Lateral Thoracic Artery Axial Pattern Flap in Cats

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Objective—To describe the location of the lateral thoracic artery (LTA), determine dimensions of an axial pattern flap based on this artery, and report use of this flap in 2 cats.

Study Design—Ex vivo study and case reports.

Animals—Cat cadavers (n = 8); cats (n = 2) with thoracic limb skin defects.

Methods—Dissection of the LTA was carried out on 1 side of each cadaver and the contralateral side was used for injection studies. In 4 specimens, the LTA was cannulated and injected with positive contrast material and the flap was raised and radiographed. In 4 specimens, the flap was injected with methylene blue. Adequacy of flap injection was subjectively evaluated and leakage of methylene blue from the cut edge was noted.

Results—The cutaneous location of the LTA caudal to the triceps muscle was confirmed. Mean flap size was 8.7 cm × 15.5 cm for a mature, averaged-sized cat. Perfusion of the entire flap was demonstrated and viability of the flap was confirmed in 2 clinical cases.

Conclusion—The LTA flap is useful for repair of skin defects of the brachium and antebrachium in cats.

Clinical Relevance—The LTA flap is an alternative technique for repair of skin defects involving the thoracic limb of cats.

INTRODUCTION

Closure of skin defects on distal extremities can be a surgical challenge because skin on the extremities is sparse, with high motion areas located over joints. Free skin grafts may be used to treat defects; however, an ideal recipient bed and complete immobilization are required for graft survival. Skin flaps are also suitable for treatment of extremity skin defects. Skin flaps have an intact circulation and may be used in areas with poor vascularity and where immobilization is undesirable.

Skin flaps can be random subdermal plexus flaps or axial pattern flaps based on their blood supply. Axial pattern flaps, which include a direct cutaneous artery and vein, have a superior blood supply. When compared with subdermal plexus flaps of equal size, the viable area in axial pattern flaps is ~50% larger than in subdermal plexus flaps. Furthermore, axial pattern flaps rarely require a delayed procedure typically used to enhance circulation in long subdermal plexus flaps.

Important differences may exist between analogous skin flaps in the dog and cat. Axial skin flaps described in cats are based on the superficial temporal artery, caudal auricular artery, omocervical artery, thoracodorsal artery, and caudal superficial epigastric artery. Skin flaps developed using the skin folds in dogs and cats have been described for closure of proximal thoracic limb wounds. Some authors have speculated that the thoracic limb skin-fold, when carefully mobilized, may actually be an axial skin flap supplied by the lateral thoracic artery (LTA). In dogs, an axial skin flap based on the
LTA has been described for closure of wounds of the proximal aspect of the thoracic limb. To our knowledge, the flap has not been described in the cat. Thus, our purpose was to describe the anatomic location of the LTA in the cat, in particular the cutaneous segment, and to describe the dimensions of an axial skin flap based on this artery. In addition, we report the successful use of this flap in 2 cats with extensive skin defects involving the thoracic limb.

MATERIALS AND METHODS

Anatomic Study

The LTA was dissected in 8 cats euthanatized for reasons unrelated to this study. All cats were administered 5000 U heparin intravenously (IV), during euthanasia. Immediately after death, a median sternotomy was performed and the internal thoracic artery was located and cannulated with an 18 g IV catheter with the catheter tip located within the subclavian artery. Methylene blue (1%; 0.5 mL) was injected into the axillary artery via the subclavian artery. The axilla was dissected to locate the LTA as it branches caudally from the axillary artery. The LTA was cannulated with a 25 g IV catheter and secured with a 4/0 chromic catgut ligature. Methylene blue (1%; 3 mL) was injected into the LTA to facilitate observation of the LTA and its branches. The main arterial trunk of the LTA and its various branches were dissected without the aid of magnification.

Flap Perfusion

The perfusion study was performed using methylene blue and positive contrast angiography. Each study was performed on 4 cats on the contralateral side to the anatomic study.

Methylene Blue. A 25 g IV catheter was placed into the LTA and secured. A skin flap was then made based on the anatomic findings and its dorsoventral and the craniocaudal dimensions measured. The incisions, including the cutaneous trunci muscle when present, were continued until they reached the level of the last rib muscular branch. A maximum of 3 mL methylene blue was injected into the LTA using a 1 mL syringe with minimal pressure. Injection continued until leakage of methylene blue occurred from the cut surface. The distribution of blood vessels reaching the flap periphery was recorded.

Barium Sulfate. A positive contrast vascular study was performed by injecting 2 mL barium sulfate (Liquibar, 60% [w/w] barium sulfate; E-Z-EM Inc., Westbury, NY) through an LTA catheter. The thoracic limb and skin flap were removed en bloc. The skin flap was placed directly onto a high-resolution X-ray film cassette (Agfa-Gevaeret N.V., Monstel, Belgium) and was radiographed during injection of the contrast material. Radiographs were then evaluated to determine whether the flap was adequately perfused.

