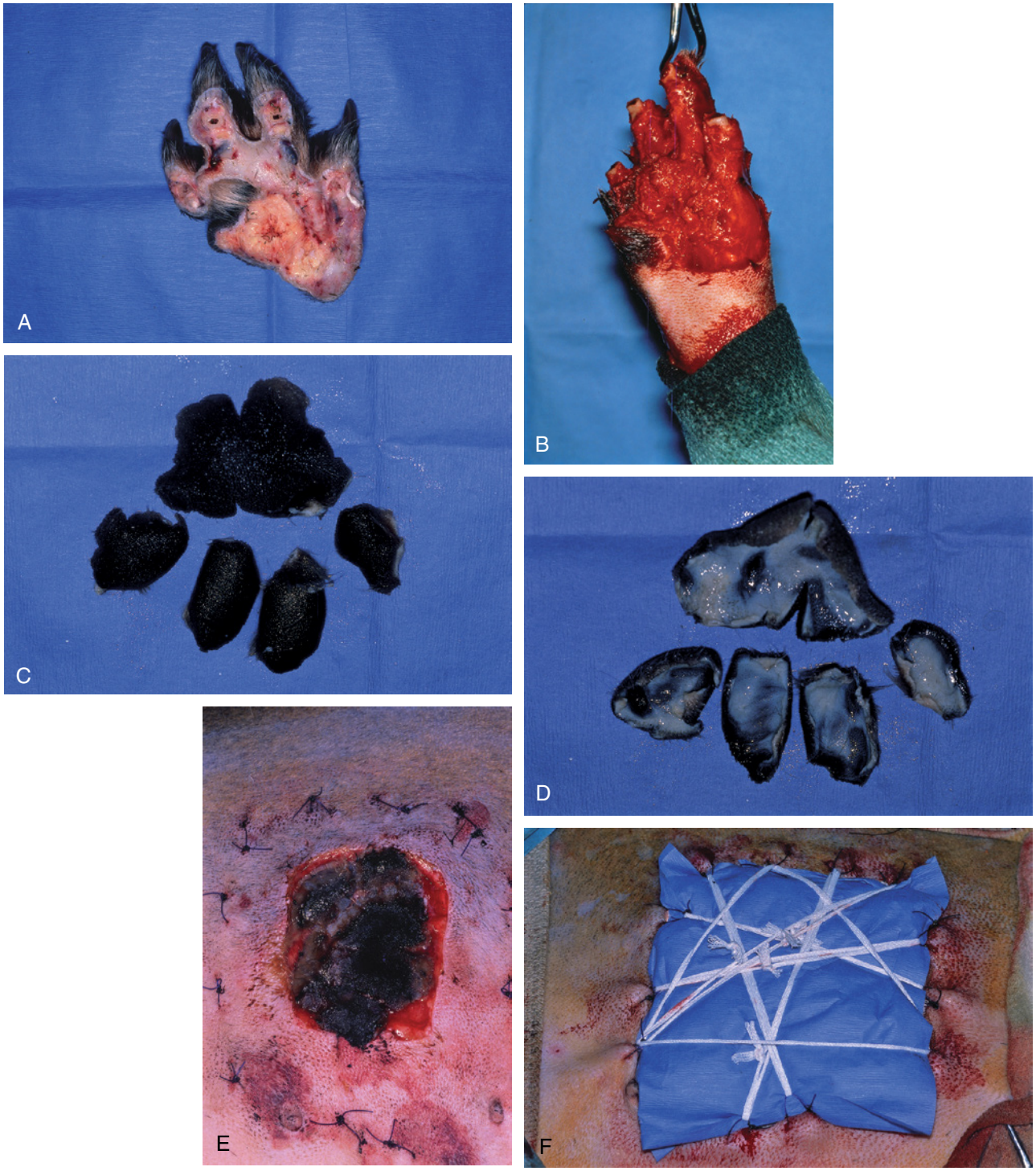


FIG. 18-14 (A, B) Left rear paw denuded of the metatarsal and digital pads, secondary to a wire snaring the paw. The patient was immediately referred to the hospital by the patient's veterinarian. The pads were immediately placed in chilled saline and neomycin, creating a 5% solution. (C, D) The pads were separated and the digital cushions resected. (E) The cupped pad grafts were incised to flatten their surfaces. Pads were sutured to the cutaneous trunci muscle in a predetermined location to accommodate future elevation of the denuded paw. (F) A tie-over dressing to immobilize and protect the grafted pads. (continued)

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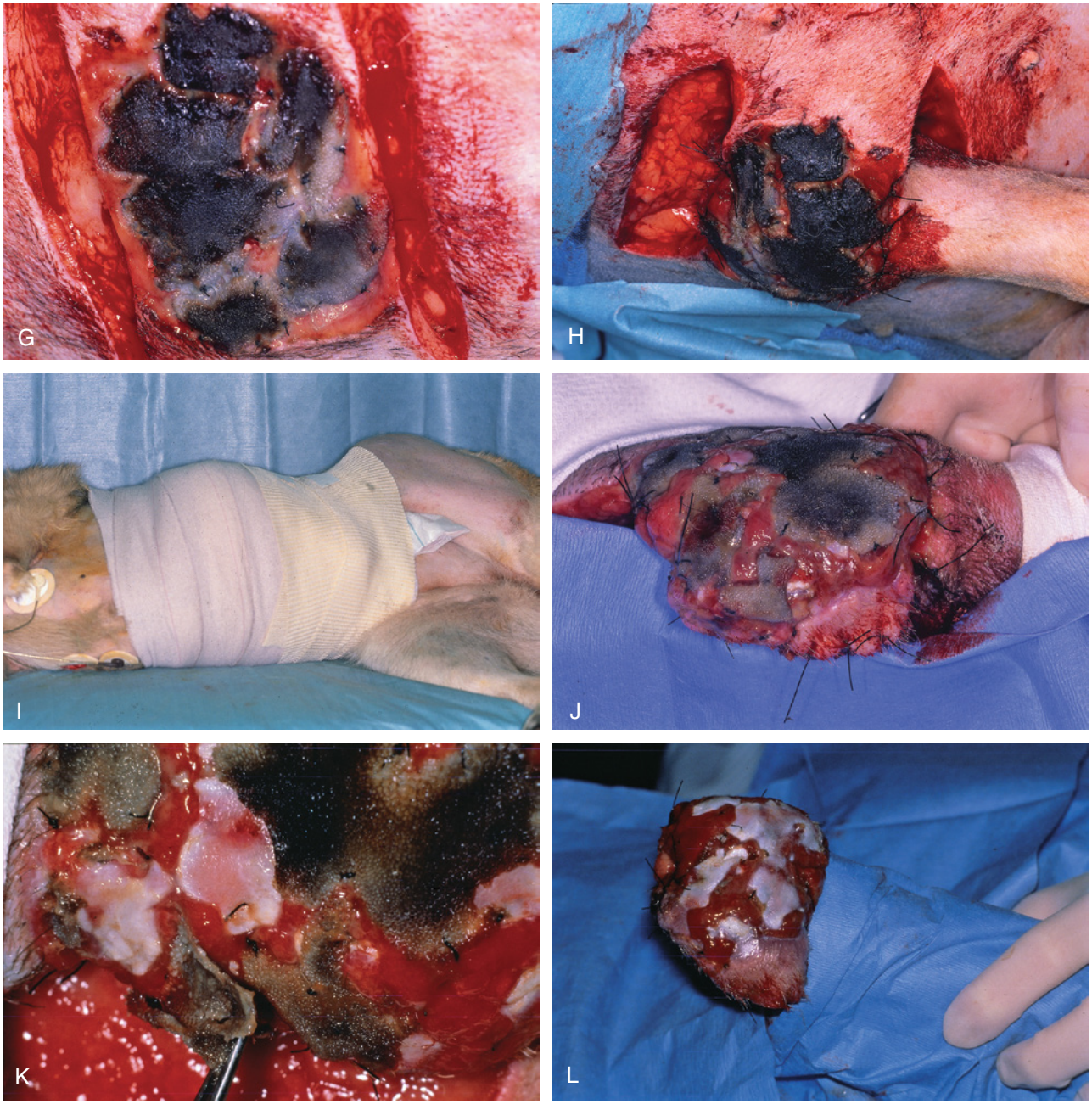
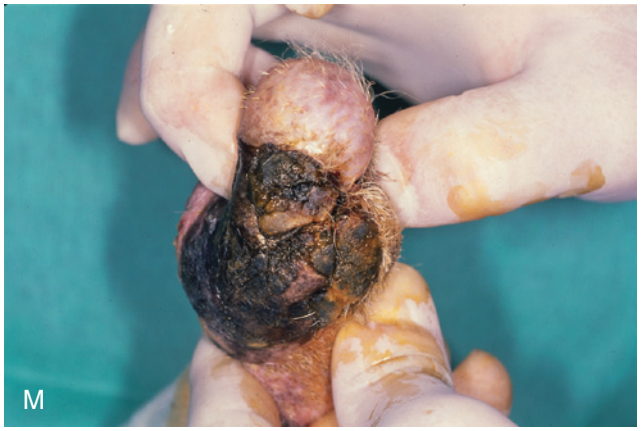


FIG. 18-14 (Continued) (G) Two parallel skin incisions were made cranial and caudal to the graft bed 7 days after application. (H) The bipedicle flap incorporating the graft bed was undermined below the hypodermis. Skin incisions were extended to a length sufficient to accommodate the paw defect. The apposing skin and wound borders were sutured together. (I) Cotton padding was applied between the elevated limb and abdominal wall, followed by a layer of elastic adhesive tape (Elastikon, Johnson & Johnson). (J) One week after application, the pedicles were divided in stages (one-half every 2 days). Completion of the division process. (K) Close-up view of pad grafts reimplanted to the hind paw. The outer corneal pad layers separate, revealing the germinal epithelium. (L) The epithelium expands over the interposing granulation tissue. (continued)

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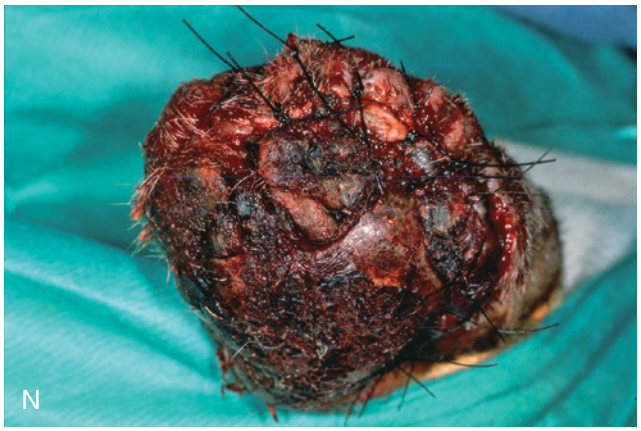


FIG. 18-14 (Continued) (M) Redundant scar tissue was resected approximately 6 weeks after completion of the pad transfer, which aligned the cornified pad surface for optimal weight bearing. (N) Tension sutures were used to shift the pad tissue into its final location. (Source: Pavletic MM. 1994. Foot salvage and delayed reimplantation of severed metatarsal and digital pads using a bipedicle direct flap technique. *J Am Anim Hosp Assoc* 30:539–547. Reproduced with permission of The American Animal Hospital Association.) (See Plate 139.)

DIGITAL FLAPS FOR WOUND CLOSURE

Closure of distal-extremity defects, secondary to trauma or tumor resection, can be problematic due to the unavailability of loose elastic skin (Fig. 18-15). Tumor resection involving the digits and interdigital area is particularly challenging. Centrally located interdigital masses may be resected with adequate surgical margins, leaving sufficient skin to close the defect and refashion a supportive toe web (Fig. 18-16). Resection of larger and/or eccentrically located interdigital masses may necessitate wider resection. In many of these cases, the healthy skin along the lateral and palmar/plantar aspect of one digit, including the pad, may be safely preserved. Careful dissection and removal of the phalanges create a digital flap for closure of the defect. This technique also can be useful for closure of skin defects involving digits 2 or 5, using digital flaps created from toes 3 or 4, respectively (see Plates 135 and 136). The pad tissue usually is placed in a nonweight-bearing location on the paw, but closure of the defect is effectively accomplished (Figs 18-16 and 18-17). In some cases, the pad is not required for closure and the salvaged digital skin can be used as a simple transposition skin flap (Fig. 18-18).

FUSION PODOPLASTY

Chronic pododermatitis is the result of an overall failure to control the underlying condition. In most cases the primary pathogen is *Staphylococcus aureus*, but it may include secondary infections from *Proteus* spp., *Pseudomonas aeruginosa*, and *E. coli*. Other causes may include allergies, mycoses, parasites, irritants, neoplasia, metabolic disease, neurologic disorders, or autoimmune disease. Moreover, a chronic foreign-body reaction may be noted from the ingrowth of hair follicles and sebaceous gland proliferation/rupture (Fig. 18-19). The skin can appear as thickened, inflamed, and ulcerated. Fistulous tracts may be noted, along with a serosanguinous to purulent discharge.

Tourniquets are quite useful in controlling hemorrhage, improving both visualization and execution of the surgical procedure. From the author's experience, autoclaved Vetrap (3M) is very effective as a tourniquet using the normal precautions associated with its use. Wrapping of the paw begins at the digits and progresses proximally, usually to the level of the tarsus or carpus. The wrap can be split and retracted to expose the surgical area(s) of the paw. (See Chapter 6, Use of Tourniquets for Lower-Extremity Procedures.) On removal, electrocautery is useful to control bleeders. The postoperative application of a bandage is normally effective in controlling small areas of capillary hemorrhage.

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FIG. 18-15 (A) Vehicular trauma to a canine paw, with destruction of the central digital pads. (B) Excision of the granulation bed and exposed ends of the second phalanges. (C) Closure. Note that digital pads 2 and 5 were reepithelializing and eventually formed a functional weight-bearing surface.

Fusion podoplasty is considered for those cases of end-stage pododermatitis refractory to both medical and conservative surgical management. Fusion podoplasty refers to the obliteration of the interdigital web and palmar/plantar cutaneous space between the metatarsal/metacarpal pad and digits. Fusion podoplasty also has been used in cases where permanent flexor tendon injury has resulted in digital pad irritation and ulceration secondary to abnormal weight bearing by the dog (Plate 141). Having the dog wear a protective boot is advisable to protect the foot from ulceration when ambulating on hard, abrasive surfaces and to avoid podoplasty.

> Keep in mind that partial podoplasty is often sufficient to control multiple interdigital granulomas without resorting to the daunting complete podoplasty.

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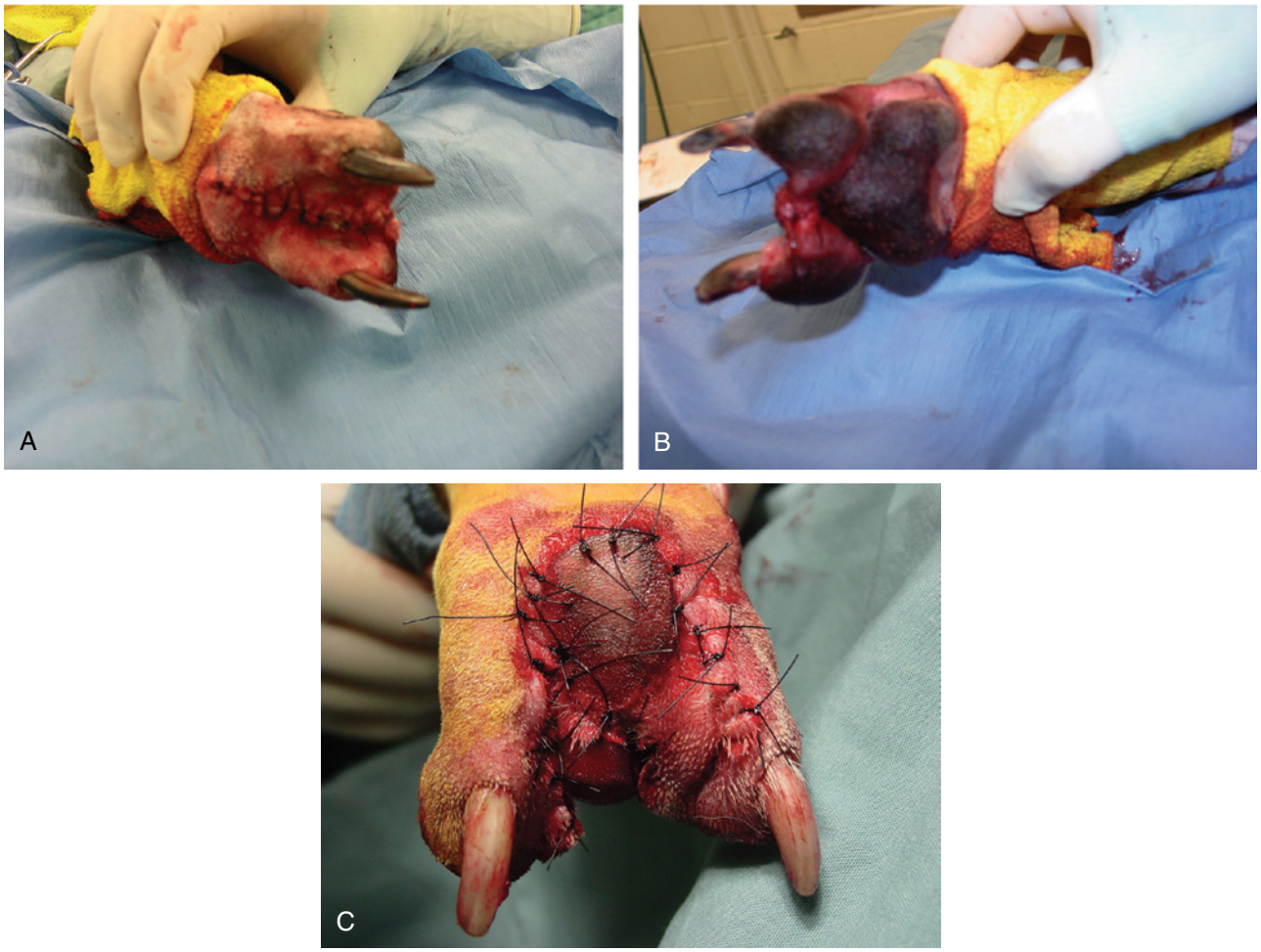


FIG. 18-16 (A) Resection of the central two toes due to neoplasia. (B) Lower view of the foot. Restoration of a digital web helps support the remaining toes and provides a more natural cosmetic appearance. (C) Wide resection of a soft tissue sarcoma. Resection of the lateral and plantar aspect of the adjacent digit was not required to obtain surgical margins. The phalanges were dissected free of the resultant digital flap. The flap was transposed into the defect, completing the closure. (See Plate 135.)

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FIG. 18-17 (A) Recurrent soft tissue sarcoma referral. (B) Wide excision of the mass. (C) Closure was accomplished using the lateral digital skin and pad surface. (See Plate 136.)

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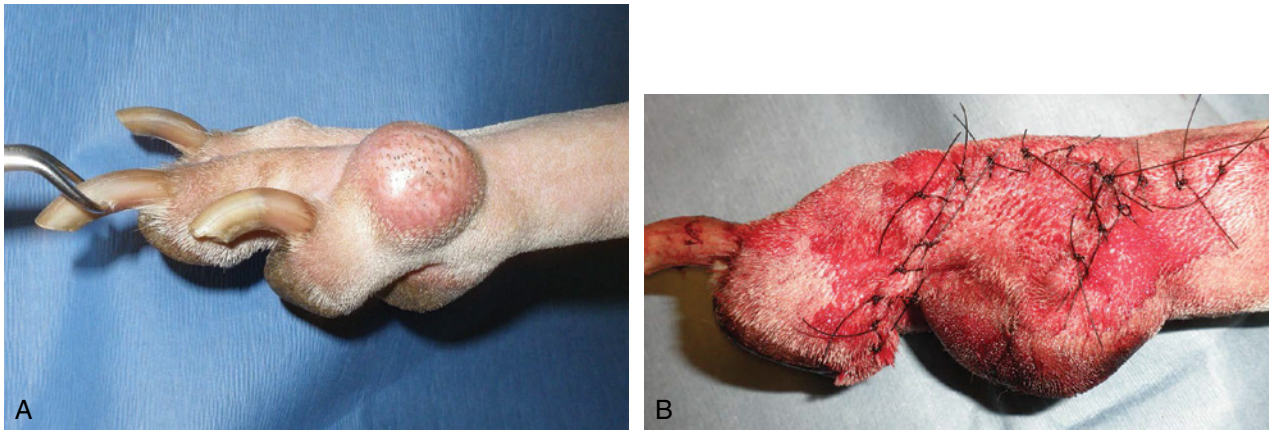


FIG. 18-18 (A) Mast cell tumor involving fifth digit. (B) Amputation of the fourth and fifth digits was required to obtain surgical margins. The uninvolved skin of the medial aspect of the fourth digit was transposed into the surgical defect. The digital pad of the fourth digit was not required and was trimmed off this flap prior to suturing the skin. (See Plate 136.)



FIG. 18-19 (A) Bulldog with chronic proliferative pododermatitis (arrow) refractory to medical management. This fold of tissue formed part of the abnormal weight-bearing surface. (B) Interdigital abscessation (arrows). A foreign body reaction was noted secondary to ingrowth of hair follicles and ruptured sebaceous glands in the subcutis. (C) Partial podoplasty of the proliferative tissue. (D) Interdigital resection of the abnormal interdigital tissues. The foot was bandaged for 3 weeks, with bandage changes performed every 4–5 days. In larger dogs, a fiberglass splint may be indicated for additional protective support.

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Plate 135

Digital Flap Technique: Major Digital/ Interdigital Defects

DESCRIPTION

The digital skin and pad can be salvaged to close problematic defects involving the paw. In this case example, the centrally located neoplasm is resected where it overlies digit 3 and the adjacent toe web associated with digit 4 (see Fig. 18-16).

SURGICAL TECHNIQUE

(A) Illustration of a neoplasm involves digit 3 with extension toward the interdigital area adjacent to digit 4. The dashed line represents the area of resection.

(B) Amputation of digit 3, the interdigital skin, and the medial half of digit 4, including careful dissection and removal of the first, second, and third phalanges. In this example, the small band of skin (dashed lines) is resected to facilitate placement of the flap.

(C) The lateral and palmar/plantar cutaneous tissue, with the attached pad of digit 4, is transposed into the large surgical defect.

COMMENTS

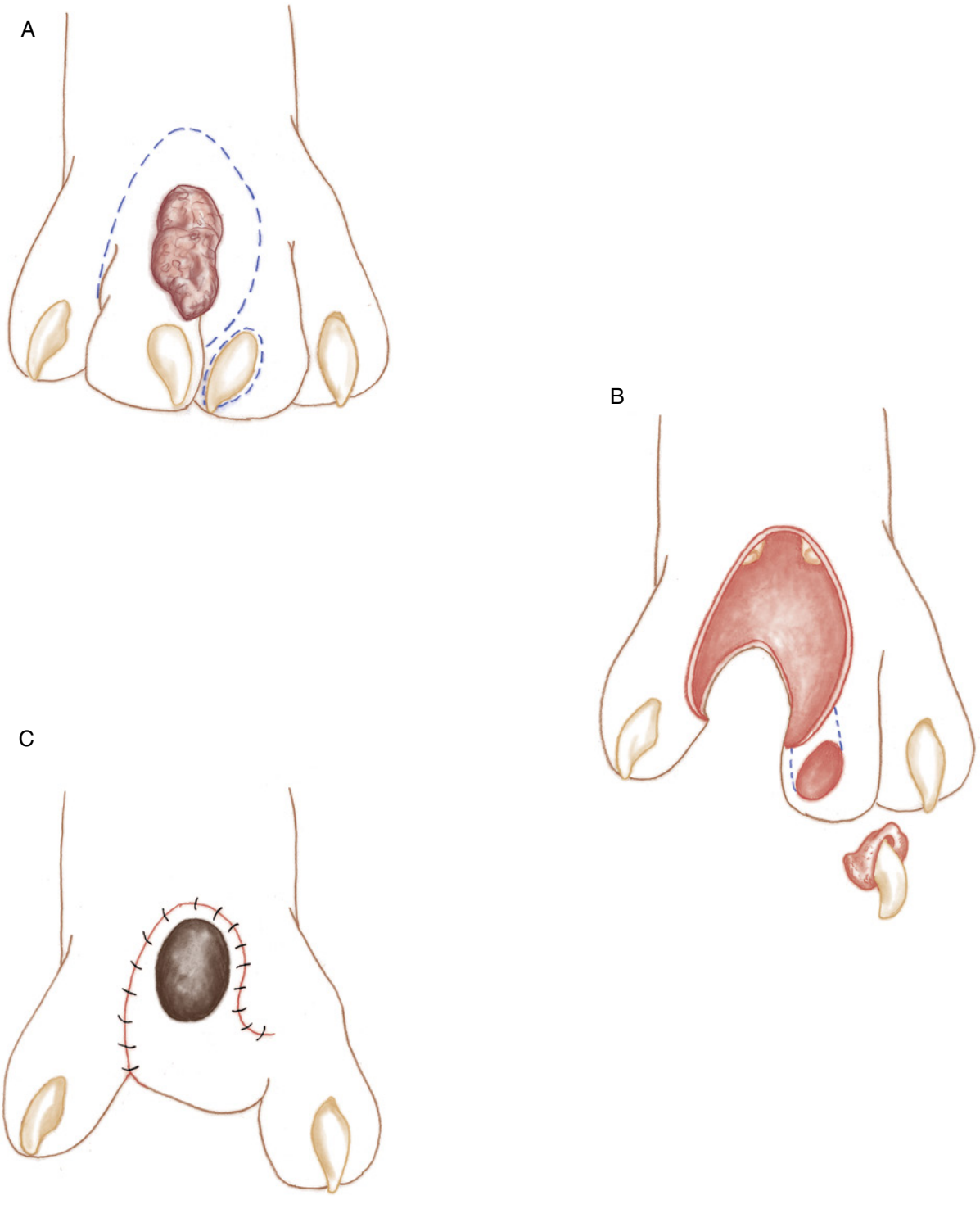
This is a remarkably simple and effective technique for closure of surgical defects of the paw secondary to tumor resection. The lateral skin and attached pad surface of digit 4, uninvolved with the neoplasm, nicely transpose into the surgical defect. Surgical margins around any neoplasm will depend on the underlying (base) surgical margins as well as the cutaneous perimeter obtained. The surgical perimeter and base of the surgical specimen should be marked with India ink and submitted for histopathologic examination to assess the surgical margins (see Plate 136). Having this flap available for closure can give the surgeon confidence that the defect, secondary to tumor resection, can be largely or completely closed.

Dogs can have a functional limb with two or fewer toes (i.e., no digits; see Plate 138), contrary to statements in the older veterinary literature. However, a dog may favor the leg to a variable degree, especially during the first few weeks postoperatively; owners should be made aware of this probability prior to surgery. Bandage protection, with possible supplementation with a fiberglass splint, of the area may be necessary over a 3-week period to ensure healing is complete.

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Plate 135



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Plate 136 Digital Flap Technique: Major Defects of Digits Two or Five

DESCRIPTION

The uninvolved portions of the third or fourth digit, adjacent to a neoplasm involving digits 2 or 5, can be used to close the surgical defect created. Portions of the adjacent metacarpal or metatarsal bone can be resected, if needed, to achieve surgical margins (see Figs. 18-17 and 18-18).

SURGICAL TECHNIQUE

(A) Neoplasm involving the dorsolateral surface of the second digit. Dashed lines signify the area of excision, including a portion of the second metacarpal bone.

(B) Resection of the second digit and adjacent portion of the third digit. The phalanges of the third digit are carefully dissected and resected to preserve circulation to the remaining digital skin and pad.

(C) The skin and toe pad of digit 3 are pivoted into the surgical defect and sutured to the adjacent cutaneous borders.

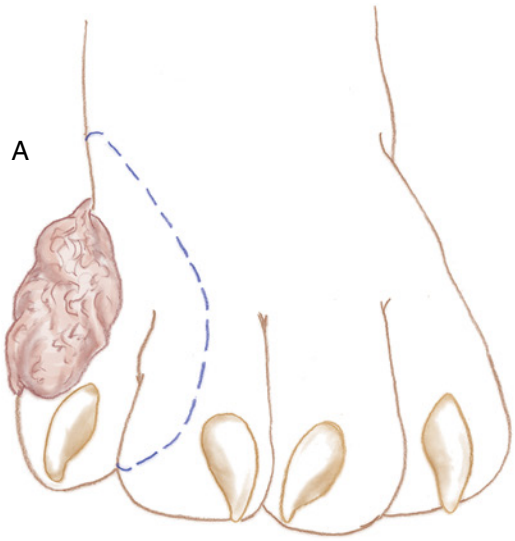
COMMENTS

As also noted in Plate 135, digital flaps rely on salvaging the skin and digital pad tissues that are not involved in the disease process. Having this source of tissue available for wound closure enables the surgeon to resect tumors more aggressively, with the confidence that wound closure can be reasonably achieved in this problematic area. Dogs can have a functional limb with two or fewer toes (i.e., no digits, see Plate 138), although the dog may favor the limb to a variable degree, especially during the first few weeks following surgery. Owners should be made aware of this possibility prior to surgery in order to avoid any misunderstanding. Bandaging for a 3-week period, with possible supplementation with a fiberglass splint, is useful in helping to ensure that healing occurs without complication.

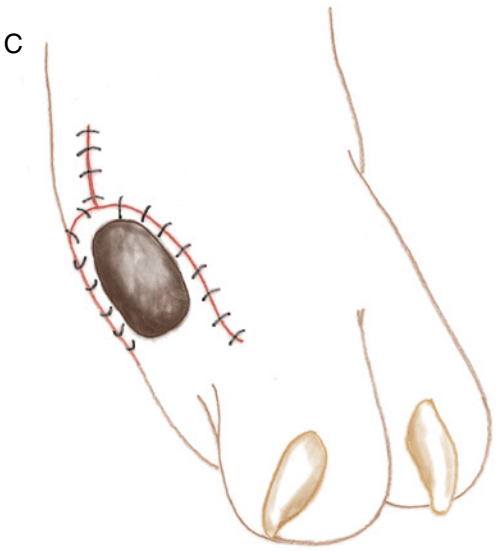
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Plate 136







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Plate 137

Digital Pad Transfer

DESCRIPTION

Digital pads tethered on a vascularized cutaneous pedicle can be transplanted within their arc of rotation to defects in weight-bearing surface areas. This is most evident when portions of the metatarsal or metacarpal pads are lost. Similarly, abnormal weight bearing as a result of limb trauma may require a digital pad to be positioned over an ulcerated area (see Figs. 18-10 and 18-11).

SURGICAL TECHNIQUE

(A) A no. 15 blade is used to incise around the circumference of the nail bed. The third phalanx is carefully dissected out and disarticulated.

(B) An incision is made on the underlying skin surface to gain exposure to the second and third phalanges (dotted line).

(C) The surgeon should limit dissection to the immediate periosteal surface area. Care is taken to preserve circulation to the digital pad as the phalanges are removed. A tourniquet applied proximal to the surgical area can improve tissue dissection. The circumferential access incision for excision of the third phalanx is sutured closed.

(D) The pad graft is rotated into a prepared weight-bearing defect and sutured into place with 2-0 or 3-0 nonabsorbable suture material. The opposing pad borders are trimmed to ensure accurate abutment of these structures. The foot is placed in a bandage reinforced with a fiberglass splint until suture removal, approximately 3 weeks later. The bandage and support splint are changed every 3–5 days.

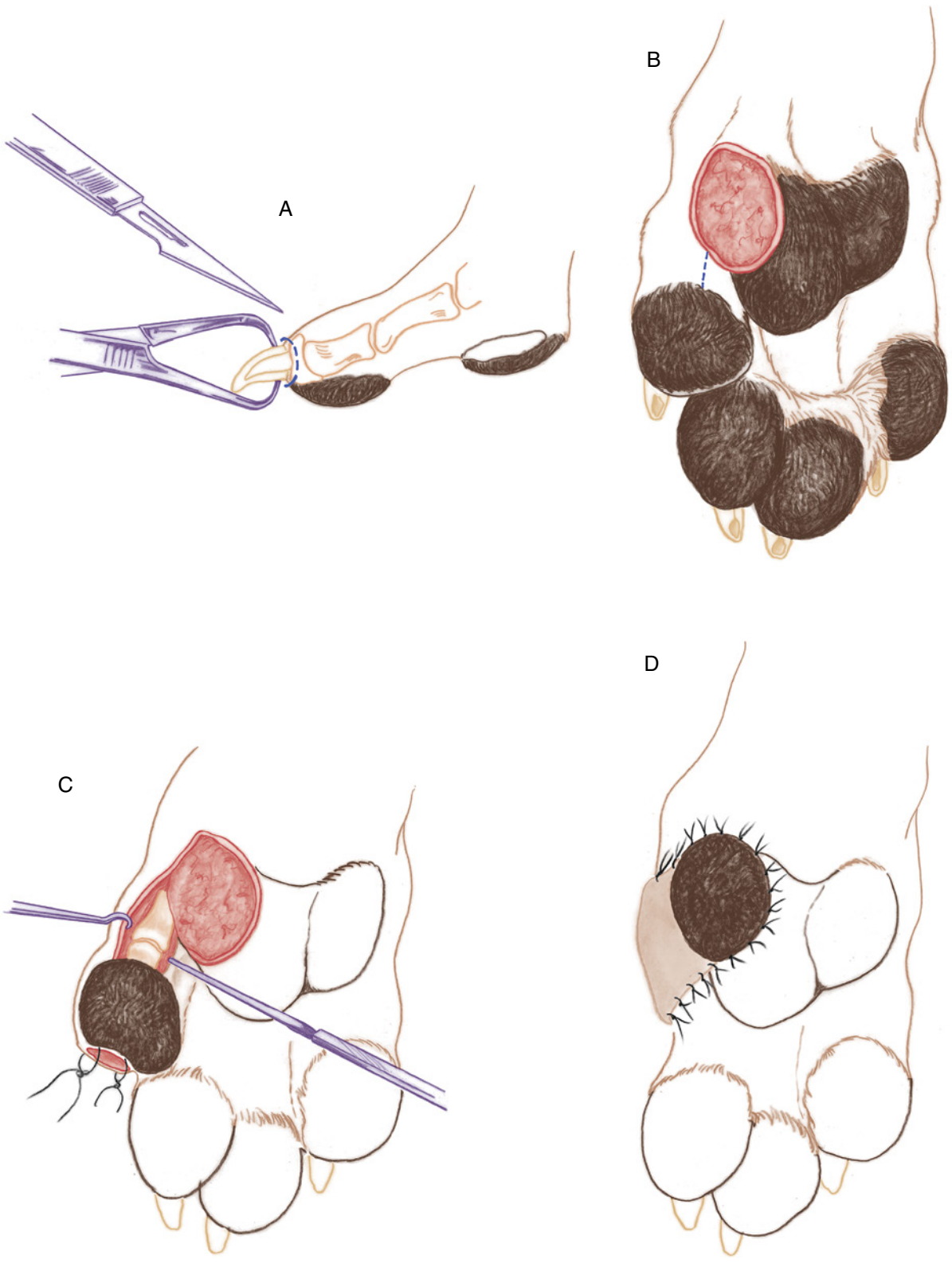
COMMENTS

A ventral incision is preferable to a dorsal incision, thus enabling immediate placement of the flap into its new position. Normally the first phalanx does not require removal. The veterinary surgeon will find that pad healing is slower than with other skin closures. Partial dehiscence may be noted, but the sutures can easily be replaced. A heavily padded bandage with external support is required to promote healing in this weight-bearing area.

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Plate 137



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Plate 138 Metatarsal/Metacarpal Pad Transfer

DESCRIPTION

Loss of the digital pads as a result of trauma or disease may require repositioning of the metacarpal or metatarsal pad to provide for an appropriate surface for weight bearing (see Figs 18-12 and 18-13).

SURGICAL TECHNIQUE

(A) Severely damaged or necrotic digits (A_1) are resected, as shown in (A_2). The wound is managed in preparation for eventual pad transfer.

(B) Metacarpal or metatarsal bones are partially resected to permit the proximal advancement of the respective metacarpal or metatarsal pad (arrows).

(C) The metatarsal or metacarpal pad is sutured into position with 2-0 monofilament, nonabsorbable sutures. A reinforced bandage, with possible supplementation with a fiberglass splint, is applied to protect the surgical site for up to 3 weeks after surgery.

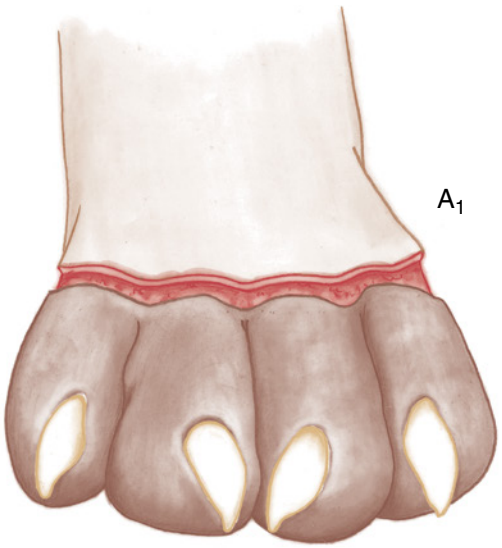
COMMENTS

Removal of the ends of the metatarsal or metacarpal bones facilitates repositioning of their respective pads. Reduction in bone length also helps to prevent "bottoming out," in which bone deeply penetrates the cushion of the transplanted pad, increasing the likelihood of ulceration and discomfort.

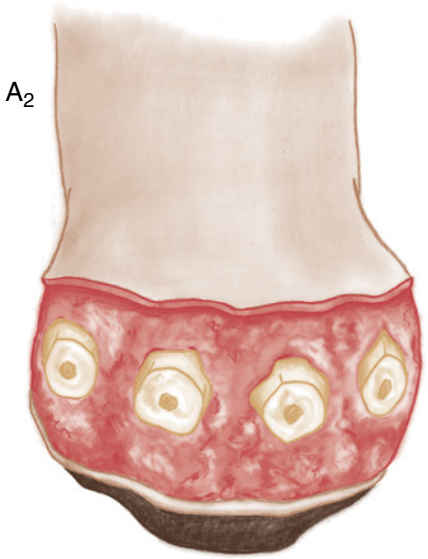
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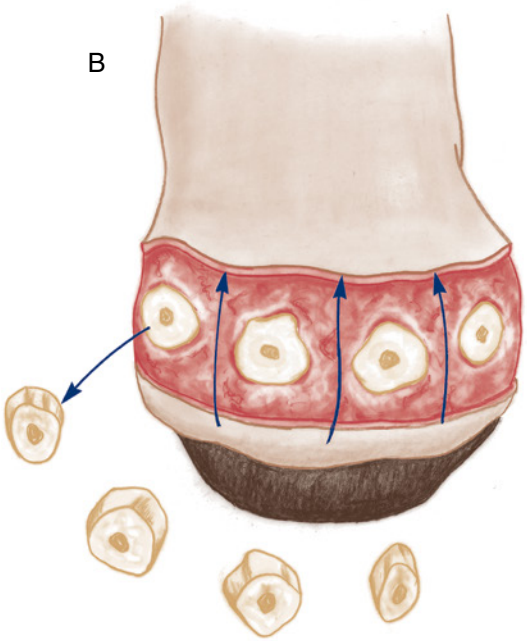
Plate 138



A_1



A_2



B



C

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Plate 139 Pad Grafting

DESCRIPTION

Complete traumatic loss of the pads of a foot presents a significant problem to the dog: amputation may be necessary. However, several digital and metacarpal/metatarsal pads have the potential to be grafted onto the limb. This plate is a case summary (see Fig. 18-14).

SURGICAL TECHNIQUE

(A) Individual foot pads in this case are separated (dotted lines; A_1). The pad cushion is excised down to the dermal layer of the avulsed or harvested digital pad or metatarsal/metacarpal pad (A_2). The pads are incised to permit their placement flatly onto the proposed bed (A_3, A_4). Each pad is sutured onto the cutaneous trunci muscle after surgical removal of the overlying skin.

(B) The temporary recipient bed for the graft is determined by placement of the injured foot up to the side of the patient (direct flap technique). A tie-over dressing is used to secure the graft for 7 days.

(C) In 7 days, a bipedicle flap incorporating the graft is elevated (see Plate 41). The injured foot is positioned beneath the flap and sutured to its edges. In 14 days, one-half of each pedicle is divided (every 2 days), beginning with the ventral pedicle. Divided segments are sutured to wound borders.

(D) Several days after application, the horny pad layer will separate from the underlying germinal epithelium. These opaque epithelial islands will coalesce. The foot is supported in a heavily padded reinforced bandage, with possible supplementation with a fiberglass splint, until a thick stratum corneum forms. In time, a protective hunting boot may be employed for protection. Redundant tissue may be excised to reposition the reimplanted pad for proper weight bearing.

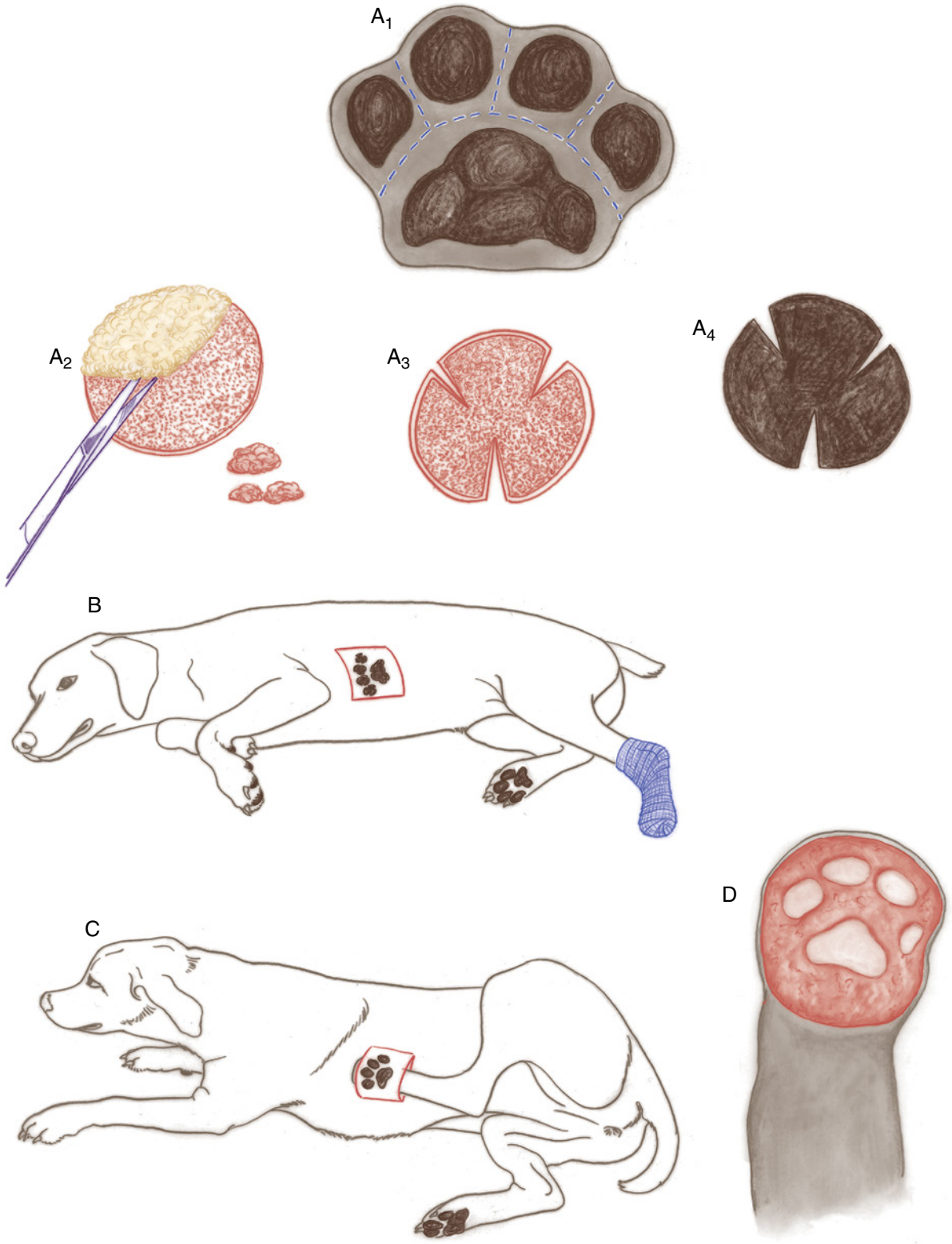
COMMENTS

This two-stage procedure is technically demanding. The pad is preserved on a temporary vascular recipient site while the wound is being prepared for flap transfer. This technique has the main advantage of providing a thick subcutaneous layer that replaces the pad cushion, which cannot be achieved by direct pad application to the granulation bed. The feasibility of pad grafting was demonstrated by this technique. Other options for foot salvage include (1) the microvascular transplantation of a digital pad from another foot and (2) the graft of a digital pad from another foot, in those cases in which the technique demonstrated is not feasible.

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Plate 139



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Plate 140 Segmental Pad Grafting Technique

DESCRIPTION

Small, rectangular segments of digital pad epithelium can be harvested as free grafts to reepithelialize large defects of the metacarpal or metatarsal pads. Development and successful use of this technique were reported by Bradley et al. (1994).

SURGICAL TECHNIQUE

(A) The digital pads of uninvolved feet can be used to harvest small pad grafts.

(B) Segmental pad grafts are harvested as small, 10–15 mm long, 5–10 mm wide grafts, depending on the size of the dog and the size of the defect to be covered. A scalpel blade (no. 11 or 15) is used to incise and elevate the grafts. Sutures can be used to approximate the donor defects.

(C) Each graft is inspected to ensure that no pad cushion is covering the overlying dermal surface of each graft. A suture is placed in each graft prior to application.

(D) Example of a hindlimb injury, with loss of digits and loss of the outer portion of the metatarsal pad. Surviving remnants of the cushion layer of the metatarsal pad are covered by granulation tissue.

(E) Segmental pad grafts are sutured to the prepared granulation bed. A nonadherent dressing with ointment is secured to the graft area with skin staples or sutures, followed by application of a firm, reinforced, protective bandage.

(F) Approximately 3 weeks after graft application, epithelialization can be noted extending from the graft margins. The outer, horny layer of the graft will begin to soften and separate from the underlying, regenerative epithelium.

COMMENTS

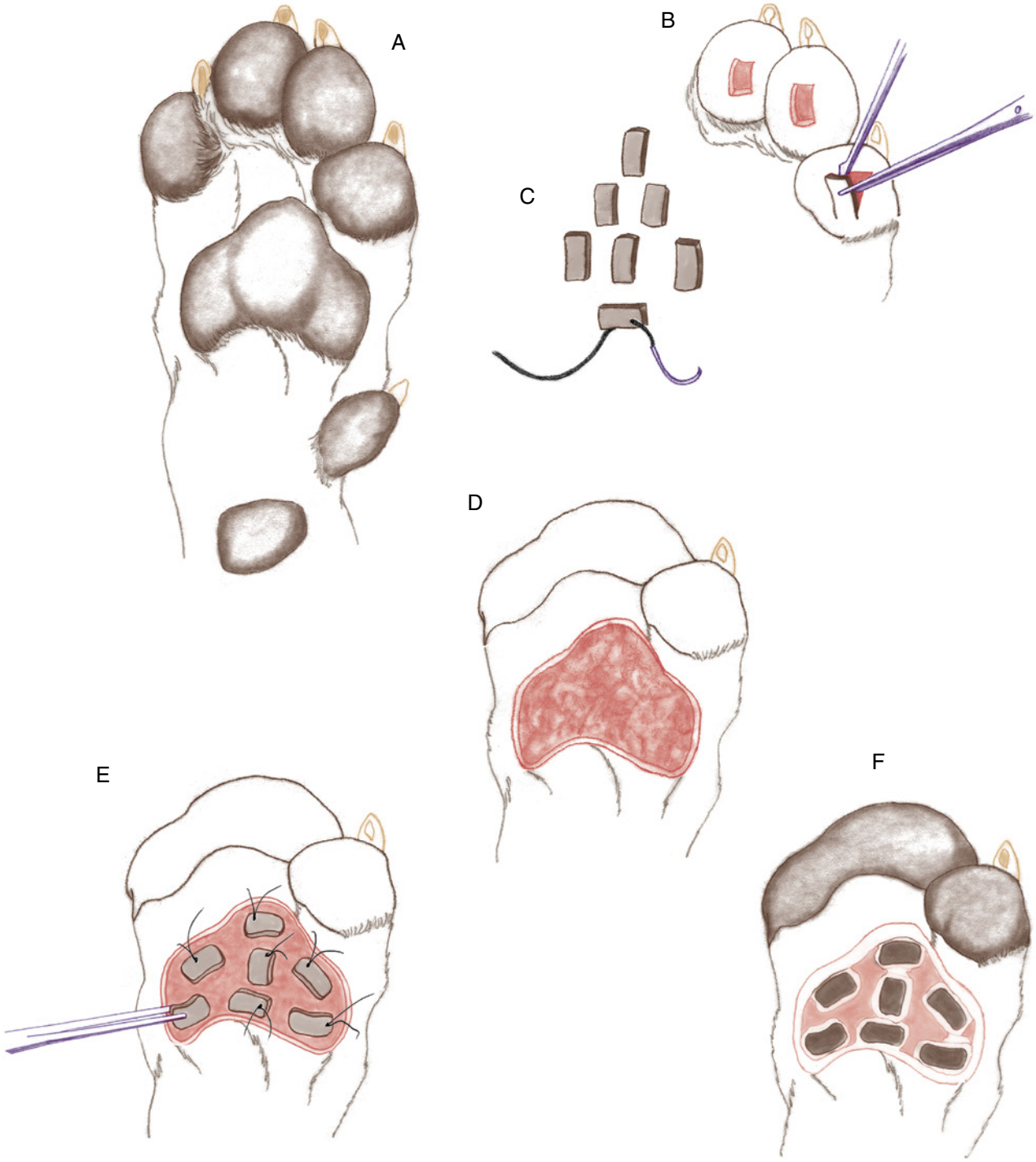
Pad grafting for reconstruction of the metacarpal/metatarsal is best considered when all the digits have been lost. Small segmental grafts from viable digits do permit coverage of large defects of the important metatarsal/metacarpal pads, without the need to sacrifice an entire digit. However, multiple small wounds are created in several digits with this technique. The larger segmental grafts aligned along the perimeter of the defect can help ensure that pad epithelium has a greater likelihood of covering the open (metatarsal/metacarpal) pad wound, rather than wound contraction and epithelialization from the wound margins. (Contact inhibition of epithelial cells from the pad grafts preclude the advancement of the cutaneous epithelium.) As noted, it is preferable to apply the grafts over the vascularized remnant of the pad cushion, which has the resilience to absorb the forces a foot is subjected to during normal activity. It can take several weeks before these epithelial islands coalesce and, in turn, reform the thick durable pad surface. During this time, the area necessarily must be protected with padded bandages and splints.

An alternative to this technique would be to sacrifice a single digit and graft the pad surface onto the recipient area. The accessory carpal pad is a potential donor area, although its size and pliability as a pad graft vary with individual dogs. If one or more intact digits are present, the phalanges of one or two toes can be resected and the resultant digital flap(s) substituted for the missing metatarsal/metacarpal pad (Plate 137); this is a preferable alternative to pad grafting.

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Plate 140



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Plate 141

Fusion Podoplasty

DESCRIPTION

Fusion podoplasty, first reported by Swaim et al. (1991), is reserved for those dogs with advanced (end-stage) interdigital pyoderma (intertrigo) that has failed to respond to medical therapy. All four paws may be involved: for these patients, the forepaws may be operated on first, followed by the hindpaws 1 month later.

SURGICAL TECHNIQUE

(A_1, A_2) After surgical preparation of the paws, a surgical marking pen is used to outline the areas that require resection. On the palmar/plantar surface of the paw, the anterior border of the metacarpal or metatarsal pad is excised along with the interpad skin fold. Skin (2–4 mm) is preserved along the lateral and medial margins of each nail bed. Skin excisions are adjusted so that opposing interdigital skin margins align between each toe to facilitate suture alignment. Note that the skin excision terminates at the midpoint of each digital pad.

(B) After excision of the diseased interdigital and palmar/plantar interpad folds is performed, opposing pad margins are carefully trimmed with a scalpel blade to assure accurate edge-to-edge suture alignment.

(C, D) The dorsal surface of the paw is usually sutured first, followed by closure of the palmar/plantar surfaces: skin to skin, lateral to medial digital pad borders, caudal digital pad borders to the anterior border of the metacarpal/metatarsal pad.

The end of each digit is not sutured in order to provide drainage. A strip of Penrose drain is placed in the interpad defect prior to closure of the palmar/plantar surface, with the ends of the drain segment exiting through a small stab incision in the skin, lateral and medial to the anterior border of the metacarpal/metatarsal pad. On each side 2 cm of the drain are exposed and secured with two sutures. Bandaging and splinting of the paws are performed prior to anesthetic recovery of the patient.

COMMENTS

Although this procedure is infrequently used, it is invaluable for those patients with end-stage intertrigo of the paws. Partial fusion podoplasty is used when only selective areas of the paw are involved (Fig 18-19). Electrocautery is required to help control hemorrhage when resecting skin with chronic pyoderma and fibrosis. Partial dehiscence is common and these areas usually heal by contraction and epithelialization. Bandage care is critical to a successful surgical outcome. A thick protective bandage supplemented with a fiberglass cast is placed on the patient following surgery.

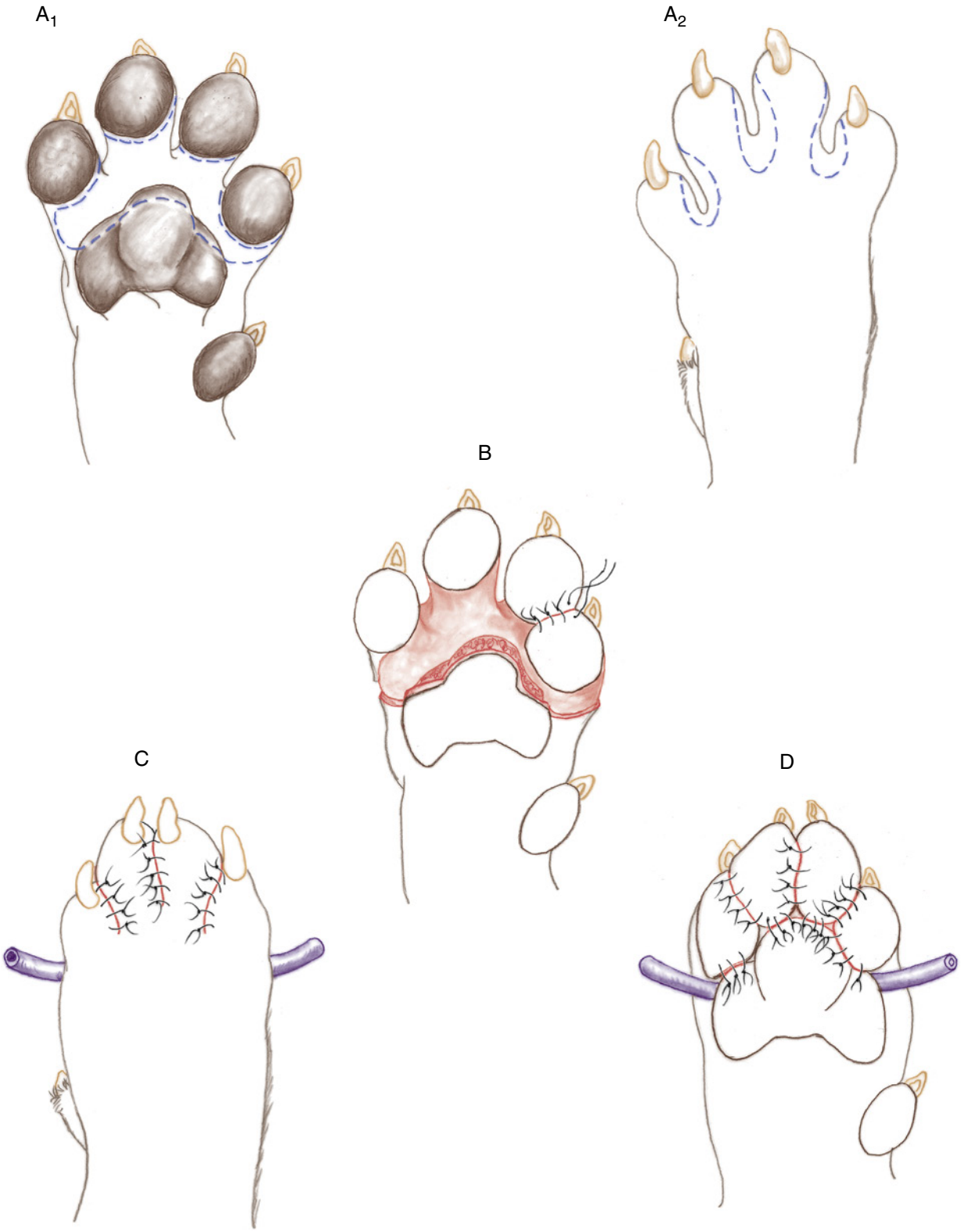
During the first week, excessive drainage may warrant daily bandage changes; absorbent pads or polyurethane foam (see Chapter 5) may be used to help retain tissue discharge between bandage changes. Broad-spectrum systemic antibiotics are advisable. Topical gentamycin ointment or silver sulfadiazine ointment may be used if a *Pseudomonas* infection is noted postoperatively. Chlorhexidine swabs may be used to clean the surgical area prior to bandage reapplication. During the second and third weeks of bandaging/splinting, changes usually can be decreased to every second or third day. The drain is removed in 7–10 days; bandaging is discontinued when healing is complete (approximately 3 weeks). A support bandage or protective boot is applied to protect each paw for a few additional weeks.

Fusion podoplasty is expensive and time consuming to perform, especially if more than one paw is involved. As noted, many patients presenting with multiple interdigital granulomas or diseased skin segments can be managed with partial podoplasty, rather than committing to the more demanding complete podoplasty (see Fig. 18-19).

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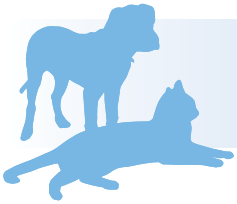
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Plate 141



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19

Major Eyelid Reconstruction

Introduction *764*

The Eyelids *764*

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Plate 143: Lip-to-Lid Procedure *772*

Plate 144: Oral Mucosal Graft onto Skin Flap *776*

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Plate 146: Hubner Technique Using a Free Tarsomarginal Graft for Eyelid Reconstruction *780*

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INTRODUCTION

There are numerous surgical procedures employed to remove damaged and diseased segments of the upper and lower eyelids. A number of articles and ophthalmology textbooks discuss these procedures. The techniques available for extensive loss of this structure are more limited. With defects limited to the external cutaneous surface of the eyelids, reconstruction can be performed with the adjacent skin by simple undermining and advancement, transposition flaps, or single-pedicle advancement flaps (Fig. 19-1). One study (Jack et al. 2018) demonstrated that healing by second intention resulted in satisfactory outcomes in three dogs after major loss of the lower eyelid margin. It is important to note the potential impact that a major loss of skin adjacent to the eyelids can have on their normal function. Subsequent skin closure under tension can deviate the position of the eyelids and their ability to close. In particular, local transposition flaps can prevent this complication by recruiting skin adjacent to the defect (Figs 19-2–19-5). Plate 142 demonstrates simple skin flap options for eyelid defects.

This chapter covers four specialized reconstructive surgical techniques that can be useful for major eyelid reconstruction, including the mucocutaneous subdermal plexus flap (lip-to-lid procedure), a combined mucosal graft/transposition skin flap technique, eyelid tarrsomarginal graft replacement of major upper eyelid defects (Hubner technique), and a third eyelid–skin flap technique (see Plates 143–146).

THE EYELIDS

Lesions involving the eyelids may be excised and closed directly when less than one-third of the eyelid margin is involved. The lateral canthal ligament can be divided to relieve eyelid tension during direct closure, if necessary.



FIG. 19-1 (A) Mast cell tumor, right upper-eyelid area of a domestic long-hair cat (arrow). (B) Arrow denotes outline of a transposition flap. (C) Elevation and rotation of the flap. (D) Reconstruction of the right upper eyelid, cutaneous surface. The arrow denotes the location of the flap drawn onto the donor site. Slight elevation of the right upper eyelid margin relaxed a few weeks later.

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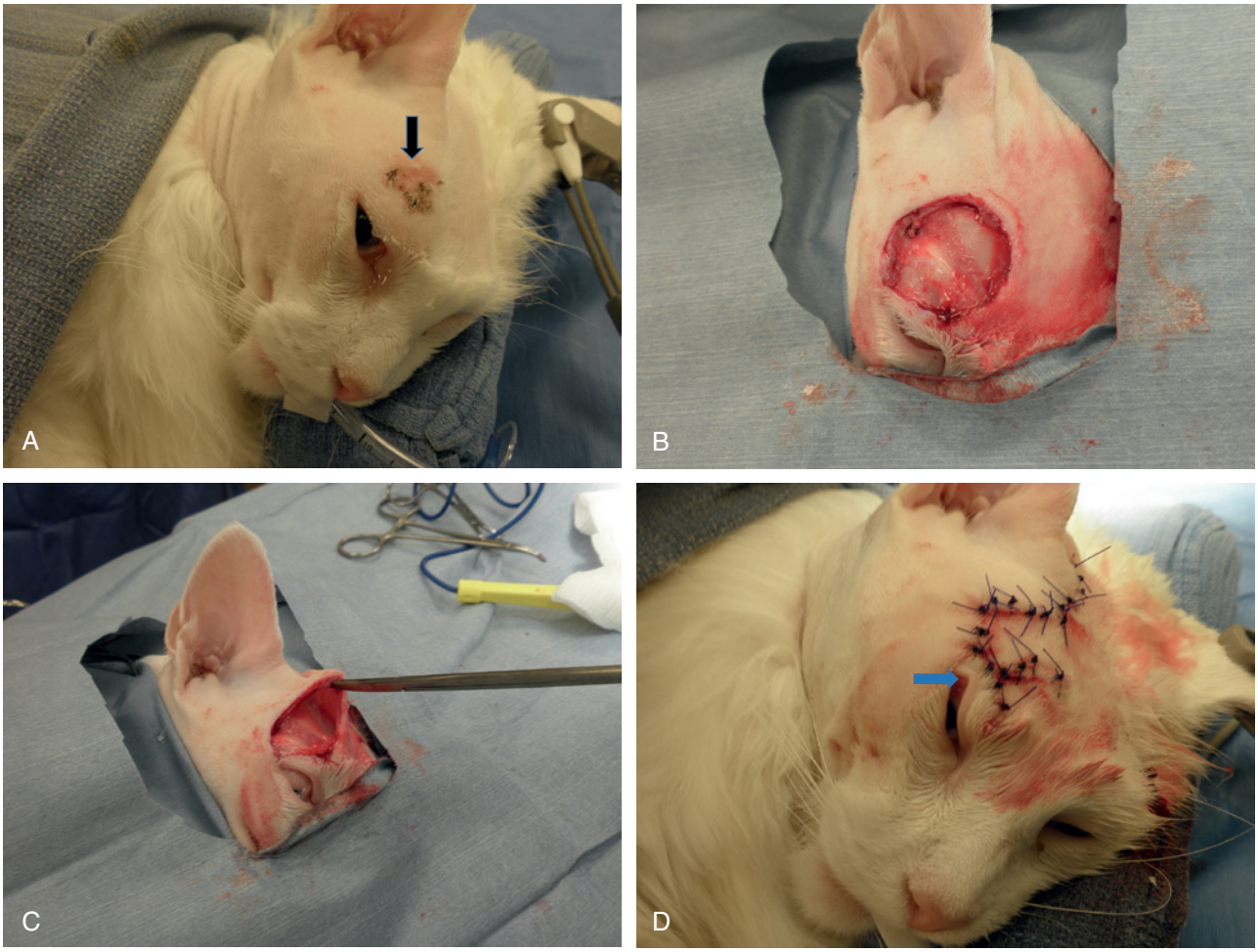


FIG. 19-2 (A) Cutaneous carcinoma dorsal to the right upper eyelid (arrow). (B) Resection of the tumor. (C) Elevation of the dorsal skin in preparation for elevation of a transposition skin flap. (D) Closure with a transposition skin flap. Note the slight dorsal deviation of the upper eyelid margin (arrow). This small deviation subsequently resolved within two weeks following surgery.

Cryosurgery and thermal destruction of eyelid tumors have been used with variable success in place of surgical excision.

As noted, extensive wounds involving the cutaneous surface of the eyelid can be successfully closed with local pedicle grafts. Skin flaps alone, however, are inadequate for reconstruction of eyelid losses that include the palpebral conjunctiva, unless the remaining conjunctiva can be mobilized to line the flap's dermal surface on transfer. This can be accomplished by simple undermining and advancement of the adjacent conjunctival margins or by using conjunctival flaps from the opposing eyelid. A variation of the latter technique is the full-thickness cross-lid flap. The lower eyelid is considered a suitable donor site for large upper-eyelid defects. However, the use of the upper eyelid for lower-lid reconstruction is less desirable because of potential compromise to the vital function the upper eyelid normally provides for corneal protection.

Free oral mucosa and nasal mucosal grafts, including a thin layer of nasal septal cartilage, have been successfully used as a conjunctival substitute to reconstruct eyelids. The mucosal grafts are generally transplanted onto a local pedicle graft, and the resulting composite flap is transferred to the recipient site after the mucosal graft "takes" (Plate 144). Conjunctival grafting from the lower eyelid (Hubner technique) has been used for upper-eyelid reconstruction (Plate 146). The third eyelid has been used as a conjunctival substitute for loss of the lower eyelid, with a skin flap used to restore its cutaneous surface (Plate 145).

To bypass the serious drawbacks involved with major eyelid reconstructive surgery, the author also has developed the lip-to-lid procedure whereby a portion of the upper lip is used to replace full-thickness lower eyelid defects (Figs 19-6 and 19-7). This same technique also can be used to reconstruct the entire upper eyelid. See Plate 143.

See Chapter 25 for additional clinical flap examples.

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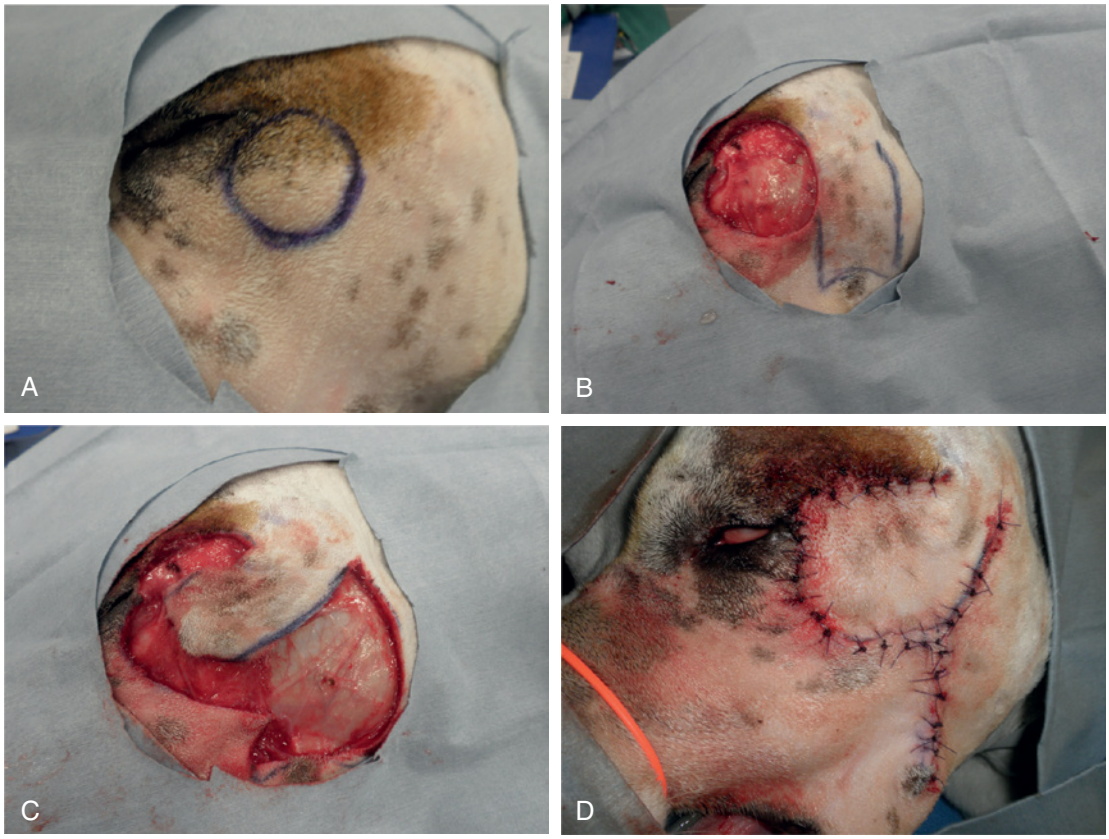


FIG. 19-3 (A) Surgical outline of mast cell tumor for resection caudal to left lateral canthus. (B) Wide tumor resection. The outline of the transposition flap for closure. (C) Elevation and rotation of the local transposition flap. (D) Completion of the closure. The lateral canthus was unaffected and normal eyelid function was retained.



FIG. 19-4 (A) Ulcerated adenoma, left forehead in a geriatric terrier. Outline of the area of resection. (B) Resection of the growth followed by elevation of a transposition skin flap. (C) Rotation of the flap followed by closure of the donor and recipient sites.

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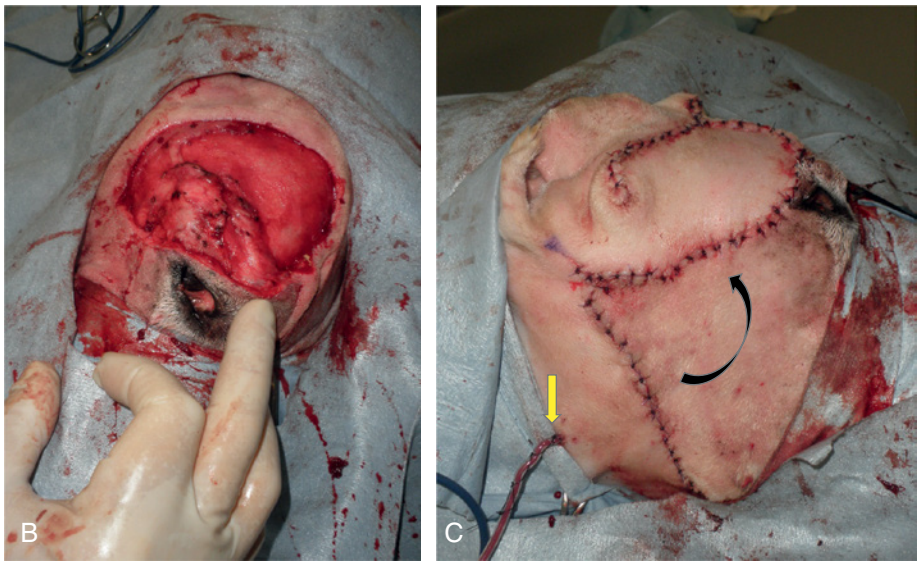


FIG. 19-5 (A) Soft tissue sarcoma caudal to right upper eyelid. (B) Wide surgical resection. (C) Closure with a transposition skin flap rotated from the right lateral facial area (curved arrow). The yellow arrow denotes placement of a Jackson-Pratt drain system.

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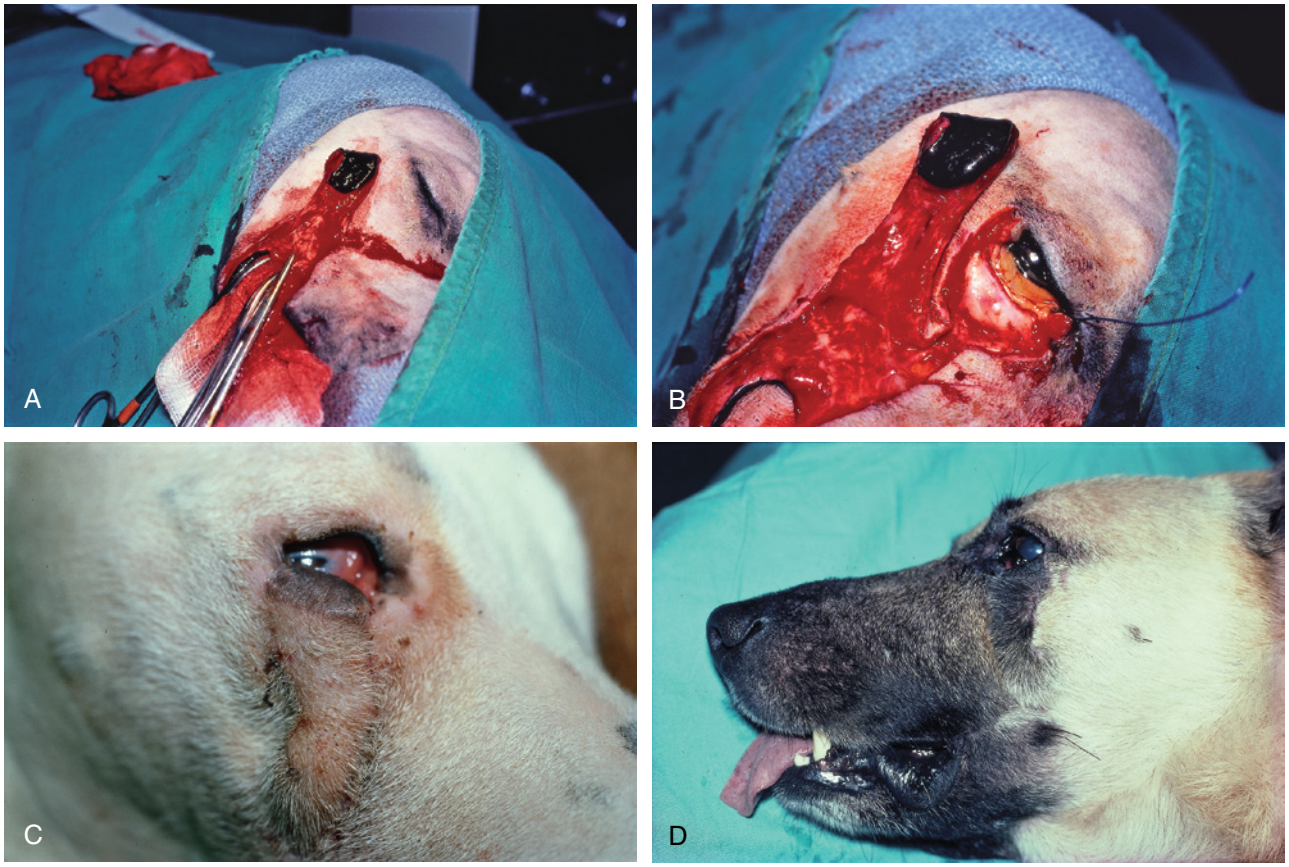


FIG. 19-6 (A) Lip replacement of the right lower eyelid. Elevation of the labial flap. (B) Resection of the lower eyelid and creation of a bridge incision for placement of the composite labial flap. (C) View of the flap, 2 weeks postoperatively. Note the prominent pigmentation of the labial margin in this white dog. (D) Note the misdirected hair growth and darker fur highlighting the flap skin.



FIG. 19-7 Close-up view of lip-to-lid transplant. (Source: Pavletic MM, Nafe LA, Confer AW. 1982. Mucocutaneous subdermal plexus flap from the lip for lower eyelid restoration in the dog. *J Am Vet Med Assoc* 180:921–926. Reproduced with permission of the American Veterinary Medical Association.)

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Plate 142 Skin Flap Options for Cutaneous Defects of the Eyelid Regions

DESCRIPTION

Local skin flaps can be employed to reconstruct the cutaneous surfaces of the upper or lower eyelids. A transposition flap is one of the ideal pedicle grafts to consider and can be used for defects involving the upper and lower eyelids as well as the lateral and medial canthal areas. With extensive loss of the conjunctiva, full-thickness reconstruction of the eyelid would be required. See Plates 143–145 for major eyelid restoration.

SURGICAL TECHNIQUE

(A) Example of various cutaneous lesions involving the eyelid area.
(B) Surgical excision of the cutaneous growths, and examples of transposition and advancement flap options.
(C) Transfer and suture closure of the respective skin flaps. Inset: A buried intradermal suture, applied to the underlying muscle fascia as a point of fixation, is being used to offset elastic retraction forces on advancement flaps.

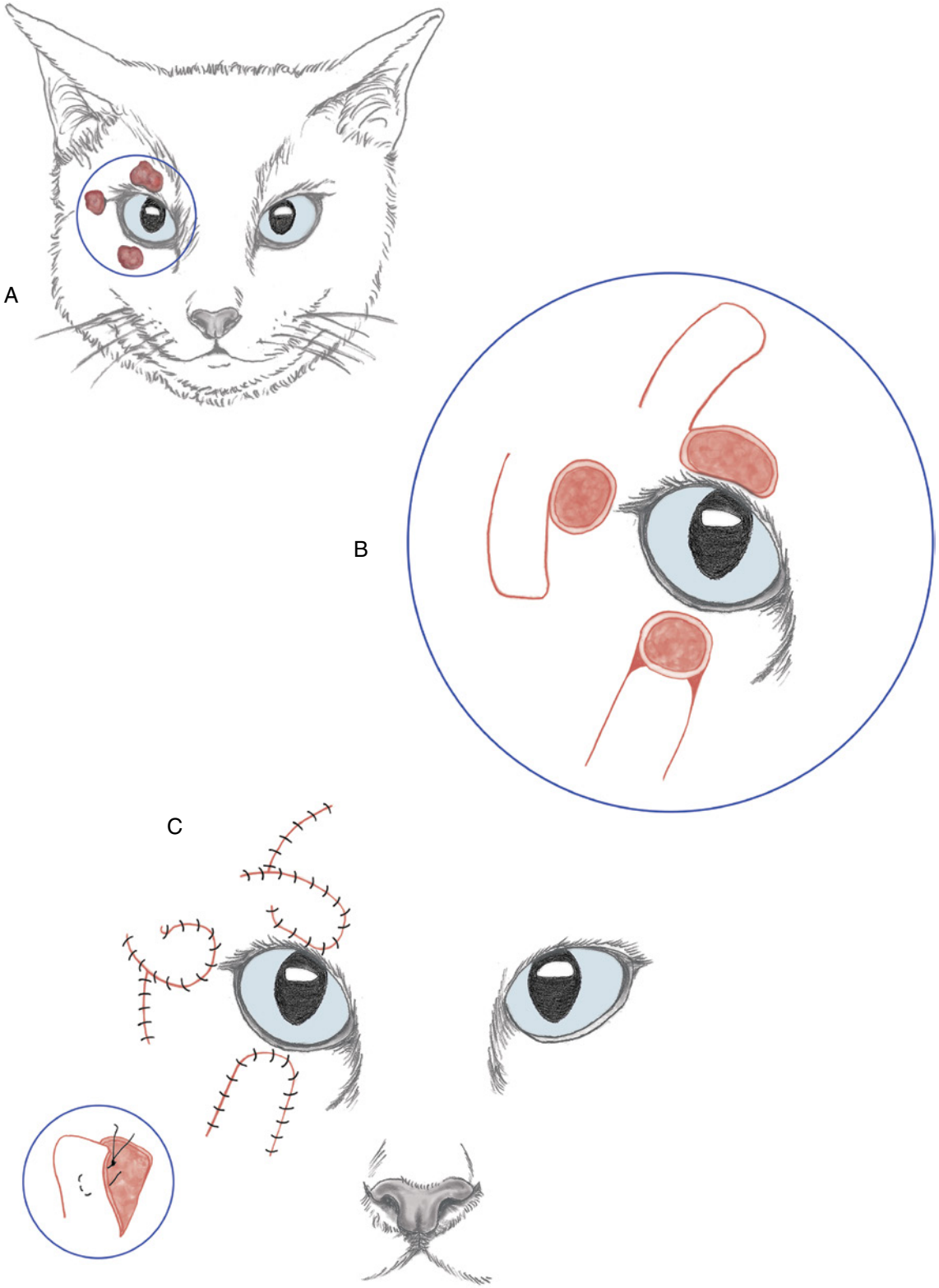
COMMENTS

As discussed in Chapter 9 (Tension-Relieving Techniques) and Chapter 11 (Local Flaps), transposition skin flaps donate skin to close cutaneous defects, whereas advancement flaps close defects primarily by their elastic stretch or advancement. There is a tendency for the inherent elasticity of the advanced skin to contract back toward the donor site. For this reason, care must be taken when closing defects around the eyelids by skin advancement techniques without considering options to neutralize this tendency. In many cases the transposition flap is a better option, especially for larger defects involving the territory of the upper and lower eyelids (Figs 19-1–19-5).

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Plate 142



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Plate 143 Lip-to-Lid Procedure

DESCRIPTION

A mucocutaneous subdermal plexus flap from the upper lip can be used to replace the entire lower lid after extensive trauma or tumor excision. It can be modified for upper-eyelid reconstruction.

SURGICAL TECHNIQUE

(A) The proposed full-thickness lip incisions are drawn with a marking pen at a 45–50° angle to a line passing through the medial and lateral canthi.

(B) Elevation of the full-thickness lip flap exposes the mucosal surface. Reference incision lines slightly diverge to avoid accidental narrowing of the cutaneous pedicle. Gauze pads beneath the lip will support it when incising the lip margin.

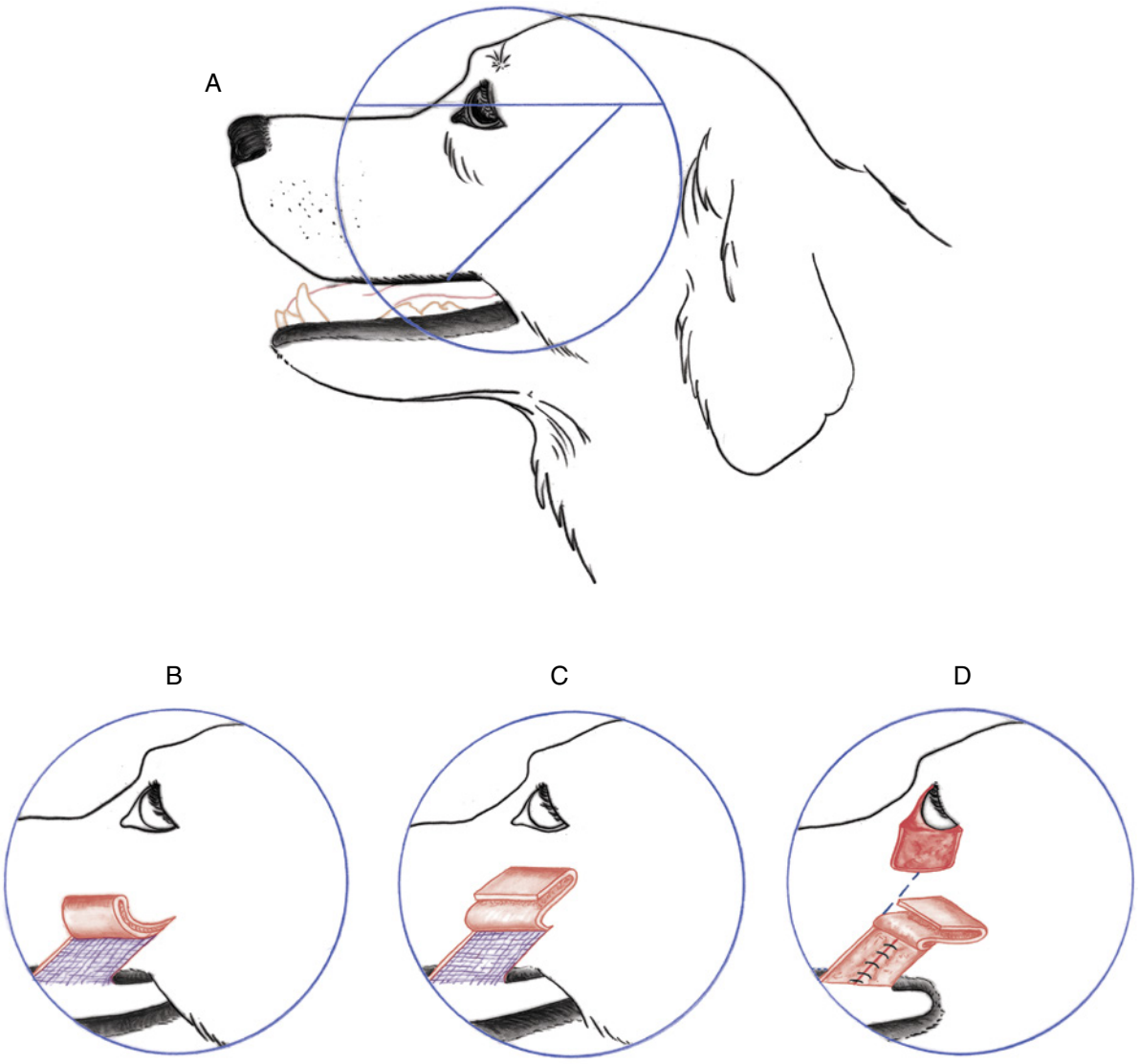
(C) The oral mucosa is carefully split at a level sufficient to replace the missing lower-lid conjunctiva. The cutaneous pedicle is carefully dissected from the oral mucosa and underlying structures, beneath the platysma muscle. Care must be exercised to avoid traumatizing the pedicle's vital subdermal plexus, to avoid severing any underlying facial structures, and to avoid the development of an unnecessarily long cutaneous transfer pedicle.

(D) The oral mucosal defect is apposed with a buried suture pattern using 3-0 absorbable sutures. A bridge incision (dashed line) is used to connect the donor and recipient beds for suture placement of the transfer pedicle. Undermining of the mucosal border of the flap should be avoided to prevent circulatory compromise.

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Plate 143



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Plate 143

(Continued)

(E) The flap is initially sutured into place by apposing the oral mucosa to the remaining conjunctival edges with a buried, interrupted suture pattern using 4-0 absorbable sutures. Lastly, the cutaneous surface is sutured with a simple interrupted pattern. The cutaneous recipient bed is closed to complete the transfer. Folds and skin puckers should be left alone to avoid vascular compromise to the graft in this first stage.

(F) In 4–6 weeks, the surgeon has the option of removing the cutaneous transfer pedicle and closing the defect by simple apposition of skin edges.

(G) An optional second-stage revision procedure will improve cosmetic results. Second-stage revision can be simultaneously used to reestablish a more normal "eyelid" border in the event of partial necrosis or excessive thickness of the outer lip margin.

COMMENTS

This technique can be used to reconstruct the entire upper or lower eyelid. Defects limited to the cutaneous layer of the eyelid are best restored with skin flaps. Eyelid replacement with a labial flap is reserved for wide, full-thickness defects if more conservative options for closure are unsuitable. The lip flap is a composite mucocutaneous subdermal plexus flap. Skin, oral mucosa, and portions of the orbicularis oris and buccinator muscles are used to replace the full-thickness loss of the lower eyelid. Unlike a subdermal plexus flap lined with conjunctiva or a free mucosal graft, the lip graft has a central muscular layer, thus giving more normal thickness and natural rigidity as an eyelid substitute. In addition, the wide mucocutaneous junction and hairless lip margin serve as a natural buffer zone between the cornea and the hairy skin.

The blood supply to the oral mucosa is from numerous arterial and venous anastomoses between the cutaneous subdermal plexus and the submucosal capillary network. Care must be taken to ensure maintenance of adequate perfusion pressure to the terminal portion of the flap by using meticulous, atraumatic surgical technique; avoiding unnecessarily long grafts (cutaneous transfer pedicles); avoiding undermining between the graft's oral mucosal and cutaneous layers; avoiding direct placement of tissue forceps to the outer mucocutaneous border; and creating lip flaps with slightly diverging incisions to avoid accidental pedicle narrowing. No effort should be made to remove "dog-ears" or tissue folds during graft transfer because that could inadvertently compromise the blood supply. As indicated, an optional revision procedure can be used in 4–6 weeks to improve the cosmetic results.

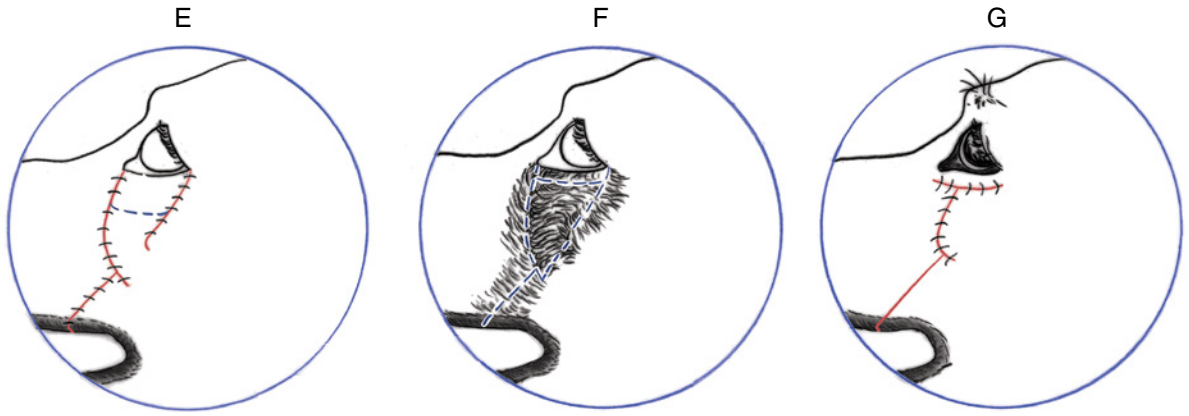
During elevation of the flap, care must be taken to avoid accidental injury to underlying structures, including the facial vein, parotid duct, and buccal nerve.

A right angle or T extension of labial mucosa can be included with the labial flap for simultaneous restoration of portions of the upper eyelid. A second surgical procedure may later be required to form or mold this larger graft for optimal cosmetic and functional results.

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Plate 143



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Plate 144 Oral Mucosal Graft onto Skin Flap

DESCRIPTION

The upper lip and cheek are excellent sources of mucosa for reconstructive surgical techniques requiring this unique epithelial surface. Mucosa can be grafted onto a local transposition flap that can be rotated to the eye defect 1 week after surgical graft application.

SURGICAL TECHNIQUE

(A) Example of a lower-eyelid neoplasm. The solid line is the proposed outline of a transposition flap in preparation for a mucosal graft. The dashed line shows an alternate position for upper-eyelid reconstruction.

