

# Skin-Fold Advancement Flaps for Closing Large Proximal Limb and Trunk Defects in Dogs and Cats

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**Objective**—To describe the use of skin-fold advancement flaps for covering large skin defects in dogs and cats.

**Study Design**—Clinical study.

**Animals**—Eight client-owned animals: 6 dogs and 2 cats.

**Methods**—Six dogs and 2 cats underwent reconstruction of soft-tissue wounds resulting from traumatic, neoplastic, or infectious lesions. Skin-fold flaps were created by division of the medial and lateral attachment to the proximal limb or the dorsal and ventral attachment to the trunk, enabling closure of adjacent defects on the trunk or proximal limb, respectively.

**Results**—Skin-fold flaps proved effective for closing defects in all animals. Necrosis of a portion of the flap occurred in 2 dogs due to technical errors, but the resultant defects remained amenable to primary closure. All wounds ultimately healed primarily, without major complications.

**Conclusion and Clinical Relevance**—The skin-fold advancement flap is a versatile technique that lends itself to use in a variety of locations, depending on which attachments are divided. The clinical results are comparable with those reported for axial pattern and subdermal plexus flaps.

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**S**KIN-FOLD ADVANCEMENT FLAPS (SFAFs) were first devised as a means of closing large sternal and inguinal wounds in dogs and cats,<sup>1</sup> and continue to be successfully used for this purpose. The flank folds and elbow folds consist of lateral and medial layers of skin, separated by loose connective tissue. Each fold has four attachments: medial and lateral attachments to the upper limb, and dorsal and ventral attachments to the trunk. SFAFs are created by division of any three attachments, followed by separation of the medial and lateral skin layers to produce a U-shaped flap. The flap relies on the subdermal plexus of the remaining skin attachment for its blood supply. The original article described division of the attachments to the limb and ventral trunk, creating flaps that could be advanced medially into sternal and inguinal defects.<sup>1</sup> However, it has been our evolving

experience that SFAFs are extremely versatile, and that division of the other attachments permits cranial or caudal advancement of the skin folds onto the medial or lateral upper limb, or dorsal advancement onto the lateral aspect of the chest or flank.<sup>2</sup>

The purpose of this article is to describe the use of SFAFs in a series of canine and feline patients with wounds in locations other than the sternal and inguinal regions.

## CASE REPORTS

### *Case 1*

A 2-year-old male castrated Chinchilla cat (4 kg) was referred for surgical excision of multiple cutaneous/subcutaneous nodules on the caudodorsal midline, extending from

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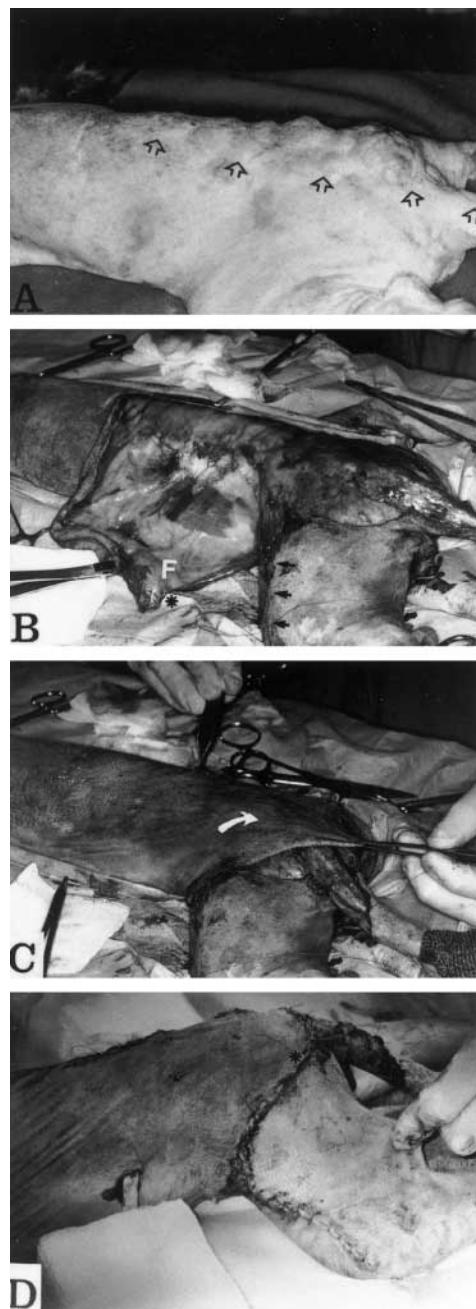
the caudal thorax to the tail base (Fig 1A). A previous diagnosis of "pseudomycetoma" due to *Microsporum canis* infection had been made. The lesions proved refractory to treatment with griseofulvin (500 mg every 24 hours), potassium iodide (dose not recorded), itraconazole (25 mg every 24 hours), or ketoconazole (50 to 100 mg every 12 hours). The cat was otherwise in good health, and negative for feline immunodeficiency virus antibodies or feline leukemia virus antigen.

