CHAPTER EIGHT

Axial Pattern Flaps

Лuclrey Remedios

INTRODUCTION

Large skin wounds, arising from trauma or surgical excision, can present reconstructive problems to the veterinary surgeon. The amount of local skin tension and the paucity of adjacent tissue may preclude primary closure of wounds, especially those involving the head, limbs and perineal regions. Other management options include second intention healing, tissue expanders, skin grafts and skin flaps. Second intention healing is associated with prolonged healing time and may result in a fragile epithelial surface and excessive wound contracture. Tissue expanders are implanted in the subcutaneous space and slowly expand the skin adjacent to a wound (Madison *et ai,* 1989). The redundant skin is then used to reconstruct the defect. Some disadvantages of expanders are implant cost, expander failure, and wound dehiscence and expander exposure. Free skin grafts are avascular and require optimal recipient beds and rapid revascularization for survival. Accordingly, traumatic wounds often require prolonged periods of open management prior to skin graft transfer. Skin flaps, which retain intact circulation from donor sites, are used in early wound reconstruction of suboptimal wound beds and are associated with fewer complications than second intention healing, tissue expanders or grafts.

BLOOD SUPPLY TO THE SKIN

In the dog and cat, the cutaneous circulation is connected to deep segmental vessels by direct cutaneous arteries and veins. These direct cutaneous vessels travel through intermuscular fascial septae and run parallel to the overlying skin at the subdermal level. Each direct cutaneous artery supplies an angiosome, or territory, composed of the superficial cutaneous musculature, subcutaneous tissue and skin (Figure 8.1).

The subdermal plexus is the major conduit of arterial supply to the skin. Where a layer of cutaneous muscle is present, the subdermal plexus lies both superficial and deep to it. In small animals, the major cutaneous muscles include the cutaneous trunci, platysma, sphincter colli superficial, prepucialis and supramammaricus muscles. Where the panniculus muscle is absent, such as in the middle and distal portions of the limbs, the subdermal plexus courses in the subcutaneous tissue on the deep face of the dermis. Branches from the subdermal plexus ascend to supply the dermis and epidermis. Thus, disruption of the subdermal plexus impairs circulation to the superficial skin layers.

CLASSIFICATION OF SKIN FLAPS

Skin flaps are classified according to blood supply as axial pattern or subdermal plexus. Axial pattern flaps are based on the angiosomes of direct cutaneous arteries and veins. All tissues within a defined

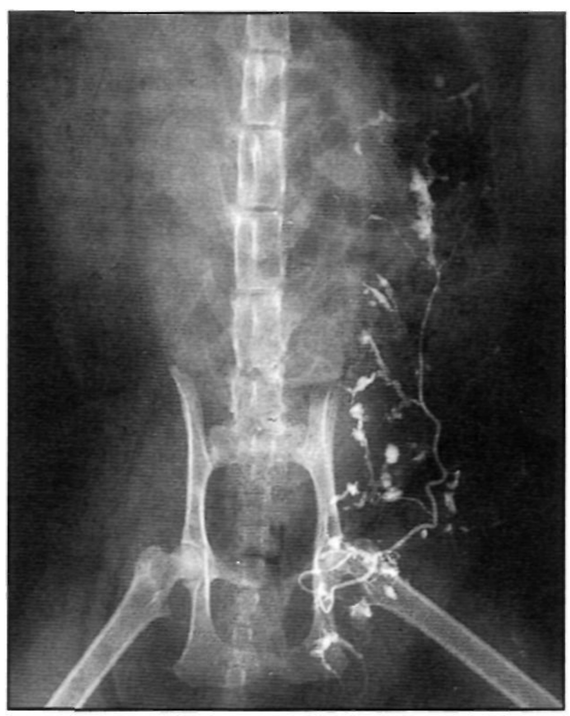


Figure 8.1: Selective angiography of the vascular territory of the caudal superficial epigastric artery. This vessel supplies the glandular and subcutaneous tissue and skin of mammary glands 2, 3, 4 and 5 in the cat.

