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Outcome of superficial brachial axial pattern flaps used to close skin defects in dogs: 16 cases (1996-2019)

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(Article begins on next page)

**Outcome of superficial brachial axial pattern flaps used to  
close skin defects in dogs: a multi-centre cohort study (1996-  
2019)**

**Keywords:** superficial brachial, antebrachium, skin reconstruction, axial pattern  
flap, surgical oncology

**Word count:**

## **Summary:**

**Objectives** – To report the complication rate, type of complications and outcome of the superficial brachial axial pattern flap used for closure of skin defects in dogs.

**Methods** – Medical records of dogs treated with a superficial brachial axial pattern flap for closure of a skin defect were reviewed. Information regarding signalment, reason for axial pattern flap use, skin flap size, flap healing, postoperative complications and need for revision surgery was collected.

**Results** – Sixteen dogs were included in the study. Indications for the superficial brachial axial pattern flap included closure following tumor removal (15/16, 94%) and wound closure after elbow callus removal (1/16, 6%). Postoperative complications occurred in all dogs and included partial dehiscence (7/16, 44%), partial flap necrosis (6/16, 38%), seroma formation (5/16, 31%), flap oedema (3/16, 19%) and complete flap necrosis (2/16, 13%). Eight flaps (50%) healed without open wound management or additional surgery. Three dogs (19%) required revision surgery.

**Clinical significance** – Although use of the superficial brachial axial pattern flap was associated with a high rate of complications, most complications were managed without additional surgery and all wounds eventually healed.

## **Introduction**

Axial pattern flaps are used in dogs and cats to close large skin defects resulting from trauma or surgical treatment of neoplasia, as an alternative to other skin reconstruction techniques such as tension-relieving techniques or subdermal plexus skin flaps (Hunt 2018, Wardlaw & Lanz 2018). Axial pattern flaps are based on a direct cutaneous artery and vein, and allow closure of a larger skin defects compared to other techniques due to their improved viability (Wardlaw & Lanz 2018). A variety of axial pattern flaps have been described in dogs and cats in experimental and clinical settings (Pavletic 1990, Field *et al.* 2015), although limited information is available for some axial pattern flaps.

For skin defects affecting the antebrachium, management options may include open wound management and second intention healing, tension-relieving techniques, local (subdermal plexus) skin flaps or use of an axial pattern flap (Hunt 2018; Wardlaw & Lanz 2018). The superficial brachial axial pattern flap is based on the cutaneous branch of the superficial brachial artery, which is itself a branch of the brachial artery. In an experimental setting, Henney and Pavletic (1988) described this axial pattern flap as being centred over the dorsal third of the flexor surface of the elbow. The flap then runs dorsally, parallel to the humeral shaft, and ends at the level of the greater tubercle (Henney & Pavletic 1988, Wardlaw & Lanz 2018). This flap has been used in dogs to cover defects of the cranial antebrachium or elbow in experimental studies (Henney & Pavletic 1988, Pavletic 1990) and in clinical cases (Field *et al.* 2015, Shafiuzama *et al.* 2017). Although flap survival has been reported to be over 90% in experimental

conditions (Henney & Pavletic 1988), this flap is usually considered less robust compared to other axial pattern flaps (Wardlaw & Lanz 2018).

There is limited information regarding the clinical use of the superficial brachial axial pattern flap, with only four clinical cases being reported in the literature. Reported complications comprise seroma formation flap dehiscence and distal flap necrosis, but a detailed description of complications and flap survival rate is lacking (Henney & Pavletic 1988, Field *et al.* 2015, Shafiuzama *et al.* 2017).

The aim of this study was to describe the complications and outcome of superficial brachial axial pattern flaps used to close skin defects in dogs and to answer two questions: how many superficial brachial axial pattern flaps heal without any wound complications and how many superficial brachial axial pattern flaps heal without the need for revision surgery.

## **Materials and Methods**

This study was approved by the Association for Veterinary Soft Tissue Surgery (AVSTS) Research Cooperative (ARC) and the Animal Health Trust (UK) Clinical Research Ethics Committee.

Members of AVSTS were invited to participate via the ARC mailing list and medical records were collected for dogs that were treated with a superficial brachial axial pattern flap for treatment of skin defects between 1996 and the end of the study. Animals were included in the study if the medical records were complete with sufficient descriptions

of flap appearance to allow outcome to be reliably assessed for a minimum period of 2 weeks after surgery.

The following information was collected from the medical records: signalment, location of the skin defect, cause of the skin defect, histological diagnosis, time between injury and skin reconstruction (if applicable), surgery and anaesthesia times, local or regional anaesthesia techniques, flap dimensions (length and width), anatomic landmarks used, use of surgical drains or bandages, peri-operative and post-operative antimicrobial administration, pre-operative and post-operative chemotherapy administration, oncological outcome (if applicable), presence and type of complications, flap outcome and follow-up time. Flap outcome was defined as “optimal” (complete healing without wound dehiscence or necrosis), “partial flap dehiscence or necrosis not requiring revision surgery”, or “flap dehiscence requiring revision surgery” (with or without flap necrosis).