Surgical removal of the lesions necessitated excision of a strip of skin extending from the caudal thorax to the tail base, including all skin covering the dorsal aspect of the sacrum. The resulting defect was approximately 20 × 8 cm. It was not possible to mobilize sufficient local skin to close the caudal portion of the defect primarily, so an advancement flap was created using the left flank fold (Fig 1B). The medial and lateral attachments of the flank fold to the left limb were divided, and the lateral incision extended dorsally to join the caudal skin margin of the excision site. Mobilization and unfolding of the flank fold created a flap large enough to be advanced dorsocaudally into the sacral defect and sutured in place without tension (Fig 1C and 1D).

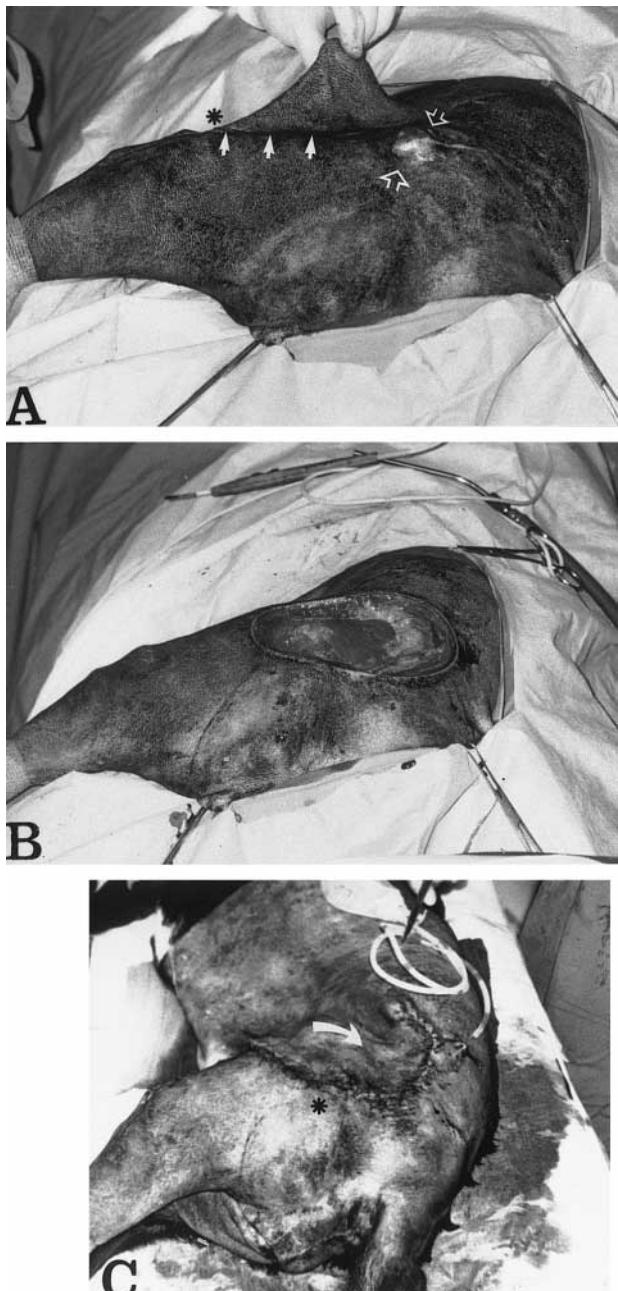
The cat recovered well from surgery, although development of a large hematoma at the operative site resulted in reduction of the packed cell volume to a nadir of 12%. It returned to normal by the time of suture removal. The entire skin flap remained viable and healed uneventfully. The cat was managed postoperatively with a variety of antifungal drug regimens (including the aforementioned drugs, terbinafine, and amphotericin B) that proved unsuccessful at eradicating the infection. At the time of writing, 3 years after surgery, the disease is controlled by administration of itraconazole (100 mg/d for 2 out of every 3 days).

### Case 2

An 11-year-old female spayed Labrador cross dog was presented for excision of a subcutaneous hemangiopericytoma over the greater trochanter of the left femur. The neoplasm had recurred after excision by another veterinarian (Fig 2A). A SFAF, created by dividing the attachments to the left hindlimb, was planned. The neoplasm and original surgical scar were removed en bloc with approximately 3 cm of normal skin laterally, and the underlying subcutaneous fat and superficial gluteal muscle (Fig 2B). The resultant defect was approximately 12 cm in diameter. The left flank fold was mobilized as planned, and the lateral incision extended to meet the caudal skin edge of the tumor excision site. The resulting SFAF was advanced dorsocaudally, enabling tension-free primary closure of the wound (Fig 2C). The incisions healed uneventfully, with survival of the entire flap. Histopathologic examination of the



**Fig 1.** (A) Pseudomycetoma lesions extending along the dorsal lumbar, sacral, and caudal region of a Chinchilla cat (open arrows). (B) Skin defect after excision of the lesions in (A). The left flank fold (F) has been mobilized by dividing its attachments to the hindlimb (arrows). The portion of skin previously residing at the point of the stifle is indicated by an asterisk. (C) The resulting flank fold flap is advanced dorsally and caudally into the sacral defect (curved arrow). (D) Postoperative view, showing that the defect has been closed by primary intention, and the suture line on the cranial aspect of the hindlimb where the flap was mobilized. Note the final location of the skin marked with the asterisk.