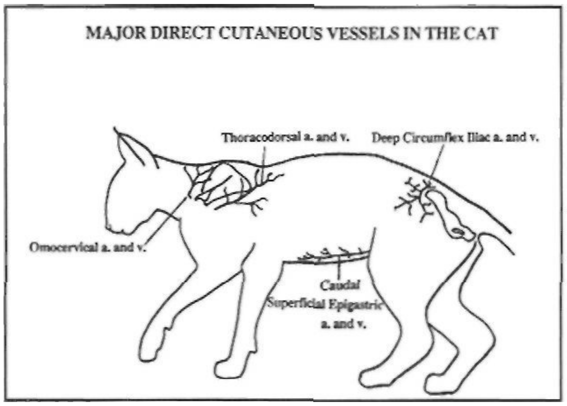


Figure 8.2: Identification of direct cutaneous vessels and their associated axial pattern flaps has been reported in the cat and dog. Such skin flaps can be used to reconstruct wounds involving the head and neck, the forelimb, the hindlimb and perineal regions.

vascular territory can be elevated from the body and will survive as long as the direct cutaneous vascular pedicle remains intact. Direct cutaneous arteries that sustain a large area of skin allow the development of axial pattern flaps of considerable length without vascular compromise. Subdermal plexus flaps are dependent upon terminal branches of the cutaneous circulation. As such, subdermal plexus flaps are limited in length when compared to axial pattern flaps. The mean survival area of axial pattern flaps is 50% greater than that of similarly sized subdermal plexus flaps.

AXIAL PATTERN SKIN FLAPS

Each axial pattern flap is based on the vascular territory supplied by distinct direct cutaneous vessels (Taylor and Palmer, 1987). These vessels and their angiosomes have been identified and mapped in the dog and cat (Figure 8.2). In general, the location of each vascular pedicle and the relative sizes of the supplied territories are similar in dogs and cats. However, the extremely pliable feline skin and similarity in body size and limb length facilitates more distal limb coverage provided by axial pattern flaps in cats than dogs.

Because axial pattern skin flaps have an excellent blood supply, they have several advantages over other methods of reconstruction:

- Axial pattern flaps can cover most large defects using one-stage procedures
- They have excellent survival rates, ranging from 96-100%
- Unlike free skin grafts, axial pattern flaps can be used to reconstruct indicated wounds associated with less than optimal conditions such as contamination, uneven surfaces or exposed bone, tendon and cartilage
- Early wound reconstruction without prolonged periods of open wound management is feasible
- The blood supply associated with axial pattern flaps minimizes the risk of postoperative infection. In instances of infection, overall flap survival is not adversely affected if treated with appropriate antibiotics (Trevor *et ai,* 1992)
- Axial pattern flaps are relatively simple to dissect and do not require specialized equipment.

There are some disadvantages associated with axial pattern flaps:

- Extensive surgical dissection of the donor bed is required for flap elevation
- Closure of the donor bed may require undermining and walking sutures to appose the surgically created defect
- The cosmetic appearance of the recipient area differs from that of the surrounding skin: characteristics such as hair direction, colour and length, glandular formation and the amount of subcutaneous fat are retained from the donor site (Figure 8.3).

Figure 8.3: A caudal superficial epigastric flap has been rotated from the ventral abdomen to cover a distal tibial defect in a cat. This axial pattern flap is transferred with its associated mammary glands and subcutaneous fat. Direction of fur growth is different from the recipient bed.

Figure 8.4: Prior to surgery; the limits of the caudal superficial epigastric flap are drawn on the skin with a felt-tipped marker.

Preoperative considerations

The cause and nature of a wound are important preoperative considerations that influence the appropriate time of closure. Surgically created defects, most commonly associated with tumour excision, are usually clean wounds. Because these wounds are uncontaminated and devoid of residual necrotic tissue, axial pattern flaps can be harvested and transferred directly on to the fresh wound bed. Traumatic wounds are contaminated or dirty, and are often associated with continued tissue necrosis for several days after injury. Such wounds often require several days of open management prior to delayed primary reconstruction using an axial pattern flap.