(B) The upper lip is retracted to expose its mucosal surface. Stay sutures can be used to hold the lip in an elevated position; skin hooks or towel clamps also may be used. A mucosal graft is elevated from the upper lip in this example. The graft is prepared in a fashion described for full-thickness skin grafts (Plate 80). A no. 15 scalpel blade is used to elevate a premeasured segment of mucosa. It is advisable to harvest slightly larger grafts than what is measured: mucosal grafts can contract (shrink) considerably on elevation. Minimize the amount of underlying tissue by keeping the scalpel blade close to the submucosal surface during graft elevation. Metzenbaum scissors can be used to trim any tissue adhered to the submucosal surface of the graft, as discussed in the section on skin grafting (Plate 80).

(C) The thin, prepared mucosal graft is meshed prior to application to the flap's dermal surface with fine (4-0 or 5-0) absorbable sutures.

(D) The flap is replaced in its donor bed for 4–7 days.

(E) The flap is reelevated and placed in the donor defect after tumor removal. Borders of the mucosal graft are sutured to the borders of the remaining conjunctiva with 4-0 absorbable sutures. Completion of the closure, using 3-0 to 4-0 nonabsorbable skin sutures.

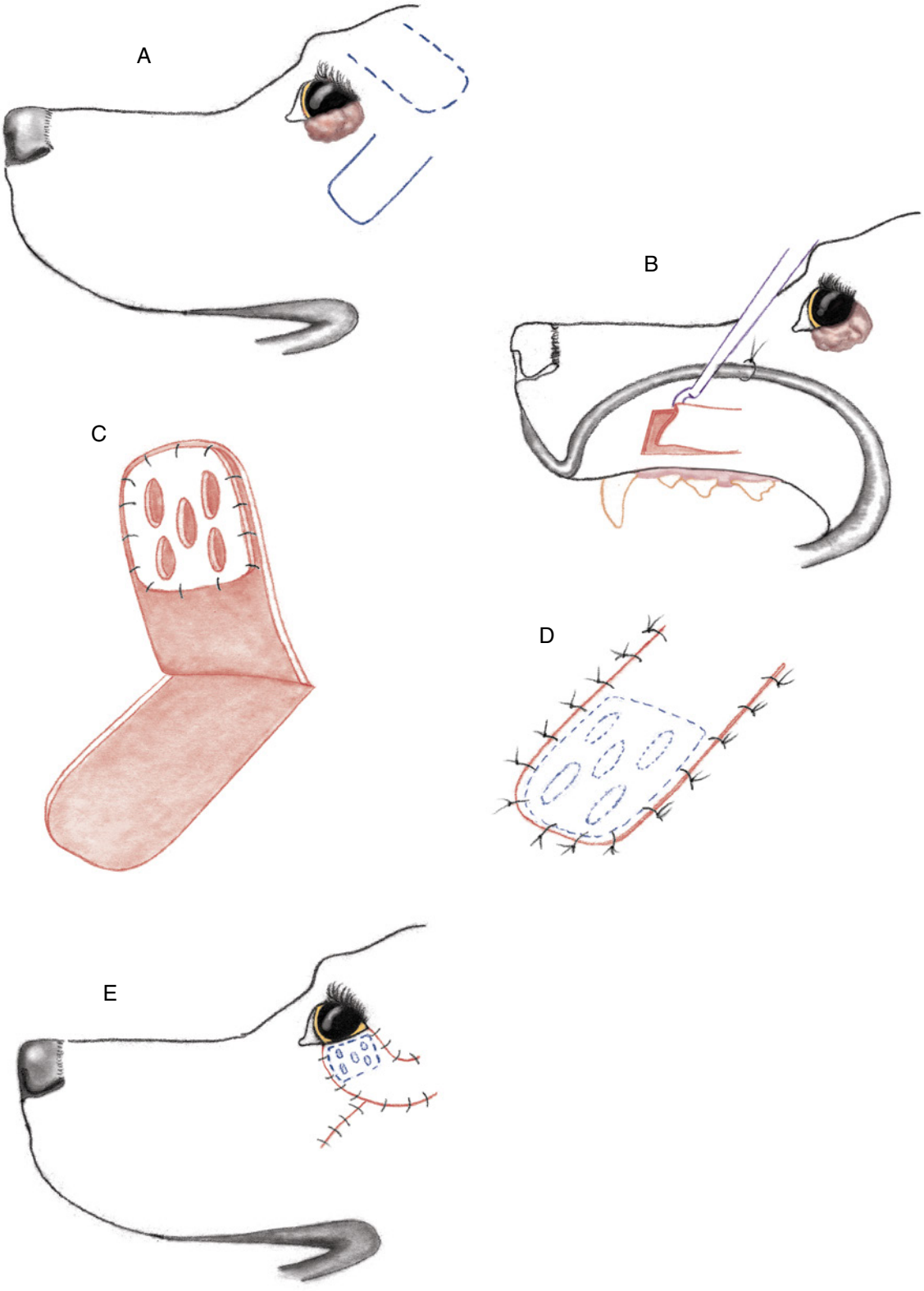
COMMENTS

For complete eyelid reconstruction, this technique or the lip-to-lid procedure (Plate 143) can be employed. The lip-to-lid procedure has some tactical advantages over mucosal onlay grafts of the transposition flap, with additional tissue bulk provided by the orbicularis oris and buccinator muscles. Moreover, the mucosal border of the lip-to-lid transfer is more mobile than the adherent mucosal graft transfer discussed in this plate. This technique can be used for mucosal graft transfer to other significant mucosal defects (e.g., prepuce, nasal cavity). Mucosal grafts can be employed for preputial reconstruction when simpler penile coverage techniques have failed.

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Plate 144



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Plate 145 Third Eyelid–Skin Flap Reconstruction of the Lower Eyelid

DESCRIPTION

This is an alternative technique for lower-eyelid reconstruction, using a portion of the third eyelid as a conjunctival replacement, in combination with a local transposition skin flap, reported by Schmidt et al. (2005).

SURGICAL TECHNIQUE

(A) Example of a malignant neoplasm involving the lower eyelid.
(B) Full-thickness excision of the entire medial half of the lower eyelid.
(C) A no. 15 scalpel blade can be used to facilitate resection of the outer conjunctival surface of the third eyelid. Elevation of a 90° transposition flap.
(D) The flap is sutured to the dorsal margin of the third eyelid and adjacent cutaneous margins. The donor area is sutured in routine fashion.
(E) Example of the same technique used for restoration of the lateral half of the lower eyelid. This requires mobilizing and advancing the third eyelid laterally.

COMMENTS

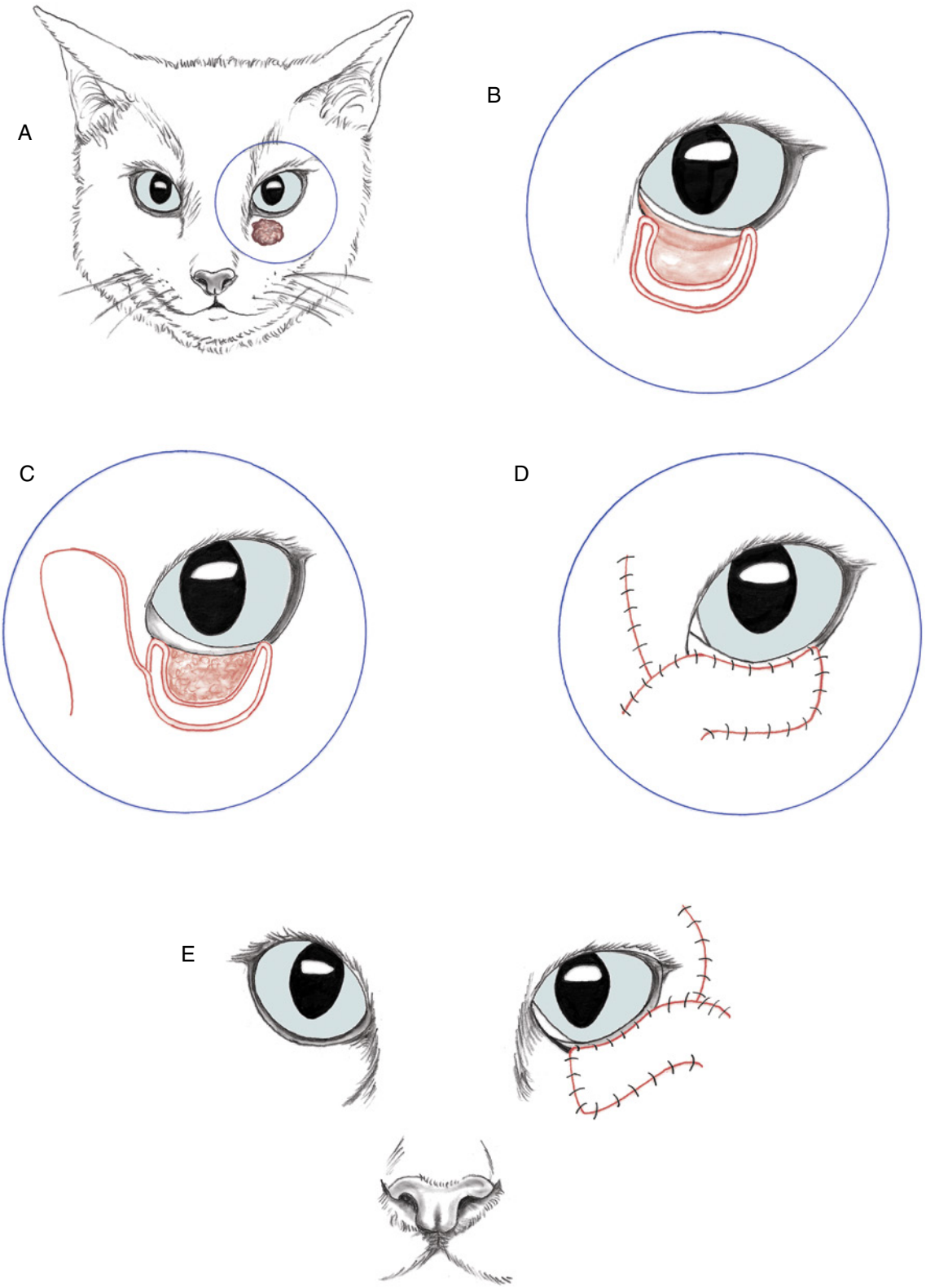
The third eyelid flap can be used to replace the medial or lateral half of the lower eyelid. No adverse effects were reported with this technique. If necessary, a canthotomy can be performed to help restore the palpebral fissure to its normal size.

Hair should be periodically trimmed near the dorsal flap margin to prevent irritation to the cornea.

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Plate 145



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Plate 146 Hubner Technique Using a Free Tarsomarginal Graft for Eyelid Reconstruction

DESCRIPTION

The Hubner technique requires the harvesting of a tarsomarginal conjunctival graft that includes the eyelid margin. In this example, the prepared free graft is used to replace a major upper-eyelid defect. The conjunctival graft is finally covered by an advancement skin flap.

SURGICAL TECHNIQUE

(A) Upper-eyelid neoplasm. The dashed line represents margins for resection. The dashed line of the lower eyelid represents the outline for harvesting the conjunctival graft.

(B) Full-thickness resection of the upper-eyelid neoplasm. Separate instruments are used to harvest the lower-eyelid graft. The graft length area was half the width of the tumor and the margin resected.

(C) Inset: The skin and subcutaneous tissues are resected down to the underlying subconjunctival surface. The 3 mm strip of the eyelid margin is preserved with this mucosal graft. The delicate harvested graft is kept moist with sterile saline throughout the surgery. The mucosal graft is secured to the conjunctival margins of the upper-eyelid defect with 5-0 absorbable sutures. (The conjunctival mucosa is in direct contact with the ocular surface.) The lower-eyelid donor defect is closed by apposing the mucosal margins followed by the skin margins.

(D) The exposed submucosal surface is covered with a single-pedicle advancement skin flap. The flap margins are sutured to the cutaneous margins of the surgical defect. Absorbable sutures are (4-0 or 5-0) used.

COMMENTS

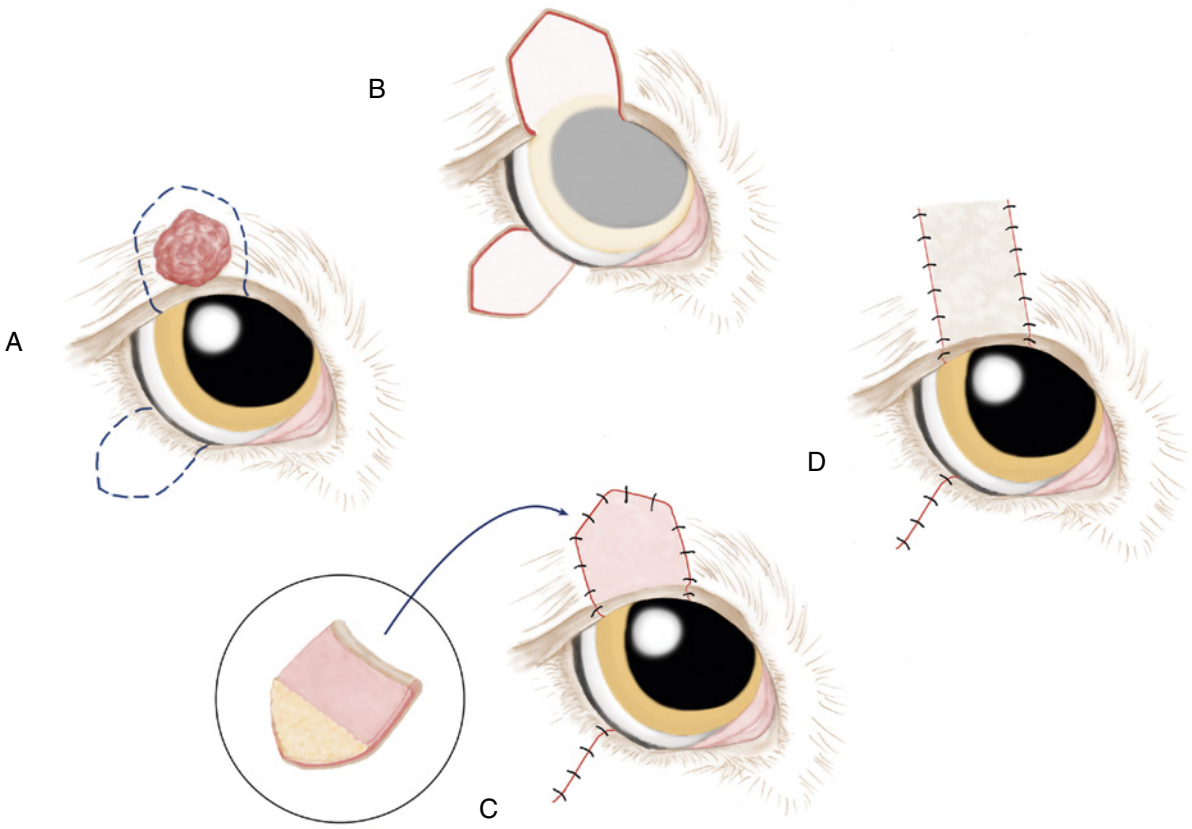
This technique is yet another option to consider for eyelid reconstruction. Because the upper eyelid plays a dominant role in protecting the eye, the Hubner technique prioritizes its reconstruction in this plate, using the lower eyelid as the donor site for harvesting the conjunctiva. In Vimont et al. (2018), the Hubner technique was used to reconstruct up to three-quarters of the upper- or lower-eyelid length. One-quarter to one-third of the eyelid can be used for graft harvesting in humans, depending on the laxity of the eyelid margin. (In Poinsard et al. 2018, the technique was employed to reconstruct one-quarter to two-thirds of the length of the upper or lower eyelid.)

Based on the research using the "lip-to-lid" procedure, a mucosal graft harvested from the upper lip may be a reasonable alternative to using the opposing eyelid as a donor site.

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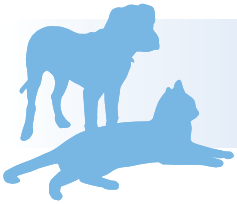
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Plate 146



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20

Nasal Reconstruction

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INTRODUCTION: NASAL ANATOMY

The external nose of the dog consists of a fixed bony case and a movable cartilaginous framework. Muscles connected to the cartilage component permit the dog and cat to move the external nose in response to various smells and tactile stimuli. The flattened apical portion of the nose is called the *nasal plane* (planum nasale); the central groove between the nostrils is the *philtrum*.

The bony nasal aperture serves as a support frame for the nasal cartilage; dorsal and lateral nasal ligaments provide support to the dominant dorsolateral nasal cartilages. The flexible external nose is composed of several individual cartilages, including the paired dorsolateral and ventrolateral nasal cartilages, paired accessory cartilages, and a singular cartilaginous nasal septum. The ventral part of the septal cartilage is the vomeronasal cartilage. A membranous nasal septum connects the immovable caudal cartilaginous nasal septum to the mobile rostral septum.

There are three interconnected nasal meatuses in the dog: the dorsal meatus, middle meatus, and ventral meatus. The common nasal meatus is a longitudinal, narrow space on either side of the nasal septum; it is coextensive with these three meatuses. The nasopharyngeal meatus is an extension of the ventral nasal meatus.

The nasal cavity and external nose are supplied by an extensive capillary network, in turn supplied by an interconnecting network of arteries and veins. This extensive collateral circulation helps maintain a blood supply to these tissues despite significant trauma. Similarly, it is this outstanding circulation that enables the surgeon to manipulate these tissues during reconstructive surgical procedures with less risk of ischemic necrosis.

In general descriptive terminology, the external nose can be named according to specific anatomic regions: the central nasal region between the nostrils or *central planum*, the lateral nasal or *rolled alar cartilages*, and the lower rostral base of the nostril or *sulcus* (Fig. 20-1). The external nose is a highly specialized functional structure that contributes significantly to the dog's general cosmetic appearance. There is no simple or practical method to precisely reconstruct large areas of this tissue lost from trauma or surgical resection. Reconstruction of the human nose secondary to trauma or tumor removal may require a single surgical technique or multiple surgeries to optimize the cosmetic outcome for the patient, depending on the extent of the defect. The dog, however, has a hairless, pigmented epithelial coverage etched with polygonal-shaped indentations or grooves; replication of this surface and underlying cartilage framework can be difficult or impossible to achieve in a practical fashion, as compared with the human.

With the exception of controversial cosmetic ear-cropping and tail-docking procedures advocated for some breeds of dog, many veterinarians have reservations about performing surgery strictly for cosmetic purposes, unless there are other benefits to the patient in correcting a given defect. The attitudes of dog owners also vary on the subject of cosmetic surgery. Many owners take particular pride in their pet's appearance. Some owners/breeders seek out cosmetic surgery to improve the appearance of their pet for dog-show competition. Other owners simply are disturbed or shocked by the cosmetic outcome of a given surgery, despite the fact that patient function and comfort have been restored or maintained. In this chapter, different techniques are presented as options to help improve function to the nose while closing a given defect with the hope of achieving a more reasonable cosmetic outcome in a single surgical procedure.

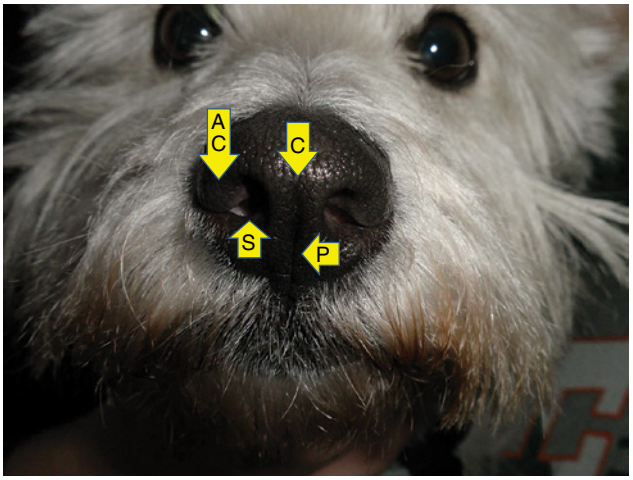


FIG. 20-1 Frontal view of the nose (nasal planum), demonstrating the rolled (lateral) alar cartilages (AC), central planum (C), sulcus (S), and philtrum (P).

TRAUMATIC WOUND MANAGEMENT

Lacerations and superficial abrasions occasionally are noted in the dog and can be managed with basic wound-management techniques. Shearing wounds, usually secondary to vehicular trauma, generally are unilateral injuries from the patient tumbling to one side during impact from behind, driving the patient's rostrolateral facial area into the pavement. Management of these wounds includes control of hemorrhage, surgical debridement, and treatment of any infection present. Minor wounds can heal by second intention with basic care. More extensive wounds, which often include the rostral upper lip, may require additional surgical intervention for optimal cosmetic and functional results. Regional skin can be undermined, advanced, and sutured to the nasal mucosal and cutaneous epithelial tissue that composes

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the border of the defect. Alternatively, a compound upper labial advancement or pivot flaps can be employed for simultaneous closure of that portion of the rostral (full-thickness) lip and nasal planum that has been destroyed (see Plates 88, 97, and 98).

Blunt frontal impact can result in the upward displacement of the nose, with subsequent tearing of the underlying connective tissue attachments and adjacent labial mucosa. Minor avulsion wounds may be managed by suturing the avulsed labial mucosa around the upper incisors (see Plate 84). More extensive avulsion wounds can result in the upward displacement of the nose, labial tissues, and facial skin; simply reapposing the labial mucosa may not sufficiently stabilize the nose, resulting in its lateral displacement. As discussed in Chapter 15, stabilization can be facilitated by placement of absorbable anchor sutures through one palatine fissure and into the exposed nasal septal cartilage, before passing the straight needle through the opposite foramen and into the oral cavity (see Fig. 15-6). Two sutures are placed in this fashion and tied once lavage, debridement, and hemostasis are achieved. Once tied, the labial mucosal laceration is closed with a simple interrupted or continuous suture pattern. Although uncommon, trauma to the nasal cartilage can result in membranous scar tissue obstruction of the nasal opening caudal to the framework of the nasal cartilage. In one case referred to the author, a canine patient could not breathe through their nose, necessitating a ventral labial approach to gain access to the ventral nasal meatus. Scar tissue resection was followed by insertion of tubular plastic stents through the common nasal meatus, secured to each common nasal meatus with sutures for approximately 2 weeks.

NEOPLASIA

Neoplasms involving the nasal planum are occasionally encountered in small animal practice. Squamous cell carcinoma is one of the most common neoplasms in the dog and cat. Tumor resection can be accomplished by scalpel, laser, or cryosurgery (Fig. 20-2). Radiation therapy may be an option in select cases and can be discussed with an oncologist or radiation therapist. Computer-aided tomography is used to better define the extent of tumor invasion. Depending on the location of the tumor, it is possible to remove tumors completely, yet preserve portions of the nasal planum to "reconstruct" the nose for better functional and cosmetic results. One example is salvaging the pigmented sulcus to reform an outer nostril (Figs 20-3 and 20-4). It is often not necessary to simply resect the neoplasm and appose the cutaneous margins to the adjacent mucosal margins, accepting the less functional and less attractive cosmetic result obtained by complete nasal planectomy (Fig. 20-2).

NEOPLASMS AND SURGICAL MARGINS

Limited tumor excision, simply to achieve optimal cosmetic results and facilitate closure, likely will result in tumor recurrence within weeks after surgery. A 10–20 mm margin around a well-demarcated growth may be sufficient to obtain "surgical margins" in many patients, although highly invasive tumors may necessitate wider margins of healthy tissue to ensure their complete removal. This basic principle of cancer surgery, however, must be tempered with avoiding unnecessarily aggressive excision of all tumors regardless of their type size, location, and classification. Tissues excised should be submitted for histopathologic examination to ensure that neoplastic cells do not extend to the surgical margins of the specimen. Additional resection of tissues and/or alternative cancer therapy options would be indicated under these circumstances.

NASAL RECONSTRUCTION OPTIONS

Skin Flaps

An advancement flap from the dorsal muzzle can be placed over the exposed nasal septum in some dogs and cats with sufficient skin laxity, improving the cosmetic appearance of the patient while protecting the nasal mucosa from irritation secondary to exposure (Fig. 20-5). See Plate 147. Transposition skin flaps also can be highly effective in coverage of defects of the external nasal surface (Fig. 20-6).

Sulcus Flaps

Paired, small, 90°-angle transposition flaps may be used to replace the central nasal planum after resection of lesions restricted to this area (Plate 148).

Using skin flaps or simple skin advancement alone is especially useful in closing partial losses of the nasal planum and underlying supportive cartilage framework. Partial loss (one-third) of the circumference of the nasal meatus is unlikely to cause stenosis and simple skin coverage may be adequate (see Fig. 20-3, Fig. 20-4, and Fig. 20-6 as examples). Larger losses of the mucosal circumference of the nostril may benefit from a variation of the lip-to-lid procedure (Plate 143), the "lip-to-nose" technique (Plate 154), as noted in later Fig. 20-12. Plate 155 demonstrates this variation in the cat.

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FIG. 20-2 (A, B) Nasal planectomy in the dog. The nasal mucosa is directly exposed to the external environment and cosmetic results are considered poor. (C, D) Complete nasal planectomy for squamous cell carcinoma without reconstruction. The owners were disappointed in the cosmetic results. Note the inflammation of the exposed nasal turbinates. There are multiple options to improve mucosal coverage and obtain a better cosmetic outcome simultaneously. (E) Nasal planectomy for squamous cell carcinoma results in a skeletal or "Phantom of the Opera" cosmetic outcome. The exposed nasal mucosa was periodically inflamed as a result of its external exposure to the environment.

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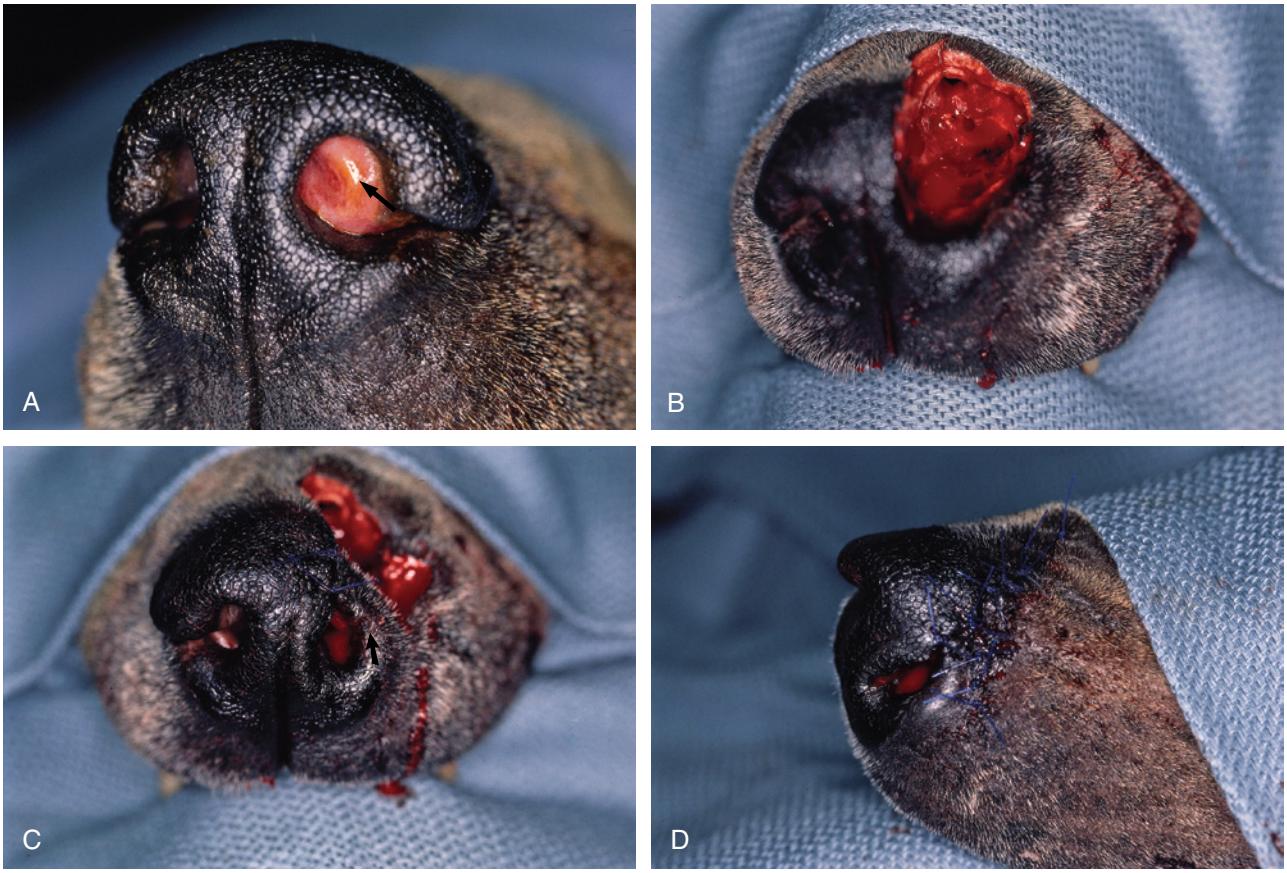


FIG. 20-3 (A) Expansile granulomatous mass (benign) involving the left alar cartilage area (arrow). (B) Complete resection of the lesion. (C) Upward rotation of the remaining nasal cartilage (sulcus), recreating the left nostril. (D) Closure of the skin defect. Mild asymmetry is present from loss of the alar tissue. However, the owner was pleased with the cosmetic result and functional outcome for the patient.

Selective Resection of Nasal Septal Tumors

In some cases neoplasms may primarily involve the cartilaginous nasal septum of the external nose. An alternative to complete nasal planectomy would be selective excision of the nasal septum for those smaller tumors without clinical evidence of extensive infiltration of the planum (Plate 149). An incision can be made to elevate the dermis and epidermis of the central planum, thereby gaining exposure of the septum for wide excision. The elevated planum is resutured at the completion of tumor removal. As a result, the external cosmetic appearance of the nose can be maintained; loss of the septum causes no notable respiratory problems (Fig. 20-7). To enhance exposure of the nasal septum, the comparatively thin dorsal nasal cartilage can be incised at the 12 o'clock position of the nostril. Retraction of the incision can enhance exposure of the more caudal aspect of the rostral septal area (Figs 20-8 and 20-9). This technique can be used alone or in combination with elevation of the external septal planum technique (Plate 150).

Besides the use of skin flaps for nasal planectomy already noted (Fig. 20-5 and Plate 147), the following techniques can be considered to reconstruct the external nose, including alar fold flaps (Plate 151), musculofascial island labial flaps (Plate 152), circumferential inversion of the labial mucosa (Plate 153), and the "lip-to-nose" variation of the "lip-to-lid" procedure (Plates 154 and 155).

Bilateral Alar Cartilage Flaps

Centrally located tumors involving the external nose can be widely excised. If the rolled alar cartilages are not involved in the disease process, each alar prominence can be carefully contoured with a scalpel blade, pivoted, and sutured together. The smaller external nasal silhouette created results in a better cosmetic outcome compared to complete planectomy. Moreover, the nasal mucosa is recessed and better protected from exposure by the creation of this dorsal "cartilage" shelf (Fig. 20-10). See Plate 151.

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FIG. 20-4 (A) Mast cell tumor involving the left alar region. (B) Carbon dioxide laser resection of the alar region. (C) Upward rotation of the pigmented sulcus, followed by skin closure. Surgical margins were obtained on this grade II mast cell tumor. (D) Patient 3 weeks after surgery. (E) Close-up view. The patient was breathing normally with resolution of postsurgical inflammation. The owner was pleased with the outcome. (F) The patient 4 years later. Note the pigmentation of the skin that obscures the nasal asymmetry. The owners were pleased with the outcome and reported that their dog is clinically normal.

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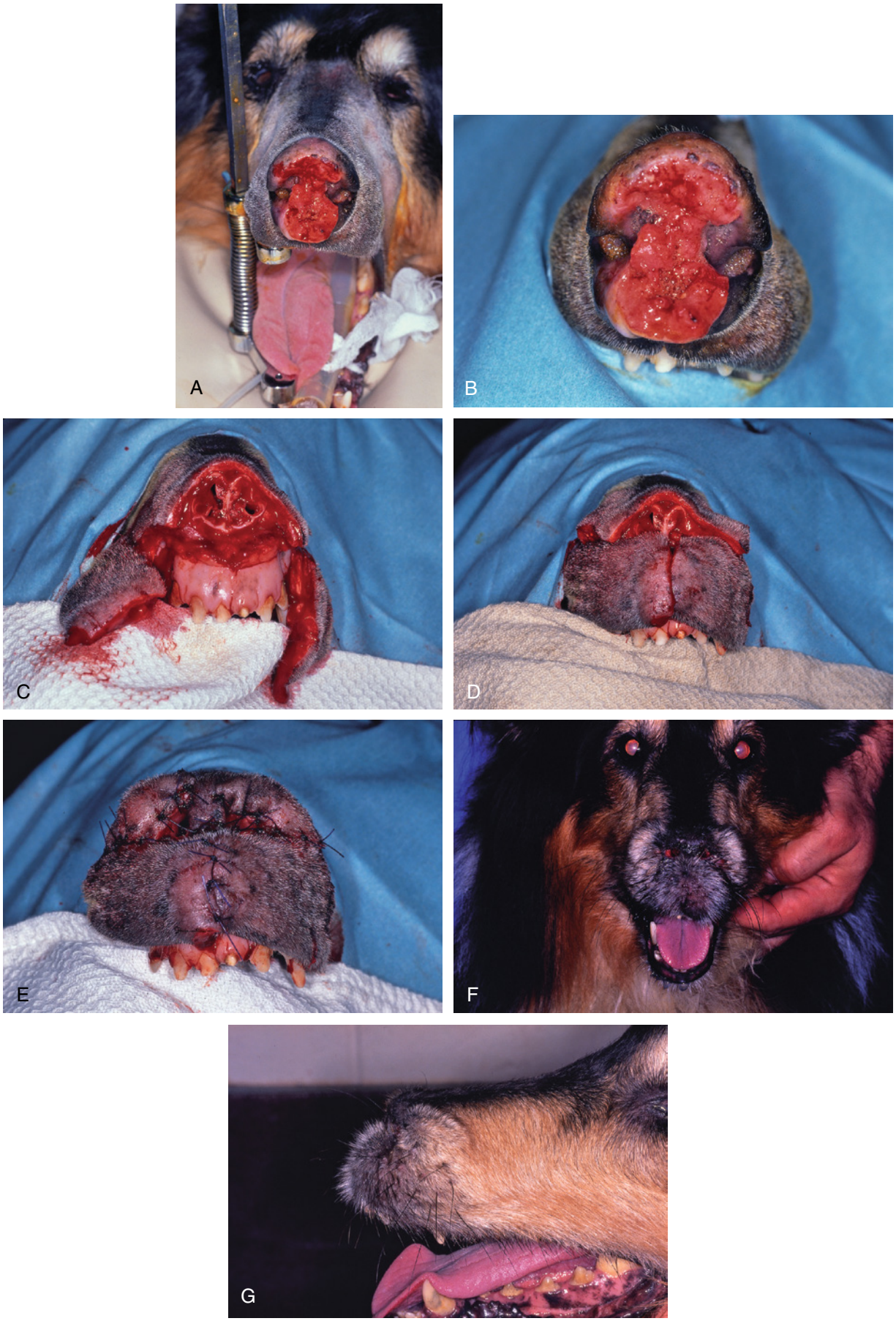


FIG. 20-5 (A, B) Squamous cell carcinoma, requiring complete nasal planectomy. (C) Complete excision of the external nose and rostral lip. (D) Initial closure with bilateral labial advancement flaps. (E) Simple restoration of external septum using an advancement skin flap. The redundant skin margins were sutured to the nasal mucosa, creating the appearance of the alar folds. (F, G) Postoperative outcome. The patient had no recurrence of squamous cell carcinoma when followed for over 1 year.

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FIG. 20-6 (A) A mast cell tumor of the dorsal nasal planum. (B) Laser-assisted resection of this neoplasm. (C) A 90° transposition skin flap has been sutured into position. (D) Completion of the flap transfer and closure of the donor area. (E) Lateral view of the surgical area postoperatively. (F) The patient, 2 weeks after surgery. The owners were pleased with the surgical results and the patient breathed normally.

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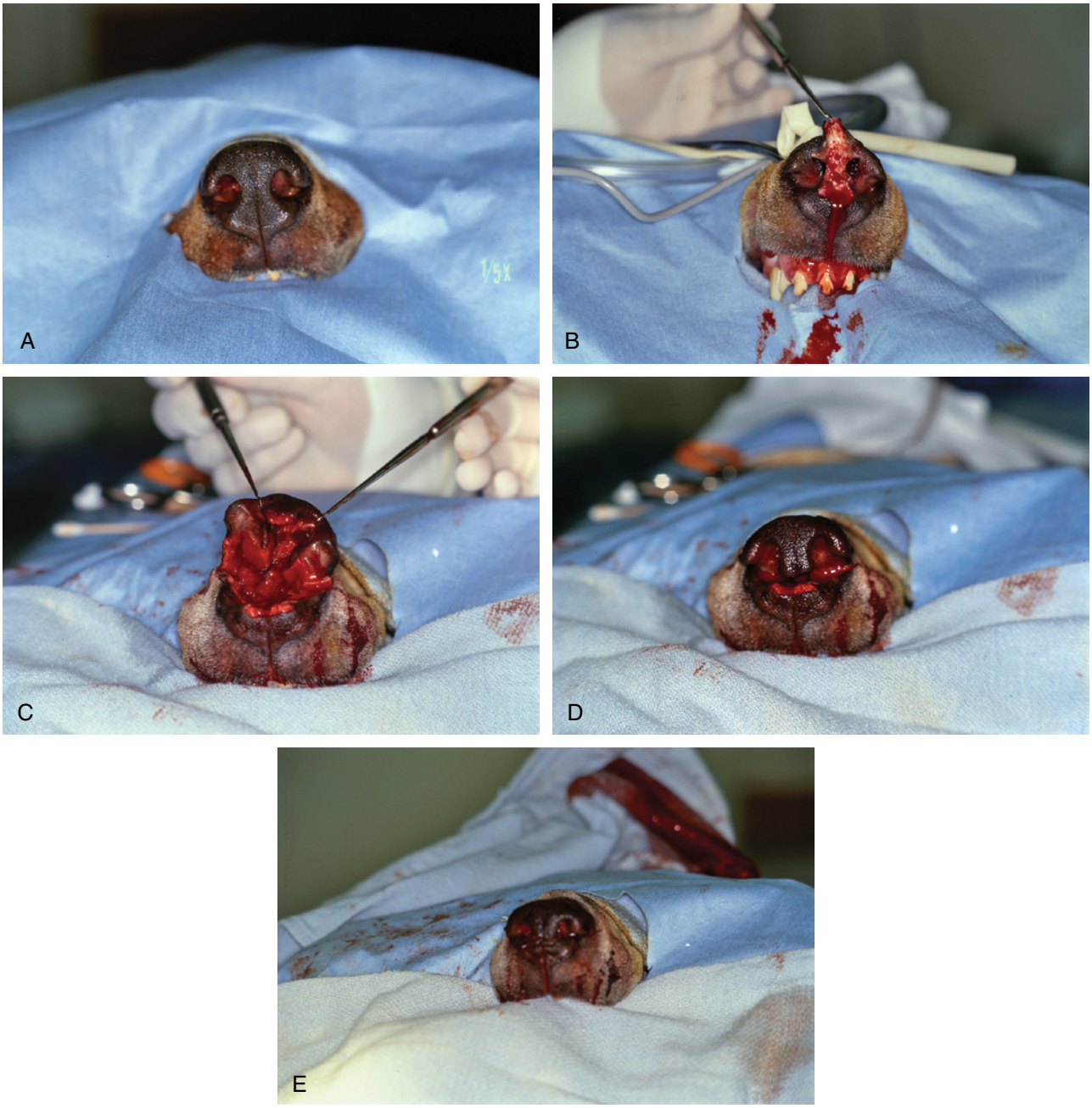


FIG. 20-7 (A) Septal carcinoma. (B) Dorsal elevation of the external nasal septum as a flap. (C) Skin hooks and self-retaining retractors enable the surgeon to expose the nasal septum several centimeters in a rostral–caudal direction. (D) Completion of the surgical resection, with realignment of the external septal flap. (E) The flap was resutured to its original position. Cosmetic and functional results were excellent, despite the extensive intranasal surgery performed. Note this technique can be used in combination with nasal splitting to enhance exposure. (See Plates 149 and 150.)

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FIG. 20-8 (A) Squamous cell carcinoma involving the sulcus and adjacent nasal septum (arrow). (B) The rostral lip was divided >1 cm lateral to the visual border of the mass. The laser was used to incise the dorsal nasal surface, medial to the alar fold (blue arrows); this provided superior exposure to the nasal septum. Tumor highlighted by the red arrow. (C) Resection of the involved sulcus, lip, and nasal septum. (D) The right labial border was advanced and sutured into position, replacing the resected labial tissue and inner sulcus. This was followed by closure of the dorsal nasal planum access incision. (E) Dorsal postoperative view of the sutured dorsal nasal access incision. (F) The patient 2 weeks after surgery. The dog was breathing normally. (See Plates 149 and 150.)

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FIG. 20-9 (A) Left nasal septal squamous cell carcinoma. (B) Close-up view of the nose. (C) Dorsal nasal split to gain access to the cartilaginous septum. In this example, the nasal septum was not elevated as a flap. (D) Resection of the septum. (E) Simple closure using a deep layer of interrupted absorbable sutures, followed by external absorbable interrupted sutures. (See Plates 149 and 150.)

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FIG. 20-10 (A) Squamous cell carcinoma of the lower nasal planum. (B) Wide resection of the mass: the alar fold flaps were not involved in the neoplastic process and were preserved. (C) The epithelial border of each alar fold was resected, followed by suture apposition. (D) Final closure using bilateral labial advancement flaps. (E, F) Postoperative views of the patient. The alar folds created the semblance of an external nose while protecting the inner nasal mucosa from exposure. No recurrence of the neoplasm after 1 year. (See Plate 151.)

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Musculofascial Island Labial Flap

In the event that complete planectomy is required for tumor removal, the adjacent upper lip can be used to partially reconstruct the canine nose. An incision, 3 or 4 cm caudal and parallel to the rostral labial border, is made through the entire thickness of the lip. The cutaneous and mucosal surfaces are carefully excised, leaving the terminal 3 cm of skin, mucosa, and associated labial border. This musculofascial labial flap and associated island of epithelium are transposed dorsally and sutured into position. The remaining skin and labial tissues are reapposed to complete the procedure. Partial removal of the epithelial surfaces enables the surgeon to bury the pedicle beneath the skin. Although not identical to the original nose, the cosmetic appearance, judged by frontal and side views of the patient, is improved. Moreover, recreation of the dorsal nasal shelf further protects the nasal mucosa (Fig. 20-11). See Plate 152.

Labial Mucosal Inversion Technique

An alternative technique for improving nasal mucosal protection reported by Gallegos et al. (2007) uses suturing of the labial mucosa to the nasal cartilage ring after nasal planectomy. Following this, the labial borders are folded rostrally, inverting the labial mucosa, thereby partially covering the nasal opening. Segments of the lip are resected to reestablish the midline of the upper lip. The net result of this surgery is the creation of a mucosal antechamber for the nasal cavity, surrounded by pigmented labial tissue. Cosmetic results are reported to be better than those achieved by nasal planectomy alone (Plate 153).

OPTIONS FOR MANAGING NASAL STENOSIS

Stenosis of Reconstructed Nasal Openings

Significant *circumferential* gaps or loss of nasal mucosa involving the nasal meatus can result in narrowing of the reconstructed nostrils. Accurate alignment of nasal mucosal tissues with the skin or adjacent mucosal tissues used in nasal reconstruction can reduce this postoperative complication. In mild cases of nasal stenosis, scar tissue may be resected and the nasal openings enlarged, apposing the available skin and mucosa. In cases of severe stenosis, the following techniques are options to consider for this problematic condition: compound labial mucosal flaps, mucosal grafts with stent support, or creating a large window in the intranasal septum.

Compound Labial Flap Variation of Lip-to-Lid Procedure (see Plate 154)

The "lip-to-lid" procedure (Plate 143) allows for one-stage reconstruction of the entire upper or lower eyelid by providing oral mucosa as a substitute for conjunctiva. This same technique can be employed to reconstruct the nostril (Fig. 20-12). This technique may provide an option for those pets that have stricture of one or both nostrils secondary to surgery. With a black labial border, cosmetic results can be surprisingly good. More importantly, the oral mucosa can prevent stricture formation of the nostril. This technique can also be used in cats (Plate 155).

Oral Mucosal Graft Application to Circular Stents for Nostril Stenosis

Mucosal grafts have been suggested as a method to prevent stricture of the nostril after loss of the mucosal surface of the nasal meatus secondary to surgical trauma. This also has been seen by the author with excessive use of the laser to enlarge the nostrils of brachycephalic cats. (A salvage technique option is noted in Fig. 20-13.) The technique is a variation used in human penile reconstruction for severe hypospadias; its use for stenotic nares was reported by Welch and Swaim (2003). It entails harvesting a premeasured rectangular segment of upper labial or buccal mucosa; the mucosal surface is inverted and sutured around the plastic stent tube. It is then inserted into the prepared nostril site. Once healed, the plastic stent tube is removed. The stent must be sufficiently large to firmly compress the submucosal surface to the surrounding granulation bed for revascularization (Fig. 20-14). It may be wise to use a large stent (in proportion to the size of the patient) to offset the risk of narrowing of the newly formed nostril lining (Plate 156).

Septal Window Technique for Loss of Nostril

With the loss of a nostril secondary to trauma, major tumor resection, or extensive stenosis, it is possible to salvage this unilateral problematic condition by creating a large septal window inside the nasal cavity. This allows air to pass from the stenotic side of the nasal cavity to the opposite nasal cavity and out the opposite nostril (Plate 157). Without this septal outlet, the patient cannot clear the stenotic nasal passage by snorting or sneezing.

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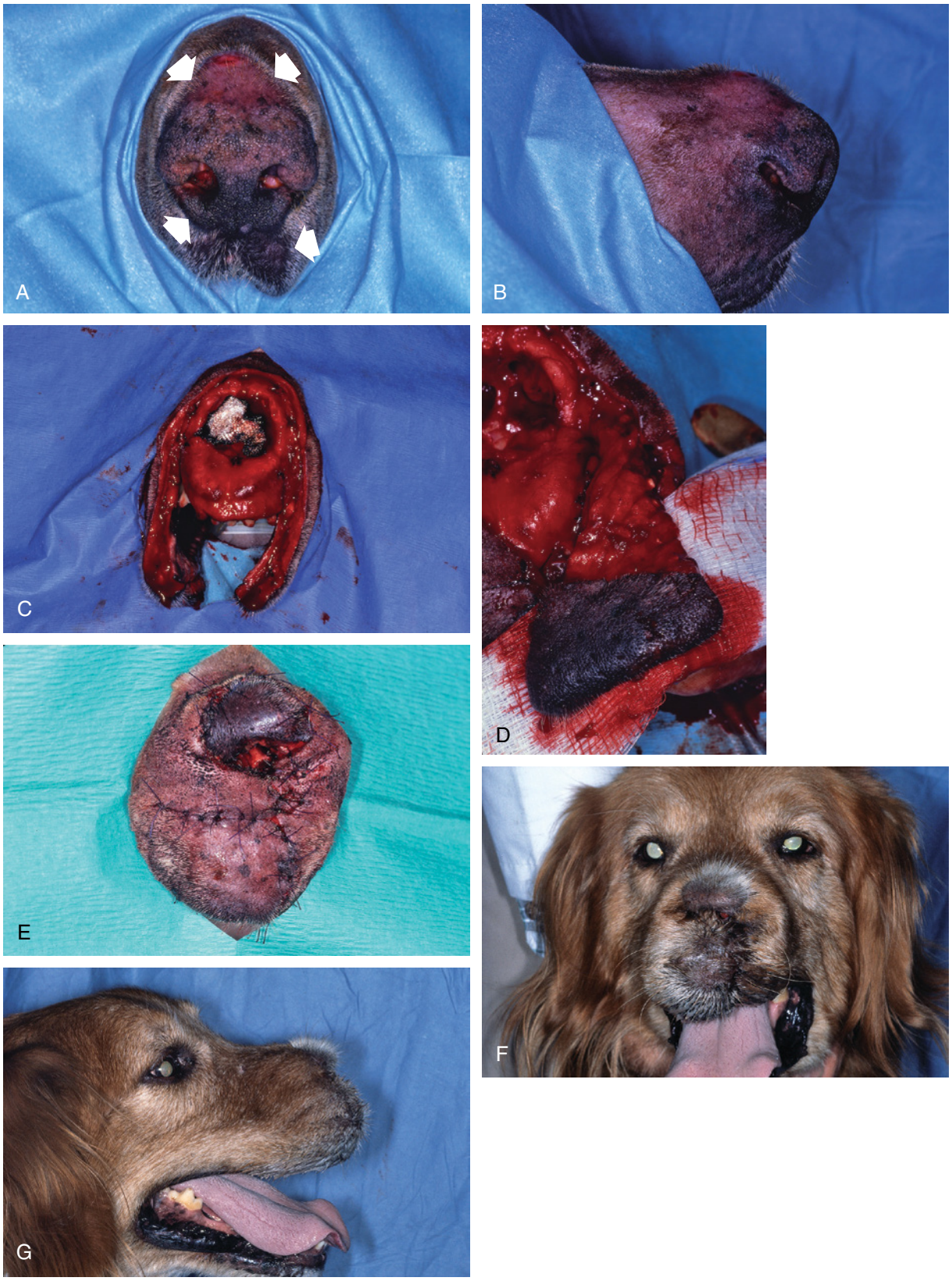


FIG. 20-11 (A, B) Extensive squamous cell carcinoma of the nasal planum and adjacent lip (arrows). (C) Wide excision of the neoplasm. (D) Creation of a nasolabial island flap from the left labial tissue. (E) Transposition of the island of labial tissue over the dorsum of the nasal opening, creating a "protective awning" to the recessed nasal mucosa. Closure of the labial defect using the remaining available labial tissues. (F, G) Postoperative outcome. No tumor recurrence was noted after 1 year. In hindsight, resection of redundant labial tissue would have improved the cosmetic appearance in this patient. The owner was quite pleased with the results. (See Plate 152.)

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FIG. 20-12 (A) Mast cell tumor (arrow) involving the right alar fold and adjacent planum of a greyhound. (B) Resection of the lateral half of the nasal planum. Note the composite labial flap (arrow) partially elevated. (C) Elevation of the labial flap, including the pigmented border and attached oral mucosa. The oral mucosal portion of the flap will replace the large nasal mucosal defect. (D) The mucosal margins were sutured into position followed by closure of the cutaneous margins. The black labial border matches the black nasal planum.
(E) Completion of the closure. With hair regrowth, the cosmetic results were excellent. The patient breathes normally. (F) The patient, 3 years later. (See Plate 154.)

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FIG. 20-13 (A) This Persian cat presented with complete stenosis of the nostrils; a laser was used to surgically enlarge the nostrils, resulting in the complete destruction of the mucosal lining of each nostril. Fibrosis collapsed each meatus. (B) Close-up view of the patient. A second attempt at opening the nostrils with a carbon dioxide laser also failed. Correction of this problematic case would have required oral mucosa transplantation to create a stable nostril lining. (C) The frustrated and financially constrained owners requested the simplest technique to allow their cat to breathe through the nose. A dorsal rhinotomy was performed, creating a 10 mm hole in the nasal bone. (D) The skin margins were sutured to preplaced holes drilled along the perimeter of the bony ostium created. The result was cosmetically poor but the cat was able to breathe through the opening. The owners occasionally cleaned the area of mucus with cotton-tipped applicators.

If used in combination with partial resection of the nasal bone, the septal window can reduce intranasal pressure formed within the involved nasal cavity. Otherwise, when the patient exhales they will force air through the skin incision, resulting in dehiscence and increasing postoperative subcutaneous emphysema (Fig. 20-15).

Cantilever Suture Technique

Rostral maxillectomy can result in a loss of nasal cartilage support, with drooping of the nose postoperatively. Breathing through the deviated external nose becomes difficult or impossible. A "cantilever" suture technique, developed by the author, can be used to elevate the nose (Fig. 20-16). See Plate 158.

Stenotic Nares Corrective Procedures

Stenotic nares is most commonly associated with brachycephalic dogs in general and most commonly associated with the English bulldog and French bulldog breeds. In cats, stenotic nares is commonly associated with brachycephalic breeds. The external noses of dogs and cats are anatomically different and surgical correction of stenotic nares differs. Unlike dogs, cats uncommonly have concomitant soft palate elongation and everted saccules.

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FIG. 20-14 (A) Mixed-breed neutered dog estimated to be 1 year old that was referred for an extensive shotgun wound to the external nose and adjacent nasal and maxillary bones. A previous attempt at closing the open nasal defect by skin advancement had failed. The left nasal vestibule was scarred closed; the dorsal and right half of the external nose were nonexistent. An irregular oval defect was overlying the dorsal area of the right maxillary and nasal bones with loss of the adjacent nasal septum and turbinates. Source: Pavletic MM. 2021. Full-thickness labial flaps to reconstruct facial defects in four dogs. *Vet Surg* 50: 1338–1349. Reproduced with permission. (B) Scar contracture of the wound resulted in dorsal deviation of the rostral aspect of the maxillary labia. The left eye sustained damage with corneal scarring, obscuring vision. The left upper canine tooth (204) was shattered. (C) Right lateral view of the nasocutaneous fistula overlying the right rostral nasal cavity. (D) Mucosa harvested from the right upper lip. The width of the graft was determined by the circumference of the established nostril opening (6 mm) after core resection of the central scar with a no. 11 scalpel blade. The exposed submucosal tissue was removed down to the underlying mucous membrane to help ensure revascularization. (continued)

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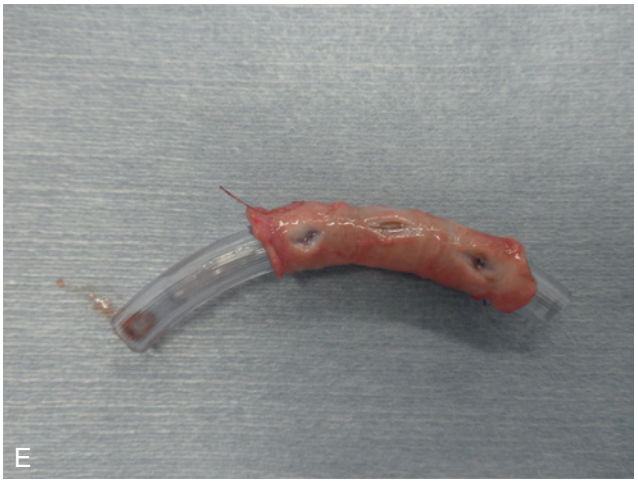






FIG. 20-14 (Continued) (E) The prepared mucosal graft was secured around the plastic tube stent; the marginal length of the graft was apposed to itself with absorbable sutures. The mucosal surface is facing the plastic tube surface. The plastic graft stent was slightly larger than the circumference of the prepared left nostril tunnel to ensure the close contact of graft tissue with the wound bed to promote graft revascularization. Small release incisions were used to mesh the graft, offsetting natural graft contraction of the tissues, while providing drainage. (F) Forceps were used to slightly dilate the prepared nostril opening. The graft stent was slowly rotated into position with quarter turns, making sure the graft contacted the circumference of the left nostril bed uniformly. The rostral end of the graft stent was sutured to the inner margin of the external nostril. After placement of the graft, the remaining dorsal lateral nasal defect was closed with a right full-thickness labial flap. The labial border was positioned rostrally to reconstruct the right nostril opening. The mucosal surface of the flap completely replaced the right nasal defect. (See Plates 154 and 156.) (G) The right nostril with the visible outline of the labial flap (yellow arrow). Sutures were removed, including the left nasal stent. Viable pink mucosa can be noted lining the left nostril.

In dogs, correction of stenotic nares ("rhinoplasty") is normally performed in conjunction with elongated soft palate resection and everted saccule removal. Procedures employed in brachycephalic dogs with stenotic nares include vertical wedge resection, horizontal wedge resection, alapexy, ala-vestibuloplasty (Trader's technique) (Fig. 20-17), punch resection alaplasty, and dorsal offset rhinoplasty.

By contrast, surgical procedures used to treat stenotic nares in brachycephalic cats include punch resection alaplasty, the use of a single advancement flap, ala-vestibuloplasty (resection of the ala nasi or alar wings), small wedge resection, and use of the carbon dioxide laser to remove the lower portion of each alar fold. More recently the author has reported the combined use of the "alar fold lift-up" and "sulcus pull-down" techniques for correcting stenotic nares in brachycephalic cats (Fig 20-18). (See Plate 159.) Although all these techniques have been reported to improve nasal breathing in dogs, the author prefers the vertical wedge resection technique outlined in Plate 160. Readers are directed to the standard references pertaining to brachycephalic obstructive airway disease for information pertaining to canine soft palate and everted saccule procedure

See Chapter 25 for additional clinical flap examples.

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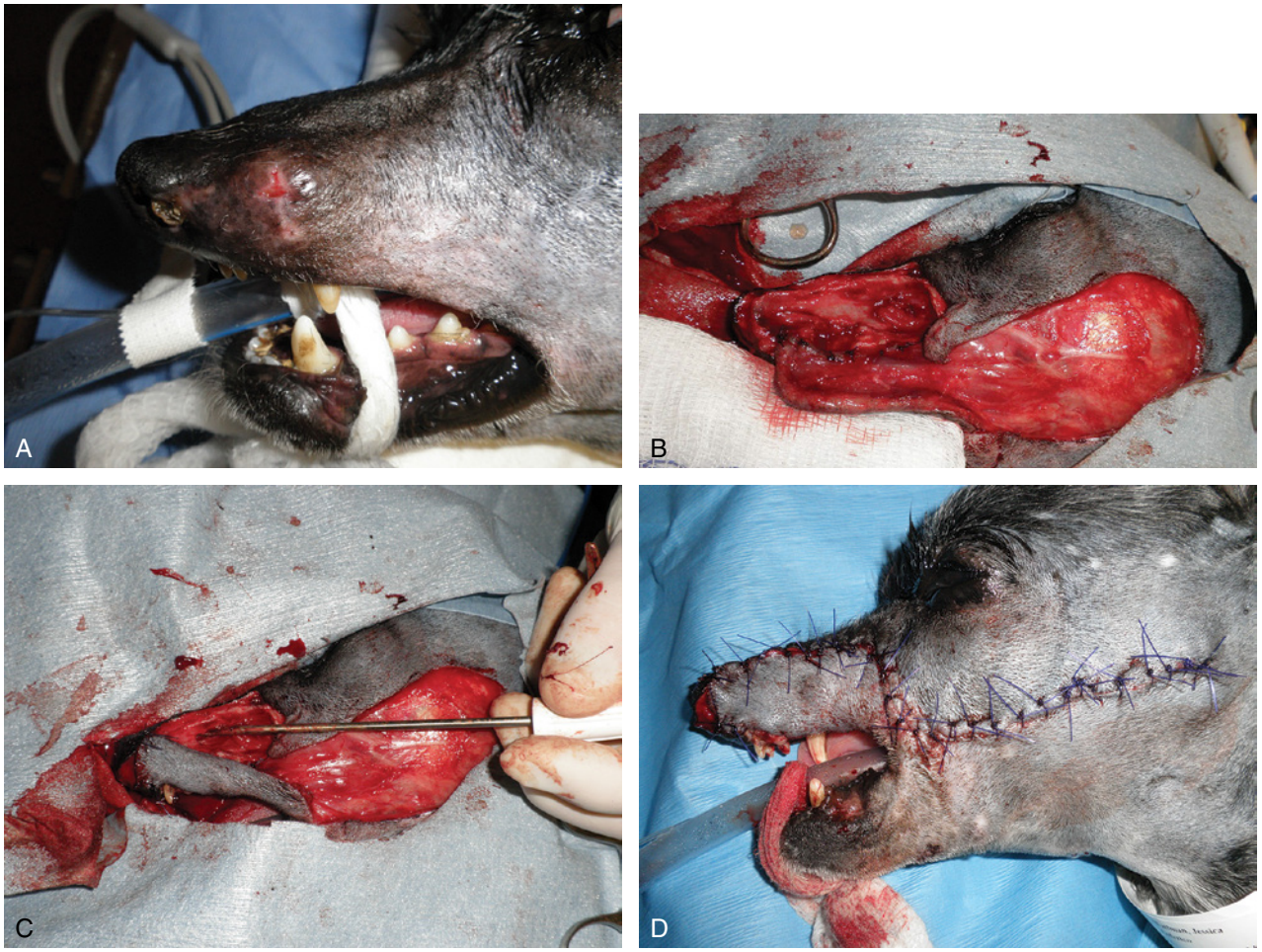


FIG. 20-15 (A) Recurrence of fibrosarcoma in a poodle cross, 3 years after surgical resection and adjunctive radiation therapy. (B) The left half of the external nose and facial bone were resected with a surgical saw. Note the facial flap, with its pedicle aligned with the intact oral commissure. In this image the dorsal border of the flap is sutured to the hard palate. (C) A window is being created in the nasal septum (metallic pointer) prior to final closure of the defect. Creation of a large window will help ensure the free passage of air into the right nasal chamber. (D) Completion of the flap closure. Postoperatively, the patient developed subcutaneous emphysema that resolved several days later. Focal dehiscence of the dorsal incision was noted secondary to air being forced through this site. This was corrected by enlarging the septal window, which was partially obstructed with mucus and blood. Creating a larger septal window could have prevented this complication. (See Plate 156.)

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FIG. 20-16 (A) Fibrosarcoma of the rostral maxilla. (B) Surgical resection of the rostral maxilla. (C) Resection of the maxilla followed by closure, suturing the labial mucosa. Note the "T" closure in conjunction with suturing the caudal mucosal borders to the incised border of the hard palate. (D) Patient placed in sternal recumbency. Note the downward collapse of the external nose. (E, F) Dorsal midline incision rostral to left and right medial canthus. A hole was drilled and two strands of 00 polypropylene suture were placed through the bone tunnel using a straight needle. (continued)

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FIG. 20-16 (Continued) (G) Each straight needle is directed beneath the skin toward the right alar fold. (H) A small stab incision in the lateral alar fold is created and the needle exits this site. (I) The suture needle is directed across the nose to the small access incision created in the left alar fold. (J) The straight suture needle is directed caudally beneath the skin toward the skin incision. (K, L) The two suture loops are tightened causing the external nose to rise slightly; when satisfied with the position, the individual strands are tied. (M) Completion of the cantilever suture technique. This procedure has been quite effective in the author's hands. (See Plate 158.)

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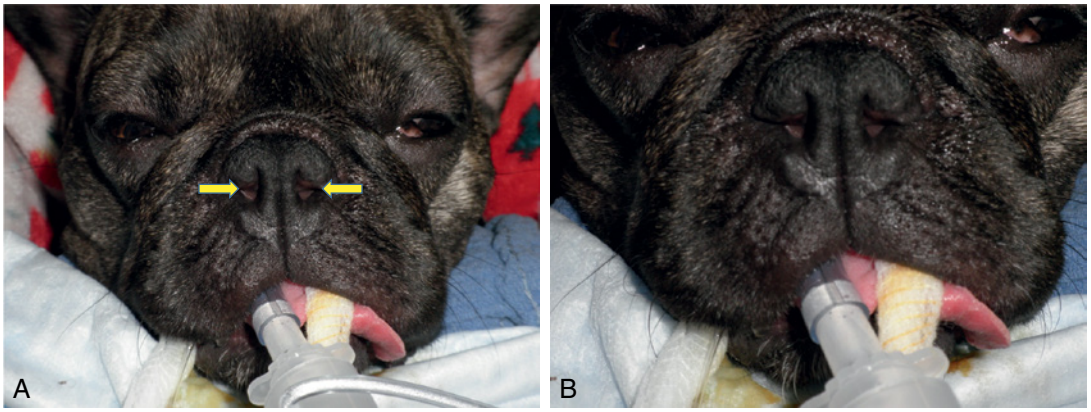


FIG. 20-17 (A) French bulldog that had the lower portion of each alar fold resected horizontally (arrows). (B) Close-up view. Functional results were achieved, although the cosmetic results are less than that achieved by wedge resection. (See Plate 160.)



FIG 20-18 (A) Persian cat with severe nasal stenosis. (B) Correction using the alar fold lift-up and sulcus pull-down techniques. Source: Pavletic MM, Trout NJ. 2023. Successful correction of stenotic nares using combined Alar Fold Lift-up and sulcus pull-down techniques in brachycephalic cats: 8 cases (2017–2022). *J Am Vet Med Assoc* 10.2460/javma.23.01.0054. Reproduced with permission of The American Veterinary Medical Association. (C) Persian cat nasal stenosis. (D) Correction using the alar fold lift-up and sulcus pull-down techniques. (E) Persian cat, stenotic nares. (F) Postoperative view following the alar fold lift-up and sulcus pull-down techniques. (See Plate 159.)

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Plate 147

Septal Coverage Using Cutaneous Advancement Flaps

DESCRIPTION

Complete nasal planectomy, usually secondary to wide tumor resection, results in exposure of the nasal septum and adjacent rostral nasal mucosa. This results in a poor cosmetic appearance and a variable degree of mucosal irritation secondary to exposure. A dorsal midline, single-pedicle advancement flap can be advanced over the septum to improve cosmetic results and help protect the otherwise exposed mucous membranes and exposed cartilage surfaces.

SURGICAL TECHNIQUE

(A) After complete nasal planectomy, a 10–15 mm wide advancement flap can be incised in increments of sufficient length to stretch forward and downward over the nasal septum (dashed lines). Slightly diverging incisions are used as the flap is incised progressively.

(B) The terminal end of the flap is sutured to the lower cutaneous border created after nasal planectomy. Fine 4-0 monofilament sutures are used to atraumatically secure the flap into position. The dermal surface of the flap usually contacts the rostral edge of the nasal septum. Note that redundant skin folds are created lateral to the flap after advancement (arrows).

(C) The remaining skin folds are sutured to the edges of the mucosa exposed after nasal planectomy. The crescent folds of skin simulate the curve of the resected lateral nasal cartilages to improve the cosmetic and functional outcome after complete nasal planectomy.

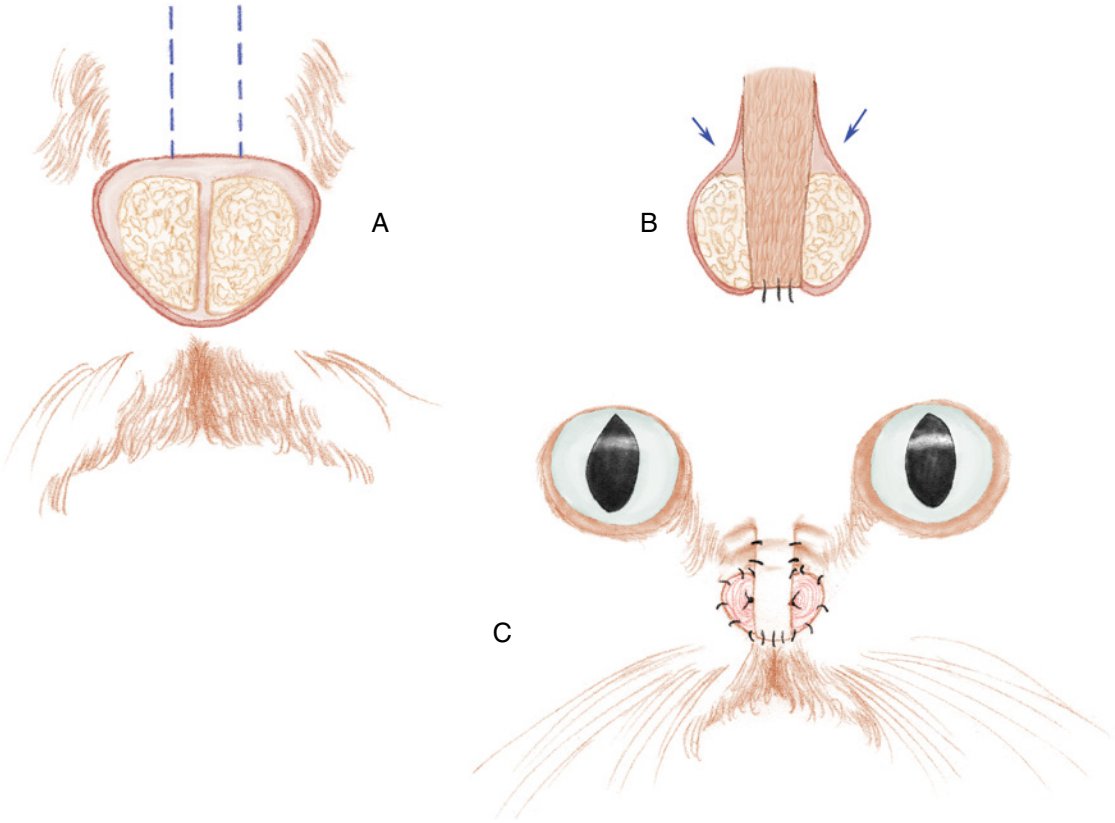
COMMENTS

Simple flap advancement, and the skin ridges created, help cover the remaining nasal septal cartilage and exposed mucosa after resection of the nasal planum. Use of this technique in part depends on the availability of skin for mobilization as a single-pedicle advancement flap. The cosmetic improvements can be quite favorable compared to the classic "Phantom of the Opera" or skeletal appearance of dogs and cats after planectomy. Partial coverage of the mucosa can decrease damage to this delicate epithelial layer from desiccation and exposure to the elements. An Elizabethan collar should be used to protect the surgical site until suture removal.

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Plate 147



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Plate 148

Bilateral Sulcus Flap Technique

DESCRIPTION

Selective resection of lesions confined to the rostral septal region can be closed with two small transposition flaps, using the left and right "sulcus" regions, along the lower borders of the common nasal meatus.

SURGICAL TECHNIQUE

(A) A lesion confined to the rostral aspect of the septal region is prepared for surgical resection.

(B) After resection of the lesion, two 10 mm flaps are outlined (dashed lines) of sufficient length to reach the dorsal border of the surgical defect. Note that the base of each 90° transposition flap is separated in order to avoid compromising circulation entering the pedicle of each sill flap.

(C) Each flap is rotated dorsally and sutured into position with 4-0 monofilament sutures.

(D) The shared medial borders of each flap are carefully sutured. An anchor suture may be placed along the lateral border and secured to the adjacent septal mucosa, if necessary. The donor site of each flap is closed directly.

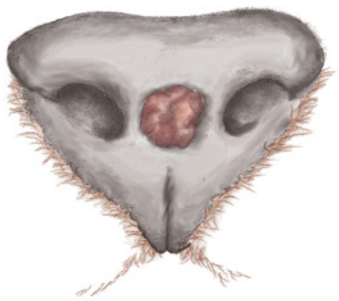
COMMENTS

The sulcus flaps use the pigmented epithelium adjacent to the defect for optimal cosmetic results. Because these flaps are small and their capillary circulation fragile, meticulous, atraumatic surgical technique and careful suture placement are essential for an optimal outcome. This is a highly vascular area: electrocautery and topical vasoconstricting agents are useful to control hemorrhage after surgical resection of the lesion. A surgical laser unit can be very effective in minimizing hemorrhage. Postoperatively, an Elizabethan collar should be used to protect the delicate flap from rubbing and pawing by the patient. Provided that tissues are viable, small areas of dehiscence can be reinforced with additional sutures.

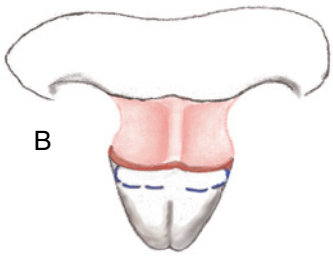
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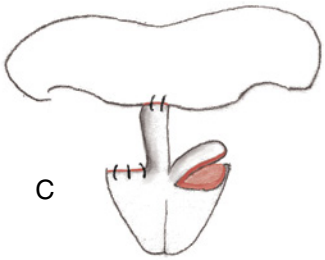
Plate 148



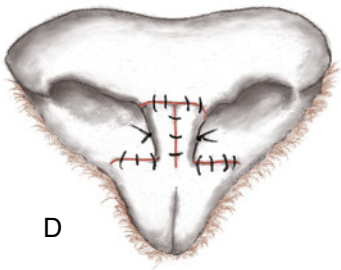
A



B



C



D

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Plate 149 Septal Resection Technique

DESCRIPTION

There are occasions on which neoplasms, such as squamous cell carcinoma, are confined to the rostral nasal septum without infiltration of the nasal planum. It is possible to elevate the central planum as a dorsally based flap, thereby preserving this tissue while gaining access to the isolated lesion.

SURGICAL TECHNIQUE

(A) The dashed line represents the site for incising the central nasal planum.

(B) The scalpel blade is angled 5–10 mm caudal to the surface of the planum. A skin hook facilitates elevation of the "hinge" flap. Hemorrhage is controlled with electrocautery, topical vasoconstrictors, and topical hemostatic agents. A laser surgical unit can be very effective in limiting hemorrhage.

(C) The diseased segment of septal cartilage is resected with a sufficient margin of normal tissue (10 mm minimum). The mass is submitted for histopathologic analysis.

(D) When hemorrhage has been controlled, the flap is resutured into position using a simple interrupted suture pattern.

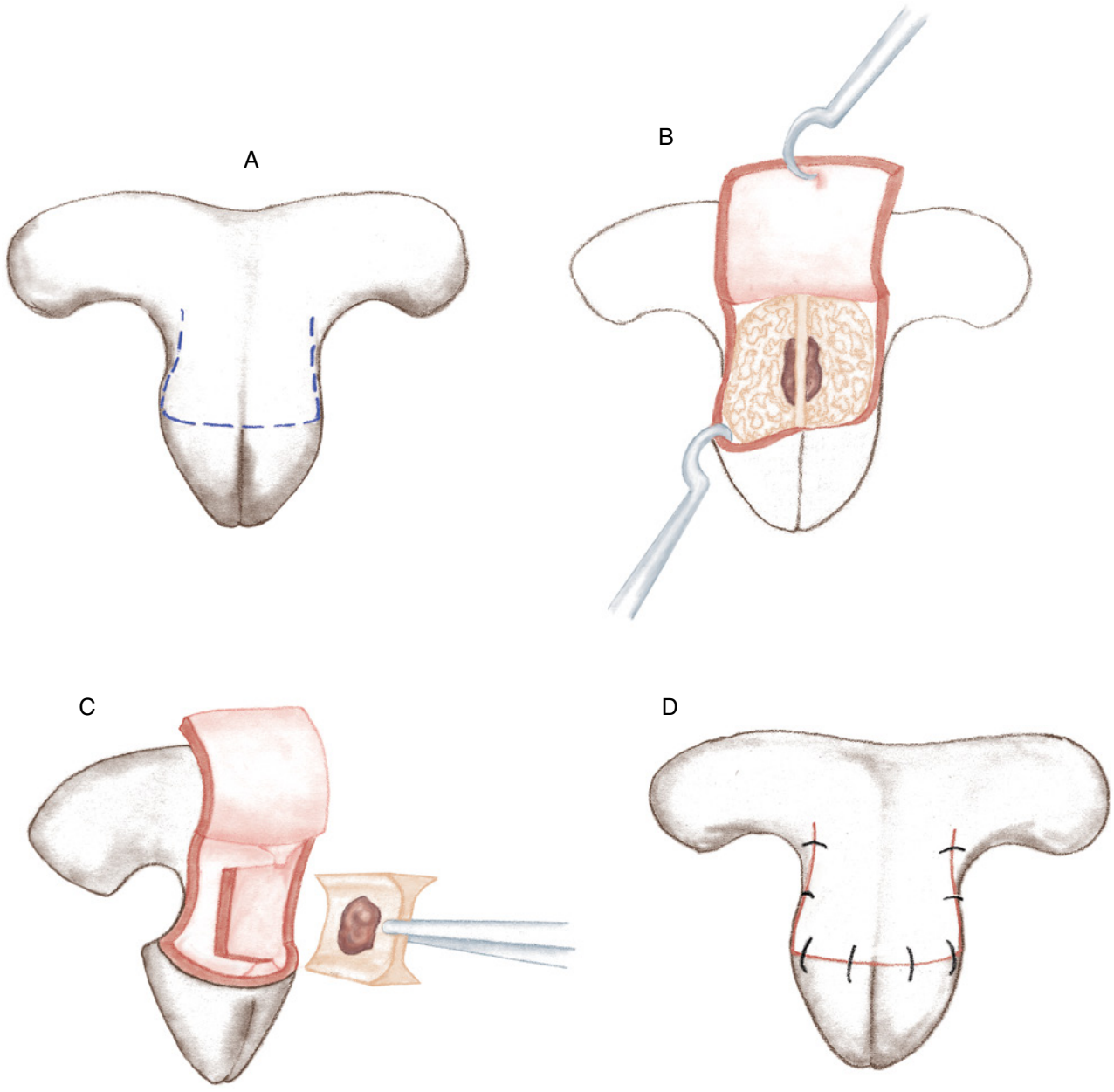
COMMENTS

With the use of a self-retaining retractor, aggressive excision of the cartilaginous nasal septum can be accomplished; the external cosmetic appearance after replacement of the hinge flap is often completely normal. As discussed, the number one priority is obtaining adequate surgical margins around the neoplasm. This flap technique should be considered when it is apparent that the tumor is confined to the septum but has not invaded the rostral nasal planum. Like other nasal surgical procedures, hemorrhage can be significant; smaller patients in particular may be candidates for a transfusion. A laser surgical unit may help minimize this surgical complication. An Elizabethan collar is used to protect the area from self-mutilation for approximately 2 weeks. Note this technique can be used alone or in combination with dorsal nasal splitting to gain additional exposure to the septum (Plate 150).

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Plate 149



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Plate 150 Dorsal Nasal Splitting Technique to Enhance Exposure of Septum

DESCRIPTION

To enhance exposure of the nasal septum for tumor resection, incising the thin dorsal nasal cartilage enhances exposure of the more caudal aspect of this structure. This can be combined with the septal resection technique (Plate 149) or used on its own, depending on the location of the septal mass.

SURGICAL TECHNIQUE

(A) Outline of the nasal planum. The dashed line represents the dorsal nasal incision and elevation of the rostral portion of the nasal septum, as noted in Plate 149.

(B) Following full-thickness division of the thin layer of the dorsal nasal planum and creation of the rostral septal flap, skin hooks can be used to retract the incised borders giving wider exposure of the nasal septum. The dashed line represents the area of resection of the septal growth.

(C) Closure of the dorsal nasal incision and replacement of the external septum of the planum. Interrupted intradermal sutures can be used to realign the dorsal nasal incision. External 3-0 or 4-0 absorbable sutures can be considered for closure using a simple interrupted pattern.

COMMENTS

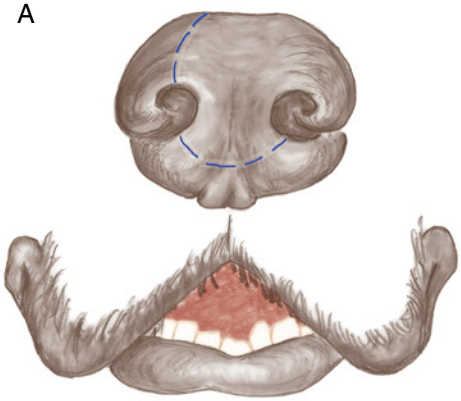
The author developed this technique to provide additional caudal exposure of the cartilaginous nasal septum, facilitating tumors confined to this structure. The nasal tissue is comparatively thin at the incision site, making this procedure relatively simple to perform. With the exception of the linear scar created from the dorsal incision, postoperative functional and cosmetic results are excellent. Any future inspection of the surgical area can be easily performed by insertion of a scope through both nostrils. The dorsal access incision can be used without elevation of the external nasal septum (Plate 149) for those lesions located in the caudal cartilaginous septum.

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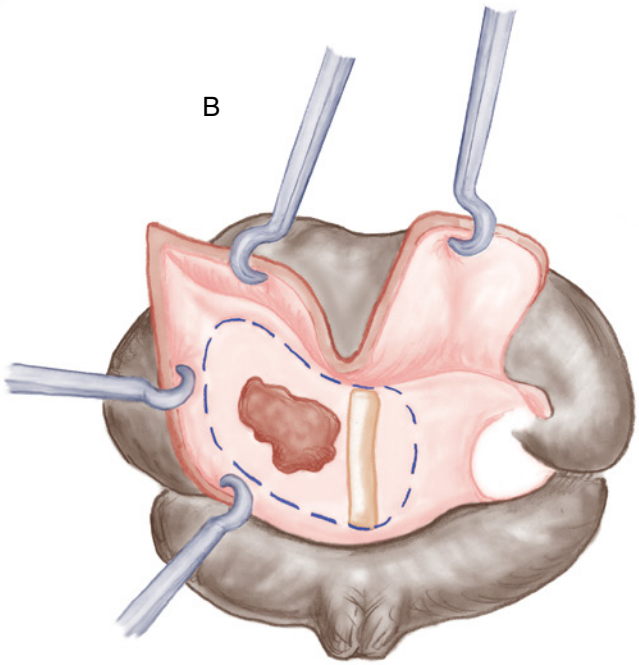
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Plate 150

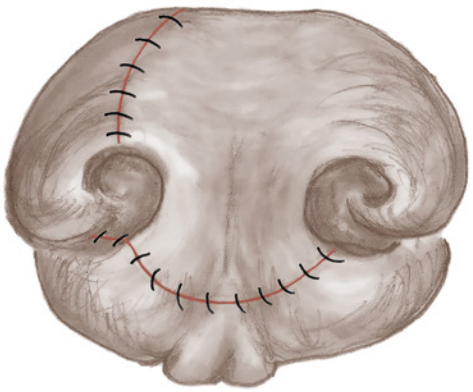
A



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C



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Plate 151 Alar Fold Flaps

DESCRIPTION

Nasal planectomy generally is reserved for the removal of invasive tumors. The lateral nasal cartilage or alar folds are not involved in the disease process in some cases. In this example, a subtotal planectomy is performed and a "nose" is fashioned from the lateral cartilages to improve cosmetic results and help shelter the exposed nasal mucosa from irritation secondary to environmental exposure.

SURGICAL TECHNIQUE

(A) Outline of resection of a malignant tumor.
(B) Complete resection of the rostral lip, philtrum, and nasal planum. The alar folds, not involved in the disease process, were preserved. The dashed lines represent the tips of the alar folds that require resection.
(C) The folds are rotated upward, the cut ends of which are sutured together.
(D) The dorsal borders of the alar folds are sutured to the adjacent cutaneous border. The dashed lines represent the site for bilateral full-thickness labial advancement flap incisions.
(E) The bilateral advancement flaps of the lip are sutured together in three layers: mucosal, musculofascial, and cutaneous surfaces independently. Note that the dorsal mucosal borders of the labial advancement flaps are sutured to the mucosa along the gingival border.
(F) The skin incisions are sutured to complete the procedure.

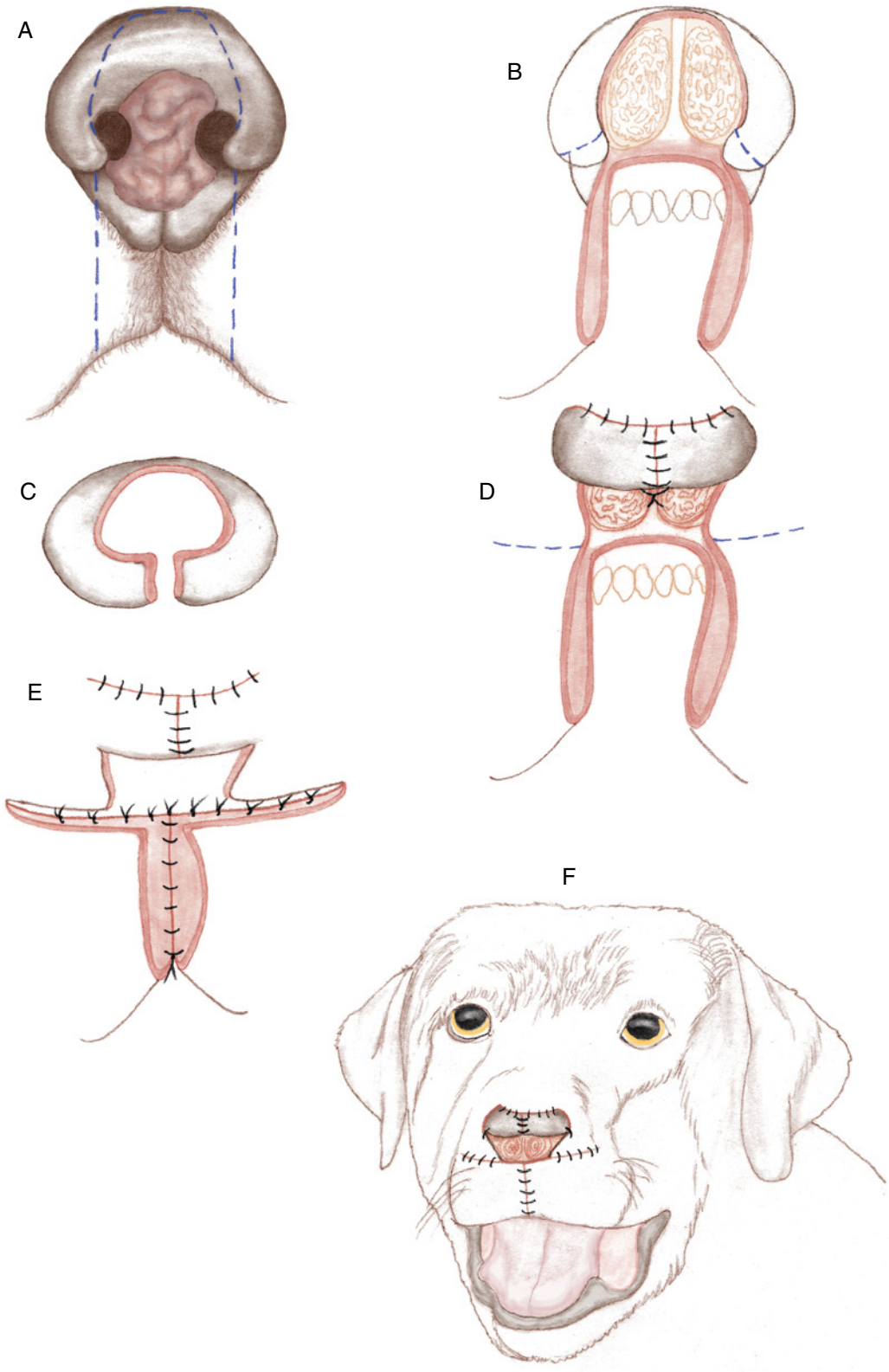
COMMENTS

This is one option for creating some semblance of a pigmented nose for the dog. It must be stated that obtaining surgical margins is a priority in cancer surgery and should not be sacrificed at the expense of obtaining a more satisfactory cosmetic outcome. However, indiscriminate removal of tissues in the absence of clinical judgment is unsatisfactory. Computer-aided tomography may be useful to help define the limits of the tumor. An Elizabethan collar should be used to prevent rubbing and pawing of the area postoperatively. Nasal discharge should be expected: cleaning with moistened, cotton-tipped applicators should be gentle and minimized during the first 10–14 days after surgery.

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Plate 151



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Plate 152 Musculofascial Island Labial Flap

DESCRIPTION

With extensive tumor invasion, the nasal planum and rostral upper labial tissues may require wide resection to achieve adequate surgical margins. Adjacent labial tissue can be used to reconstruct the nasal defect.

SURGICAL TECHNIQUE

(A) The dashed lines represent the limits of surgical removal of a neoplasm, which has extensively invaded the nasal planum.

(B) Resection of the entire nasal planum and rostral labial area.

(C) A full-thickness incision is made approximately 3–4 cm from the rostral border of the remaining (left) lip in this clinical example. The dashed lines define the area where the skin will be dissected free of the underlying musculofascial pedicle. The arrows signify the similar site for mucosal resection.

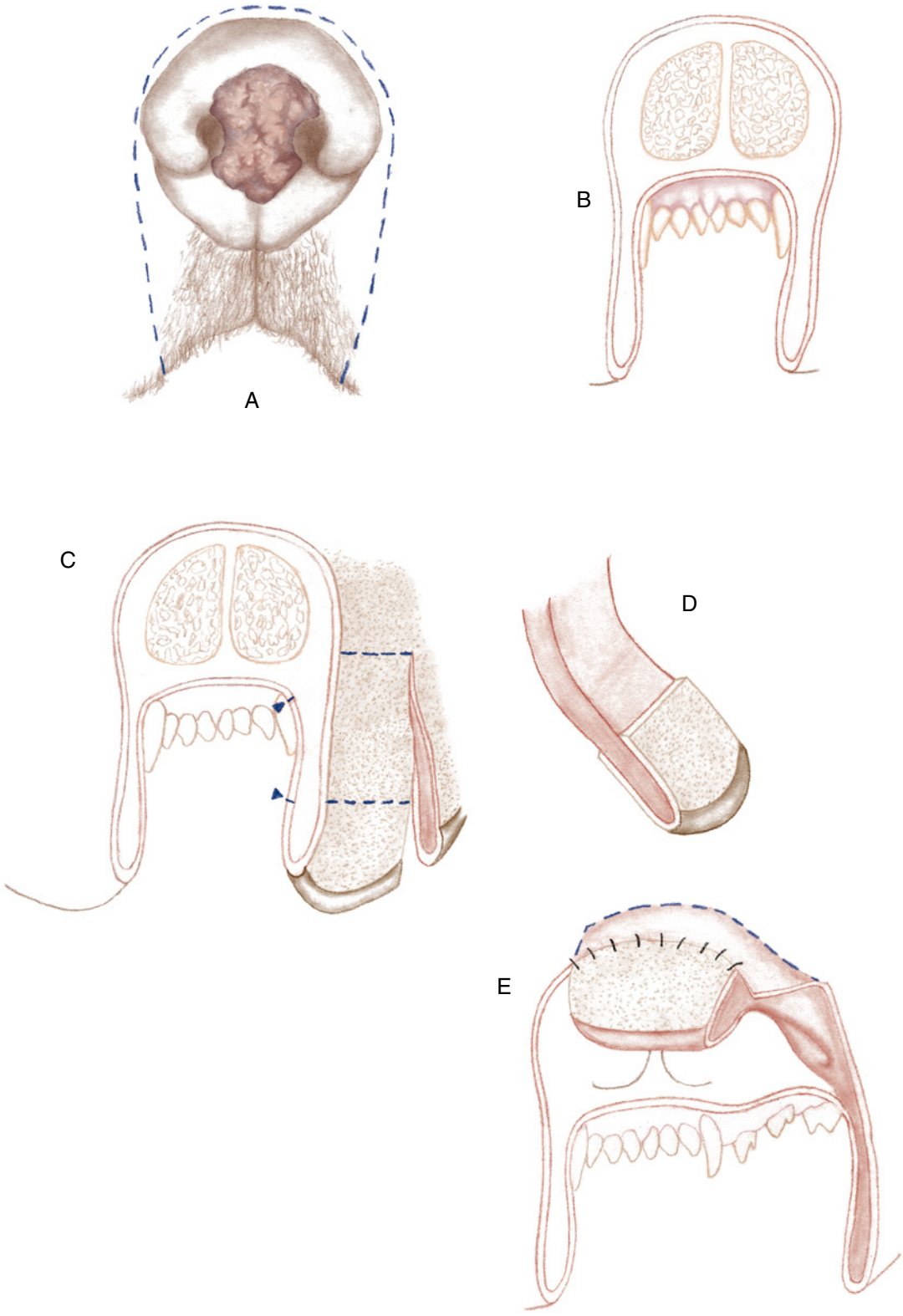
(D) A musculofascial flap is created with a terminal island of labial epithelium (skin, labial margin, labial mucosa).