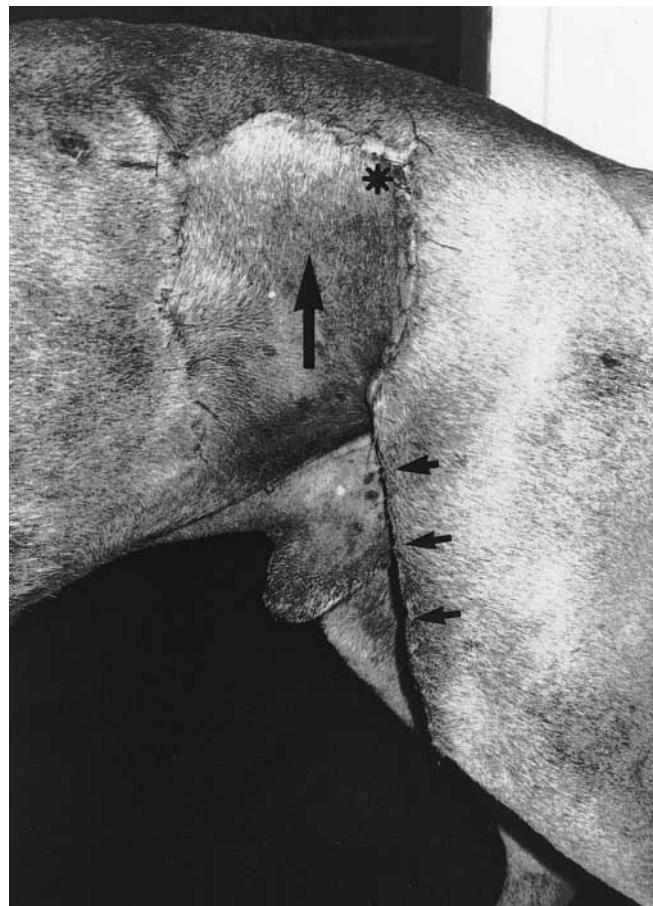
**Fig 2.** (A) Regrowth of a hemangiopericytoma at the site of original excision (open arrows). A flank fold advancement flap, created by dividing the attachments to the left hindlimb (arrows), is planned. An asterisk indicates the skin at the point of the stifle. (B) Wound resulting from excision of the lesion and old surgical scar in (A), with 3-cm margins. (C) The skin fold flap is mobilized as indicated in (A), and advanced dorsally and caudally (white arrow) to enable tension-free closure of the defect. Note the final location of the skin marked by an asterisk in (A).

surgical specimen showed excision to be complete. There was no evidence of recurrence at the time of writing, 9 months' postoperatively.

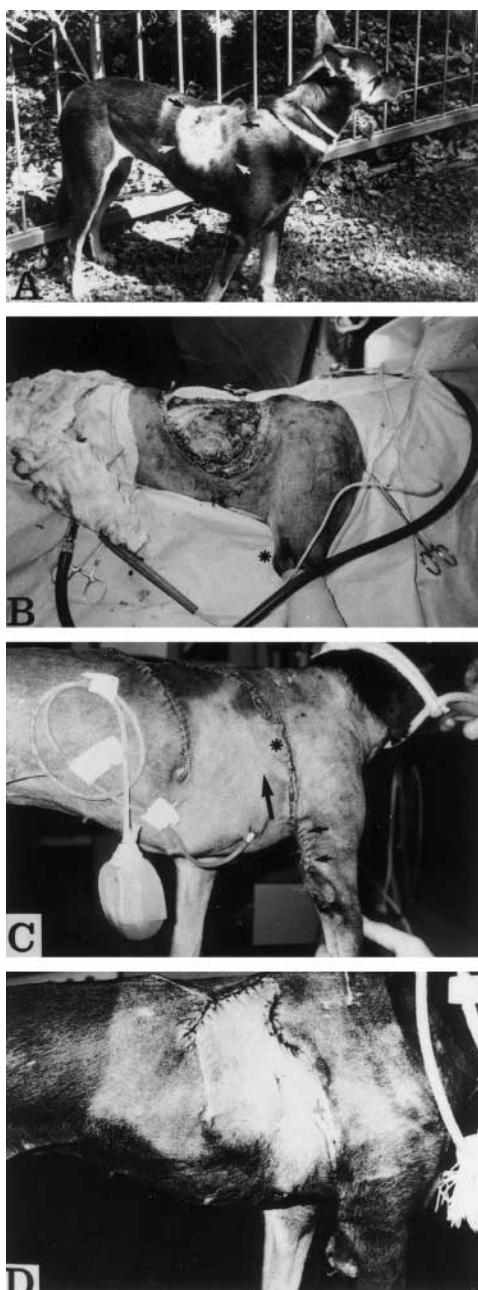
### Case 3

A 2-year-old female spayed DSH cat was referred for treatment of an extensive wound resulting from dog-bite injuries to the dorsal and lateral flanks. Necrosis of skin occurred over the entire left lateral flank to the level of the hip joint. The wounds were debrided repeatedly and left to heal by secondary intention (with frequent bandage changes). A healthy bed of granulation tissue was present by day 20. Although wound contraction substantially reduced the size of the skin defect, healing of the wound on the left caudal flank and thigh was impaired, presumably due to excessive limb movement.