Adequate planning must be undertaken prior to dissection of axial pattern flaps. It is essential to know which flaps are most appropriate given the size, dimensions and location of the wound. The vascular limits of each flap determine the size and length of flap that can be harvested and transferred to an adjacent or distant location. Preoperatively, measurements should be taken to ensure the length and size of flap can reach and cover the wound. A smaller flap, less than total vascular flap territory, can be raised if dictated by the size and location of the wound. However, with large skin defects, all possible flap designs and methods of reconstruction should be considered. For example, closure of a large wound involving the perineal area may require an axial pattern in conjunction with a subdermal plexus flap; coverage of an extensive limb wound may require both an axial pattern flap and skin graft. For distant skin wounds, an extended axial pattern flap that incorporates an adjacent angiosome can be harvested. Blood supply between the additional angiosome and the primary flap is maintained by anastomotic 'choke' vessels. These communications, however, are fragile, and survival of the entire extended flap is less predictable than the primary flap.

It is essential to know the following: the anatomical landmarks associated with the location of the vascular pedicle; the direction in which these vessels travel in relation to the underlying tissues; and the boundaries of vascular territory. A felt-tipped marker should be used preoperatively to delineate the anatomical location of the vascular pedicle and the limits of the flap (Figure 8.4). The patient must be positioned carefully prior to outlining the proposed flap, since skin distortion may alter the relationship of the skin to the underlying anatomical landmarks.

Axial pattern flaps can also be harvested as peninsular or island configurations. Peninsular axial pattern flaps are incised at each flap edge but retain a border of intact skin directly adjacent to the vascular pedicle (Figure 8.5). Mobility of the peninsular flap is decreased because of the skin attachment. Island axial pattern flaps have no cutaneous attachments and are connected to the donor bed only by the direct cutaneous artery and vein (Figure 8.6). The island configuration enhances flap mobility and prevents 'dog-ear' formation at the flap base. However, the vessels lose some protection from the overlying skin and may be kinked or placed under tension more easily during flap rotation. Island flaps and peninsular axial pattern flaps have similar survival areas.

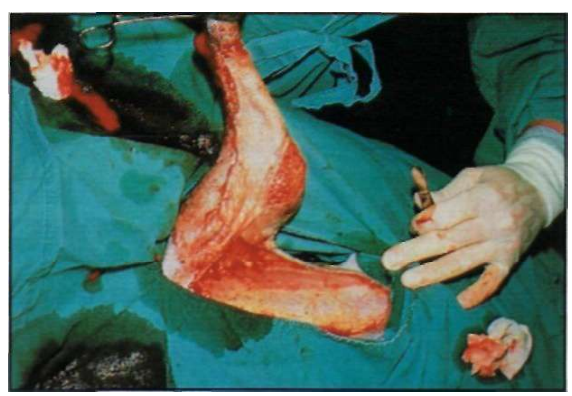


Figure 8.5: The peninsular axial pattern flap retains a border of intact skin directly adjacent to the vascular pedicle. This caudal superficial epigastric flap maintains connection to the skin in the area of the inguinal ring where the vacular pedicle emerges. Rotation of this flap distally is limited by the peninsular configuration.

Figure 8.6: This caudal superficial epigastric flap is harvested in an island configuration and does not retain any cutaneous attachments. Although rotation of this flap is enhanced, care has to be taken to avoid kinking the vessels.

Flap dissection

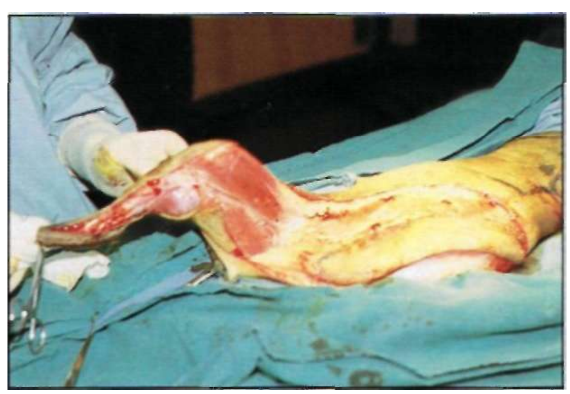
This is done in the following way:

1. Dissection of an axial pattern flap begins with sharp incision of the flap borders followed by elevation of the flap
2. It is easiest and safest to establish the plane of dissection at the border furthest from the vascular pedicle. The level of surgical dissection should always be beneath the cutaneous muscle layer so as to preserve the subdermal plexus. In areas devoid of this muscle, such as the middle to distal limbs, dissection should be performed in the deep subcutaneous layer
3. Once the appropriate tissue plane is identified, elevation of the entire flap is performed, using sharp scissor dissection, towards the vascular pedicle. Haemostasis can be achieved using electrocautery. Upon approaching the direct cutaneous artery and vein, dissection must proceed cautiously to avoid inadvertent laceration of these vessels
4. The vascular pedicle does not have to be entirely exposed; rather, a surrounding cushion of subcutaneous fat can be left in place
5. The entire axial pattern flap is rotated to cover the wound. It is important that the vascular pedicle is not kinked or placed under tension during flap transfer and rotation. Flap rotation up to 180 degrees can be performed safely
6. Wounds that are located distant to the donor bed require a bridging excision of intact skin to connect the donor and recipient sites (Figure 8.7)
7. Prior to closure, passive or active drains are placed within the recipient bed
8. Subcutaneous tacking sutures are best avoided at the recipient site to prevent inadvertent impairment of the flap vasculature. Subcutaneous walking sutures are, however, useful to decrease dead space, diminish tension and appose the skin edges in the donor bed
9. The flap borders are sutured on to the recipient borders using several simple interrupted skin sutures to tack the flap into position. The remaining incision lines can be filled in rapidly using a series of simple continuous sutures or skin staples. The skin edges of the donor bed are closed routinely.

Postoperative considerations

The most common postoperative complications associated with axial pattern skin flaps are oedema, seroma formation and poor wound drainage (Trevor *et al,* 1992). These problems arise as a consequence of the extensive soft tissue dissection performed at the donor and recipient beds. Passive or active suction drains are placed for at least 3-4 days after surgery to decrease dead space and prevent seroma formation. The application of soft padded bandages protects drains from contamination, decreases dead space and helps to prevent fluid accumulation. Soft padded bandages must be applied without excessive tension to prevent compromise of the flap's pedicle.

Other complications that can occur following the use of an axial pattern flap are distal flap necrosis, dehiscence and infection. Errors in preoperative plan-



Figttre H. 7: This distal tibial wound required a bridging excision over intact skin on the medial side of the femur to connect the donor bed (caudal superficial epigastric flap) to the recipient one.

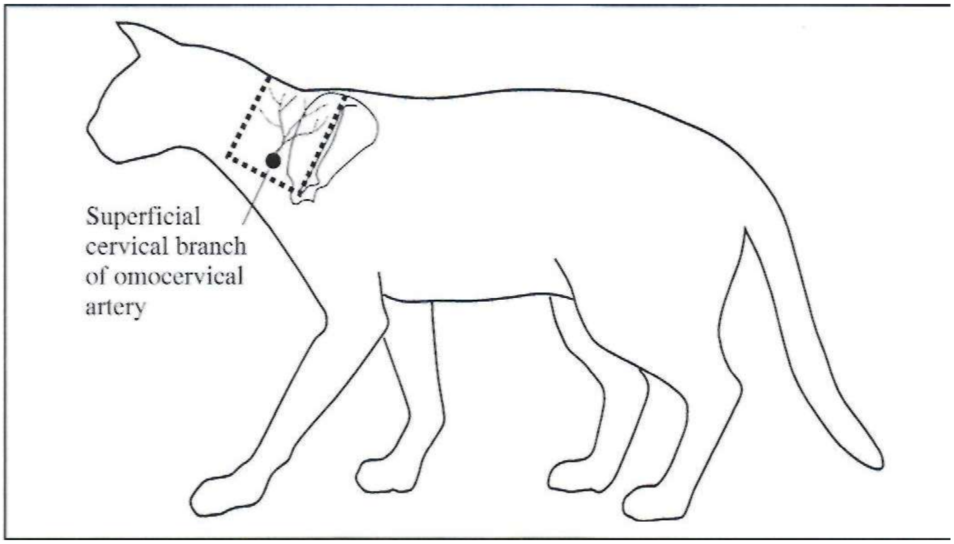


Figure 8.8: The superficial branch of the omocervical artery; used in the omocervical flap originates at the prescapular lymph node and branches craniodorsally. This flap is hardy and very useful in head and neck reconstruction.

ning may lead to a flap that exceeds its vascular territory, resulting in distal necrosis and dehiscence. Postoperative infection is not common, due to the excellent blood supply provided by axial pattern flaps. If infections do occur, dehiscence at the flap-recipient skin edge is an early and prominent clinical feature. Drainage, debridement, lavage and appropriate antibiotic administration are required. With control of local infection, the overall survival of axial pattern skin flaps is not adversely affected.