(E) The musculofascial island flap is rotated upward and placed over the exposed nasal cavity. Skin borders are trimmed to create a symmetric labial island, prior to suturing the opposing cutaneous borders (3-0 monofilament, nonabsorbable sutures). The flap's labial mucosa is sutured in a similar fashion, using absorbable sutures. The musculofascial pedicle is covered by the advancing facial skin.

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Plate 152



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Plate 152

(Continued)

(F) Bilateral full-thickness labial advancement flaps are created (dashed lines) to close the labial defect.
(G) Mucosal borders (lip to gingiva, lip to lip) are apposed with absorbable sutures; skin is sutured with nonabsorbable sutures. The middle musculofascial layer of the lips also can be sutured to further minimize the risk of postoperative wound dehiscence.
(H) Completion of the closure. The transplanted lip now covers a single, large, common nasal opening.

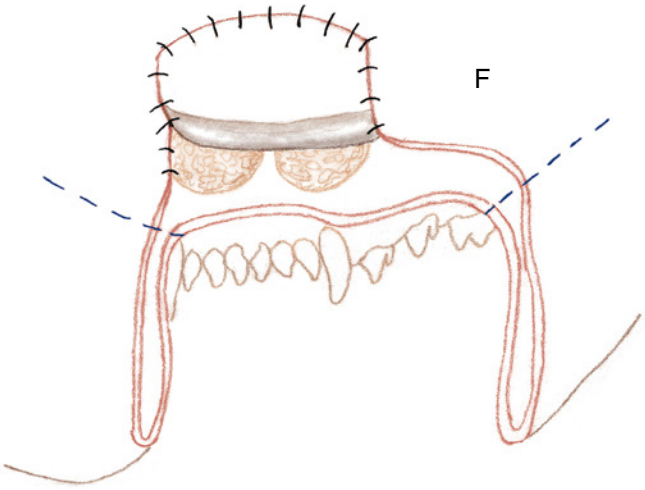
COMMENTS

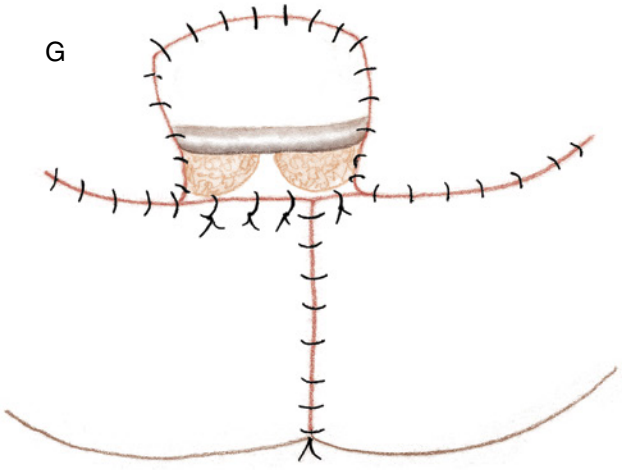
The island labial flap creates a protective "canopy" over the nasal mucosa and exposed cartilage borders. There is a more natural appearance in both frontal and side views of the patient. The bilateral labial advancement flaps can be trimmed of redundant skin and mucosa in order to give a more natural rostral curvature to the recreated lip. Otherwise, the reconstructed lip will be somewhat wider and straighter than the original labial silhouette. This is a somewhat minor cosmetic consideration. Another option to consider is the "lip-to-nose" ("lip-to-lid" variation), as illustrated in Plates 154 and 155.

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Plate 152







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Plate 153

Labial Mucosal Inversion Technique

DESCRIPTION

Gallegos et al. (2007) reported a labial mucosal technique for closure of defects involving the nasal planum and adjacent rostral labial tissue in two dogs. The technique involves inverting the labial mucosa by suturing the adjacent labial mucosal borders around the circumference of the resected nasal cartilage. This is followed by apposition of the opposing labial margins. The infolded or inverted mucosa forms a recessed antechamber to the nasal cavity.

SURGICAL TECHNIQUE

(A) Resection of the external nose and adjacent labial tissue.

(B) The adjacent labial mucosal borders are secured with sutures to the circumference of the incised edge of the remaining nasal cartilage. The curved arrows denote the elevation of the incised labial mucosal margins toward the dorsal midline. The asterisks identify the final location of the incised edges of the lower labial area. See (C).

(C) The labial mucosa sutured around the circumference of the nasal cartilage border. Note that a portion of the labial margins is resected (brackets): this will allow for apposition of these opposing cut surfaces to reestablish the labial midline beneath the nasal area. An incision also is created in the labial mucosa from the left to right side: the solid line represents the midpoint (M) of this mucosal incision. The dashed lines represent the location where this mucosal incision will fold on itself (curved arrows). Absorbable sutures are used to secure this mucosal incision. The closure of this mucosal incision will separate the oral and nasal compartments.

(D) The opposing (excised) labial borders are sutured together in two layers (mucosa, skin), completing the procedure. The faint dotted line represents closure of the mucosal incision described in (C). The pigmented labial margin borders the mucosal antechamber to the nasal cavity.

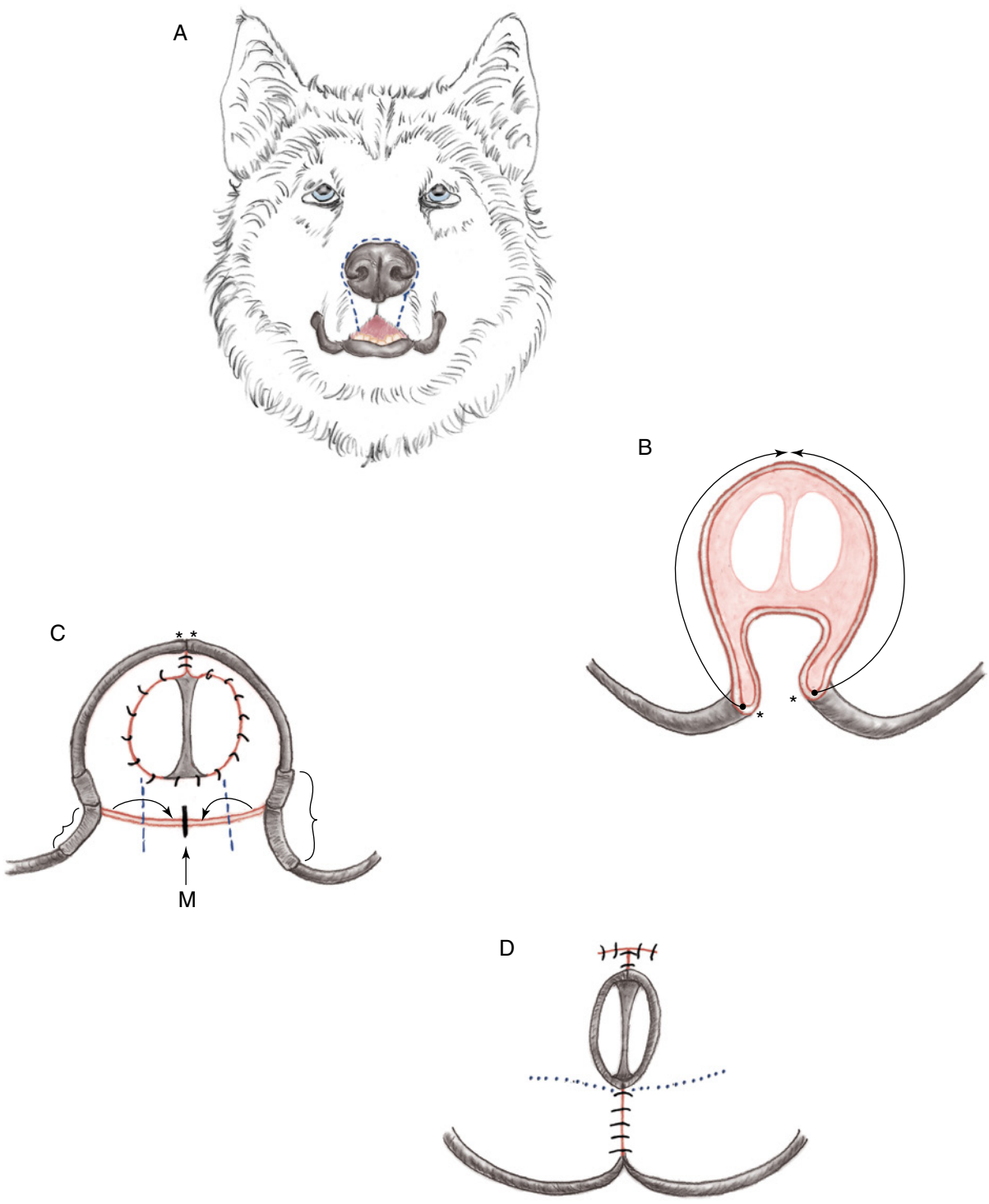
COMMENTS

The procedure reportedly provides a better cosmetic result than nasal planectomy alone, although other reconstructive techniques (in this chapter) also are available to improve functional and cosmetic results. The folded labial margins create a labial mucosal antechamber, cloaking the nasal cavity. This provides an elliptical labial opening, protecting the delicate nasal mucosa from direct exposure to the external environment.

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Plate 153



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Plate 154 Nasal Reconstruction ("Lip-to-Nose") with the "Lip-to-Lid" Technique Variation

DESCRIPTION

This technique is an effective adaption of the author's "lip-to-lid" procedure for reconstruction of the upper or lower eyelids (see Plate 126). In this procedure, a labial flap is used to reconstruct the lateral half of the nose, with the mucosa replacing the loss of the nostril after tumor resection. The pigmented labial border can improve the cosmetic results.

SURGICAL TECHNIQUE

(A) Outline of the nasal resection.

(B) Outline of the labial flap. The width of the labial flap is determined by measuring the semi-circular arc of the dorsolateral margin of the nostril to be resected. Note that pigmented labial margin of the flap will curve slightly in an attempt to copy the natural arc of the outer nostril. This slight arc can avoid creating a narrow (straight-slit) nostril opening once sutured into position. (It is advisable to make a flap wider than anticipated to offset elastic contraction ["shrinkage"] that occurs after its elevation.)

(C) Elevation and division of the dorsal mucosal border. The mucosal rectangle attached to this compound flap will replace the mucosal surface lost to tumor resection, thereby reducing the risk of nasal stricture formation.

(D) Small tacking sutures are used to align the dorsal and ventral borders of the flap's mucosal margin to the remaining nasal mucosal borders. This is followed by placement of the skin sutures. Note the labial border of the flap should slightly bend outwards when suturing the skin margins.

(E) Closure of the donor area of the lip. The mucosal defect is closed with absorbable sutures followed by closure of the skin.

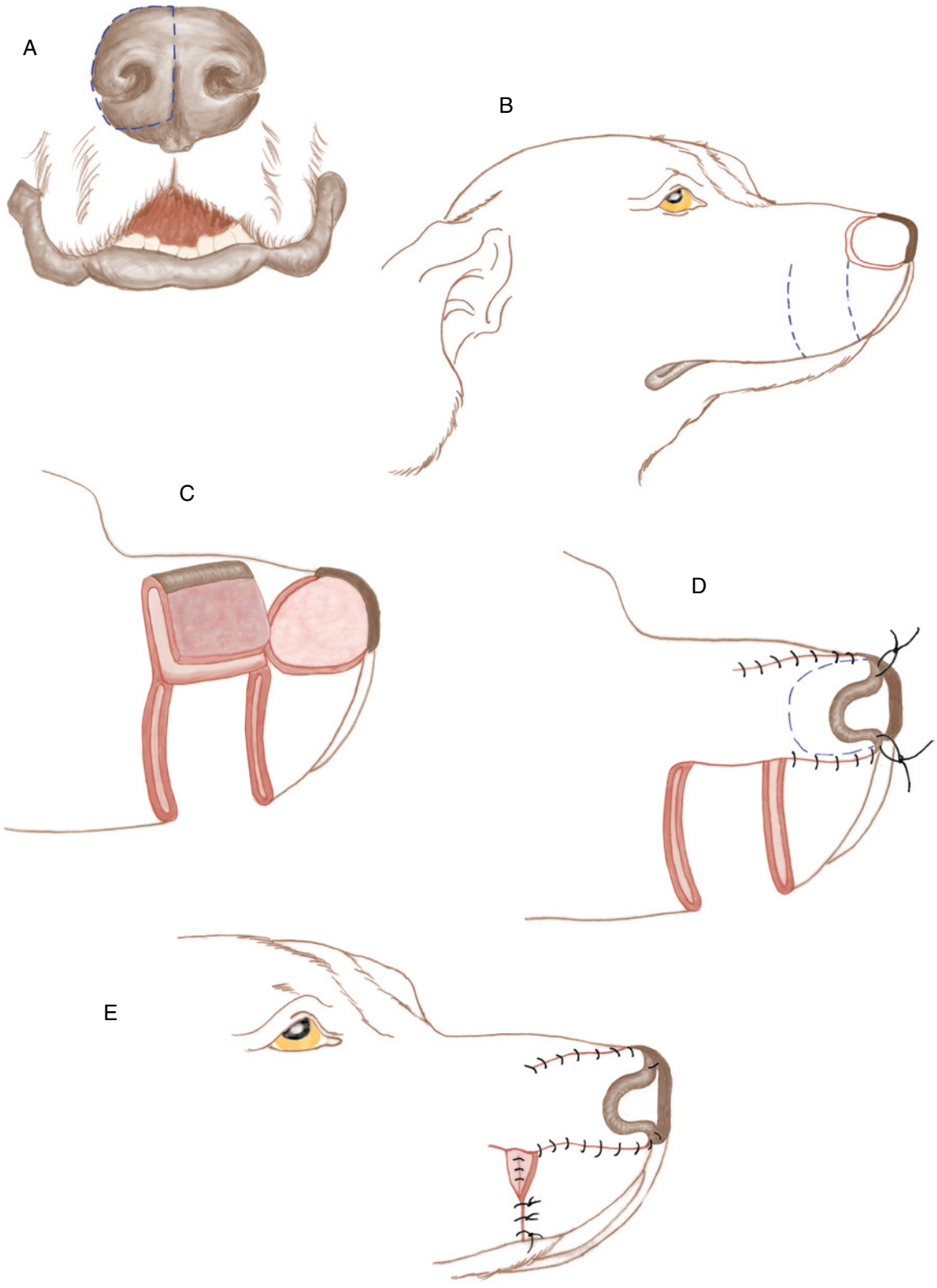
COMMENTS

This variation of the lip to lid procedure is a useful option to reconstruct the lateral nasal area and restore the integrity of the nasal meatus. It is an option for patients with unilateral or bilateral nasal stenosis. The dark pigmented labial border forms a natural surface to match the pigmented surface of the external nasal planum.

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Plate 154



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Plate 155 Nasal Reconstruction Using the "Lip-to-Nose" Technique in Cats

DESCRIPTION

A variation of the lip-to-lid procedure.

SURGICAL TECHNIQUE

(A) Nasal tumor in a cat.

(B) Outline of a full-thickness labial flap. The width of the labial flap is determined by measuring the semi-circular arc of the dorsolateral margin of the nostril resected (see Plate 154). Note that the pigmented labial margin of the flap will curve slightly in an attempt to copy the natural arc of the outer nostril. This slight arc can avoid creating a narrow (straight-slit) nostril opening once sutured into position. (It is advisable to make a flap wider than anticipated to offset the elastic contraction ["shrinkage"] that occurs after its elevation.)

(C) Full-thickness labial flap elevation and division of the dorsal mucosal border. The mucosal rectangle attached to this compound flap will replace the nasal mucosal surface lost to tumor resection, thereby reducing the risk of nasal stricture formation.

(D) Small tacking sutures are used to align the dorsal and ventral borders of the flap's mucosal margin to the remaining nasal mucosal borders. This is followed by placement of the skin sutures. Note that the labial border of the flap should slightly bend outward when suturing the skin margins. The donor labial defect is closed (mucosal closure followed by skin closure using absorbable sutures). The mucosal defect is closed followed by closure of the skin using absorbable sutures.

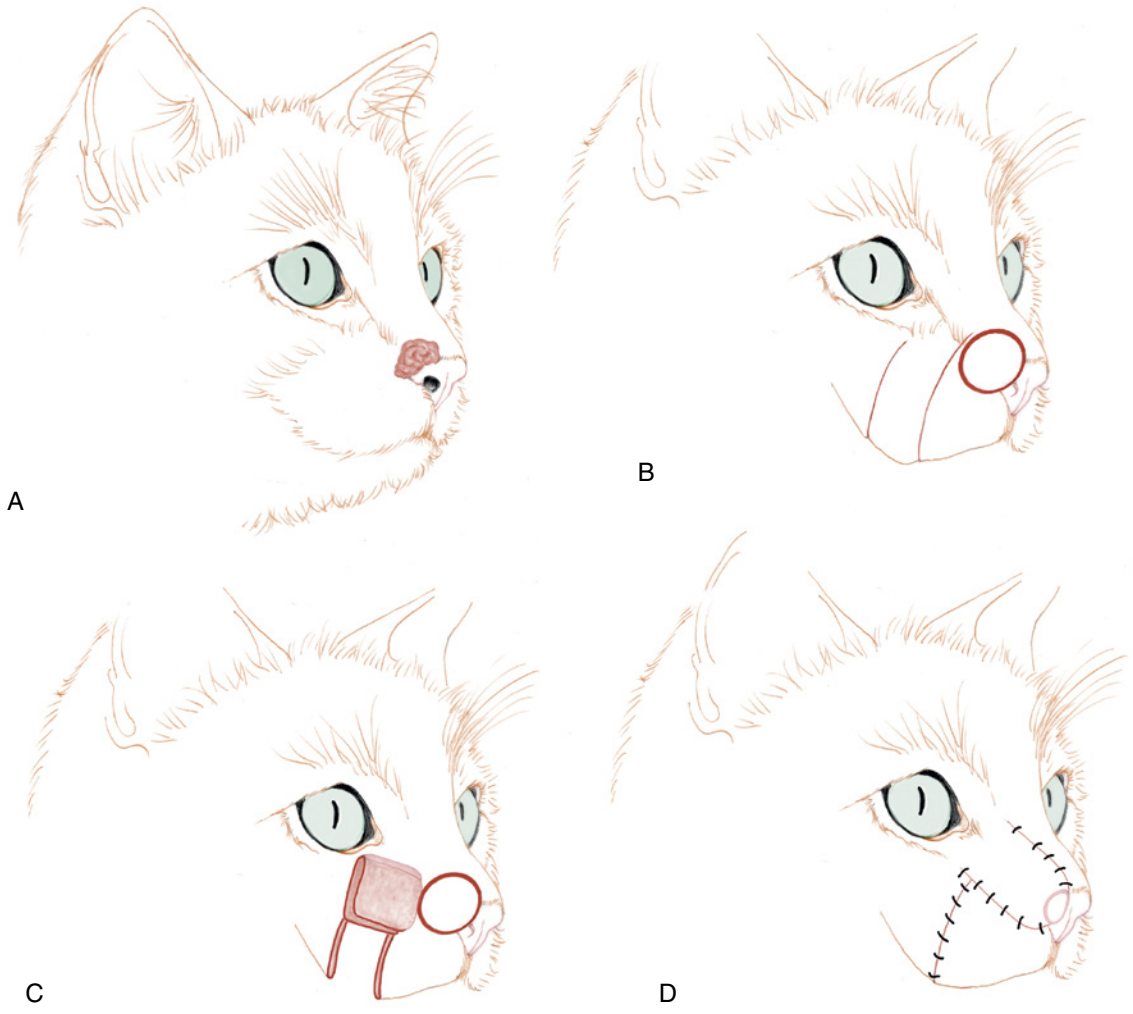
COMMENTS

This variation of the lip-to-lid procedure is a useful option to reconstruct the dorsolateral nasal area and restore the integrity of the nasal meatus in cats as well as dogs (Plate 154). The pigmented labial border forms a more natural mucocutaneous margin for the external nasal planum.

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Plate 155



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Plate 156 Oral Mucosal Graft with Nasal Stenting

DESCRIPTION

Plastic tubing serves as a nasal stent to which an inverted mucosal graft is applied and sutured to itself. The stenotic nostrils are dissected open and dilated to accommodate insertion of the graft stent. The exposed tubular submucosa is revascularized from its contact with the granulation tunnel. Once healed, the plastic stent tube is removed.

SURGICAL TECHNIQUE

(A) Illustration of bilateral stenotic nares secondary to loss of mucosa normally covering the circumference of the nostrils.

(B) The collapsed nostrils are dissected open and dilated. Scar tissue can be resected with a no. 11 blade to create a circular tunnel for the mucosal covered stent. (A dorsal access incision illustrated in Plate 150 can be used to facilitate this procedure.) The stent tubing can be used to determine the appropriate size of the circular opening formed.

(C) The largest-diameter tubing that will fit into the nasal tunnel created is selected for graft application. The length of tubing/graft required to traverse the fibrotic zone is measured to gain access to the nasal cavity. The width of the graft is determined by measuring the outer surface area of the stent tube. The mucosal surface is inverted, with the submucosal surface facing outward. The graft is sutured along the length of the apposing seam with absorbable sutures.

(D) The completed stent–graft is inserted into the prepared nasal tunnel, followed by securing the plastic tubing into position using external sutures to the external meatus recreated. In 7–10 days, the plastic stent is removed. An Elizabethan collar is used to protect the nose from rubbing or pawing throughout this postoperative period.

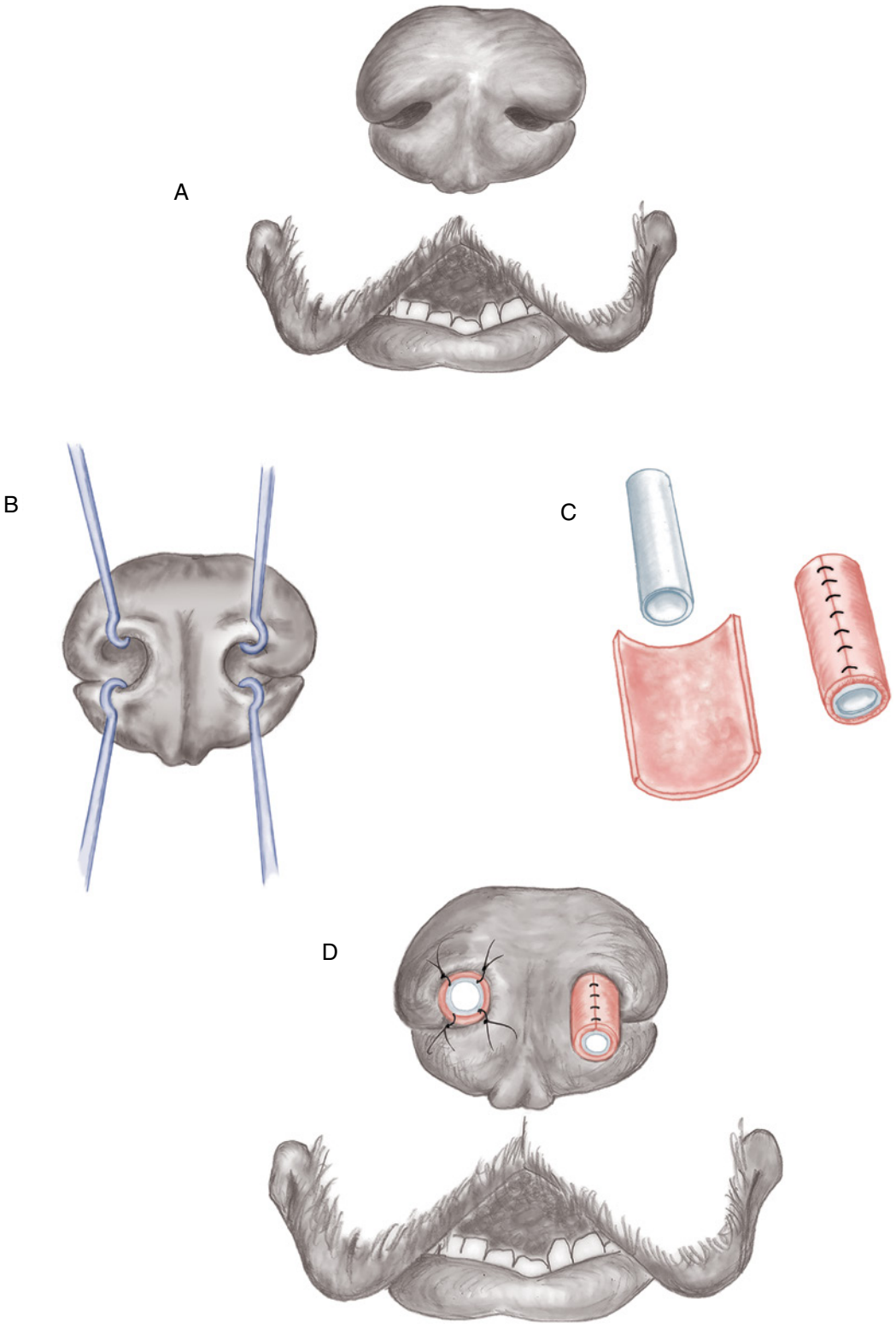
COMMENTS

This technique is rarely used. Its efficacy requires forming a mucosa-lined tunnel that does not shrink or collapse after removal of the plastic tube. One potential option to counteract any collapse that might occur, after a successful graft take, is to use an expandable stent if this occurs. As noted, spitting the dorsal nasal area (Plate 150) may be considered to facilitate removal of the scar tissue and positioning the tube/mucosa.

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Plate 156



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Plate 157 Intranasal Septal Window Technique

DESCRIPTION

With the unilateral loss of a nostril secondary to extensive trauma or tumor resection, one option to allow air flow through the obstructed nasal cavity is to create a large window in the intranasal septum. This allows air to pass from the compromised nasal passage through the intact contralateral nasal passage and nostril.

SURGICAL TECHNIQUE

(A) In this example, the left half of the external nose and associated nasal tissue was resected as a result of neoplasia. Access to the lateral nasal cavity may be performed at the time of tumor excision, through the same excision. If this is not feasible or required, a lateral access incision is used to expose the lateral nasal bone. The area outlined is removed with a Hall air drill.

(B) Any nasal turbinate tissue obscuring the septum is resected. A no. 11 or no. 15 scalpel blade can be used to incise the cartilaginous septum. Curved surgical scissors or sharp bone rongeurs can be used to trim a large window, exposing the opposite nasal cavity. Removal of the central 25–30% of the nasal septum is suggested to ensure air passes easily through this window postoperatively.

(C) In this example, the lateral access incision was advanced to the rostral incision: the skin is sutured to the nasal defect and the lateral nasal access incision is closed accordingly.

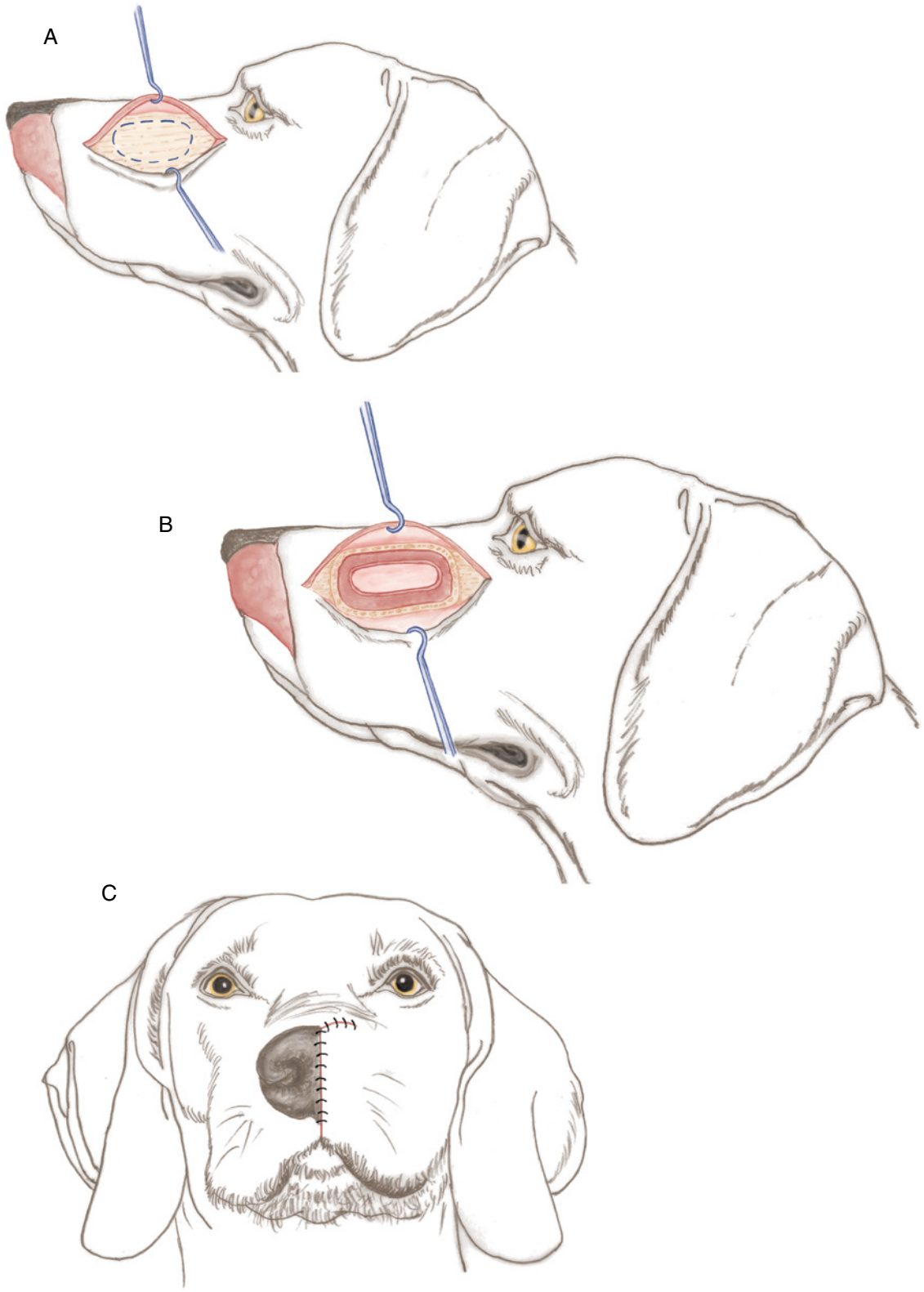
COMMENTS

This procedure has the added benefit of allowing the patient to clear the compromised nasal passage by sneezing or snorting of normal mucus and tissue fluid accumulation. It also can eliminate intranasal pressure when the patient attempts to exhale through the nasal passages (see Fig. 20-15).

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Plate 157



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Plate 158 Cantilever Suture Technique

DESCRIPTION

Rostral maxillectomy can result in the ventral collapse or drooping of the nasal cartilage. This downward deviation can decrease the ability of the dog to breathe through each common nasal meatus. This cosmetic and functional defect can be offset by using a buried mattress suture to elevate the nasal cartilage.

SURGICAL TECHNIQUE

(A_1, A_2) Rostral maxillectomy for an oral neoplasm, with subsequent closure, using the upper labial mucosa. Loss of this tissue support can result in significant ventral deviation of the nasal cartilages.

(B) Downward deviation of the nasal cartilage is assessed on completion of rostral maxillectomy. Placement of the dog in sternal recumbency and elevation of the head will enable the surgeon to determine the severity of the nasal cartilage deviation. Those patients with pronounced deviation are candidates for this technique.

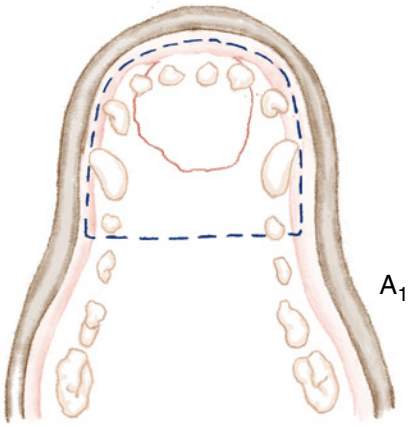
(C) A midline skin incision, 3–5 cm long, is made over the muzzle, rostral to the medial canthus of each eye. The skin is undermined and retracted to expose the bone. Self-retaining retractors will facilitate exposure.

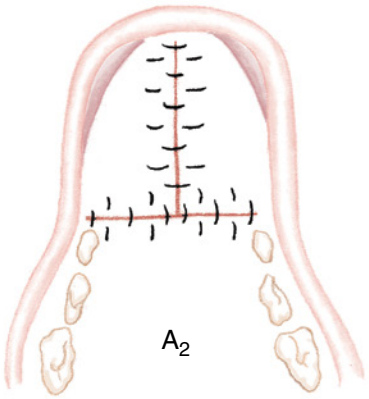
(D_1, D_2) A small (1/16 inch) Steinman pin is inserted into a Jacobs pin chuck. The pin is driven below the silhouette of the nasal bone to the opposite side, as illustrated. A 16- or 18-gauge needle is placed in the hole, serving as a guide for the threading of 0 or 1 monofilament polypropylene suture strands. A long, straight cutting needle is preferable. One or two sutures may be employed, depending on the size of the patient.

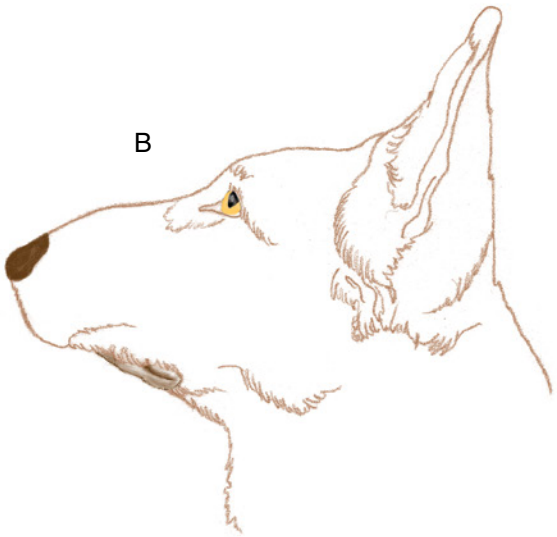
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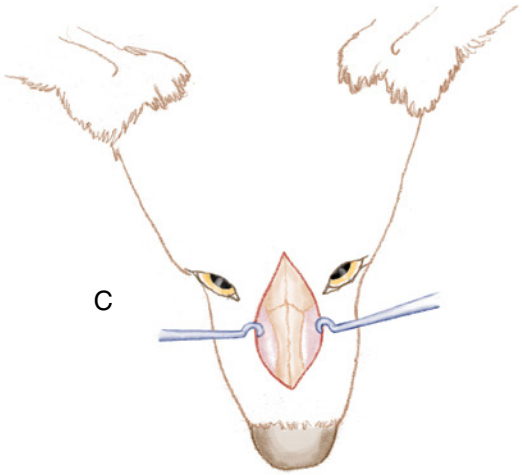
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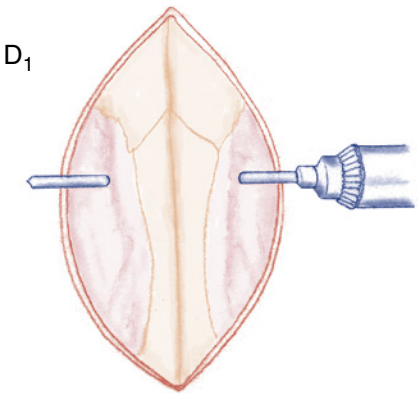
Plate 158

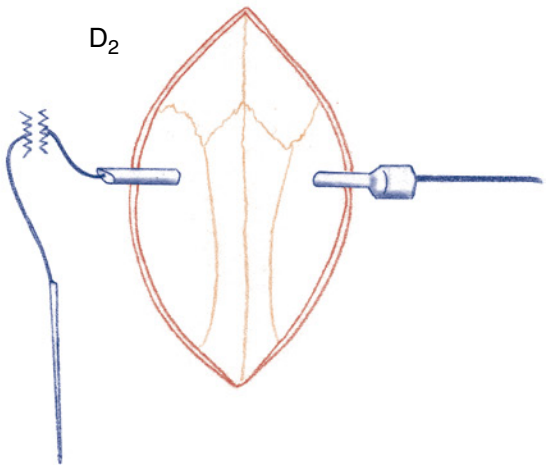












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Plate 158

(Continued)

(E) A 1 cm incision is made through the epithelial surface of each lateral cartilage, as illustrated. The illustration shows the general course of the cantilever suture.

(F) A close-up view of the nasal cartilage. The straight needle is passed beneath the epithelial surface and guided out of the lateral cartilage incision (the left incision in this example). The needle is redirected across the nasal cartilage and out of the opposite incision. The straight needle then is directed back to the original midline incision.

(G) The first throw of a surgeon's knot is used to help assess the most appropriate tension to apply to the cantilever suture before completing the knot.

(H) The dorsal incision is closed. The lateral nasal cartilage incisions do not require suture closure. The cantilever suture recesses into cartilage below the epithelial surface, partially collapsing these access incisions.

COMMENTS

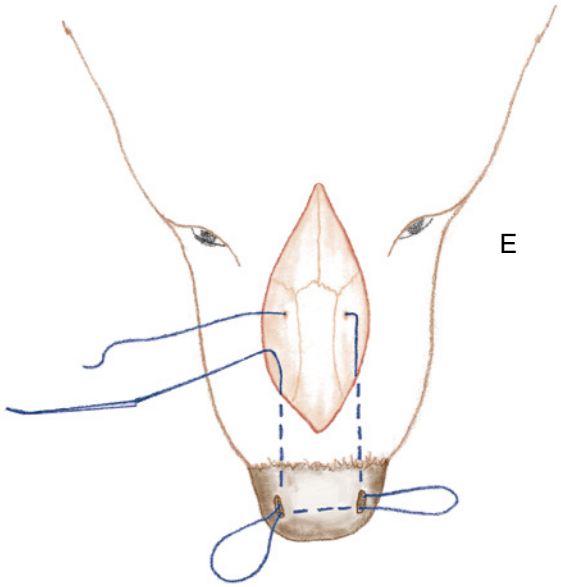
This technique can be quite effective in elevating the nasal cartilage. However, tightening the suture will create a depression or dimple in the lateral nasal cartilages. Although this could be avoided by making deeper access incisions, there is greater purchase of cartilage by using the technique illustrated. An Elizabethan collar is advisable during the first 10–14 days after surgery. (See Fig. 20-16.)

In one clinical case, the dog struck its nose several months later, resulting in a small amount of ventral deviation of the nasal cartilage. This particular patient did not require reoperation.

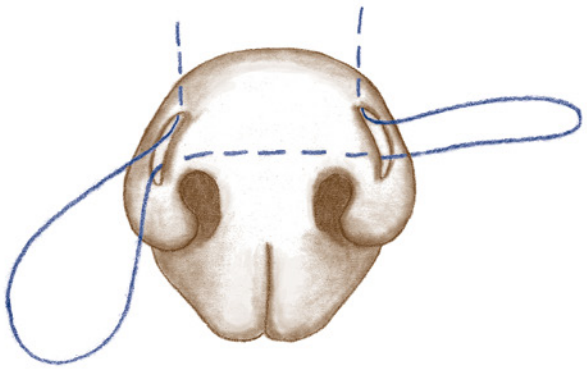
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Plate 158



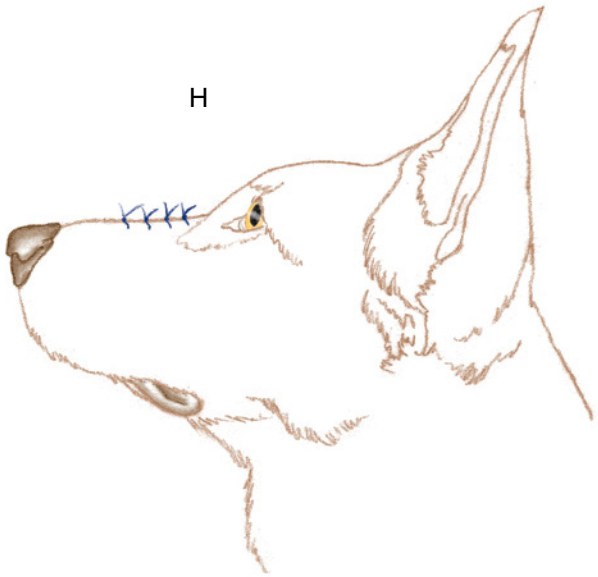
E



F



G



H

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Plate 159

Alar Fold Lift-Up and Sulcus Pull-Down Techniques for Feline Stenotic Nares

DESCRIPTION

Combining the alar fold lift-up and sulcus pull-down techniques is a simple and effective method of correcting stenotic nares in cats. This procedure requires the removal of small segments of skin using a 4 mm biopsy punch or no. 15 scalpel blade, dorsolateral to the alar folds and ventral to the sulcus. Closure of the cutaneous defects will elevate the alar folds and draw the excessive fold of skin ventral to the sulcus. Because the skin in both areas is affixed to the underlying tissue fascia, stretching or relaxation of the skin has not been noted in the author's long-term study on cats.

SURGICAL TECHNIQUE

(A) Illustration of the facial profile of a brachycephalic cat (left) in comparison to a domestic shorthair cat (right). Along with the flattened facial silhouette of brachycephalic cats, the external nose also is smaller than in other cat breeds.

(B) A 4 mm punch is used to resect a skin segment dorsolateral to the adjacent alar fold, followed by removal of the cutaneous plug.

(C) The dorsolateral punch defect is closed with 4-0 absorbable poliglecaprone sutures.

(D) This is followed by skin punch placement in the slight downward curvature of the skin rostral to each nasal sulcus.

(E) The procedure is performed bilaterally for completion of the alar fold lift-up and sulcus pull-down procedures. (Source: Pavletic MM, Trout NJ. 2023. Successful correction of stenotic nares using combined Alar Fold Lift-up and Sulcus Pull-down techniques in brachycephalic cats: 8 cases (2017–2022). *J Am Vet Med Assoc* 261(9):1–5. Reproduced with permission of The American Veterinary Medical Association.)

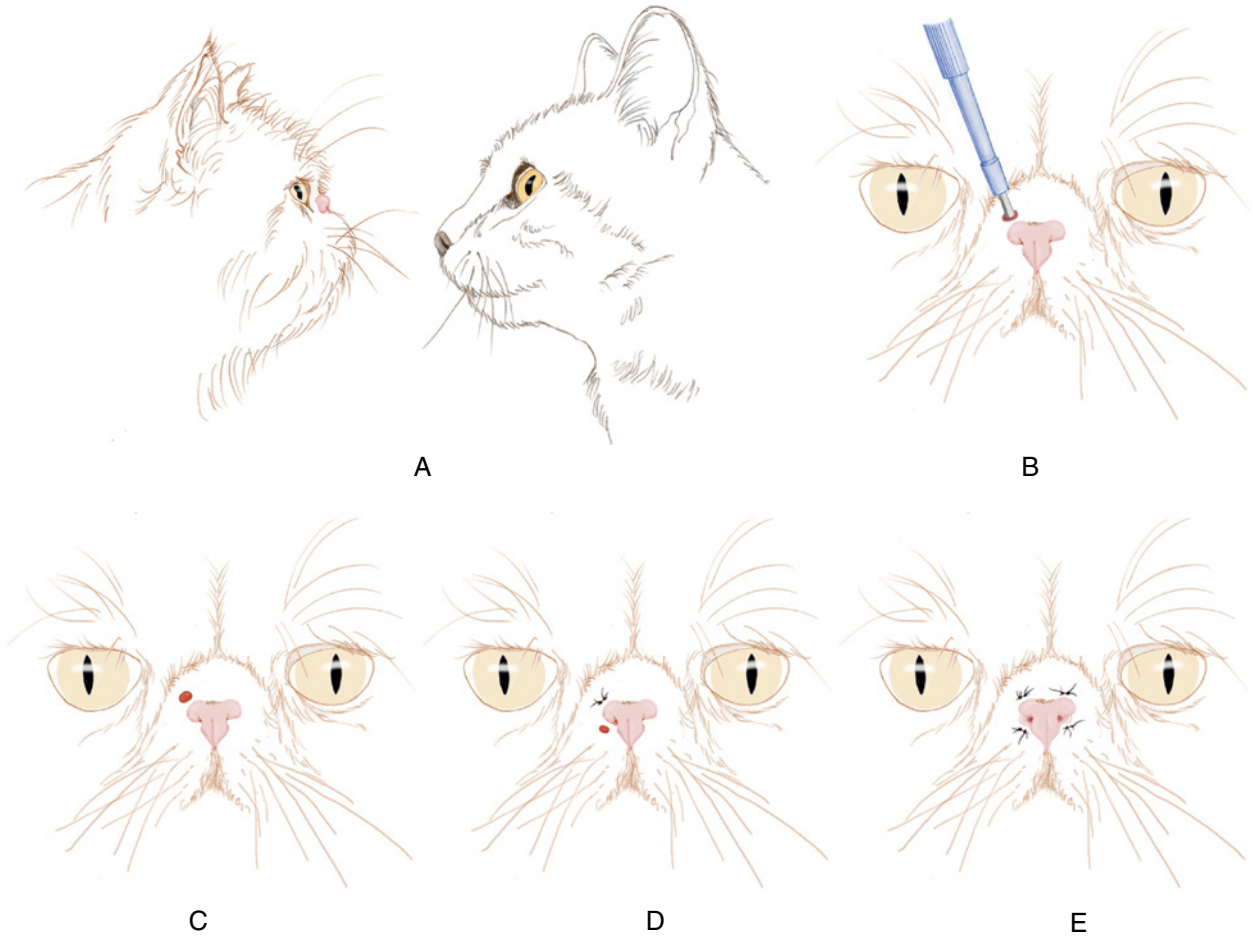
COMMENTS

Poiseuille's law basically defines a 16-fold increase in air-flow resistance with a 50% decrease in airway radius. As a result, relatively small improvements in the radius of the nostril can dramatically improve nasal breathing. This simple method of correcting feline stenotic nares can be performed on an outpatient basis. No special instrumentation is required. There is no alteration of the external nose compared to the other techniques in the feline veterinary literature. Bleeding and postsurgical pain are minimal. (See Fig. 20-18).

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Plate 159



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Plate 160

Alarplasty for Stenotic Nares in Brachycephalic Dogs

DESCRIPTION

Vertical wedge resection of the lower alar margins is a simple and effective method of correcting stenotic nares in brachycephalic dogs. The second common surgical option is ala-vestibuloplasty, in which the ventral portion of the alar folds is excised using a scalpel blade or surgical laser.

SURGICAL TECHNIQUE

(A_1) Outline of the vertical wedge resection of the ventral alar folds (dashed lines).

(B_1) A no. 11 scalpel blade is used to resect each wedge. The wedge can be enlarged intraoperatively if a trial suture does not show the desired enlargement of the nostril. The incisions are normally closed with absorbable 4-0 poliglecaprone interrupted sutures.

(A_2) Ala-vestibuloplasty (Trader's technique). This procedure requires the horizontal resection of the lower portion of each ala (dashed lines).

(B_2) Resection can be performed with a no. 15 scalpel blade or surgical laser. The open defect heals by second intention.

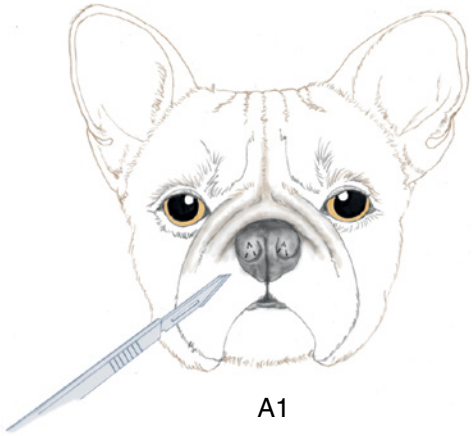
COMMENTS

Poiseuille's law basically defines a 16-fold increase in air-flow resistance with a 50% decrease in airway radius. As a result, relatively small improvements in the radius of the nostril can dramatically improve nasal breathing. There are several techniques in the literature for correcting stenotic nares in brachycephalic dogs. In general, all of these procedures will enlarge the nostrils to a variable degree. There is no comparative clinical study on which procedure is "best." One study using silicone molds of the external nose of a French bulldog (Franklin et al. 2023) indicated that ala-vestibuloplasty resulted in a larger nasal opening. Limitations of the study include the fact that silicone does not accurately replicate the tissues comprising the external nose in the dog or its normal mechanical function. Selection is in part the preference of the surgeon as well as their technique and personal postoperative results. My current preference is vertical wedge resection based on its simplicity, beneficial postoperative results, and the more natural cosmetic outcome.

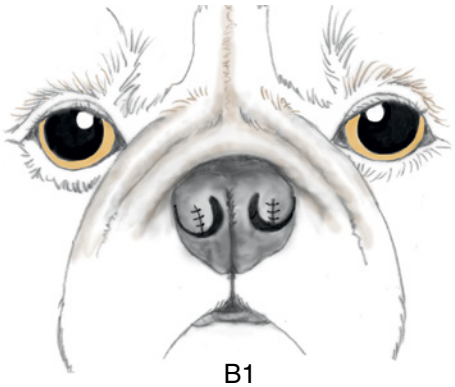
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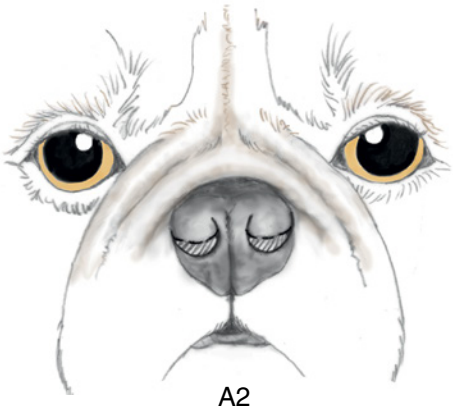
Plate 160



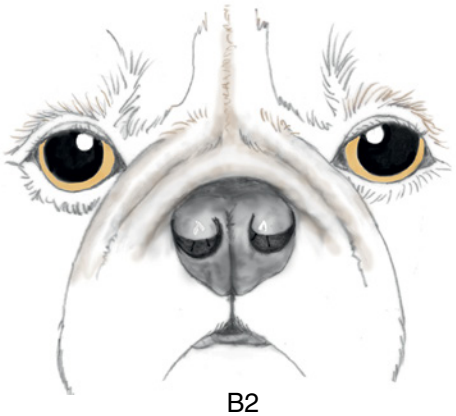
A1



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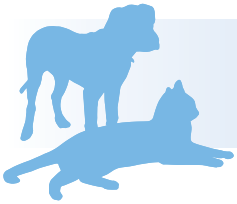
A2



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21

Cosmetic Closure Techniques

Cosmetic Considerations *840*
Causes of Scars *840*
Minimization of Scarring *840*
Dog-Ears *842*
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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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COSMETIC CONSIDERATIONS

Surface scars generally are considered secondary in importance to the successful closure of a wound. The veterinarian is frequently relieved when a large open wound finally is covered with an epithelial surface and considers the final product, in relative terms, superior to the original wound. Today, most owners are aware of the advances in human cosmetic surgery. More individuals expect a higher-quality surgical "product" for the money spent on their pets. Owners naturally take great pride in their pets' appearance. Breeders and trainers of show dogs wish to conceal scars and blemishes that detract from their canine and feline investments. Even the less particular owners occasionally judge the overall quality of a surgery by the visible component: the quality of the closure.

The author has not been a proponent of cosmetic surgery in animals for the sake of cosmetics alone. However, the veterinary surgeon should know how to minimize scarring and optimize cosmetic results when surgery is required to close a wound, excise tumors, or remove unstable scars. Indeed, one of the greatest achievements of a surgeon is the successful restoration of function to a damaged area without leaving a visible scar as a reminder.

CAUSES OF SCARS

All wounds heal, to a variable degree, by scar tissue, and owners must be advised of this inevitable result. The surgeon has the potential to modify the size and severity of the scar and mask its presence. A basic understanding of the causes of excessive scar formation is necessary to help "control" this process.

As noted in Chapters 2 and 3, open wounds can heal by wound contraction and epithelialization. Initially, elastic retraction of skin edges and severe tissue trauma can make accurate assessment of the wound difficult. As inflammation and swelling subside, the true magnitude of the injury is more apparent. The subsequent decrease in skin tension enables wound contraction to proceed. If sufficient skin peripheral to the wound is available, centripetal advancement of skin over the defect proceeds over the first 6 weeks. Thereafter, the remainder of the open wound must close primarily by epithelialization. In veterinary medicine, wound contraction is largely a beneficial response when loose skin is present to promote myofibroblastic contraction. Full-thickness movement of the skin over the wound minimizes the size of the epithelialized scar. In contrast, those processes that impede contraction result in wounds that require epithelial cell migration to complete the closure. Epithelialized scars lack the properties of normal skin. Moreover, in fur-bearing animals the poor cosmetic results are highlighted by the hairless patches that form, especially in animals that lack a dense hair coat. Gaping wounds are more likely to form visible epithelialized scars unless accurately approximated to minimize the width of the wound. In some cases, it may be more practical to resect scars on completion of healing by second intention to improve functional and cosmetic results (Fig. 21-1). There are occasions on which accurate apposition of a skin laceration can later result in "scar spread" or widening of the linear scar. This is secondary to the presence of skin tension or elastic retraction of the incisional closure site. If the scar is problematic, it can be resected at a later time, when regional skin relaxes by stress relaxation.

> Scar revision is easier to perform after second-intention healing is complete and regional inflammation has subsided.
>
> Scar excision is followed by accurate apposition of the healthy skin bordering the defect.

MINIMIZATION OF SCARRING

Surgical Technique

Meticulous atraumatic surgical technique helps to minimize scarring. Not all wounds closed by accurate approximation remain as thin scars. The elastic retraction of skin borders under tension may result in wider scars. Meticulous use of subcuticular patterns can help offset elastic retraction. W-plasty (Plate 162) and Z-plasty in humans also can position a major component of the scar into a neighboring skin fold or crease, thus hiding its presence. Alteration of the angle of incision relative to tension lines also reduces the visibility of the resultant scar. Relieving skin tension peripheral to a wound can help offset widening of the scar after primary closure. Carefully placed bandages can be used to protect the healing closure from external trauma or tissue disruption.

Suture Considerations

Suture patterns and suture materials and their duration of implantation can influence the severity of the scar. This is particularly true for the external skin sutures. Smaller-diameter suture materials enable the surgeon to use greater numbers of sutures for meticulous skin apposition. Everting

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FIG. 21-1 (A–C) Retriever with multiple fragile scars, as a result of vehicular trauma. This large scar (arrows) was overlying the right shoulder. (D, E) Several weeks after healing, scars were resected, and normal fur-bearing skin was apposed using a buried intradermal suture pattern followed by simple interrupted sutures (3-0 monofilament nylon). Improved cosmetic results were achieved, although selective areas had limited "scar spread" weeks after closure. Hair regrowth covered the smaller surgical scars.

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suture patterns (e.g., vertical mattress suture pattern) are preferable to patterns that invert skin edges. Inverted scars create shadows in areas with sparse hair growth. Similarly, improperly placed sutures that fail to sufficiently stabilize skin borders can result in inverted skin edges or undesirable "stair stepping," in which one skin border is elevated above the opposite skin edge. In thicker skin, split-thickness suture placement through the opposing dermal borders can accurately align skin margins and limit this displacement of cutaneous margins.

Early removal of sutures (within a week) reduces the likelihood of suture tract inflammation. The use of a fine (3-0 to 5-0) subcuticular pattern in combination with smaller-diameter skin sutures (3-0 to 5-0) provides an excellent means of supporting the skin. Alternate sutures are removed, beginning after day 5 in an uncomplicated wound. Skin tapes used to support skin wounds after early suture removal in human cosmetic surgery are not particularly well suited for use in small animals. Carefully placed bandages, however, can provide added protection to the wound, if necessary. Skin staples and surgical glues have been used for skin apposition in animals. Although a controlled study comparing cosmetic results is lacking, closure appears to be adequate for routine surgical use. Optimal apposition, however, still is best achieved by suturing by hand.

When feasible, skin incision and subsequent closure perpendicular to the direction of hair growth will cover the resultant scar more effectively. While this is likely to be irrelevant in breeds with dense and long hair coats, it is more important in patients with short hair coats because they tend to show scars much more readily. In some cases, access incisions to underlying body structures can be "hidden" by placing them into a less visible site.

Scar Spread

Widening of the healed scar can occur over time. In small animals, this is most likely the result of persistent tension at the surgical closure. Elastic retraction of the skin margins can slowly widen the scar. In small animals with a dense, long hair coat, scar spread may not be noticeable compared to dogs and cats with a short, thinner coat. While scar revision surgery is possible, revision for purely cosmetic reasons is not advocated, unless there is an issue with scar instability or functional compromise to the patient.

DOG-EARS

The term "dog-ears" is used in human reconstructive surgery for skin puckers or elevations of the skin at the end of an incision. While the terminology is somewhat awkward to use for the small animal surgeon, it describes these folds of tissue. In surgery, it is commonly the result of closing a wound at too great an angle or when one side of the incision is longer than the opposite opposing side. In human reconstructive surgery, there are several techniques used to remove dog-ears in order to provide a better cosmetic result. From my experience, the two techniques in Plate 163 are the simplest methods to deal with dog-ears.

My personal observation in surgery includes two other elevations that may be noted by the veterinary surgeon: (1) There can be considerable disparity in skin thickness in the dog and in the cat to a lesser degree. Thicker skin is less elastic. Closure of a wound that encroaches into an area of thicker skin can result in a bulge or elevation. (2) Closure of a wound may result in increased incisional tension that dissipates at the terminal end(s) of the incision: this also will result in an incisional bulge ("girdle effect"). There is little that can be done for these incisional bulges or elevations. Over time the skin tends to flatten and hair regrowth masks the minor closure anomaly.

In older veterinary texts, the use of "Burow's triangles" has been advised for reducing dog-ears or "bunching" of the skin at the base of a flap' this technique is most commonly reported with use of single-pedicle advancement flaps. In general, this technique is not considered necessary in small animal surgery. Bunching is not commonly noted with local flaps and any small elevations normally flatten over time.

Serrated surgical skin scissors can be useful in trimming small skin areas, including dog-ears, to obtain a flatter uniform skin closure. Pictured in Fig. 21-2 are the Sontec® (475-188) Freeman Kaye Scissors (Sontec Instruments, Inc., Centennial, CO) currently used at Angell Animal Medical Center to contour small areas of skin prior to wound closure. The serrated border grasps the skin during cutting for more precise control.

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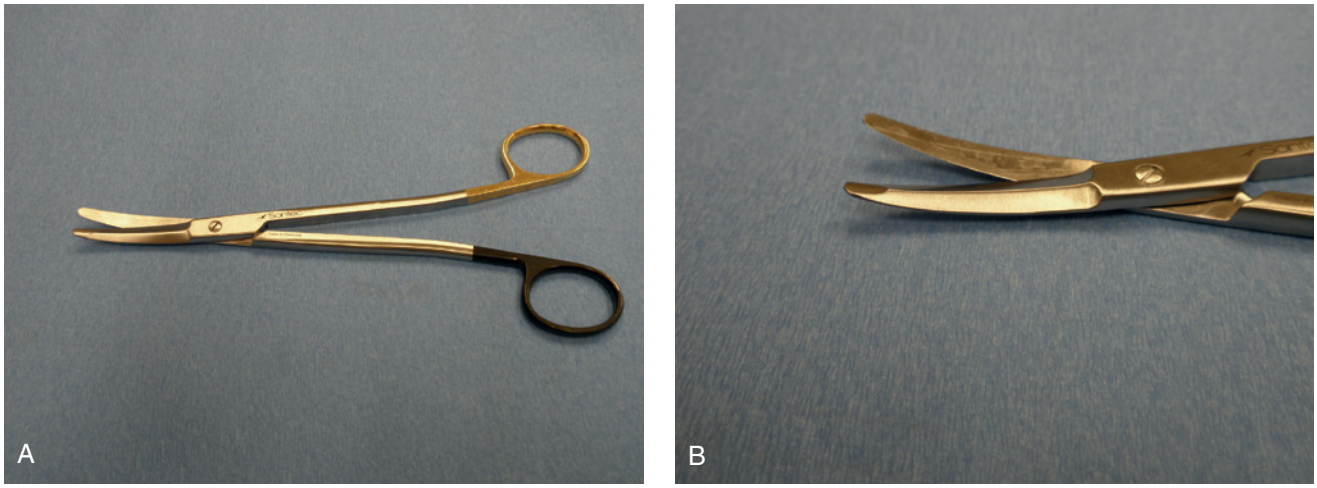


Fig. 21-2 (A) Freeman Kaye Scissors (Sontec 475-188). One edge is finely serrated to grip small skin segments requiring removal, such as small dog-ears. (B) Close-up view. The lower blade with the notched end contains fine sharp serrations. These scissors can be easier to control than a scalpel blade for resecting/contouring small areas of a skin incision prior to closure. They are also useful for resection of portions of the pinna.

Suggested Reading

Grabb WC, Smith JW. 1979. *Plastic Surgery*. Boston, MA: Little, Brown.

Swaim SF. 1980. *Surgery of Traumatized Skin: Management and Reconstruction in the Dog and Cat*. Philadelphia, PA: WB Saunders.

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Plate 161 Scar Concealment

DESCRIPTION

Incisions can be positioned to improve the concealment of surgical scars. This is most frequently requested by owners of show dogs, especially those breeds with a short hair coat.

SURGICAL TECHNIQUE

(A) When feasible, closure of wounds perpendicular to hair growth can reduce the visibility of the resultant scar.

(B) In comparison, the linear scar from wound closure parallel to the hair-growth pattern is more likely to be visible.

(C) Incisions can be placed in a less discernable area. Example: a medial arthrotomy incision is less visible compared to a lateral incision overlying the knee. Carefully undermining and retracting of the skin border still permit lateral arthrotomy.

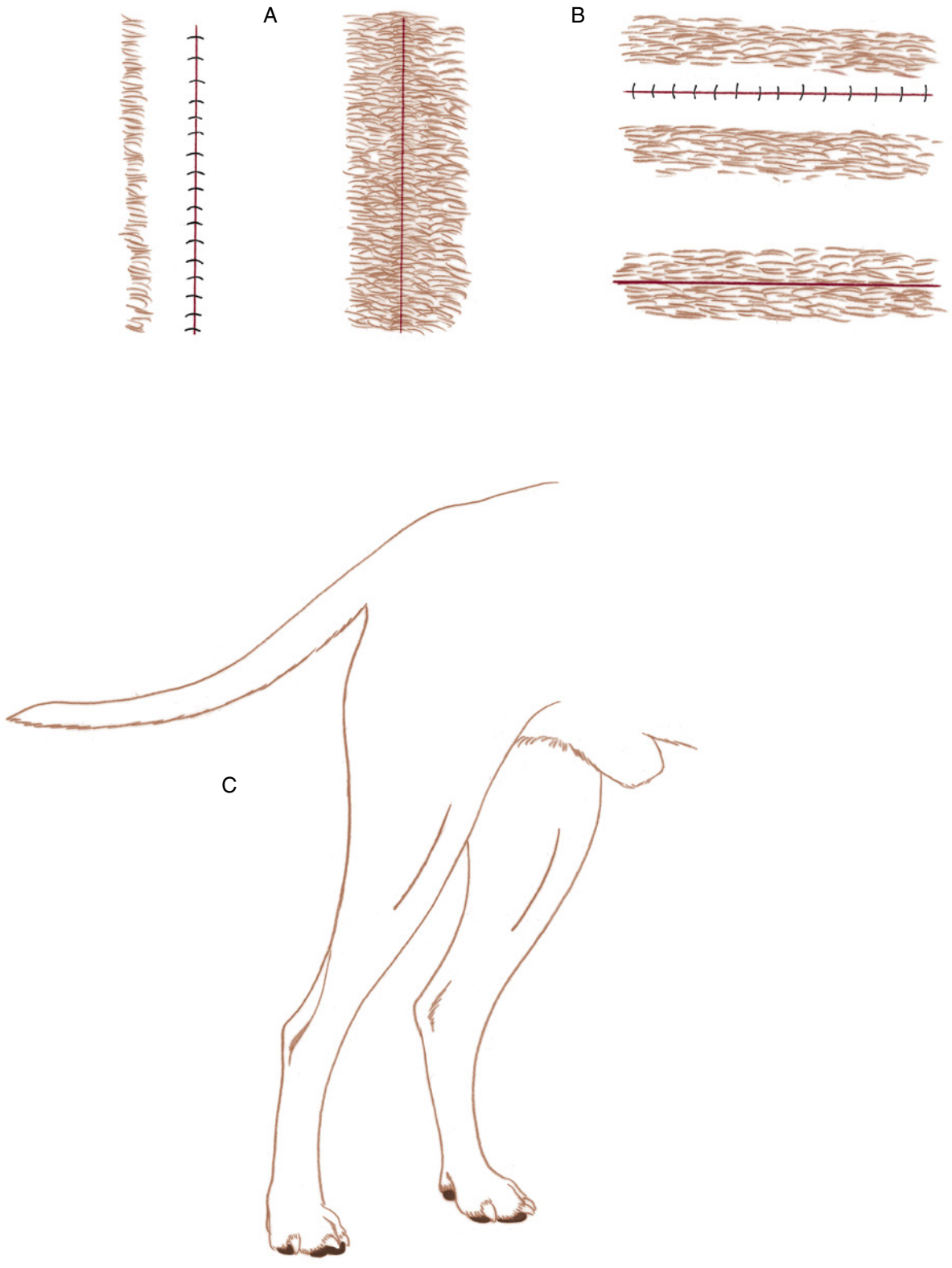
COMMENTS

Positioning of the scar depends on the laxity and elasticity of the skin, the local skin tension, and the shape of the defect requiring closure. Concealment of scars requires careful thought and planning by the surgeon to optimize the cosmetic outcome.

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Plate 161



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Plate 162 W-Plasty

DESCRIPTION

W-plasty is a means of breaking a linear scar into a zigzag design, thereby reducing its visibility.

SURGICAL TECHNIQUE

(A) A W-plasty template is created from X-ray film, plastic, or metal. The general outline and measurements of the W-plasty template are illustrated. Equilateral triangles (60° angles) can be used for the sake of simplicity.

(B) A fine-point marking pen or a toothpick inserted in a vial of gentian violet or methylene blue dye is used to draw the outline of the template outside the border of the scar. Opposing patterns are offset to allow each line to interdigitate properly with an equal number of triangles. The ends of the W-plasty are in the form of Ammon's triangles to prevent "dog-ears."

(C) A no. 11 or 15 scalpel blade is used to incise along the outline. A fine subcuticular pattern, 3-0 to 5-0, can be placed in the deep dermal surface in the center of each flap for initial apposition.

(D) Simple interrupted skin sutures (3-0 to 5-0) are placed in each flap to complete the closure.

COMMENTS

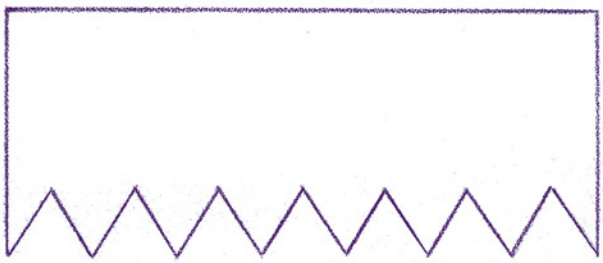
W-plasty has been reported to reduce scar expansion postoperatively by aligning the new zigzag scar, in part, with skin tension lines. Its use is most applicable for cosmetic scar revision rather than primary closure. It is best to avoid this technique if there is excessive tension perpendicular to the scar that would preclude proper execution of the W-plasty procedure, which requires a degree of skin laxity.

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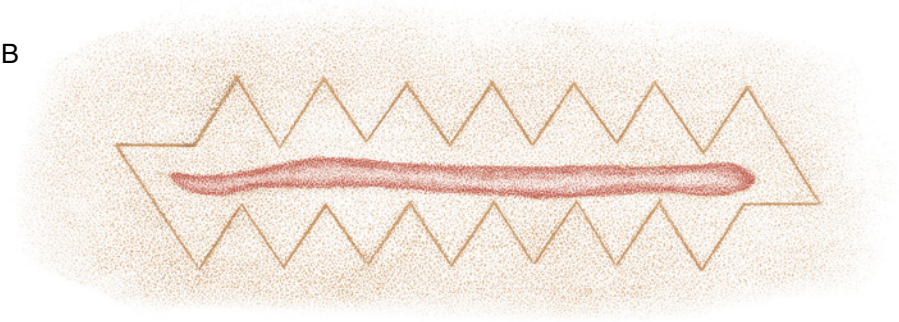
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Plate 162

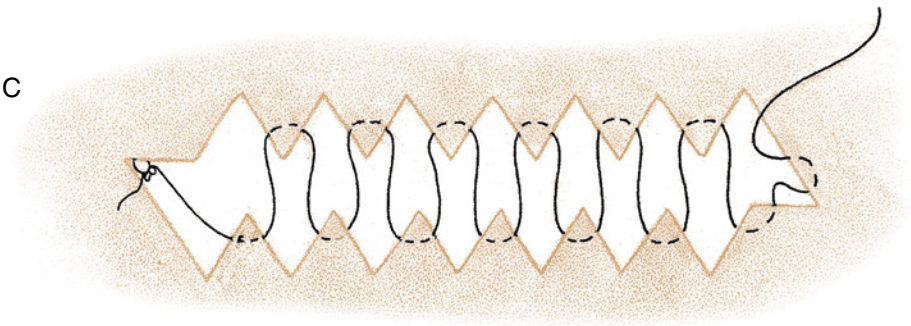
A



B



C



D



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Plate 163

Dog-Ear: Surgical Correction

DESCRIPTION

"Dog-ears" are skin puckers or folds that occasionally form at the end of incisions or at the base of skin flaps. This bunching of skin usually is the result of closing the sides of the wound at too great an angle. A dog-ear also can result when one side of the ellipse is longer than the other, leading to redundant skin (on one side) at the end of the incision. It is occasionally desirable to remove these skin folds for optimum cosmetic results.

SURGICAL TECHNIQUE

(A) Fusiform defects with a 4 : 1 length-to-width ratio rarely form dog-ears on closure.

(B) This is an example of excision of a dog-ear formed by closure of an incision ending at a great angle. Two simple options for elliptical excision (B_1, B_2) of the redundant fold are illustrated. The dashed line denotes redundant skin excised.

(C) This is an example of correction of a dog-ear resulting when one side of the incision is redundant compared to its opposing skin border. The dashed line denotes redundant skin to be excised.

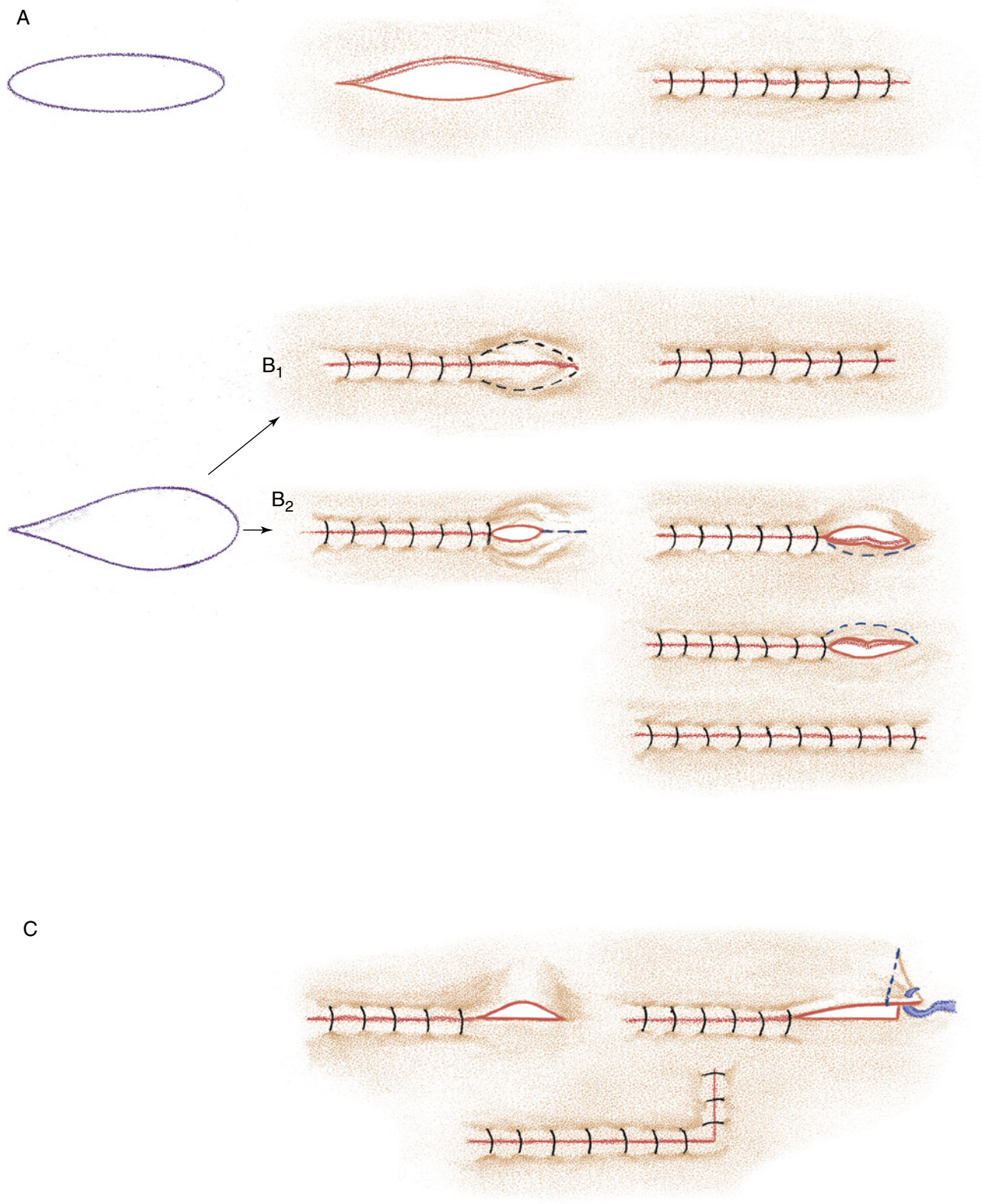
COMMENTS

Many dog-ears flatten without surgical excision. Thin, elastic skin is less prone to dog-ear formation compared to thicker skin, especially over the back and cervical area in the dog. For symmetrical fusiform defects, a length-to-width ratio of 4 : 1 is reported to prevent dog-ear formation. The terminal portion of a fusiform defect can be tapered to minimize skin bunching. However, adherence to such a ratio, in many instances, would create unnecessarily long incisions compared to closure and selective excision of any dog-ear(s) that might form. As noted, short fusiform defects in thin, elastic skin may not result in dog-ears. Dog-ears that form at the base of a flap on transfer are best left alone in order to avoid circulatory compromise of the pedicle graft from attempted removal. If they fail to flatten on healing of the surgical area, surgical excision can be undertaken later.

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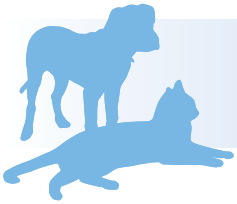
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Plate 163



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22

Preputial Reconstructive Surgery

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INTRODUCTION

The prepuce is a tubular sheath of skin (parietal layer) lined with mucosa (inner visceral layer) that covers a portion of the penile shaft (pars longa glandis, bulbus glandis). The mucosal layer reflects off the bulbus glandis, forming a fornix, as the mucosa covers the external penis to the urethral orifice. The skin is firmly attached to and continuous with the ventral abdominal skin, forming a sling to support and protect the penis from trauma and exposure. The cranial 1–3 cm of the prepuce protrudes forward from the skin, reflecting off the abdominal wall. The preputial orifice normally allows for the unimpeded extrusion and retraction of the penile shaft.

The preputial muscle, located in the hypodermis, is an extension of the cutaneous trunci muscle; it attaches to the cranial and dorsal aspect of the prepuce. The primary function of this muscle is to draw the prepuce forward to cover the glans penis after erection.

The primary source of circulation to the parietal and visceral layers is from the external pudendal artery and dorsal artery of the penis. The visceral layer also is supplied, to a lesser degree, by the artery of the bulb of the penis.

Based on its anatomy and blood supply, the prepuce is easily elevated from the abdominal wall for relocation. Similarly, a central preputial incision can be used to expose the penile shaft without compromising circulation to this structure.

Normally the cranial 1–3 cm of the prepuce can be amputated in many dogs and still provide adequate coverage to the penis. Phallopexy (Plate 167) can be used to improve coverage if needed. The preputialis muscle is not important to improving penile coverage (see Preputial Advancement Technique, Plate 166, for cases of paraphimosis).

SURGICAL CONDITIONS

The prepuce is susceptible to trauma, although direct trauma from automobile accidents and bite wounds, for example, is relatively uncommon from the author's clinical experience. Foreign bodies also are quite rare, although migrating awns, seeds, or fragments of plant material reportedly can imbed in the preputial cavity, causing a purulent or hemorrhagic discharge. Complete examination of the prepuce and penis can be accomplished by careful retraction and examination through the orifice. In some cases, a narrow vaginal speculum, otoscope, or forceps may be used to better visualize the preputial cavity. In more problematic cases, a midline preputial incision can facilitate examination and surgery of the penis and preputial lining. *Balanoposthitis* is common in male dogs and may mask foreign bodies as an underlying cause of this condition.

Like other anatomic structures, neoplasia is occasionally encountered, including mast cell tumors, carcinomas, papillomas, transmissible venereal tumors, melanomas, and perianal gland tumors. Similarly, tumors of the penis may extend to the prepuce or form a mechanical impediment to normal function of the prepuce and penis. Biopsies are a necessary component of the diagnosis and management of these conditions.

Congenital and acquired anomalies of the prepuce, however, are occasionally noted. This chapter will discuss surgical correction of persistent frenulum, phimosis, paraphimosis, hypospadias, and preputial urethrostomy.

Persistent Frenulum

A condition commonly seen in miniature poodles, cocker spaniels, and Pekingese, persistence of the penile frenulum may also be seen in other breeds. The frenulum normally ruptures by puberty in most dogs. This membranous tissue band connects the ventral penile shaft to the ventral mucosal surface of the prepuce.

The frenulum can prevent extrusion of the penis during physical examination. During penile erection, presence of the frenulum restricts extrusion of the penis and results in its ventral bowing of this structure. Persistent frenulum can contribute to urethral prolapse on rare occasions (Fig. 22-1). Persistent frenulum is easily remedied by cutting the band with a pair of scissors under light sedation. Bleeding is normally minimal.

Phimosis

Phimosis refers to the condition of the male foreskin in humans, where the skin is tight and unable to retract back behind the head of the penis. In dogs, the most common cause of phimosis is a small preputial orifice (congenital or acquired secondary to trauma or neoplasia) (Fig. 22-2). (If the penis can be easily extruded from the preputial ostium, then the dog does not have phimosis.) There are occasions in which neoplasms can partially obstruct the preputial orifice, including mast cell tumors and carcinomas (Fig. 22-3). Phallic tumors also can preclude extrusion of the penis (Fig. 22-4). Basic management of phimosis is enlargement of the preputial ostium (Plate 164). Obstructive lesions involving the preputial orifice and penile masses normally require surgical removal.

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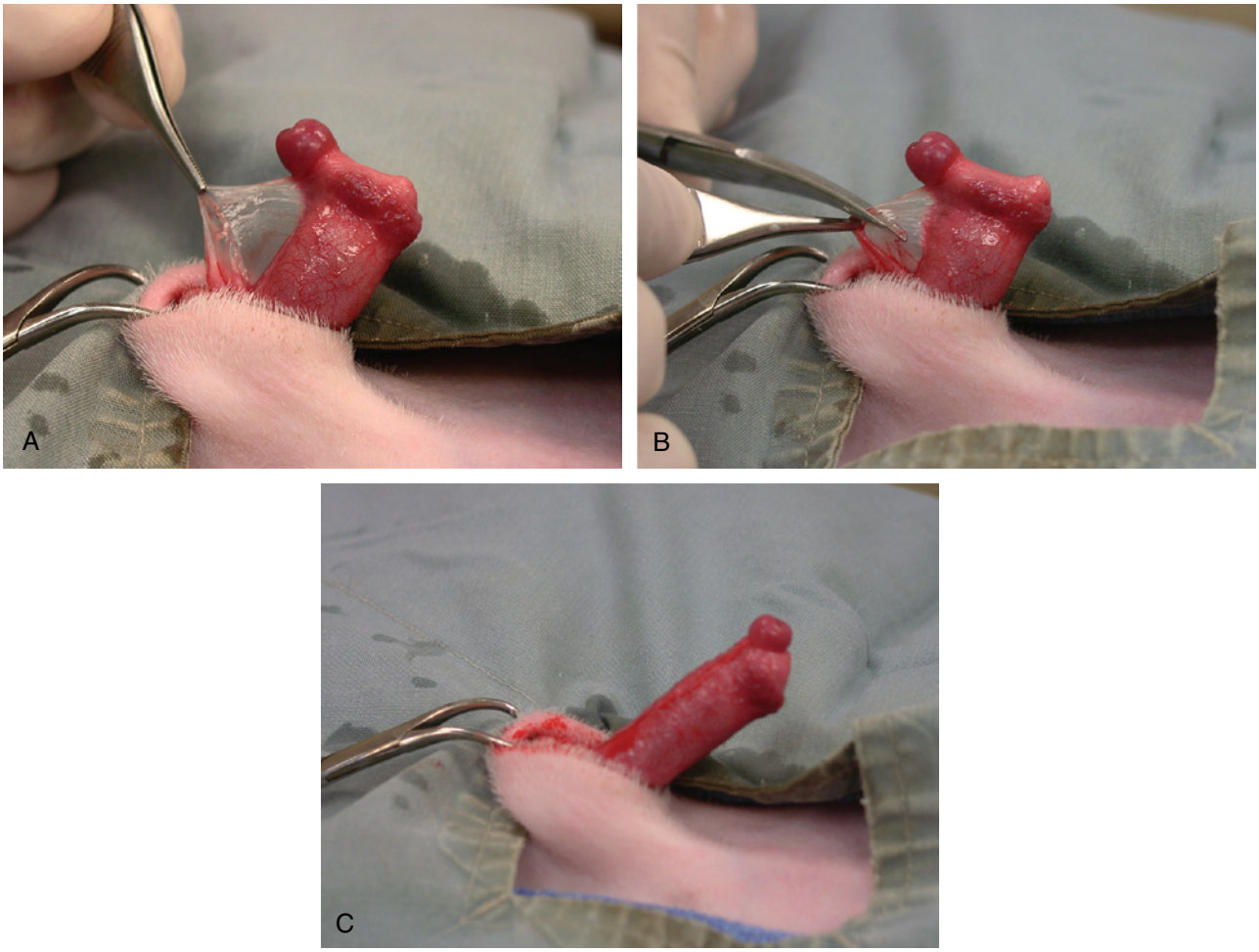


FIG. 22-1 (A) Persistent frenulum in an 8-month-old Yorkshire terrier. Chronic penile traction by the frenulum contributed to the formation of urethral prolapse. (B) Simple division with scissors. Bleeding is minimal. (C) Restoration of penile mobility. The urethral prolapse was managed by laser resection and closure with 5-0 absorbable sutures, using a simple interrupted suture pattern.

Microphallus

Although uncommon, dogs may have a small penis (micropenis, microphallus) relative to the length and diameter of the prepuce, making exposure of the penis problematic. While micropenis, in relation to a proportionately larger prepuce, normally causes no issues in dogs, one report (Zhang et al. 2023) noted a neutered male shih tzu with urine dribbling and recurrent urinary tract infections as a result of this anomaly. Following preputial shortening, improvement in the urine dribbling and resolution of the urinary tract infections were noted.

The surgical removal of the cranial preputial protrusion to remove a tumor usually does not result in significant penile exposure or paraphimosis.

Paraphimosis

In humans, paraphimosis refers to the strangulation of the glans penis due to retraction of the narrow inflamed foreskin. In veterinary medicine, paraphimosis is defined more broadly as the inability of the penis to retract into the prepuce after its extrusion from the preputial ostium. There are several causes of paraphimosis, including the following:

1. Filamentous hair at the tip of the prepuce, wrapping or adhering to the exposed penile shaft; preputial discharge can serve as a glue-like substrate
2. Small preputial orifice that entraps the penile shaft
3. Chronic exposure and drying of the penile surface, causing a friction or drag effect on the outer skin surface of the preputial orifice; the prepuce also may be thin and flaccid, contributing to this condition

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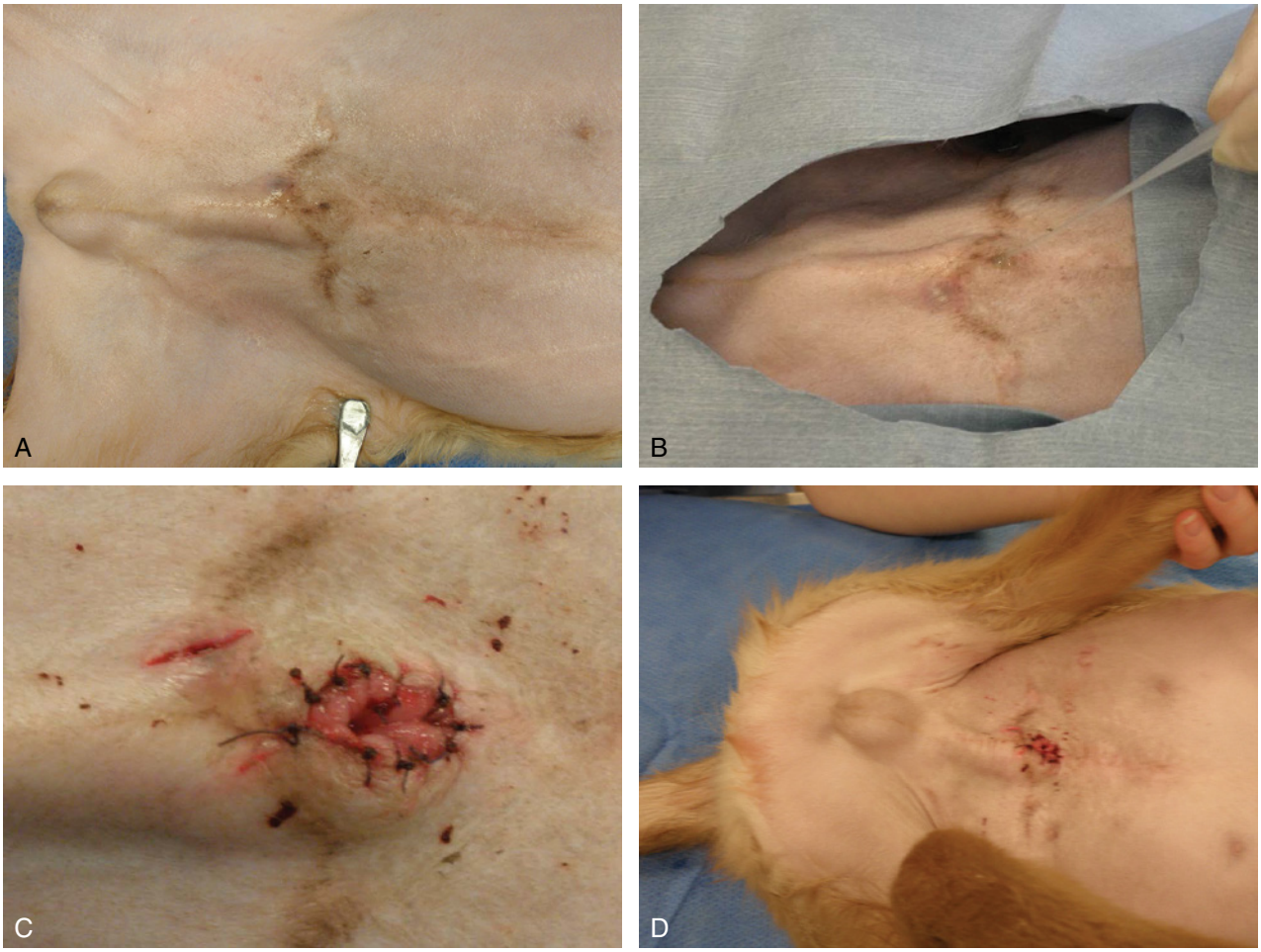


FIG. 22-2 (A) A 16-week-old golden retriever puppy with phimosis secondary to stricture of preputial ostium. (B) A tom-cat catheter demonstrates the diameter of the preputial ostium. (C) An incision was used to enlarge the preputial ostium. The mucosa was sutured to the cutaneous margins. The penis could be extruded and spontaneously retracted. (D) Prior to anesthetic recovery, the pelvic limbs were flexed and extended to ensure appropriate penile coverage.

4. Adjacent or underlying scarring (secondary to trauma or caudal abdominal surgery) that restricts preputial coverage of the penile shaft
5. Underdeveloped prepuce (congenital) or preputial tissue loss secondary to trauma or surgery
6. Ineffectual retractor penis muscle (the author is not convinced this is a significant factor contributing to paraphimosis)

The author does not believe shortening or imbricating the preputialis muscle is either necessary or useful in the correction of paraphimosis. Preputial advancement alone can correct most of these cases. There are other options to correct paraphimosis that do not involve "corrective surgery" of the preputialis muscle.