A SFAF was created using the left flank fold. The dorsal and ventral attachments to the trunk were divided, and the flap unfolded caudodorsally into the granulating wound. This enabled closure of the defect, and release of the skin fold's attachments to the body reduced tension associated



**Fig 3.** Use of a dorsal flank fold advancement flap to close a defect in the left flank after excision of a hemangiosarcoma in a boxer. The flank fold has been divided from its attachments to the hindlimb (small arrows) and advanced dorsally (large arrow) to enable closure of the defect. The asterisk indicates skin that previously resided at the point of the stifle.



**Fig 4.** (A) Cutaneous pythiosis (arrows) in a 4-year-old Australian kelpie. The extent of the lesion is indicated by arrows. (B) Skin defect resulting from en bloc excision of the lesion in (A). The asterisk indicates skin residing at the point of the elbow. (C) The right elbow fold has been mobilized by dividing its attachments to the right front limb (small black arrows), and advanced dorsally (large arrow) to close the defect by primary intention. Areas of discoloration at the distal (dorsal) end of the flap proceeded to full-thickness necrosis. The asterisk indicates the final position of skin that previously resided at the point of the elbow. (D) The necrotic areas have been excised and the defects sutured.

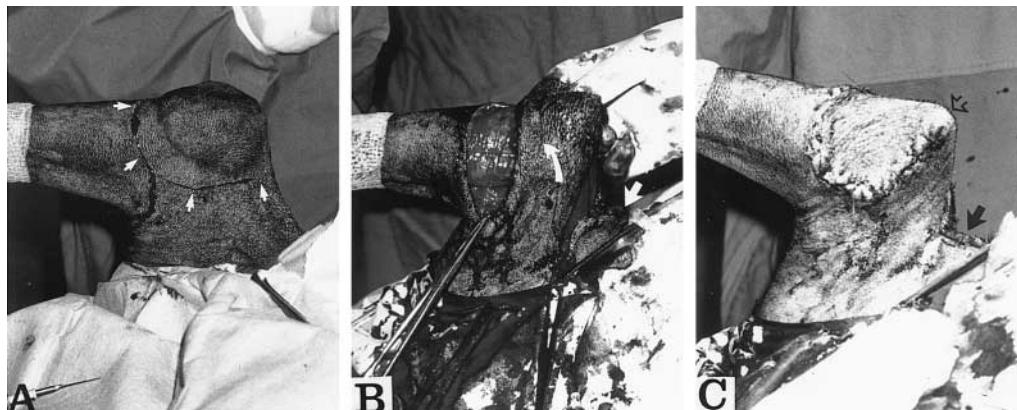
with limb movement. The wound healed by primary intention, with survival of the entire flap.

#### Case 4

A 9-year-old male castrated boxer was presented for treatment of a subcutaneous hemangiosarcoma of the left



**Fig 5.** (A) Closure of a skin defect created on the lateral aspect of the elbow by en bloc excision of a malignant round cell tumor. The elbow fold has been mobilized by dividing its attachments to the trunk (white arrows) and rotating it into the defect (curved arrow). (B) The wound has healed without complication.



**Fig 6.** (A) Excision of a hemangiopericytoma from the right elbow of a 9-year-old Labrador cross (arrows). (B) The right elbow fold is mobilized by dividing its attachments to the trunk (thick white arrow) and rotating it into the defect (curved arrow). (C) The wound has been closed without tension. The wound created by mobilization of the skin fold is indicated by the solid black arrow. Pressure necrosis occurred at the point of the elbow (open arrow), presumably as a result of removing the protective bandage too early. The resulting wound was later sutured and healed by primary intention.

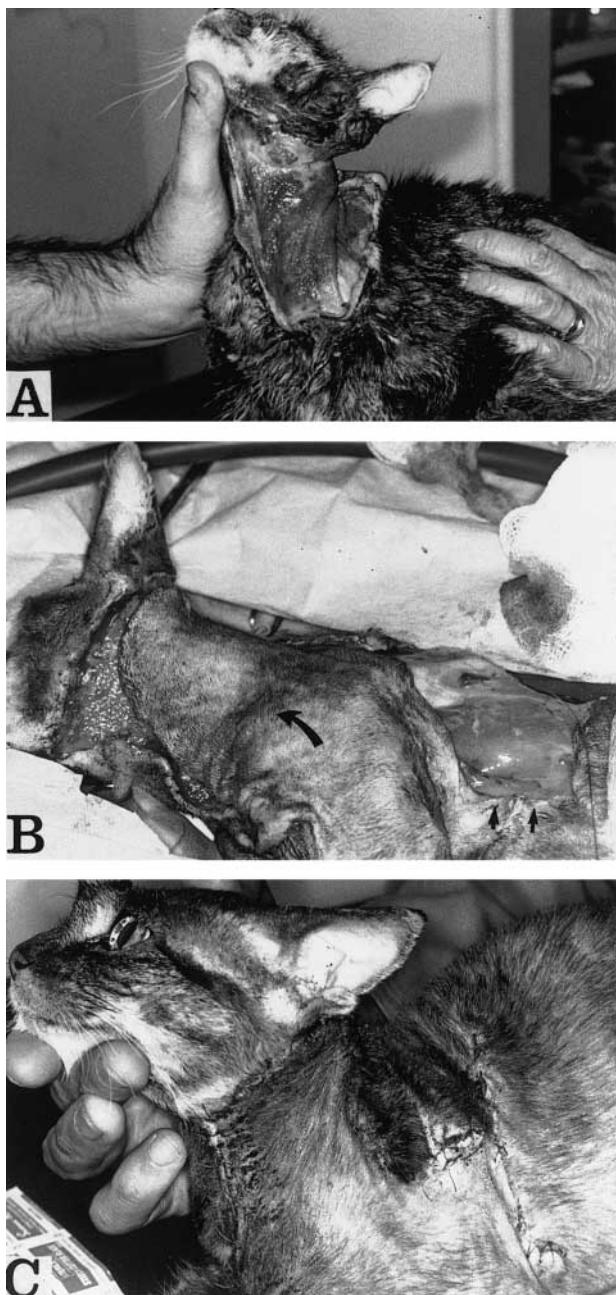
flank. On palpation, the neoplasm appeared to arise from either the lateral abdominal musculature or connective tissue. Thoracic radiography and abdominal ultrasonography failed to demonstrate evidence of metastatic disease. Although the long-term prognosis was considered guarded, the owners opted for surgical excision, followed by adjunctive chemotherapy.