Head and neck reconstruction

Axial pattern flaps for the reconstruction of head and neck wounds include the omocervical, the superficial temporal and the caudal auricular flaps (Pavletic, 1981; Smith *etai,* 1991; Fahie and Smith, 1997).

Omocervical flap

The axial pattern flap which is based on the superficial cervical branch of the omocervical artery is often referred to as the omocervical flap. This vessel originates at the prescapular lymph node and radiates craniodorsally (Figure 8.8):

1. After the patient is anesthetized and placed in lateral recumbency with the forelimb, head and neck at natural angles, the cranial shoulder depression is identified (Figure 8.9). This point denotes the emergence of the superficial cervical branch of the omocervical artery from the deep vasculature. A line from the distal aspect of the prescapular lymph node to the acromion defines the ventral flap limit
2. The dorsal edge is formed by the dorsal midline. The cranial limit of the flap is at a point equal to the distance between the cranial shoulder depression and the scapular spine. This border extends dorsally, parallel to the scapular spine. The caudal border is a line parallel with the spine of the scapula. After delineation of the edges with a marker, the flap borders are incised sharply
3. Dissection is commenced at the dorsal border first and the flap is elevated in a dorsal to ventral direction, at a level below the sphincter colli superficialis muscle. As elevation nears the ventral border and the emergence of the superficial cervical artery, dissection must proceed cautiously
4. The donor and recipient beds can be connected by a bridging excision of intact skin lying between these two areas (Figure 8.10a)
5. Following rotation of the flap and drain placement, the flap is tacked into place with a

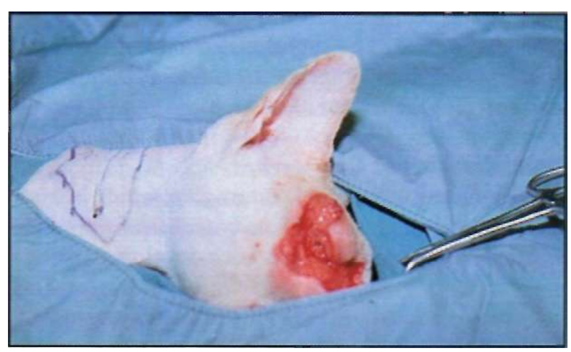


Figure 8.9: This patient required facial reconstruction following extensive orbital and periorbital tumour excision. The cranial shoulder depression is identified as the point of emergence of the superficial branch of the omocervical artery. The flap borders are then delineated. A line from the prescapular lymph node to the acromion defines the ventral flap limit. The dorsal edge is formed by the dorsal midline. The cranial limit of the flap is at a point equal to the distance between the cranial shoulder depression and the scapular spine. This border extends dorsally. parallel to the scapular spine. The caudal border is a line parallel with the scapular spine.

Courtesy of Dr D. Fuller

few simple interrupted sutures, and the remaining edges apposed
6. The donor bed is closed primarily (Figure 8.10b).

This reliable and versatile flap can be used to cover defects that involve the face, head and ear.

For large facial defects, extended omocervical flaps can be raised. This configuration incorporates the contralateral omocervical angiosome, thus creating a flap of sizeable dimensions:

1. Dissection of this extended flap proceeds as in the primary omocervical flap except that the flap borders continue across the dorsal midline to the contralateral shoulder depression
2. At this point, the contralateral superficial branch of the omocervical artery is identified and ligated
3. The flap is then rotated to cover any facial defects that are located rostrally in the nasal, mandibular and maxillary regions.