RESULTS

Anatomic Study

The axillary artery exits the thoracic cavity cranial to the 1st rib. The superficial cervical artery has been defined as the last branch of the subclavian artery and it was cranially directed in all specimens. The external thoracic artery is the 1st branch of the axillary artery, is cranially directed, and branches from the axillary artery in close proximity to the origin of the LTA. The LTA is the 2nd branch of the axillary artery, is caudally directed, and initially runs deep to the axillary lymph node, which it supplies, before giving off muscular branches to the deep pectoral muscle and the latissimus dorsi muscle. The main branch of the LTA continues caudally in close association with the dorsal margin of the deep pectoral muscle. The LTA becomes superficial caudal to the triceps muscle and continues in the subcutaneous tissue to the level of the last rib. Multiple branches from the LTA supply the skin dorsal and ventral to the main trunk of the artery. The longest of these branches reached the midline ventrally and the midthorax dorsally. A rich network of blood vessels, originating from the primary branches, was noticed in the subcutaneous tissues throughout the flap (Fig 1). Anastomoses were also noted between the cutaneous component of the LTA and 4 or 5 consecutive intercostal arteries and as well as the thoracodorsal artery.

The LTA becomes superficial caudal to the triceps muscle and adjacent to the dorsal border of the deep pectoral muscle. This point could be palpated on careful examination and was defined as the center of the flap in the dorsoventral direction. The ventral border of the flap was defined as the ventral midline, from the caudal aspect of the triceps muscle to the last rib. The dorsal border was defined as a line parallel to the ventral border at a distance equal to the distance from the center of the flap to

Fig 1. Distribution of blood vessels after injection of methylene blue into the lateral thoracic artery (LTA) flap.
the ventral border. The caudal border coincided with the last rib and the cranial border lies adjacent to the caudal border of the triceps muscle (Fig 2). Mean (± SD) size of the LTA skin flap was 8.7 ± 0.5 cm in the dorsoventral direction and 15.5 ± 0.7 cm in the craniocaudal direction for a mature, averaged-sized cat.

**Flap Injection**

Methylene blue leakage occurred from cut vessels every 0.5–2 cm along the periphery of the flap. A similar pattern was seen with positive contrast angiography. Branches from the main arterial trunk were numerous, arising every 1–2 cm and radiating to the edge of the flap (Fig 3). The vascular network within the skin flap observed in the anatomic study was not seen.

**Clinical Reports**

**Cat 1.** A young mature domestic short-hair spayed female cat was admitted for treatment of an extensive thoracic limb skin wound resulting from vehicular trauma. After debridement, an extensive circumferential skin defect remained from the paw to the axilla (Fig 4). A narrow strip of viable skin remained on the cranial aspect of the humerus. Wounds were treated by lavage and debridement every 2–3 days. Cefazolin (25 mg/kg IV every 8 hours) and butorphanol (0.4 mg/kg intramuscularly [IM] every 4 hours) were administered until a healthy bed of granulation tissue was established 10 days later. A skin flap based on the LTA but shorter than described earlier was raised; the LTA was identified at the base of the flap. The flap was rotated 90° to cover the defect in the axilla, brachium, and antebrachium (Fig 5). Subcutaneous tissues were closed with 3/0 polydioxanone suture and the skin edges apposed with 3/0 monofilament nylon suture. A free skin graft, harvested from the skin overlying the ipsilateral scapula, was placed on the dorsal aspect of the manus. The leg was immobilized in a modified Robert Jones Bandage for 10 days and the bandaged changed on day 3 and day 7. The postoperative complications were edema of the flap on the caudal aspect of the antebrachium and necrosis of a small area of the flap at one of the distal corners. Closure of the secondary defect limited extension of the ipsilateral hind limb, however, this resolved spontaneously over the next 2 weeks.

**Cat 2.** A 1-year-old domestic short-hair male cat was admitted with a degloving injury of the right antebrachium from vehicular trauma. The wound was initially treated by debridement and lavage. Most of the...
residual skin sutured during initial wound treatment necrosed, leaving a skin defect that extended the length of the antebrachium and carpus on the dorsal, caudal, and lateral aspects. Every 2 days, the wound was debrided, lavaged, and bandaged with wet-to-dry gauze dressings. Reconstruction surgery was performed at 8 days when granulation tissue covered \( \frac{80}{100} \) of the wound. Cefazolin (25 mg/kg IV every 8 hours) and butorphanol (0.4 mg/kg IM every 4 hours) were administered throughout treatment of the open wounds until 7 days after surgical reconstruction performed by raising an LTA-based skin flap. A bridging incision was made on the medial aspect of the brachium and the flap was rotated to fill the defect. The subcutaneous tissue and skin were closed in layers as described above. Healing was uneventful.

Fig 5. Cat 1: 3 days postoperatively. The lateral thoracic artery (LTA) flap was used to cover the defect from the axilla to the carpus, and a free skin graft was used to cover the defect on the paw.