The hemangiosarcoma was resected en bloc with 3-cm margins, necessitating removal of an approximately 12-cm-diameter segment of skin between the caudal rib and the iliac crest, and full-thickness excision of the underlying lateral abdominal wall. The defect in the abdominal wall was reconstructed using omentum and polypropylene mesh. The skin wound was closed using a SFAF created from the left flank fold, with its pedicle based ventrally. The medial and lateral limb attachments were divided, and the lateral incision continued dorsally to join the caudal skin margin of the excision site. The skin fold was then advanced dorsally and cranially to close the wound (Fig 3). Primary-intention healing occurred, with complete survival of the skin flap. Chemotherapy (doxorubicin,  $30 \text{ mg/m}^2$  intravenously every 3 weeks) was commenced at the time of suture removal; however, metastasis to the spleen and liver was detected 3 months' postoperatively, and the dog was euthanatized.

#### Case 5

A 4-year-old female spayed Australian kelpie (11 kg) was referred for treatment of cutaneous/subcutaneous pythiosis. The principal lesion was approximately  $12 \times 15 \text{ cm}$  in diameter, involving the skin and subcutis caudal to the right scapula (Fig 4A). A second lesion ( $5 \times 10 \text{ cm}$ ) also was present, caudal to the left scapula.

Treatment with itraconazole (100 mg every 24 hours with food) and amphotericin B (0.8 mg/kg every 3 days, diluted in 500 mL 0.45% saline and 2.5% glucose, and administered over 4 to 6 hours intravenously) was instituted, and resulted in reduced exudation from the lesions, but no decrease in size of the infected area. The main lesion was resected surgically (Fig 4B), and the wound closed using a SFAF created from the right elbow fold. The medial and lateral attachments of the skin fold to the limb were divided, and the lateral incision continued dorsally to meet the cranial edge of the excision site. The flap was unfolded and advanced dorsally, enabling primary closure of the skin defect without tension (Fig 4C). The cutaneous trunci muscle was detached from its origin to achieve the necessary amount of advancement. Regions of discoloration ( $4 \times 4 \text{ cm}$ ) were evident at the dorsal and cranial edges of the skin flap 2 days after surgery (Fig 4C), and these proceeded to full-thickness necrosis, suggesting that the limits of viability of a subdermal advancement flap in this location had been exceeded. During a second surgical intervention, the necrotic tissue was resected and the wound closed primarily (Fig 4D), and the left-sided lesion was resected and closed primarily. Recurrence of pythiosis at the site of excision of the left-sided lesion occurred 2 weeks later. At a third surgery, this lesion was resected. Treatment with itraconazole was continued throughout these interventions, but amphotericin B was replaced by liposomal amphotericin B starting at the time of the third surgery. The cutaneous lesions did not recur; however, the dog was euthanatized by the referring veterinarian 4 months after surgery for intestinal obstruction. Histologic examination of specimens obtained at necropsy confirmed intestinal pythiosis.



**Fig 7.** (A) Skin defect resulting from a cat-fight abscess. (B) Creation of a combined elbow fold/thoracodorsal flap. The ventral attachment of the elbow fold to the trunk has been divided (small black arrows) and the incision continued dorsally and caudally to include the landmarks of the thoracodorsal skin flap. The combined flap has been rotated cranially to close the wound by primary intention (curved arrow). (C) The wound has healed uneventfully with complete survival of the flap.

#### Case 6

An 8-year-old male rottweiler (49 kg) was referred for treatment of a 4-cm-diameter ulcerated callus on the lateral

aspect of the right elbow. Histopathology of the ulcer revealed a malignant round cell tumor. Fine-needle aspiration of a 1-cm-diameter nodule on the right thorax was suggestive of a mast cell tumor, and it was suspected that the elbow lesion was also a mast cell tumor.

The elbow lesion was resected en bloc with a 3-cm margin of normal skin, with subcutaneous tissue, periosteum, and partial corticectomy of the olecranon providing a deep tissue margin. The wound was reconstructed using a SFAF harvested from the right elbow fold. The dorsal and ventral trunical attachments were divided, enabling rotation of the SFAF into the excision site (Fig 5A). The thoracic mast cell tumor was also removed (with a 3-cm margin), and the wound closed primarily.