## **Results**

### ***Patient characteristics***

Sixteen dogs met the inclusion criteria, with a median age of 102 months (range 7-156 months) at the time of surgery. Breeds included Boxer (n=5), German Shepherd Dog (n=5), Golden Retriever (n=2), English Setter (n=2), crossbreed (n=2), Miniature Schnauzer (n=1), Rhodesian Ridgeback (n=1) and Labrador (n=1) with a median weight of 28kg (range 10-46.7kg). Five dogs were entire males, six were neutered males, one was an entire female and four were neutered females.

### ***Flap indications and characteristics***

The superficial brachial axial pattern flap was used for wound closure after removal of a neoplastic mass (15/16 dogs, Figure 1) or for management of a wound breakdown after surgery for removal of an elbow callus in one dog. Histological diagnoses included mast cell tumour in seven dogs, low-grade soft tissue sarcoma in seven dogs (perivascular wall tumour in five dogs and peripheral nerve sheath tumour in two dogs) and high-grade soft tissue sarcoma in one dog. One dog with a perivascular wall tumour on the left carpus underwent pre-operative radiotherapy. None of the dogs received pre-operative chemotherapy.

The location of the skin defect was reported in 15 dogs and included the proximal antebrachium in six dogs, the mid to distal antebrachium in five dogs, the carpus in three dogs and the olecranon in one dog. The size of the defect as measured at the time of surgery was reported in 12 dogs and ranged from 22.4cm<sup>2</sup> to 96cm<sup>2</sup> (median 48cm<sup>2</sup>).

The primary surgeon performing the superficial brachial axial pattern flap was an ECVS diplomate in all but one case. The length of the harvested superficial brachial axial pattern flap was reported in 13 dogs and ranged from 14cm to 19cm (median 16cm). This corresponded to 100% of the maximum angiosome described in the literature (Henney & Pavletic 1988) in nine dogs and 75%, 80%, 95% and 110% of the maximum angiosome in a crossbreed dog, a Boxer, a crossbreed dog and an English Setter, respectively. The width of the superficial brachial axial pattern flap was reported in 10 dogs and was 100% of the maximum angiosome described in the literature

(Henney & Pavletic 1988) in nine dogs and 90% of the maximum angiosome in the remaining dog.

Anaesthetic time was reported in nine dogs with a median of 140 minutes (range 105-225 minutes). Surgical time was reported in 12 dogs with a median of 75 minutes (range 40-150 minutes).

### ***Preoperative and postoperative care***

Local anaesthetic techniques were used in two dogs and included one brachial plexus nerve block using bupivacaine (Marcain; AstraZeneca) and one local instillation of ropivacaine (Ropivacaine Hydrochloride; Sandoz).

Thirteen dogs received peri-operative antibiotics. Nine dogs received post-operative antibiotics for between 7 to 20 days. An active suction drain was placed at the time of the initial surgery in five dogs and remained in place for a median of 4 days (range 3-5 days). A bandage was used postoperatively in six dogs and remained in place for a median of 14.5 days (range 7-22 days).

### ***Complications***

Complications were reported in all dogs (Table 1) and included partial necrosis in seven dogs (Figure 2), partial dehiscence in six dogs (Figure 3), seroma or haematoma in five dogs, oedema in three dogs, wound infection in one dog, prolonged wound discharge in one dog, development of an area of ingrown hair at the base of the flap in one dog



and complete flap failure with 100% necrosis in two dogs (Table 2). Seven dogs had more than one complication. In dogs with partial necrosis of the flap, necrosis involved between 2% and 50% of the flap (median 10%) and the median time from surgery to necrosis was 7 days (range 3-43 days). In dogs with partial dehiscence of the flap, dehiscence involved between 2% and 50% of the flap (median 10%).

Complications were managed conservatively in three dogs, including one dog with 5% partial dehiscence of the flap, one dog with flap oedema as the sole complication and one dog with prolonged wound discharge as the sole complication. In one dog that developed an area of ingrown hair at the base of the flap, the affected area was excised several months after the flap had healed. In four dogs, drainage of a postoperative seroma was performed as the sole postoperative treatment; all these dogs had an active suction drain placed postoperatively. In five dogs, a period of open wound management was necessary after partial dehiscence or necrosis (for four dogs) or complete necrosis (for one dog), but the wound eventually healed after 16, 17, 20, 38 and 72 days. In two dogs, surgical debridement and partial closure was required after partial flap necrosis or dehiscence, and the flap eventually healed after 45 and 58 days. In one dog with complete flap necrosis, revision surgery with a bipedicle flap was performed 150 days postoperatively, after a long period of open wound management.