Of particular concern is the entrapment of the penis secondary to a comparatively small-diameter preputial ostium. Penile erection or traumatic swelling of the extruded penis may occur with a small or inelastic preputial orifice, creating a "rubber band" effect on the penile shaft. Venous and lymphatic outflow are restricted: progressive swelling will collapse the arterial and venous circulation. Without prompt intervention, penile infarction/necrosis follows (Fig. 22-5A).

Most cases of paraphimosis do not result in penile necrosis. Smaller dogs, in particular, can present with paraphimosis despite a seemingly normal preputial opening. The preputial sheath may appear somewhat thin and flaccid, with the penis protruding. The penis can be manually replaced without difficulty, but may intermittently protrude thereafter. The exposed penile mucosa rapidly dries, with loss of its normal lubricating

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FIG. 22-3 (A) Phimosis secondary to mast cell tumor. (B) Laser resection of this neoplasm. (C) Ventral closure improved penile coverage; the penis was easily extruded through the reformed preputial orifice. (D) Resection of a preputial carcinoma, causing phimosis. (E, F) Resection with a carbon dioxide laser was followed by surgical closure.

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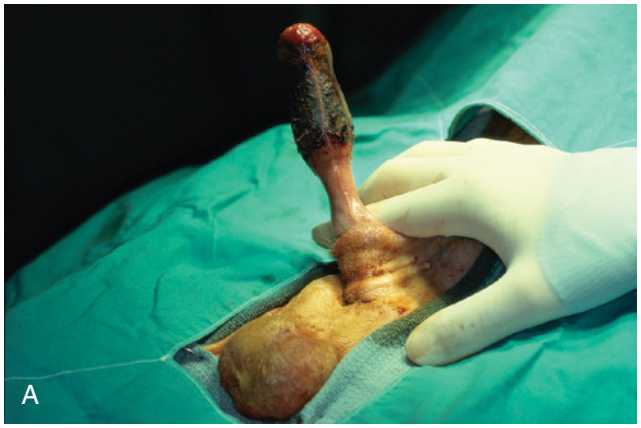
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FIG. 22-4 Transmissible venereal tumor in a 6-year-old German shepherd, impairing penile extrusion. Surgical debulking was followed by vincristine chemotherapy.

properties. In turn, the skin surrounding the preputial orifice literally is dragged inward as the penile shaft attempts to retract (Figs 22-5B–C, 22-6, and 22-7). In some cases, long-term lubrication and prompt penile replacement into the preputial cavity (over a period of 1 month) *by an attentive owner* may allow the desiccated mucosal surface to recover, with restoration of natural lubrication. If this therapy fails, surgical advancement of the prepuce, with preputial ostium enlargement (if necessary), can correct this mild variety of paraphimosis. A second surgical option is phallopexy.

Although uncommon, pelvic trauma or restrictive surgical scars beneath the prepuce (abdominal scar after cystotomy as an example) may result in inadequate penile exposure. Division of the scar followed by preputial advancement is required to correct this cause of paraphimosis (Fig. 22-8). If the preputial orifice is also





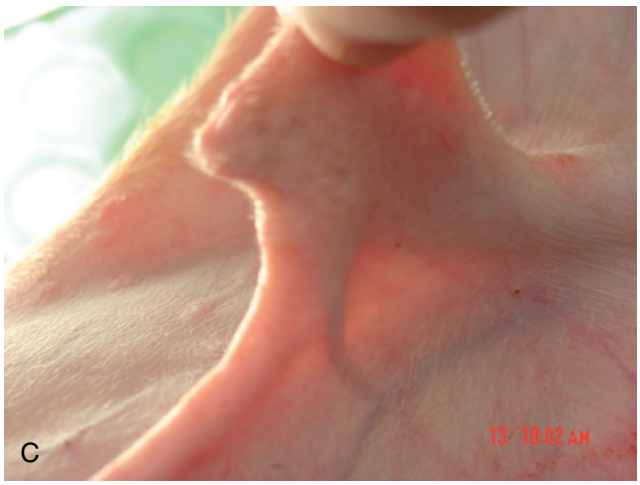


FIG. 22-5 (A) Strangulation necrosis secondary to paraphimosis. (B) Desiccation of the penis from chronic exposure. Note the inversion of the preputial skin caused by frictional contact with the damaged penile mucosa. (C) Note the thin, flaccid skin comprising the prepuce. The penis could be manually replaced in the preputial cavity without difficulty. In this case, application of an antibacterial ointment containing triamcinolone (Quadritop, Butler Animal Health Supply, LLC, Aurora, CO) three times a day over the next month was curative. The owner was instructed to replace the penis every time it extruded. If conservative therapy had failed, surgical correction would have been performed.

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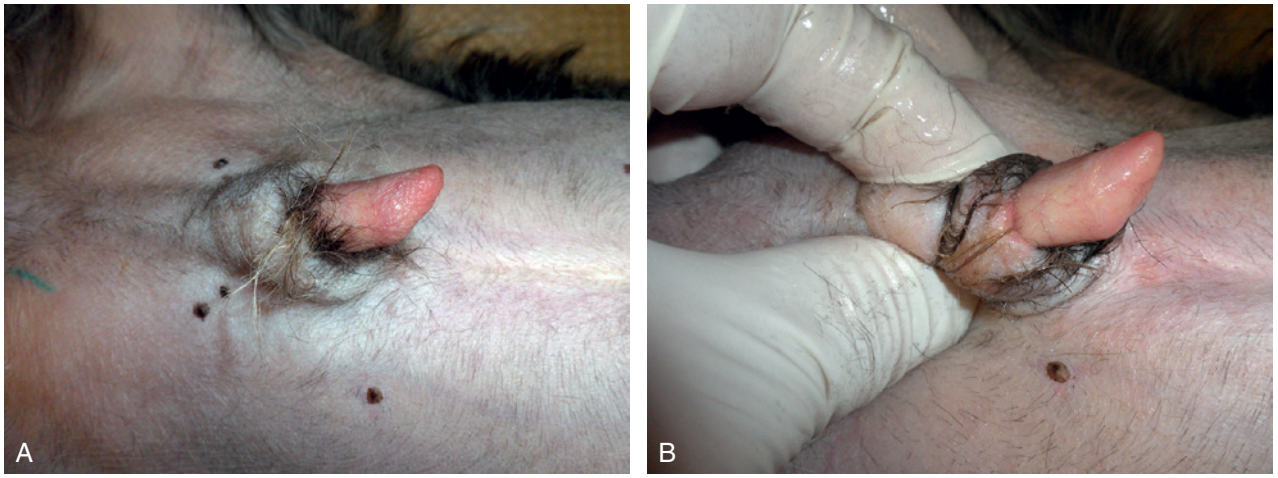


FIG. 22-6 (A) Paraphimosis with chronic penile exposure. Hair encircling the penile shaft and inversion of the ostium was noted. The dry penile mucosa creates a frictional surface against the inverted skin. (B) Manual retraction of the preputial ostium to expose the inverted skin surrounding the penile shaft.

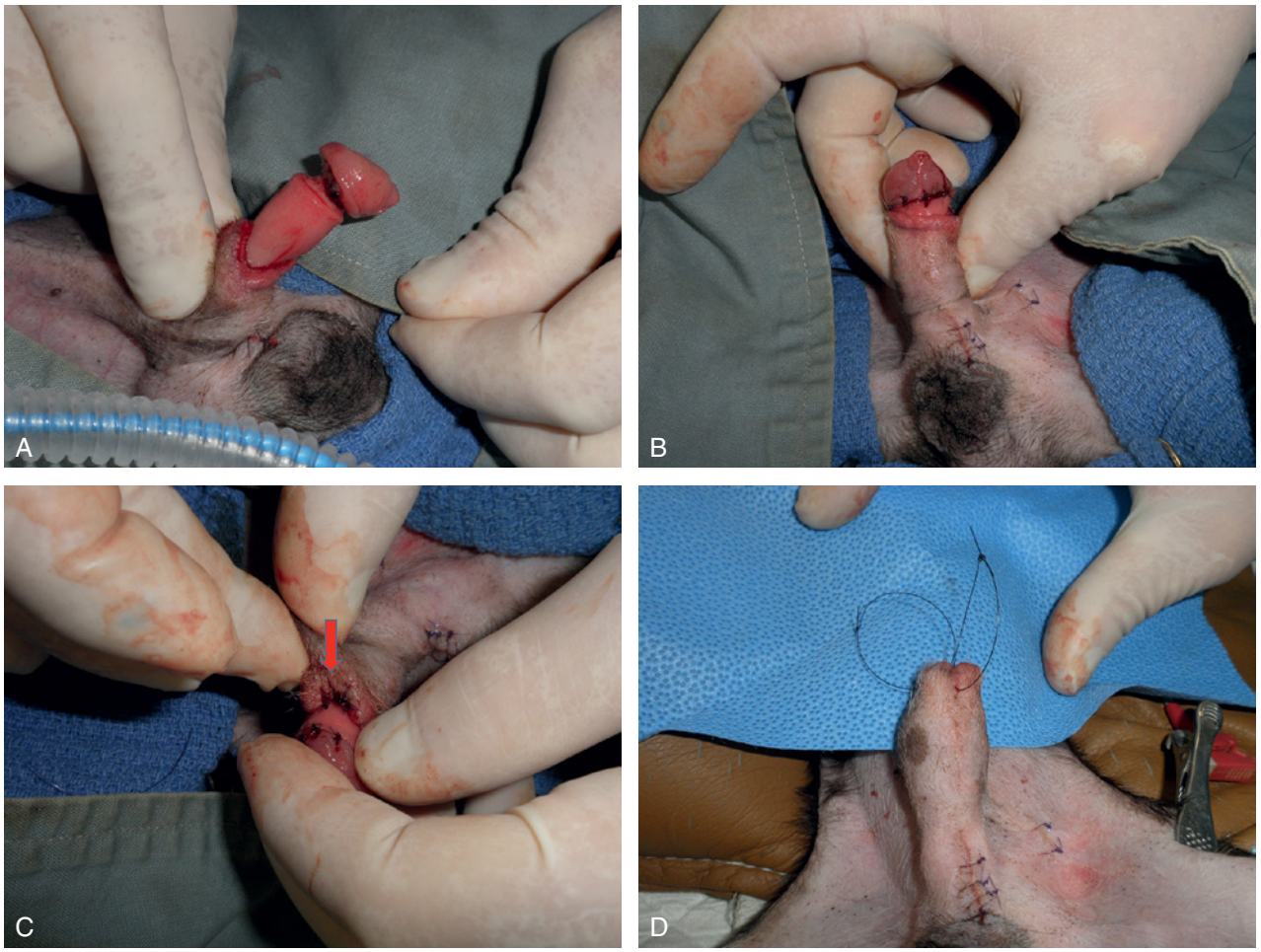


FIG. 22-7 (A) Partial penile avulsion secondary to mating with resultant paraphimosis. (B) Approximation of the tear encircling the penile tip with absorbable 4-0 sutures. (C) Enlargement of the preputial circumference (arrow) as noted in Plate 164. (D) Temporary placement of two traction sutures (2-0 nylon) to facilitate advancement of the prepuce over the traumatized penis. Forward traction on the sutures enabled easy coverage of the traumatized penis postoperatively when the edematous penis was exposed outside the preputial ostium. Sutures were removed 1 week later. The patient made a full recovery.

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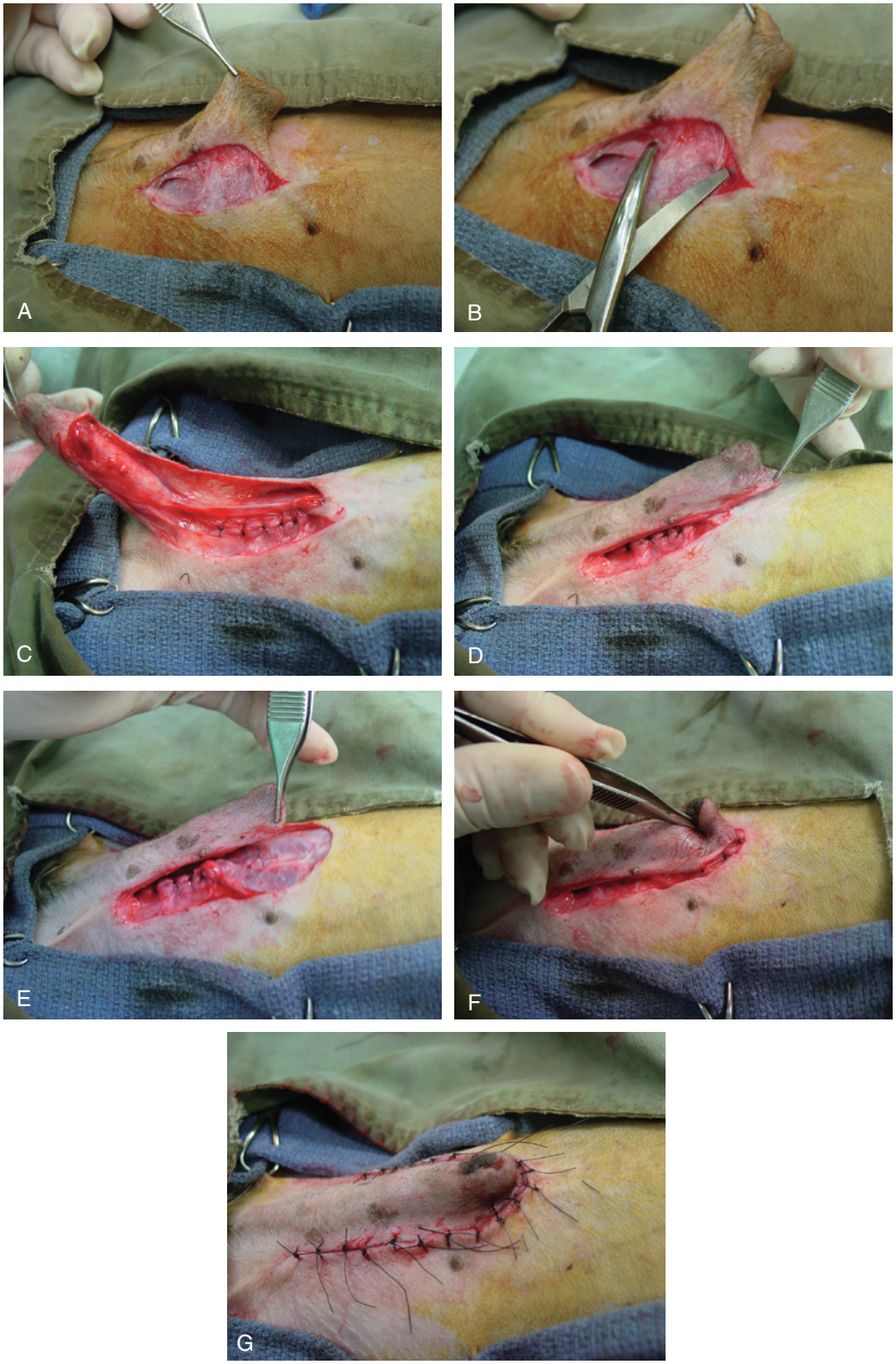


FIG. 22-8 (A) Scar tissue between the base of the prepuce and the abdominal wall as a cause of paraphimosis. The dog had previous cystotomies for bladder stones. (B) Division of the scar. A midline cystotomy was performed to remove the stones, followed by preputial elevation and advancement. (C) Aggressive elevation of the prepuce and penis for advancement. (D) After preputial elevation, the base of the prepuce was grasped and advanced to determine its new forward location. (E) Resection of the skin in preparation for preputial advancement. (F) Intradermal, monofilament nylon sutures were used to secure the prepuce to the fascia of the external abdominal oblique muscle. (G) Closure of the skin incision, completing the surgery. The preputial orifice was normal diameter and required no corrective enlargement. (See Plate 166.)

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marginally small, ostium enlargement can be performed at the time of preputial advancement (Fig. 22-9). Prior to surgery, the patient is positioned in dorsal recumbency on the surgical table and the hindlimbs are flexed and extended to determine the position that enhances exposure of the penis. This helps to ensure the prepuce is advanced sufficiently to cover the exposed penis. The legs are secured in this position prior to final surgical preparation and draping of the patient (Fig. 22-10).

Additional penile coverage (1 or 2 cm) can be obtained by excision of the ventral margins of the preputial orifice, creating a sling-like extension of penile coverage (Fig. 22-11). Reciprocally, dorsal enlargement of the orifice will be required. Care must be taken to prevent narrowing of the preputial ostium to the point at which it can potentially entrap the penis.

Phallopexy, first described in the horse, is another viable surgical option that is often effective in managing paraphimosis in dogs (Plate 167). This procedure entails creating a scar between the dorsal penile shaft and less mobile internal dorsal mucosal lamina of the prepuce via a dorsolateral preputial incision (Fig. 22-12). It may be used in place of, or in conjunction with, preputial advancement, depending on the severity of the case (Plate 167).

Partial penile amputation, as an alternative option, is usually considered if other surgical procedures fail to completely cover the penis. In most cases, only the terminal portion of the penis, anterior to the os penis, would require resection. Intermittent bleeding may be expected for 5–7 days postoperatively.

Major preputial reconstruction has been attempted with the use of mucosal grafts and utilization of the adjacent ventral abdominal skin. These techniques are multistage procedures that require considerable cost and effort to perform. A more practical approach is to use one or more of the techniques discussed here to improve penile coverage followed by, in many cases, partial penile amputation (if necessary). In severe cases, penile amputation with a scrotal or prescrotal urethrostomy is a viable option to consider.

Hypospadias

Embryologically, hypospadias is a failure in fusion of the urogenital folds, resulting in the premature involution of the interstitial cells of the developing testes. The loss of androgen production results in incomplete masculinization of the external genitalia. It has been reported to be most common in the Boston terrier, although the author has seen it in a variety of breeds, including large-breed dogs (German shepherds, mixed-breed dogs, Newfoundlands). It is exceedingly rare in the cat (Fig. 22-13). Undescending testicles and renal anomalies have been reported in humans, with one report in the veterinary literature of a renal aplasia and cryptorchidism in an 8-month-old beagle. Urinary incontinence also has been reported in the dog; this has not been noted by the author to date.

Hobson (1990) described five basic areas in which an abnormal urethral meatus may occur in hypospadias: glandular, penile, scrotal, perineal (subanal), and anal. Of these forms, subanal urethral openings are the greatest concern due to the greater risk of lower urinary tract infections. An abnormal meatus involving the glans or penile shaft (Fig. 22-14) is uncommon in dogs and may be noted as an incidental finding. More extensive changes of the external genitalia can be seen with the other forms of hypospadias, with incomplete formation or agenesis of the penis and prepuce (Fig. 22-15). A dog with a scrotal or lower perineal urethral meatus essentially urinates in a fashion similar to patients that have had a scrotal or prescrotal urethrostomy. As noted, a urethral meatus adjacent to the ventral anal margin is exposed to fecal contamination, and recurrent bacterial cystitis is commonly seen in these patients (Fig. 22-16). Castration is recommended at the time of corrective surgery for hypospadias (Figs 22-17 and 22-18).

SURGICAL TECHNIQUES

Preputial Urethrostomy Technique

In the event of penile necrosis involving the penis at the level of the preputial fornix, the preputial urethrostomy technique is an alternative to prescrotal or scrotal urethrostomy (see Plate 169). The urethral end, after amputation, is anastomosed to the adjacent preputial mucosa. Use of a ventral midline preputiotomy incision will greatly facilitate this surgical technique (Fig. 22-19).

Emergency Enlargement of the Preputial Orifice: Paraphimosis

In those cases of paraphimosis with lymphatic and circulatory compromise to the penis, immediate enlargement of the prepuce may be accomplished with a ventral or dorsal incision (a ventral incision is the easier to perform). Sedation or the use of a local lidocaine block may be considered. However, because of the extreme penile swelling and circumferential tension of the preputial orifice, a quick cut with sharp scissors or a scalpel blade may be used to provide immediate tension relief. The lubricated end of a Bard-Parker scalpel handle may be partially inserted between the penis and preputial orifice to

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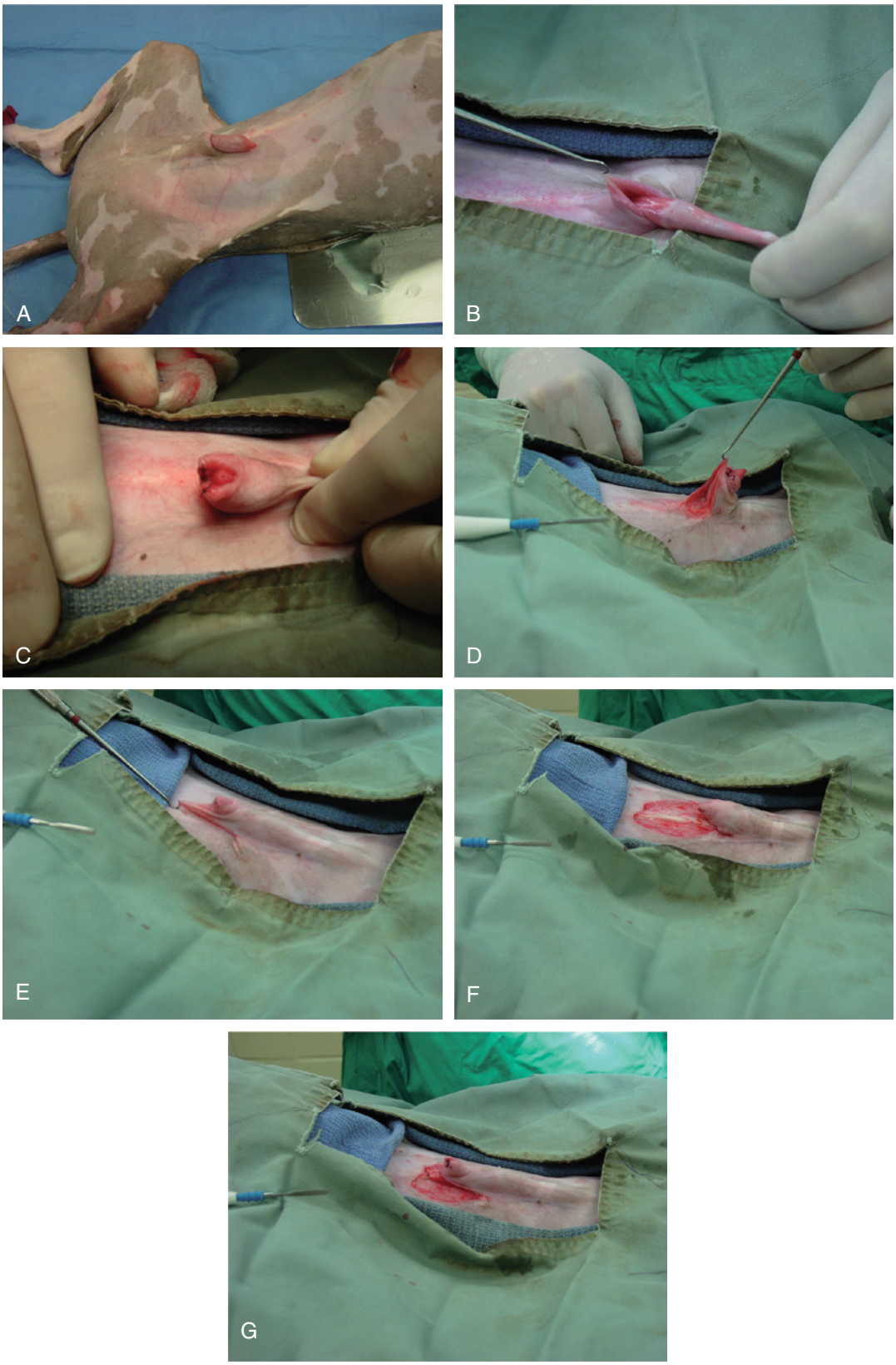


FIG. 22-9 (A) Penile mucosa desiccation secondary to long-term exposure. (B) Note the delineation between the unexposed and exposed penile mucosa. (C) A dorsal "release" incision and closure were required to enlarge the preputial orifice. (D) Following preputial enlargement, the prepuce was advanced. (E) Forward intraoperative advancement to determine the appropriate location for preputial advancement. (F) Resection of skin to accommodate the prepuce. (G) After securing the cranial base of the prepuce to the external abdominal oblique muscle, the skin incision was closed to complete the procedure. (See Plate 166.)

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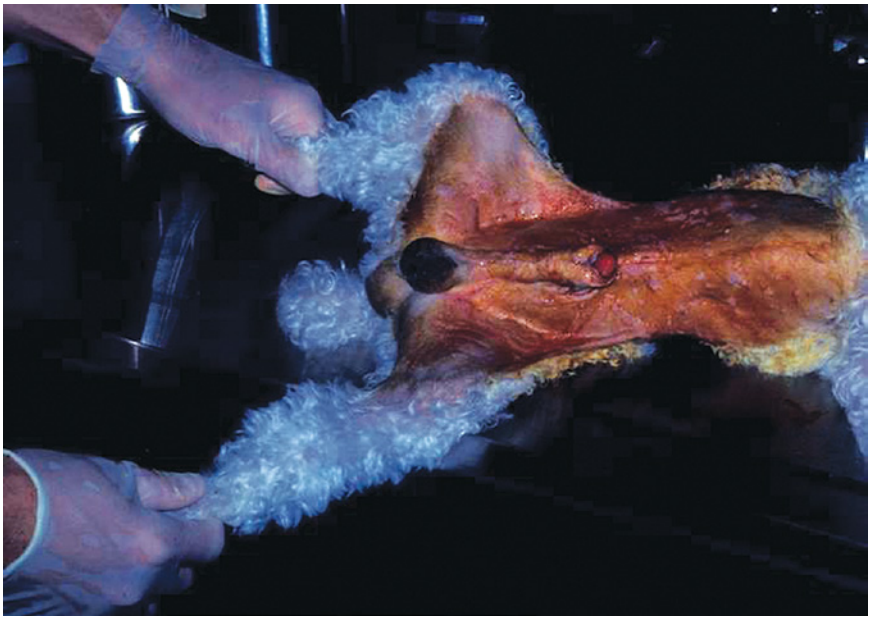


FIG. 22-10 It is important to flex and extend the pelvic limbs to find the position that exposes the penis. The legs are tied into this position and preputial advancement is performed. Hindlimb manipulation is repeated after surgery before anesthetic recovery.

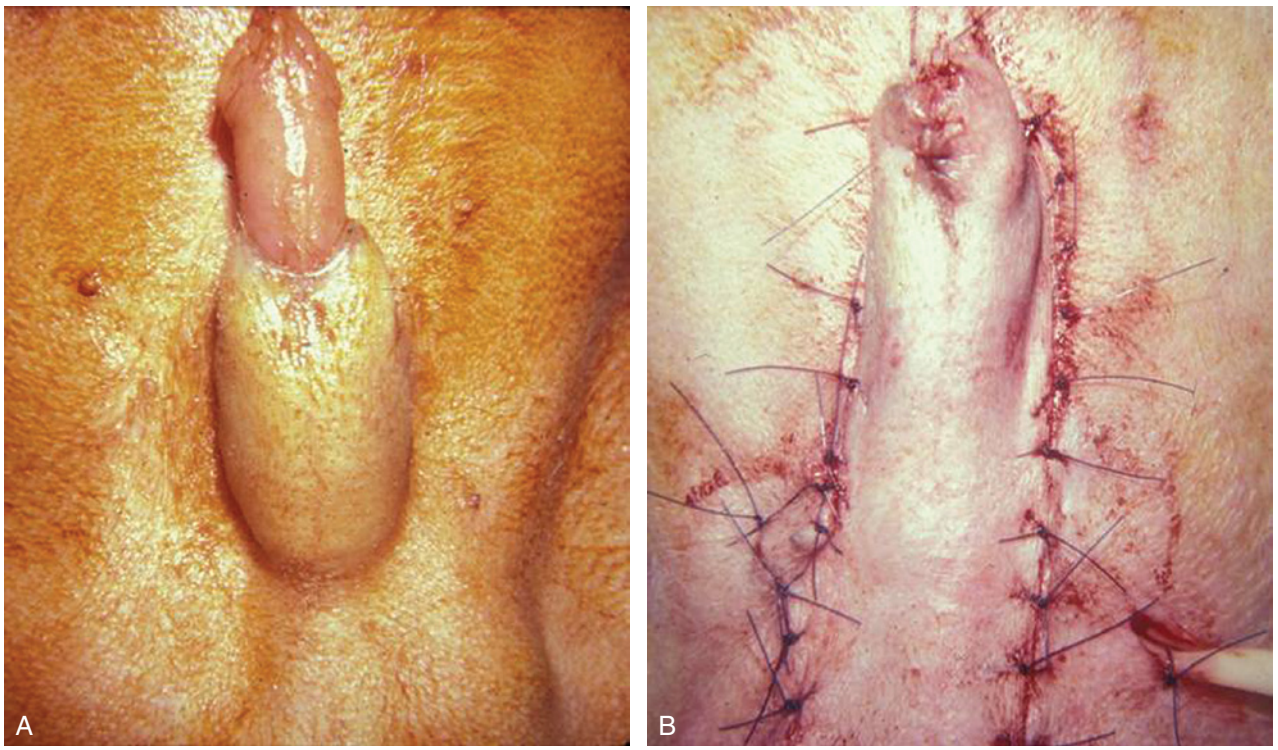


FIG. 22-11 (A) Severe pelvic trauma secondary to vehicular trauma. Severe paraphimosis was later noted, likely secondary to scar tissue formation. (B) Complete preputial elevation and advancement. To further improve coverage of the rostral tip of the penis, the ventral half of the preputial ostium was closed. The dorsal margin was reciprocally enlarged to ensure the penis could extrude and retract normally (see Plate 164).

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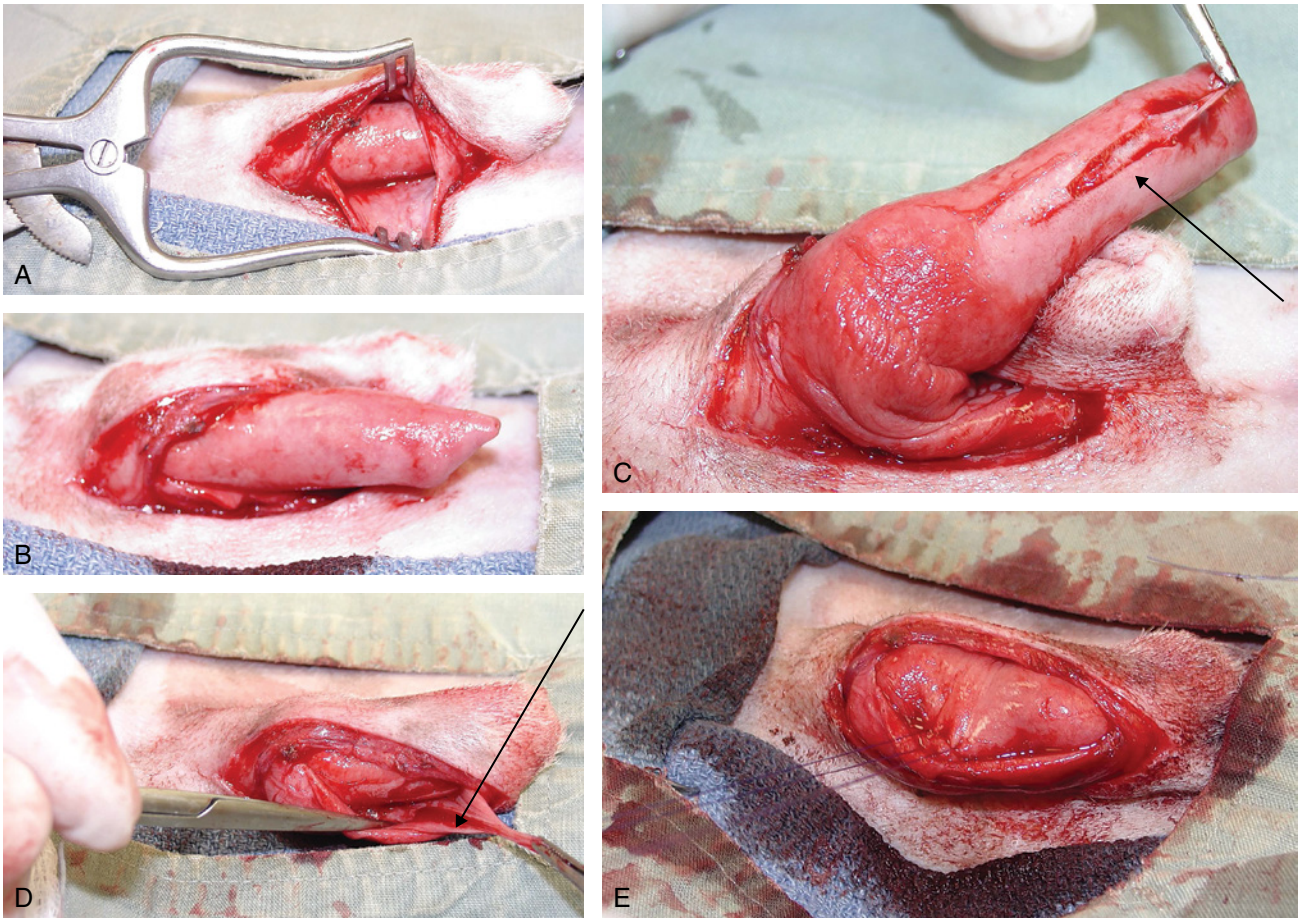


FIG. 22-12 Phallopexy technique. (A) A lateral preputiotomy incision exposes the dorsal preputial mucosal wall and penile shaft. (B) The penis is easily exposed through the preputiotomy incision. (C) An incision is made on the dorsal penile mucosa (arrow), 2 cm from the penile tip. A thin band of mucosa is being removed to facilitate suturing. (D) A dorsal preputial mucosal incision is made 3 cm caudal to the preputial ostium (arrow). A thin band of mucosa can be resected to facilitate suture placement with the penile shaft incision. (E) 4-0 absorbable sutures are preplaced between the apposing mucosal incisions. Sutures can be placed on the left and right incisional margins for greater security. The preputial mucosa is apposed followed by the skin incision to complete the procedure. (See Plate 167.)

protect the penile shaft when a scalpel blade is used. In general, a 10–20 mm incision will release the circumferential tension. The exposed penis can be treated with topical lidocaine to reduce local discomfort. K-Y lubrication can be applied to the penis to permit its replacement into the prepuce. Conservative management for paraphimosis includes the application of ointment to prevent desiccation of the exposed penis; systemic corticosteroids also may be considered to reduce edema. Topical 50% dextrose also may be used as a hyperosmotic agent to reduce edema after performing the preputiotomy. Cold compresses may be used to help decrease swelling, but may not be well tolerated by the patient without the adjunctive use of analgesics and sedatives.

The penis is assessed for viability; extensive necrosis usually is associated with a deep purple to black appearance to the entrapped penile shaft. However, hemorrhage, venous stasis, and a mottled appearance of the penile shaft may warrant a conservative "wait and reassess" approach over the next 5–7 days. In many cases, even dramatic swelling of the penile shaft can resolve, provided that extensive tissue necrosis is not present. Patchy areas of mucosal necrosis on the penile surface normally heal by second intention. A urinary catheter may be required if swelling has obstructed the urethra.

Extensive necrosis of the penis is managed by partial penile amputation. *Note:* Although preputial shortening surgery has been advocated in the past for dogs undergoing partial penile amputation, it has *not* been the author's experience that this procedure is at all necessary. Urine passes through the prepuce unimpeded, without irritation of its mucosal lining.

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FIG. 22-13 Rare examples of hypospadias in two cats. Both patients had a history of recurrent urinary tract infections due to the proximity of the abnormal urethral orifice to the anus. (A) This was surgically corrected by increasing the distance between these two structures by dissecting between the anus and urethra followed by advancing the lateral skin surfaces together. (B) A second cat with hypospadias. The arrow denotes the urethra immediately below the anus. The small raised pink knob is the rudimentary penis. The patient was previously neutered by the animal shelter. (C) Like canine patients with subanal hypospadias, the lateral tissues were inverted to create a short urethral extension independent of the anus.

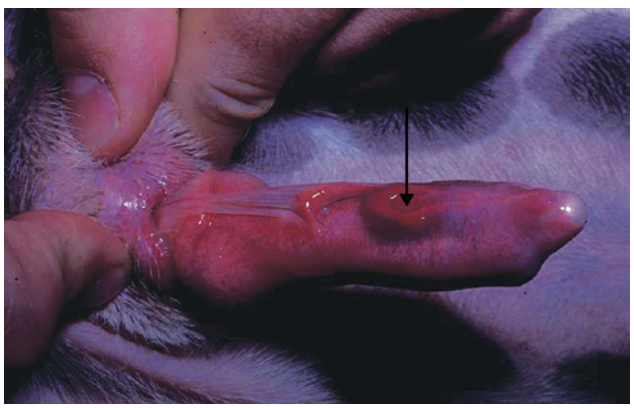


FIG. 22-14 Example of penile hypospadias in a Dalmatian.

Although rare, the author has seen two puppies with paraphimosis associated with nursing. This can occur if the prepuce is grasped when a litter mate is attempting to locate the mammary teat. Treatment required the manual repositioning of the prepuce to cover the penile shaft with the use of a water-based lubricant.

Permanent Enlargement of the Preputial Ostium

Permanent treatment of phimosis or paraphimosis normally requires enlargement of the preputial orifice. A dorsal incision of approximately 10–15 mm is made

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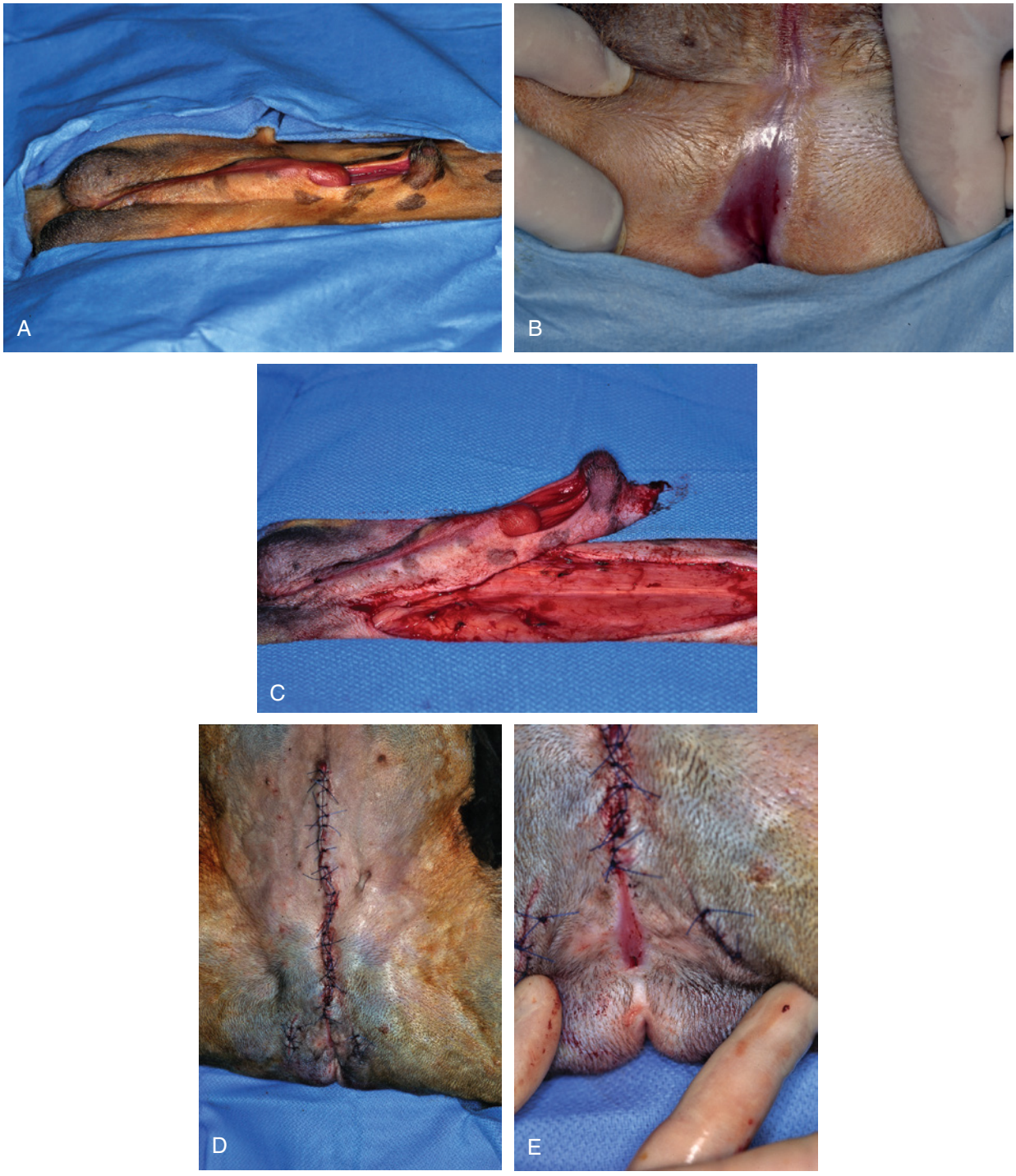


FIG. 22-15 (A) Hypospadias in a Newfoundland. (B) Note the urethral opening at the level of the ischial arch. (C) Resection of the rudimentary penis and prepuce. (D) Closure of the surgical defect. (E) Close-up view of the urethra. Note the two separate incisions required to castrate this dog.

through the entire thickness of the prepuce. The incision can be increased in small increments until the penis can be easily extruded. The skin is sutured to the apposing mucosa with 4-0 absorbable sutures, thereby creating a permanent triangular or "V" notch. If an emergency ventral preputiotomy incision was performed prior to this procedure, it may be sutured at this time (see Plate 164).

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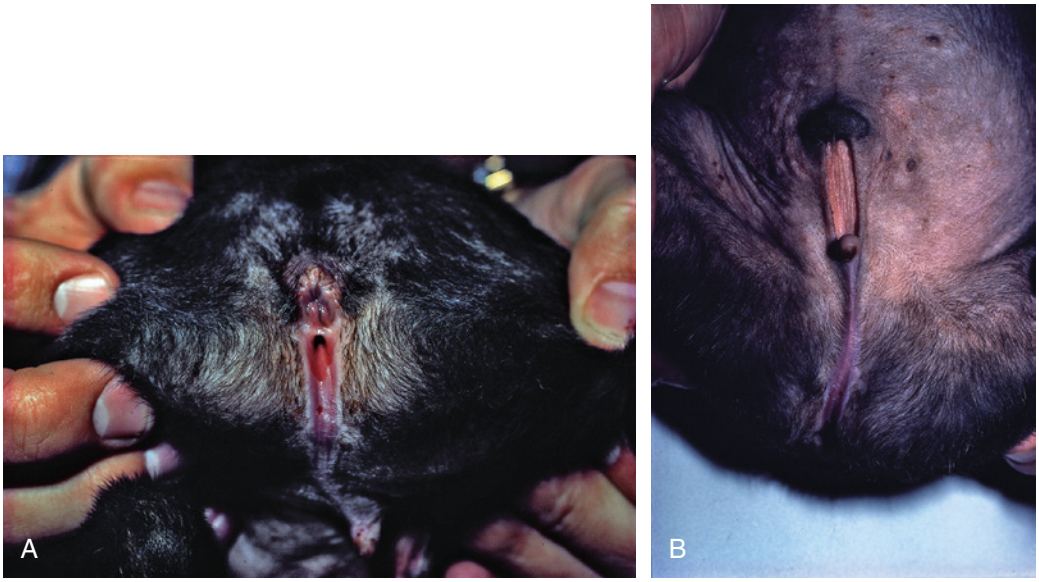


FIG. 22-16 (A) Hypospadias in the perineal area, immediately below the anus. (B) Note the incomplete formation of the penis and prepuce.

Ventral Preputial Ostium Closure to Improve Coverage to the Penile Tip

If 1–2 cm of additional ventral penile coverage is still required despite aggressive preputial advancement, or phallopexy, the mucocutaneous junction of the ventral preputial orifice can be resected: the mucosa and skin are sutured together to give better ventral penile coverage. However, a reciprocal dorsal preputial incision is required to enlarge the prepuce, as discussed earlier (see Plate 165). Ventral preputial closure also can be used in a dog with an excessively large ostium.

Preputial Advancement: Coverage of the Chronically Exposed Penile

Preputial advancement is accomplished by creating a U-shaped incision anterior to the cranial base of the prepuce and advancing the prepuce to a more cranial position. There are a few key points that need to be followed for successful use of this surgical technique (see Plate 166). One cadaver study (Yiapanis et al. 2021) in dogs suggested that greater cranial translation or advancement of the prepuce could be accomplished by division of the skin caudal to the bulbis glandis followed by dissection of the mucosa from the bulbis glandis. There is no current clinical research on this study.

Preputial advancement occasionally can result in changing the direction of the urine stream, with the patient urinating on the lower thorax. This is especially evident in dogs with a prominent dome-shaped lower thorax. Treatment for this is the author's technique of altering the preputial ostium to divert the urine stream in a downward direction (Plate 170).

Phallopexy: Coverage of the Chronically Exposed Penis

Phallopexy was originally reported for use in equine patients. In dogs, a dorsal penile mucosal incision is sutured to a reciprocal dorsal preputial mucosal incision in a position to maintain permanent caudal traction on the penile shaft (see Plate 167). There is no comparative study to determine whether phallopexy or preputial advancement is the superior procedure. It is the author's experience that both methods are effective, but the author currently prefers the phallopexy technique. These two techniques also may be combined in more challenging cases.

To date, the author has not seen patients inadvertently urinating on themselves using the phallopexy technique, unlike the preputial advancement technique. However, this urinary problem can be corrected with the urine diversion technique (see Plate 170).

Surgical Management of Hypospadias

Surgical management of hypospadias depends on the location and severity of the anomaly. Incomplete formation of the penis, prepuce, and scrotum is common, and the abnormal urethral opening will vary in location. The testicles are usually located beneath separate skin or

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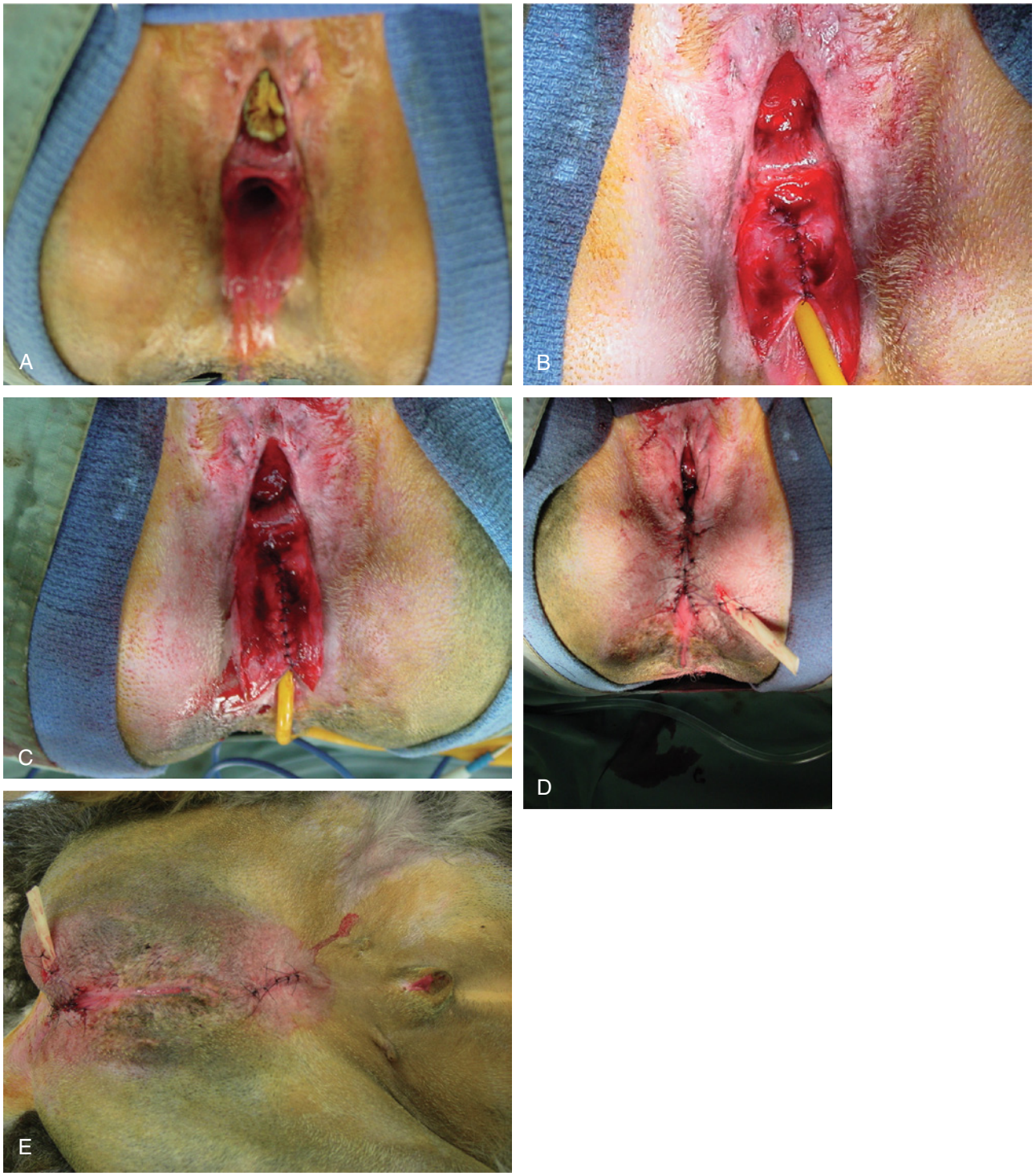


FIG. 22-17 (A) German shepherd with urethral opening immediately below the anus. (B) Creation of a urethral tube extension with an inversed tubed skin flap. (C) Completion of the inverse tube. (D) The skin margins were advanced over the tube flap, completing the procedure. (E) Abdominal view of rudimentary penis. A small area of irritated epithelium was resected. (Source: Pavletic MM. 2007. Reconstruction of the urethra by use of an inverse tubed bipedicle flap in a dog with hypospadias. *J Am Vet Med Assoc* 231:71–73. Reproduced with permission of The American Veterinary Medical Association.) (See Plate 168.)

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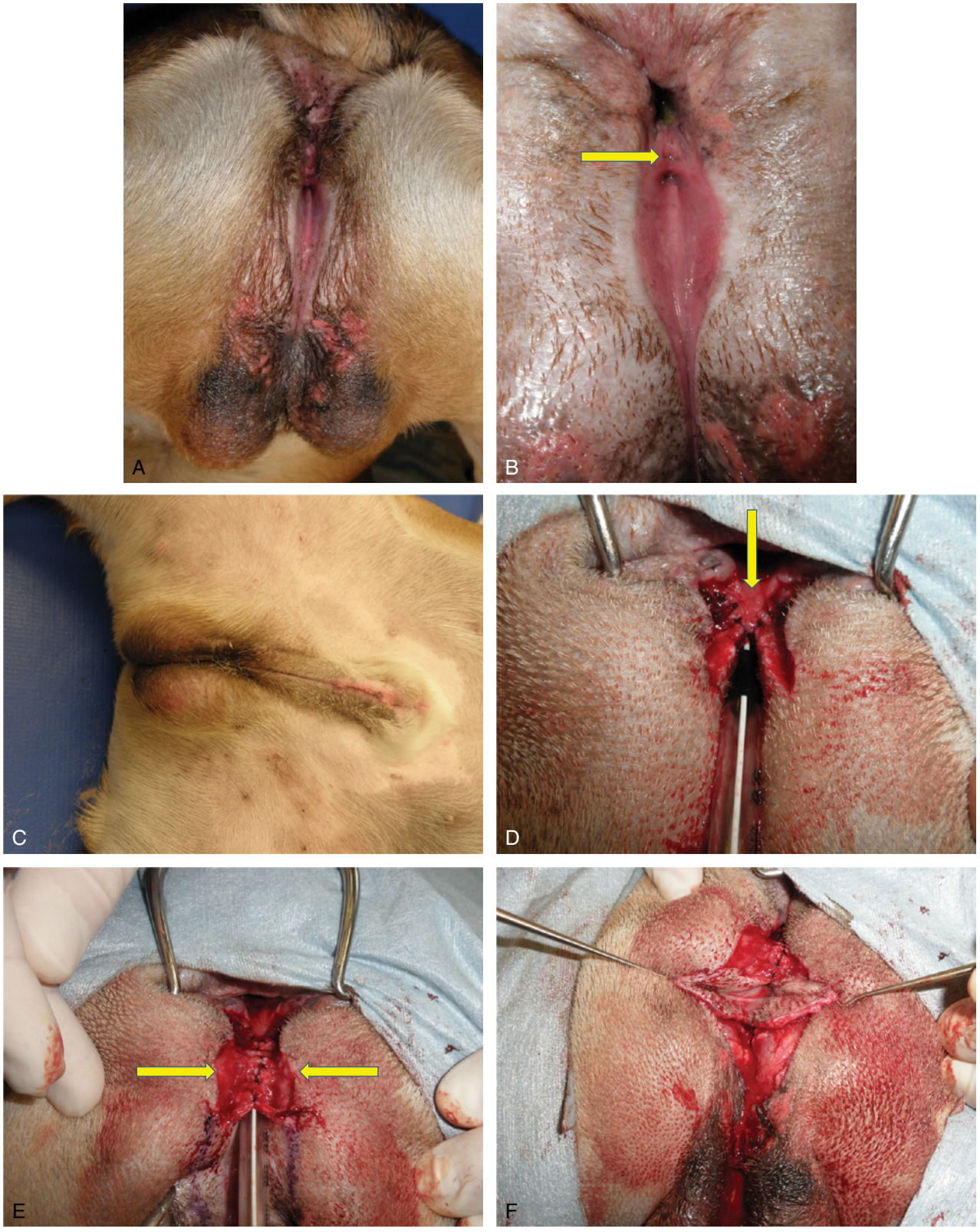


FIG. 22-18 (A) A 6-month-old bulldog with subanal hypospadias. (B) Close-up view. Note the ventral anal mucosa (arrow). This tissue will be integrated into the proximal reconstruction of a new urethra. (C) Abdominal view. Note that the prepuce and penis are nonexistent. The scrotal sac is divided by a strip of mucosa, representing the undeveloped urethra. (D) A sterile tracheotomy tube is used as a template for creating a wide urethral tube extension. The arrow denotes an anal mucosal flap folded ventrally. This mucosal flap will divert the arc of the urine stream into the lower urethral extension. (E) Based on measurements, two parallel incisions are created and the inner borders of skin/mucosa are folded over the tube (arrows). Absorbable synthetic suture is used to suture the apposing flap margins. A 4 cm urethral tube extension is created. (F) The skin at the terminal end of the urethral tube requires elevation from the deep crease of the abnormal perineum. (G) Skin margins are advanced over the inverted urethral tube. Completion of the closure. (H) The patient was neutered. The scrotal segments and adjacent tissue were resected. (I) 2-week recheck. The owner reported the dog passes a forceful stream of urine behind itself without contamination of the perineum. (See Plate 168.)

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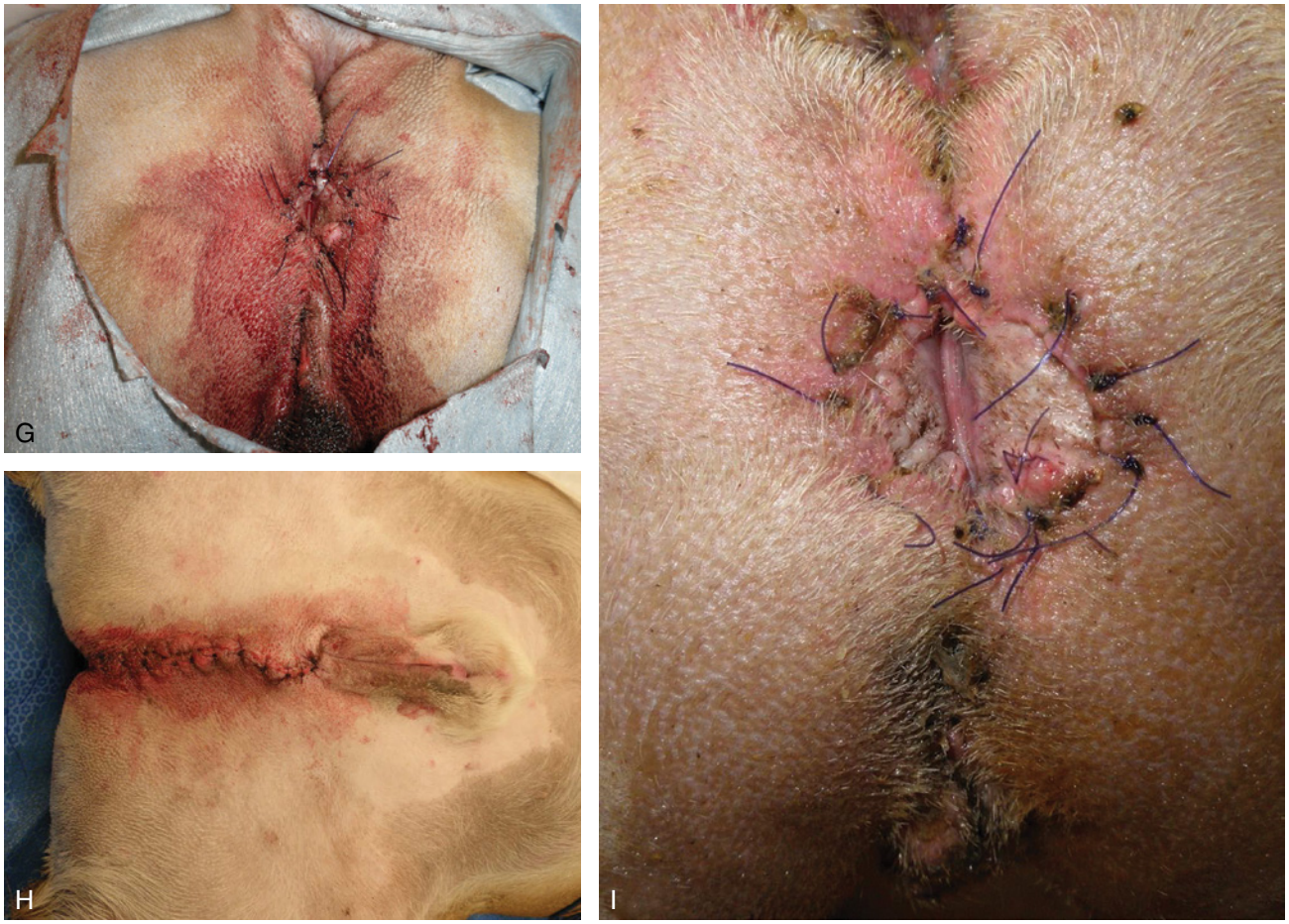


FIG. 22-18 (Continued)

scrotal pouches divided by a rudimentary band of mucosal epithelium between them. If the urethral opening is located anterior to the ischial arch (scrotal or prescrotal area), the patient can urinate relatively normally, in a fashion similar to a dog with a scrotal or prescrotal urethrostomy. If the urethral opening is located in the perineum, a variable degree of urine scalding may be expected. If the urethral opening is immediately below the anus, ascending urinary tract infections are fairly common and may necessitate creation of a urethral tube extension using the available hairless skin and uroepithelium present (Plate 168). This procedure will divert urine ventral to the anus, thereby reducing the potential of fecal contamination; local skin irritation may be noted from urine contact to the adjacent skin unless the area is kept groomed and cleaned. Topical antibiotic ointments may be used to control occasional bouts of dermatitis.

Many articles advise removal of the rudimentary penis and prepuce at the time of castration. The presence of these tissues may be a source of irritation to the dog. However, in many cases these tissues cause no problem and their removal is not mandatory. Castration, however, is advisable.

Urine Diversion Technique to Alter Direction of the Urine Stream in Male Dogs

There are occasions when a male dog inadvertently urinates on a forelimb or lower thorax. Since the original publication of this technique (Pavletic and Brum 2009), a number of pet owners have presented their dog to Angell Animal Medical Center for this corrective procedure. This condition is problematic for the patient and the frustrated owner, necessitating bathing the urine-soaked area after each urination. Because of this hygiene issue, owners banish their dog from resting on the household furniture.

This anomaly is the result of the anatomic conformation of the patient's trunk and prepuce. A prominent dome-shaped thorax and unusually elevated (tucked-up) abdominal wall can result in the urine stream exiting the prepuce, striking the lower thorax and/or forelimb. The preputial ostium also may be more open dorsally, contributing to the urine stream being directed to one forelimb or sternal area. Unfortunately, the author has seen this condition occur following preputial advancement for correcting paraphimosis. This is the result of alteration of

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FIG. 22-19 (A) Penile necrosis secondary to paraphimosis. (B) A preputiotomy was performed to expose the necrotic penile shaft. (C) Carbon dioxide laser resection of the necrotic penile segment. (D) Anastomosis of the urethra to the preputial mucosa. A release incision cranial to the prepuce facilitated the caudal displacement of the prepuce prior to the securing the urethra to the preputial mucosa. (E) Closure of the preputial mucosa. Closure of the skin completed the procedure. (Source: Pavletic MM, O'Bell SA. 2007. Subtotal penile amputation and urethrostomy in a dog. *J Am Vet Med Assoc* 230:375–77. Reproduced with permission of The American Veterinary Medical Association.) (See Plate 169.)

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the angle of the prepuce following its advancement, with urine striking the lower thoracic skin.

Surgical diversion of the urine stream can be accomplished by altering the preputial ostium (Plate 170). The craniodorsal 50–60% of the ostium can be closed "side to side" after resection of the mucocutaneous junction. Absorbable suture (4-0) is used to appose the preputial mucosa and skin. Reciprocal enlargement of the preputial ostium is performed by incising the ventral midline of the ostium sufficiently to easily extrude the penis. As a result, the urine stream strikes the closed cranial preputial ostium, with the stream diverted ventrally (Figs 22-20). Congenital or acquired loss of the preputial ostium also can result in urine striking the dog. Reconstruction of the prepuce can alleviate this problem (Figs 22-21 and 22-22).

Tumor Resection and Closure Options

The closure technique after preputial tumor resection will depend on the location of the growth, its surface area and depth of preputial involvement, and the surgical margins required for complete tumor removal. Importantly, male dogs can have variable skin laxity in this area that will influence the method of closure. For replacement of cutaneous defects, undermining and advancement, tacking sutures to offset elastic retraction, relaxing incisions, and the use of local flaps are effective options (alone or in combination). The caudal superficial epigastric axial pattern flap is capable of complete replacement of the skin surface, although this is rarely required. Preputial reconstruction is more complicated when large segments of the mucosal surface are excised. Oral mucosal grafts in combination with flap closure have been reported. For small to moderate mucosal defects, relaxing incisions can be used in combination with forward stretching or advancement of the remaining mucosa (Figs 22-23, 22-24, and 22-25).

> With surgery involving the preputial ostium, it is important to ensure the penis can be extruded and allowed to retract naturally into the prepuce intraoperatively. This is particularly important in order to avoid paraphimosis from secondary entrapment of the penis.

Complete Preputial Reconstruction

With the absence of the prepuce, there are two basic options to consider: (1) penile amputation and urethrostomy formation or (2) the combined use of a skin flap(s) with a mucosal graft harvested from the upper lip and buccal mucosa. The caudal superficial epigastric flap combined with a mucosal graft has been reported for preputial restoration. A cadaver study in dogs (Milgram et al. 2019) demonstrated the feasibility of elevating the mucosa from the bulbis glandis and penis circumferentially for use in preputial reconstruction by inclusion of the dorsal penile artery.

See Chapter 25 for additional clinical flap examples.

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FIG. 22-20 (A) Preputial ostium in a standard poodle. The dog constantly urinated on the left front limb and lower thoracic wall, at the level of the xiphoid process. (B) Excision of the mucocutaneous junction of the upper half of the preputial ostium. Absorbable interrupted sutures (4-0) are used to close the mucosa, followed by the skin. (C) Partial closure of the ostium is followed by enlarging the ostium ventrally, using a midline ventral incision of sufficient length to allow normal extrusion of the penis. (D) The V-shaped notch created by this incision is closed by suturing the individual mucosal and cutaneous borders separately. The urine stream will strike the closed dorsal ostium site, curving or rerouting flow in a ventral or downward direction. (E) The penis could be easily extruded through the new preputial ostium. Postoperatively, the urine stream went directly downward, to the relief of the frustrated owners. (Source: Pavletic MM, Brum DE. (2009). Diversion of urine stream by surgical modification of the preputial ostium in a dog. *J Am Vet Med Assoc* 235:1067–1068. Reproduced with permission of The American Veterinary Medical Association.) (See Plate 170.)

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FIG. 22-21 (A) Young retriever adopted by the owners with an abnormal preputial ostium. The dog would spray urine on the abdominal skin cranial to this defect. (B) The dorsal margin of the preputial mucosa is incised and elevated with a skin hook. (C) The elevated mucosal tissue is rotated to the left and sutured to the opposing border. This created a preputial ostium capable of deviating the urine stream from the penis in a ventral direction. (D) The skin is incised, creating a small rotational flap that is pivoted to the left, covering the exposed submucosal layer. (E) Completion of the closure. The penis could be easily extruded and retracted normally. Postoperatively, the patient urinated normally with the urine stream diverted between the patient's extremities.

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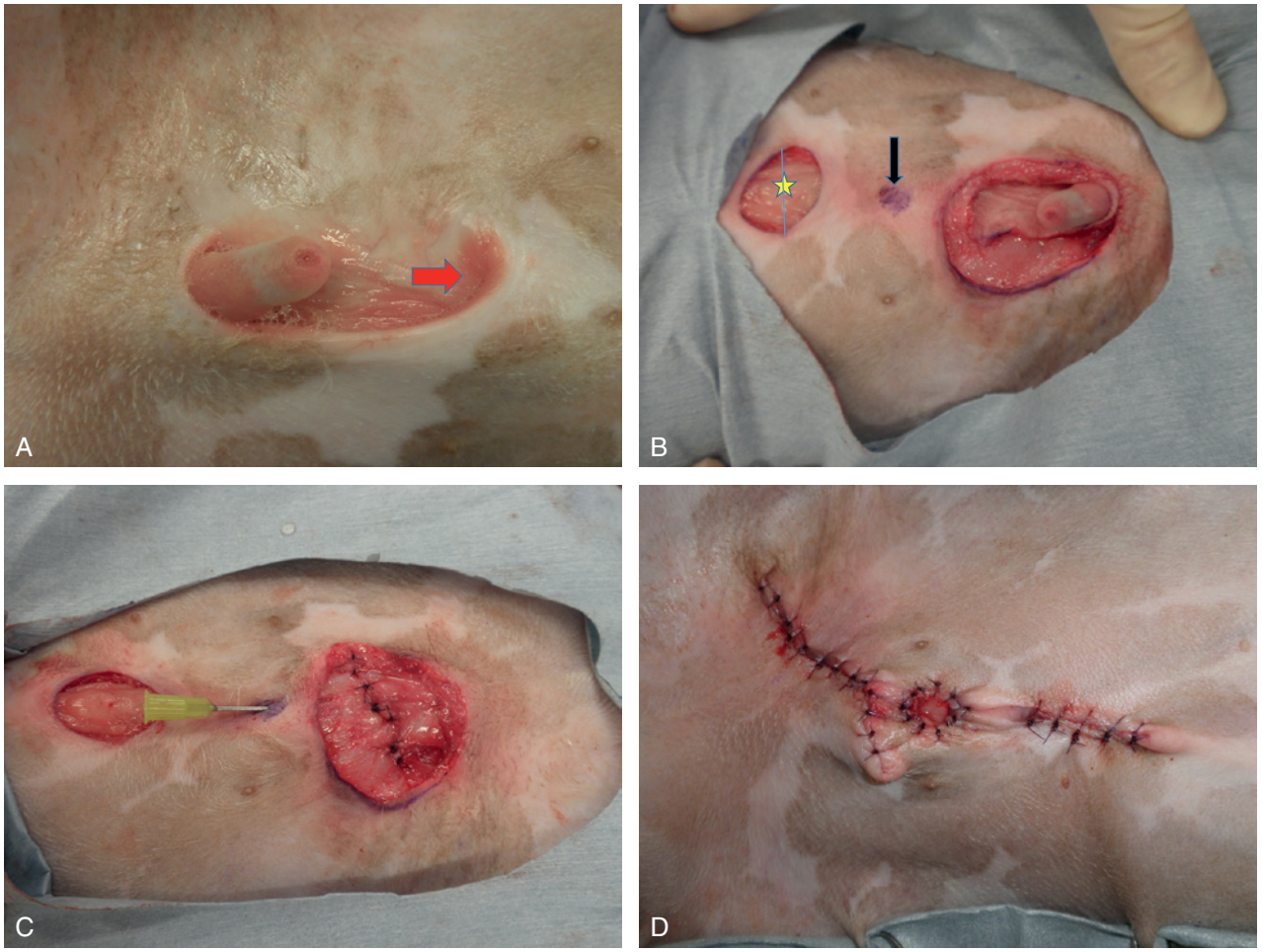


FIG. 22-22 (A) Mixed-breed dog, 5 months old, with congenital defect of the central prepuce. The dog would urinate on his lower abdomen. The cranial 2 cm of the prepuce is denoted by the arrow. The was no preputial ostium. (B) Separation of the skin margin from the preputial mucosa. The ink mark (arrow) denotes the cranial end of the prepuce. The cranial incision (star) is a release incision to facilitate closure. (C) Closure of the preputial mucosa by apposition of the cranial and caudal margins. The hypodermic needle is the location for creating a new preputial ostium and the location of the cranial preputial cavity. (D) Creation of the new preputial ostium. The skin was apposed over the preputial mucosa closure. The release incision was closed perpendicular to the original incision. The new preputial ostium was large enough to allow for the exposure and retraction of the penis.

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FIG. 22-23 (A) Mast cell tumor involving the preputial ostium. A surgical pen denotes a 2 cm margin from the marked base of the mass. The two lines denote the midline of the abdomen. (B) Resection of the tumor including the underlying preputial mucosa. (C) Resection of the mass. A small portion of the uninvolved mucocutaneous border of the ostium was preserved to form the dorsal margin of the reconstructed ostium. (D) Forward stretching of the mucosal cylinder to facilitate penile coverage. Monofilament nylon sutures are used to secure the leading submucosal border to the abdominal muscle fascia to prevent its retraction. (E) The cutaneous margins are advanced: dermal tacking sutures are used to negate elastic retraction of the advanced borders (dermal sutures secured to the abdominal muscle fascia). (F) Completion of the closure. The urine exited in a ventral direction postoperatively without soiling the patient's skin.

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FIG. 22-24 (A) Mast cell tumor involving the lower preputial surface immediately caudal to the ventral margin of the ostium. (B) Resection of the mast cell tumor, including the underlying preputial mucosa. (C) A no. 15 blade was used to create a dorsal release incision in the mucosa, facilitating the reconstruction of the ventral mucosal defect. (D) Absorbable sutures were used to close the ventral mucosal defect. Forceps define the new preputial ostium. (E) Closure of the cutaneous defect. Tacking dermal sutures were used to advance the remaining lateral borders, offsetting elastic retraction of their margins. (F) Completion of the closure. Note the two release incisions used to facilitate the advancement and apposition of the lateral skin margins.

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FIG. 22-25 (A) Mast cell tumor involving the right lateral base of the prepuce. The surgical marking pen (gentian violet) is the 2 cm perimeter around the base of the tumor. The skin is incised along the outer border of the ink outline. (B) Following closure of the mucosal defect, the lateral skin was undermined. Note the use of dermal tacking sutures applied to the abdominal muscle fascia. These sutures promote the advancement of the skin while minimizing the natural tendency of this skin to retract to its original position. (C) Completion of the closure. (D) Instrument insertion of the restored preputial ostium. Extrusion of the penis and assessing its retraction into the prepuce are important to help ensure paraphimosis (or phimosis) will not occur postoperatively.

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Plate 164

Preputial Ostium Enlargement

DESCRIPTION

Enlargement of the preputial orifice or ostium is normally performed to correct phimosis and those cases of paraphimosis where the size of this orifice is marginal.

SURGICAL TECHNIQUE

(A_1, A_2) Cranial and lateral views of the preputial orifice. The dorsal midline incision is created in small increments; the penis is extruded after each progressive incision to ensure the penis can easily enter/exit the ostium.

(B_1, B_2) The penis can be extruded and replaced without difficulty into the prepuce.

(C_1, C_2) The opposing skin and mucosal borders are sutured with 4-0 absorbable sutures, creating a permanent V-shaped notch.

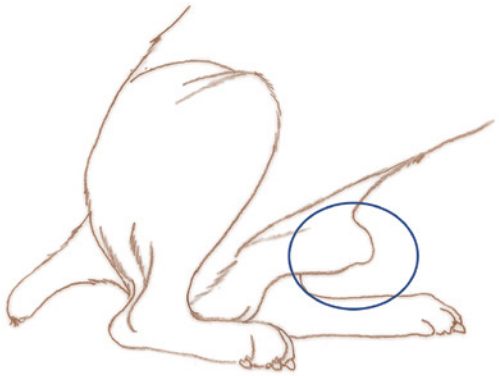
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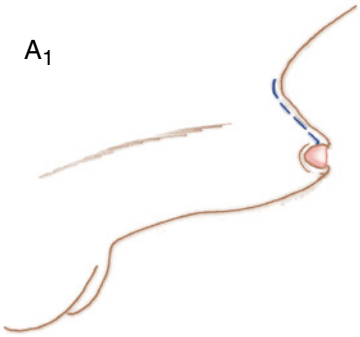
In those urgent/emergent cases of paraphimosis with penile entrapment, the ventral ostium is more accessible for temporary emergency enlargement by creating a linear incision using blunt-tipped scissors. A scalpel blade also can be used, but insertion of a lubricated Bard-Parker scalpel handle inside the ostium is advisable, providing a protective shield to the enlarged penis. As long as the penile viability is maintained, permanent ostium enlargement is performed as illustrated.

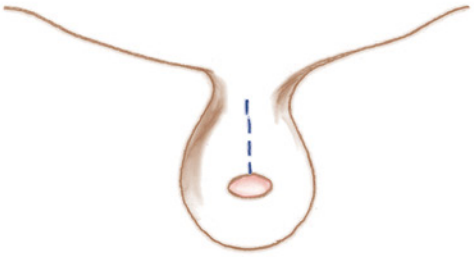
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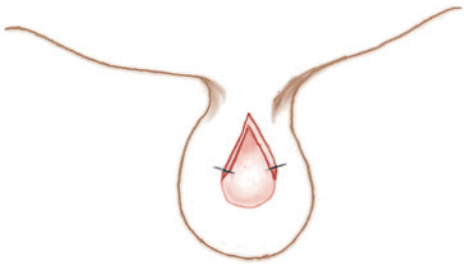
Plate 164

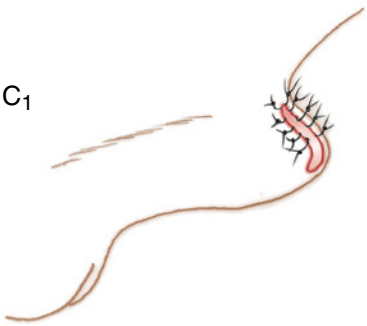


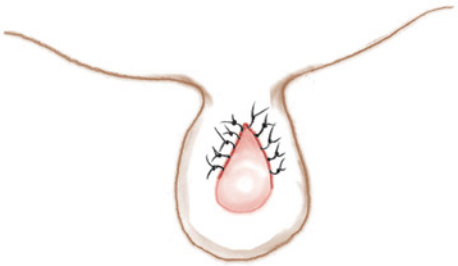












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Plate 165

Preputial Ostium Reduction

DESCRIPTION

Ventral reduction in the size of the ostium is used for two purposes: correction of an excessively large ostium to prevent penile exposure or to create a ventral sling cover in conjunction with preputial advancement (Plate 166) for moderate to severe cases of paraphimosis. In the latter case, a reciprocal enlargement of the orifice is required (Plate 164).

SURGICAL TECHNIQUE

(A_1, A_2) Lateral and frontal view of the ostium and exposed penile tip.
(B_1, B_2) Excision of the ventral "third" of the mucocutaneous junction of the ostium.
(C_1, C_2) Apposition of the mucosal surface with absorbable 4-0 sutures.
(D_1, D_2) Closure of the cutaneous margins.

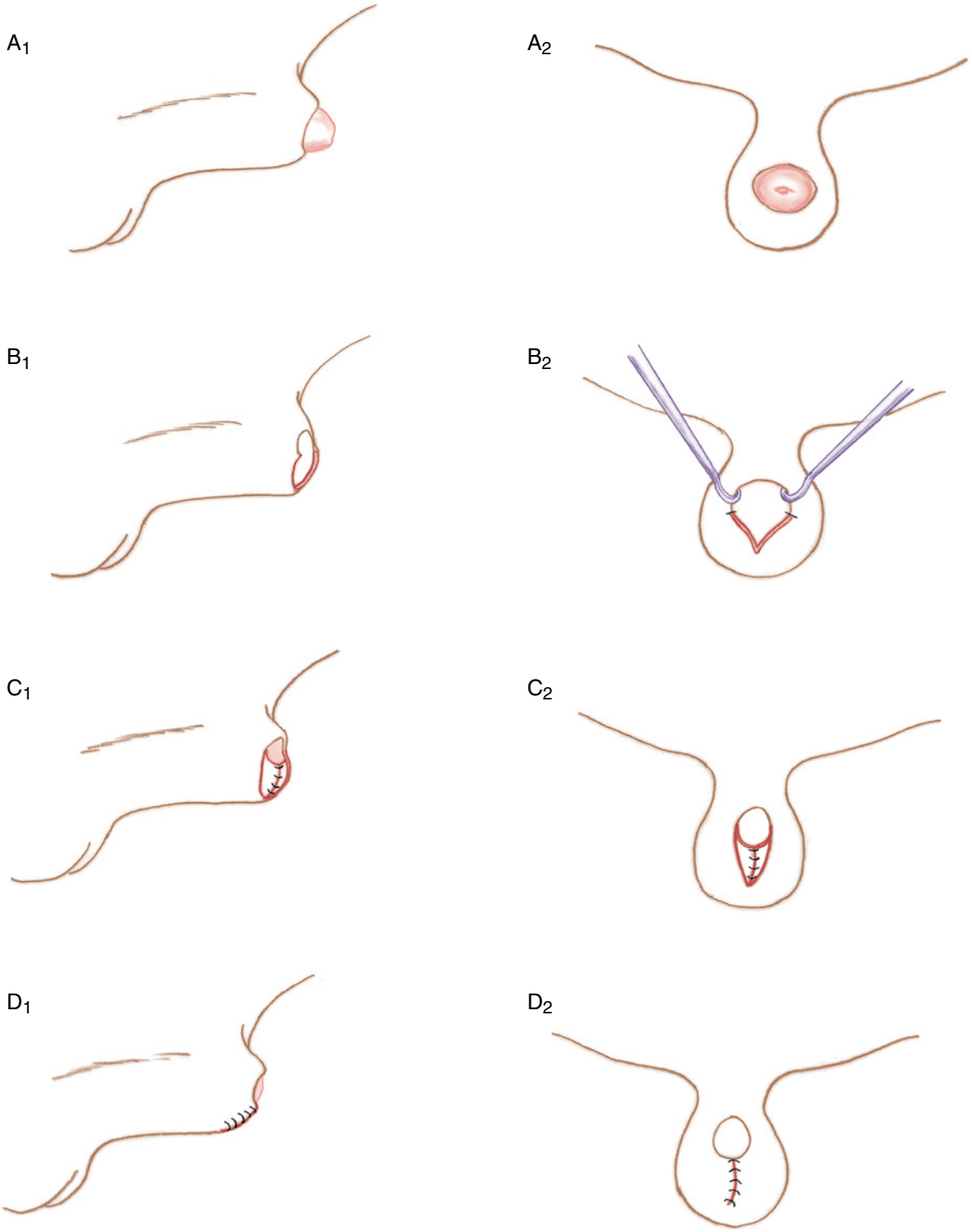
COMMENTS

Partial ventral closure of the orifice alone, as a primary treatment for paraphimosis, must be done with caution: should the dog have an erection, strangulation of the exteriorized penis is possible. Intraoperatively, the penis is extruded after surgically manipulating the ostium to help ensure this orifice is the appropriate size. The author normally reserves this technique as an adjunct to preputial advancement to gain an additional 1–2 cm of coverage of the penile tip, with reciprocal enlargement of the dorsal portion of the ostium. As noted, phallopexy (Plate 167) also is a surgical option to consider for those challenging cases of paraphimosis.

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Plate 165



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Plate 166 Preputial Advancement Technique

DESCRIPTION

Preputial advancement is a common surgical technique employed for managing paraphimosis. Enlargement of the preputial orifice or ostium can be performed if necessary (see Plate 164). An alternative to preputial advancement is a modification of the Bolz phallopexy technique, described in Plate 167.

SURGICAL TECHNIQUE

(A) Example of paraphimosis. The surgeon can initially assess preputial advancement by grasping the prepuce with forceps and applying forward traction.

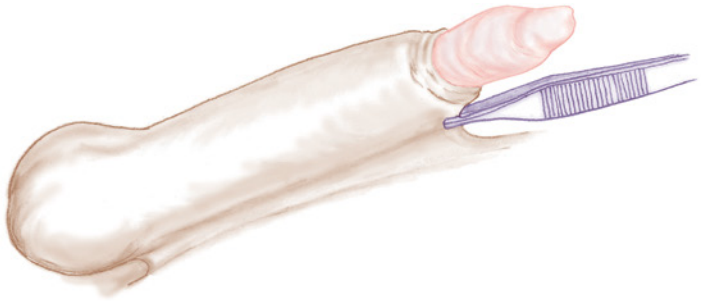
(B) A curved incision is created from this cranial point in a caudal direction: the width of the curve will approximate the width of the prepuce and attached cutaneous skin margin. A second curved incision is created anterior to the base of the prepuce and extends caudally a few centimeters along the junction of the prepuce and ventral abdominal wall. The skin within this area (dashed lines) is resected.

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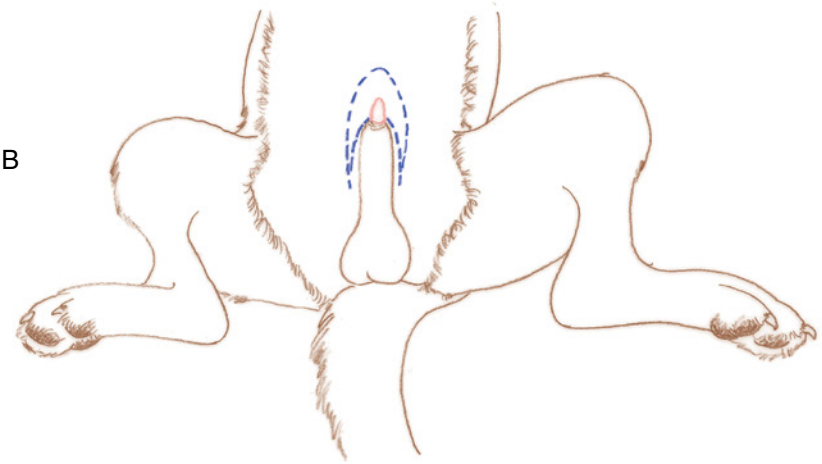
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Plate 166

A



B



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Plate 166

(Continued)

(C) Skin hooks or stay sutures applied to the incised skin border are ideally suited for forward traction to the undermined prepuce. The prepuce is undermined and the lateral incisions extended to facilitate advancement as needed. The prepuce is ideally advanced to the point at which the penis retracts into the preputial cavity 1–2 cm from the ostium. (It is the author's experience that overcompensation does not create a problem.) Three or four nonabsorbable (monofilament nylon or prolene) or slowly absorbable sutures are used to secure the cranial dermal border of the prepuce to the external abdominal oblique muscle fascia (3-0 or 4-0, depending on patient size and skin thickness). The hindlimbs can be manipulated (flexed and extended) to ensure penile coverage is complete. The remaining incision can be closed with an intradermal suture pattern.

(D) This is followed by closure of the skin with a simple interrupted suture pattern (3-0 or 4-0).

COMMENTS

Positioning of the patient's rear legs can affect the outcome of this procedure. The author normally places the legs in a neutral to slightly extended position to promote penile extrusion. Unless this is done, the surgeon may underestimate the forward advancement required to properly cover the penis.

The entire penis and prepuce can be completely elevated from the abdominal wall without compromising their circulation. This would suggest that surgeons can be more aggressive in elevating the prepuce prior to advancement. Any restrictive scar bands that underlie the prepuce must be divided to facilitate preputial advancement.

A key to effective preputial advancement is often overlooked in the veterinary literature: securing the dermal surface of the advanced preputial border to the external abdominal oblique muscle fascia. Otherwise, the elastic skin of the abdomen can stretch, negating the penile coverage gained by this surgical technique. Securing the lead dermal border of the prepuce to the abdominal wall dramatically reduces tension on the skin anterior to the point of advancement.

It has been the author's experience that imbrication or shortening of the preputialis muscle alone cannot correct paraphimosis. Preputial advancement alone can correct paraphimosis without the need to operate on this thin muscle. Simply put, surgical manipulation of the preputialis muscle is not necessary.

If, after maximal advancement, there is persistent exposure of the penile tip, the ventral border of the preputial ostium can be closed to improve ventral coverage. Reciprocally, a small dorsal incision can be made to enlarge the ostium (see Plates 164 and 165).

In cases where preputial advancement and modification of the preputial ostium fail to cover the penis, phallopexy also can be performed. Partial penile amputation is considered as a last resort in those rare problematic cases where combined techniques fail and the exposed penis is a source of discomfort to the dog. In this case only a small portion of the penis, anterior to the os penis, normally requires removal.

Preputial advancement can be problematic in small dogs with a prominent dome-shaped thorax. Preputial advancement over the more dorsally "tucked" abdominal wall of a dog can result in the urine stream striking the abdomen and lower curvature of the caudal thorax. This can be remedied by closure of the dorsal ostium, described in Fig. 22-20 (See Plate 170). Under these circumstances, phallopexy (Plate 167) may be a better surgical alternative in patients with this body conformation.

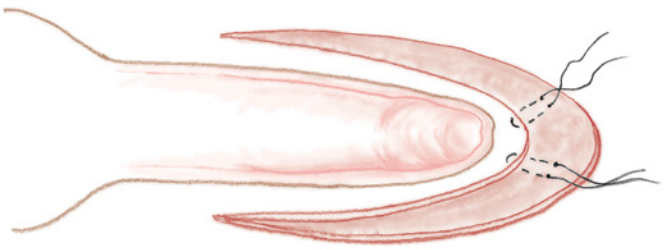
Surgeons have been concerned about overcompensating for paraphimosis, causing the penis to be displaced too far caudally in the preputial cavity. The fear is that urine irritation will cause balanoposthitis. From the author's clinical experience, this is rarely a cause for concern. The mucosal lining of the prepuce routinely tolerates urine exposure. Preputial shortening, advocated in some textbooks after partial penile amputation, is normally considered unnecessary.

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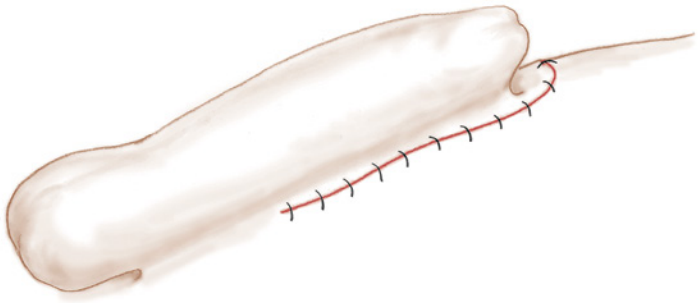
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Plate 166

C



D



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Plate 167

Phallopexy

DESCRIPTION

Phallopexy creates a permanent adhesion between the inner preputial lining and adjacent penile surface to prevent recurrent paraphimosis. It may be used as an alternative to the preputial advancement technique discussed in Plate 166, depending on the severity of the condition. This is based on the technique published by Somerville and Anderson (2001).

SURGICAL TECHNIQUE

(A) A 4–6 cm skin incision is made along the junction of the prepuce and dorsal body wall, approximately 3 cm caudal to the preputial ostium. The incision is extended through the parietal preputial layer, exposing the penile shaft. The excision can be enlarged to facilitate surgical exposure. Small self-retaining retractors are inserted to facilitate visualization.

(B) A 3–5 cm mucosal incision is created along the dorsal midline of the preputial cavity beginning 3 cm caudal to the preputial ostium to the level of the preputial fornix caudally: a 3–5 mm strip of mucosa can be resected to facilitate suture placement. To expose the dorsal penile surface, the penile shaft can be exteriorized through the preputial orifice. The dorsal surface of the penile shaft is exposed: a superficial reciprocal penile incision is created approximately 2 cm from the tip of the penis. Iris scissors can be used to meticulously remove a thin strip of penile mucosa to facilitate suture placement.

(C) A couple of "trial" interrupted sutures (3-0 or 4-0, slowly absorbable) are placed at the anterior aspect of the apposed incisions. Exteriorization of the penis is then attempted through the preputial orifice. Sutures can be repositioned to improve caudal traction to the penis if necessary. If complete exteriorization of the penis through the ostium cannot be performed manually, several (six to eight) interrupted absorbable sutures (3-0 or 4-0 polydioxanone) are used to appose the dorsal preputial and penile mucosal incisions. The author normally places interrupted sutures in both the left and right sides of the incisions rather than a single row of sutures for better security. Hemorrhage is noted with this procedure, but this is normally controlled when the sutures are secured.

(D, E) Closure of the preputial mucosa is followed by closure of the cutaneous access incision, completing the surgery. Castration can be performed prior to or after phallopexy.