The elbow and thoracic wounds healed without complication (Fig 5B). Histopathologic evaluation of the surgical specimens confirmed complete excision of two grade II mast cell tumors. They had not recurred at the time of writing, 3 years after surgery.

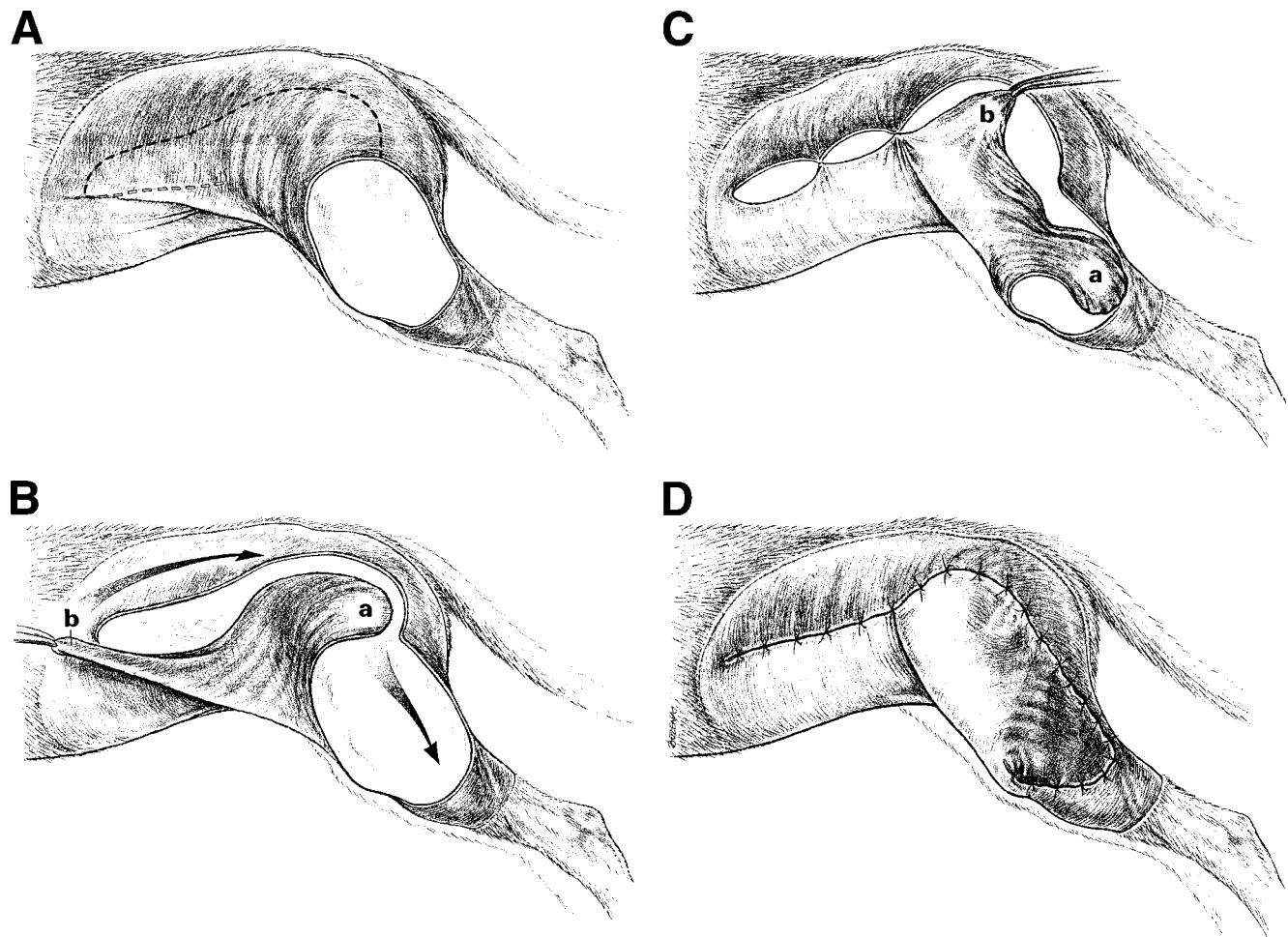
#### Case 7

A 9-year-old female spayed Labrador cross dog (27 kg) was presented for surgical excision of a 6-cm subcutaneous hemangiopericytoma from the caudomedial aspect of the left elbow. The mass was removed with wide skin margins (Fig 6A), the subcutaneous tissue, and the tensor fascia antebrachii muscle, forming a deep margin. The wound was reconstructed using a SFAF based on the left elbow fold. Division of the dorsal and ventral attachments to the trunk, and extension of the dorsal incision cranially to meet the dorsal skin edge of the excision wound, enabled advancement of the flap cranially to close the defect (Fig 6B and 6C).

The majority of the flap survived and healed well; however, full-thickness necrosis developed over the point of the olecranon. This was thought to have resulted from pressure necrosis, because the padded bandage was removed 48 hours after surgery rather than remaining in place for 10 to 14 days as planned. The resulting wound developed a healthy bed of granulation tissue and was closed surgically 4 weeks later. Histopathologic examination of the surgical specimen suggested that removal of the neoplasm had been complete. Recurrence had not occurred at the time of writing, 3 years after surgery.