Superficial temporal flap

An axial pattern flap based on the superficial temporal artery has been described experimentally in cats to reconstruct maxillofacial skin defects (Fahie and Smith, 1997). At the moment, there is minimal clinical information describing the use of this technique. The superficial temporal artery, a terminal branch of the external carotid artery, supplies the frontalis muscle and skin of the temporal area. This vessel emerges at the ventral base of the auricular cartilage and travels dorsally. The lateral orbital rim defines the rostral limit of the flap and the caudal limit is the further caudal aspect of the zygomatic arch. The lateral limits extend to the dorsal orbital rims of the right and left eye. Elevation should be performed below the level of the frontalis muscle. The superficial temporal flap has a similar area of coverage as the omocervical, as both will reach to the rostral nasal area.

Caudal auricular flap

The caudal auricular axial pattern flap, which is based on the stemocleidomastoideus branches of the caudal auricular artery and vein, has been developed in dogs:

1. The stemocleidomastoideus branches originate from the caudal auricular artery at its base on the ventrolateral surface of the annular cartilage. The vessels then course caudally to supply the skin of the neck
2. The stemocleidomastoideus branches can be difficult to identify, and extreme care should be taken when dissecting the base of the flap
3. Harvesting a peninsular axial flap which retains an intact skin border at the base may prevent damage to these fragile vessels. The lateral aspect of the wing of the atlas forms the cranial border of the flap. A line starting at a point halfway along the scapular spine and extending dorsally defines the caudal border. Two parallel lines extending from the atlas to the scapular spine form the dorsal and ventral limits. Elevation should be performed below the level of the platsyma muscle
4. After rotation, this flap could potentially be used to cover defects of the head and neck.

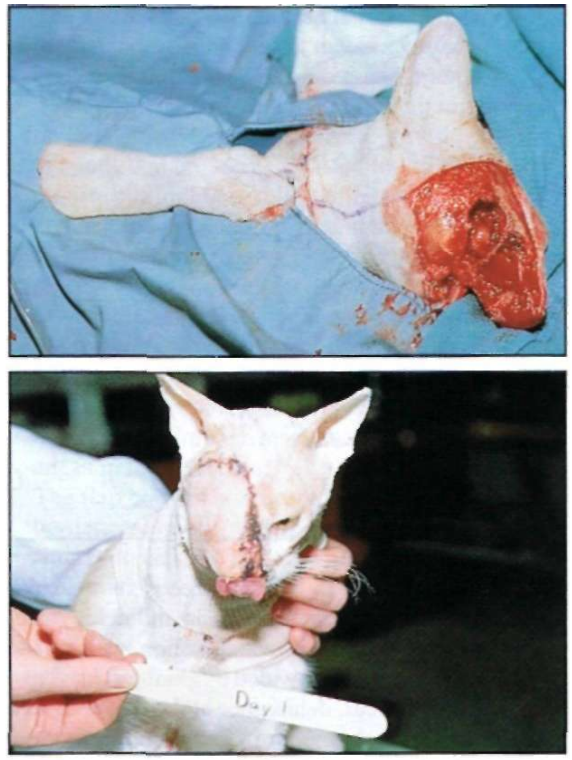


Figure 8.10: Following elevation and rotation, the flap is sutured into place with a combination of simple interrupted and continuous sutures. The donor bed is closed primarily.

Courtesy ofD. Fowler.

Forelimb reconstruction

Axial pattern flaps used in the cutaneous reconstruction of forelimb wounds in small animals include the thoracodorsal and superficial brachial flaps (Pavletic, 1981; Shields Henney and Pavletic, 1988; Remedios ex «/., 1989).

Thoracodorsal flap

The thoracodorsal flap is based on a cutaneous branch of the thoracodorsal artery and vein. These vessels emerge from the intermuscular fascia at the caudal shoulder depression, approximately at the level of the acromion. The vessels then branch and travel caudodorsally (Figure 8.11). The cranial limit of the thoracodorsal flap is defined by a line extending along the scapular spine dorsally. The caudal edge is parallel to the cranial incision and originates at a point approximately equal to the distance from the scapular spine to the caudal shoulder depression. The ventral limit is