COMMENTS

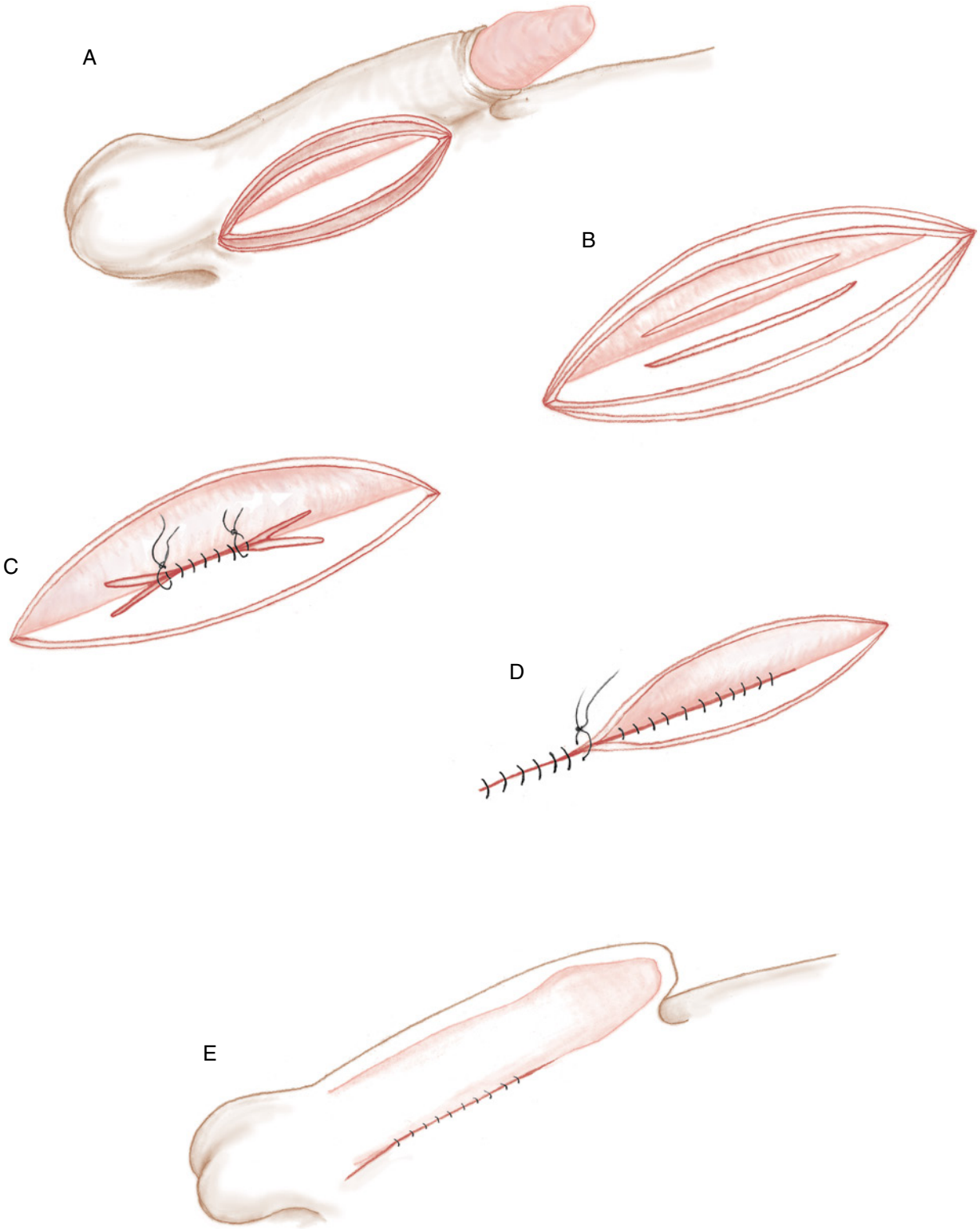
This is a variation of the Bolz phallopexy technique used to treat paraphimosis in horses. Somerville and Anderson (2001) reported that the dorsal preputial wall is less mobile than its ventral counterpart, possibly providing a better anchor for phallopexy. They also noted that the penile urethra is more superficial ventrally. (A ventral phallopexy may be possible if the penile incision is placed 1 cm lateral to the ventral midline of the glans penis to avoid injury to the urethra. The penile mucosal incision is sutured to the ventral preputial mucosal incision used to expose the penis.) (See Fig. 22-12).

Somerville and Anderson (2001) expressed concern that excessive penile retraction could result in urine pooling with secondary balanoposthitis. The author's experience has indicated that this potential complication does not occur, and the risk of this problem has been grossly overstated (or perpetuated) in the veterinary literature. It is for this reason that preputial shortening after partial penile amputation is unnecessary.

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Plate 167



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Plate 168 Urethral Reconstruction for Subanal Hypospadias

DESCRIPTION

Perineal (subanal) hypospadias predisposes patients to recurrent ascending urinary tract infections. Reconstruction of a urethral extension can separate the terminal urethra from the anal orifice, dramatically reducing bacterial contamination and secondary cystitis.

SURGICAL TECHNIQUE

(A) Illustration of perineal (subanal) hypospadias.

(B) Insertion of a red rubber catheter, approximating the diameter of the terminal urethra. Alternatively, a small sterilized endotracheal tube also may be used in a similar fashion depending on the diameter available. The circumference of the urethra can be calculated by multiplying the diameter of the intact urethra by 3.14 (π). (If the terminal urethra is 15 mm in diameter, then the circumference is 47.1 mm.) The arms of the U incision, in this example, would be 47 mm apart, with the curvature of the U incision dorsal to the urethral orifice. Incisions are extended ventrally 4–7 cm, depending on the size of the dog.

(C) The skin is gently undermined and folded inward: the opposing skin borders are sutured with a series of simple interrupted absorbable sutures (3-0, 4-0). The upper portion of the U is sutured, creating a Y closure. Note that an adjacent anal mucosal flap can be folded ventrally to facilitate closure of the most proximal aspect of the urethral extension tube.

(D) The outer skin borders are advanced and sutured over the "inverse urethral tube."

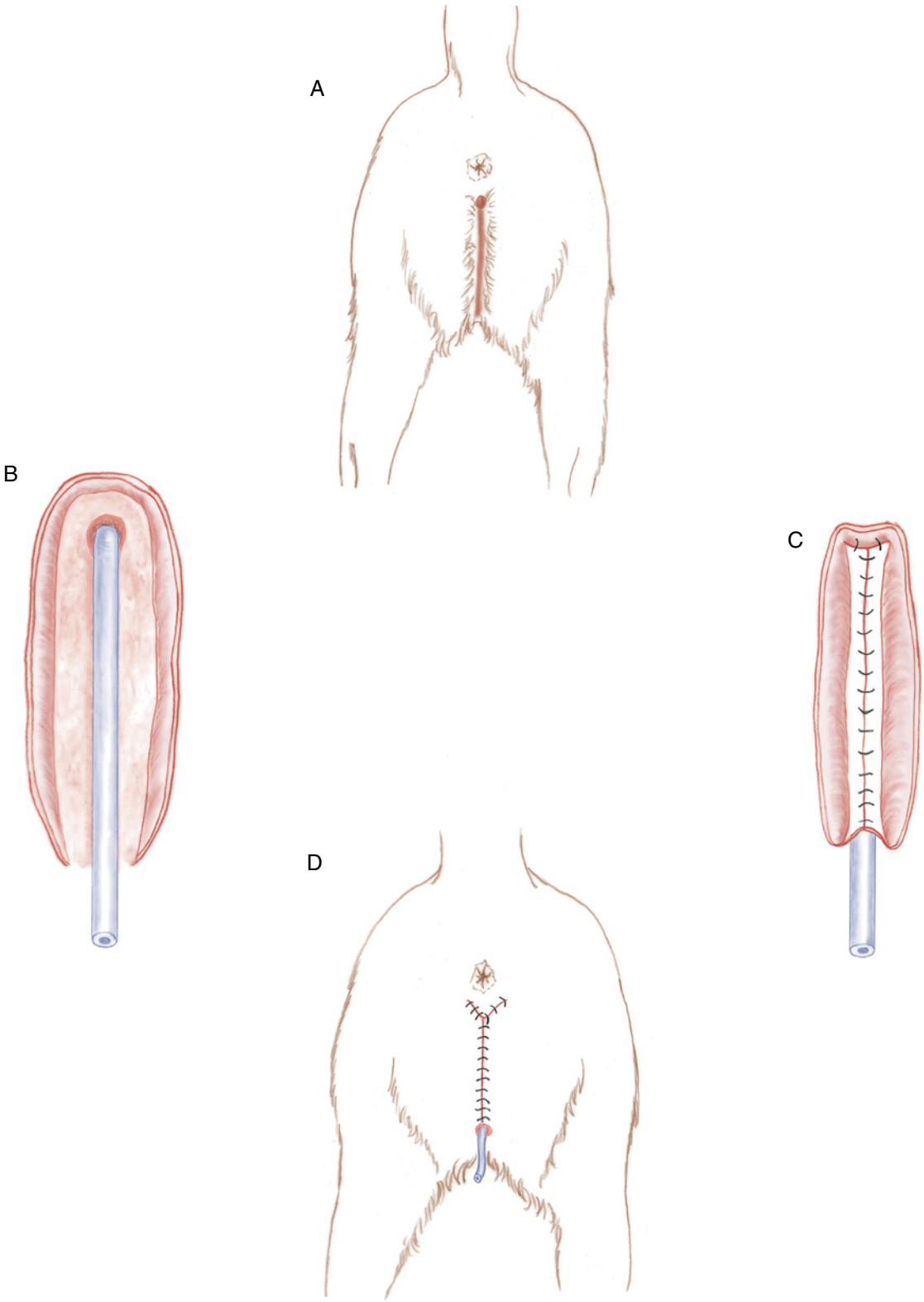
COMMENTS

A Foley catheter can be connected to a closed collection system if postoperative swelling is anticipated and removed as tissue edema subsides (3–5 days as a suggested guideline). Alternatively, the surgeon may elect not to use a catheter postoperatively and to closely assess the urinations before deciding on placing a urinary catheter. Long hair should be trimmed around the orifice to help prevent future irritation from urine contact with the adjacent skin. (See Figs. 22-17 and 22-18).

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Plate 168



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Plate 169

Preputial Urethrostomy Technique

DESCRIPTION

Penile amputation secondary to trauma or disease will dictate the location of a urethrostomy. In those cases of penile resection at the level of the preputial fornix, anastomosis of the terminal urethra to the preputial mucosa can result in a simple and effective permanent urethrostomy. Urine exits the preputial ostium in a steady stream, eliminating the urine irritation and scalding occasionally noted with prescrotal urethrostomies. A ventral preputiotomy incision simplifies penile amputation and urethral anastomosis to the inner preputial mucosal lining.

SURGICAL TECHNIQUE

(A) Full-thickness ventral preputiotomy incision. The penis is extruded and penile amputation of the necrotic penis (secondary to strangulation necrosis secondary to paraphimosis) is performed caudal to the os penis in this example. A carbon dioxide laser may be used to reduce hemorrhage.

(B) The terminal urethra is sutured to the caudal border of the preputial mucosa. Absorbable suture (4-0 or 5-0) is used for the anastomosis. (It is also possible to anastomose the terminal urethra via a small circular incision created in the adjacent preputial mucosal surface.)

(C) Continuation of the suturing of the urethra to the preputial mucosa. (*Note*: If tension is noted during anastomosis, a release incision can be made cranial to the anterior base of the prepuce; this facilitates the caudal displacement of the prepuce. On completion, the release incision can be closed.)

(D) After anastomosis, the preputial access incision is closed, first by closure of the mucosal layer.

(E) The cutaneous preputiotomy incision is closed, completing the procedure.

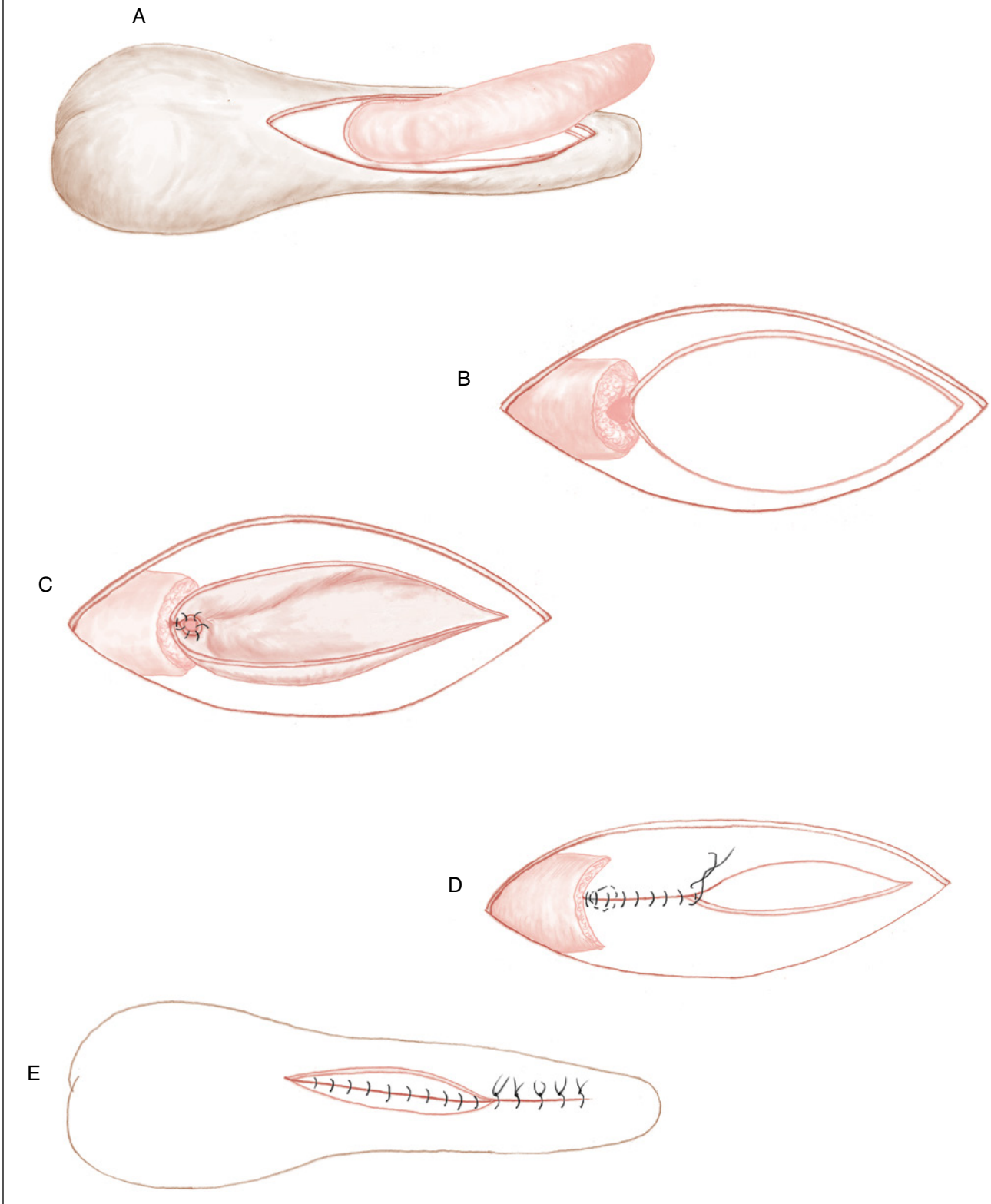
COMMENTS

A release incision, cranial to the preputial attachment to the abdominal skin, can be used to facilitate shifting of the prepuce caudally: this can reduce tension at the site of the urethral anastomosis to the preputial mucosa. The preputial cavity serves as a satisfactory conduit for urine passage from the urethrostomy site. If postoperative swelling is anticipated, it may be advisable to place a Foley catheter through the preputial ostium, guiding the catheter into the new urethral stoma prior to closure of the preputiotomy incision. The catheter can be left in for 3–5 days, at which time swelling would be expected to decrease. (See Fig. 22-19).

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Plate 169



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Plate 170 Urine Diversion Technique

DESCRIPTION

The prepuce protects the penis, but also plays a major role in the shape and direction of the urine stream. As a result, occasionally male dogs will inadvertently urinate on their lower chest or front leg as a result of their anatomic conformation. The technique of preputial advancement (Plate 166) for correction of paraphimosis also can alter the direction of the urine stream, resulting in the urine stream striking the anterior abdomen and thorax postoperatively. The author has seen various dog breeds that present with this problem. This condition is especially evident in dogs with a prominent dome-shaped thorax with an elevated/tucked abdomen. Regardless of the cause, partial closure of the dorsal half of the preputial ostium and reciprocally enlarging the ventral portion of the ostium will curve the urine stream downward, eliminating contamination to the patient's body.

SURGICAL TECHNIQUE

(A) Focus on the preputial ostium.
(B) The mucocutaneous junction of the dorsal half of the preputial ostium is trimmed or incised (dashed line), thereby separating the mucosal and cutaneous margins.
(C) Complete separation of the mucosal and cutaneous surfaces.
(D) 3-0 or 4-0 absorbable sutures are used to appose the mucosal margins.
(E) The incised skin margins are apposed, completing the dorsal closure. The dashed line denotes the location to incise the ventral margin of the ostium.
(F) The ventral incision is extended to create the original diameter of the ostium. The cutaneous margin is sutured to its opposing mucosal margins. The penis is extruded to ensure it is capable of spontaneously sliding back into the preputial cavity prior to anesthetic recovery.
(G) Transparent view of the penis within the prepuce. Urine exiting the penis strikes the preputial closure, deviating the urine stream ventrally (arrow).

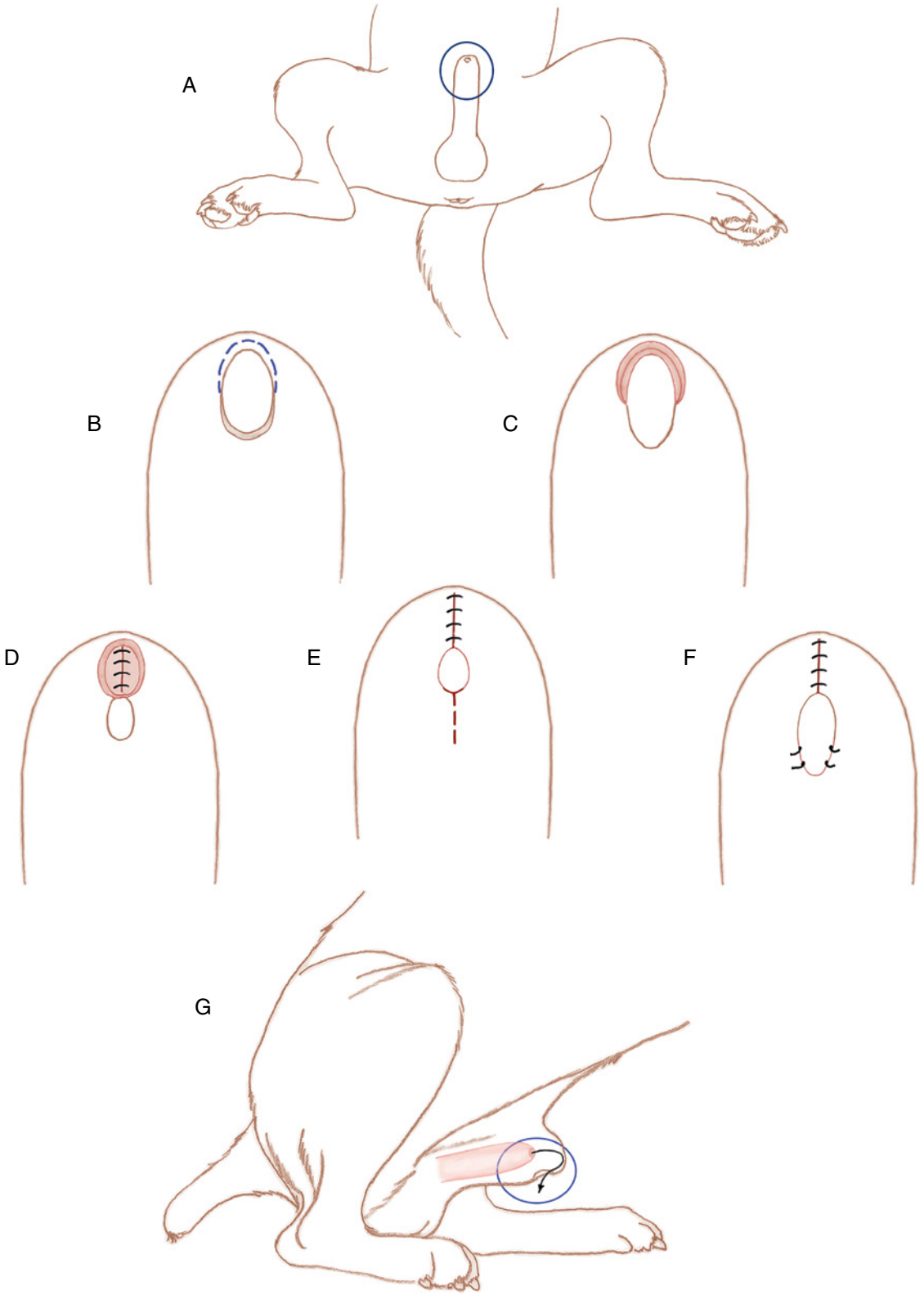
COMMENTS

Owners express considerable frustration when their male dogs urinate on themselves, necessitating washing the affected body area periodically throughout the day. The author has used this technique successfully on a number of dogs since the initial publication of this procedure. This urine diversion technique is both simple and effective in changing the direction of the urine stream ventrally. It is important to enlarge the ventral portion of the ostium sufficiently to avoid the risk of paraphimosis. The urine stream strikes the upper half of the ostium and this closed segment, curving the flow ventrally between the dog's legs. As noted, preputial advancement for paraphimosis can result in dogs urinating on themselves; this technique is the solution to that problem. (See Fig. 22-20).

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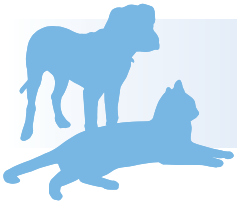
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Plate 170



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23

Pinnal Reconstructive Surgery

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Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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INTRODUCTION

In the past, veterinary surgery of the pinna was primarily focused on the management of aural hematomas and ear cropping. The evolution of veterinary reconstructive surgery better allows us to address the variety of traumatic wounds involving the external ear. Moreover, these surgical techniques allow us to resect neoplastic lesions of the pinna without resorting to unnecessarily aggressive excision of this structure. Pet owners resistant to resection of the entire pinna are relieved to know that in many cases complete tumor resection can be achieved and the surgical defect restored with the techniques discussed in this review of pinnal reconstructive surgery.

ANATOMY OF THE PINNA

The auricle or pinna (*auricula*) is a flat plate of cartilage covered by two layers of skin. The *apex* of the pinna points dorsally in erect-ear dogs and cats. It points ventrally in folded ears. The lateral and medial designations of the pinnal surface are confusing, considering that the convex surface faces medially in erect ears whereas the convex surface in a floppy ear primarily can face laterally. Dogs and cats also are capable of pivoting their ears' positions. The confusion of "lateral versus medial" can be avoided by referring to the *concave* or *inner* pinnal surface and the *convex* or *outer* pinnal surface of the outer ear.

The margins or borders of the pinna face rostrally and caudally. The rostral border of the auricular cartilage is nearly straight whereas the caudal border is somewhat curved. The free edge of the auricular cartilage is called the *helix*: it is divided into *medial (rostral)* and *lateral (caudal)* parts, which join to form the apex or tip of the ear (Fig. 23-1).

The size, shape, and conformation of the pinna can vary considerably between breeds and species (Fig. 23-2). The two pinnal surfaces have visibly different cutaneous surfaces, including hair growth, skin laxity, and thickness. The skin on the (medial) concave or inner pinnal surface is affixed to the underlying perichondrium, whereas the (lateral) convex or outer pinnal skin is loosely attached to the underlying perichondrium except for the terminal third of the pinna. The hair coat is notably denser on the convex surface whereas the hair growth on the concave surface is comparatively sparse.

The anatomic structure of the pinna has been largely overlooked in surgery. The looser, elastic skin in the lower two-thirds of the lateral or convex pinnal surface facilitates tumor resection and closure of defects. By contrast, the entire concave or inner pinnal cutaneous surface is firmly affixed to the underlying perichondrium, as is the terminal third of the pinna on the convex surface. Surgical procedures are more challenging in the areas where the skin is affixed to the perichondrium. In these areas the attached cartilage limits the overlying skin's elasticity: attempts at appositional closure of wounds are met with local dimpling and folding of the pinna.

Three Zones of the Pinna

For the sake of clarity, the pinna can be divided into thirds or three zones based on the relative availability of pliable skin overlying the lateral (outer, convex) pinnal surface. Additionally, reconstructive surgical procedures can be utilized for closure of problematic wounds in zones I and II. The skin of the lower third of the outer pinna (zone I) is highly mobile and easily lifted from the underlying pinnal cartilage (Fig. 23-3). The skin overlying the central third of this pinnal surface (zone II) also can be lifted from the pinnal cartilage but is less ample and mobile. The lateral skin of the apex of the pinna (zone III) thins and affixes to the perichondrium, beginning at the junction of zones II–III. By contrast, the medial (inner, concave) pinnal skin is affixed to the underlying perichondrium.

Wound closure and reconstructive surgical options vary in these three zones of the lateral pinna (Fig. 23-4). Skin of zones I and II (convex/lateral pinnal surface) facilitates both resection of tumors and closure of the surgical defects. This loose skin can be advanced or pivoted as a transposition flap. Moreover, the skin surrounding the base of the ear (cervical skin, dorsum of head) is a major donor source for skin flap elevation and reconstruction of large portions of the pinna. In order to close wounds involving the medial or inner pinnal surface, the adjacent facial skin is the primary donor area for transposition flap reconstruction. Of the various pedicle graft techniques, 90° transposition flaps are particularly effective for the more problematic pinnal wounds.

The terminal third of the ear is problematic for restoration of either pinnal surface. Separation of the skin from the perichondrium by undermining is exceedingly difficult on either side of the pinna in this distant zone (III). With the exception of comparatively small tumors, neoplasms are best managed by full-thickness resection of this region.

Dividing the pinna into three zones allows the surgeon to better plan how to close surgical or traumatic defects based on the anatomy of the pinna (Fig. 23-4).

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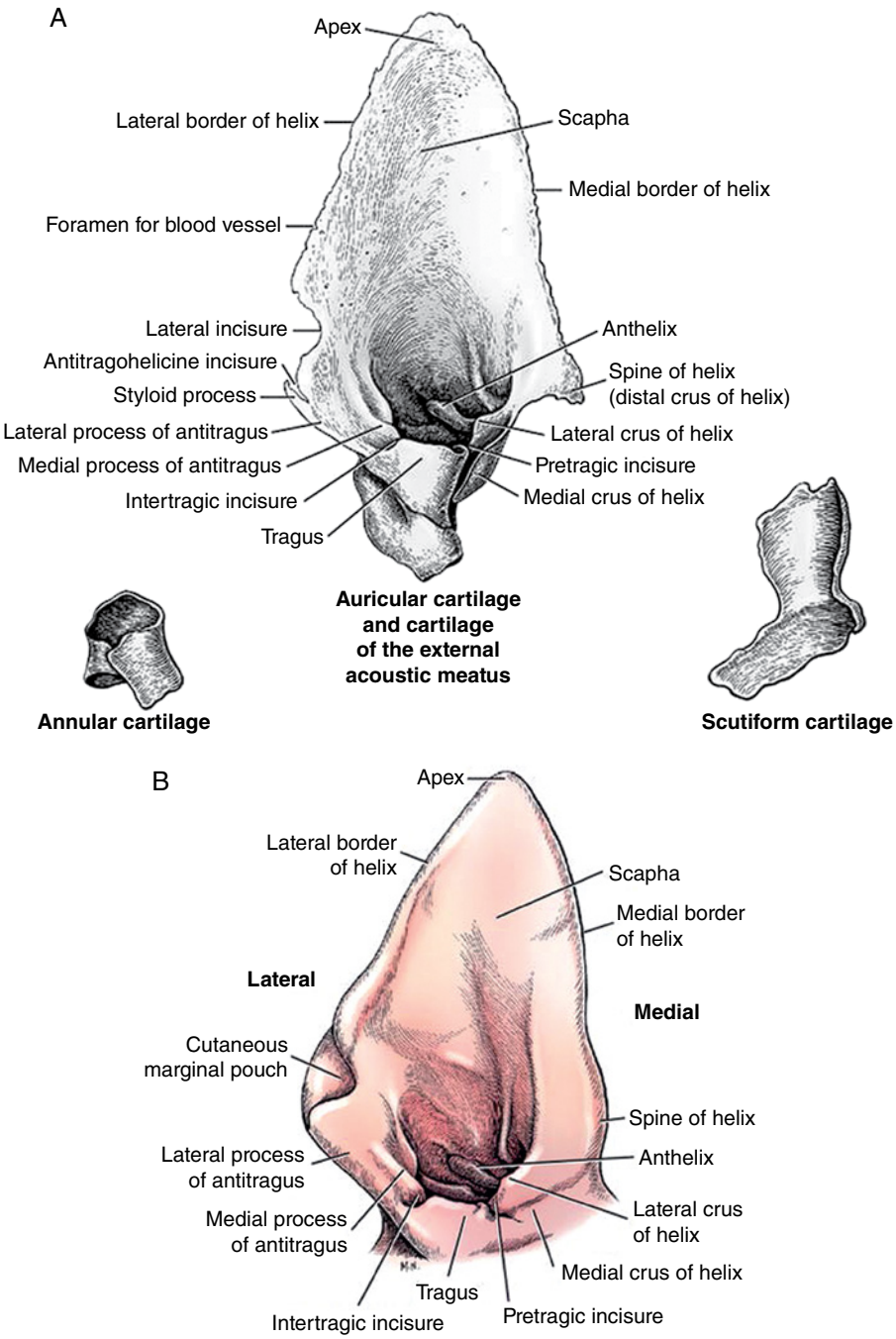


FIG. 23-1 (A, B) The anatomy of the pinna. (Source: Evans HE, de Lahunta A. 2013. *Miller's Anatomy of the Dog*, 4th ed. Philadelphia, PA, Elsevier. Reproduced with permission of Elsevier.)

The lower rostral and caudal helical margins of the pinna occasionally require tumor resection. Reconstruction is relatively simple to perform based on the comparatively ample amount of loose elastic skin around the base of the pinna. This available donor area can be advanced or transposed into surgical or traumatic skin defects into these two areas (see Plates 171 and 172).

While veterinary surgery now has the means to reconstruct the entire pinna, multistage procedures to perform this task are lacking in practicality. Clearly the pinna has a function, but all animals can function without this anatomic structure. "Pinnectomy" is normally reserved for neoplasms involving a large portion of the pinna or traumatic loss of this structure (Fig. 23-5). However, in many

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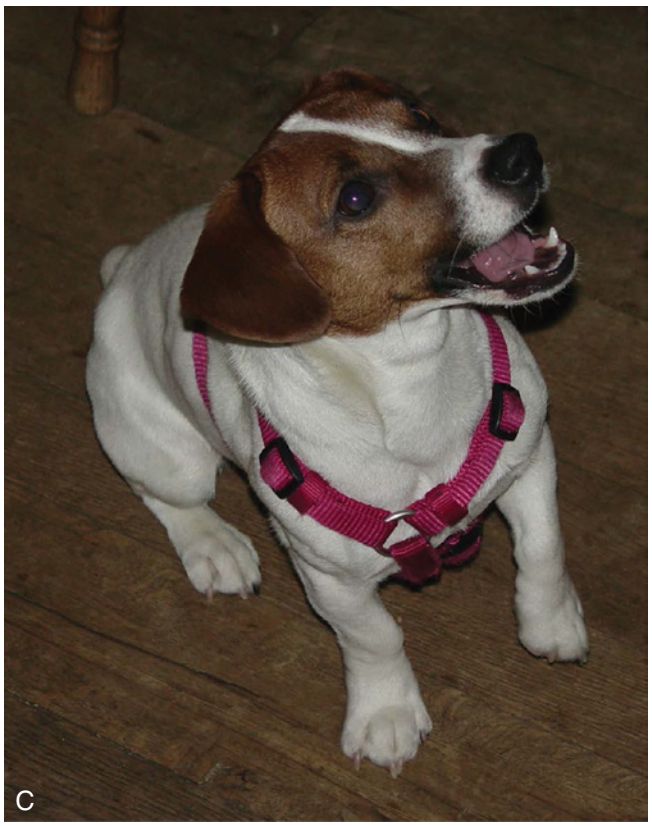


FIG. 23-2 Three examples of the general ear conformation in dogs. (A) The Bassett represents the dependent ear. (B) The erect ear represented by this pit bull. (C) The folded ear of the author's Jack Russell. The conformation of the ears, their width, and their length vary considerably in canine breeds, less so in the cat.

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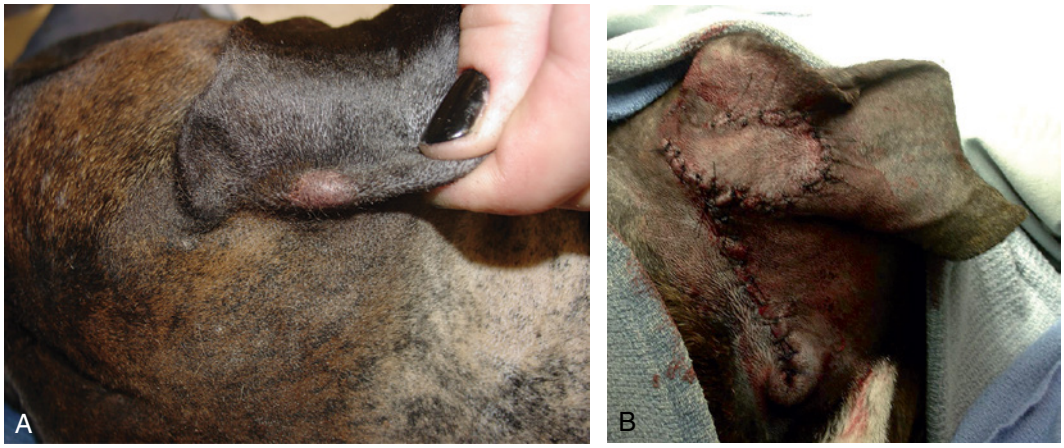


FIG. 23-3 (A) Mast cell tumor, lateral base (zone I) of the pinna. Note the considerable laxity of the skin in this region, unattached to the underlying pinnal cartilage. (B) After tumor resection, a transposition flap was used to advantage in the closure of the cutaneous defect.

cases skin flaps can be used to close a major pinnal defect while simultaneously improving the cosmetic outcome in one stage. From my clinical experience, owners commonly opt for preserving the pinna when practically feasible.

Circulation to the Pinna

The concave surface of the pinna has three auricular branches: the lateral, intermediate, and medial auricular vessels. Each generally supplies its respective three vertical vascular zones. However, they provide collateral circulation to their neighboring zones. The caudal auricular artery is a branch of the external carotid artery from which the lateral, intermediate, medial, and deep auricular arteries arise. The lateral auricular branch arises from the muscular branch to the splenius or from the intermediate auricular artery. It is a large artery as it passes the caudal border of the parotid salivary gland. It terminates by anastomosing with the intermediate auricular artery. The intermediate auricular branch is the largest artery of the ear. It arises from the caudal auricular artery, deep to the caudoauricular muscles. It sends several anastomosing branches laterally and medially over the auricular cartilage. The medial auricular branch arises adjacent to the intermediate auricular artery; it crosses the caudal portion of the temporal muscle, becoming subcutaneous as it ascends the pinna. It anastomoses with the larger intermediate auricular artery. It is important to note that short branches of each pinnal artery perforate the cartilage through small scaphal foramina to supply the fascia and dermis of the concave (medial/inner) surface of the pinna (Fig. 23-4).

Candling the Pinna

After clipping the pinna of fur, a light source can be used to illuminate the pinnal vasculature. A marking pen can be used to draw the general outline of each branch on the skin in order to help preserve them during surgical procedures (see later Fig. 23-21).

Survival of the pinna is largely dependent on maintaining the basic integrity of these three vascular branches. Although there are no supportive studies, the anastomotic relationship of the three auricular vessels supplying the pinna would suggest that any single branch could be sacrificed without necrosis of a portion of the pinna. (There was one case, seen by the author, in which a surgical colleague inadvertently damaged both the medial and intermediate branches during ear canal ablation, resulting in necrosis of the caudal third of the pinna.) Based on its broad arborization over the pinna, the centrally located intermediate branch is likely able to sustain circulation to the entire pinna with the loss of the medial and lateral branches, although this selective loss of circulation is unlikely to occur outside the surgical suite. From my clinical experience, individual branches of these three vessels have been ligated during tumor removal without adverse effect on the pinna. Diseases that compromise circulation, such as immune-mediated vasculitis, can result in tissue loss originating in the terminal third (zone III) of the pinna (Fig. 23-6).

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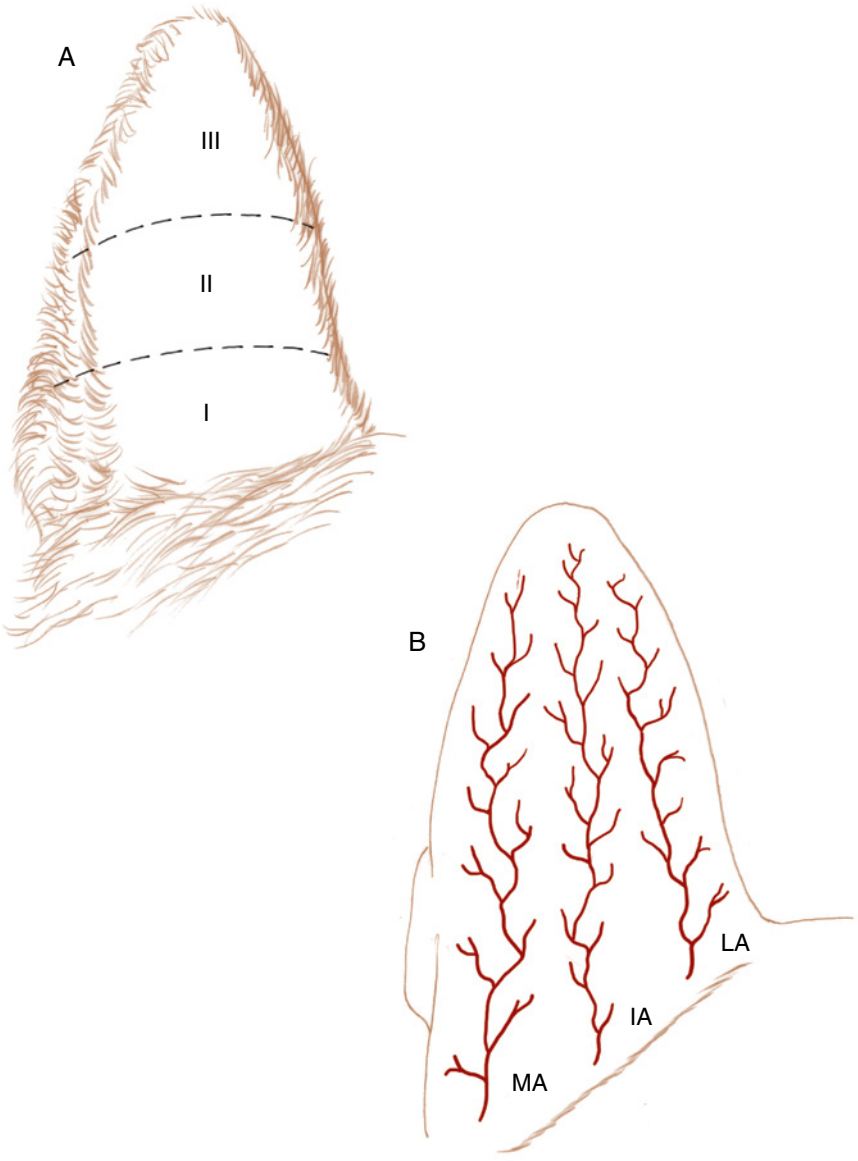


FIG. 23-4 (A) The lateral (convex) aspect of the pinna (left ear). Based on the relative skin laxity of the lateral pinna, the ear can be divided into three zones. Zone I has an ample amount of loose elastic skin. In zone II, the skin is unattached to the underlying perichondrium; skin laxity progressively decreases as the skin approaches the terminal third of the ear. In this terminal zone III, the skin is closely attached to the perichondrium, as is the skin covering the entire medial surface of the pinna. The skin in zone I and the adjacent skin surrounding the base of the pinna are areas where skin can be readily mobilized as skin flaps to close pinnal defects. Zone II skin, to a lesser degree, is available for potential flap development. (B) There are three major arteries (with accompanying veins) supplying the pinna located on the lateral/convex pinnal surface: the more rostral lateral artery (LA); the central or intermediate artery (IA); and the more caudally located medial artery (MA). The intermediate artery is the largest of the three branches. Small branches perforate the scaphal cartilage through small channels or foramina, allowing the vessels to provide circulation to the medial (concave) surface of the pinna (see Fig. 23-1). Loss of the intermediate and lateral arteries risks loss of the rostral portion of the pinna. Reciprocally, loss of the intermediate and medial arteries risks loss of the caudal portion of the pinna. Loss of a single pinnal vessel is likely sustained by the adjacent collateral circulation.

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FIG. 23-5 Extensive neoplasia involving the right pinna of this mixed-breed dog. The extensive involvement of the pinna dictated complete resection of the pinna.

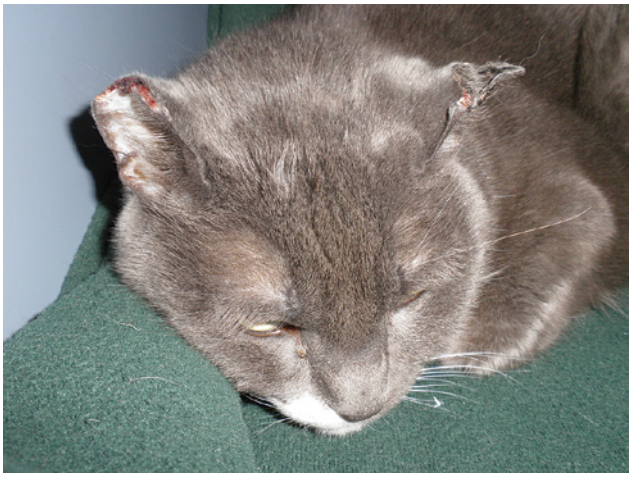


FIG. 23-6 Immune-mediated disease: vasculitis resulted in loss of circulation to the terminal pinna (zone III).

The length of the ear can be divided into three vascular zones, each capable of surviving independently if the ear was divided between each branch. The central or intermediate branch is the largest and is capable of supplying circulation to the pinna with loss of the medial or lateral vessels. However, loss of the intermediate branch along with loss of the medial or lateral branch may result in necrosis to that portion of the pinna. Understanding this allows the surgeon to better plan what is required to reconstruct the pinna after resection of the damaged or diseased section.



FIG. 23-7 Bite wound of the left pinna. Debridement included the compromised skin, marginal pinnal cartilage, and a portion of the vertical ear canal. Fortunately, the elastic skin at the base of the lateral pinna enabled closure of this wound with basic undermining and skin advancement.

SURGICAL CONDITIONS

Trauma

Like other cutaneous surfaces of the body, the ears are subject to a variety of traumata, in part depending on the relative size of the pet's pinna. Bite wounds and vehicular trauma account for most of the traumatic wounds seen by the author (Fig. 23-7). The pinna is also subject to trauma secondary to excessive scratching with the back paws or blunt trauma secondary to head shaking secondary to otitis externa. With extensive head shaking, the ear may strike hard surfaces in the house resulting in aural hematoma formation.

Bite wounds and lacerations are managed similarly to other cutaneous injuries, which normally entails debridement of necrotic tissue and suture apposition of the skin to cover exposed cartilage when possible. It is generally preferable to close the skin wound to protect the cartilage from exposure, desiccation, and necrosis. However, granulation tissue can form from viable cartilage and the overlying perichondrium; smaller open wounds may heal by contraction and epithelization. Small surgical defects involving a portion of the terminal third of the pinna (concave or convex surfaces) may be managed as open wounds and normally heal by second intention with basic topical care/protection.

With extensive trauma, more aggressive debridement and reconstruction may be warranted. In many cases the trauma may be on the more exposed convex/outer side of the pinna, where the availability of looser skin can facilitate wound closure.

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As previously noted, significant loss of skin to the lateral pinnal surface is often easily managed as a result of the availability of loose elastic skin at the base of the ear and the lower portion of the lateral pinna (zone I). Skin can be advanced or pivoted into place, usually in the form of a transposition skin flap.

Tumors

There are a variety of neoplasms associated with the pinna, including carcinomas, sarcomas, mast cell tumors, melanomas, basal cell tumors, cutaneous plasmacytomas, histiocytomas, and adenomas. Which of the pinnal zones and surfaces (medial/convex vs. lateral/concave) are involved will help dictate the most appropriate surgical technique required for closure. Although diffuse neoplastic involvement may require complete amputation of the pinna (Fig. 23-5), many smaller neoplasms can be successfully resected and closed with the used of pedicle grafts (Fig. 23-8). Comparatively minor surgical defects involving a portion of the concave or terminal third of the pinna (concave or convex surfaces) may be managed as open wounds to heal by second intention.

As noted, the lower two-thirds of the pinna (concave and convex surfaces) are adjacent to donor areas for flap development. The terminal third of the ear is least



FIG. 23-8 (A) Resection of a mast cell tumor involving the medial aspect of the pinna. Note the skin and cartilage are resected as a unit. Automatic resection of the cartilage normally gives the surgeon a base margin for most neoplasms. The skin of the lateral pinna is retained. Note the measured outline of a transposition flap (surgical gentian violet marking pen). The flap is placed anterior to the external ear canal opening. (B) The flap is rotated and sutured into place. (C) Close-up view of the transposition skin flap.

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conducive to reconstructive surgery based on (1) the skin (lateral and medial surfaces) being affixed to the perichondrium and (2) this zone's (III) relative distance from potential donor skin for flap coverage. As previously stated, the terminal third of the ear normally requires full-thickness resection.

WOUND MANAGEMENT AND RECONSTRUCTIVE SURGICAL TECHNIQUES

General Considerations

The location, size, and depth of the defect dictate which surgical options to consider for closure. For tumors, the additional tissue required to obtain surgical margins (perimeter and depth [base] margins) will enhance the size of the defect requiring closure. In traumatic wounds, debridement of necrotic and severely compromised skin is a factor in the decision-making process. Defects closest to adjacent donor skin (zones I and II) are most amenable to closure with transposition flaps.

Simple Closure Options, Helical Margins

Loss of a portion of the helical borders can be trimmed or contoured followed by suture apposition of the opposing skin margins to cover the exposed cartilage margin. It is possible to use a no. 15 scalpel blade to slightly recess the cartilaginous border in order to improve skin coverage of the exposed cartilage. Full-thickness triangular or "notched" defects may be closed by apposing the two borders, particularly when the base width of the defect is proportionally narrow. The notched defect may be partially covered by hair regrowth to obscure its visibility. Attempts to close wider triangular defects of the helical margins normally result in local cupping or bowing of the affected pinnal margin during closure; this may be acceptable or provide no practical advantage over simply closing the edges and leaving a notched defect.

Closure by Skin Advancement

The base of each helical border is easily reconstructed by advancement of the loose elastic skin cranial or caudal to the defect (Fig. 23-9). The skin fold is elevated and sutured to the respective lateral and medial aspects of the full-thickness pinnal defect (see Plates 171 and 172). Similarly, the skin adjacent to the lateral base of the pinna (dorsum of the head) is easily advanced to close cutaneous defects (zones I and II). This skin is also an ideal source for transposition flap elevation followed by simple linear closure of the donor defect. If the rostral or caudal donor area also is resected with the respective pinnal area, a transposition flap can be used to close the entire area (Fig. 23-10).

The skin rostral and caudal to the base of the pinna is usually available to close partial or full-thickness defects of the adjacent pinna. Closure is simple to perform and the cosmetic results are normally excellent.

Skin Flap Options

Transposition Skin Flaps

The transposition flap is the most useful and versatile of the pedicle grafting techniques used in small animal reconstructive surgery (Plates 173–176). Its use for pinnal defects is no exception. Transposition flap development ideally requires a source of loose elastic skin to facilitate both its elevation and closure of the donor site. The skin surrounding the entire circumference of the pinnal base facilitates the use of this flap for covering defects in zones I and II (Fig. 23-11). The loosest skin in the lower third of the lateral pinna (zone I) also can be used to close defects in the middle aspect (Fig. 23-12) of the lateral pinna. How far a transposition flap can extend toward the upper limits of zone II depends on the relative length of the pinna (Fig. 23-13). Surprisingly, larger transposition flaps (Fig. 23-14) can be used to cover much of the broad surface area of the medial or lateral pinna. They also can be used to simultaneously reconstruct the lateral and medial surfaces of the pinna for loss of the rostral or caudal third of the pinna (Figs 23-15 and 23-16).

The transposition flap remains the single best option to close both small and large defects of the lateral and medial pinnal surfaces. Flap development should not compromise the opening of the ear canal. Care is taken to avoid altering skin tension adjacent to the upper eyelid area.

Axial Pattern Flaps

The caudal auricular axial pattern flap (Plate 71) is the closest of the larger axial pattern flaps for major pinnal defects. Despite this, local transposition flaps are effective in this capacity, although the use of this axial

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FIG. 23-9 (A) Mast cell tumor involving the caudal base of the lateral pinna (zone II). (B) Wide resection (>2 cm) of this growth. (C) Simple undermining and advancement of the adjacent elastic skin. Keep in mind that significant elastic retraction of the skin after its advancement can alter the ear carriage. If this is the situation, a transposition flap should be considered.

pattern flap is a serious consideration in the face of extensive trauma to the pinna and surrounding area of the head.

Direct Flaps in Pinnal Reconstructive Surgery

Rarely used or needed, a flap can be elevated on the dorsum of the head and lateral facial areas, allowing the placement of a pinnal surface area defect beneath it. The overlapped flap is sutured to the margins of the defect; the ear is secured to the head with a protective wrap for 14–21 days. Once the body of the flap has healed to the recipient bed during this time, the pedicle is eventually divided in stages (one-half followed by division of the second half 3 days later). Effective use of the transposition flap has precluded the need for distant direct flaps, although the technique is still on the list of potential options for closing large pinnal wounds (Plate 177).

Direct flaps are rarely used in reconstructive surgery of the pinna. Nonetheless, there may be unique circumstances where this staged flap procedure is the best option to close a problematic wound.

Free Grafts

Like other body regions, free grafting of the pinna is feasible, provided there is a vascularized wound bed and a method to satisfactorily immobilize the ear to ensure a satisfactory "take." Yet the use of skin flaps remains a technically easier and more economical option in most cases.

Free grafts are rarely required to restore portions of the pinna, but do remain a viable option. The primary problem is effective immobilization of the pinna to help ensure a successful graft "take."

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FIG. 23-10 (A) Mast cell tumor involving the rostral pinna and adjacent facial skin. (B) Full-thickness resection of the rostral pinna and facial skin. This necessitated the elevation and rotation of a 90° transposition flap from the lateral facial/cervical skin. (C) The flap simultaneously closed the facial and pinna defects. (D) The patient, 3 weeks postoperatively. The upper eyelid functioned normally.

Full-Thickness Pinnal Resection

Zone III Resection

As discussed, the lateral and medial skin surfacing the distal third of the ear (zone III) is closely attached to the underlying perichondrium, similar to the medial pinnal surface. Resection of the skin while retaining the thin underlying cartilage is difficult to achieve and the most distant location makes it difficult to take advantage of a suitable donor area for skin advancement or flap development. As a result, full-thickness resection of this region is the most practical method of dealing with extensive trauma or neoplasia. Linear resection perpendicular to the long axis of the ear can be performed, but the cosmetic result can be improved by slightly curving the incision (Fig. 23-17). (See Plate 178.)

Central Zone Resection and Closure

On occasion a neoplasm may involve the central area of the ear. Based on the circulation to the pinna, the central third of the pinna can be resected as an inverted triangle; the rostral and caudal "thirds" of the pinna are then sutured together (Fig. 23-18). A new pinna is reformed, albeit smaller (Fig. 23-19). Surgical margins can be achieved with improved cosmetic results when compared to subtotal pinnectomy (Plate 179).

The author also has resected tumors involving the center of the pinna in which the masses were removed with a full-thickness circular resection to obtain surgical margins. The lateral and medial pinnal vessels were preserved. Closure of the medial and lateral cutaneous surfaces, *in a proximal to distal direction*, results in a bend in the ear. In a floppy-eared dog, this cosmetic blemish is diminished by its natural folded position (Fig. 23-20). Alternatively, closure in a

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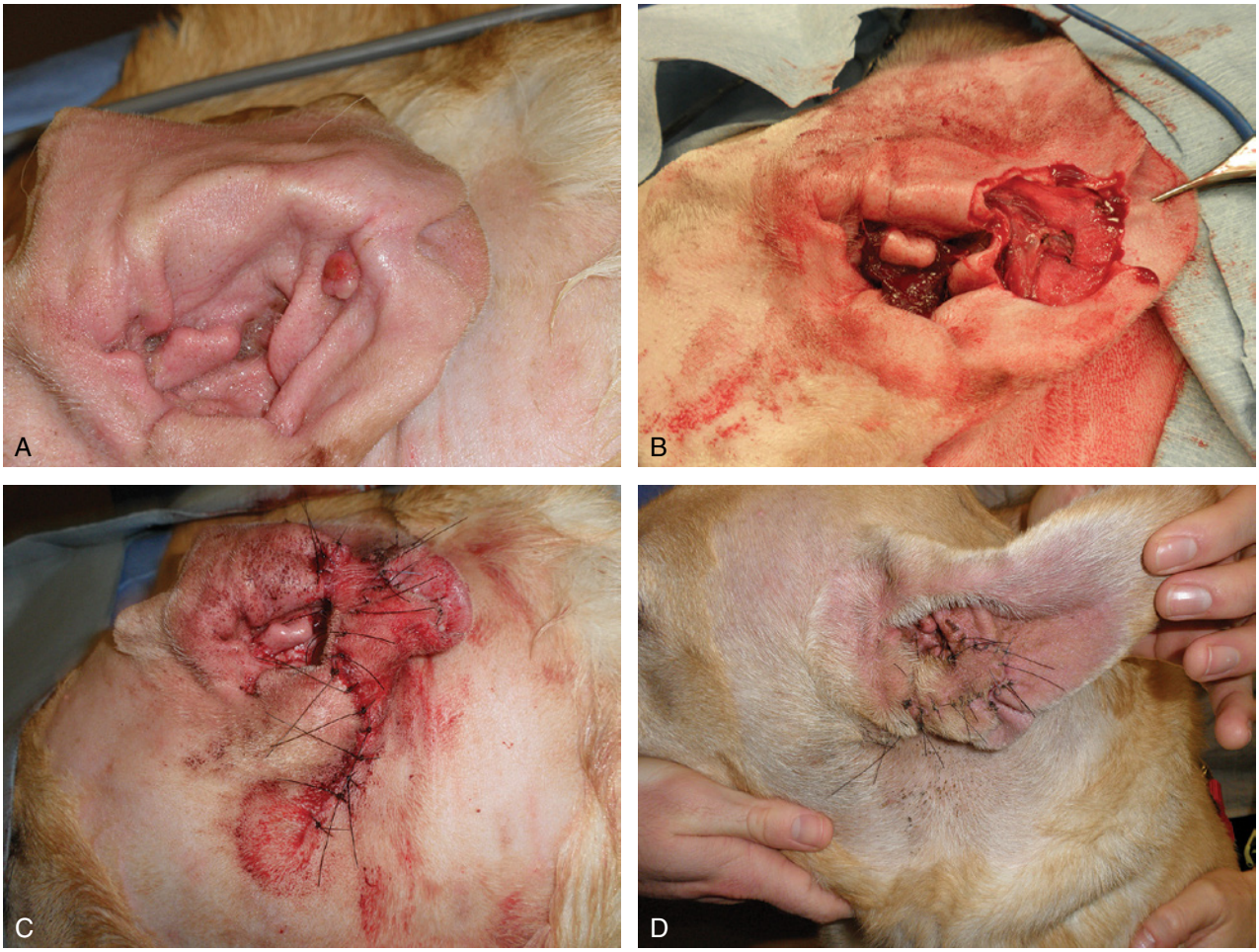


FIG. 23-11 (A) Mast cell tumor on the medial pinna. (B) Resection of skin and underlying attached cartilage. (C) In this case, a transposition flap was rotated caudal to the ear canal opening. (D) At 2 weeks, the flap has healed into the defect. Surgical margins were complete.

lateral direction results in a narrower pinna (Fig. 23-21). The surgeon must determine what is the best method of closure based on the tissue available and cosmetic outcome desired for a given patient (Plate 180).

As noted, extensive trauma or disease involvement of the pinna may necessitate subtotal or complete pinnal resection. The procedure is technically easy to perform, but the cosmetic results are disappointing even to understanding pet owners (Fig. 23-22). The dog and cat can live perfectly well without the pinna (Figs 23-23 and 23-24). Although it is feasible to reconstruct the pinna by combining flap techniques, it has no practicality and falls under the umbrella of pure cosmetic surgery. However, a small skin fold can be used to form a small pinna at the time of wound closure.

Summary

The variety of reconstructive surgical techniques reviewed allow surgeons to restore external ear defects secondary to trauma and resection of tumors. For example, the author introduced partial vertical ear canal resection in cats. This comparatively simple procedure preserved both function and cosmesis of the ear following removal of growths involving the proximal third of the vertical ear canal (Plate 181). Moreover, these basic techniques give the small animal surgeon additional latitude for more aggressive resection of malignant tumors, with the assurance that closure can be achieved economically in a single-stage surgical procedure.

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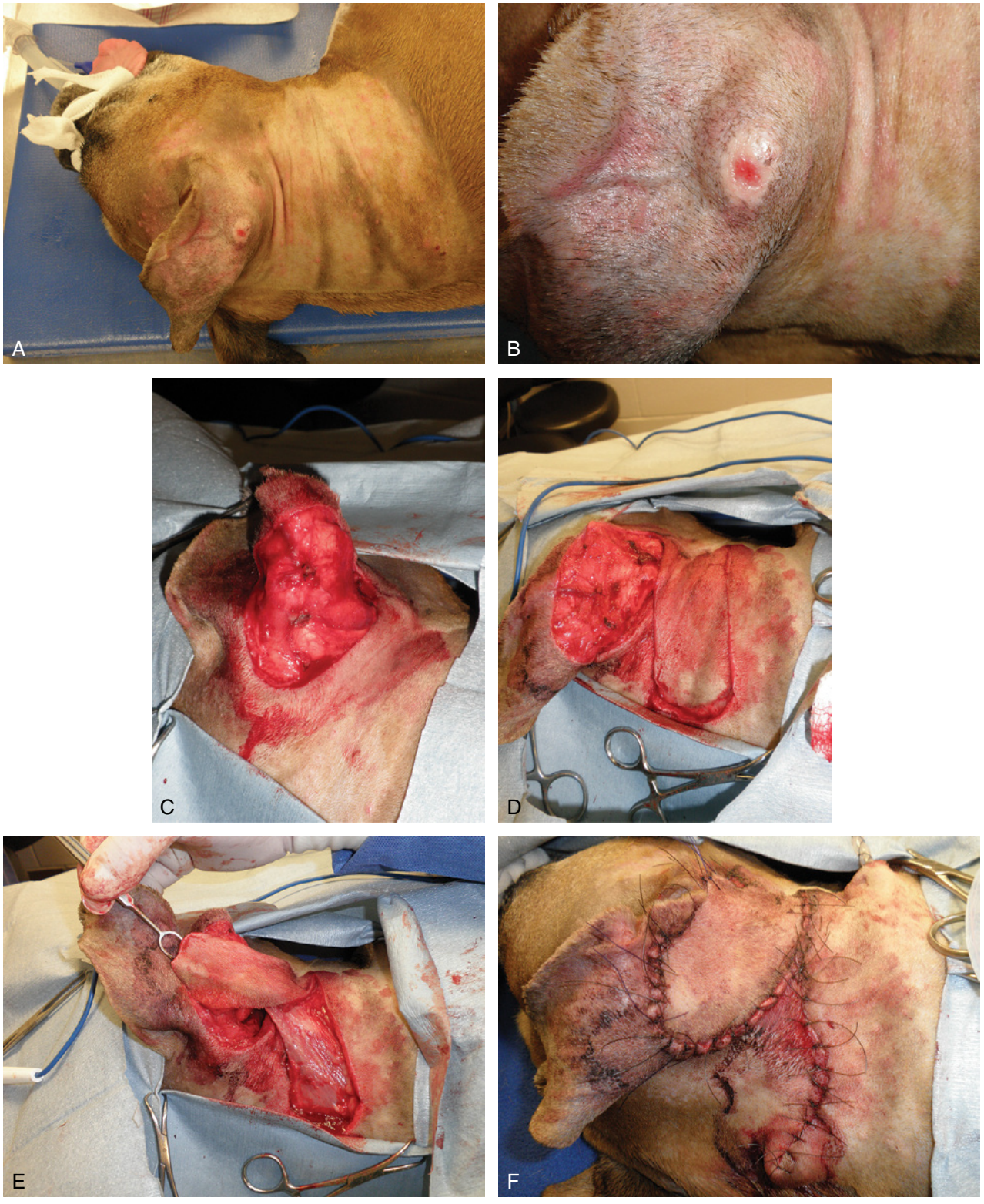


FIG. 23-12 (A, B) Mast cell tumor involving the lateral pinna with poorly defined margins. (C) Wide resection including the thin underlying musculofascial layer with tangential partial-thickness removal of the lateral pinnal cartilage. (D) In this case a transposition flap was developed, utilizing the lateral cervical skin caudal to the base of this defect. (E) Rotation of the transposition skin flap into the recipient bed. (F) Closure of the pinnal defect and donor site.

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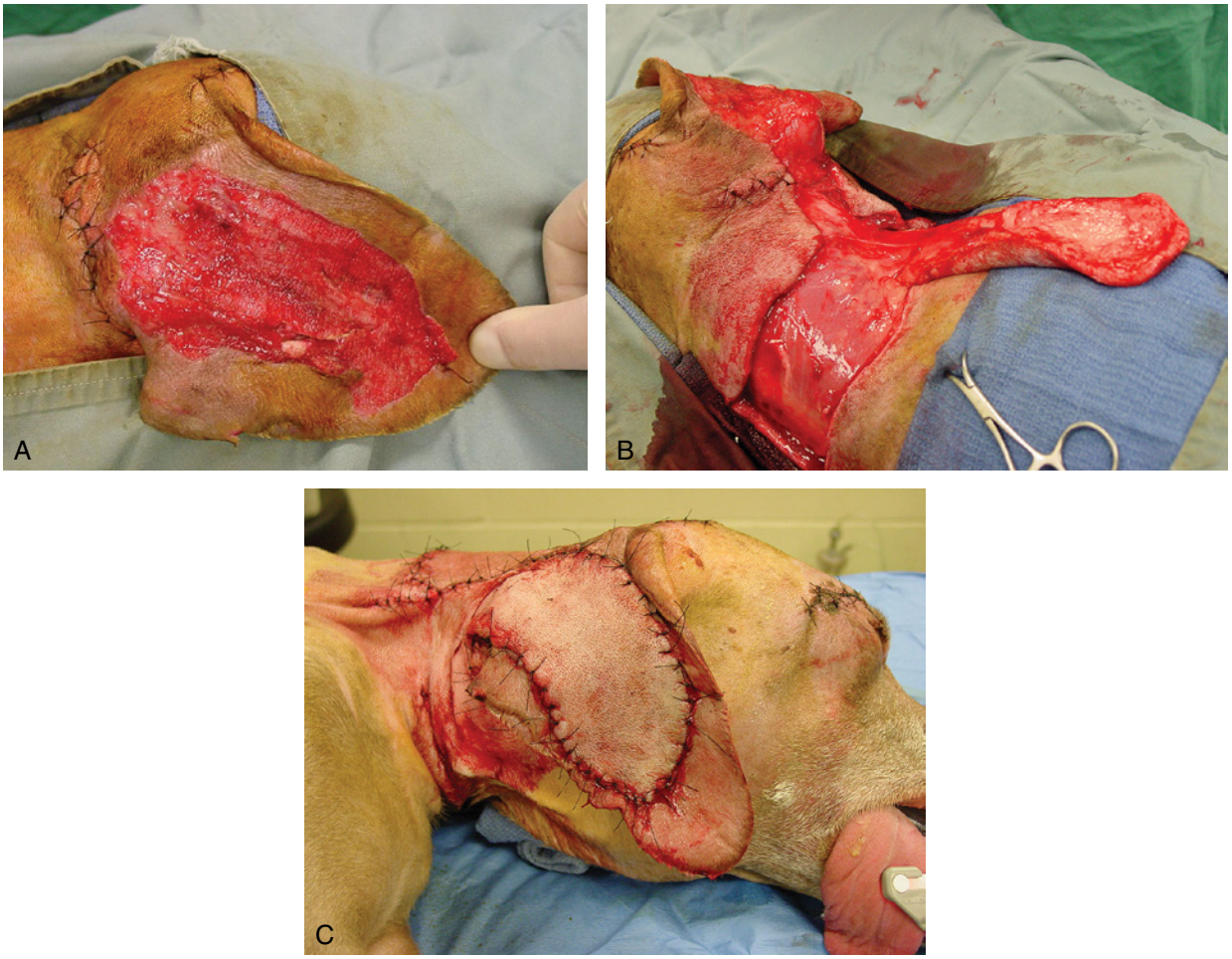


FIG. 23-13 (A) Vehicular trauma with loss of the majority of the lateral pinnal surface. (B) Elevation of a transposition flap and creation of a small bridge incision to facilitate flap transfer to the recipient wound bed. (C) Completion of the flap transfer. The entire transposition flap survived.

In cases of neoplasia, the primary goal of the surgeon is the complete removal of the tumor with surgical margins around its perimeter and base. In many of these cases, both surgical margins and preservation of the pinna can be achieved without resorting to complete excision of the pinna.

AURAL HEMATOMA MANAGEMENT OPTIONS

Treatment Overview

Aural hematomas are commonly seen in dogs and cats. A major contributing cause of their formation is blunt trauma, including head shaking secondary to otitis externa. Occasionally, dogs present with aural hematomas without a history of trauma or otitis externa. One theory previously proposed was that aural hematomas have an immune-mediated basis, but this theory has been challenged in a subsequent study.

It is the rupture of the small vascular branches perforating the pinnal cartilage (scapha) that gives rise to aural hematoma formation. Shearing forces are likely created from head shaking or blunt trauma to the pinna, with a "stress-riser effect" occurring at the interface of the cartilage surface and perforator vessels entering the scaphal foramina: the hematoma forms *within* the scaphal cartilage. The expanding blood/serum volume normally forms an elongated or oval pocket parallel to the length of the pinna. As a result, the central scaphal cartilage partially separates or delaminates into medial and lateral halves.

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FIG. 23-14 (A) Expansile granulomatous mass involving the rostral half of the medial pinna. (B) Resection of the involved skin and underlying cartilage. Closure options are (1) apposing the rostral border of the lateral pinnal skin to the caudal border of the defect; or (2) use of a transposition flap to maintain the width of the pinna. (C) Elevation of a transposition flap from the lateral facial area. (D) Flap rotated into the defect, close-up view.

There is a common misconception among many veterinarians that aural hematomas form between the medial pinnal skin and underlying perichondrium. In fact, the hemorrhage occurs within the cartilage, causing the lateral and medial walls to partially delaminate. The author believes that one or more vessels tear within the vascular channels or foramina that perforate the scapha, caused by a trauma-induced stress-riser effect (vessel–cartilage interface). Central hemorrhage generates hydraulic pressure that forces the flat medial/lateral cartilage surfaces apart.

There are a few nonsurgical treatments reported for managing aural hematomas, including intralesional and systemic corticosteroid therapy and hematoma aspiration followed by the application of a compression bandage. Variable results and improvement of the pinna have been reported with the use of corticosteroids. In one study (Itoh et al. 2022), repeated injections of triamcinolone acetonide was performed during the first month until resolution of the effusion. Oral prednisolone was also administered with a gradual tapering of the dosage. Although some results were encouraging,

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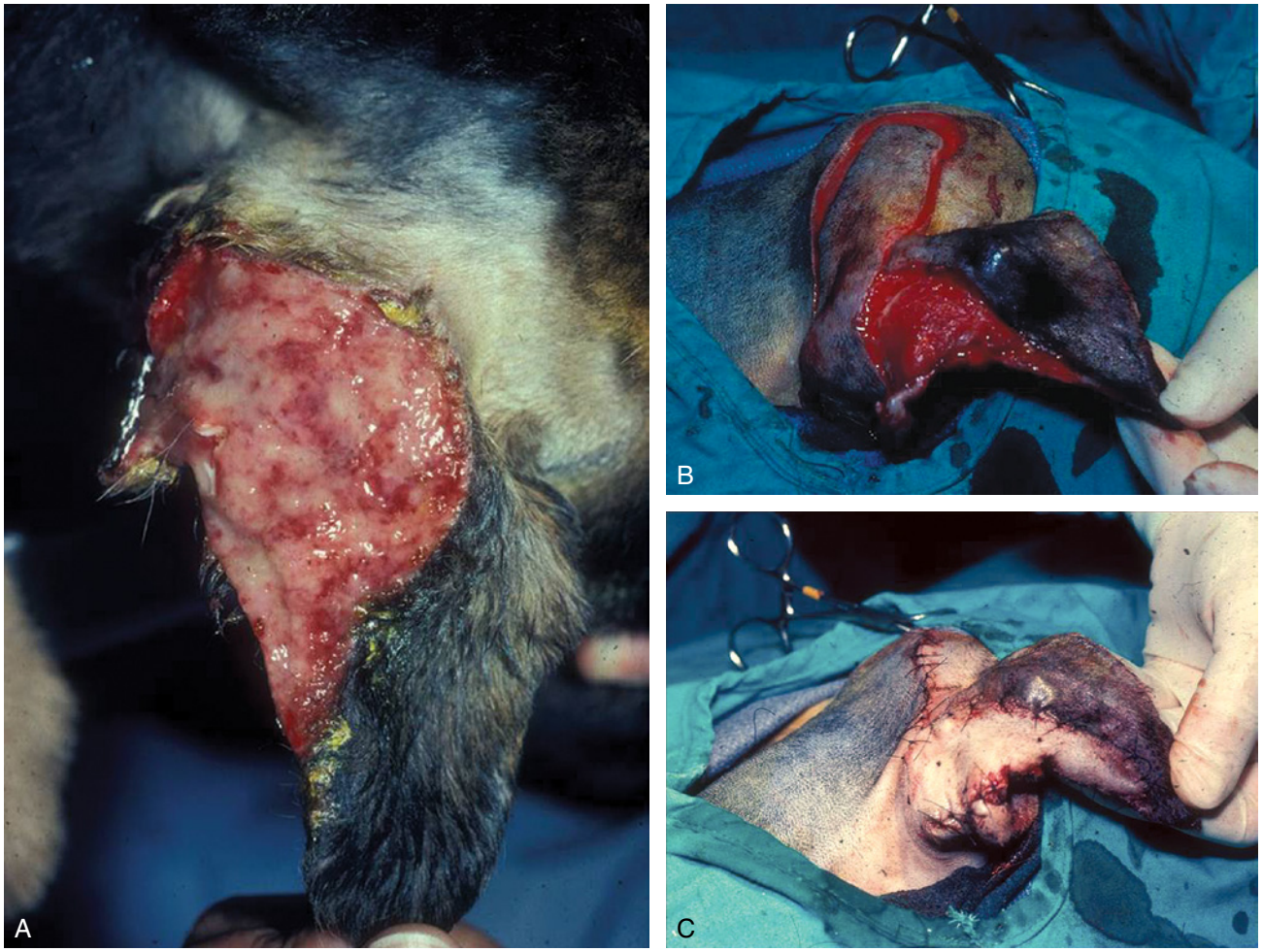


FIG. 23-15 (A) Bite wound to the caudal pinna, with loss of cartilage and skin from the lateral and medial pinnal surfaces. (B) A transposition flap was elevated from the lateral base of the pinna and skin from the dorsum of the head with the flap extending rostrally. (C) The flap width equals the combined width of the lateral and medial pinnal cutaneous defects. The flap folds along its long axis to replace both pinnal surfaces.

recurrence of the hematoma was noted in 31% of cases. Without treatment for extended periods of time, thickening of the pinna with scar deformity has been noted (Fig. 23-25).

Surgical drainage has been advocated for those cases that fail to respond to these conservative medical approaches or as the primary method for resolving this condition. Drainage techniques involving the concave/medial surface of the pinna include (1) the commonly employed incisional drainage (linear/sigmoid incision) with a scalpel, supplemented with through-and-through sutures (Plate 182); (2) fenestration of the concave pinnal surface with a biopsy punch; (3) passive drainage techniques including placement of fenestrated catheters or the insertion of the Larson's teat cannula; and (4) an active (vacuum) drainage technique utilizing a 3–5 ml Vacutainer° glass tube (Becton, Dickinson) and fenestrated butterfly catheter placed in the hematoma pocket via a stab incision in the medial pinnal surface. A bandage is normally required with these drainage techniques to protect the affected pinna until healing/resolution of the hematoma. Lastly, the use of cyanoacrylate glues has been reported to close the hematoma pocket, but the severe inflammatory tissue response precludes their use.

Incisional drainage over the medial pinnal surface is the classic method to manage aural hematomas. The "lazy S" or "sigmoid" incision does not prevent deformity of the ear compared to the conventional linear incision. Both techniques produce significant scar tissue formation to permanently collapse the hematoma pocket. Unfortunately, thickening and deformity of the pinna are noted to a variable degree as the collagen contracts and the scar remodels. (See Plate 182.)

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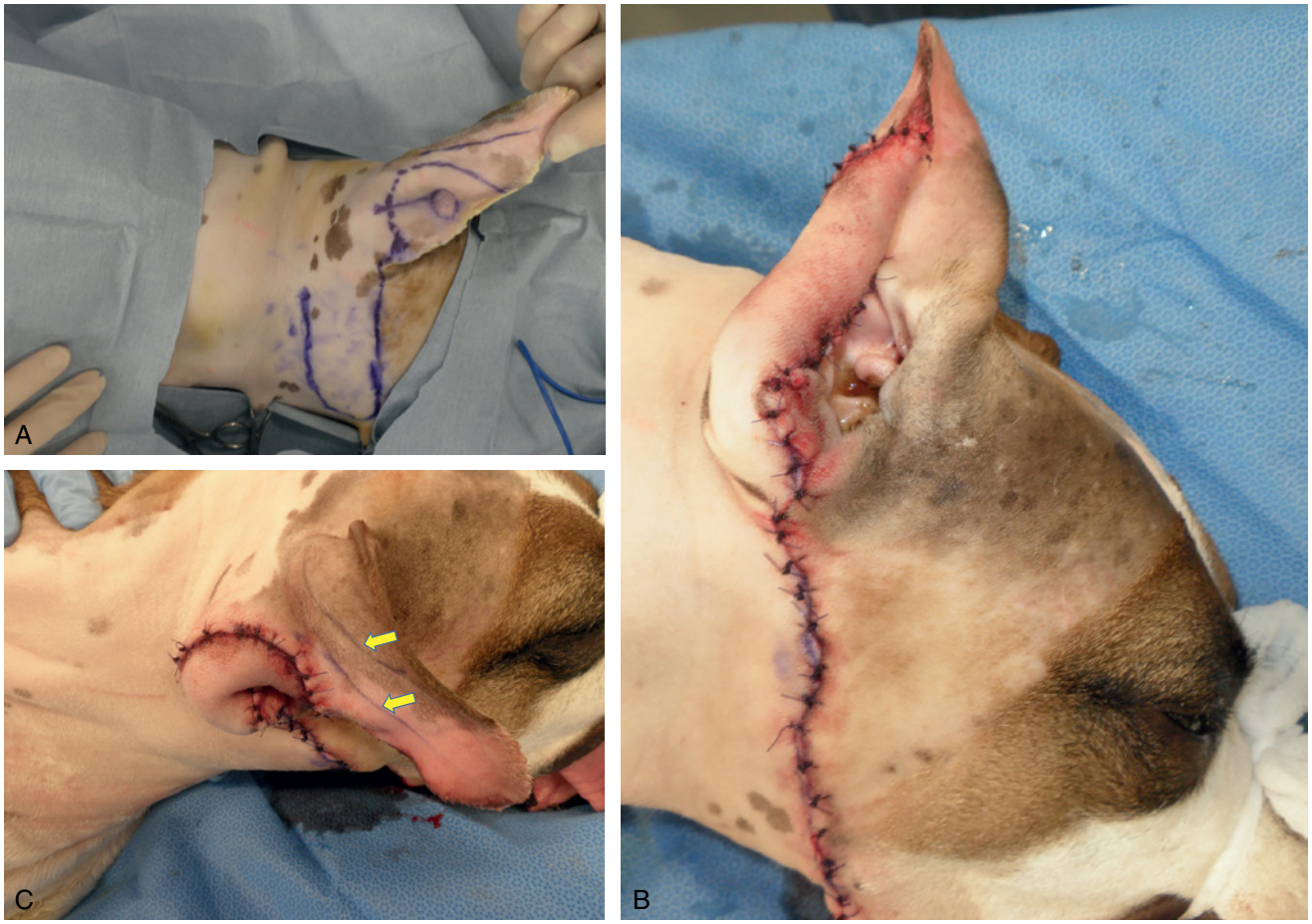


FIG. 23-16 (A) Mast cell tumor involving the right pinna in a mixed-breed dog. A surgical marking pen was used to outline the resection, the location of the pinnal vessels, and the transposition flap. (B) Flap closure of the pinnal defect and donor area. (C) View of the closure with the right pinna folded down. Note the outline of the pinnal vessels highlighted with a surgical marking pen (arrows).

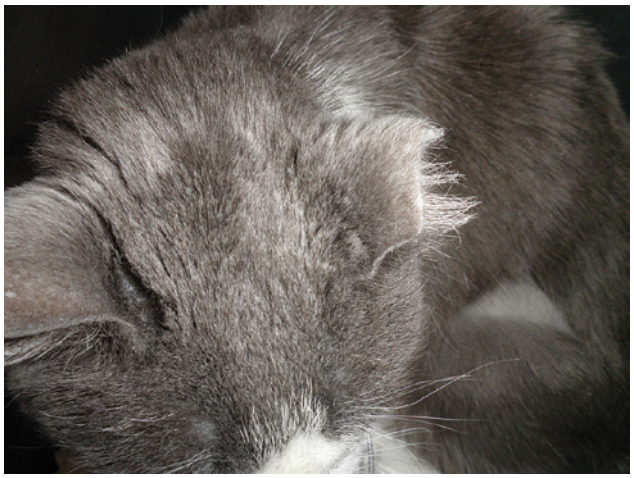


FIG. 23-17 Amputation of zones II and III of the pinna with a linear incision. Curving the incision slightly would have improved the cosmetic results in this case.

Aural Hematoma Management Complications

Complications seen with aural hematoma management include (1) recurrent hematoma formation secondary to reinjury, insufficient drainage, or incomplete healing; (2) permanent pinnal thickening and wrinkling/deformity of the ear secondary to fibrosis and contracture (Fig. 23-26); (3) obstruction or premature displacement of drain tubes; (4) delayed incisional healing; and (5) problematic bandage application/maintenance to protect and immobilize the affected ear, while providing local access to the drainage site. Securing a bandage can be particularly vexing, based on the pinna's length, width, relative shape, and carriage (erect, dependent, partially folded) (see Plate 183). It is common for the veterinarian to periodically reinforce or replace the bandage on subsequent visits until healing is complete. Unruly dogs also may require the adjunctive

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FIG. 23-18 (A) Feline mast cell tumor involving the central region of the medial pinnal surface. (B) "Inverted" triangular resection of the central pinna. (C) The remaining rostral and caudal portions of the pinna are apposed and the lateral and medial cutaneous margins are sutured together to complete the closure. (D) A smaller pinna is formed with reasonable cosmetic results.

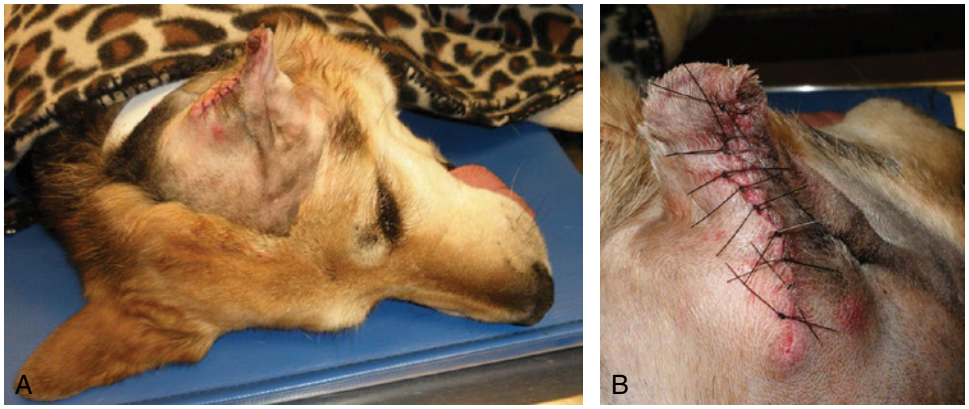


FIG. 23-19 (A) Central resection of the pinna using the inverted triangle design, creating a smaller pinna. (B) Close-up view of the lateral pinnal surface. (See Plate 180.)

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FIG. 23-20 (A) Aggressive resection of carcinoma, central pinna, with resection of the medial skin, cartilage, and lateral pinnal cutaneous area. (B) Linear closure of the medial pinnal defect. (C) Linear closure of the lateral pinnal cutaneous defect. (D) Postoperative view of the left pinna with noticeable fold. (E) Despite the fold, the dependent pinna, with hair regrowth, is cosmetically acceptable. The owners were pleased; surgical margins were obtained.

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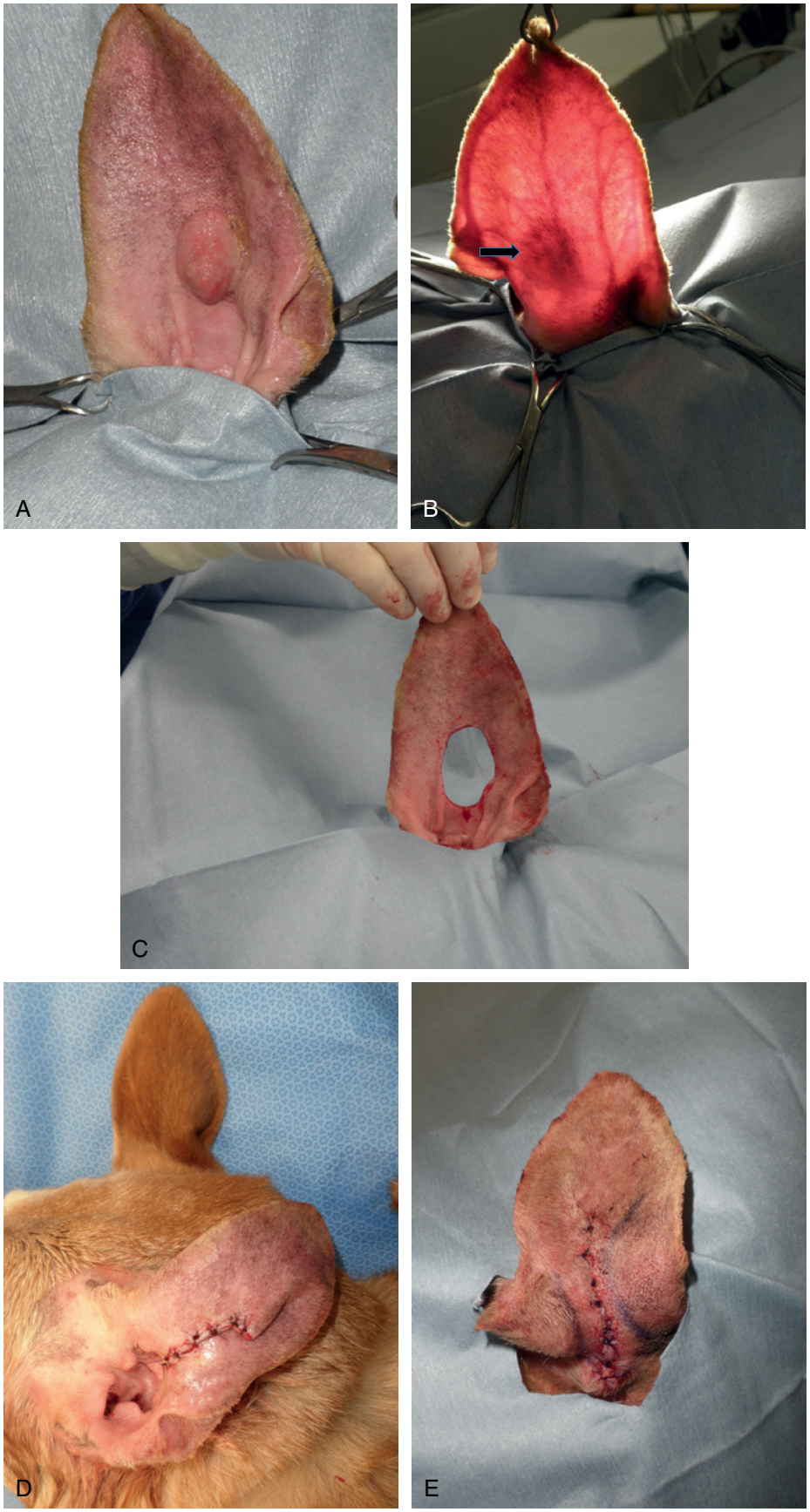


FIG. 23-21 (A) Mast cell tumor, central pinna. (B) Surgical lamp illumination ("candling") of the pinna, demonstrating the pinnal vessels in relation to the mass (arrow). A surgical marking pen can be used to draw the location of the pinnal vasculature prior to surgery to help ensure their preservation. (C) Central resection of the mass. The medial and lateral arteries preserve the integrity of the remaining pinna. (D) Closure of the medial pinna. (E) Closure of the lateral pinna. The ear is narrower but hair regrowth obscured this surgical result.

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FIG. 23-22 (A) Unusual case of angiosarcoma. The patient presented with a history of a chronic serous effusion from the pinnal surface. (B) Medial surface of the pinna. (C) Complete amputation of the right pinna. Surgical margins were obtained.

use of an Elizabethan collar to prevent repetitive pawing. The cost associated with open wound care and periodic bandage changes can be cumulatively expensive.

Laterally Placed Vacuum Drain Placement

Previous reports only describe access to the hematoma from the medial or concave cutaneous surface of the pinna as the most visually direct approach to drain the hematoma cavity (Plate 182). However, a simpler, minimally invasive method of draining aural hematomas can be achieved via a lateral approach to the pinna, using a vacuum drain system devised by the author (Plate 184).

The best cosmetic results are noted when aural hematomas are addressed within a week of their formation using the author's vacuum drain system. Using this minimally invasive technique, additional surgical trauma/scarring is avoided. Moreover, patients are more comfortable. No prolonged bandaging and dressing changes are required as with incisional drainage.

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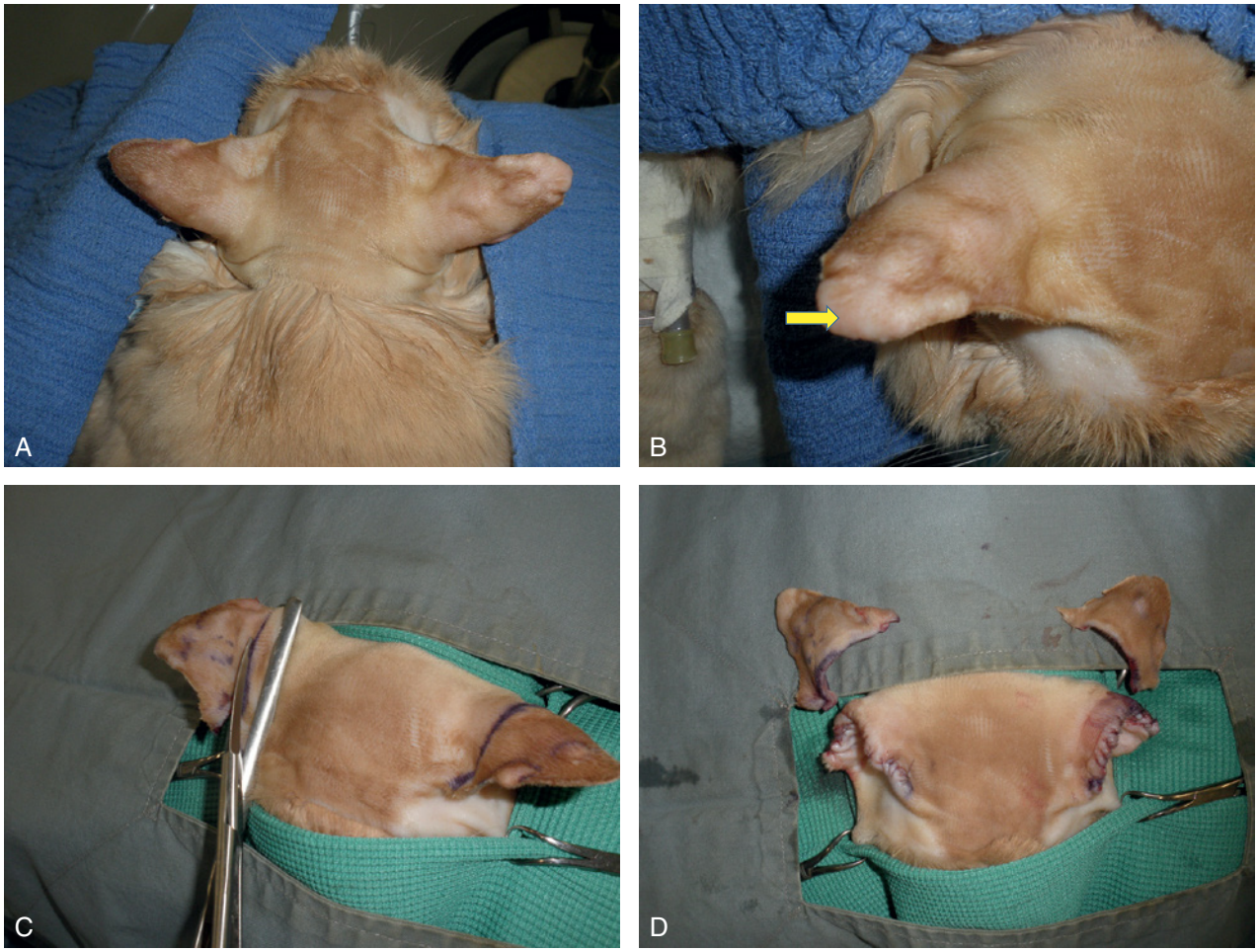


FIG. 23-23 (A) Domestic cat with bilateral carcinoma in situ. (B) Close-up view of the right ear demonstrating the lesion at the apex of the pinna (arrow). (C) Subtotal pinnectomy was performed on both ears. Doyen intestinal clamps are useful in controlling hemorrhage and isolating the pinna for resection. A surgical marking pen was used to outline point of pinnal resections. Freeman Kaye Scissors (Sontec 475-188) were used to excise the pinnal area involved (see Figure 21-2). (D) Completion of the bilateral pinnectomies. 4-0 absorbable suture was used in a continuous pattern to close both incisions. Note that the more mobile lateral pinnal skin is primarily responsible for covering the exposed cartilage margins.