#### Case 8

A 12-year-old female spayed DSH cat (2.6 kg) was presented for reconstruction of a large skin defect extending from the neck to the dorsal head that had resulted from a cat-fight wound infection 14 days earlier. The initial abscess had been treated with antibiotics and drainage, but there was progressive necrosis of overlying and adjacent skin neces-



**Fig 8.** Schematic representation of the creation of a skin fold flap for closure of a defect on the lateral stifle in a cadaver. (A-C) Division of the dorsal (closed, dashed line) and ventral (open, dashed line) attachments of the flank fold to the trunk enables caudal and distal advancement of the SFAF into a large skin defect (arrows). Movement of the skin at the site of the bridging incision between the flank fold and the skin defect (a) and the cranial extent of the flank fold (b) can be seen in (B and C). (D) Final result after skin suturing.

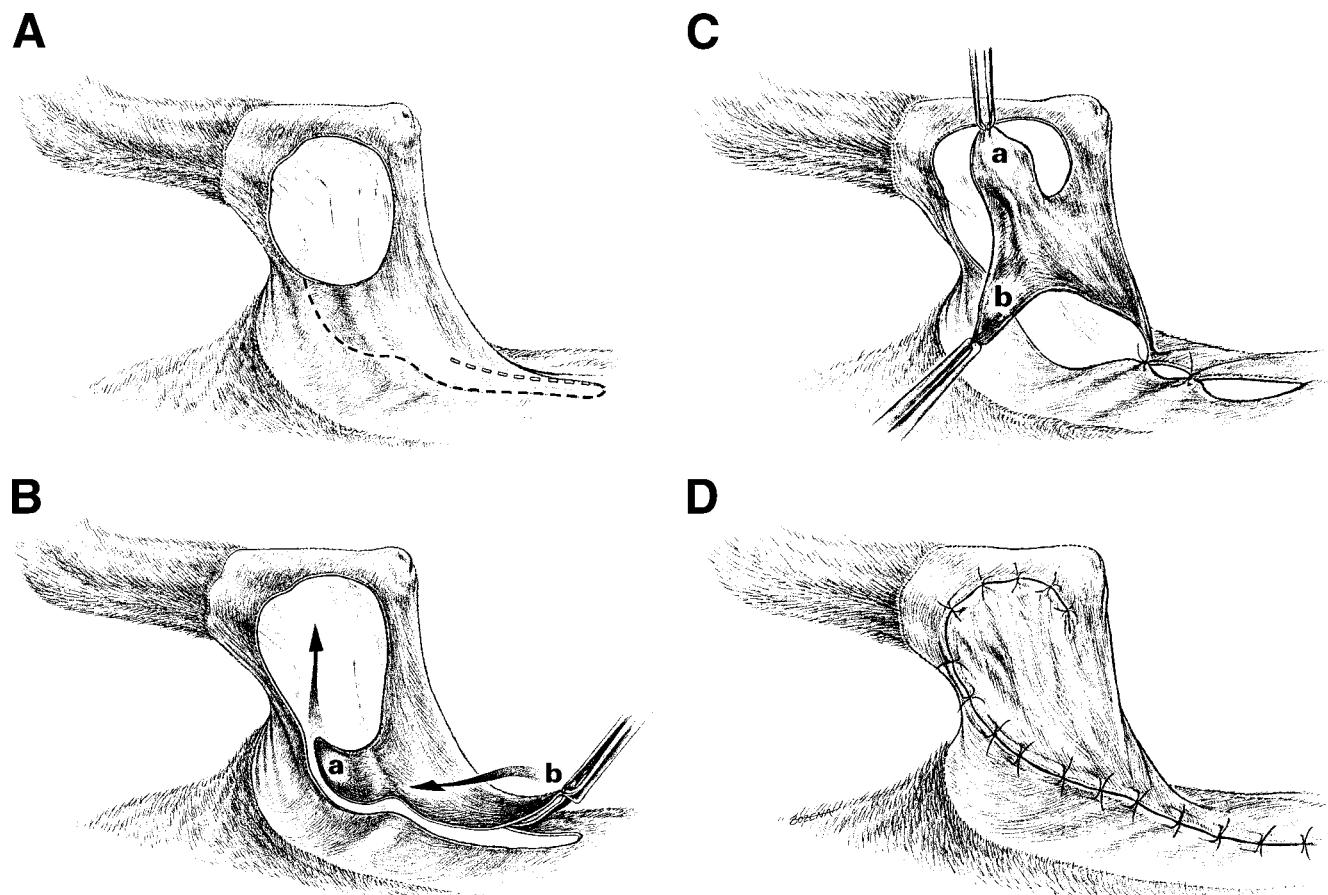
situting multiple debridements. At the time of referral, the wound bed was covered with healthy granulation tissue. Wound contraction had commenced, but skin was still absent from the entire left side of the neck, extending from the cranial border of the left scapula to the caudal angle of the left mandible, and from the dorsal midline to the jugular furrow on the right (Fig 7A).