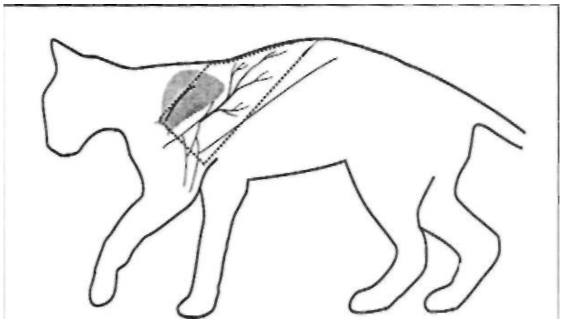


Figure 8.11: The thoracodorsal artery emerges at the caudal shoulder depression and radiates caudodorsally. The cranial limit of the thoracodorsal flap is defined by the scapular spine. The caudal edge is parallel to the cranial incision and originates at a point equal to the distance from the scapular spine to the caudal shoulder depression. The dorsal border is the midline and the ventral border is marked by a line extending from the acromion to the axilla.

marked by a line extending from the acromion caudal ly to the axilla. The dorsal border is defined by the dorsal midline, although the contralateral angiosome can be harvested to increase Πap dimensions:

1. With the patient in lateral recumbency and thoracic limb positioned to simulate a natural standing angle, the borders of the thoracodorsal flap are drawn on the skin surface (Figure 8.12)
2. The location of the vascular pedicle at the caudal shoulder depression should be palpated and identified accordingly
3. Dissection of the thoracodorsal flap starts at the dorsal midline and extends, below the level of the cutaneous trunci muscle, towards the ventral border

Figure 8.12: The borders of the thoracodorsal flap are drawn on the skin surface with a felt-tipped marker.

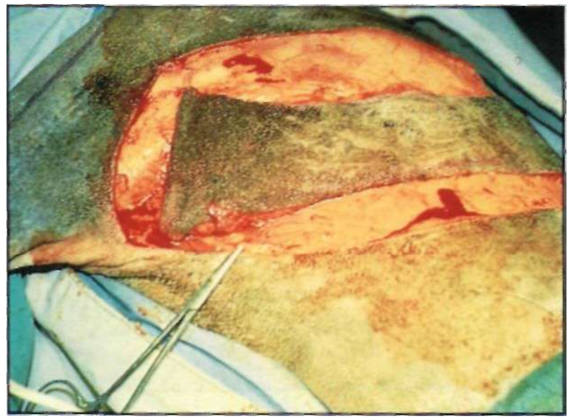


Figure 8.13: The borders of the thoracodorsal flap are incised. Dissection should begin at the dorsal edge and proceed ventrally. At the vascular pedicle (the location is denoted by the haemostat). the surgeon should exercise caution.

4. Initially, surgical elevation of the flap can be rapid, but as the vascular pedicle is approached, cautious and meticulous dissection should be performed (Figure 8.13)
5. To avoid thrombosis and damage, the vascular pedicle does not have to be completely stripped of surrounding fat; rather, isolated only to achieve adequate mobility (Figure 8.14a)
6. After elevation, the thoracodorsal flap is rotated to cover defects of the thorax, shoulder and axillary regions.

However, the most clinically useful application of the thoracodorsal flap is in reconstruction of forelimb defects (Figure 8.14b,c). The rotated thoracodorsal flap reliably covers the mid- to distal antebrachium in dogs and the proximal carpus in cats (Figure 8.15).

Extended thoracodorsal flaps that incorporate adjacent angiosomes have been described. Dissection of these flaps extends over the dorsal midline to the contralateral thoracodorsal vascular pedicle. As the adjacent angiosome depends upon choke communications with the primary flap, distant survival of these extended flaps is less reliable.

Superficial brachial flap

The superficial brachial Πap has been described, to reconstruct skin defects involving the lower antebrachium of dogs. The superficial brachial artery emerges at a point 3 cm cranioproximal to the elbow, travels medial to the cephalic vein and branches to the skin of the craniodistal humerus. The base of the flap is centred over the cranial flexor surface of the elbow. The flap extends and tapers proximally to the greater tubercle, parallel to the shaft of the humerus.

The superficial brachial artery is a small diameter vessel and is difficult **to identify** intraoperatively. These conditions **limit the clinical** application of this flap as it is susceptible to vascular damage and