The loose skin at the base of the outer pinna provides a more protective location for securing the drain without the need for a bandage. Managed early, deformity of the ear can be minimized in the dog (Fig. 23-27). Presently, feline aural hematomas managed with this technique have a variable degree of "crinkling," most likely the result of excessive stretching of the thin, delaminated cartilage comprising the wall of the hematoma. Excessive stretching of the delaminated pinnal cartilage in dogs and cats has been noted to result in a permanent wrinkle or fold when the vacuum pulls the asymmetric halves together (Fig. 23-24).

The author has reported that some bending or "crinkling" of the pinna can occur when the lateral and medial cartilaginous walls of the hematoma are stretched. When the hematoma is drained, the apposed cartilage surfaces do not uniformly realign; this results in permanent bends or folds forming to a variable degree. From the author's experience, this is most noticeable in feline aural hematomas (Fig. 23-28).

See Chapter 25 for additional clinical flap examples.

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FIG. 23-24 (A) Carcinoma involving the right pinna in a mixed-breed dog. (B) Surgical marking pen outlines the surgical resection. Doyen intestinal forceps are used in reducing hemorrhage during partial pinnectomy. Doyen forceps also immobilize the pinna intraoperatively, facilitating the entire surgical closure. (C) Resection of the pinna growth. (D) Completion of subtotal pinnectomy. Surgical closure of the margin was performed using a continuous suture pattern with 4-0 absorbable suture (polydioxanone). Leaving a ridge of the pinnal base gives a visual reference to the ear.

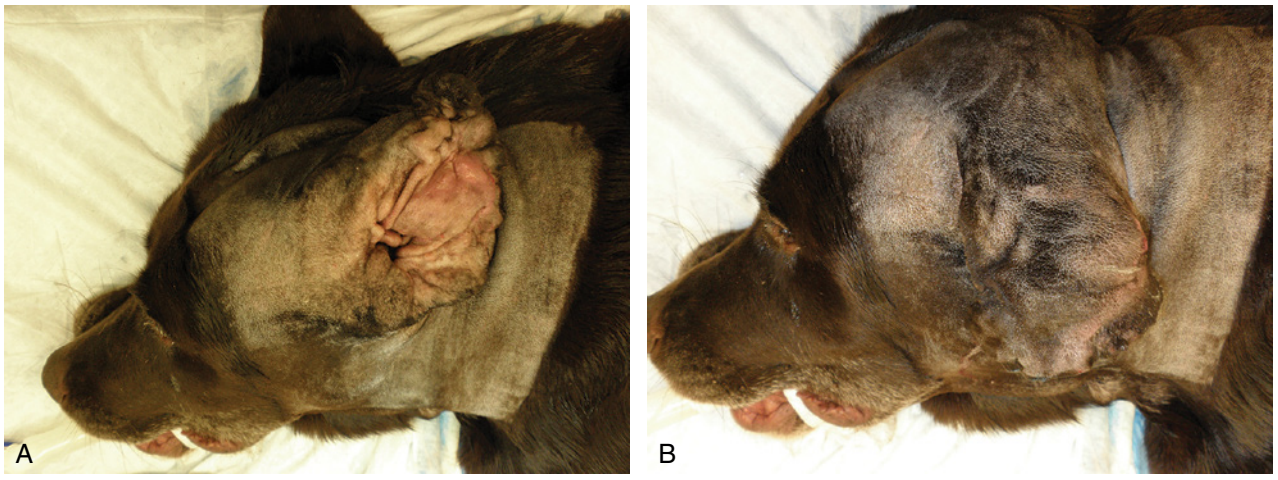


FIG. 23-25 (A) Chronic aural hematoma. Note the folding and thickening associated with this untreated pinna. (B) Lateral pinnal surface with visible thickening and folding.

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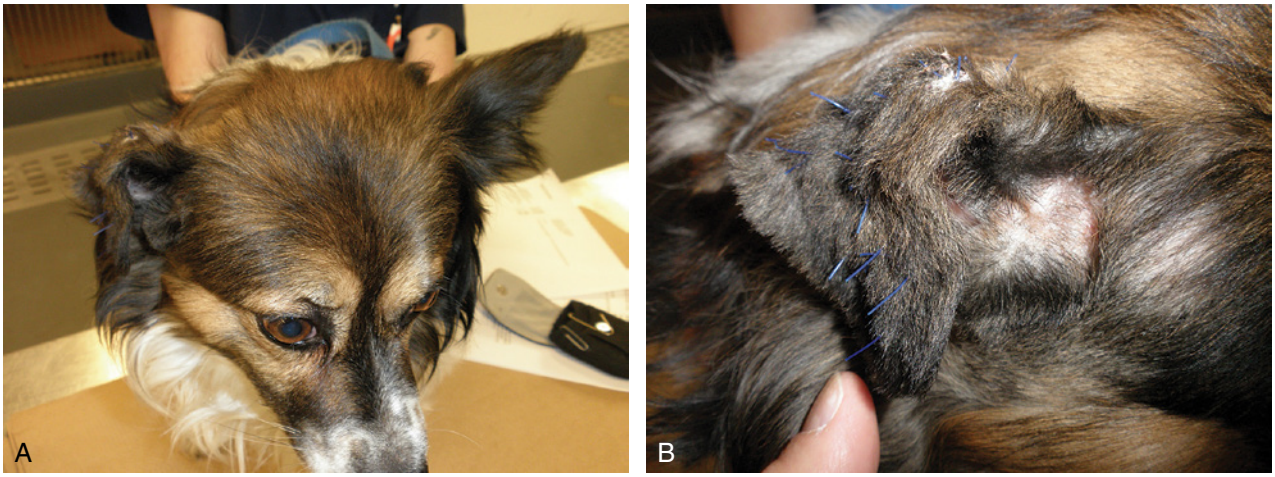


FIG. 23-26 (A) Aural hematoma managed with a linear incision. Note the downward folding and distortion of the ear secondary to fibrous connective tissue and wound contraction. (B) Close-up view of the permanently distorted pinna, lateral surface. The through-and-through sutures are visible.

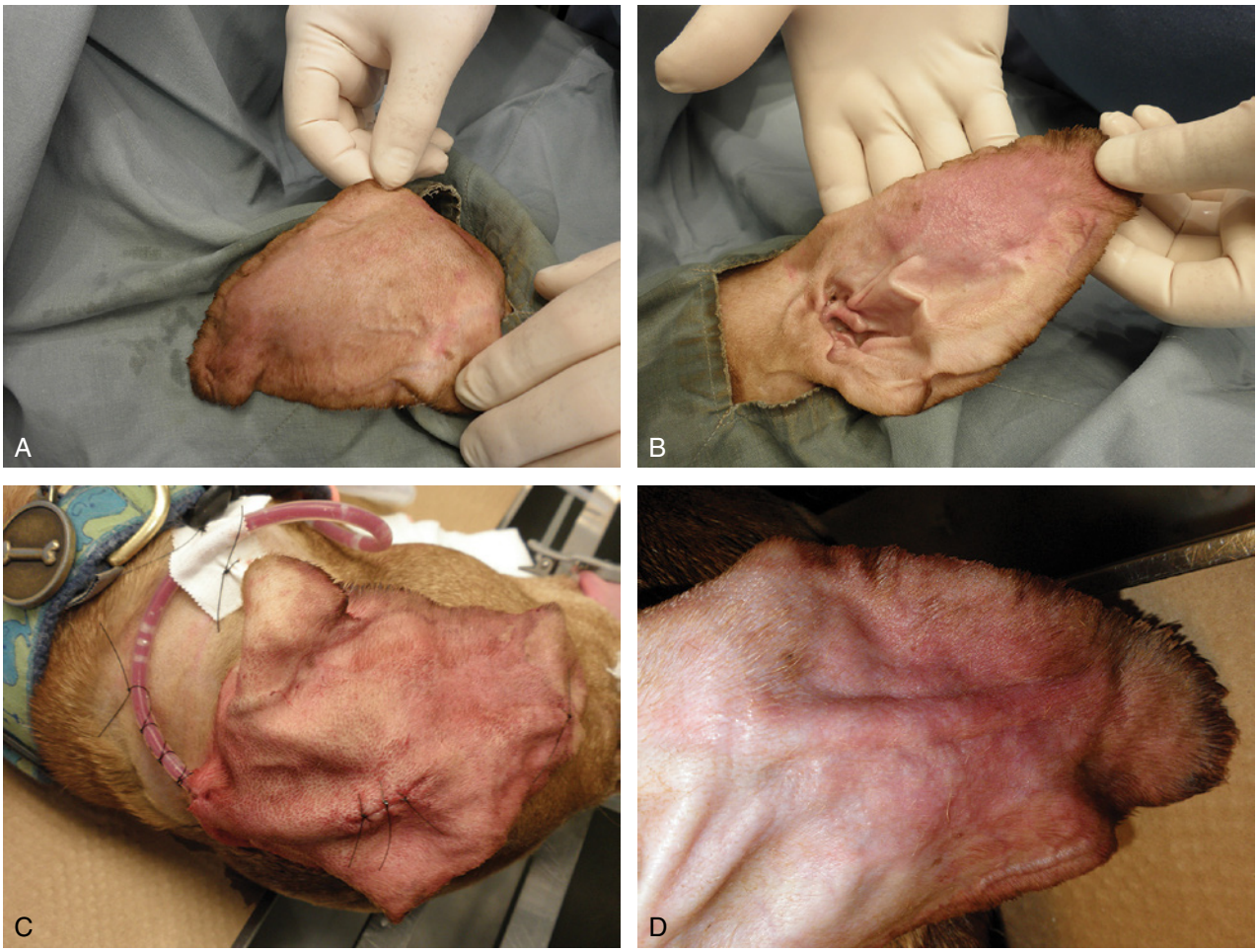


FIG. 23-27 (A) Acute aural hematoma, lateral surface. (B) Medial surface. (C) Lateral placement of a Hemaduct® drain (Cardinal Health) on the lateral pinnal surface (see Plate 184). (D) Medial pinnal view. Note the hematoma is collapsed, highlighting the silhouette of the Hemaduct drain.

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FIG. 23-28 (A) Large aural hematoma in a cat. The delaminated cartilage is grossly stretched by the expanding fluid pocket. (B) Placement of the vacuum drain system. Note the drain exits further from the base of the ear. The patient is aggressive; having the drain tube exiting caudally enables the owner and veterinarian to empty the reservoir with less risk of being bitten. (C) A band of Elastikon (Johnson & Johnson) encircles the trunk; a surgical shoe cover is stapled onto the Elastikon to form a convenient pocket to secure the reservoir. The owner could measure and drain the reservoir safely, especially with the patient wearing an Elizabethan collar postoperatively. (D) Day 18, drain removal. Note the left pinna is slightly folded. Deformation of the pinnal cartilage results from the asymmetric stretching of the cartilage. Interestingly, the right pinna had a previous hematoma managed by surgical drainage: note the greater deformation.

Suggested Reading

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Plate 171

Skin Advancement Closure: Rostral Pinnal Base

DESCRIPTION

The skin rostral to the base of the ear can be effectively elevated and directed into the defect after creating a full-thickness pinnal defect.

SURGICAL TECHNIQUE

(A) A mass involving the rostral base of the pinna is prepared for surgical resection. The dashed line represents the area for full-thickness surgical resection of this pinnal area.
(B) Full-thickness resection of the rostral pinnal base. The dashed line represents the previous location of the pinnal crease.
(C) The facial skin, rostral to the pinnal defect, is undermined, elevated, and directed into the surgical wound.
(D) The cutaneous margins are apposed to the respective medial and lateral cutaneous margins of the pinnal defect with a series of 3-0 interrupted skin sutures.

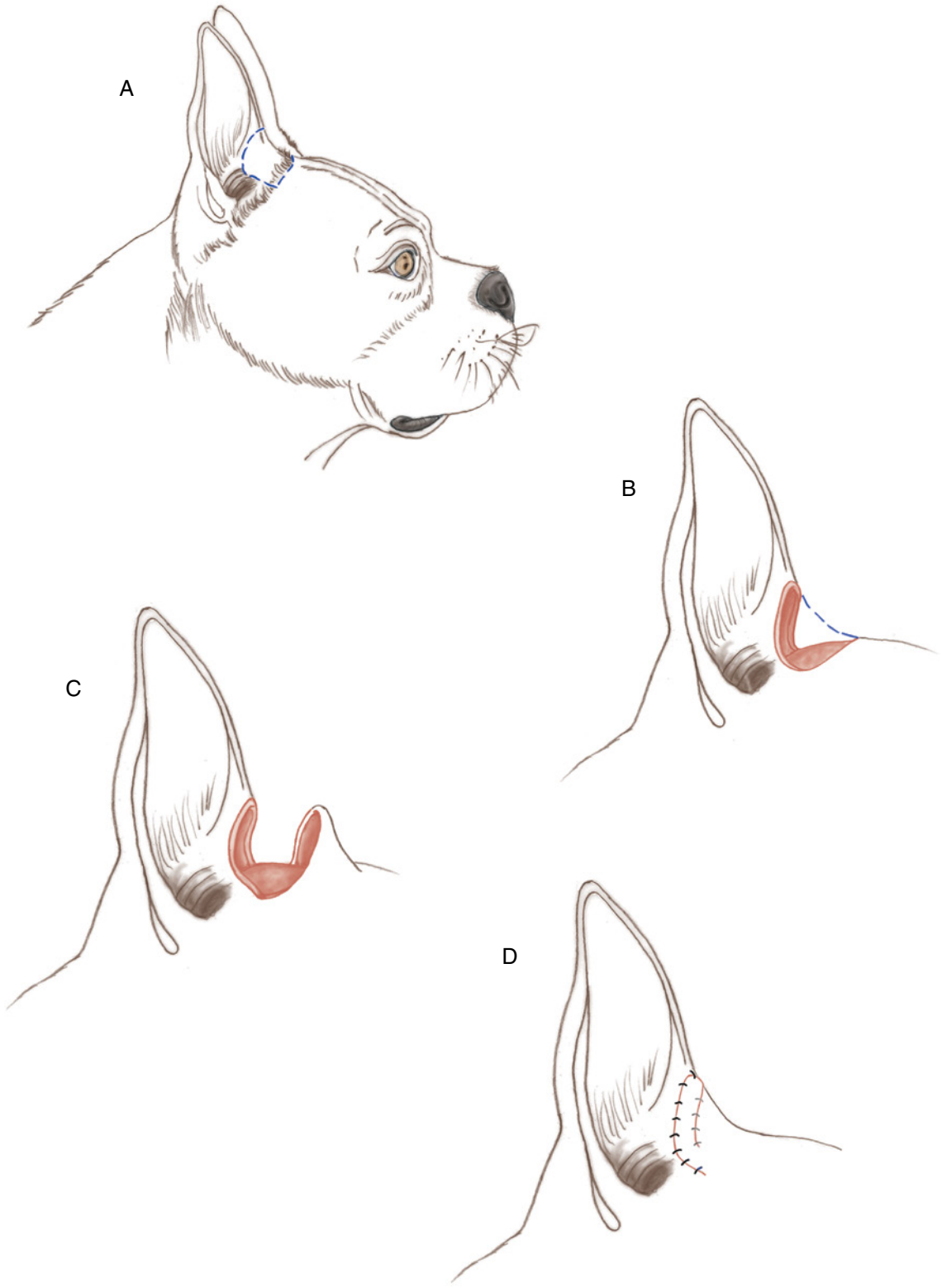
COMMENTS

The skin overlying the head in this location is elastic and easily advanced to the surgical defect created by full-thickness resection of the rostral pinnal border and cutaneous base. If wider tumor resection includes skin in the donor area, a transposition flap can be elevated from the lateral facial skin at the base of the ear and pivoted 90° to close this more challenging defect.

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Plate 171



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Plate 172

Skin Advancement Closure: Caudal Pinnal Base

DESCRIPTION

The skin caudal to the base of the ear can be effectively elevated and directed into the defect after creating a full-thickness pinnal defect.

SURGICAL TECHNIQUE

(A) A mass involving the caudal base of the pinna is prepared for surgical resection. The dashed line represents the area for surgical removal.
(B) Full-thickness resection of the caudal pinnal base. The dashed line represents the previous location of the pinnal crease.
(C) The cervical skin, caudal to the pinnal defect, is undermined and directed into the surgical wound.
(D) The cutaneous margins are apposed to the respective medial and lateral cutaneous margins of the pinnal defect with a series of 3-0 interrupted skin sutures.

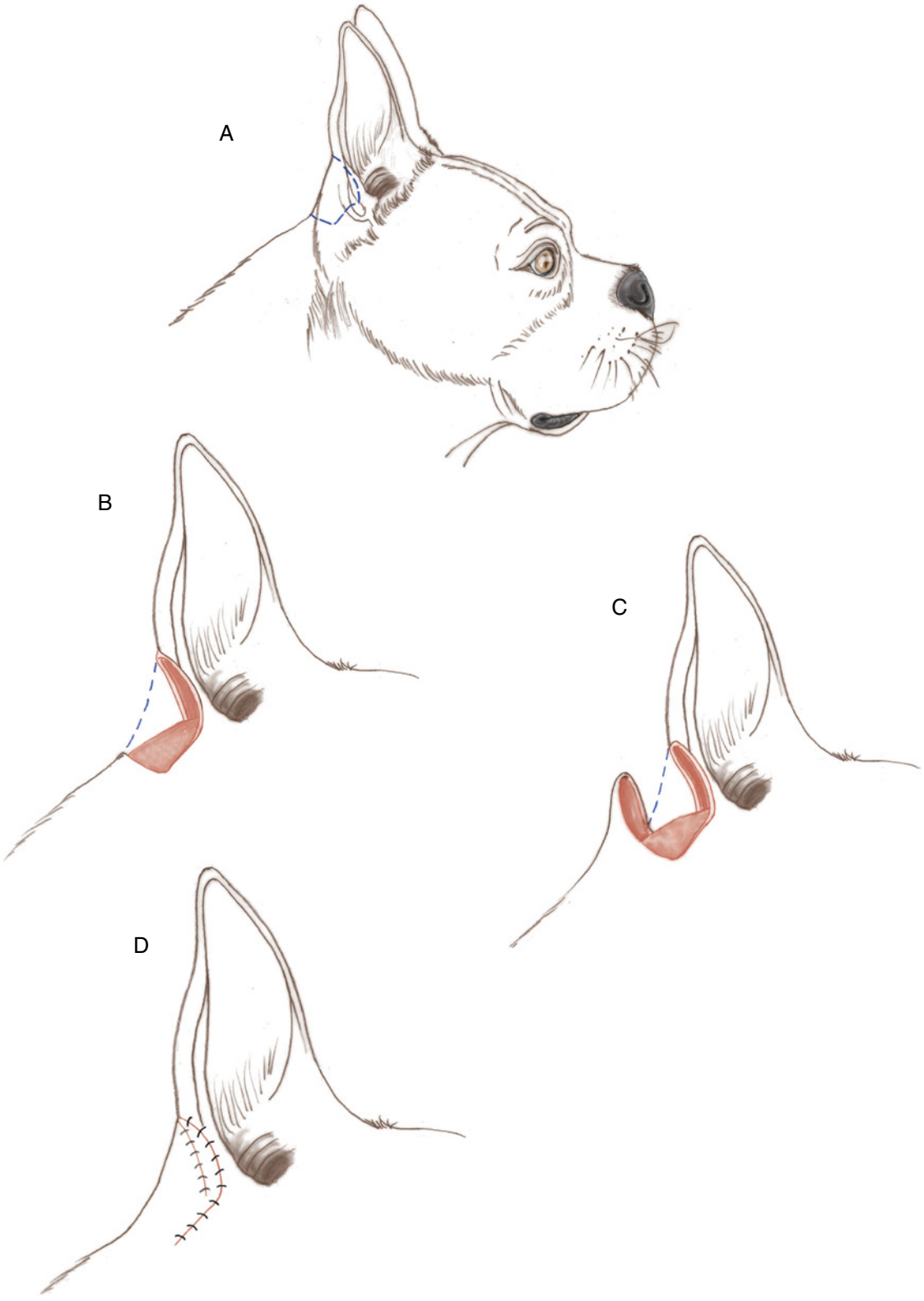
COMMENTS

The ample elastic cervical skin in this location is easily advanced into the surgical defect created by full-thickness resection of the rostral pinnal border and cutaneous base. If tumor resection extends well into this donor area, a transposition flap can be elevated from the lateral cervical skin at the base of the ear and pivoted 90° to close this more challenging defect.

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Plate 172



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Plate 173 Transposition Flap Technique for Smaller Medial Pinnal Defects

DESCRIPTION

The surgical removal of diseased skin involving the lower "half" (zones I and II) of the medial/concave pinnal surface requires the removal of the underlying pinnal cartilage. In this location, the lateral/convex pinnal skin is not attached to the underlying perichondrium. Closure of the defect can be accomplished by elevating a transposition flap from the donor skin overlying the facial area adjacent to the external ear canal opening.

SURGICAL TECHNIQUE

(A) In this illustration, a small mast cell tumor is located in the lower third (zone I) of the medial pinnal surface. The guidelines for transposition flap development (Plates 42–44) are utilized to outline the flap. Note that the base or pedicle of this flap is adjacent to the lower margin of the defect. The surgical marking pen and flexible ruler assist in accurately outlining the skin flap.

(B) In this example, circular resection of the medial skin and underlying cartilage is performed, including a >10 mm margin around the outer perimeter of the growth. (A surgical marking pen and flexible ruler facilitate accurate outlining of the margin to be resected with the mass.) Note that the skin of the lateral pinnal area remains intact. Following tumor resection, the transposition flap is elevated and rotated into the defect. A bridge incision is used to connect the donor and recipient sites, allowing the flap to be sutured into position.

(C) Closure of the donor and recipient areas using 3-0 or 4-0 absorbable skin sutures. The lower margins of the flap are sutured to the bridge incision whereas the distant flap surface is sutured into the surgical defect.

COMMENTS

Because manual removal of sutures in this area can be problematic, absorbable Monocryl skin sutures normally begin to degrade and fall out around 4 weeks after surgery (five or six throws per suture are advisable for Monocryl, to ensure each knot is secure).

Resection of the pinnal cartilage automatically occurs when removing inner pinnal skin due to the dermal attachment to the underlying perichondrium. In turn, removal of the cartilage segment helps ensure reasonable base margins are achieved with tumor excision. Margins of the resected tumor are marked (inked) with India ink to assess completeness of the tumor removal.

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Plate 173



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Plate 174 Transposition Flap Technique for Minor Lateral Pinnal Defects

The surgical removal of diseased skin involving the lower 60% (zones I and II) of the lateral/convex pinnal surface is technically easier to perform compared to the medial/concave surface by taking advantage of both the loose elastic skin in this pinnal region and the ample skin available at the base of the pinna (dorsum of the head and adjacent cervical area).

SURGICAL TECHNIQUE

(A) In this illustration, a mast cell tumor was resected, in this example including a 20 mm margin around the outer perimeter of this cutaneous growth. The measured transposition flap is drawn onto the adjacent donor site. (Note that the lateral cutaneous surface of the pinna is mobile, elastic skin unattached to the underlying cartilage.)

(B) The guidelines for transposition flap development (Plates 42–44) are utilized to outline the flap. Note that the base or pedicle of this flap is adjacent to the lower margin of the defect. The flap is rotated into the surgical defect.

(C) Closure of the donor and recipient areas using 3-0 or 4-0 absorbable skin sutures.

COMMENTS

Skin defects in the mid zone of the lateral pinna (zone II) can be closed using the mobile skin in the lower portion of the pinna (zone I) as well as the loose skin on the dorsum of the head and neck. In some cases skin can be undermined and advanced to close many of the smaller wounds (be aware of skin tension potentially altering the carriage of the pinna), although the transposition flap is highly effective in the more challenging cases. If removal of the underlying lateral pinnal cartilage is being considered to improve base margins, a no. 15 blade can be used to tangentially resect this tissue. Complete pinnal cartilage resection will also result in the loss of the skin affixed to the medial surface of the perichondrium. From the author's experience, partial cartilage resection is not required in most cases of skin tumor removal.

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Plate 174



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Plate 175 Large Transposition Flap Closure after Major Medial Pinnal Resection

DESCRIPTION

It is possible to remove a substantial portion of the medial pinnal skin and underlying pinnal cartilage followed by immediate reconstruction with a transposition flap from the lateral facial or cervical area adjacent to the base of the ear. This technique is also useful for full-thickness resection of the rostral or caudal third of the inner pinna.

SURGICAL TECHNIQUE

(A) In this example, a large granulomatous mass will be resected from the rostral third of the medial/concave pinna (dashed line). Note the outline of the transposition flap. Flap width must simultaneously replace the excised cutaneous areas of the lateral and medial pinna when full-thickness resection of the rostral pinna is necessary (represented by the dashed line).

(B) Full-thickness resection of the rostral third of the pinna. To maintain the normal width of the pinna, a transposition flap is elevated from the lateral facial surface, with the base of the flap adjacent to the defect, facilitating its rotation. (See Plates 42–44 for standard guidelines for transposition flap development.) The dashed line of the flap denotes the curvature of the flap being aligned with the lateral pinnal skin margin.

(C) The flap is transposed and sutured to the medial and lateral pinnal margins using a series of absorbable 3-0 interrupted skin sutures. A drain (passive Penrose drain or active Jackson-Pratt drain) can be used to control dead space.

COMMENTS

Postoperative swelling of the flap is commonly noted but normally subsides over the ensuing week. An Elizabethan collar should be used to protect the area from scratching. A protective bandage wrap, including the use of stockinette, also can be used to prevent trauma secondary to excessive head shaking. As noted, (1) resection of the medial pinnal surface area or (2) full-thickness resection of the rostral/caudal third of the pinna can be reconstructed with the transposition flap.

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Plate 175



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Plate 176 Transposition Flap for Major Lateral Pinnal Defects

DESCRIPTION

As noted in Plate 174, detailing closure of major defects of the medial pinnal surface, transposition flaps can also be highly effective in closing large areas of skin loss overlying the lateral pinnal surface.

SURGICAL TECHNIQUE

(A) Traumatic skin loss involving a major portion of the lateral pinna. The transposition flap is outlined on the adjacent cervical donor area.

(B) The elevated flap is rotated and secured to the recipient wound bed with a series of interrupted 3-0 skin sutures.

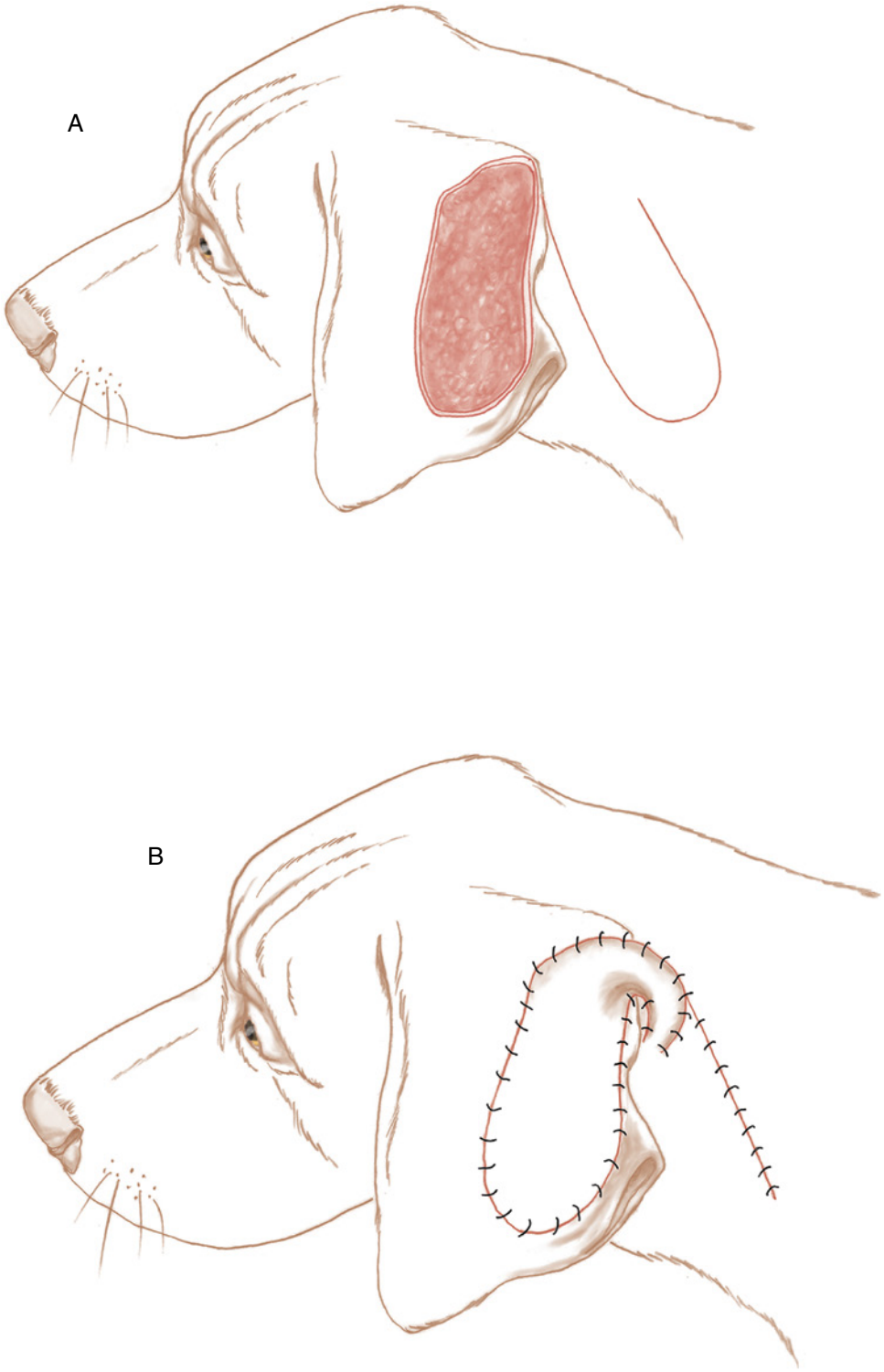
COMMENTS

Because the skin is loosely attached to the lower two-thirds of the lateral pinnal surface (zones I and II), a transposition flap can easily cover defects in this area. The caudal auricular axial pattern flap (Plate 71) is another option for closure of major defects involving the pinna, although the available skin closest to the skin defect can be more easily mobilized and transposed. The flap can become edematous postoperatively and the thicker skin used to close the lateral pinnal surface will give the ear a heavier feel when compared to the opposite normal pinna. This is normally not an issue in dogs with dependent (folded) ears. Swelling usually subsides within a week after surgery. An Elizabethan collar should be used to protect the area from scratching. A protective bandage wrap, including the use of stockinette, also can be used to prevent trauma secondary to excessive head shaking.

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Plate 176



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Plate 177

Direct Flap Reconstruction of the Pinna

DESCRIPTION

In this example there is a large skin defect that includes the caudal margin of the medial pinnal surface. A direct (hinge) flap can be used to close the defect. This is a minimal two-stage procedure.

SURGICAL TECHNIQUE

(A) In this illustration a medial pinnal defect requires closure. A single-pedicle flap has been elevated to cover the defect. Note the donor site has been sutured closed.

(B) The pinna is positioned below the elevated flap and sutured into place.

(C) Once the flap has healed into position (2–3 weeks) the pedicle is severed to complete the transfer. The incised border is sutured to the caudal pinnal border; the donor base is closed in similar fashion.

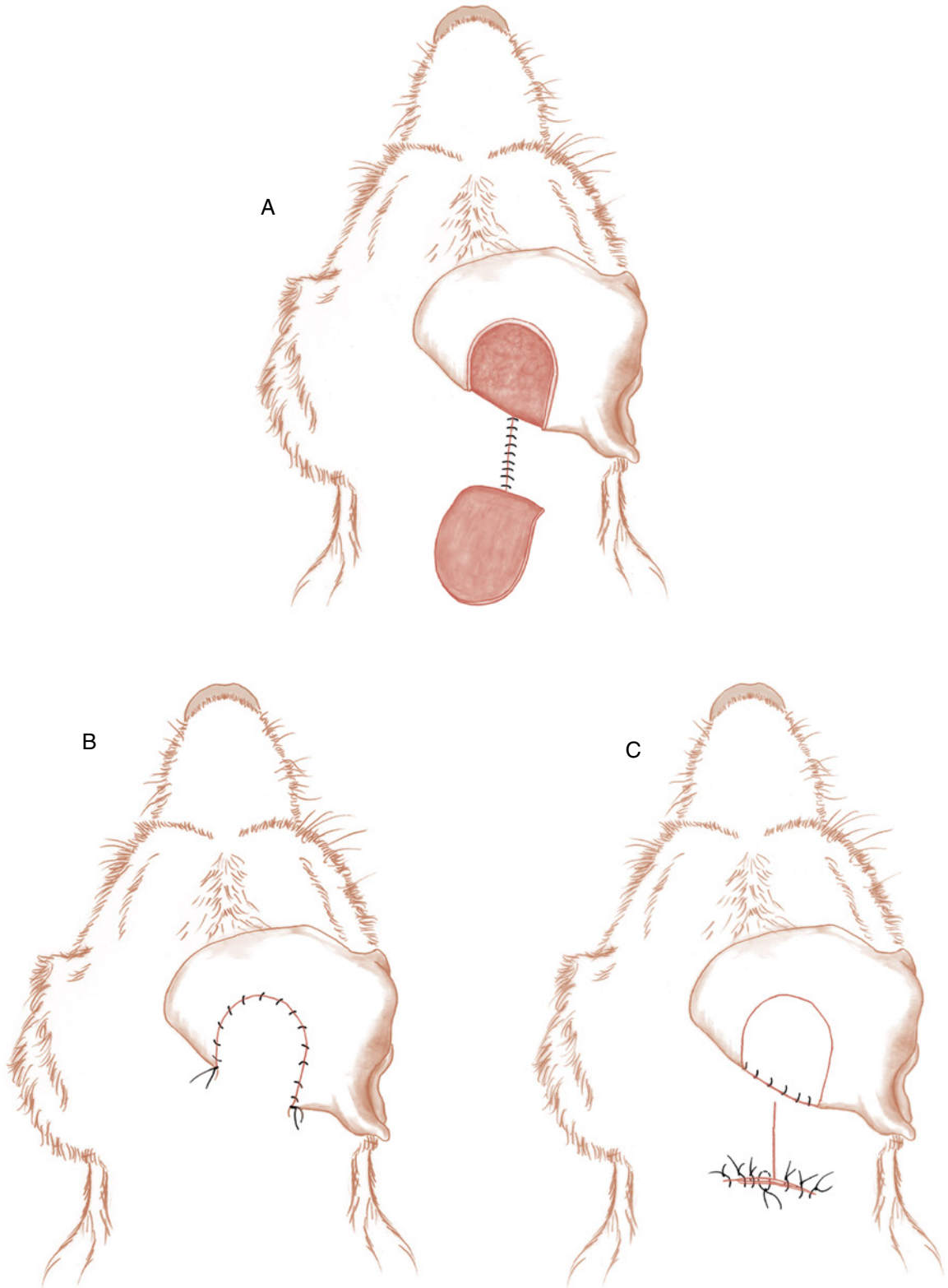
COMMENTS

An Elizabethan collar should be used to protect the area from scratching. A protective bandage should include placement of a cotton layer between the pinna and dorsum of the head to prevent dermatitis. Stockinette may be useful to maintain the position of the bandaged pinna. The pedicle or base of the flap can be divided in one surgery. It also can be divided in stages (50% followed by the remaining 50% 2–3 days apart) if there is any concern regarding flap viability. This technique is rarely used, but may work well in some problematic pinnal defects, especially those involving the medial surface.

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Plate 177



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Plate 178 Resection of the Terminal Third of the Pinna

DESCRIPTION

Anatomically, the terminal third of the ear is unique in the fact that both the lateral and medial pinnal dermal surfaces are firmly affixed to the underlying perichondrium. Extensive trauma or tumor formation in this area normally requires partial pinnectomy.

SURGICAL TECHNIQUE

(A) In this canine patient, neoplasia necessitates full-thickness resection of the terminal third (zone III) of the pinna. A surgical marking pen is used to identify the required level for pinnal resection *at the midpoint of the ear*. From this point the slightly curved outline of the line of resection is drawn onto the skin surfaces.

(B) Full-thickness resection is performed followed by apposing the lateral and medial cutaneous surfaces with 4-0 or 5-0 absorbable suture using a continuous suture pattern.

COMMENTS

The slightly curving incision provides a more cosmetic outcome compared to a straight cut, but this does create a slightly longer incision that requires closure. The surgeon will note that the more mobile lateral skin margin will better contour over the exposed pinnal cartilage whereas the medial skin is comparatively immobile, being affixed to the underlying perichondrium. A carefully placed continuous pattern using absorbable suture (such as Monocryl) is effective in closing the incision. An Elizabethan collar is advisable until healing is complete.

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Plate 178



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Plate 179 Inverted "Triangle" Resection of the Central Third of the Pinna

DESCRIPTION

Based on the pinnal vasculature, the intermediate artery and vein supplying the pinna can be sacrificed, allowing the surgeon to excise the central third of the pinna for those neoplasms located in this region of the ear. Resection is in the shape of an inverted triangle.

SURGICAL TECHNIQUE

(A) In this example, a neoplasm is located in the central portion of the medial/convex pinnal surface. The lateral and medial vascular branches of the pinnal arteries/veins are identified after clipping the ear and preparing the ear for surgery. A surgical marking pen is used to outline the placement of the skin incisions in the shape of an inverted isosceles triangle.

(B) The outlined area of the mid-pinna is resected. The excised tissue margins are inked and submitted for histopathologic examination.

(C) The remaining rostral and caudal incisional margins of the pinna are aligned together, followed by suture closure (3-0 suture material) of the respective medial and lateral skin edges.

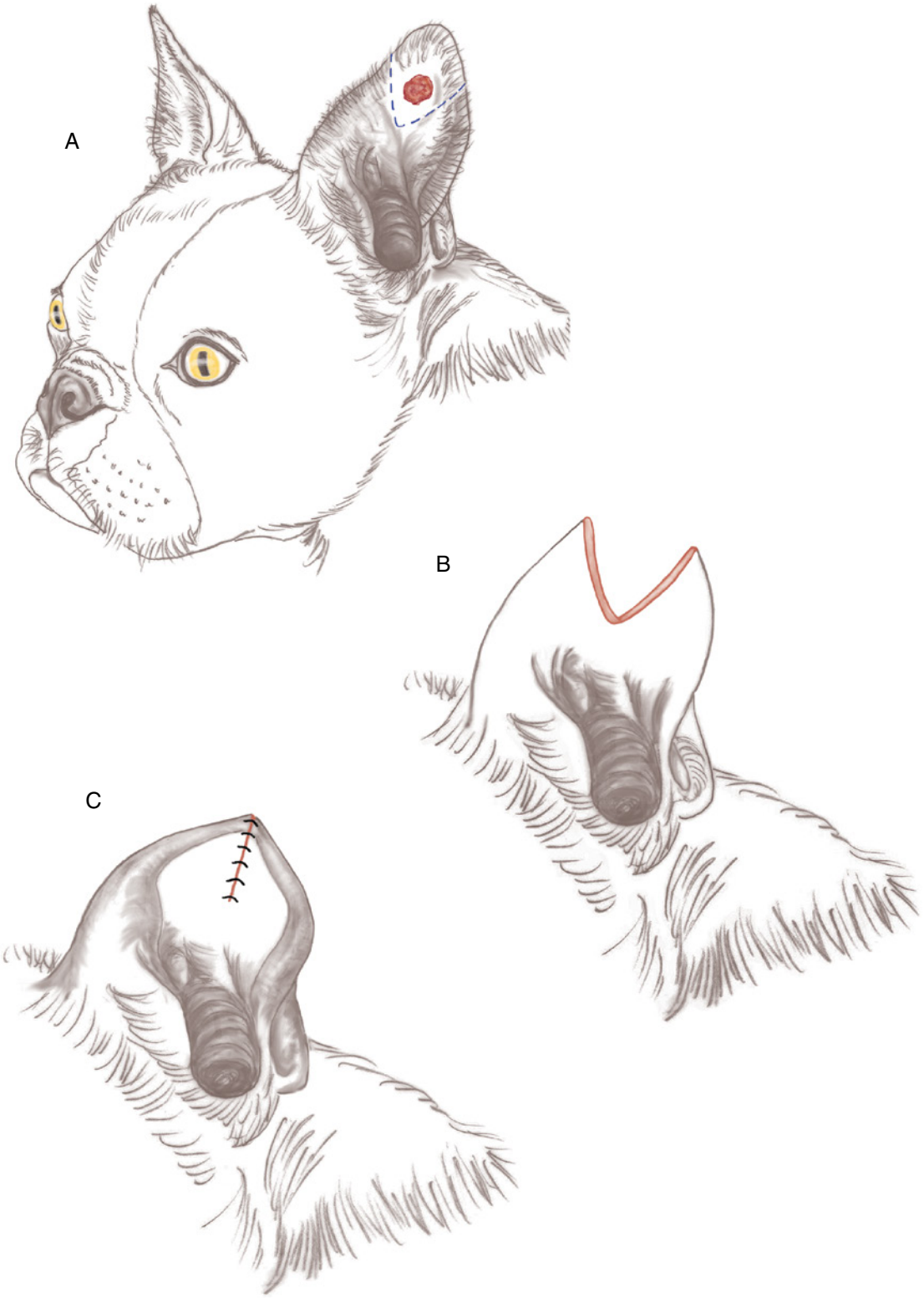
COMMENTS

This technique enables the surgeon to obtain more aggressive surgical margins for malignant tumors within the central area of the pinna. Creation of a smaller pinna can be enhanced from the regrowth of fur, especially in dogs and cats with long hair. Although the complete ear is not replicated, owners prefer this option (when possible) compared to complete pinnectomy.

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Plate 179



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Plate 180

Central Pinna Defects: Closure Options

DESCRIPTION

It is possible to resection the entire thickness of the central pinna. Circulation to the pinna is maintained by preserving the medial and lateral pinnal arteries despite sacrificing the intermediate branch during this procedure. The defect can be closed in a lateral direction or vertical direction. A variable degree of pinnal folding will be noted.

SURGICAL TECHNIQUE

(A) Full-thickness resection of the central pinna in a dog with floppy ears.

(B_1) Closure in a vertical plane, proximal-distal direction.

(C_1) Narrow silhouette of the pinna with cupping. The lateral and medial cutaneous margins of the pinna are normally closed with 3-0 poliglecaprone absorbable sutures.

(B_2) Closure in the horizontal plane. The lateral and medial cutaneous margins are normally closed with 3-0 poliglecaprone absorbable sutures.

(C_2) Closure of the lateral surface. Downward folding or cupping of the pinna will be noted. The ear will be shorter than the opposite ear following closure in the horizontal plane.

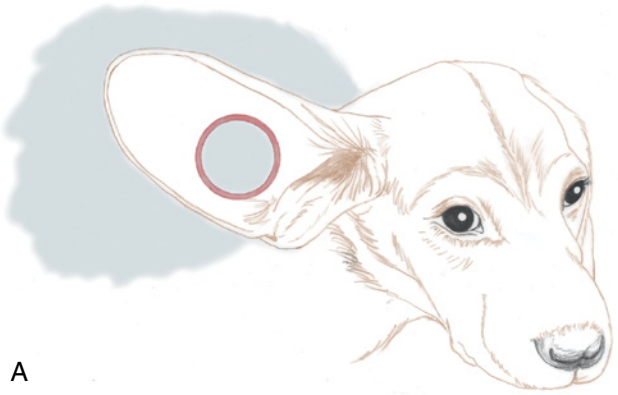
COMMENTS

The author has used this technique on several occasions in dogs. Cosmetic results vary according to the length and width of the pinna. In dogs with floppy ears, the cosmetic results are generally acceptable, especially when compared to subtotal pinnectomy. Cupping is expected due to the partial rigidity of the pinnal cartilage during closure. Intraoperatively, the surgeon can determine which closure option is most acceptable in dogs with erect ears. In dogs and cats with small ears, central pinnal resection may not be a realistic option over subtotal pinnectomy.

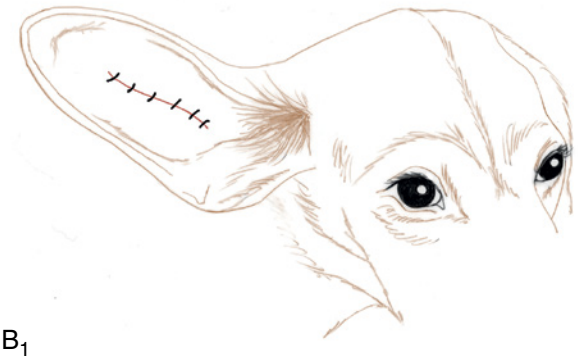
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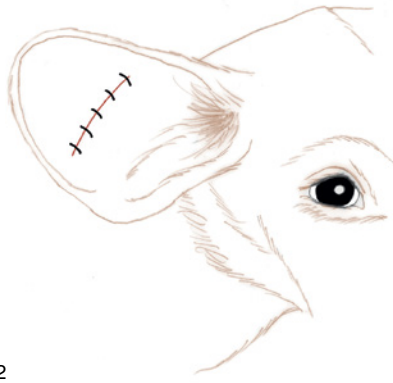
Plate 180



A



B_1



B_2



C_1



C_2

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Plate 181

Partial Vertical Ear Canal Resection in Cats

DESCRIPTION

The upper portion of the vertical ear canal is relatively wider and more funnel shaped in the cat in comparison to the dog. This allows the surgeon to resect the upper third of the vertical ear canal for tumors or other disease processes confined to this area of the ear. The margin of the pinna and the surrounding skin are approximated to the remaining vertical ear canal.

SURGICAL TECHNIQUE

(A) The dashed line represents the circular incision required to resect the diseased segment of the upper vertical ear canal.

(B) Following dissection around the perimeter of the vertical ear canal, the upper third of this canal segment is resected. This is followed by approximation of the incised pinnal base and skin to the remaining margin of the vertical ear canal.

(C) Closure with interrupted absorbable 3-0 poliglecaprone sutures. If the pinna has a tendency to droop downward following closure, tacking sutures can be placed along the medial base of the pinna and the adjacent muscle fascia using a small access incision.

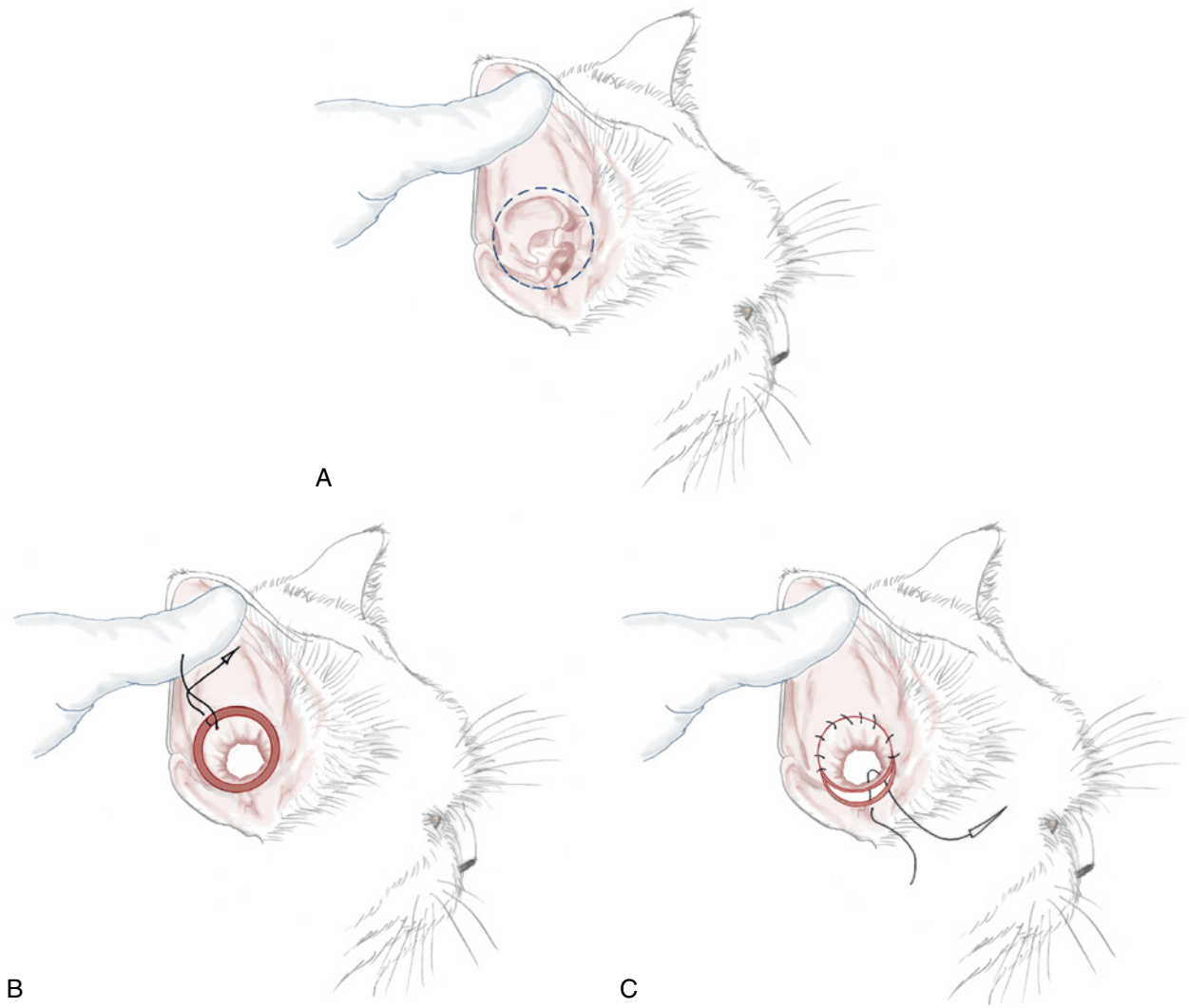
COMMENTS

This technique was developed by the author, who has found it simpler to perform when compared to the conventional vertical ear canal resection in dogs. The cosmetic and functional results in the cat are excellent.

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Plate 181



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Plate 182 Incisional Drainage of Aural Hematomas

DESCRIPTION

The classic incisional drainage technique for aural hematomas is by creating a central incision over the length of the hematoma. This incision is created on the medial (concave) pinnal surface. That is followed by the placement of "through-and-through" pinnal sutures with the knots tied on the lateral pinnal surface.

SURGICAL TECHNIQUE

(A) Both surfaces of the pinna are clipped and prepared for surgery. A no. 10 or no. 15 scalpel blade is used to incise the central area of the hematoma along its length (inner or medial surface). A 2–3 mm band of the skin and attached pinna cartilage are trimmed from one border of the incision to ensure premature closure of the incision does not occur (optimizing prolonged drainage). Note the three branches are usually visible after clipping the lateral pinnal surface of fur. A light source can be used to help illuminate the pinnal vessels and a marking pen can be used to sketch their location on the lateral cutaneous surface. This can reduce the risk of penetrating these vessels during suture placement.

(B) Mattress sutures are placed, beginning on the lateral pinnal surface through the pinna and exiting the medial surface. A straight needle facilitates suture placement. The suture needle is redirected from the medial surface to the lateral surface where the suture is tied with a slight amount of tension. Note the sutures are placed parallel to the pinnal arteries/veins to reduce the risk of damaging these vessels.

(C) 2-0 or 3-0 suture material is used, depending on the size of the patient. The suture knots are tied on the lateral pinnal surface: it is important not to tie the sutures too tightly. This is followed by placement of a bandage (see Plate 183).

COMMENTS

If otitis externa is the underlying cause of aural hematoma formation, it needs to be treated in the postoperative period. Some articles in the past suggested the use of a sigmoid ("lazy S") incision may reduce deformity of the pinna secondary to scarring. From the author's experience there is no advantage of this over a simple linear incision and its use does not prevent subsequent distortion of the ear. Regardless, pinnal scarring is greater than the minimally invasive vacuum drain technique (see Plate 184). Patients are normally uncomfortable with this technique and appropriate analgesic medications are indicated.

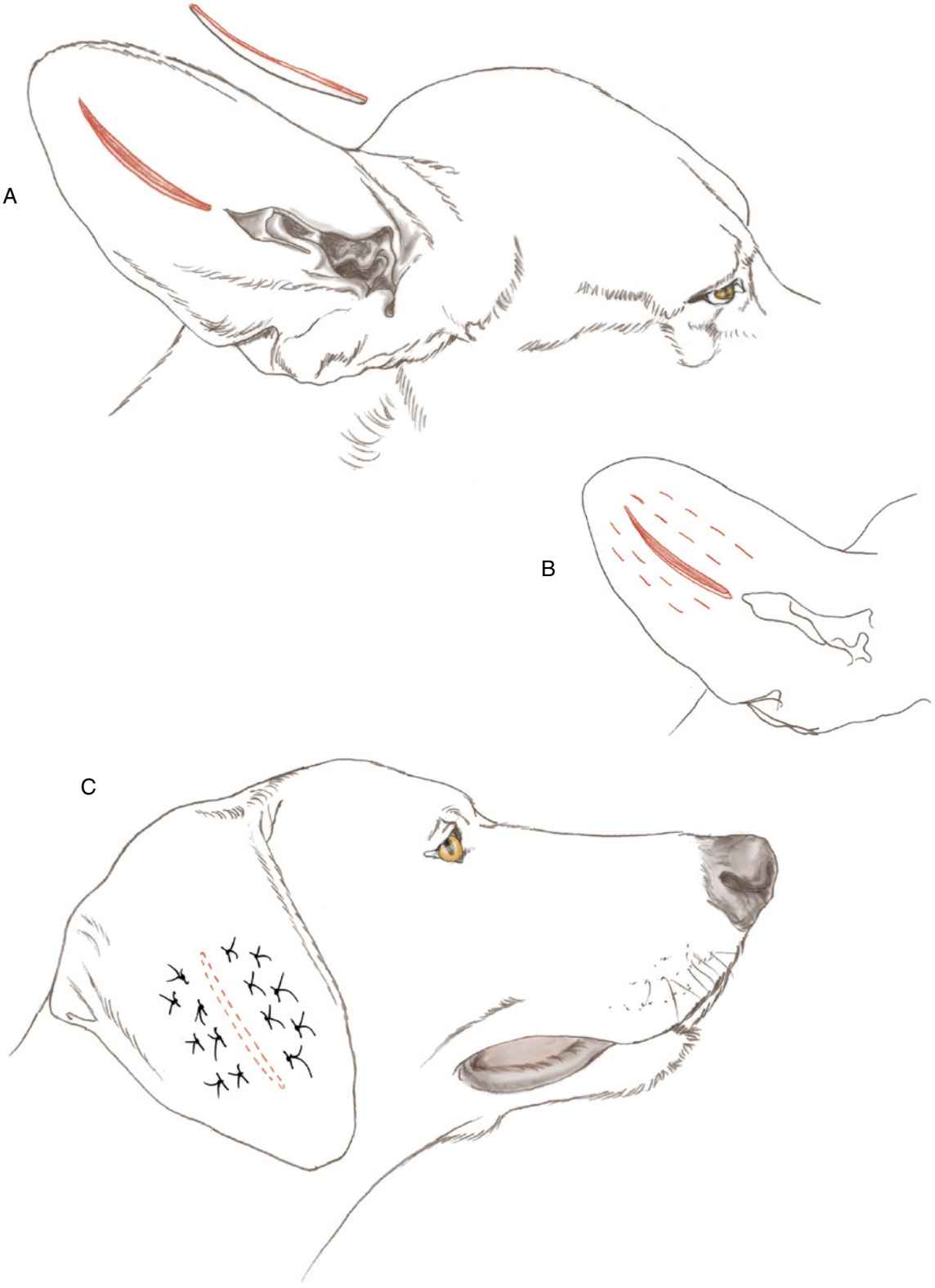
Some veterinarians secure their suture knots to buttons, soft rubber tubing, firm plastic sheets, or radiographic film to reduce suture irritation and maintain the position of the ear; the author does not. In wide ears, the pinnal vessels are farther apart: this can allow the surgeon to place sutures perpendicular to the drain incision, which provides better drainage between sutures. Sutures are normally removed 2–3 weeks postoperatively.

Bandaging for 2–3 weeks is usually indicated depending on the shape and size of the pinna. There are various bandaging techniques used by veterinarians; the author's preferred technique is noted in Plate 183. Maintaining the protective bandage and wound dressing can be a challenge in some dogs and cats. After bandage removal, it is advisable to protect the ear for an additional 10–14 days with an Elizabethan collar.

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Plate 182



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Plate 183 Bandaging the Pinna

DESCRIPTION

In this example, an aural hematoma had been managed by incisional drainage on the medial pinnal surface. This is the author's preferred bandaging technique for protecting the pinna.

TECHNIQUE

(A) Two long surgical tape strips (1- or 2-inch width) are folded over the rostral and caudal helical margins of the pinna and joined together at the apex of the pinna. The conjoined strips form a band that is wrapped around the neck (see inset).

(B) The pinna is positioned on the dorsum of the head and the loop is taped to itself, stabilizing the position of the pinna.

(C) A flat patch of cotton is applied between the lateral pinnal surface and the dorsum of the head, in order to prevent moist dermatitis from skin-to-skin contact. Layers of 2–3-inch cast padding, alternated with adherent gauze, encircle the head rostral and caudal to the opposite ear (to prevent bandage displacement). The cast padding/gauze covers the exposed pinna, leaving the open incision exposed. Elastikon, Vetrap (3M), or a combination of both is used to create the outer tertiary wrap. In this illustration, note the medicated (triple antibiotic ointment) nonadherent dressing and gauze pad that will be taped over the surgical incision. This allows the owner and veterinarian to easily change the dressing every 24–48 hours while maintaining the bandage.

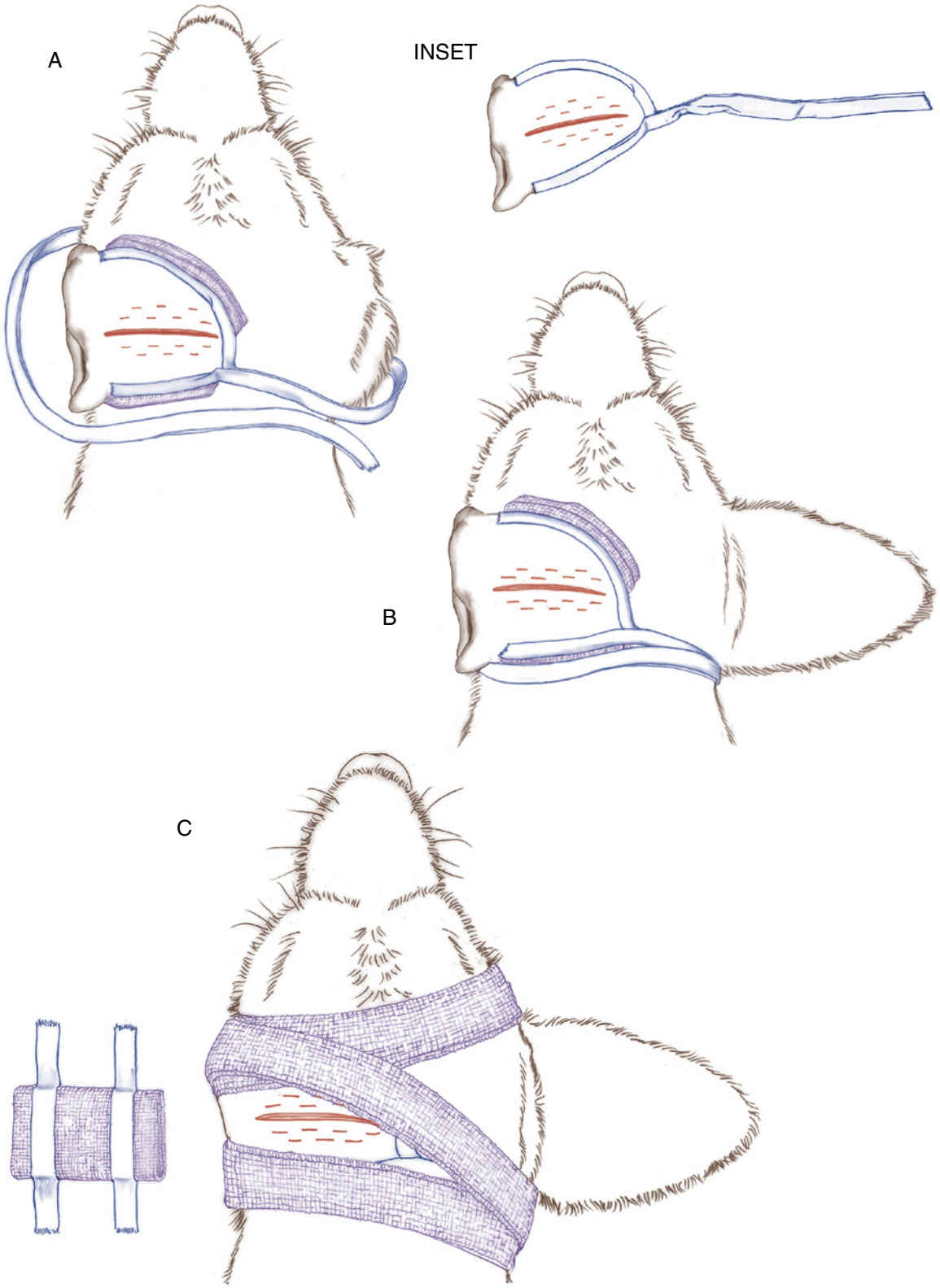
COMMENTS

Note that the opposite pinna helps maintain the position of the ear by wrapping the bandage rostral and caudal to its base. This is an effective bandage to maintain the pinna after aural hematoma drainage. It does require practice and time to become adept at placing it properly. The bandage is checked on a weekly basis to ensure it does not loosen or shift.

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Plate 183



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Plate 184 Vacuum Drain Management of Aural Hematomas

DESCRIPTION

This minimally invasive technique utilizes the insertion of a Hemaduct drain placed in the hematoma cavity on the lateral aspect of the pinna. Only an Elizabethan collar is required to protect the pinna from drain displacement and external trauma.

SURGICAL TECHNIQUE

(A) Aural hematoma involving the left pinna.

(B) On the prepared lateral/concave side of the pinna, a no. 15 blade is used to create a 1 cm access incision in the skin near the end of the hematoma (closest to the base of the ear). A no. 11 blade is then inserted through the thin cartilaginous wall of the hematoma. Mosquito hemostats are inserted into the hole and opened to enlarge the stab incision in the hematoma wall.

(C) The fenestrated portion of the Hemaduct drain is measured and shortened with scissors to the length of the hematoma cavity. It is guided into the hematoma and a single 3-0 nylon skin suture is used to secure its tip at the terminal end of the cavity. The nonfenestrated portion of the drain is shortened to the length estimated to reach the Jackson-Pratt 100 cc reservoir that will be attached to the lower portion of the dog's collar. A stab incision is created at the base of the ear; long forceps are bluntly advanced subcutaneously to the initial access incision. The end of the drain is grasped and pulled out of the stab incision.

(D) The initial access incision is closed with 3-0 nylon interrupted skin sutures. A purse string is placed in the skin at the exit of the drain and secured to the drain with a finger-trap knot using 2-0 nylon. Below this site a "butterfly" tape strip is applied to the tube; each tape tab is sutured to the skin. The end of the tube is attached to the reservoir and the drain system is activated. The reservoir loop is used to attach it to the patient's collar. An Elizabethan collar is applied to the patient before anesthetic recovery.

COMMENTS

The drain remains for 18–21 days, time enough to help ensure collagen deposition apposes the delaminated cartilage (early maturation phase of wound healing). Hemaduct drains are the best to use for this procedure: they provide optimal drainage along their linear channels and easily slide out of the surgical site when removed. Several companies on the internet sell this innovative drain and the Jackson-Pratt reservoir. Patients are normally checked on a weekly basis to ensure the drain is functional. Owners are instructed to contact their veterinarian if the hematoma appears to reform, suggesting obstruction of the drain. Owners record the amount of fluid removed from the reservoir on a daily basis: although normally minimal, (<1–2 ml/day) this helps determine when the drain is ready for final removal. The color and clarity of the fluid are also recorded. A broad-spectrum antibiotic is used over the first week; by then the pocket is collapsed and a granulation bed will have formed that is more resistant to infection. (In one Weimaraner patient seen by the author for an aural hematoma, generalized edema was noted by the owner 24 hours after drain removal. Cellulitis secondary to infection was suspected, and antibiotic therapy was implemented until the culture results returned. The patient rapidly responded to therapy and the infection resolved.)

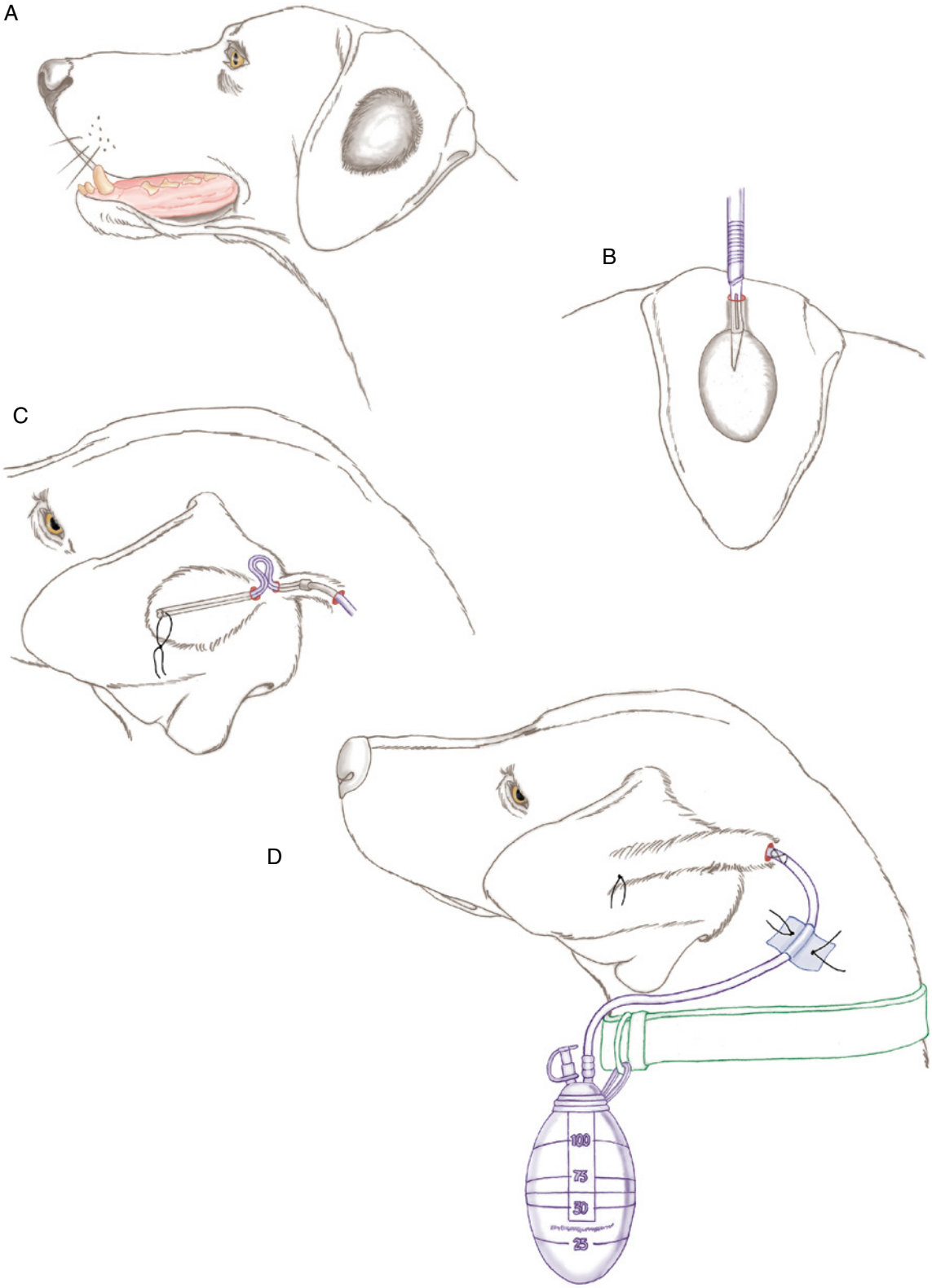
Cosmetic results are often good to excellent in dogs, provided that the hematoma is drained early in the course of its formation. This minimally invasive technique reduces scarring, is comfortable to the patient, and does not require bandaging. It must be noted that some dogs and cats can have asymmetric stretching of the delaminated cartilaginous surfaces. When apposed after activation of the vacuum reservoir, the lateral cartilage wall (subject to greater stretching and deformity than the medial wall) creates a bend or fold in the pinna.

More severe distortion of the pinna is noted in chronic untreated hematomas, with techniques that cause greater surgical trauma, and in the presence of infection. For those owners concerned about cosmetic appearance (including show dogs), early drainage using this technique is the best option to minimize contracture (wrinkling/folding) of the pinna. The author has used this technique in a limited number of cats and has found that it does not prevent wrinkling of the ear. The thin pinnal cartilage of the cat is more susceptible to deformation.

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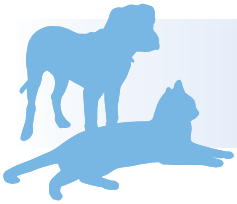
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Plate 184



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24

Miscellaneous Reconstructive Surgical Techniques

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This chapter is designed to introduce surgical techniques that fail to fit neatly into the standard surgical categories described in the preceding chapters. The omentum and scrotum, and their potential uses in reconstructive surgery, are described. Surgical management of tail fold, atresia ani, and vulvar fold intertrigo is also discussed as well as surgical techniques to help manage fecal incontinence.

OMENTUM

The omentum serves as a reservoir for immune cells as well as angiogenic and neurotrophic factors. It provides lymphatic drainage to the abdominal cavity. Surgeons are familiar with its adhesive properties to wall off inflammatory processes. An understanding of the omental circulation is important, especially when expanding its length, by surgical incision, to increase its reach to more distant areas of the body. The blood supply of the omentum, for the purpose of creating omental pedicle flaps, was researched in the dog (Doom et al. 2016a–c).

An understanding of the basic anatomy of the omentum is useful for determining how best to mobilize this tissue for wound closure.www It is basically divided into a superficial (ventral) leaf that reflects dorsally to a deep leaf. The omentum is subdivided into the greater and lesser omentum. The greater omentum (epiploon or *omentum majus*) is a lacy apron extending from the greater curvature of the stomach to the level of the urinary bladder. It covers the intestinal tract ventrally and on the sides. The greater omentum appears to be a single layer, but is actually a double peritoneal sheet (that reflects or folds back on itself distally). It is composed of connective tissue and streaks of fat that surround fine arteries passing through this tissue. The omentum is nearly transparent due to its thinness. The greater omentum is further subdivided anatomically into a large *bursal* portion and smaller *splenic* and *veil* portions.

The bursal portion of the omentum attaches cranioventrally to the greater curvature of the stomach. Distally, it reflects on itself and returns to the region dorsal to the stomach. The ventral layer and the deeper dorsal layer can be separated by gentle manual traction. Between these two surfaces is a potential pocket or cavity called the *omental bursa* or *lesser peritoneal cavity*. Except for this large constant opening, the *epiploic foramen*, the omental bursa is a closed pouch. The epiploic foramen is bounded ventrally by the peritoneum covering the portal vein and dorsally by that covering the caudal vena cava. The splenic portion of the omentum is also referred to as the *gastrosplenic ligament*. The veil portion contains the left extremity and caudal margin of the left lobe of the pancreas.

Multiple interconnecting vascular branches supply the superficial and deep leaves of the omentum. The circulation to the omentum is primarily supplied by branches of the splenic artery and left/right gastroepiploic arteries. The splenic branches are the dominant blood supply and a portion of the circulation is routed along the left border, right border, and caudal arch of the omentum. Based on this circulatory study (Doom et al. 2016a–c), the base of an omental flap should preserve the splenic branches on the left side of the omentum (Plates 185 and 186).

Surgical Applications

The omentum has been used for the following surgical applications:

- Closure of problematic abdominal hernias
- Closure of diaphragmatic defects
- Omentalization of prostatic, hepatic, and pancreatic abscesses and cysts
- Omentalization of abscesses and cysts within the abdominal cavity
- Omental overlay of gastrointestinal incisions
- Omental overlay of urinary bladder to prevent adhesions and leakage
- Omental flap transfer for thoracic wall defects
- Thoracic omentalization for pleural effusion
- Omental overlay of the caudal esophagus
- Closure of feline indolent axillary wounds
- Closure of problematic inguinal wounds and other external wounds

The omentum can reach most areas within the abdominal cavity and outer abdominal wall (Fig. 24-1). The omentum in some patients may not reach the caudal aspects of the abdominal and pelvic cavities without surgically lengthening this tissue. Similarly, lengthening procedures are required for transferring the omentum to the anterior thoracic and axillary areas (see Plates 185 and 186).

The omentum can be useful for closure of problematic defects by improving (donating) circulation to ischemic or compromised tissues as well as controlling dead space. For example, a chronic radiation burn, lacking circulation, would potentially benefit from a muscle or omental flap. Omentum has also been advocated for chronic axillary wounds in cats, when other closure options have failed. Each can provide a source of circulation to the area, not only to improve healing but to potentially serve as a vascular surface for skin graft application. The major limitation in using omentum is its relative fragility and lack of "bulk" for closing larger defects. Overextension of the omental flap can result in circulatory compromise to the more distal portion of

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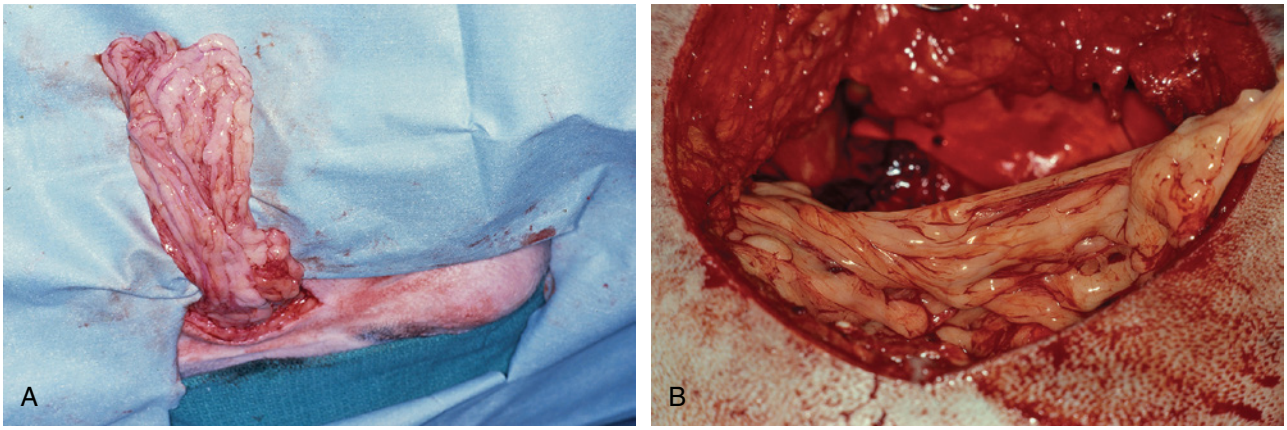


FIG. 24-1 (A) Omentum elevated out of the abdominal cavity through a midline laparotomy. This mobile tissue can be used for a variety of problematic wounds within its normal arc of rotation. (B) Resection of the caudal thoracic wall for osteosarcoma in a 2-year-old golden retriever. A portion of the diaphragm attached to the tumor was resected. Note how easily the omentum can be passed through the diaphragm and into the thoracic cavity.

this tissue. However, within its normal arc of rotation or advancement, the omentum can be gathered or folded to improve its bulk for defects involving the abdominal wall or diaphragm. Synthetic mesh can be used for added rigidity.

In thoracic wall reconstruction, the latissimus dorsi muscle flap is superior to the use of Marlex mesh (Davol) and omentum, based on the tissue bulk provided and simplicity of elevation and transfer. Nonetheless, omentum and mesh can be used in those cases in which the use of this muscle is not possible.

SCROTUM

The scrotum is a multilayered tissue enveloping the testicle; the testicles are separated by a connective tissue septum. The septum blends with the abdominal fascia dorsal to the testicles. Residing beneath the thin scrotal skin is the *dartos*, a layer comprising connective tissue, elastin fibers, and smooth muscle. Smooth muscle contraction of the dartos layer draws the testicles closer to the abdominal wall. Around each testicle is an outer parietal tunic and the visceral tunic enveloping the testicle. The cremaster muscle, derived from the internal abdominal oblique muscle (or occasionally the transversus abdominis muscle), inserts on the parietal vaginal tunic at the level of the testis. Contraction of the cremaster draws the testicles closer to the body.

The principal blood vessel to the scrotum is the external pudendal artery. The cremasteric artery arises from the femoral or deep femoral artery. The scrotal arteries run along the cranioventral surface of the testis, superficial to the common vaginal tunic. The perineal branches of the external pudendal artery supply the scrotum, in part. The draining veins follow the same course in reverse.

Surgical Application

The scrotum has been described in humans as a simple advancement-style flap for closing defects of the adjacent inner thigh. Matera et al. (2004) describe the use of the scrotal skin for closure of similar cutaneous defects, after its dissection from the underlying dartos layer (see Plate 187). The elevated skin can be advanced or transposed into adjacent cutaneous defects.

The surface area of the scrotum varies in the male, depending on the age of the dog, the size of the testicles (Fig. 24-2), and the variable effects of gravity. The scrotum has a tendency to shrink after castration, whereas the scrotum tends to have a greater surface area in the intact male dog. The author also has used the scrotum for local wound closure on a limited basis, leaving the dartos attached to the overlying skin surface.

TAIL FOLD INTERTRIGO (SCREW TAIL)

Intertrigo (skin fold dermatitis) is an inflammatory condition associated with skin creases or depressions (Fig. 24-3). Deeper creases or folds have a natural tendency to accumulate moisture; skin-to-skin contact can create local irritation, contributing to the formation of pyoderma. While diligent conservative treatment with skin-cleansing solutions and topical antibiotic agents by pet owners may

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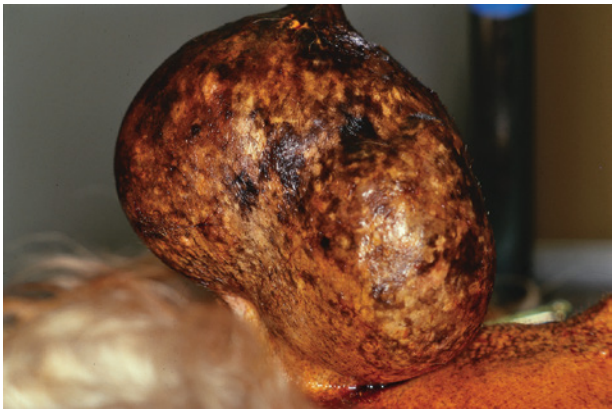


FIG. 24-2 Scrotum with enlargement secondary to a large Sertoli cell tumor. Note the capacity for the scrotum to stretch to underlying expansile masses.



FIG. 24-3 The rare English bulldog with a normal tail.

palliate this condition in accessible areas, ventral tail fold pyoderma is often impossible to maintain in this fashion.

Although rare, an English bulldog can present with a normal tail (Fig. 24-3); most present with a deviated tail. "Screw tail" is a descriptive slang term for the corkscrew-like deviation of the tail most commonly seen in the English bulldog. On occasion, it can be seen in French bulldogs, pugs, and Boston terriers. This condition also has been called "ingrown tail." In some cases, the ventral skin fold can be several centimeters deep when assessed by the insertion of cotton-tipped applicators. The deformed tail can take a ventral bend that partially or completely covers the anus, further contributing to the problem (Fig. 24-4). Intraoperatively, the dorsal surface of the deep skin fold can adhere firmly to the undersurface of the deviated coccygeal vertebrae, making surgical resection of the inverted skin fold a greater challenge. On occasion, the dorsal tail fold(s) also may develop intertrigo, but this is more amenable to conservative treatment (Fig. 24-5).

Clinical signs of tail fold intertrigo usually include the dog rubbing or scooting its rear on the floor or carpeting. The owners may note a foul odor around the tail base or note fecal accumulation beneath the distal tail segment.

Surgical Correction

Standard textbooks normally show one or two basic approaches to caudectomy for tail fold intertrigo: a dorsal linear incision over the tail or the creation of a horizontal elliptical incision around the entire tail area. Following amputation of the tail anterior to the initial point of coccygeal deviation, the skin fold and redundant skin are resected. Preservation of the major dorsal skin fold enables the surgeon to create a semblance of a short symmetric tail with satisfactory cosmetic results (Figs 24-6 and 24-7). The author's preferred approach is described in Plate 188.

DISORDERS OF THE VULVA

Vulvar Fold Pyoderma

The infolding of the vulva below the adjacent skin surface may be of a congenital or acquired nature. Hypoplasia of the vulva may result in its recession deeper to the adjacent skin (Fig. 24-8). Slight angular deviation of the vulva also has been noted in conjunction with hypoplasia (Fig. 24-9). The recessed vulva in turn can result in moisture accumulation and dermatitis. Bacterial infection normally follows this sequence. Most cases of vaginal fold pyoderma are acquired in nature. Subcutaneous fat accumulation dorsal to the vulva stretches the skin to a variable degree with the assistance of gravity. The redundant skin drapes over the vulva (Fig. 24-10). Urine scalding and moisture accumulation secondary to chronic dermatitis perpetuate the pyoderma. In long-standing cases, the skin lateral and ventral to the vulva also may appear to be thin, hairless, and somewhat shiny due to long-standing dermatitis. The upper thighs may contact each other, creating another crease for frictional contact and dermatitis.

Although many dogs with this condition do not present with a bacterial cystitis, vulvar fold pyoderma

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FIG. 24-4 (A) Tail fold pyoderma and severe ventral deviation of the tail over the anus. (B) After amputation of the tail via a dorsal T incision, firm traction of the skin fold and the tail helps remove the ventral fold. The skin dorsal to the anus is incised to complete the resection. The skin fold in this case was firmly adhered to the ventral surface of the deviated tail. (C) Note the depth or surface area of this ventral fold and the large mat of hair that accumulated in this cutaneous trough. Preservation of the major dorsal fold creates a symmetric appearance of a short tail stump.



FIG. 24-5 Screw tail with intertrigo involving both the dorsal and ventral skin folds.

may be a source of recurrent urinary tract infections in some canine patients. Surgery is considered the acceptable standard for correcting vulvar fold pyoderma (Fig. 24-11).

Surgical Technique

Surgery is focused on removal of the redundant skin and the area of intertrigo using connecting inverted U ("Dutchman's pants," inverted horseshoe) incisions.

Removal of redundant subcutaneous fat is important for correcting this condition and facilitating closure (Fig. 24-10). The lateral skin incisions can be extended below the lower vulvar margin. A small amount of skin can be resected at this location to create a "thigh tuck," which better separates the inner thigh tissues for those patients in whom chronic dermatitis extends ventral and cranial to the vulva. Care must be taken to avoid

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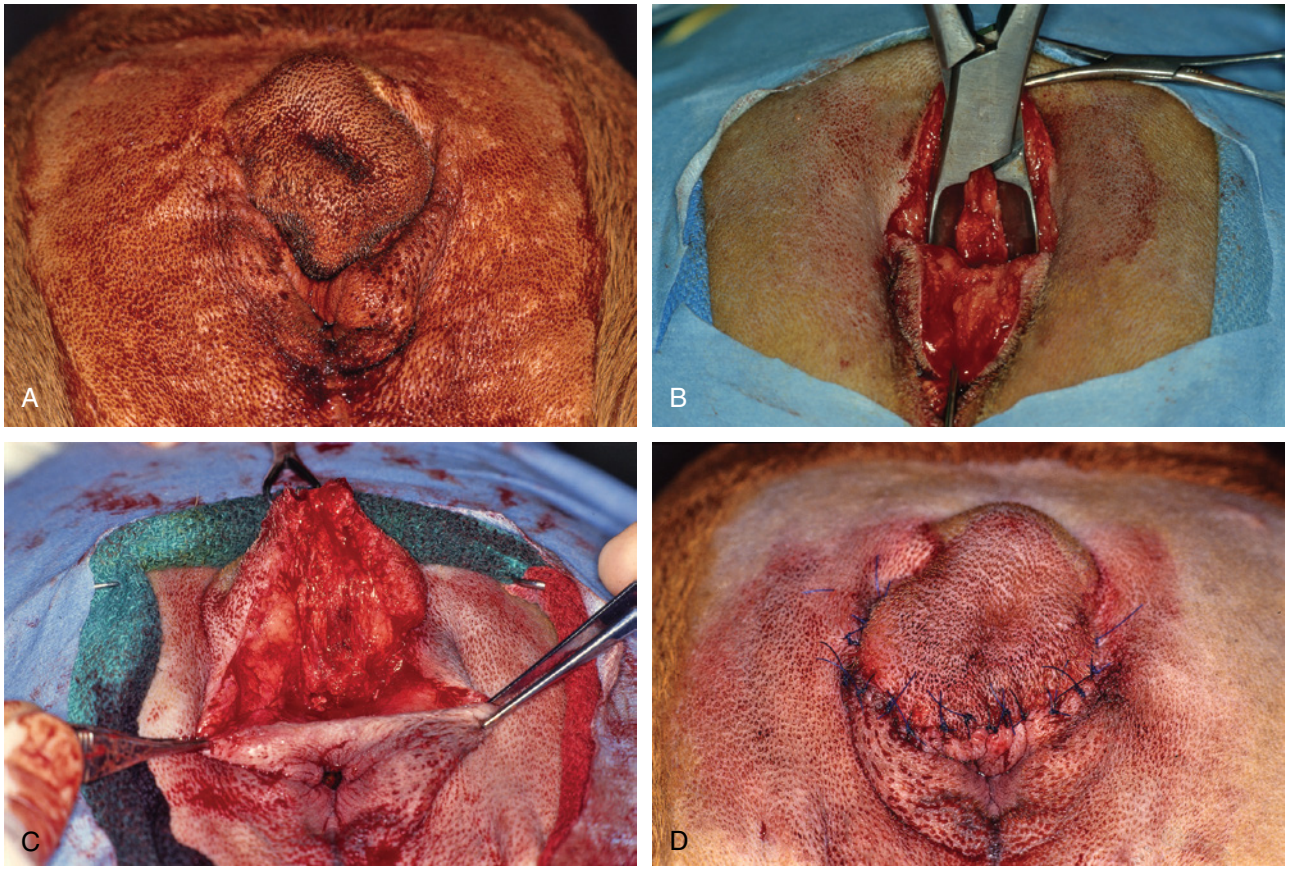


FIG. 24-6 (A) A typical case of tail fold intertrigo. (B) A skin incision caudal to the large anterior dorsal fold of the tail is followed by a central incision directed caudally, forming a T incision. The T incision simplifies dissection around the deviated tail segment, followed by its amputation with bone-cutting forceps. (C) The ventral skin fold is resected. Following control of bleeding vessels with electrocautery and ligatures, the dead space can be closed with the application of absorbable sutures. Note the elevated tail fold. (D) The elevated fold is sutured to the ventral incision, creating the illusion of a short tail stump.

excessive skin resection dorsal to the vulva (Figs 24-10 and 24-11). Wound dehiscence secondary to excessive tension can create a perineal defect that can be quite difficult to close (Plate 189).

Tumors of the Vulva

Neoplasia of the vulva is occasionally noted in older dogs, including squamous cell carcinoma and mast cell tumors (Fig. 24-12). Most of these neoplastic conditions do not present as a typical vulvar fold pyoderma. When in doubt, biopsy the lesion.

Partial or complete vulvar resection can be performed in these cases, with care taken to identify and preserve the urethral tubercle. Owners are warned that local urine scalding is a possibility, in part depending on how the patient squats to urinate (Fig. 24-12). Postoperatively, the fur should be trimmed to reduce moisture accumulation and facilitate cleaning the area after urination. Commercially available disposable baby wipes are convenient for this purpose.

As noted, mast cell tumors are common in this area, many of which can be excised and closed with local skin flaps. The author has found the transposition skin flap the most useful in this area. The skin fold overlying the vulva is a potential source of skin for flap development for closing surgical defects within their arc of rotation (Figs 24-13 and 24-14).

Congenital Defects of the Vulva

Most congenital defects of the vulva noted by the author include recession, hypoplasia, and its deviation (noted in Fig. 24-9). Although uncommon, the vulva may be incompletely developed. In one patient (Fig. 24-15), a dorsal defect of the vulvar area exposed the vagina: its proximity to the anus contributed to recurrent urinary tract infections. Closure of this defect resolved this problem.