DISCUSSION

In the dog, the LTA is a direct cutaneous artery that supplies the skin over the cranioventral body wall.\(^{16}\) Skin flaps based on this artery have been useful for treatment of large defects on the proximal aspect of the thoracic limb.\(^{15}\) The location of the LTA in cats has not been well described and the angiosome it supplies has been largely overlooked as a possible skin flap for treatment of thoracic limb skin defects. The cutaneous branch of the LTA is a substantial cutaneous blood vessel and supplies the skin on the ventrolateral body wall. An axial skin flap based on this artery is a useful flap for repair of skin defects of the feline thoracic limb.

The location of the LTA in cats and the structures supplied are similar to those in the dog. In all specimens, the LTA was consistently the 1st caudal branch of the axillary artery as it passed lateral to the 1st rib.\(^{16}\) The main trunk of the artery parallels the dorsal border of the deep pectoral muscle before becoming superficial caudal to the triceps brachii muscle. The main difference was that the LTA in cats runs caudally supplying the skin on the lateral and ventral body wall as far as the last rib whereas in the dog, the LTA only extends as far caudally as the costal arch, which corresponds to the caudal aspect of the 8th rib.\(^{15}\)

Methylene blue injection greatly facilitated identification and catheterization of the LTA. Blue coloration of the skin was not homogenous and faded with time. Additional injection of methylene blue increased the intensity of the blue coloration but did not alter the dimensions of the colored area. In contrast to Yates et al.,\(^{17}\) we injected methylene blue selectively into a single cutaneous artery. The area of blue coloration is probably a good reflection of the size of the angiosome; however, further investigation is required to validate this technique. The flap dimensions we describe were based on the anatomic study and were within the area of blue coloration. Methylene blue leakage from the cut vessels on the flap edge provided an indication of vessel patency before the contrast study.

Radiographic contrast studies have been widely used for assessment of perfusion of angiosomes and to establish borders for skin flaps.\(^{5,10,15,17}\) The use of highly concentrated barium sulfate solution is necessary for good radiographic contrast; however, use of highly viscous material limits its penetration into small blood vessels and injection under pressure may lead to rupture of the blood vessels and leakage of contrast material. We used a diluted solution of barium sulfate that resulted in adequate opacification of the flap, in contrast to the poor distribution and insufficient opacification reported by Yates et al.\(^{17}\)

Neither barium sulfate nor methylene blue injection studies have been proven to accurately define an angiosome, but both techniques do help define the location of vessels throughout the skin flap. Methylene blue penetrated smaller arterioles compared with barium sulfate, so methylene blue may be more likely to cross choke vessels, between adjacent angiosomes resulting in the perfusion of a larger area of skin. Because the skin incisions were performed before contrast injection, we cannot conclude which technique more accurately defines an angiosome. Injection studies do not accurately or objectively represent physiologic perfusion and they cannot be relied upon to define the safe borders of a skin flap, which requires in vivo assessment of viability.

The skin flaps we used in 2 cats did not extend beyond the 10th rib, and were smaller than the skin flap described in the anatomic study. Flap dimensions were determined intraoperatively by the size of the defect to be repaired. We did not raise a flap of sufficient length to close the paw defect in cat 1 because we had not appreciated the true potential length of the flap at the time of surgery.
The ventral incision was made in the sagittal plane, lateral to the line of the mammary glands, in both cats. The dorsal incision was parallel to the ventral incision and was determined by measuring the distance from the LTA to the ventral incision. Whether the skin defect, created by harvesting a flap with dimensions we reported in the anatomic study, is amenable to primary closure was not examined. The low percentage of skin flap necrosis occurring in these 2 cats is, in part, because the flaps were well within the dimensions of the maximum allowable flap. We would expect that as the length of the flap increased, so would compromise to the blood supply at the flap end.

One of the advantages of the LTA flap is its proximity to the thoracic limb. Skin flaps based on the thoracodorsal artery can reach the carpus; however, this generally requires raising the flap as an island flap rotated 180° to reach the distal defects of the thoracic limb.5 Because of the proximity of the LTA flap to the skin defect, the procedure is simplified, and less dissection is required, thus decreasing surgical time. Also, less rotation of the LTA flap is required which would decrease the likelihood of compromising its blood supply. The size of the LTA skin flap is ~35% larger than the thoracodorsal flap described by Remedios et al.5 In addition to our own observations, this suggests that a skin flap based on the LTA could be used to cover skin defects extending distally to the carpus; however, we did not examine the viability of flaps of this length.

The 2 clinical cases we report had major skin defects of the thoracic limb. In both cats, the defect was repaired with a 1-stage procedure, shortly after trauma and before presence of healthy granulation tissue over the entire wound. The 2 observed minor complications resolved without intervention. Cosmetic appearance after healing was excellent and donor sites in both cats were easily closed without tension. Thus, a skin flap based on the LTA can be used for reconstruction of major skin defects involving the thoracic limb.

REFERENCES