The skin defect was closed using a combined thoracodorsal axial pattern flap and left elbow SFAF. The ventral truncal attachment of the elbow fold was divided, and the incision continued caudodorsally using the described landmarks for the thoracodorsal axial pattern flap.<sup>3</sup> The cranial incision of the thoracodorsal flap was continued cranially to join the dorsal edge of the skin defect. During surgical mobilization of the skin fold, it became apparent that the flap was supplied by the lateral thoracic artery, suggesting that in this circumstance, where the pedicle of the flap is

attached to the limb, rather than the trunk (eg, case 5) the elbow skin fold flap may function as an axial pattern flap. The combined thoracodorsal/elbow fold flap was rotated cranially and dorsally, and reached easily to the base of the ears, enabling closure of almost the entire defect without tension (Fig 7B). The flap survived and healed uneventfully (Fig 7C). The head wound healed slowly, but completely, by secondary intention.

#### *Other Uses of the Elbow and Flank Fold*

The SFAF may also be used in locations other than those demonstrated by the present series of cases. Figures 8 and 9 are schematic representations of SFAFs being used to close defects in cadavers on the lateral aspect of the stifle, and medial aspect of the upper forelimb, respectively.



**Fig 9.** Schematic representation of a flap similar to that shown in Fig 5, used for closure of a defect on the medial aspect of the proximal forelimb. (A–C) Division of the dorsal (open, dashed line) and ventral (closed, dashed line) attachments to the trunk enables cranial advancement of the skin fold into the defect (arrows). Letters (a and b) indicate the original and final position of skin at the cranial and caudal ends of the skin fold flap, respectively.

#### Postoperative Management

In all animals, Penrose or closed suction drains were placed beneath the skin flaps, and maintained in place until drainage ceased (usually 2 to 3 days following surgery). Repeated doses of opioids (typically 0.1 mg/kg morphine increments intravenously) were required in all cases, suggesting that formation of these flaps is a painful procedure. The wounds were supported with soft, absorbent bandages that exerted gentle pressure on the surgical site, reducing postoperative discomfort, restricting movement, and discouraging fluid accumulation. The bandage was usually maintained for at least 7 days, and until suture removal (14 days) in some instances. Antibiotics (usually amoxicillin clavulanate, 12 to 20 mg/kg intramuscularly or orally every 8 to 12 hours) were administered preoperatively, and for up to 3 days postoperatively, depending on the primary disease process. In cases 3 and 8, in which contamination of the granulation tissue bed with *Pseudomonas* sp was evident before surgery, enrofloxacin (5 mg/kg every 12 hours) was administered in addition to amoxicillin/clavulanate, preop-

eratively and for 7 days postoperatively. Wound infections were not seen in any patient, although significant extravasation of blood occurred beneath the flap in case 1 and a small seroma (which resolved without treatment) developed in case 5.

#### DISCUSSION

The mobile skin of dogs and cats lends itself to transposition of large pedicle or free grafts. Thus, a number of different strategies exist for closing wounds of the trunk and upper limbs. Primary closure of large defects on the limbs and sacrum usually involve creation of axial pattern flaps, with the donor site extending a considerable distance from the initial wound.<sup>3–7</sup> The present series of cases demonstrates that SFAFs may be used successfully to close large skin defects in a number of sites other than those reported initially.<sup>1</sup> In view of the fact that 100% flap

survival occurred in all but 2 cases of this report, it seems that survival of these SFAFs is likely to be at least as good, if not better, than results previously reported for axial pattern flaps.<sup>7</sup> In most instances, they are used as local flaps; however, cases 1, 5, and 8 illustrate how they may be used to mobilize distant skin attachments, and thus enable local skin to be advanced a considerable distance into a wound.

The flaps in our patients remained viable in almost all instances, the exceptions being the flap covering a bony prominence that was not adequately protected postoperatively, and the large elbow fold flap used to reconstruct a lateral thoracic wound, in which the presence of subcutaneous cutaneus trunci muscle may have presented extra demands on the flap's vascular supply. Because SFAFs usually derive their blood supply from the subdermal vascular plexus, surgeons should take care to preserve an adequate pedicle during creation of the flaps. However, our observations suggest that the elbow fold, when carefully mobilized, may actually be an axial pattern flap, supplied by the lateral thoracic artery. This is distinct from the thoracodorsal artery, which is located more dorsally on the trunk. The amount of skin that might be harvested from this site, the vascular anatomy, and exact guidelines for mobilizing it for this purpose, are therefore worthy of further investigation.

When creating SFAFs, surgeons should ensure that all subcutaneous attachments are divided to facilitate exploitation of the skin fold's considerable elasticity. When unfolded and undermined, the flaps stretch to produce a much greater quantity of skin than might be expected by observing them in their natural position. It is also essential to adequately divide the attachments to either the limb or trunk to enable them to be moved through their maximal range and eliminate tension associated with limb movement. Flap failure may result from a number of

technical errors, including excessive tension, compromised vascular supply due to poor surgical technique or extending the flap beyond the physical limits of its blood supply, or inadequate postoperative protection.

Familiarity with a repertoire of reconstructive procedures, including the SFAF, enables surgeons to confidently perform wide excision of lesions in a variety of locations. While most surgeons are comfortable performing en bloc resections for neoplastic disease, the SFAF has assisted us in developing an "oncologic" approach to treatment of infectious lesions, combining wide excision with adjunctive therapy.

## ACKNOWLEDGMENT

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