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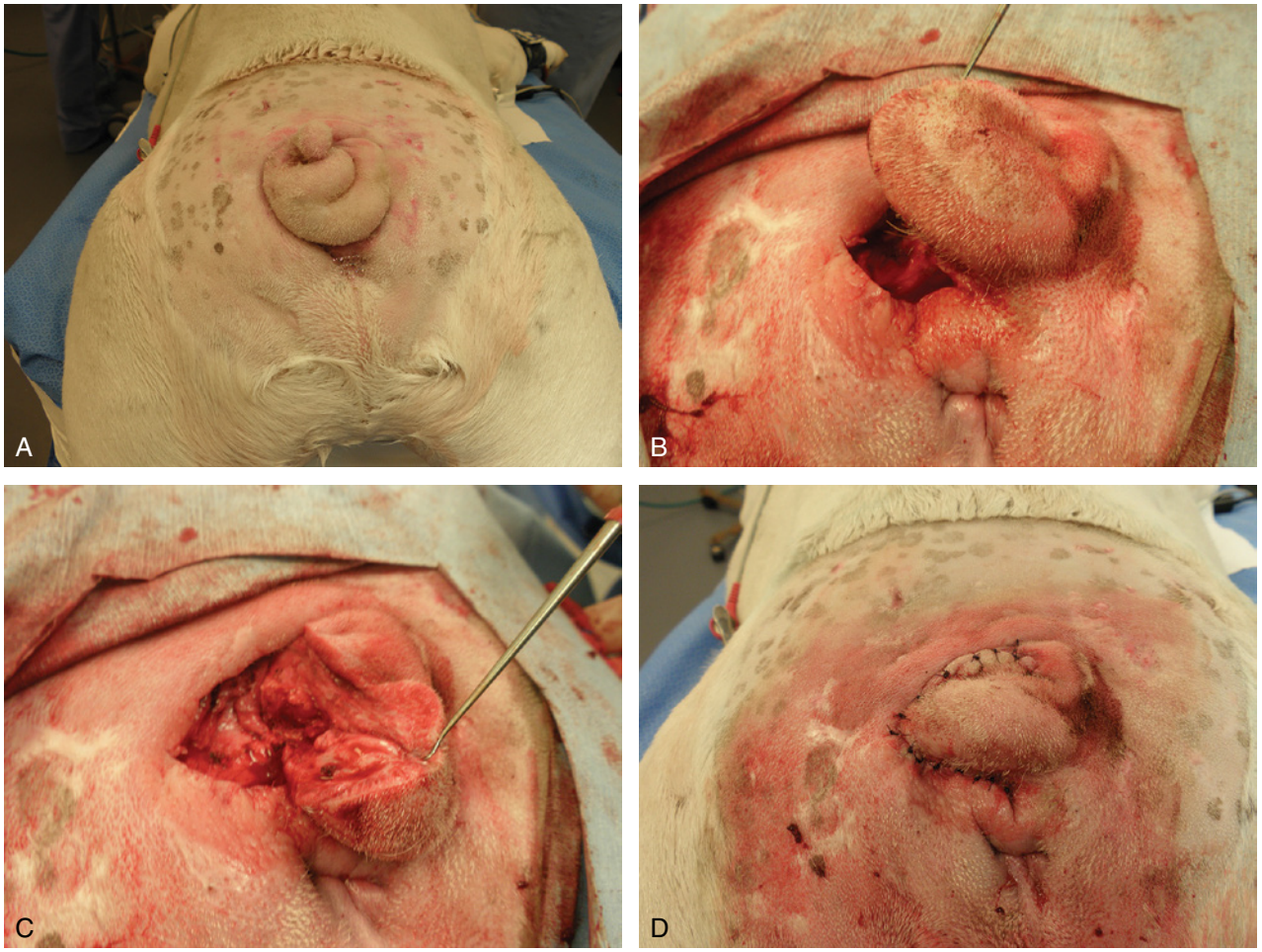


FIG. 24-7 (A) Unusual tail deviation in the bulldog, leaving a large ridge of dorsal skin on the right side. (B) The surgical approach in this case was placed to the left of the large skin fold, creating a right-sided skin flap. (C) The deviated coccygeal vertebrae were severed with bone cutters. (D) Closure of the surgical site. Note that the preservation of the large tail fold gives the impression of a small tail.

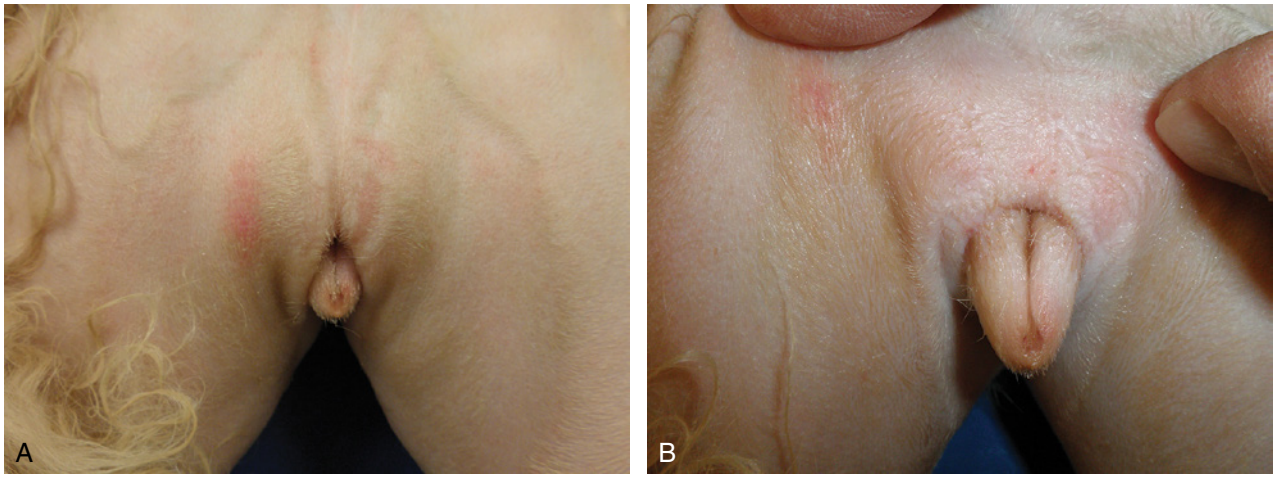


FIG. 24-8 (A) Congenital recessed vulva with the dorsal vulvar skin creating a "hooded vulva." (B) Slight traction of the peripheral skin exposing the vulva. Episioplasty was performed, eliminating the recurrent urinary tract infections in this golden retriever.

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FIG. 24-9 (A) Recessed vulva with deviation to the right in a young retriever. (B) Traction on the skin, exposing the deviated vulva. (C) The redundant dorsal skin was resected after assessment of the amount necessary to elevate the vulva and close the surgical defect without creating excessive incisional tension. (D) Interrupted absorbable intradermal sutures were placed in the skin followed by external skin sutures. Note the slight asymmetry of the vulva.

MANAGING SKIN FOLD INVERSION OF URETHROSTOMIES

Permanent urethrostomy sites may have a variable degree of skin inversion around the new ostium created in dogs. This does not appear to be a significant problem in male cats after perineal urethrostomy. In the early 1970s, a surgical procedure was attempted to evert the newly created ostium in cats. Elliptical resection of loose skin followed by closure, medial to the ischial tuberosities, was used to apply bilateral cutaneous tension to slightly evert and "open" the newly created urethrostomy. It was later noted that this technique (referred to as "Smilers") did not improve urination and dermatitis was not noted to the skin margin surrounding the mucosa.

As noted in female dogs, dermatitis around an inverted vulva can be problematic. Although less common in male dogs after permanent urethrostomy, there are occasional cases where more severe inversion of the skin surrounding the urethral ostium can be the source of recurrent urinary tract infections. The old "Smiler technique" performed in cats can be useful for this problematic condition (Fig. 24-16).

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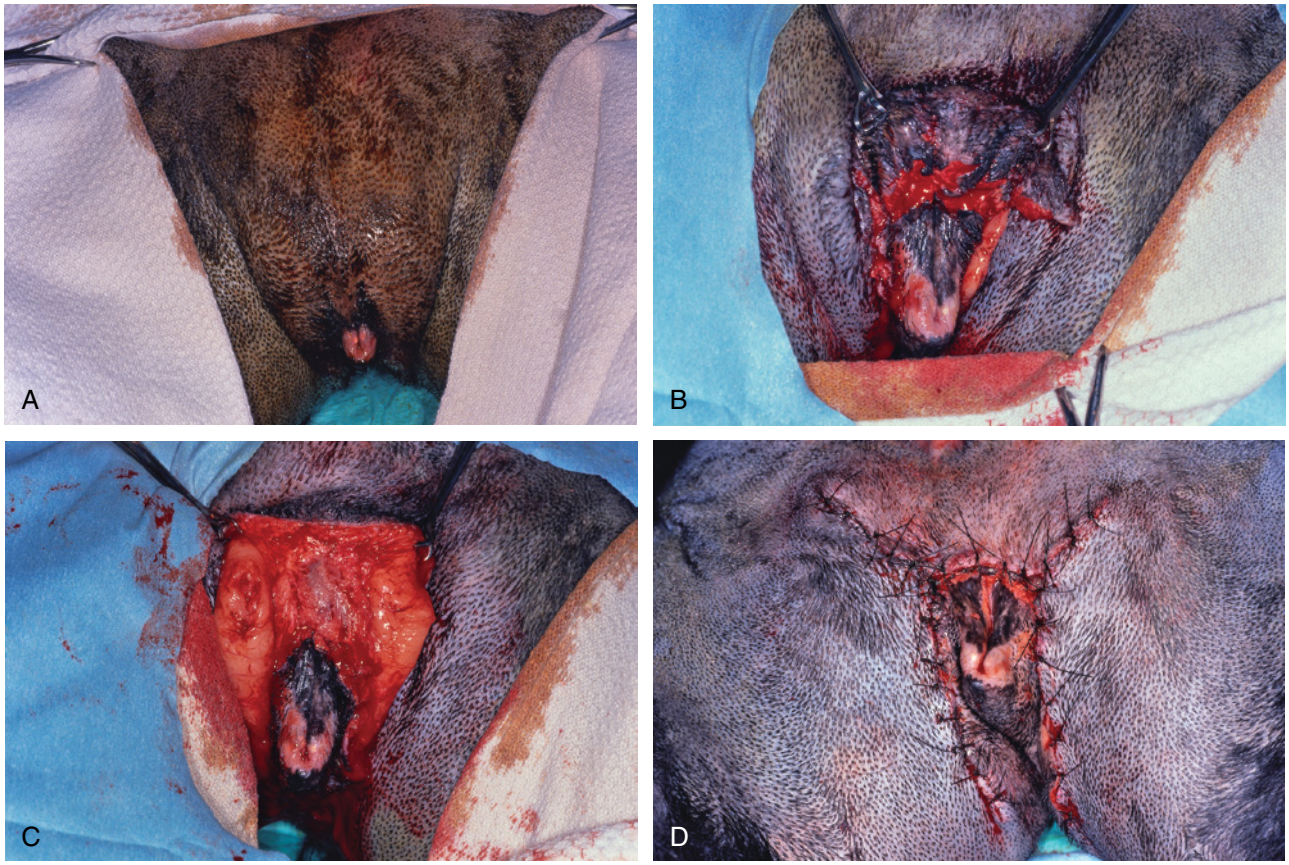


FIG. 24-10 (A) Vaginal fold pyoderma or intertrigo in an older German shepherd. Note the prominent subcutaneous fat dorsal to the obscured vulva. (B) Traction of the skin rim dorsal to the vulvar fold, demonstrating the chronic dermatitis. (C) Resection of the excessive skin and subcutaneous fat. (D) Because of the mismatch in the paired curved incisions, the skin was closed with two dorsal lateral incisions. Note the lower thigh incisions: a small amount of skin was removed ventral and lateral to the vulva bilaterally, creating a "thigh tuck." This maneuver slightly separates the thigh skin and improves skin aeration ventral and anterior to the vulva, where chronic moist dermatitis also is noted.

FECAL INCONTINENCE: TREATMENT OPTIONS

Loss of the anal sphincter function can occur secondary to denervation (complication associated with bilateral anal sacculectomy), trauma, or tumor resection. With complete anal incontinence, fecal matter is randomly released. As residue accumulates in the lower bowel, periodic peristaltic contraction moves the colonic contents into the rectum. Without a soft tissue barrier, feces will escape from the patient either at rest or during ambulation. The firmness of the feces can play a role in the severity of stool loss: soft stool escapes more readily than firm stool. Dietary control includes the use of low-residue diets. This can be combined with pharmacologic therapy (diphenoxylate hydrochloride, loperamide hydrochloride) to prolong the transit time of bowel contents, thereby increasing water resorption from the feces. Low-residue diets may reduce fecal bulk. Another alternative is to preemptively induce defecation with daily warm-water enemas. Inflation of a Foley catheter inserted into the rectum also can be used to induce involuntary fecal evacuation.

Clinical papers pertaining to the surgical management of anal incontinence involved two dogs rendered incontinent after bilateral anal sacculectomy. In both cases, a strip of fascia lata was used to create a sling beneath the terminal rectum, with its ends either sutured to the lateral tail muscles bilaterally or secured over the tail base. When applied under slight tension intraoperatively, the lower rectal wall is partially elevated, reducing the size of the anal orifice while creating a partial "retaining wall" composed of the elevated lower rectal wall. Fecal material must accumulate sufficiently for it pass over the threshold barrier formed. Both papers report "good results" with fascia lata banding, although long-term follow-up is lacking (Plate 190).

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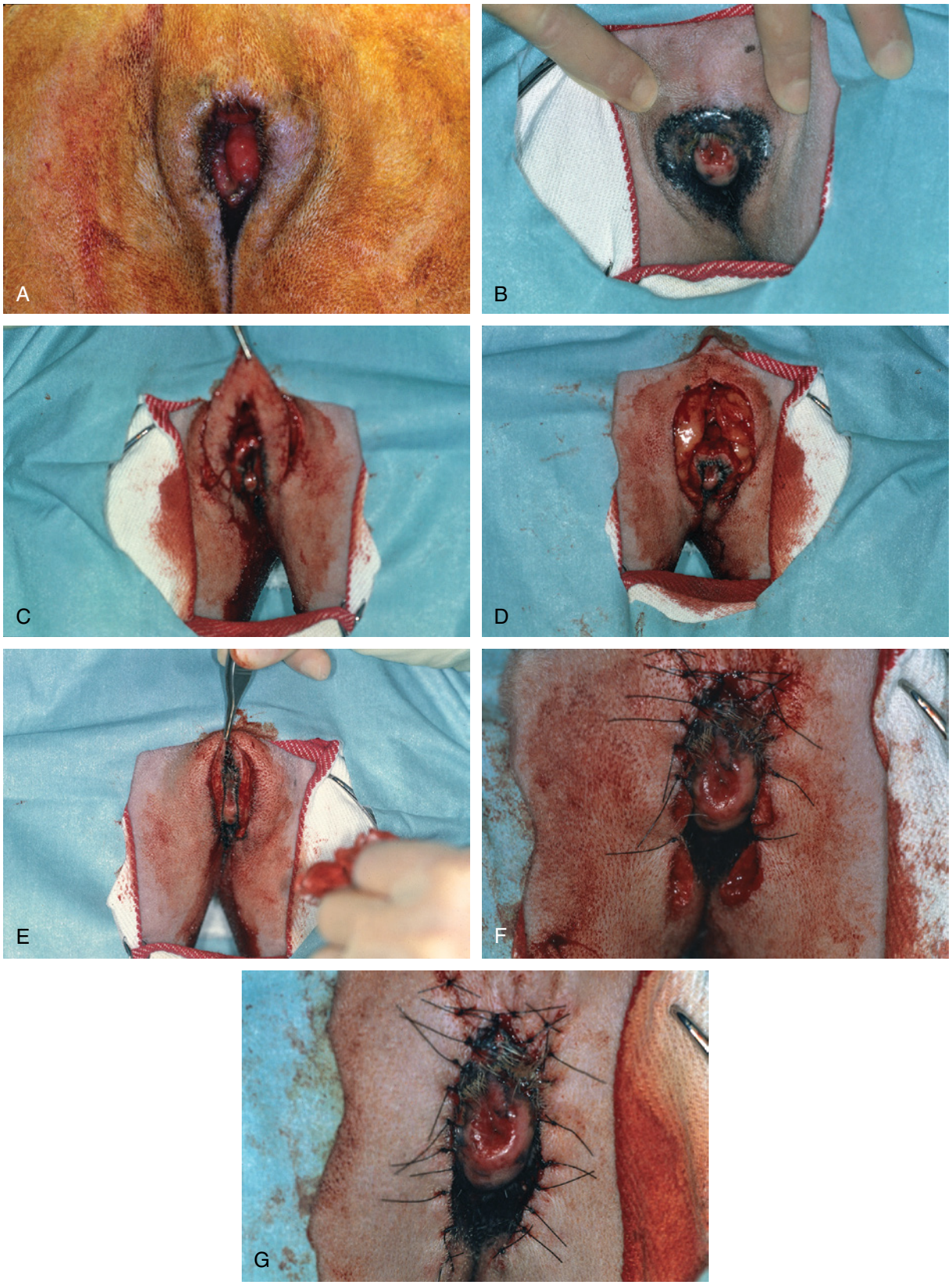


FIG. 24-11 (A, B) Vulvar fold pyoderma can be overlooked, unless an effort is made to lift and retract the overlying skin. (C, D) Excision of the redundant skin is followed by removal of the excess subcutaneous fat noted below the skin. (E) The dorsal midpoint of the vulva is lifted to the dorsal skin border. Sufficient skin was removed to prevent recurrence of the skin fold. Absorbable interrupted sutures are used to close the defect, followed by simple interrupted skin sutures. (F) An additional amount of caudal thigh skin is resected below the vulva, creating a "thigh tuck." (G) Compare this case to the canine patient in Fig. 24-10. Note how slight separation below the vulva improved exposure of the chronically inflamed skin below and anterior to the vulva.

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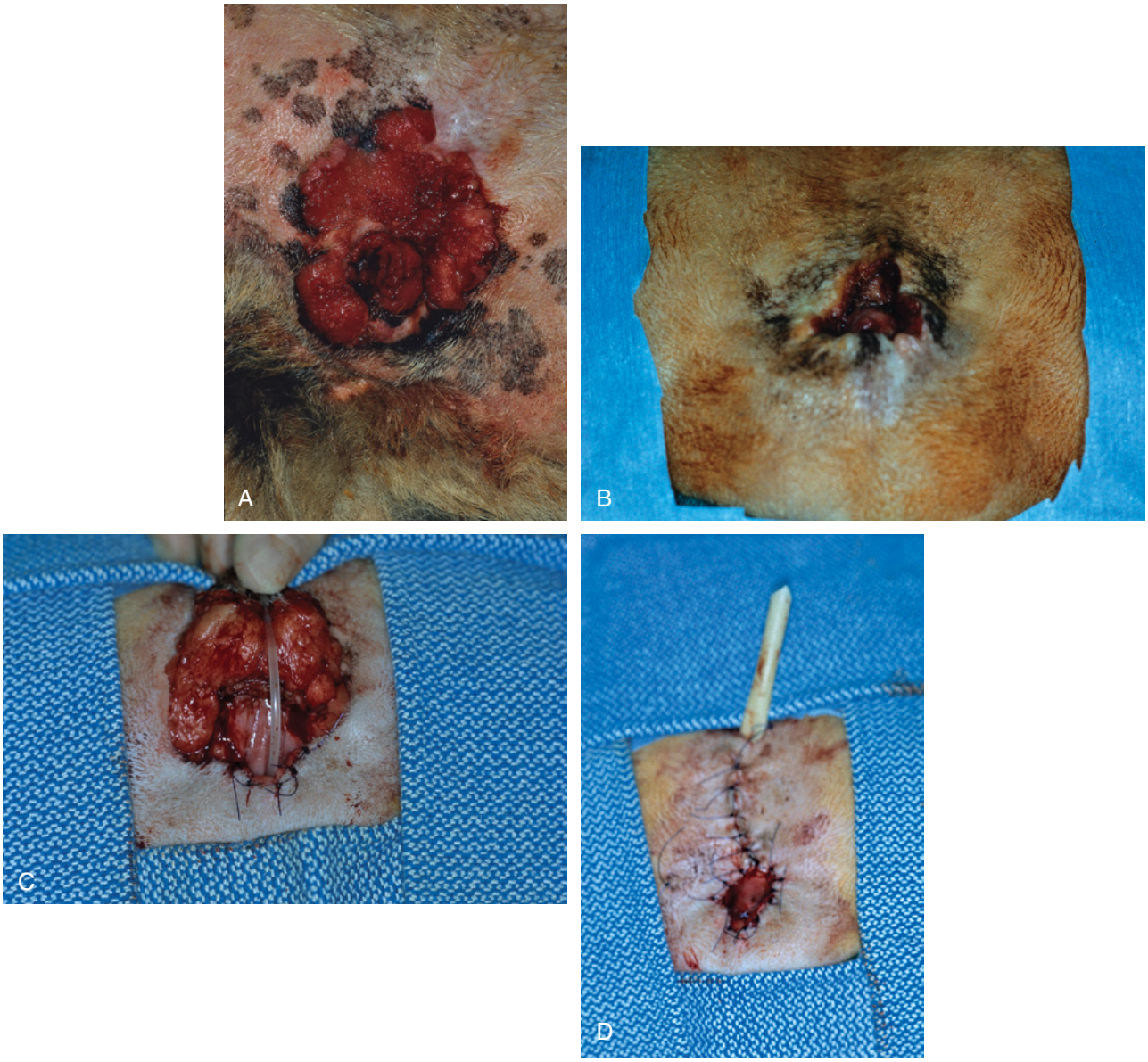


FIG. 24-12 (A) Squamous cell carcinoma involving the vulva with the patient in sternal recumbency for this photograph. (B) A second case example of squamous cell carcinoma, with the patient in dorsal recumbency. (C, D) View of the patient after resection of the vulva and adjoining skin. The urethral papilla is preserved. The author prefers to perform this particular surgery with the patient in dorsal recumbency.

A subsequent paper investigated the used of strips of a polyester-impregnated silicone band in research dogs after bilateral pudendal nerve neurectomy. These elastomeric bands were implanted around the circumference of the retained external anal sphincter muscle. Tension was adjusted so that the 1 cm band snuggly tightened around the proximal interphalangeal joint of an assistant's index finger. (The rectal insertion of an appropriate-size syringe or its casing may be a more practical option.) This elastic banding technique controlled the loss of stool by forming a distensible circumferential barrier to fecal passage (Plate 190).

Other techniques suggested for managing fecal incontinence in dogs include the use of a semitendinosus muscle flap for improving sphincter incompetence (see Plate 114). There have been experimental procedures reported in the dog, including pudendal nerve anastomosis and transposition of an electrically stimulated sartorius muscle. Veterinary clinical studies to determine the efficacy of these experimental techniques are lacking, which is most likely due to (1) the relative paucity of clinical cases and (2) the unwillingness of many owners to pursue surgical management for their incontinent pet.

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FIG. 24-13 (A) Mast cell tumor adjacent to the left vulvar fold. (B) Surgical resection. The outline of a transposition flap was measured and marked on the skin with a surgical pen (gentian violet). Forceps are used to assess the vulva to ensure its integrity is maintained. (C) The flap was transposed into the surgical defect and closed with absorbable skin sutures.

The author reported the use of the spiral rectal diaphragm technique to control sphincter incontinence in a cat (Plate 191). This long-term study demonstrated its efficacy. The spiral formed created a soft barrier, allowing stool to accumulate anterior to this natural barrier. Distention of the rectal walls would stimulate peristaltic contraction. The cat recognized this sensation and would use the litter box. The owner reported that the patient would occasionally drop a small fecal ball, but largely remained continent.

ATRESIA ANI RECONSTRUCTION

Atresia ani is a congenital defect that includes an imperforate anus; this can result in an abnormal opening in the terminal rectum. Rectovaginal fistula associated with type II atresia ani is considered to be the result of an embryologic failure of the urorectal septum to separate the cloaca into rectal and urethrovesical chambers. The condition is more common in females and may result in a fistula forming between the terminal ventral rectal wall and dorsal vaginal wall. Atresia ani is classified as four basic forms.

Classification of Atresia Ani

Type I Stenosis or narrowing associated with a patent anus.

Type II Imperforate anal membrane. The rectum may blind end adjacent to membrane. *A rectovaginal fistula may be noted.*

Type III Imperforate anus with terminal rectum located in pelvic canal (>1 cm cranial to membrane). *A rectovaginal fistula may be noted.*

Type IV Normal anus and terminal rectum; cranial rectum separated as a blind pouch with the pelvic canal. (Type IV not reported in dogs or cats.)

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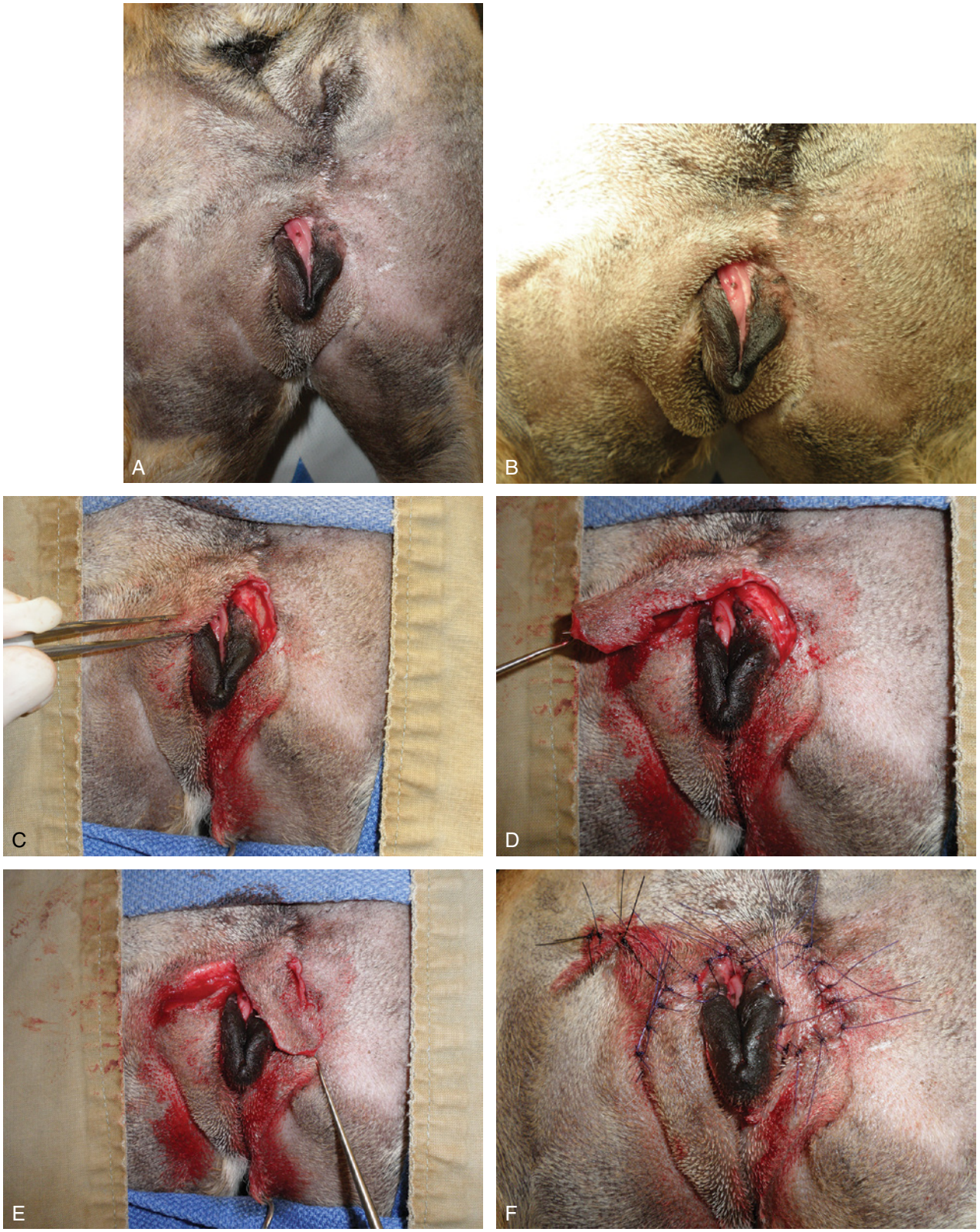


FIG. 24-14 (A) A mast cell tumor was resected from the right vulvar fold area. Closure was accomplished by skin advancement. Elastic retraction of the skin caused deviation of the vulva. (B) A close-up view of the vulva. Postoperatively, the owner reported the urine stream exited the vulva as a "spray." (C) The surgical scar was resected, allowing the right vulvar fold to return to its original position. The width of the surgical defect was measured (15 mm). The remaining vulvar skin fold was assessed for use as a transposition flap (forceps). (D) Using the remaining left lateral and dorsal skin fold area, a transposition flap was elevated. (E) The flap is transposed into the surgical defect. (F) Closure of the donor and recipient beds. Surgery restored the normal urine stream in this patient. (See Plate 192.)

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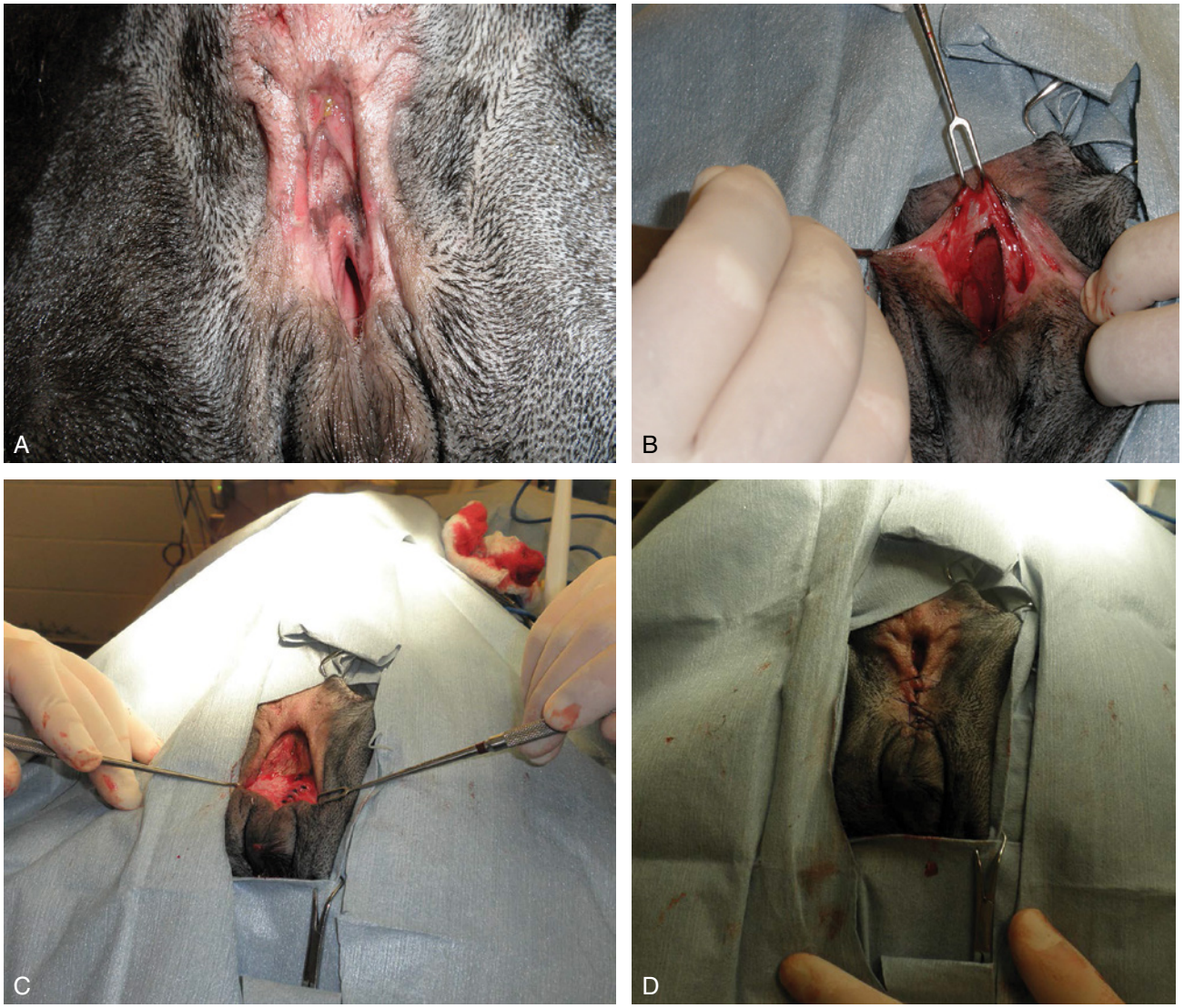


FIG. 24-15 (A) Incomplete development of the dorsal wall of the vulva and adjacent vagina. Fecal contamination resulted in recurrent urinary tract infections. (B) A U-shaped incision was created to separate the mucosa from the overlying skin. (C) Absorbable interrupted sutures were used to appose the left and right mucosal borders. (D) The skin was closed with interrupted skin sutures. Establishment of normal urine flow eliminated the recurrent urinary tract infections.

Either a depression (dimple) or a slight bulge be noted at the imperforate anal membrane in type II and III cases. In type II cases with a rectovaginal fistula, feces can be seen exiting the vulva. Less commonly, rectocutaneous fistulas or rectourethral fistulas may be associated with type II atresia ani.

Puppies and kittens are normally presented after weaning, when the owner notes straining to defecate. A complete physical exam is indicated to rule out other anomalies reported with atresia ani (cleft palate, umbilical hernia, hypospadias, tail agenesis, deafness in dogs, sacrocaudal dysgenesis, open fontanel, and feline hydrocephalus). Supplemental diagnostic tests may include basic abdominal and pelvic radiographs to assess the location of the terminal rectum. In the case of rectovaginal and rectourethral fistulation, positive contrast vaginography or urethrography can be used to further define the fistula and terminal rectum. Computed tomography may be considered in the more problematic cases.

Surgical Treatment Options

Type I atresia ani may be initially managed with bougienage or balloon dilation. However, it is not uncommon for patients to require multiple treatments. Unresponsive cases may require 360° resection of the

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FIG. 24-16 (A) Perineal view of a canine patient: the dog had a penile amputation performed as a result of trauma. (B) Traction was applied to the skin to expose a recessed urethrostomy. This male patient had recurrent urinary tract infections. (C) Two incisions, 2 cm from the urethrostomy margins, were created. Subcutaneous fat was resected to expose the adjacent fascia of the semitendinosus muscles. (D) Dermal sutures were secured to the muscle fascia. When tightened, the mucosa and cutaneous margins are everted. (E) Redundant lateral skin was excised followed by closure of the lateral skin incisions. (F) The patient at suture removal at 3-week recheck. The recurrent urinary tract infections were resolved.

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stricture. The author also has used release incisions in which the band is split into four quadrants with a no. 15 scalpel blade and ophthalmic instrumentation. The mucosal incisions are then closed perpendicular to the incision (cranio-caudal closure rather than side-to-side closure of each incision) with absorbable 4-0 or 5-0 absorbable suture material. Stool softeners are recommended postoperatively and may be required for an extended period of time.

Type II atresia ani requires the resection of the anal membrane. The center of the imperforate membrane is marked in its center with a surgical marker. The anal sphincter may be assessed by pricking the area with a hypodermic needle to elicit muscle contraction. The anal sac openings also serve as an anatomic reference. The marking pen is used to draw a small cross from the marked center. A 20-gauge hypodermic needle can be inserted into the rectum to confirm its position. A no. 11 scalpel blade can be used to incise along the cross lines incrementally. The four triangular segments are trimmed with small scissors (iris scissors) and the mucosal borders are sutured along the perimeter of the cutaneous margin. This approach is also used to gain access to the blind end of any rectal pouch. The rectal wall can be opened, advanced caudally and sutured into its new location (Plate 193).

A rectovaginal fistula is occasionally noted with type II atresia ani; less commonly it can be associated with type III atresia ani. Plate 194 outlines the surgical approach to correct this anomaly. There are a few variations used for correcting rectovaginal fistulas. The author splits the skin overlying the fistula to identify the rectal and vaginal ends of the fistula. The rectal and vaginal defects are closed independently followed by the approximation of the skin incision used to gain access to the tract.

Type III atresia ani is approached in an identical fashion. However, the blind end of the rectum is grasped with Babcock forceps and advanced caudally by blunt dissection around its perimeter. The terminal rectal wall is opened and sutured to the anocutaneous junction (Plate 195).

Hard stool can be removed from the rectum intraoperative and postoperatively. Stool softeners are used for a minimum of 1 week depending on the patient's response. Cisapride and lactulose also may be administered. Prolonged medical management may be required depending on recovery of function from the dilated rectum/colon.

Complications

Prior to surgery the risk of incontinence is always discussed as a potential complication; this depends on the presence and function of the anal sphincter muscles. Over the ensuing weeks following surgery, many patients eventually regain sphincter control. This process can take several months. Potential surgical complications include dehiscence and stricture formation. Colonic atony, megacolon, and rectal prolapse can be complications that may require surgical management.

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Plate 185 Omental Flap Options

DESCRIPTION

The omentum is a thin, lacy, mesothelial membrane with a rich capillary and lymphatic network. In reconstructive surgery, the tissue can be mobilized to close body wall defects and facilitate the revascularization and closure of problematic wounds. The omentum is essentially an anatomic purse, with the epiploic foramen serving as the opening into the omental bursa. The dorsal and ventral surfaces of the omentum can be unfolded and divided to increase its length, enabling it to reach more distant areas of the patient.

SURGICAL TECHNIQUE

(A) The surgeon's view of the omentum through a midline laparotomy.

(B) Stage 1: the omentum is lifted upward and cranially, exposing the dorsal surface of the omentum. Scissors are used to divide its dorsal pancreatic attachment. A few small branches of the splenic artery are ligated during this maneuver.

(C) This first-stage maneuver doubles the length of the omentum.

(D) Stage 2: further lengthening can be accomplished by creating an inverted L incision using scissors, beginning on the right side of the omentum. The initial incision crosses one-half to two-thirds of the width of the omental sheet created. The caudal portion of the incision extends two-thirds the length of the omental sheet, completing the stage 2 extension of the omentum.

COMMENTS

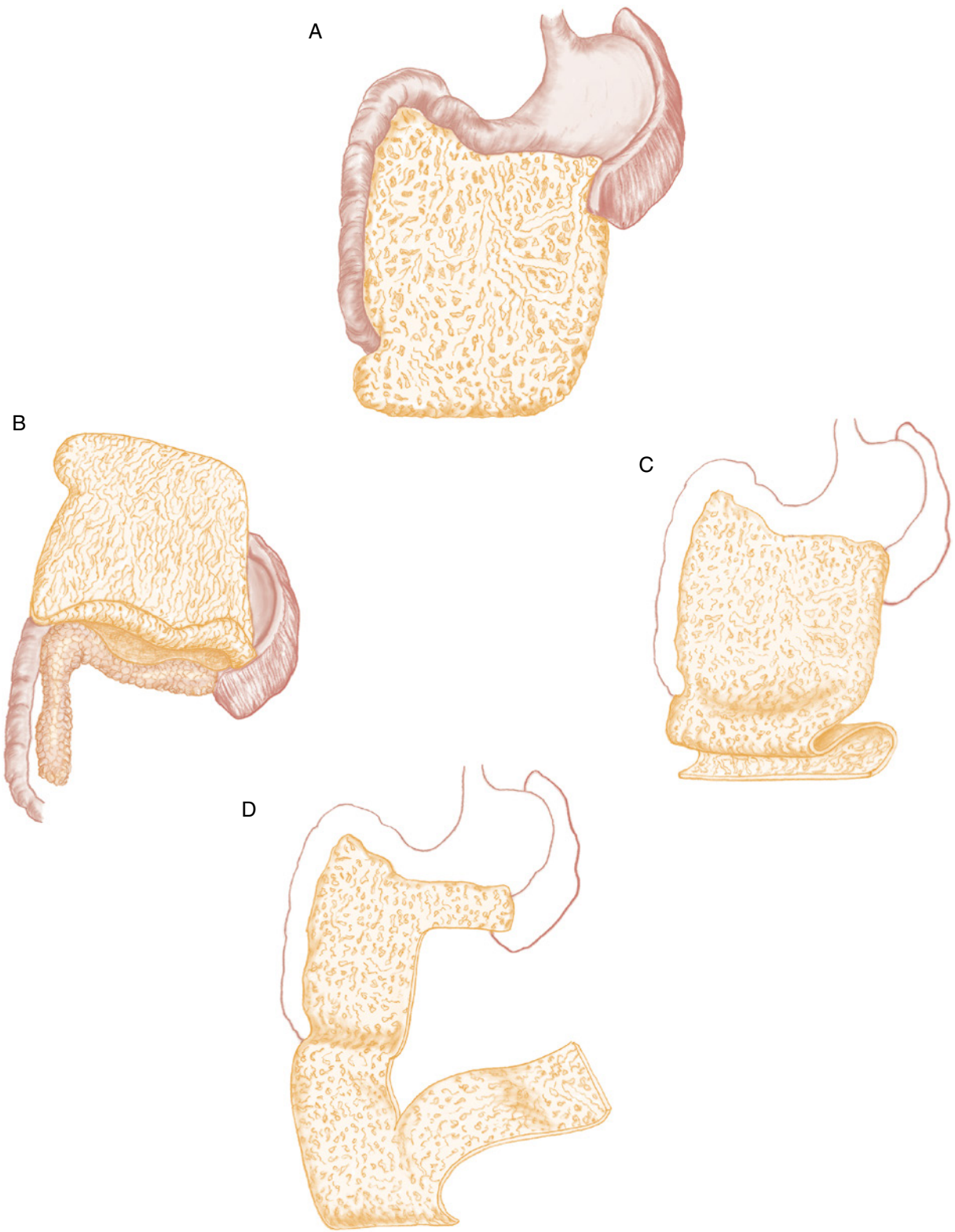
The omentum has been used for decades to close and reinforce defects in the abdominal cavity, adjacent abdominal wall, and diaphragm. "Omentalization" has become a code word for packing omentum into abscesses or cystic cavities to obliterate dead space; the omentum also provides an alternative source of circulation and the essential components required to promote the healing processes. Improving circulation also assists in the control of infection. Most intraabdominal and abdominal wall defects can be closed without lengthening the omentum. The omentum may be of sufficient length for advancement into the thoracic cavity and pelvic canal, without stage 1 lengthening. This can be performed if the intact omentum is required to reach the cranial thoracic cavity or thoracic wall. Omentum can be used in thoracic wall reconstruction using a synthetic mesh. This technique is considered inferior to the use of the latissimus dorsi muscle flap due to the simplicity of the latter technique and the greater bulk the muscle provides without the need for mesh reinforcement.

Stage 1 extension of the omentum can be performed with little likelihood of significant circulatory compromise. Further lengthening (stage 2) includes the added risk of circulatory compromise since collateral vascular channels within the omentum are necessarily divided. See Plate 186, an alternative method to preserve circulation. Caution is required during transfer of the omentum to distant body regions. When tunneled beneath the skin to reach the recipient area, care must be taken not to compress or overly stretch this delicate tissue: collapse of the capillary circulation will result in omental necrosis.

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Plate 185



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Plate 186

Alternative Method for Omental Flap Extension Based on Circulation

DESCRIPTION

In most cases, the use of the omentum is limited to abdominal surgery. When the extended omentum is required for an extraabdominal procedure, preservation of the circulation is necessary to ensure its viability. An anatomic study (Doom et al. 2016c) on the vascular supply to the omentum suggested that incorporation of the dominant splenic arterial supply should help ensure adequate circulation when extending the length of the omentum to reach more distant areas of the body.

SURGICAL TECHNIQUE

(A) The omentum. The superficial (ventral) leaf is seen on entering the abdomen. The underlying deep (dorsal) leaf is not visualized unless the caudal margin of the omental fold is elevated.

(B) The transparent omentum, highlighting the arterial branches of the superficial leaf. The deep leaf has a similar arterial network (not visualized). There are few anastomotic connections between these two vascular networks.

(C) The dashed line represents the proposed outline of an extended omental flap based on the dominant splenic arterial supply to each leaf of the omentum.

(D) Division and elevation of the extended omental flap, including the superficial and deep leaves.

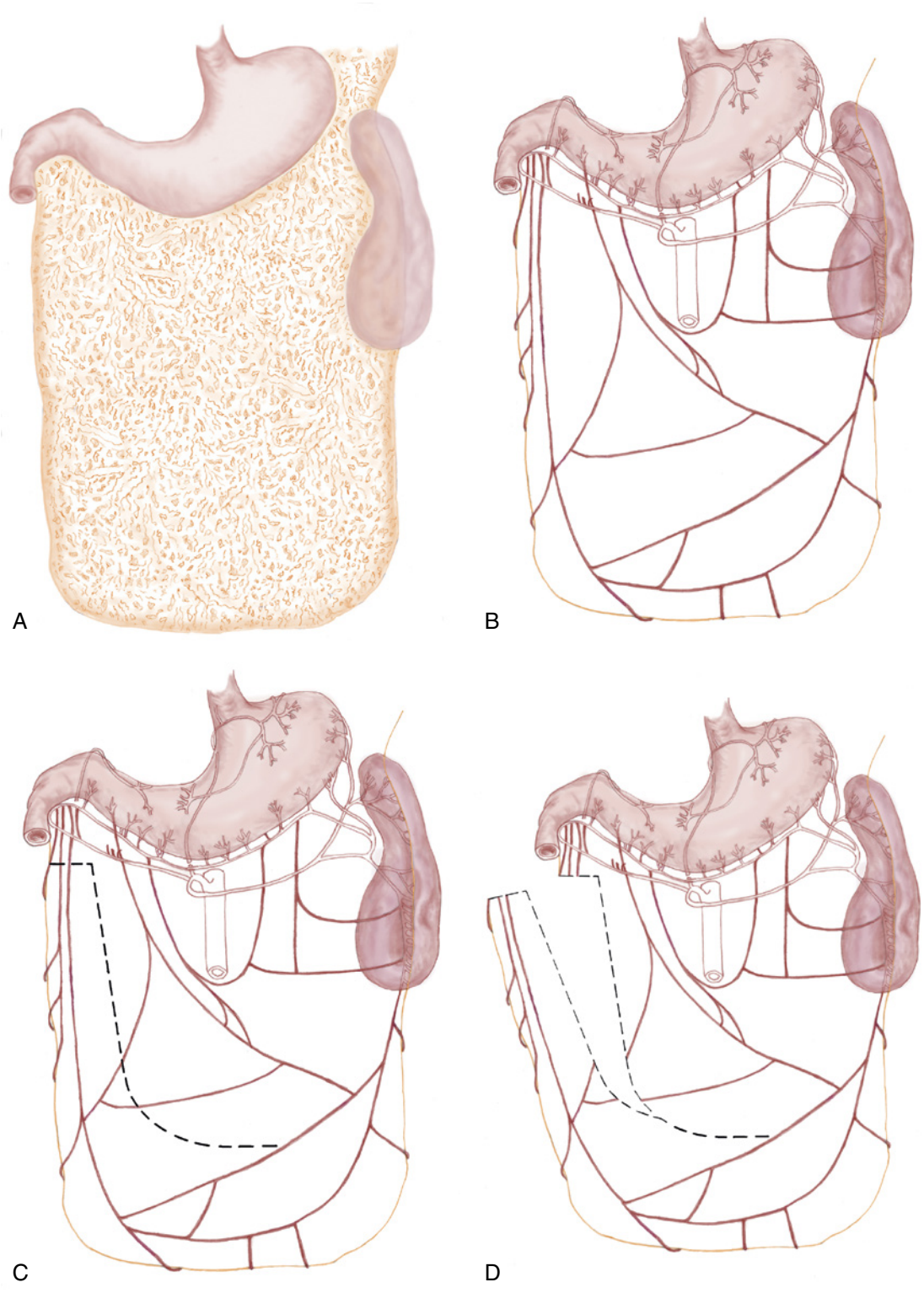
COMMENTS

Although there is no current clinical research confirming flap viability based on this study, it is logical to consider this extended flap design when attempting to maximize the length of the omental flap required to reach caudal abdominal or extraabdominal defects, including the axillary and inguinal areas in dogs.

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Plate 186



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Plate 187

Scrotal Flap Technique

DESCRIPTION

The surface area of the scrotum varies considerably in individual dogs. In older intact males the scrotum can be pendulous, whereas in younger castrated dogs the surface area can be relatively small. The scrotum can be advanced as a flap into adjacent problematic skin defects. The vascular supply to the scrotum is derived from the collateral cutaneous blood supply, perineal branches of the external pudendal artery, and cremasteric artery. The ventral scrotal artery and dorsal scrotal artery anastomose to supply the overlying scrotal tissue. These vascular branches course along the cranioventral surface of the testis, superficial to the common vaginal tunic. Branches of the scrotal artery can be identified and preserved during flap elevation.

SURGICAL TECHNIQUE

(A) Ventral view of the scrotum and adjacent inguinal area. A skin defect is noted lateral to the scrotum.

(B) Close-up view of the scrotum and adjacent cutaneous wound. An incision is made at the adjacent base of the scrotum. To preserve circulation, at least one-quarter of the circumference should be preserved. Preservation of vascular branches supplying the scrotal tissue also is desirable. In this illustration, the small area of skin interposed between the flap and wound bed (large dashed lines) can be excised to facilitate scrotal advancement.

(C) Progressive elevation of the scrotal flap. The dartos and fascia can be carefully dissected from the scrotal skin if necessary to improve flap advancement and coverage of the skin defect.

(D) Completion of the closure.

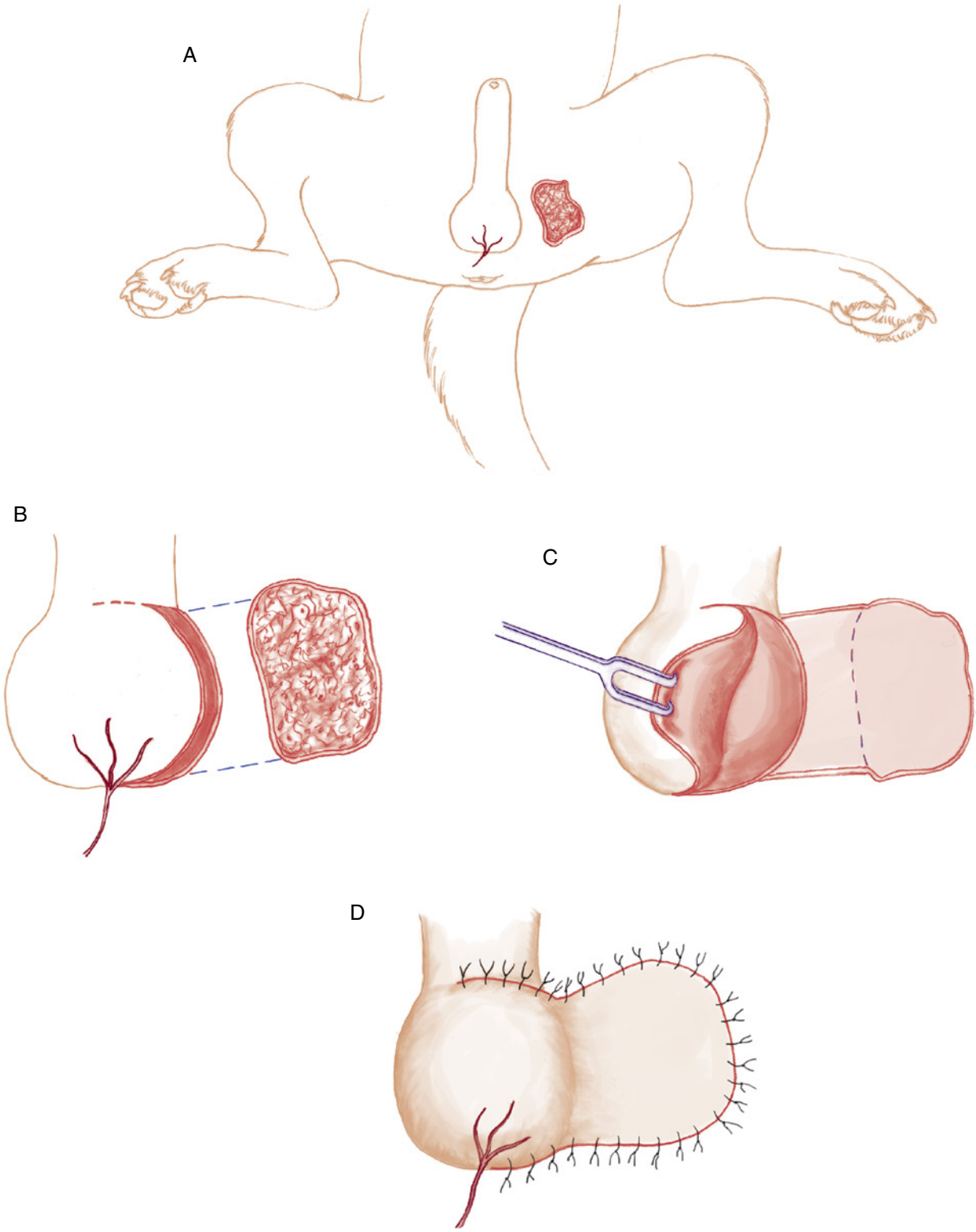
COMMENTS

The use of the scrotum as a source of skin for wound closure has been reported in the human literature. The surface area of the scrotum can vary considerably between dogs. Intact male dogs normally have a larger scrotum due to the presence of pendulous testicles. Although castration can be performed using a prescrotal incision, elevation of the scrotal flap will give the surgeon direct access to each testicle. This technique should be kept in mind when a problematic wound involves the adjacent perineum, inner thigh, or cutaneous region anterior to the scrotum.

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Plate 187



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Plate 188 Caudectomy for Tail Fold Intertrigo

DESCRIPTION

English bulldogs, French bulldogs, and Boston terriers occasionally present with a somewhat fixed, deformed tail. A fold or crease beneath the tail is prone to chronic dermatitis or intertrigo. A cotton-tipped applicator can be used to assess the depth of this fur-lined crease: occasionally, it is several centimeters in depth. The deviated tail can cover the anus, making routine defecation problematic and cleansing of the area difficult. Dogs often present with a history of scooting secondary to the dermatitis; owners may note an unpleasant odor as a result of the debris accumulation and bacterial infection.

Surgery is primarily directed at (1) resecting the abnormal coccygeal vertebrae and (2) removing the ventral crease or fold. Redundant tail skin is removed in the process, but the most cranial dorsal skin fold is preserved to fashion a new tail silhouette.

SURGICAL TECHNIQUE

(A) A T incision is created caudal to the cranial skin fold at the base of the tail (dashed lines).

(B) The triangular skin flaps created by the T incision are retracted, curved, and dissection is directed to exposure of the coccygeal vertebrae anterior to the point of tail deviation. A Carmalt clamp can be directed beneath the tail to protect the underlying dorsal rectal wall.

(C) Bone cutters are then used to cut directly through or between the exposed vertebrae. (Alternatively, some surgeons will use a scalpel to divide between individual coccygeal vertebrae.) Electrocautery is normally used to control bleeding vessels: vascular clips or ligatures may be used for larger vessels.

(D) With successful division of the vertebrae, the loose terminal tail segment is grasped with forceps. Firm traction is applied in a dorsal direction; this facilitates eversion of the invaginated or recessed ventral cutaneous fold. Metzenbaum scissors can be used to undermine and mobilize the ventral skin fold. A curved incision is made at the ventral base of the tail fold (dashed line), completing the resection of the tail and ventral skin crease.

(E) After resection of the tail and associated ventral skin folds, the area is lavaged and examined for any remaining bleeding vessels prior to closure. Absorbable sutures may be used to close dead space prior to approximating the skin margins with absorbable interrupted intradermal sutures. Simple interrupted skin sutures are used to complete the skin closure. The large preserved cranial skin fold forms a prominent peak, giving the semblance of a short, symmetric tail.

COMMENTS

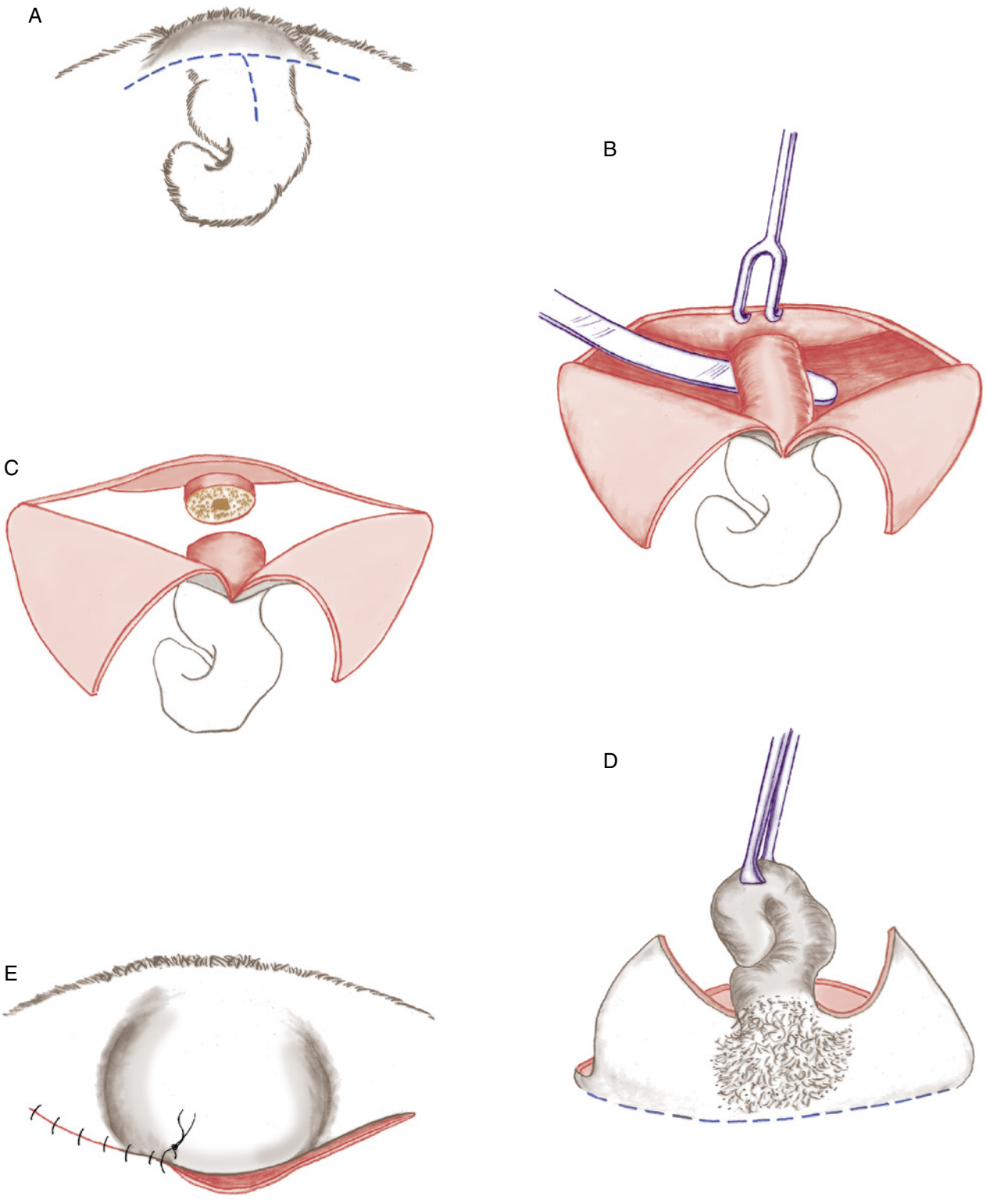
The vast majority of dogs requiring this surgery are English bulldogs. As noted, several textbooks advocate complete removal of the entire tail and associated folds. Preserving the large cranial fold achieves a pleasing cosmetic tail silhouette that better represents the appearance of the breed. During amputation, care is taken to avoid deeper dissection that may perforate the dorsal rectal wall. Dividing the tail with bone cutters is notably faster than attempting to dissect between individual vertebrae with a scalpel blade. There are surgeons who occasionally use a Gigli wire saw to amputate the abnormal tail segment.

Removal of the skin fold pocket is more challenging when its dermal surface is firmly affixed to the overlying coccygeal vertebrae. Surgical exposure is limited and normally requires the judicious use of self-retaining tissue retractors (Gelpi, Weitlaner) to gain access to this area. Careful blunt dissection and firm traction of the fold with Allis tissue forceps are necessary to separate these two surfaces; this surgical maneuver can take several minutes. If skin is inadvertently left behind, fistula formation is likely to occur.

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Plate 189 Episioplasty

DESCRIPTION

Episioplasty involves the resection of the redundant skin fold and subcutaneous fat dorsal and lateral to the vulva. It is commonly performed in the management of chronic dermatitis (intertrigo), which forms in the skin crease created by the overlapping skin. In some patients, the skin infection promotes lower urinary tract infections.

SURGICAL TECHNIQUE

(A) General outline of the episiotomy (dashed line). A purse-string suture is used to prevent fecal contamination. The ends of this suture can be looped around the base of the tail and held with needle holders or hemostats. This serves as a visual reminder to remove the purse string when surgery has been completed. (Use of a purse string may also be recorded on the anesthesia sheet as an added reminder to remove this suture at the completion of the surgery.)

(B) The dorsal midline border of the vulva is grasped with forceps and elevated to determine the appropriate point for relocating the vulva. The scalpel blade can be used to nick or mark the skin at this point. Two curved incisions are created: the dorsal incision encompasses the mark created; the second, smaller, curved incision is created dorsal to the vulvar midline. The two incisions arc downward; the dorsal incision is curved inward to meet the ventral incision. The hatched area can be resected to draw apart the thigh skin ventral to the vulva. The resultant "thigh tuck" will reduce dermatitis associated with skin contact at this level (arrows denote area of skin contact). It is important to remove the exposed redundant subcutaneous fat dorsal to the vulva prior to closure of the surgical site. Electrocautery is used to control hemorrhage. (The author also has found the carbon dioxide laser useful in resecting this redundant skin and subcutaneous tissue.)

(C) Absorbable intradermal, interrupted sutures are used to appose the cutaneous margins, followed by a simple interrupted skin suture pattern. Note how the skin resected (hatched area in B) creates slight skin traction, thereby reducing skin contact (dermatitis) below the vulva and inner thigh area (arrows).

(D) Completion of the surgery is followed by removal of the purse-string suture. Sutures are normally removed 10–14 days postoperatively.

COMMENTS

Epidural blocks are commonly performed prior to surgery. Standard textbook articles fail to address the dermatitis that is occasionally noted below and anterior to the vulva, especially in larger dogs. Removal of a small amount of skin (see B) can separate the inner thigh skin enough to better control the intertrigo occasionally noted.

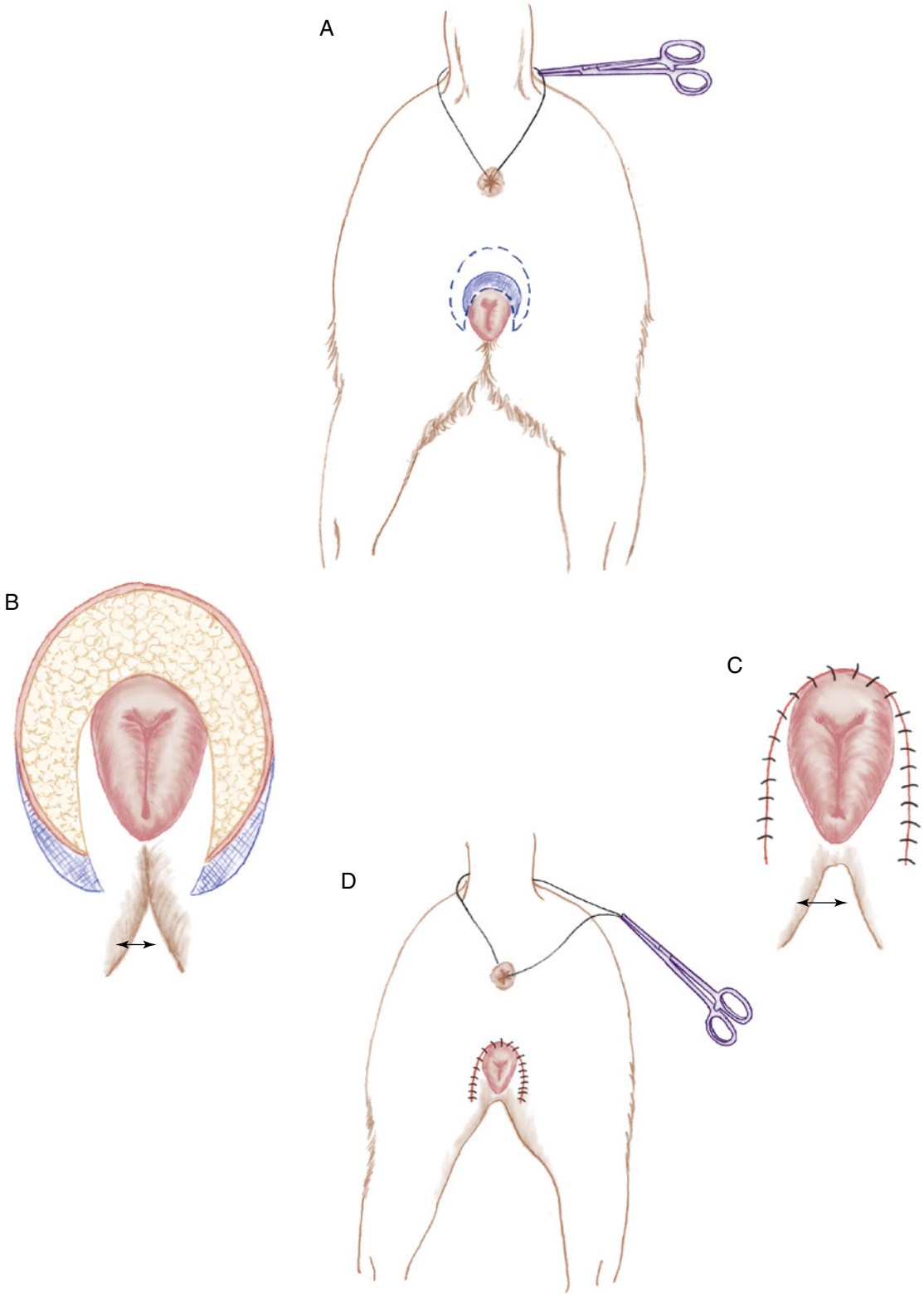
Excessive removal of skin dorsal to the vulva can, in turn, create excessive tension on the skin closure. Wound dehiscence in the perineal area can result in a problematic defect due to the relative lack of mobile skin.

The interrupted, intradermal suture pattern provides an added measure of security when closing the skin, reducing the risk of dehiscence. The author normally uses absorbable Monocryl® (poliglecaprone 25; Johnson & Johnson) sutures, which usually fall out of the skin around 4 weeks after surgery. An Elizabethan collar is advisable to prevent licking at the surgical incision.

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Plate 190

Fascia Lata Sling and Silicone Banding for Managing Fecal Incontinence

DESCRIPTION

A strip of the tensor fascia lata (TFL) or the use of a silicone strip has been reported for creating a band or sling around the terminal rectum to help control fecal incontinence. Technique variations include wrapping a strip of the TFL (1) as a loop directed around the lower rectum and passed over the base of the tail and (2) as a loop passed around the circumference of the rectum. Tightening this tissue band forms a partial barrier to stool passage, in part by elevating the lower rectal wall. This allows stools to partially accumulate anterior to the encircling band. Silicone elastic banding also has been reported as an encircling loop around the circumference of the rectum.

SURGICAL TECHNIQUE

(A) Preliminary preparation: a 10–15 mm wide fascial strip of the TFL is harvested. The length required can be predetermined by measuring the relative length required to encircle the area for placement. A cloth ruler or strand of heavy suture or cord can be used to estimate the length of the fascia lata. For additional length, two TFL fascial strips can be harvested and sutured together to create a longer strip if necessary.

Variation 1: two incisions are created lateral to the anus. Blunt forceps are used to pass the fascial strip beneath the lower rectal wall to the opposite incision. Blunt dissection with curved forceps is used to create a pathway for passage of the TFL fascia over the tail base to the opposite incision. If the fascial strip is insufficiently long, the ends of the fascial band can be sutured to the lateral tail fascia after application of sufficient tension. Alternatively, the TFL band is tightened and sutured to itself. An appropriate-diameter syringe or syringe casing can be used as a template to partially restrict the diameter of the rectum that will still allow feces to pass. A gloved index finger can be used after closure of the skin incision to confirm the relative restriction to ensure feces can pass.

(B–D) Variation 2: the TFL band is placed around the circumference of the rectum. In both technique variations, the ends of the fascia are drawn together and tightened to reduce the diameter of the terminal rectum. As noted, a syringe or syringe casing, smaller than the diameter of the rectum, can be inserted into the rectum, over which the TFL band can be tightened. The ends of the fascia are sutured together. A gloved index finger can be used after closure of the skin incision to confirm the relative restriction to ensure feces can pass.

(E) Variation 3: this illustration demonstrates placement of a 1 cm wide silicone band around the terminal rectum. As noted, tension on the silicone band is adjusted sufficiently that stool can still escape. The ends of the silicone band can be sutured to the adjacent muscle fascia. Insertion of a gloved index finger can be used to assess band tension.

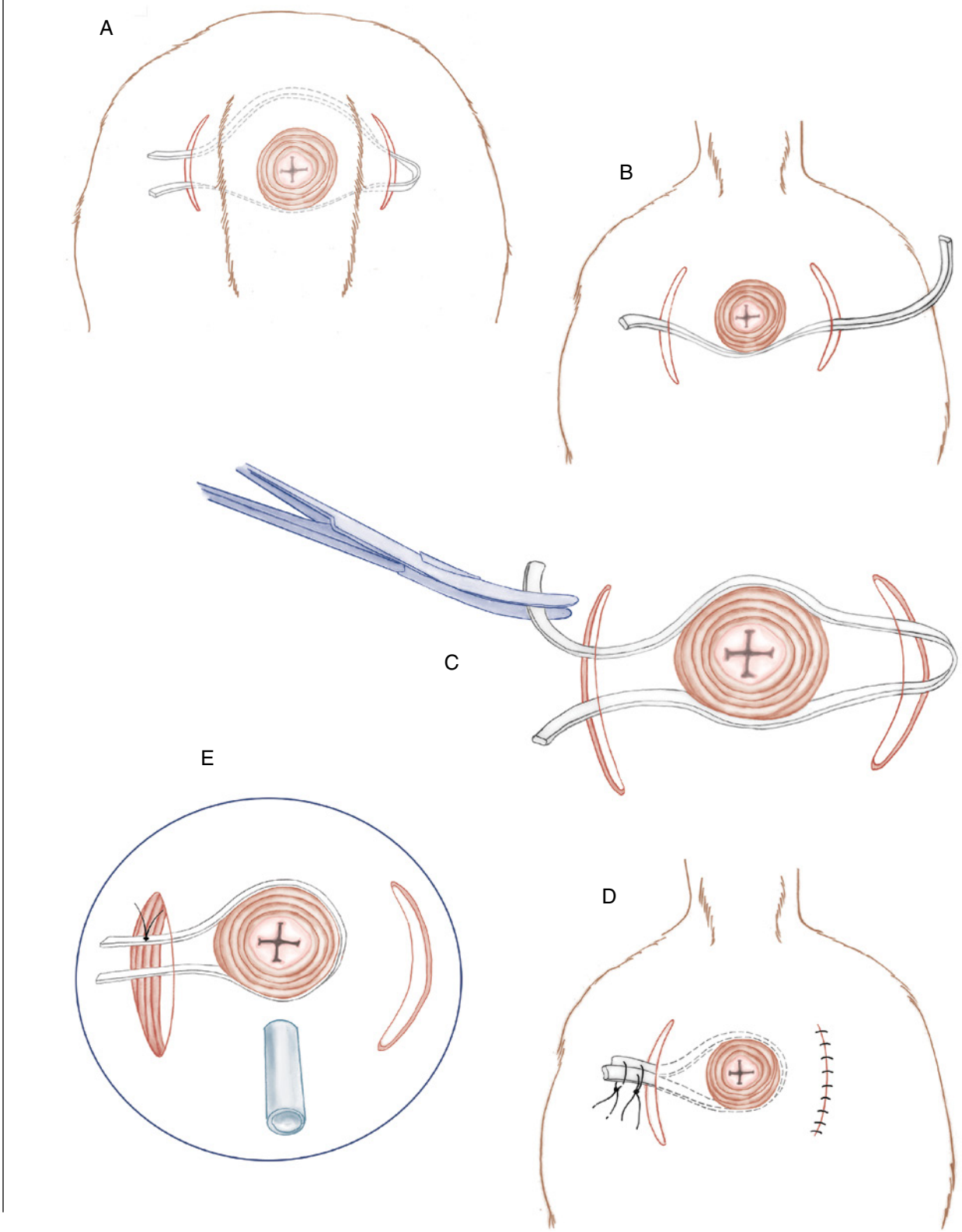
COMMENTS

These techniques are not difficult to execute, but their efficacy has yet to be supported by subsequent long-term clinical studies. Silicone elastomeric banding also suffers from a lack of supportive clinical reports. How snug to tighten bands is somewhat subjective: if applied too tight, stool may not pass easily; too loose, there will be no improvement. Owners should be warned that TFL or silicone band tension adjustment may be required. (See Plate 114 regarding the use of the semitendinosus muscle flap option.) Dietary adjustments can be considered to modify the firmness of the stools to facilitate retention as well as passage.

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Plate 191

Spiral Rectal Diaphragm Technique (Rectal Rifling)

DESCRIPTION

This technique was developed to manage a feline patient with fecal incontinence secondary to loss of the anal sphincter muscle after resection of a sarcoma involving the terminal rectum and perineum. The technique involves rotating the terminal rectum by more than 180°. This forms an elastic spiral diaphragm barrier to better retain feces.

SURGICAL TECHNIQUE

(A) Illustration of the anus and perineum in a feline patient. In this example, neoplasia required the resection of the terminal rectum and surrounding anal sphincter muscles.

(B) The anus has been resected. The terminal rectum is dissected from the pelvic fascial attachments and advanced caudally. The lines with arrows denote the dorsal and ventral points of the rectum (12 o'clock and 6 o'clock positions, respectively).

(C) The arrows denote the dorsal and ventral margins of the rectum. The rectum is rotated clockwise.

(D) The arrows denote that the rectum has been rotated by more than 180° followed by suture apposition using a simple interrupted pattern.

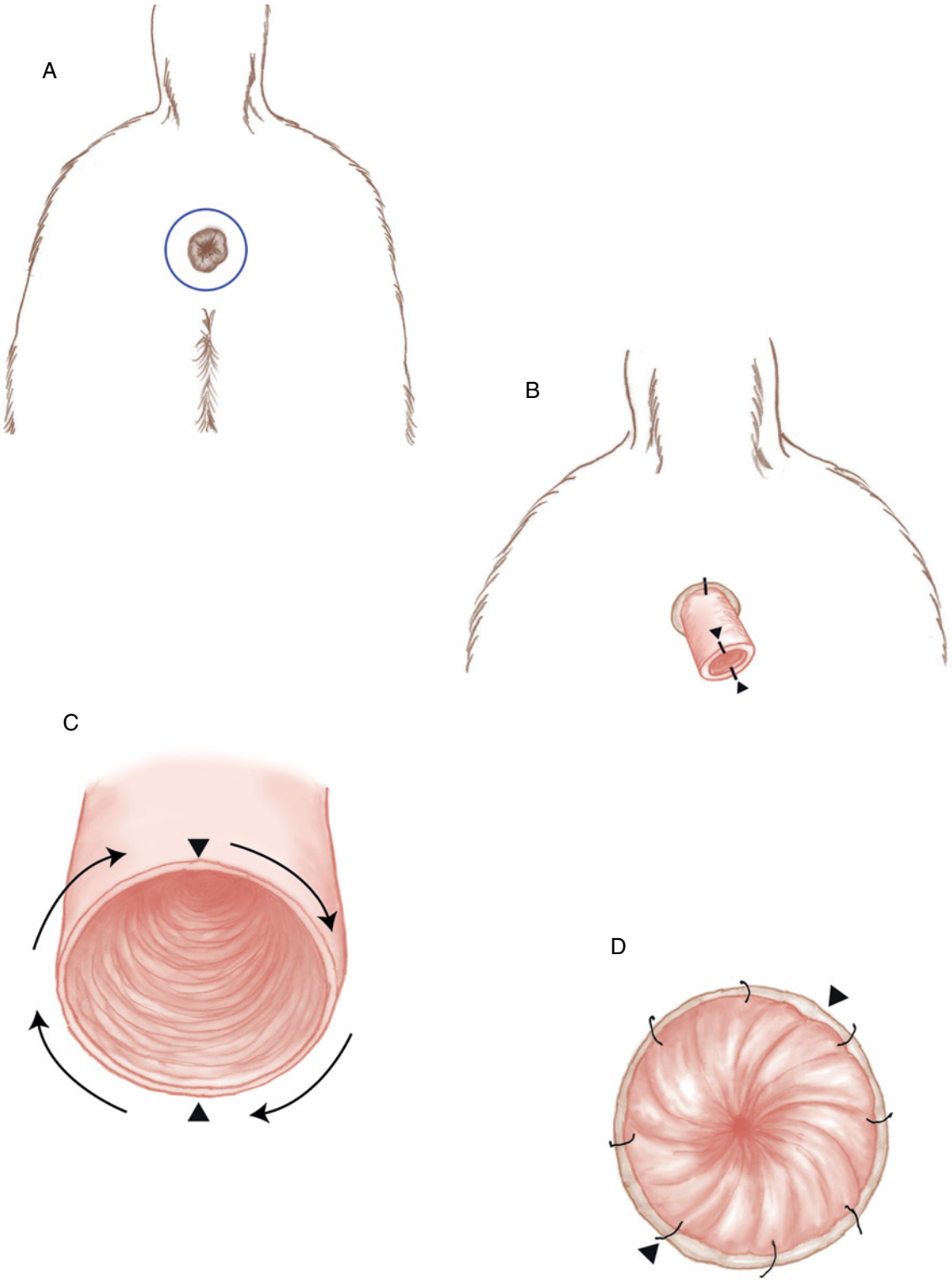
COMMENTS

The diaphragm formed by spiraling the rectal wall forms a soft barrier to passage of feces. This in turn allows feces to accumulate anterior to this barrier. Dilation of the rectum stimulates peristalsis, which the patient is able to feel. The patient in this study would go to the litter box to defecate. Occasionally the cat would drop a small ball of feces accidentally, but largely controlled its bowel movements after this procedure.

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Plate 192 Vulva Fold Skin Flap

DESCRIPTION

Resection of neoplasms adjacent to the vulva can result in deviation of the vulva following closure. This, in turn, can cause deviation of the urine stream. Use of the redundant skin of the dorsal vulva fold can prevent this complication.

SURGICAL TECHNIQUE

(A) Resection of a neoplasm involving the skin lateral to the vulva.
(B) Outline of a skin flap utilizing the dorsal vulvar skin fold after tumor resection using separate instrumentation.
(C) Rotation of the flap followed by closure of donor and recipient wound beds.

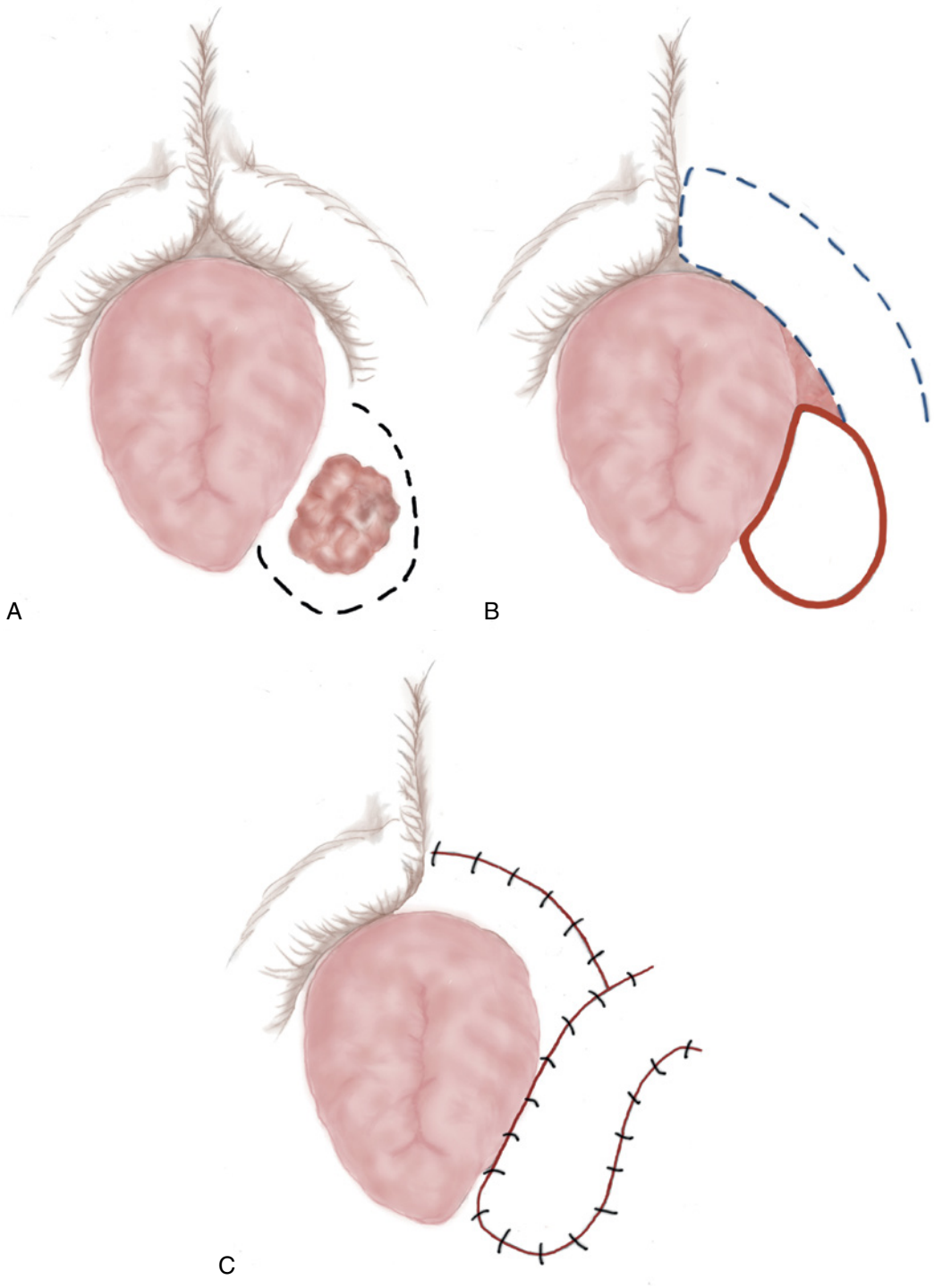
COMMENTS

This is another example of using an adjacent skin fold to close a problematic skin defect (see Plate 51). This simple-to-execute fold flap can prevent lateral deviation of the urine stream and urine spraying that the author has seen with closure of this area under skin tension.

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Plate 193

Type II Atresia Ani Repair

DESCRIPTION

Simple type II atresia ani is represented by an imperforate membrane covering the rectum.

SURGICAL TECHNIQUE

(A) The imperforate anus is covered by a thin epithelial membrane.

(B) The small dimple (on occasion a slight protrusion) is noted midway between the anal sac openings. A fine circle can be drawn around the membrane with a surgical marking pen. A 20-gauge hypodermic needle can be inserted at the midpoint to confirm the presence of the rectum. A hypodermic needle also can be used to prick the area of the external anal sphincter to stimulate contraction and help confirm its presence. A cross incision is used to split the membrane into four triangular folds with a no. 11 scalpel blade.

(C) The elevated triangular membrane segments are trimmed with small scissors and sutured one at a time to prevent retraction of the rectum. Stay sutures may be placed in the rectum to facilitate positioning during closure if necessary.

(D) The exposed rectal margin is sutured to the adjacent cutaneous border using absorbable 4-0 or 5-0 sutures.

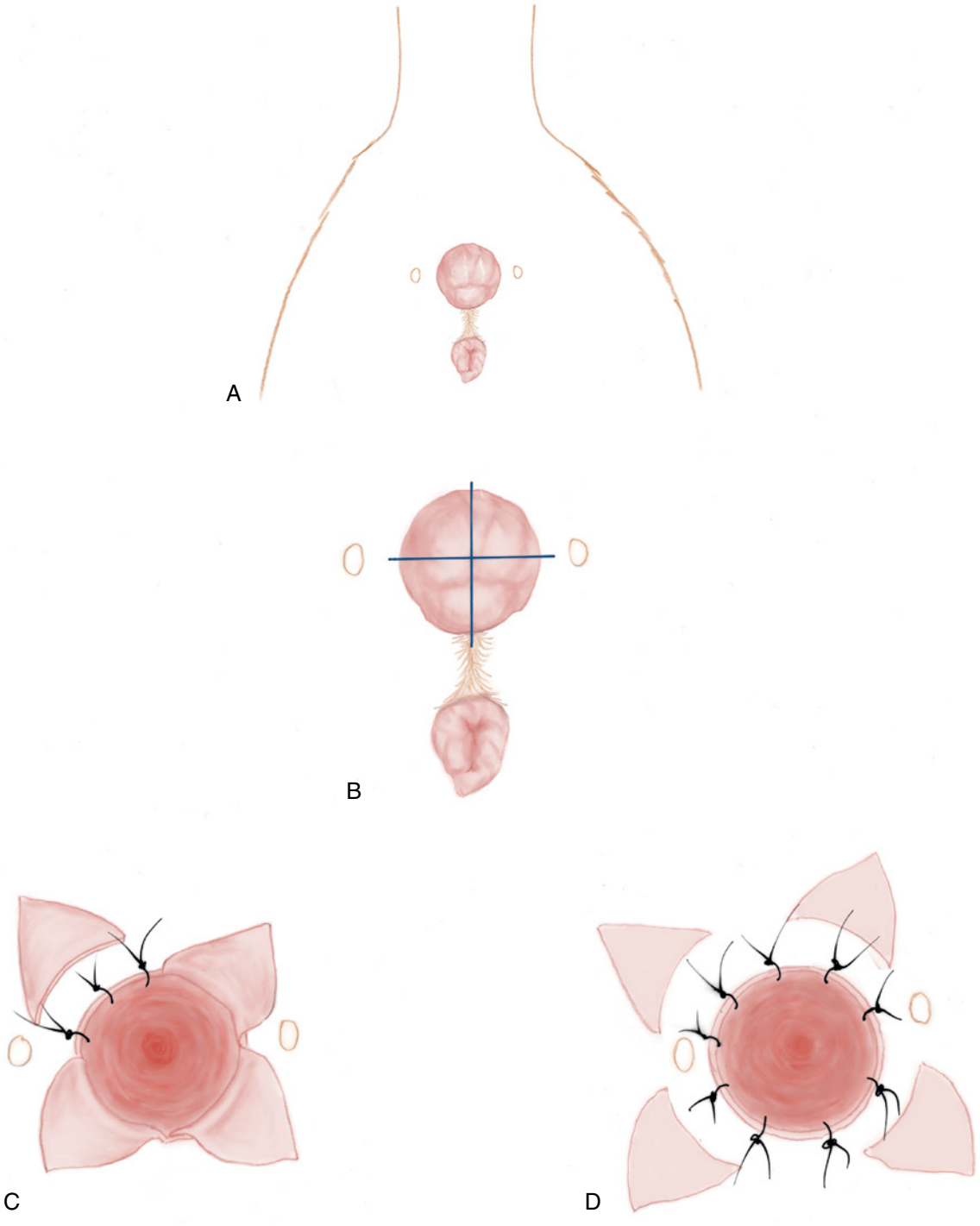
COMMENTS

This basic approach for type II atresia ani procedures is also used in approaching type III atresia ani. See the text discussion regarding atresia ani.

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Plate 193



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Plate 194 Type II Atresia Ani with Rectovaginal Fistula Repair

DESCRIPTION

Rectovaginal fistula formation may be associated with type II atresia ani.

SURGICAL TECHNIQUE

(A) Perineal view of a cat with type II atresia ani. Stool passes through the fistula and exits the vulva. The dashed line indicates removal of the anal membrane and the placement of a skin incision between the anus/vulva to expose the fistula.

(B) The membrane overlying the anus is resected and sutured as noted in Plate 193. The midline access incision over the fistula exposes the rectal and vaginal openings of the fistula. Mosquito hemostats or a catheter is inserted into the fistula through the dorsal wall defect of the vulva to facilitate placement of the incision. The fistula is dissected from the dorsal wall of the vagina. The vaginal wall defect is closed by side-to-side apposition using 4-0 or 5-0 absorbable sutures. The short fistula can be resected at the level of the ventral rectum. (Alternatively, some surgeons have incorporated the wall of the fistula into closure of the anal canal.)

(C) The midline skin incision is advanced over the surgical area. The lower rectal wall defect is incorporated into the skin closure.

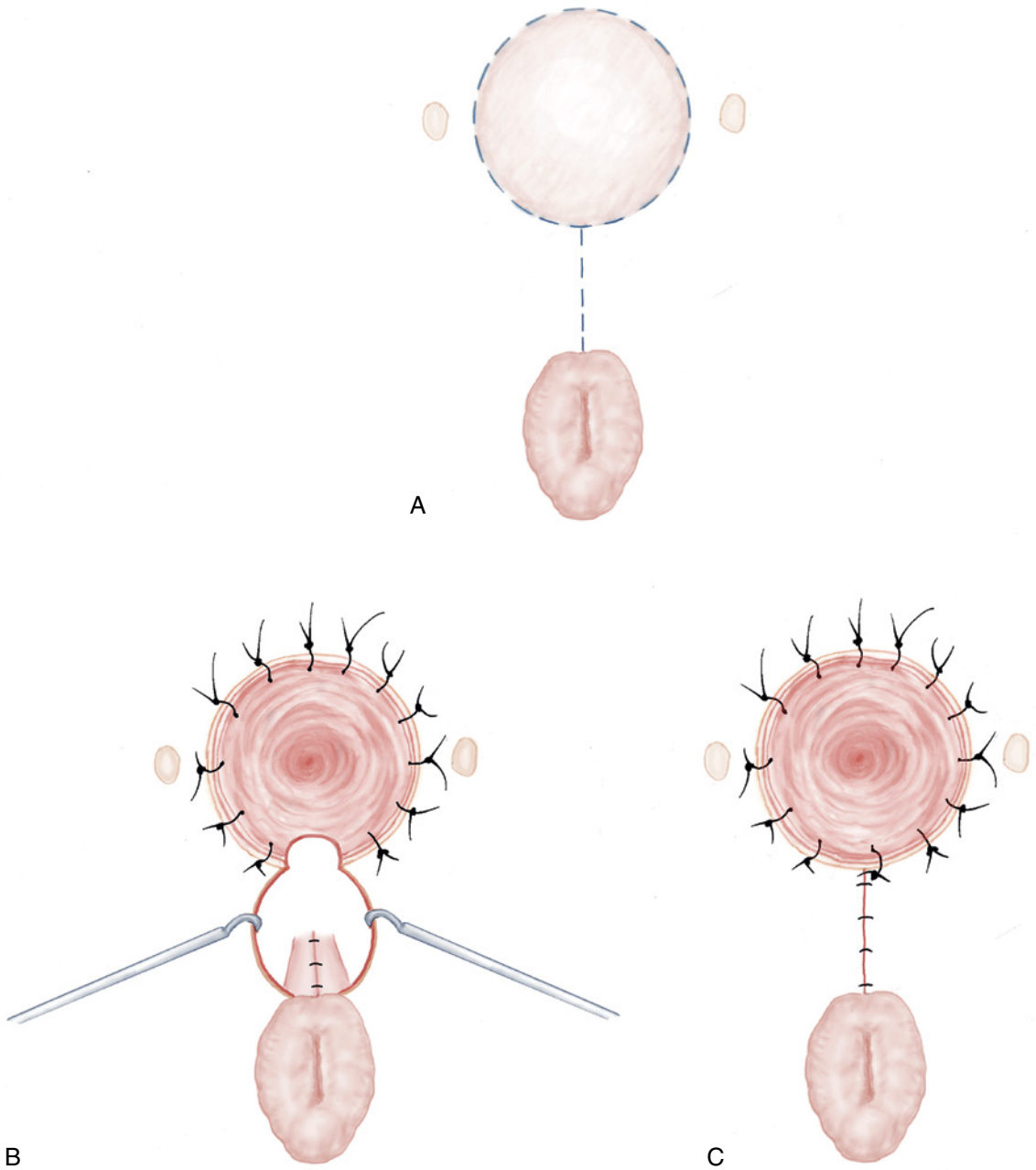
COMMENTS

Postoperative care is identical to type II atresia ani (Plate 193). See the text discussion regarding atresia ani.

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Plate 195

Type III Atresia Ani Repair

DESCRIPTION

Type III atresia ani is described as an imperforate anus with the terminal rectum located in the pelvic canal (>1 cm cranial to the membrane).

SURGICAL TECHNIQUE

(A) Imperforate anus. The terminal rectum is normally 1–2 cm cranial to the imperforate anal membrane.

(B) The approach is identical to that for type II atresia ani. The membrane is resected as noted in type II atresia ani.

(C) The dissection in the cranial direction is within the margins of the anal sphincter. The end of the rectum is identified and grasped with Babcock or Allis tissue forceps. The perimeter of the rectum is gently dissected and the terminal rectum is exteriorized to the level of the cutaneous margin.

(D) The end of the rectal cylinder is progressively excised and the margin is sutured to the adjacent skin using 4-0 or 5-0 absorbable sutures, normally in a simple interrupted pattern.

(E) Completion of the surgery.

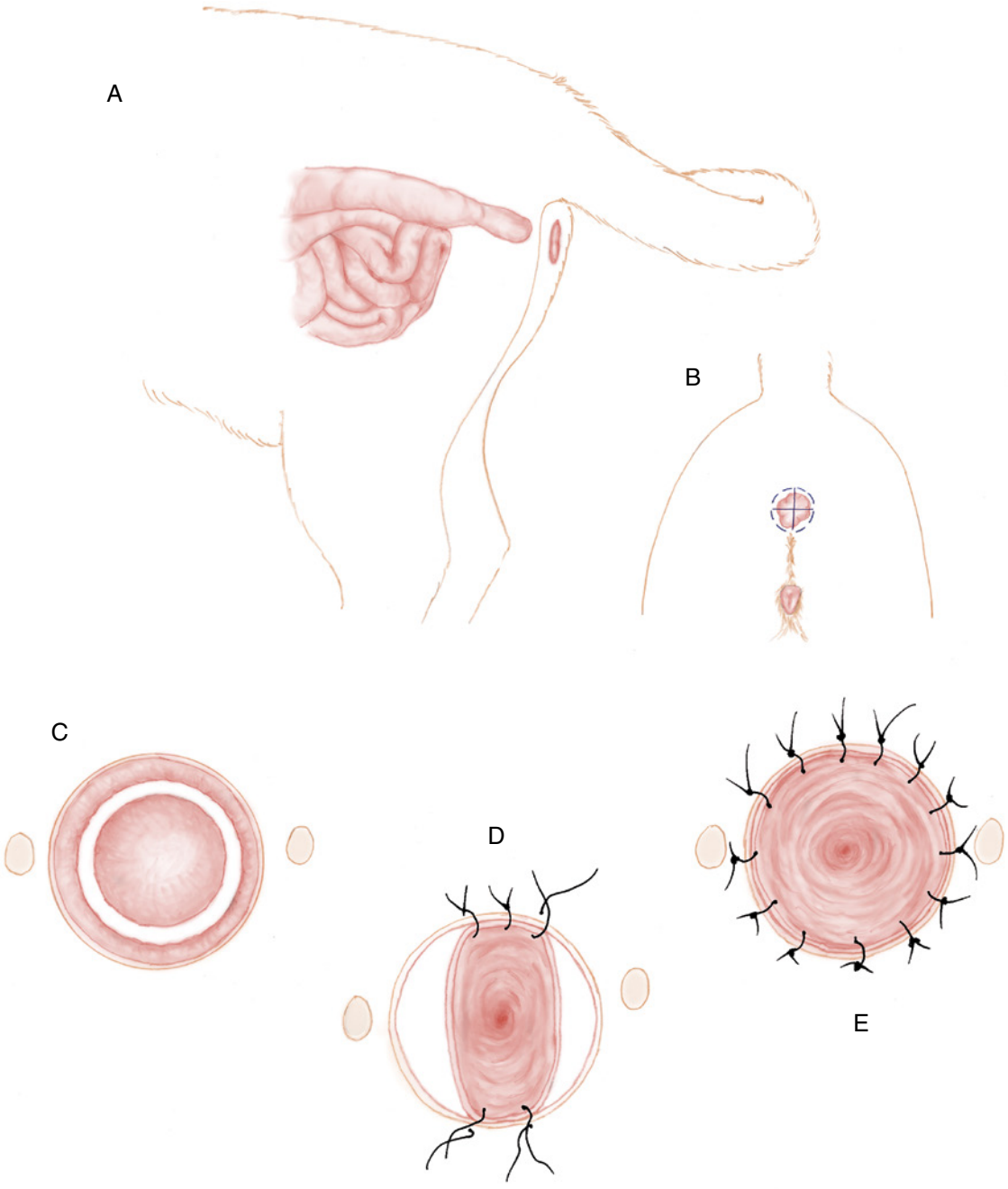
COMMENTS

Like type II atresia ani cases, impacted stool can be gently removed once the closure is complete. Postsurgical care is identical to managing type II atresia ani cases. Rectovaginal fistulas have been reported with type III atresia ani.

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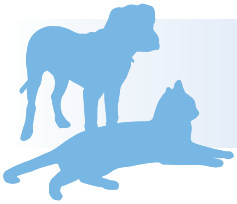
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Plate 195



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25

Extras

INTRODUCTION

It is the author's experience that reviewing multiple clinical cases enhances the ability of surgeons to better understand how to properly execute surgical procedures. This is particularly true when the veterinarian is trying to translate a particular closure technique to various body regions.

In this vein, this chapter contains additional representative clinical cases from the author's archived collection of surgical case photographs, many of which are used in educational programs. The surgical cases include the use of skin flaps and other wound-closure options discussed in the previous chapters. The reader is encouraged to study each clinical procedure in conjunction with the relevant preceding chapters.

Atlas of Small Animal Wound Management and Reconstructive Surgery, Fifth Edition. Michael M. Pavletic.
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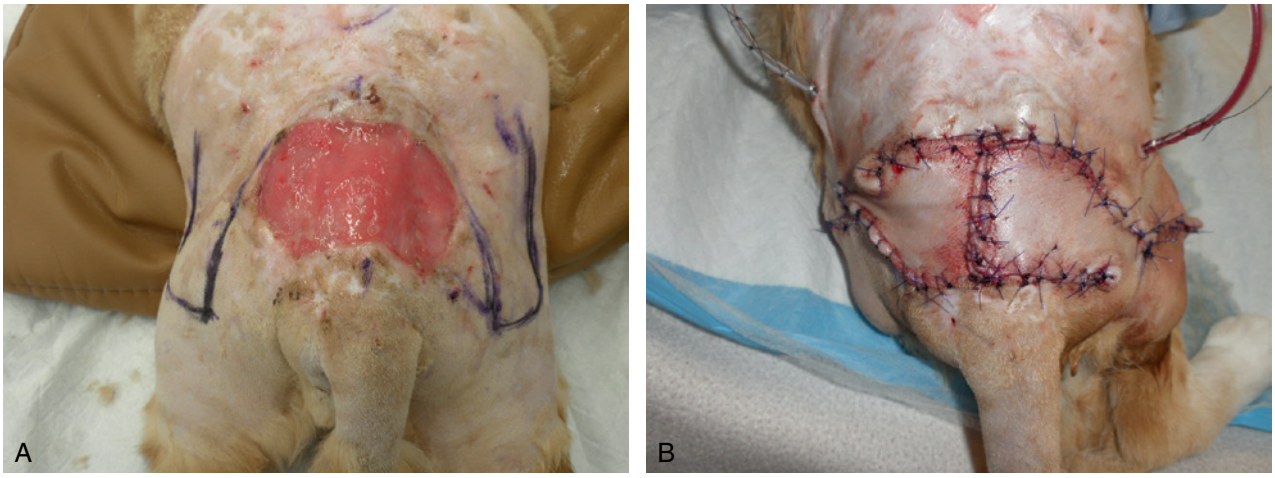


FIG. 25.1 (A) Chronic wound in a domestic short-haired cat overlying the dorsal pelvis. Outline of two transposition skin flaps. (B) Successful closure.

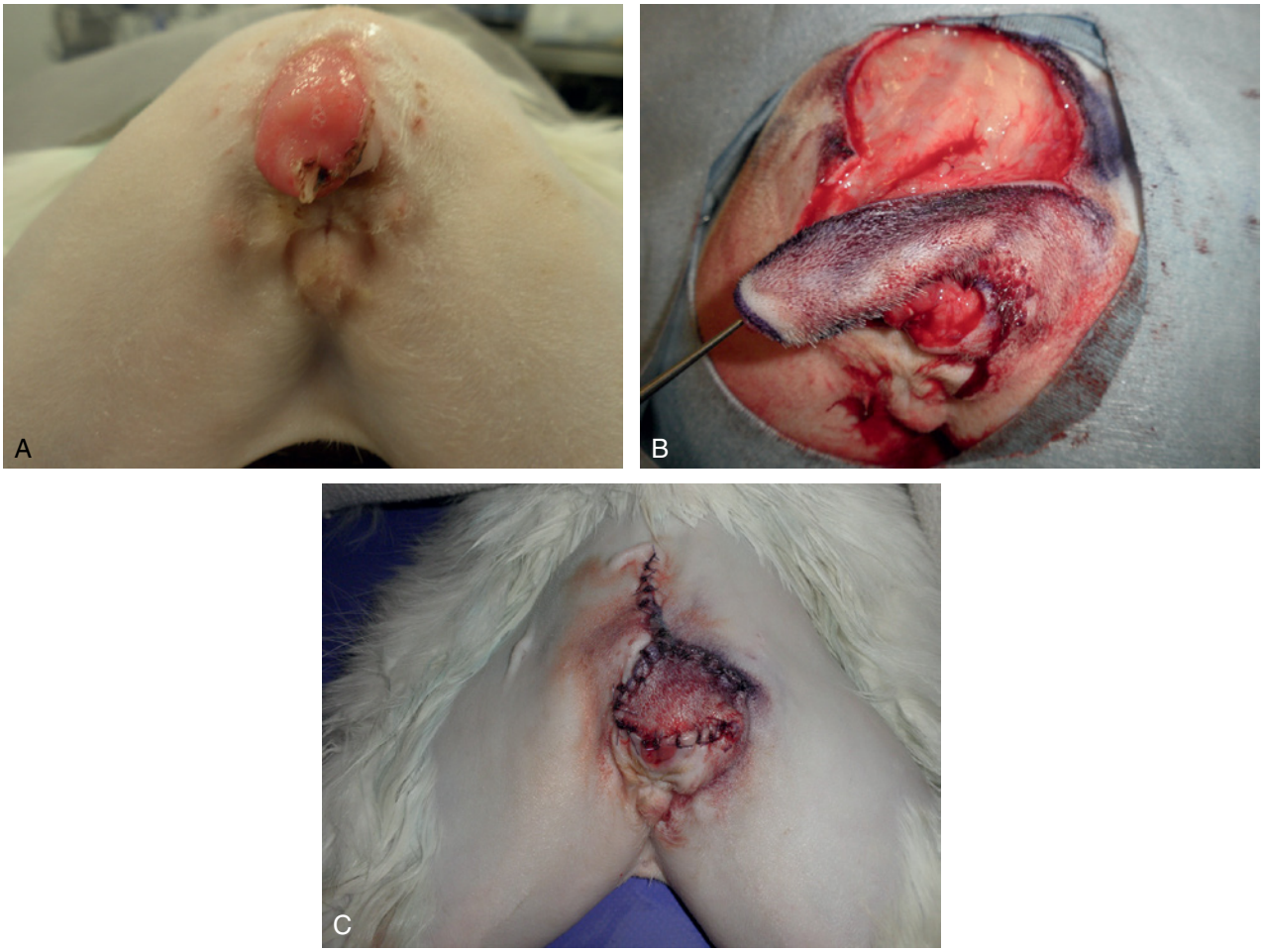


FIG. 25.2 (A) Skin and tail avulsion in a cat. The necrotic exposed coccygeal vertebra was excised. (B) Transposition skin-flap elevation and rotation over the tail defect. (C) Successful closure.

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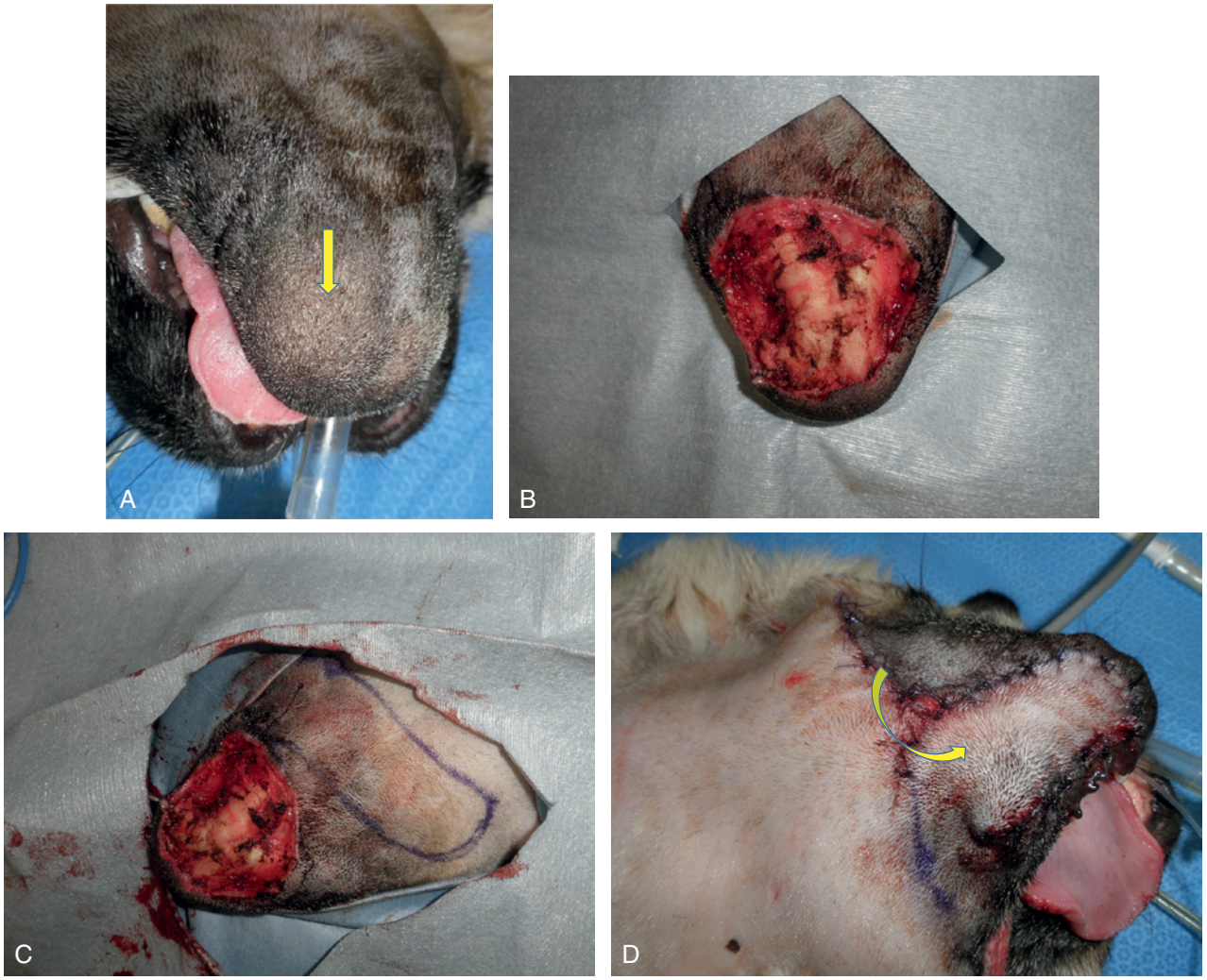


FIG. 25.3 (A) Soft tissue sarcoma (arrow), mixed-breed dog. (B) Resection of the ventral chin area. (C) Outline of a transposition flap. (D) Flap rotation (arrow) and closure of the recipient wound bed.

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FIG. 25.4 (A) Mast cell tumor (arrow), frontal view. (B) Dorsal view. (C) Resection of the mast cell tumor. (D) Transposition skin flap. The donor area takes advantage of the skin available perpendicular to the labial margin.

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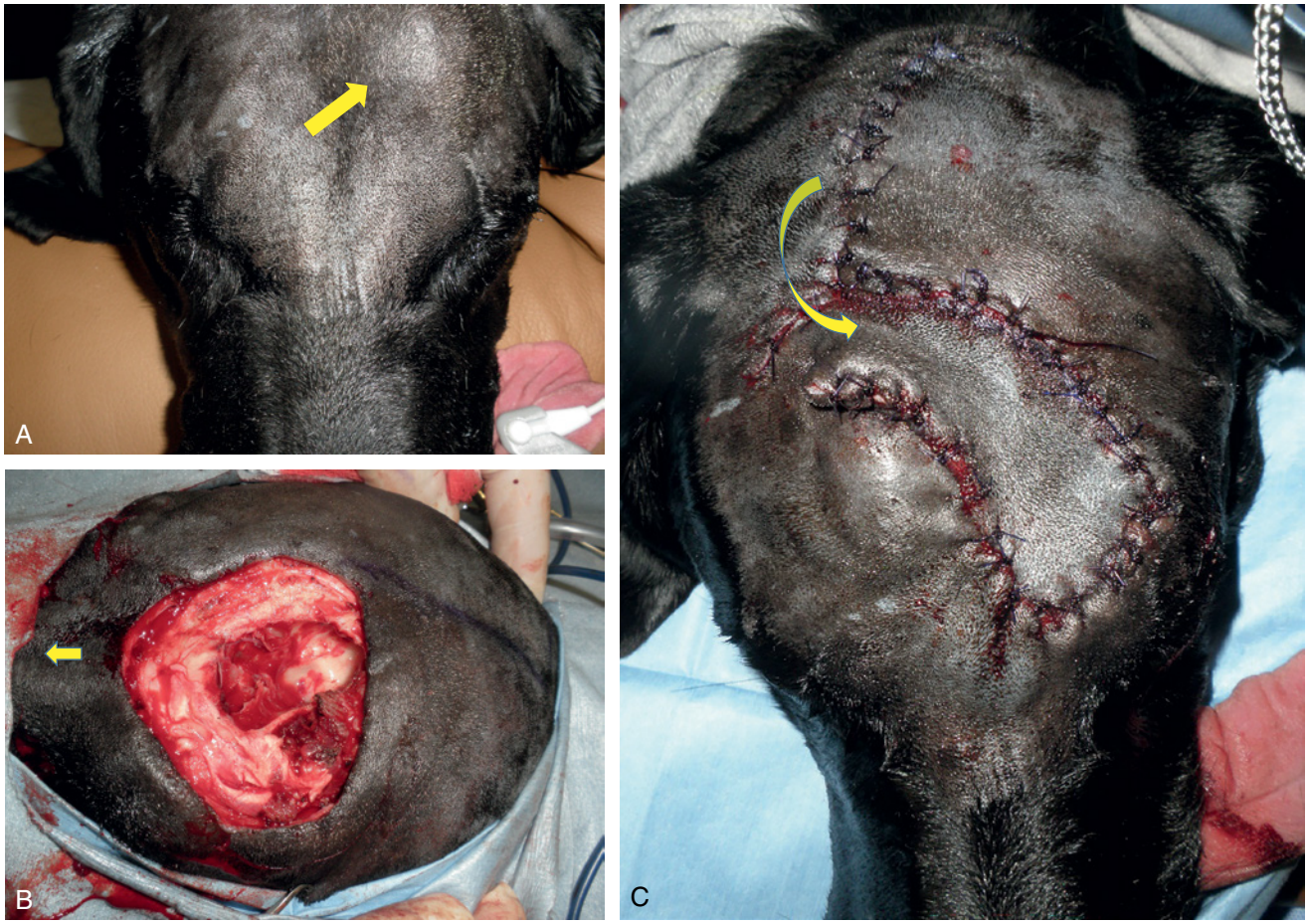


FIG. 25.5 (A) Soft tissue sarcoma (arrow) on dorsum of Labrador. (B) Wide resection. Arrow denotes rostral area of the head. (C) Closure with transposition flap (arrow) utilizing the skin between the pinnal bases.

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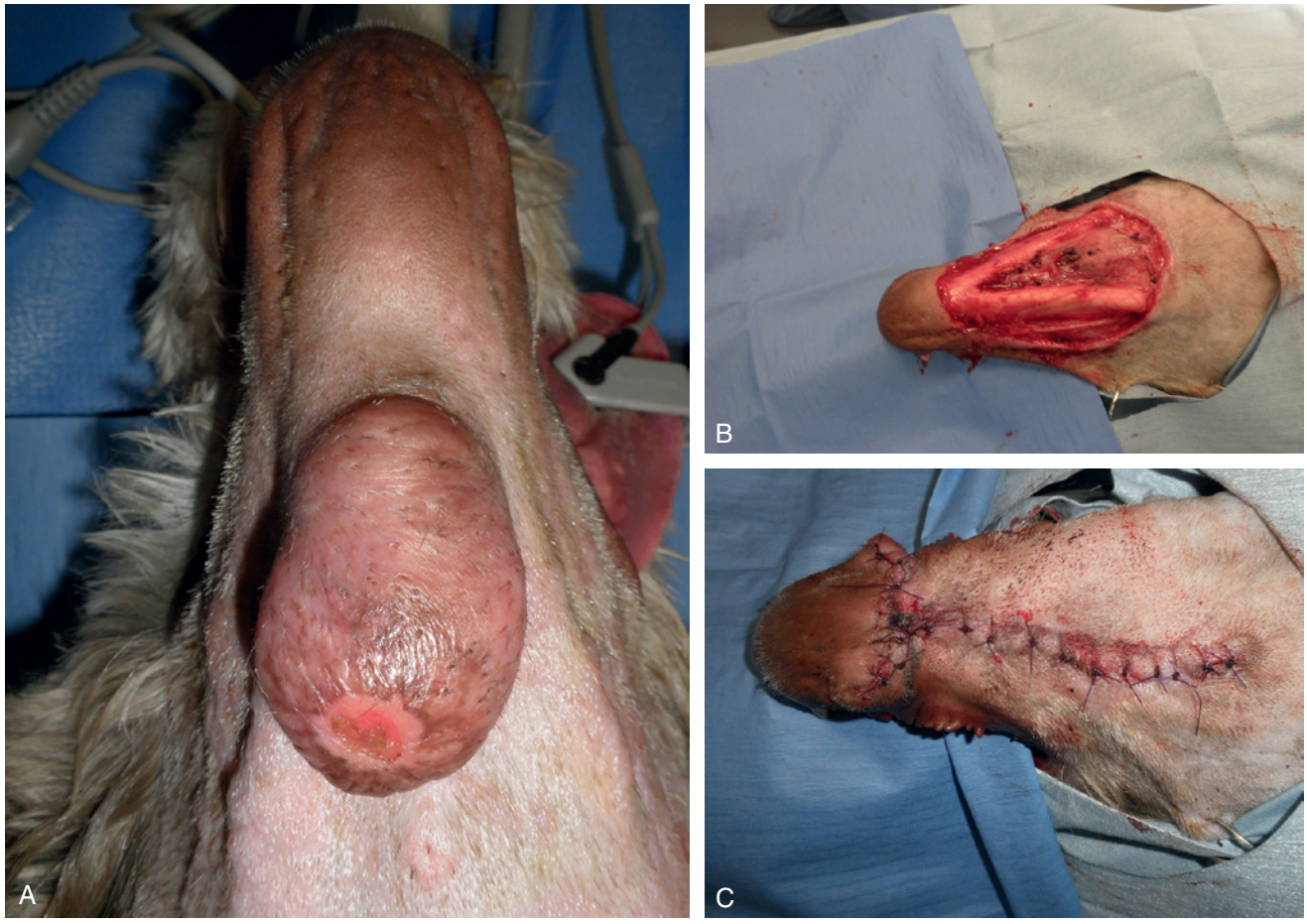


FIG. 25.6 (A) Benign fibroma, lower mandibular area. (B) Resection of the mass. (C) In this example there was sufficient elastic skin to close the defect without resorting to a skin flap. There was minimal tension and deformation of the lower labial margins.

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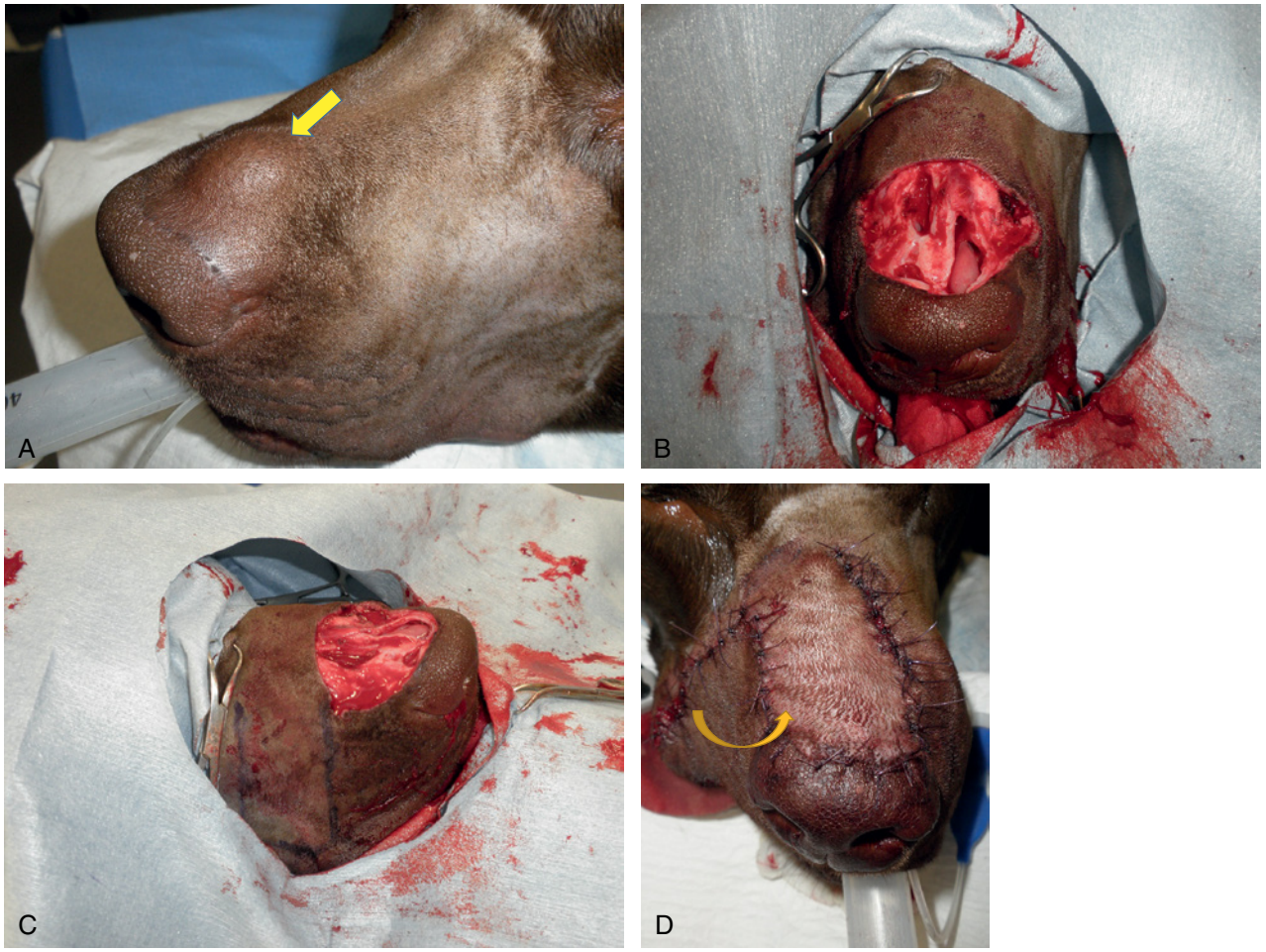


FIG. 25.7 (A) Grade II mast cell tumor, dorsal nasal area (arrow). (B) Complete tumor resection including portion of the underlying nasal cartilage. (C) Right lateral view of the measured transposition flap, positioned vertical to the upper labial border. (D) Flap elevation, rotation (arrow), and closure of the recipient site.

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FIG. 25.8 (A) Chronic skin ulceration over the calcaneus, mixed-breed dog. (B) Closure with a transposition flap. Sufficient skin laxity was present for flap development and closure of the donor area. (C) Close-up view of the flap pedicle and donor area following closure.

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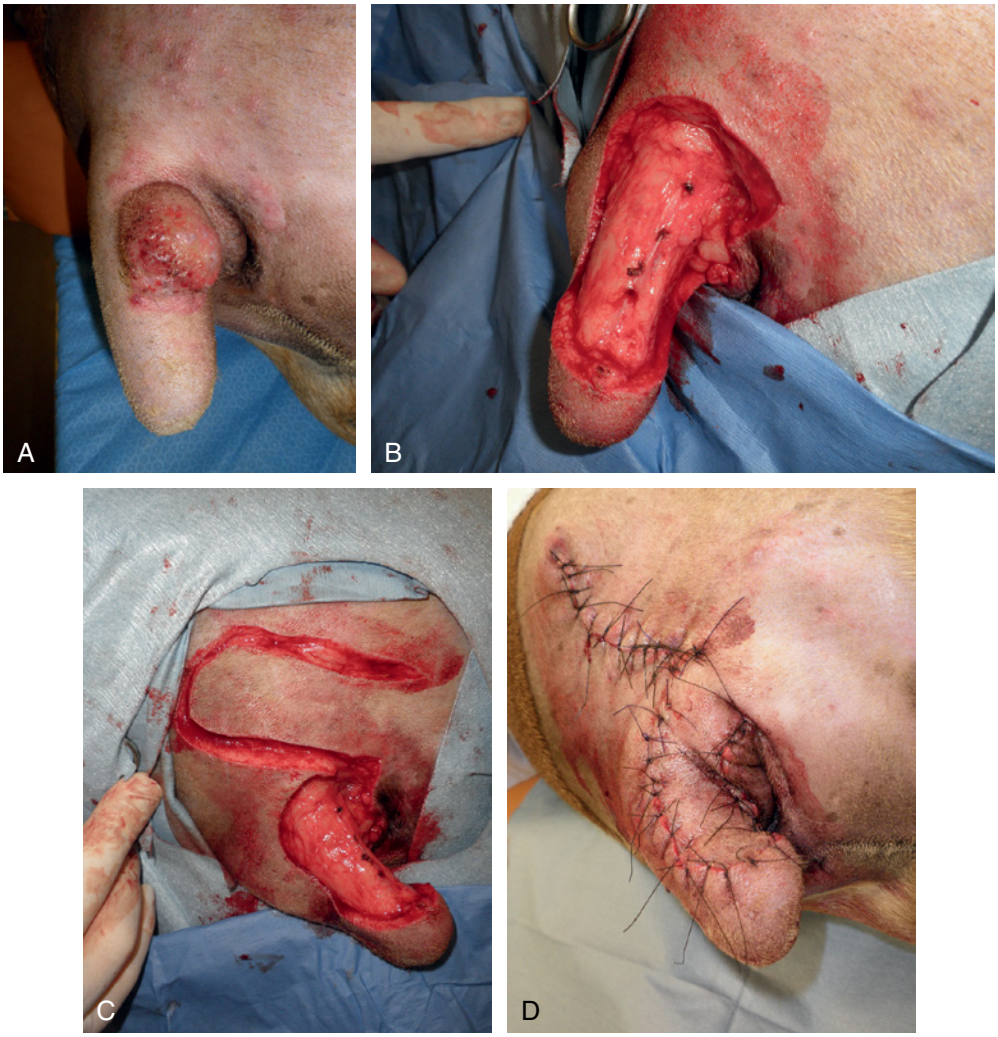


FIG. 25.9 (A) Mast cell tumor, right tail base in a mixed-breed dog. (B) Wide resection of the right lateral half of the tail. (C) Development of a transposition flap utilizing the adjacent dorsal pelvic skin. (D) Rotation of the flap followed by closure of the recipient bed.

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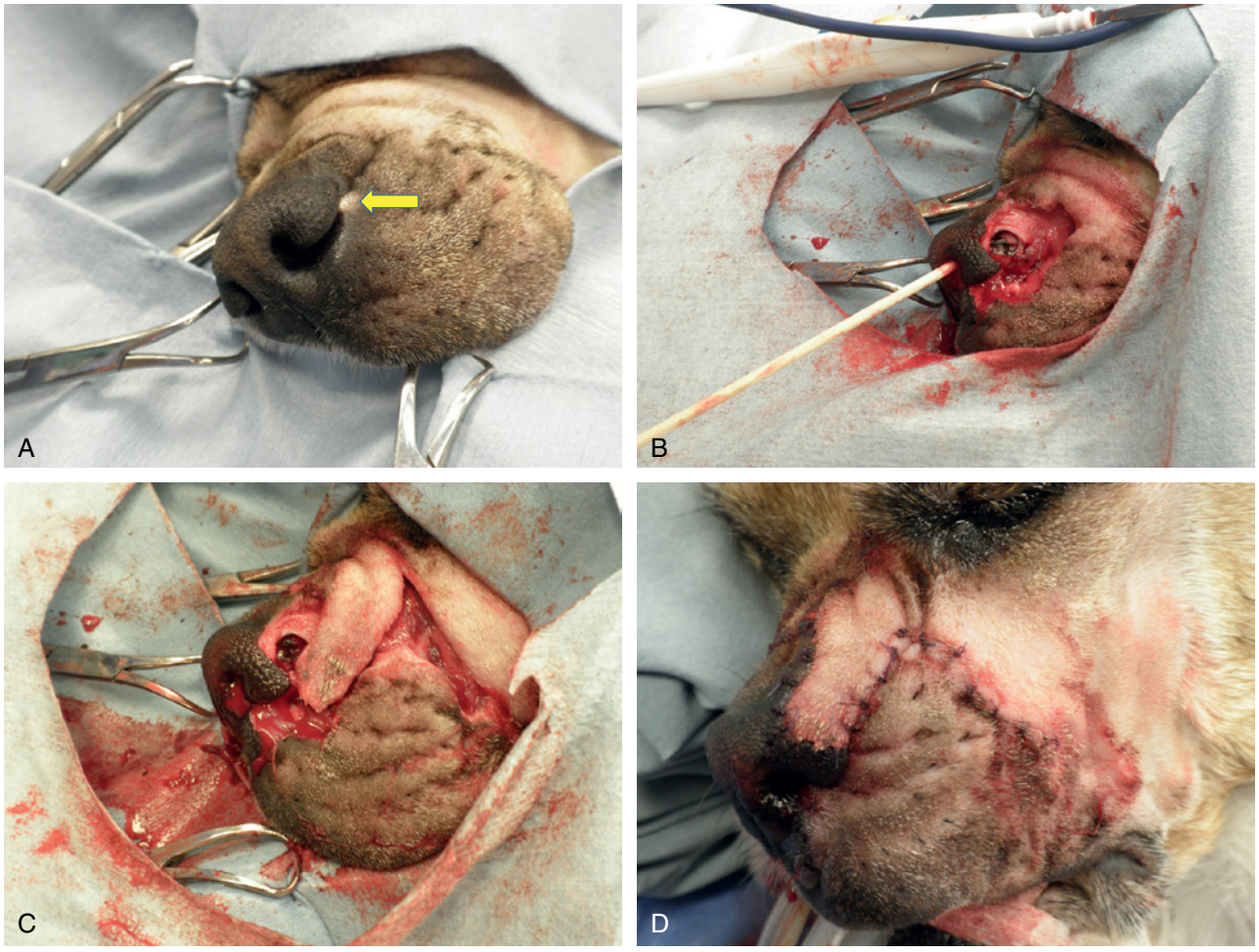


FIG. 25.10 (A) Mast cell tumor involving the left lateral sulcus (arrow). (B) Resection of the left lateral nasal tissue and adjacent skin. The cotton-tipped applicator was inserted into the nostril to highlight the cartilage defect. (C) Elevation and rotation of a transposition flap into the nasal defect. (D) Closure of the nasal defect and donor site.

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FIG. 25.11 (A) Carcinoma of the right caudal facial area in a geriatric domestic shorthair cat. (B) Wide tumor resection. (C) Elevation and rotation of a transposition flap into the defect. (D) Completion of closure of the donor and recipient areas.

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FIG. 25.12 (A) Ulcerated soft tissue sarcoma, dorsal surface of the head. (B) Frontal view. Care must be taken to assess skin tension, during closure, that could affect the right upper eyelid function. (C) Wide excision including a portion of the pinnal base. (D) Closure of the cartilage/fascial defect. (E) Complete undermining of the adjacent skin. The index finger is used to palpate for any fascial attachments that would require division. (F) Lateral view of the closure by advancement of the undermined skin. (G) Skin advancement and closure, dorsal view. The right upper eyelid is unaffected.

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FIG. 25.13 (A) Mast cell (arrow) involving the dorsal nasal area. (B) Wide resection of the dorsal nasal area, encroaching on the nasal cavity. The arrow denotes the end of the outlined transposition flap. (C) Transfer of the transposition flap to the dorsal nasal defect (arrow). (D) Lateral view following closure of the recipient and donor beds. (E) Dorsal view following closure.

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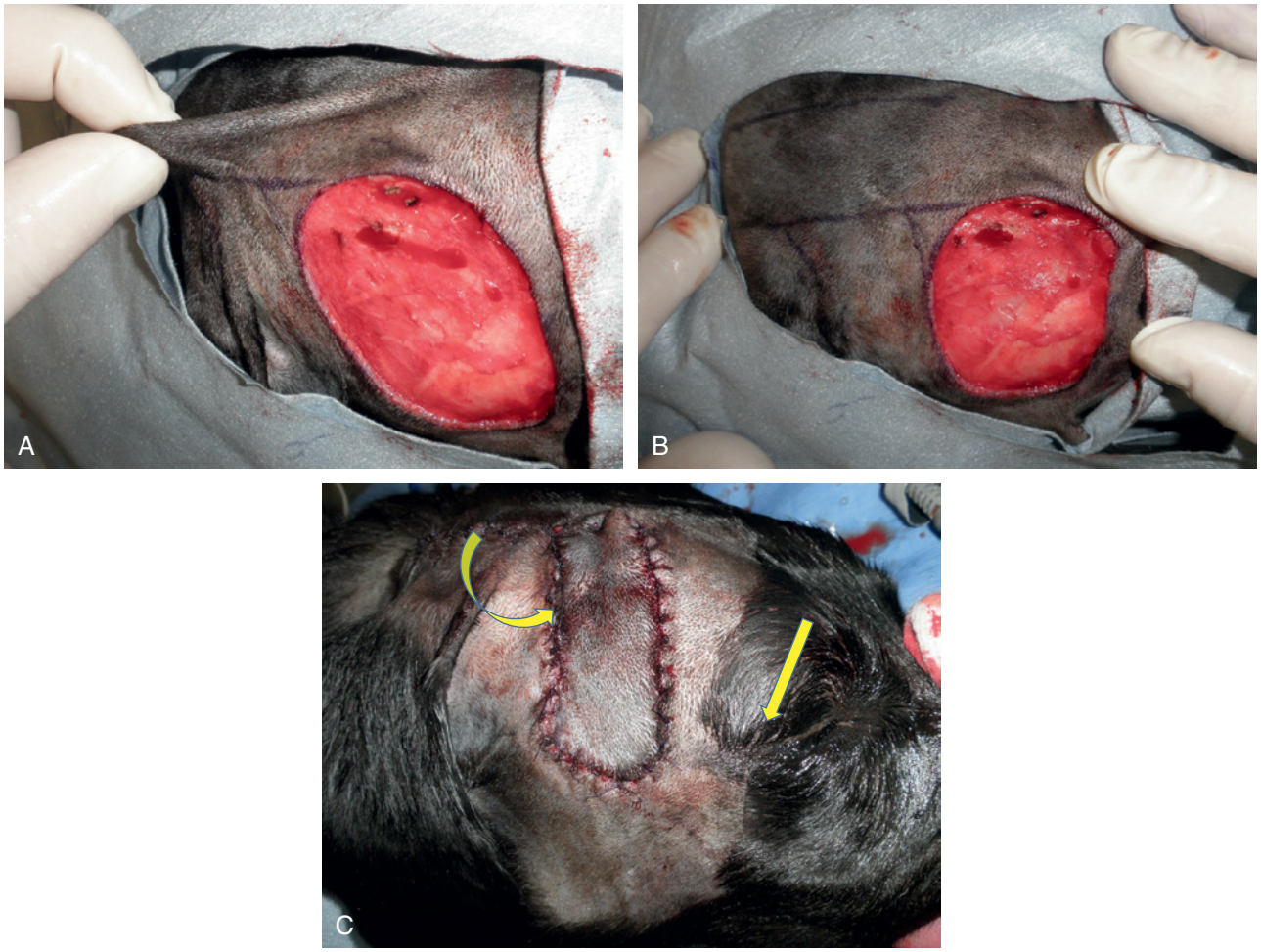


FIG. 25.14 (A) Skin defect following wide skin tumor resection involving the right lateral facial area in a Labrador cross. Note the elastic skin elevated perpendicular to the long axis of the recipient wound bed. (B) General outline of a right-angle transposition skin flap taking advantage of the available skin noted in (A). (C) Rotation of the transposition flap (curved arrow) into the recipient bed. The flap was used to close this defect in order to avoid tension on the lateral canthus and upper eyelid (arrow).

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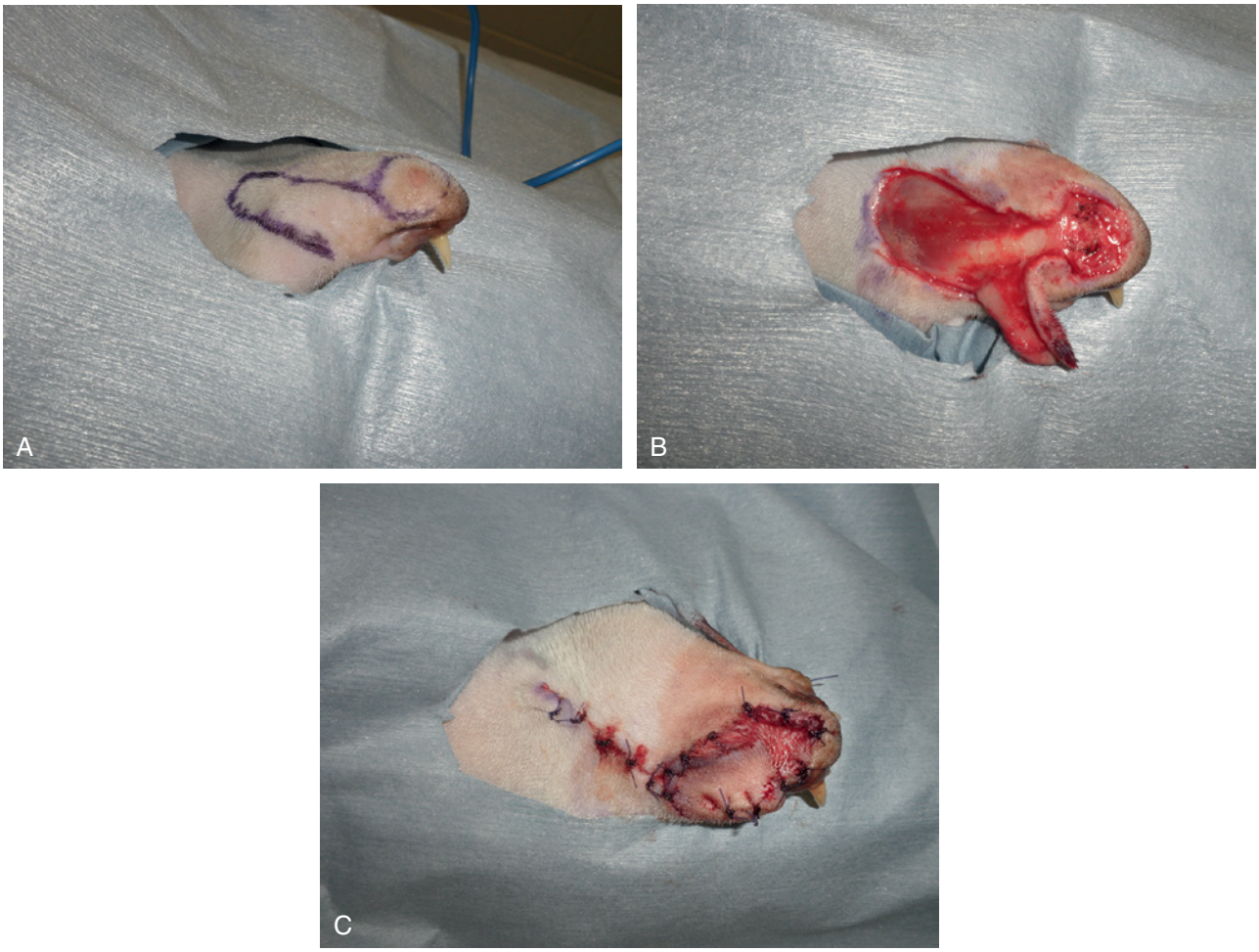


FIG. 25.15 (A) Adenoma resection of the lower chin with outline of a transposition flap in a cat. (B) Tumor resection and flap elevation. (C) Closure. The flap size is measured to ensure there is no ventral deviation or traction applied to the labial border.

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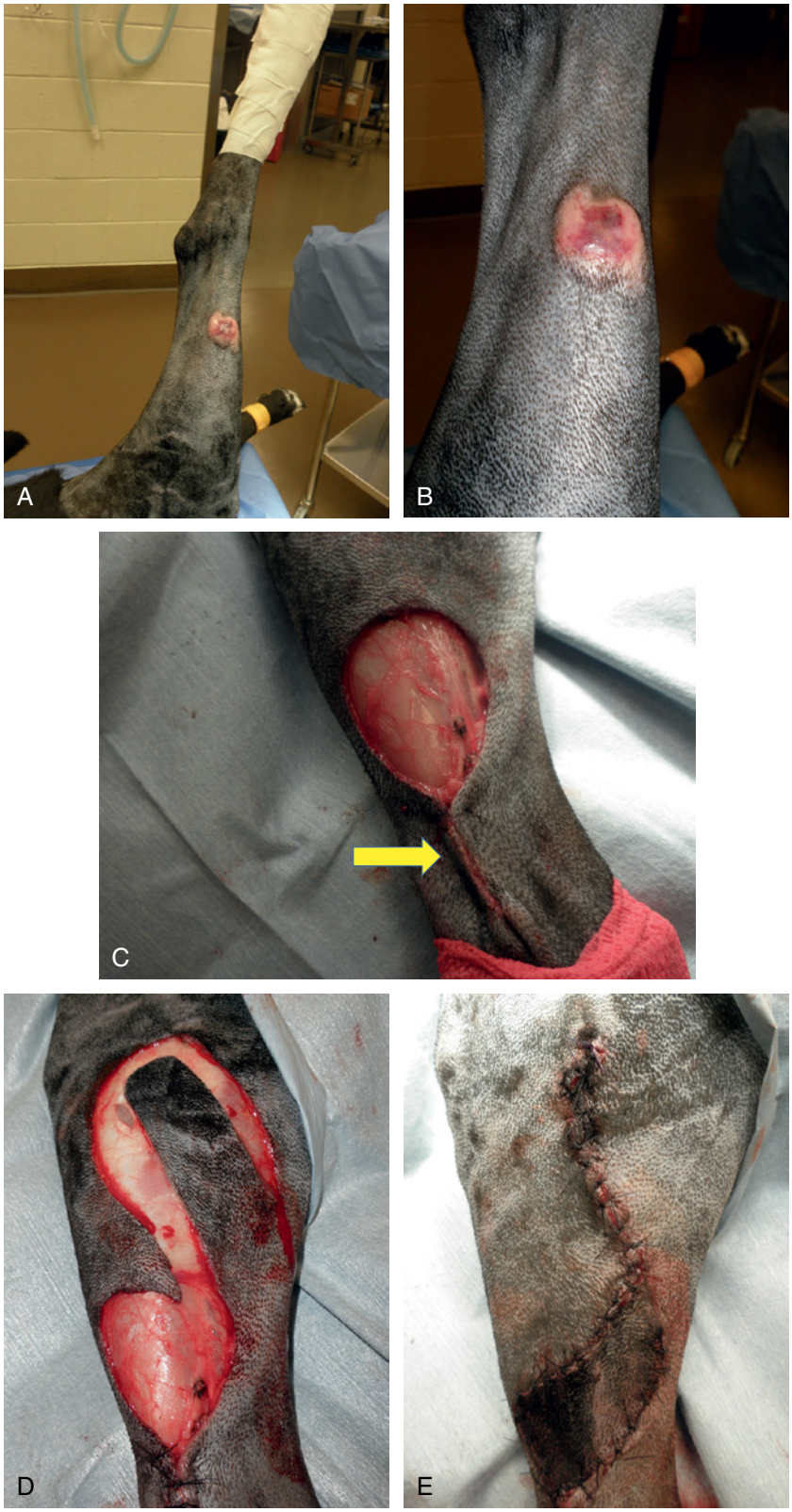


FIG. 25.16 (A) Mast cell tumor in a dog, skin of the lateral mid-tibial region. (B) Close-up view of mast cell tumor. (C) Wide tumor resection. Note that the distal portion of the defect was closed by apposition of the loose skin available (arrow). This maneuver reduces the magnitude of the skin defect; in turn this allows the remaining defect to be closed with a smaller transposition flap. (D) Development of transposition flap, taking advantage of the looser proximal circumferential skin tension. (E) Closure of the donor and recipient sites.

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FIG. 25.17 (A) Mast cell tumor (arrow), right rear extremity in a mixed-breed dog. (B) Tumor resection. Note the elevated loose skin available, parallel to the long axis of the tibia. (C) Elevating a transposition flap, utilizing the loose skin available in (B). (D) Rotation (arrow) and closure of the recipient and donor beds. Surgeons must be aware of the donor skin available in order to avoid excessive tension on the closure of the donor bed.

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FIG. 25.18 (A) Mast cell tumor (arrow), dorsal nasal area in a golden retriever. (B) Lateral view of the mast cell tumor (arrow). (C) Wide tumor resection down to the periosteum of the underlying nasal bone. (D) The loose skin available bilaterally (arrows) allowed for undermining and closure without the use of a skin flap. (E) Lateral view following closure.

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FIG. 25.19 (A) Traumatic loss of skin of the left medial thigh. (B) Elevation of the right contralateral caudal superficial epigastric axial pattern flap. Arrow denotes position of a bridge incision over the prepuce to allow for positioning of the flap into the recipient bed. (C) Completion of flap transfer. Note the Jackson-Pratt drain placed to control postoperative dead space. (D) Flap at 2 weeks. The bridge incision is highlighted with the arrow.

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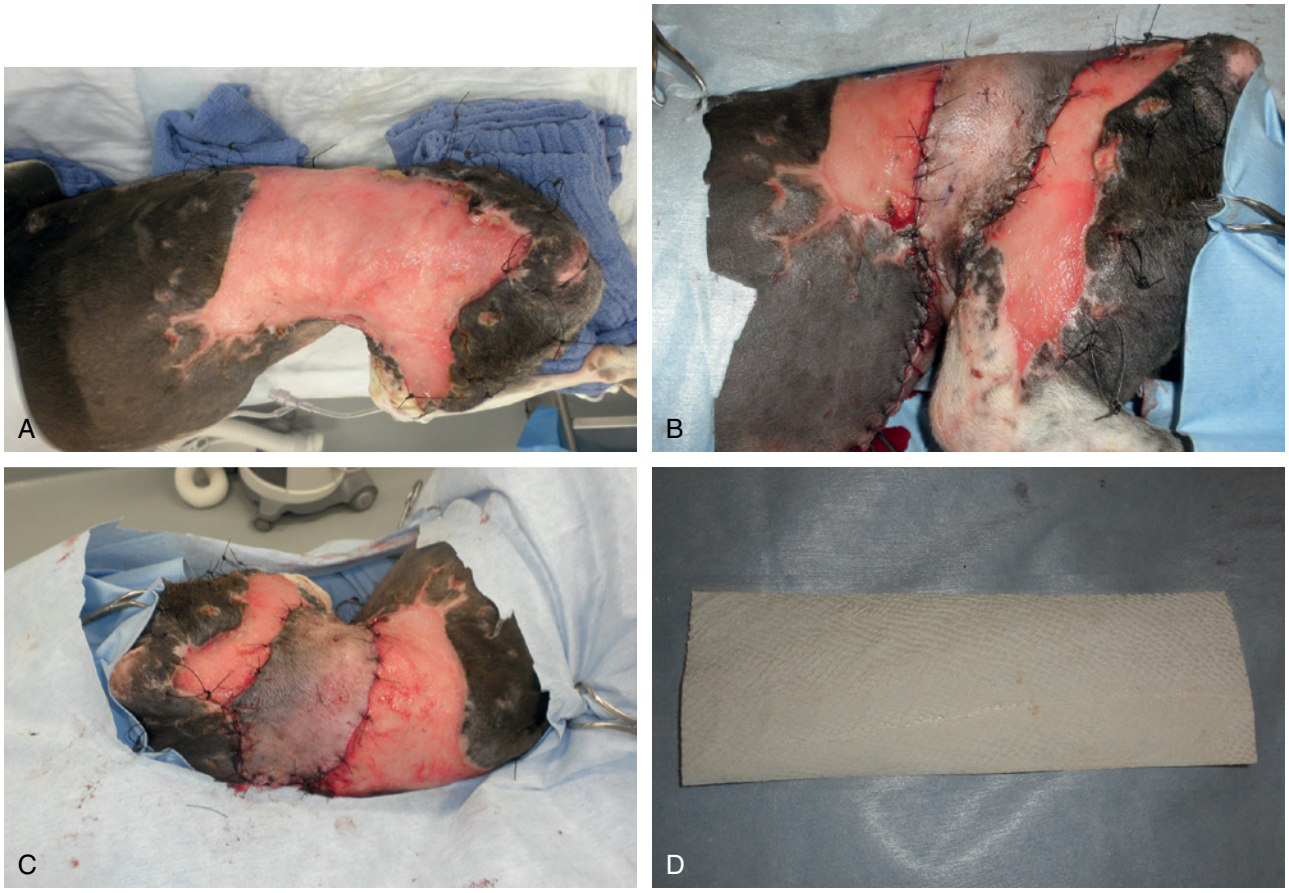


FIG. 25.20 (A) Extensive skin loss to an Italian greyhound secondary to vehicular trauma. Note the extensive skin loss to the left side of the dog, extending beyond the dorsal midline. Surgical resection of necrotic skin and subcutaneous tissue was followed by open wound management to develop an early granulation bed. Surgical towels were used to elevate the dog's trunk from the table to gain access to the ventral abdomen for elevation of the left caudal superficial epigastric axial pattern flap. (B) A left caudal superficial epigastric flap was transposed over the central third of the wound, covering the exposed crest of the left ilium. (C) Dorsal view of the flap secured with sutures. As a result of the flap transfer, two smaller areas of granulation tissue can be addressed separately. Note that splitting a large wound into two smaller defects opens up the possibility of promoting wound contraction to facilitate closure. (D) A sheet (8 × 20 cm) of medical-grade Cod FSG (Kerecis Vet, Arlington, VA) was purchased to temporarily cover the remaining two skin defects. This dry sheet of fish skin was trimmed to conform to the largest wound; the other segments were used for covering the narrower defect. (E) Hydration of the Kerecis fish skin in sterile saline prior to application. (F) Placement of the fish-skin dressing, dorsolateral view. Staples and sutures were used to secure the dressing, followed by coverage of the surgical area with a protective tie-over dressing. The Kerecis fish skin protects the exposed granulation bed while preparing the areas for the possible need for an autogenous mesh graft application. Use of this expensive product must be weighed against the potential gains in facilitating wound closure in comparison to other commercially available wound-care products. It is important to note that fish skin is appetizing to dogs and cats: bandage coverage and the use of an Elizabethan collar are recommended to prevent the patient from consuming the fish-skin graft. (G) The fish graft was replaced every 7 days. Day 14: note the dramatic contraction of the wound spurred by the expansion of the axial pattern flap. (H) Lateral view at 2 weeks. As demonstrated in Fig. 11-17 and Plate 46, central placement of the flap in a wide defect creates two smaller wounds that are more likely to heal by contraction and epithelialization. (I) Third week of fish graft application. Note how the epigastric flap has widened from wound contraction. The caudal wound overlying the left thigh is nearly closed. The cranial wound is dramatically smaller from contracting and epithelialization. No autogenous skin graft was required.

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FIG. 25.20 (Continued)

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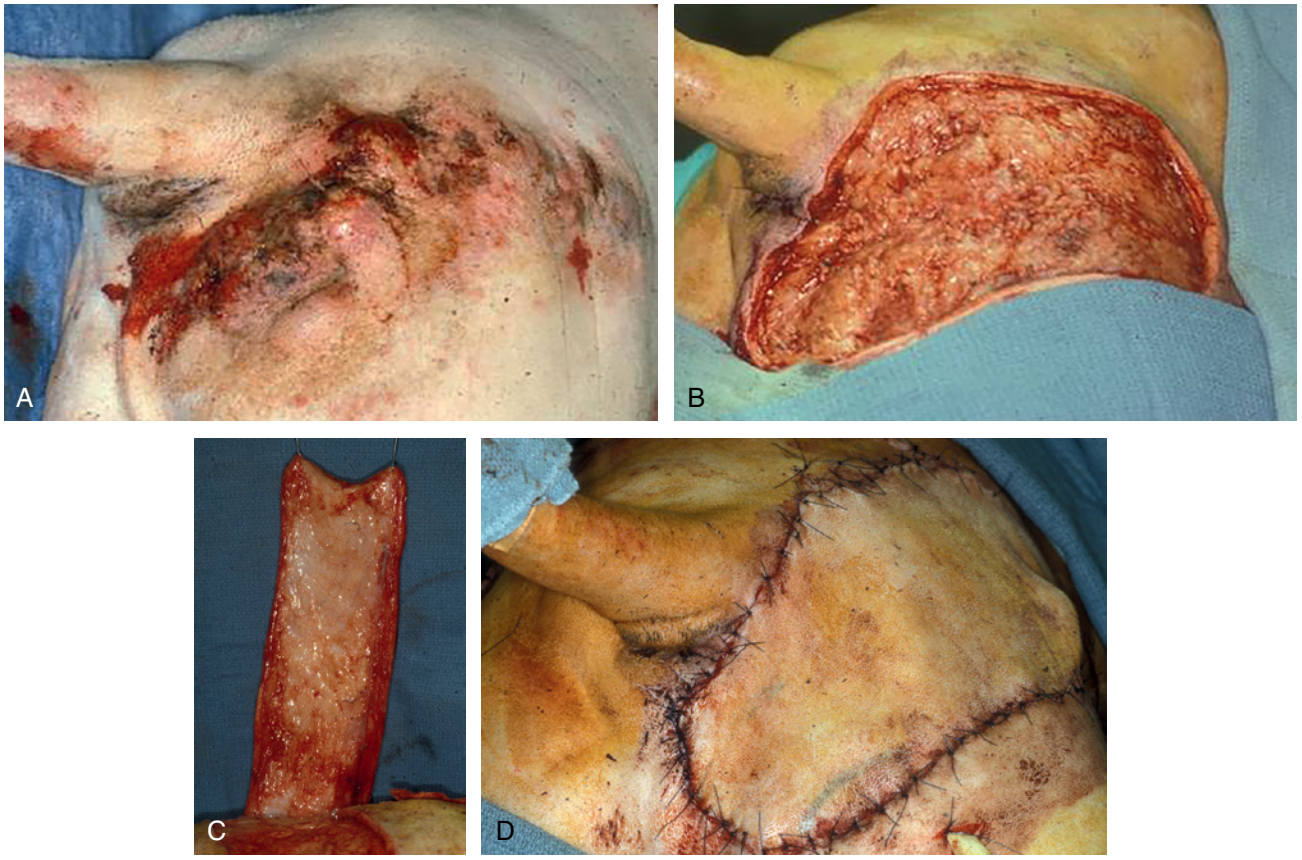


FIG. 25.21 (A) Mast cell tumor, right lateral pelvic skin. (B) Wide tumor resection. (C) Elevation of the right dorsal deep circumflex iliac axial pattern flap. (D) Surgical closure.

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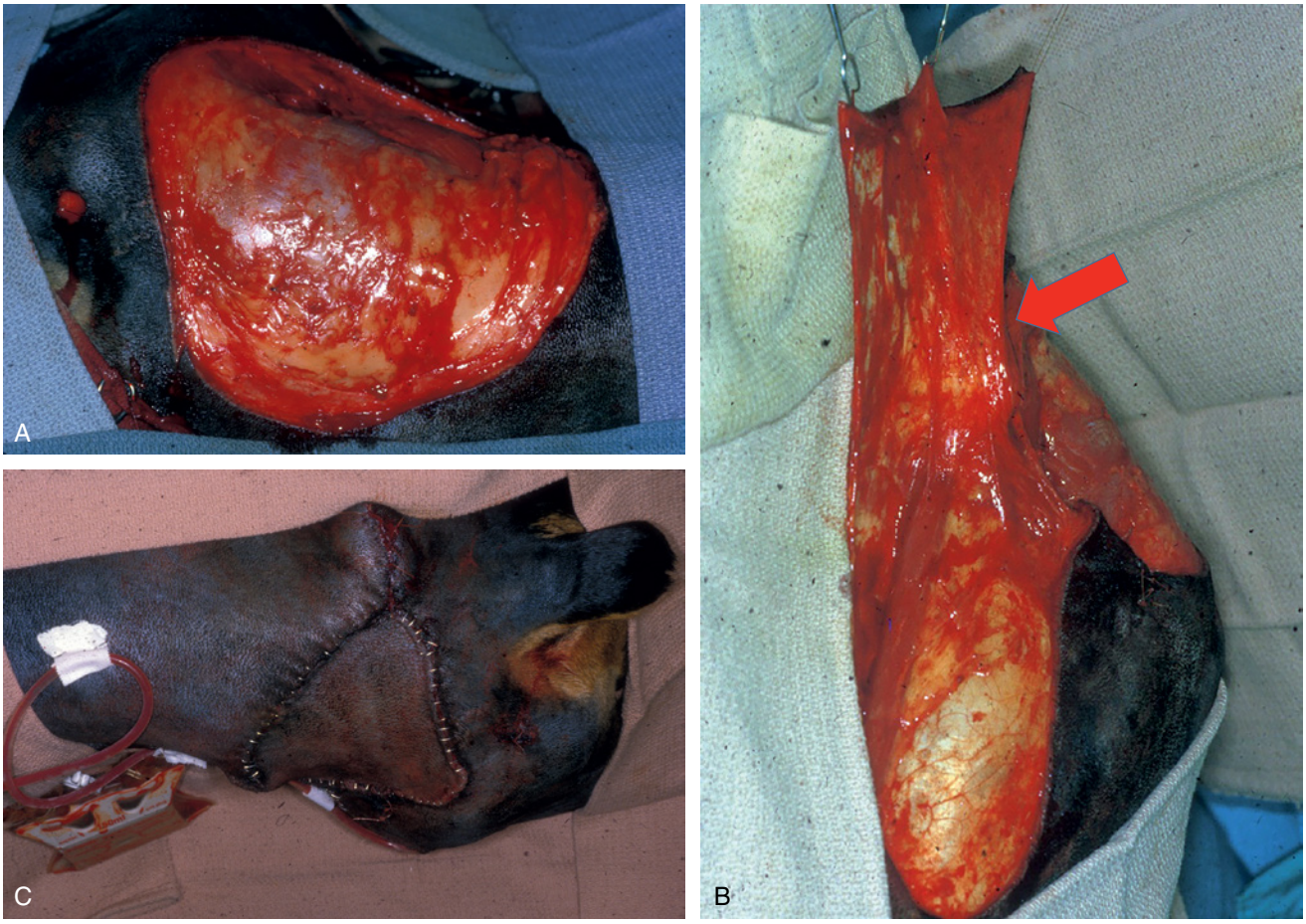


FIG. 25.22 (A) Resection of expansile granuloma involving the left dorsolateral pelvic skin. (B) Elevation of left ventral deep circumflex iliac axial pattern flap, island arterial flap variation (arrow). (C) The flap was rotated dorsally by 180° to complete closure.

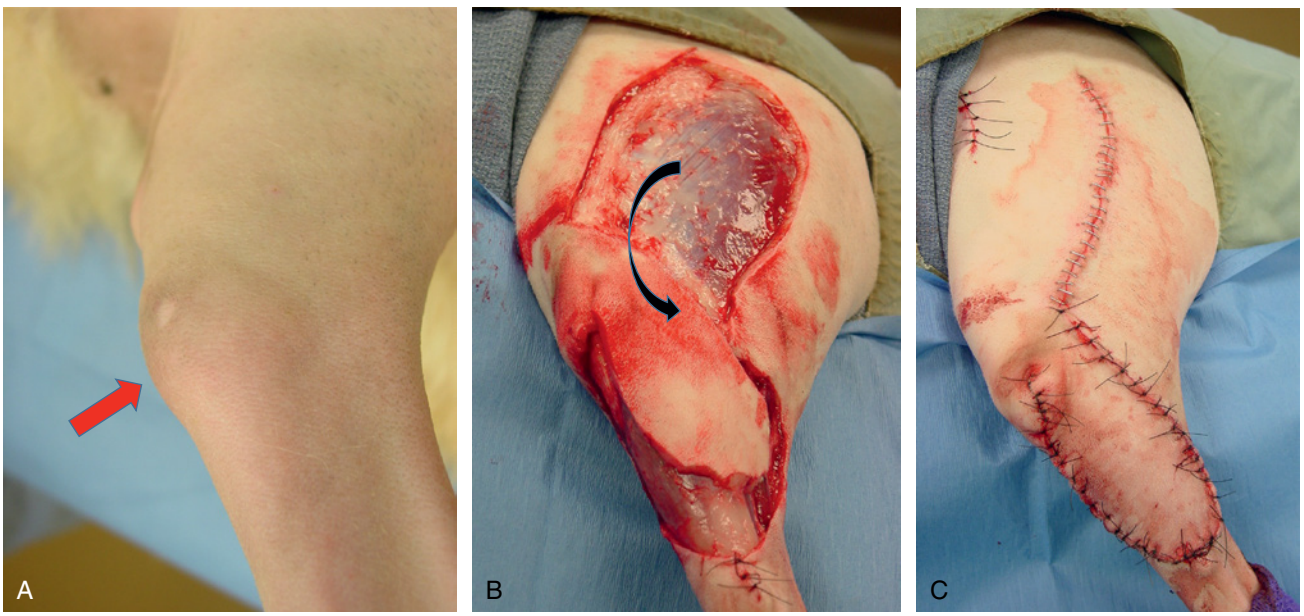


FIG. 25.23 (A) Mast cell tumor, left hindlimb, proximal-lateral tibial skin (arrow). (B) Elevation and rotation (arrow) of the left genicular axial pattern flap. (C) Completion of closure.

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FIG. 25.24 (A) Surgical pen outline of right pinnal resection for mast cell tumor. (B) Full-thickness resection of caudal pinna. (C) Outline of local transposition skin flap to replace both the lateral and medial pinnal defects. (D) Elevation of the transposition flap. Initial closure of the medial border of the pinna was followed by closure of the lateral border and donor defect. (E) View of the elevated pinna and closed donor incision.

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FIG. 25.25 (A) Sebaceous gland neoplasm involving medial pinnal surface, central area. (B) Resection of the medial pinnal skin and underlying attached pinnal cartilage. The star identifies the exposed dermal surface of the lateral skin of the pinna. The arrows denote the direction of the closure. The lateral and medial pinnal vessels maintain the viability of the pinnal tissues. (C) Closure resulted in a downward fold of the pinna in this spaniel.

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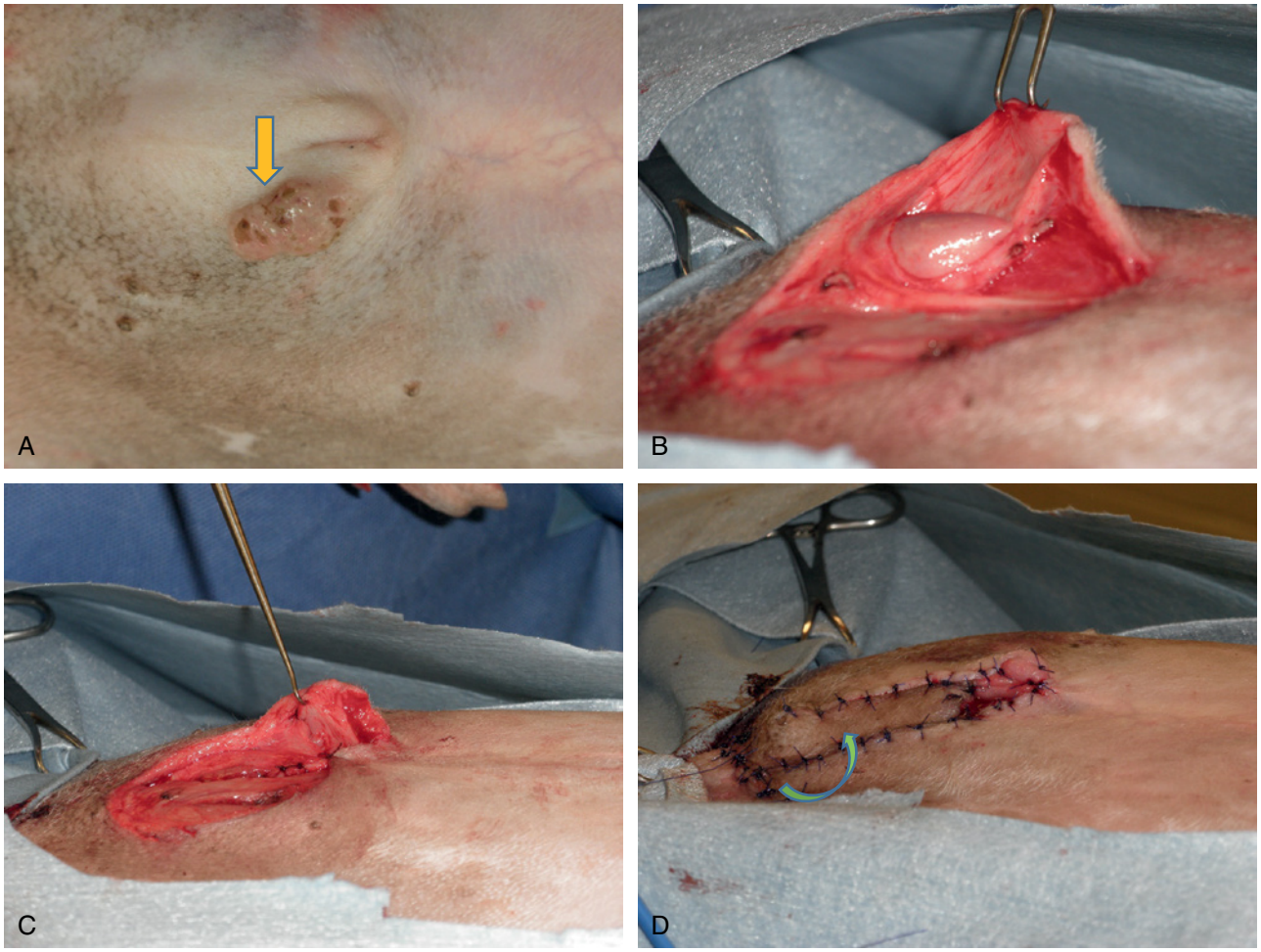


FIG. 25.26 (A) Mast cell tumor (arrow) adjacent to left side of the preputial ostium. (B) Wide resection of the mast cell tumor including a portion of the preputial ostium. (C) The intact margin of the ostium was folded over the defect after closure of the lateral portion of the preputial mucosa. (D) Lastly, a transposition flap was rotated into the remaining cutaneous defect (arrow). The donor area closure is obscured by the drape.

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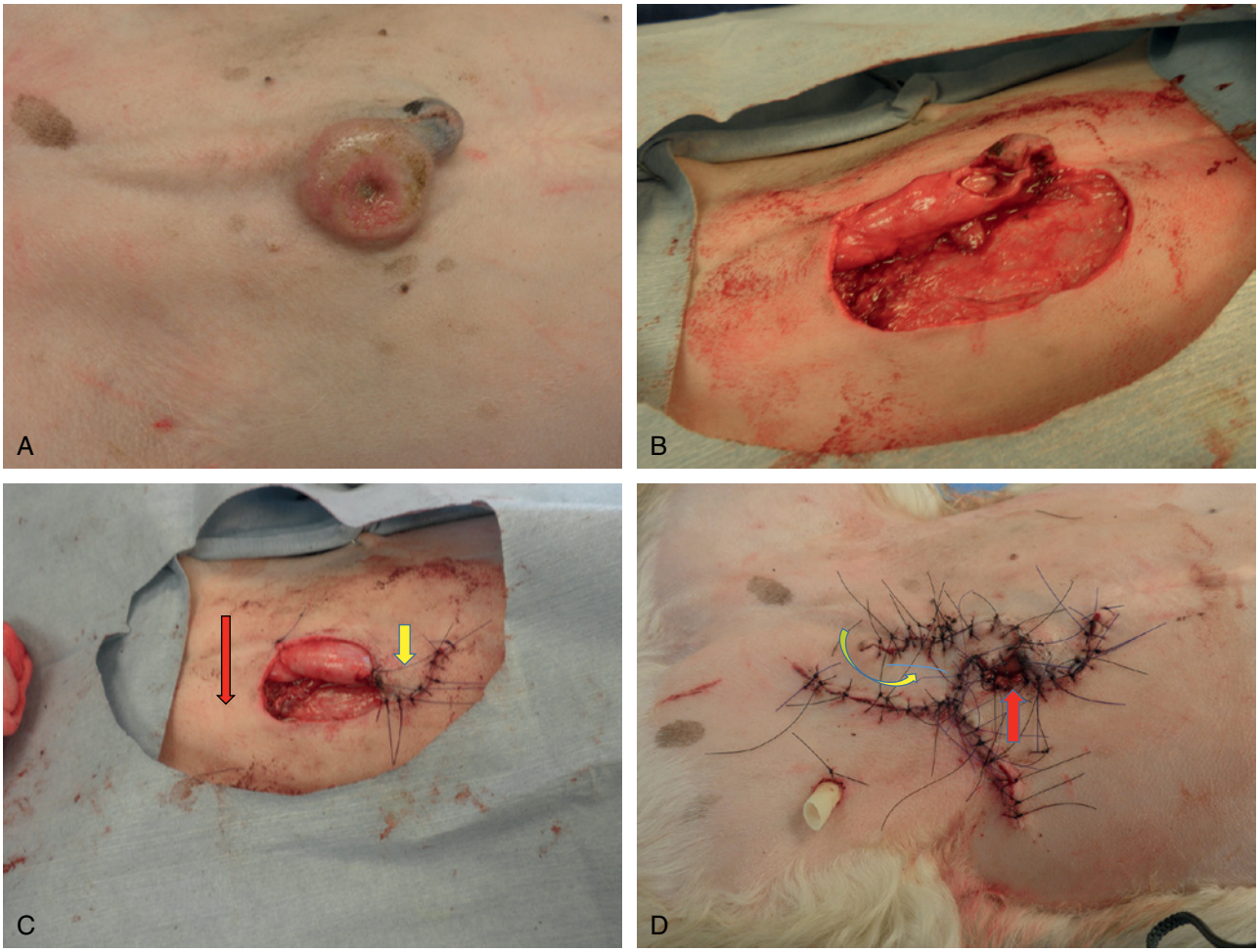


FIG. 25.27 (A) Mast cell tumor, left lateral preputial skin. (B) Wide resection including a portion of the ventral preputial ostium. (C) Advancement flap (yellow arrow) closing the skin defect cranial to the ostium. The skin caudal to the defect (red arrow) will be elevated as a transposition flap to close the remaining recipient bed. (D) Transposition flap rotated into the remaining recipient bed (yellow arrow). The red arrow denotes the restored preputial ostium. A ¼ in. Penrose drain was used to control the small pocket of dead space and removed 72 hours postoperatively.

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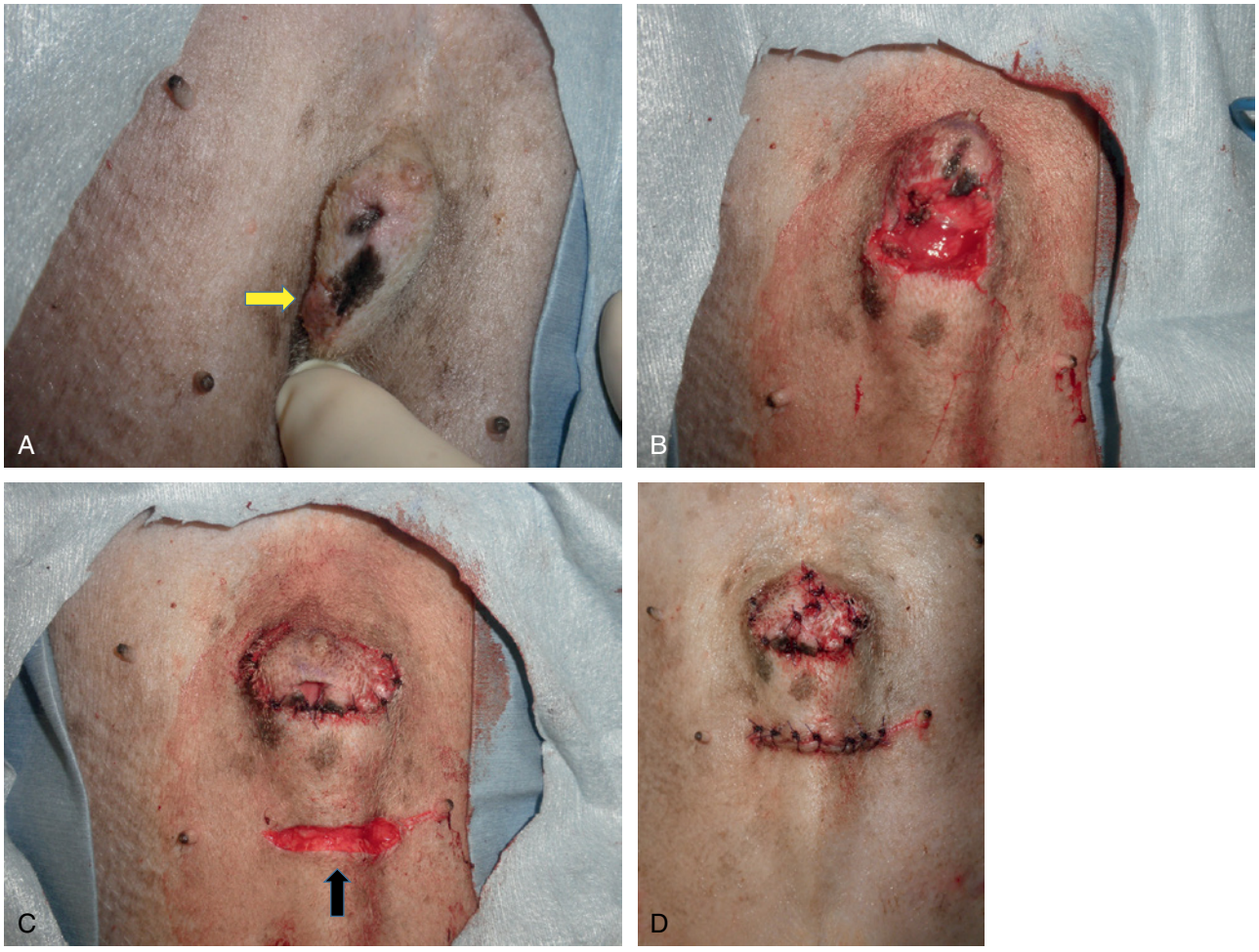


FIG. 25.28 (A) >5 mm mast cell tumor, ventral prepuce (arrow). (B) Skin and subcutaneous tissue resection. (C) Release incision (arrow), facilitating advancement of the skin. (D) Closure. By design, this is an example of a bipedicle advancement flap. Closure tension is a consideration in this area. Excessive tension can pull the ostium caudally; this can change the direction of the normal urine stream.

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FIG. 25.29 (A) French bulldog with labial mast cell tumor. (B) Elevation of the upper lip, demonstrating the expansile neoplasm. (C) Laser resection of the rostral portion of the upper lip. (D) Closure with a labial pivot flap, restoring the labial contour.

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FIG. 25.30 (A) Soft tissue sarcoma proximal to the metatarsal pad in a mixed-breed dog. (B) Surgical resection. Autoclaved Vetrap was used as a temporary tourniquet. (C) Closure of the surgical defect. The foot was protected with a bandage for a total of 3 weeks, with bandage changes every 4–5 days. The red line denotes the area for the potential use of a release incision. The author has used a release in this area if wound closure proximal to the metatarsal or metacarpal pad requires a reduction in tension.

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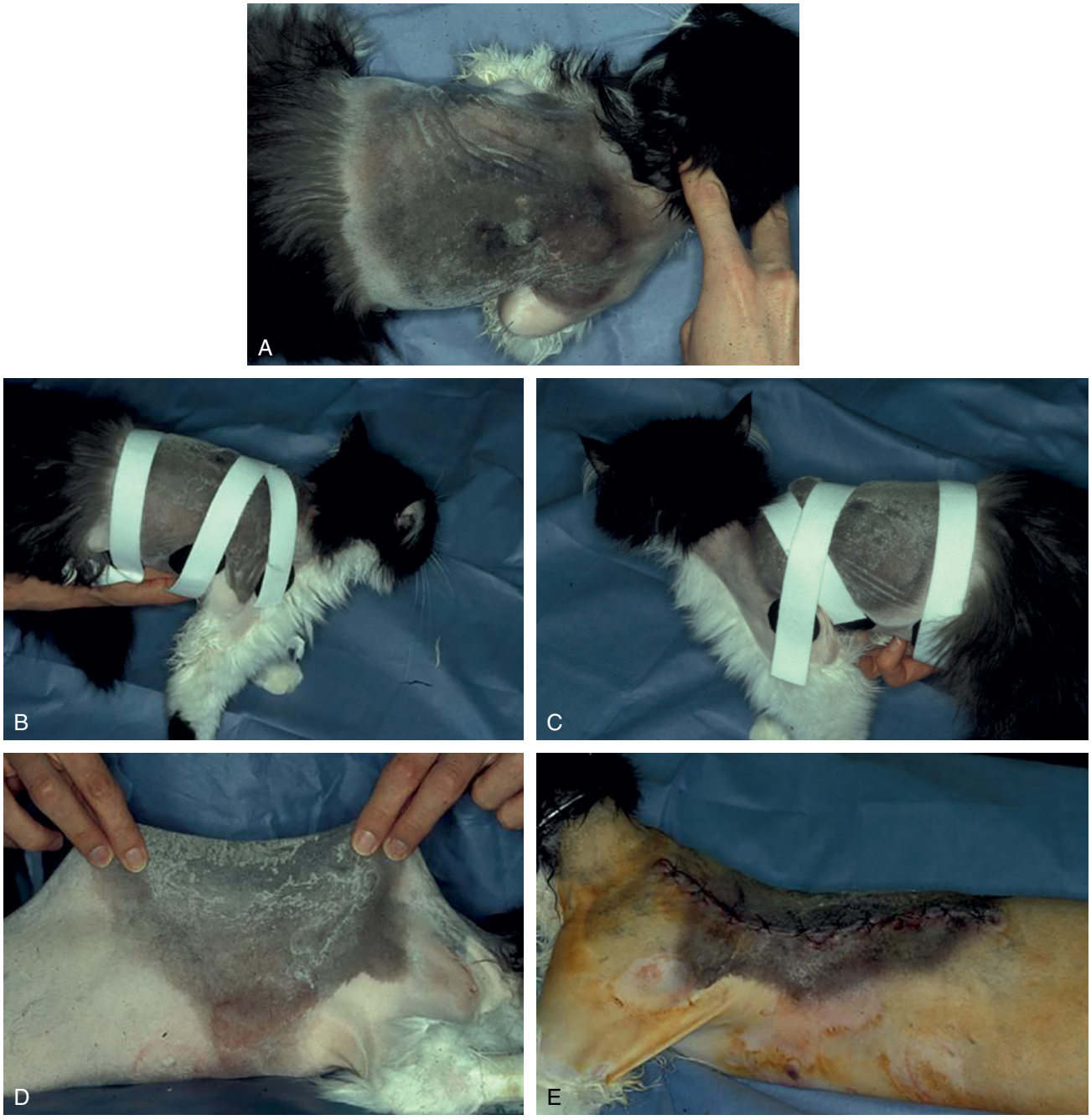


FIG. 25.31 (A) Fibrosarcoma recurrence following radiation therapy. (B) Placement of skin stretcher pads and cables to prestretch the skin (right side). (C) Left-sided placement of stretcher pads and cables. (D) Following 72 hours of stretching, circumferential skin was mobilized to facilitate wide resection and closure. (E) Completion of surgery.

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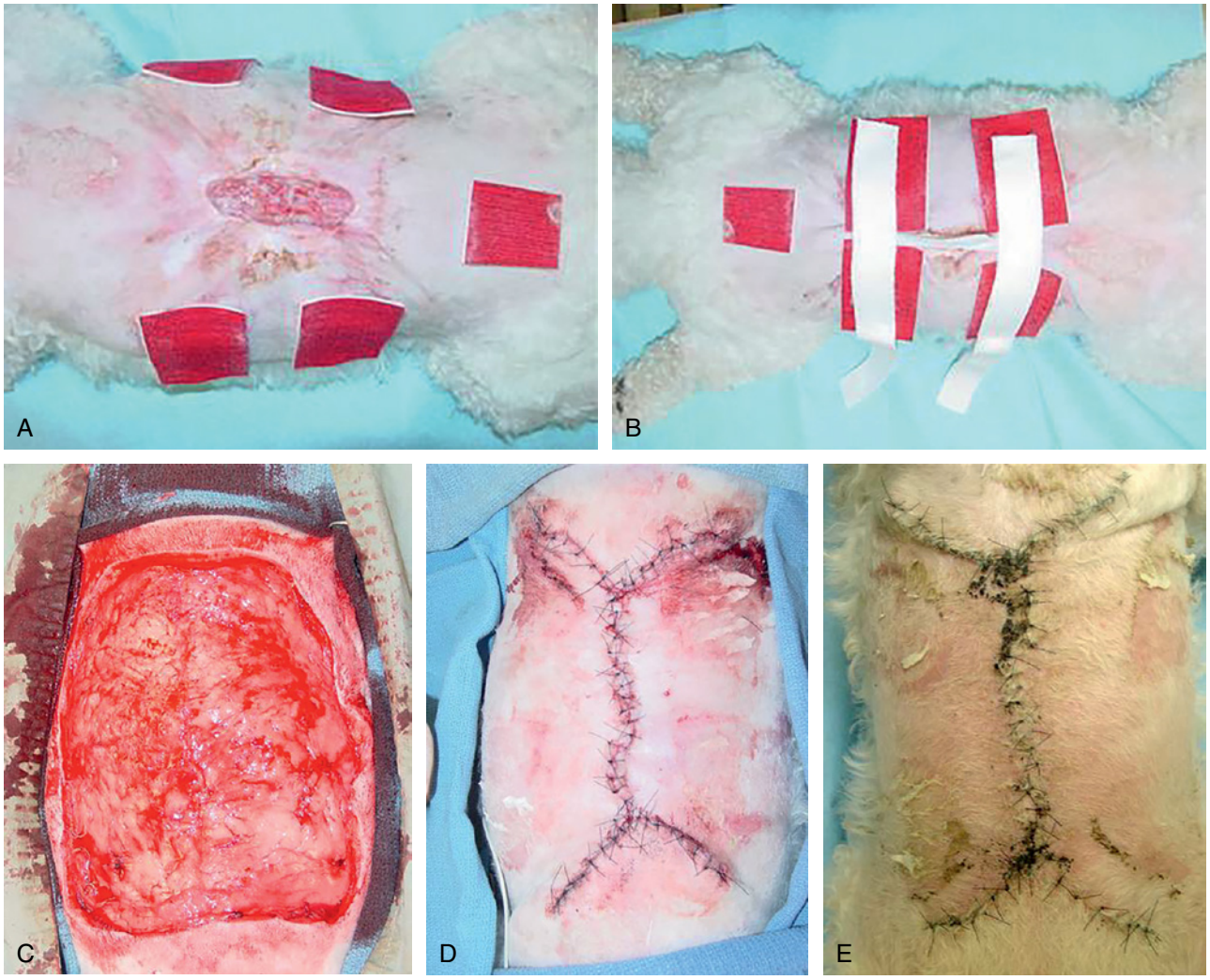


FIG. 25.32 (A) Chronic nonhealing thermal wound secondary to electrical heating pad. Note the epithelialized hairless scar surrounding the central ulcerated area. The stretcher pads applied lateral to the perimeter of the burn scar. The caudal pelvic pad was redundant. (B) Stretching of the skin at 72 hours. (C) Excision of the entire scar. (D) Completion of the closure following resection of the partially epithelialized scar. Full-thickness, hair-bearing skin approximation eliminated the large thermal scar. (E) Healing at 2 weeks. Subsequent hair regrowth covered the surgical scar, restoring function and cosmesis to the area.

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