### ***Outcome***

Overall, the superficial brachial axial pattern flap healed without further surgical intervention in eight dogs. The axial pattern flap healed after a period of open wound management in four dogs. In one dog, complete flap necrosis was treated with open

wound management and second intention healing. Revision surgery was required in three dogs; in two of these dogs, revision surgery was limited to debridement and secondary closure, and a releasing incision was performed to allow wound closure after complete flap failure in the remaining dog. The time from surgery to complete healing was reported in 13 cases and ranged from 12 days to 150 days (median 22 days).

In 12 of the 15 dogs treated for neoplasia, surgical excision was histologically confirmed to be complete. Three dogs had incomplete excision confirmed histologically. All three dogs had a perivascular wall tumour at the level of the carpus and the skin defects in these dogs were the largest (70-96 cm<sup>2</sup>). One of these dogs received post-operative radiotherapy (protocol not specified). One dog received two postoperative doses of doxorubicin for treatment of a high-grade soft tissue sarcoma. Local recurrence occurred in three dogs, two with incompletely excised perivascular wall tumors at the level of the carpus and one with a completely excised high-grade soft tissue sarcoma. Local recurrence occurred at 152, 282 and 125 days postoperatively.

## **Discussion**

In this report, we present 16 dogs that underwent reconstruction of antebrachial skin defects with a superficial brachial axial pattern flap. Although the complication rate was high, most superficial brachial axial pattern flaps healed without further surgical intervention, with only three dogs requiring revision surgery, and all wounds healed eventually.

The skin defects reconstructed with the superficial brachial axial pattern flap were located on the proximal antebrachium, distal antebrachium or carpus in 15 dogs. The superficial brachial axial pattern flap has been primarily described to reconstruct skin defects affecting the antebrachium (Pavletic 1990) although the thoracodorsal axial pattern flap and latissimus dorsi myocutaneous flap may also be extended to cover defects of the antebrachium, depending on the conformation of the dog (Pavletic 1990, Wardlaw & Lanz 2018). However, these latter techniques involve a longer flap and a longer bridging incision between the base of the flap and the proximal aspect of the cutaneous defect.

In the initial experimental study describing the use of the superficial brachial axial pattern flap in five dogs (Henney & Pavletic 1988), the superficial axial pattern flap was elevated and transposed to the cranial antebrachium, and flap survival was 92-100%. Complications comprised seroma formation, minor distal flap necrosis (<10%), minor dehiscence (managed conservatively) and surgical site infection. Similarly, although all of the four clinical cases previously described in the literature showed minor complications, flap outcome was considered good to excellent in all cases (Field *et al.* 2015, Shafiuzama *et al.* 2017). This is in keeping with our findings, where 13 out of 16 superficial brachial axial pattern flaps healed without revision surgery, although some required a period of open wound management.

The type of complications reported in this study was similar to other reports of axial pattern flaps (Aper & Smeak 2003; Aper & Smeak 2005, Emmerson *et al.* 2019, Field *et al.* 2015, Trevor *et al.* 1992, Proot *et al.* 2019) and included most commonly partial flap dehiscence, partial flap necrosis, seroma formation and oedema. However, at least

one complication was reported in each dog leading to a complication rate of 100%. However, 50% of these complications were considered minor as they did not require any open wound management or revision surgery. Aper and Smeak (2005) also reported a complication rate of 100% for the caudal superficial epigastric axial pattern flap although 90% of the complications were considered minor in this case series. The complication rate was reported to be lower in other axial pattern flaps with 80% complications for the thoracodorsal axial pattern flap (Aper & Smeak 2003), 63% complications for the caudal auricular axial pattern flap (Proot *et al.* 2019) and 63% complications for the genicular axial pattern flap (Emmerson *et al.* 2019). The reason for the relatively high complication rate associated with the superficial brachial axial pattern flap is unknown, although Henney & Pavletic (1988) noted that the superficial brachial vessels were often hard to identify and may therefore be damaged during flap dissection. Due to the location of the skin defects, the superficial brachial axial pattern flap is also commonly transposed 180 degrees, increasing the risk of twisting the direct cutaneous artery and vein. Due to the distal location of some defects, the flaps may also have been stretched rather than placed into position, which further increases the risk of vascular embarrassment. Finally, the flap is transposed over the flexor aspect of the elbow joint, which increases dynamic tension in the wound bed during limb movement.

Complete flap necrosis occurred in two dogs. Although the reason for complete necrosis was unknown, several factors may have contributed to this outcome. In both dogs the skin defects extended to the carpus, and these were the largest skin defects in our report with areas of 78cm<sup>2</sup> and 96cm<sup>2</sup>. The length of the superficial brachial axial pattern flaps used was 18cm in both cases, and the flaps extended to the acromial region, which is beyond the landmark described by Henney & Pavletic (1988). One of the two

dogs also received preoperative radiotherapy, which may have led to decreased wound healing (Henry *et al.* 2003).

In this report, three dogs (19%) underwent revision surgery to manage complications related to the axial pattern flap. Two of these revision surgeries were considered minor procedures involving secondary closure of the wound left by partial necrosis of the axial pattern flap. In the third dog, complete necrosis of the axial pattern flap occurred and was managed with open wound management for 5 months before a subdermal plexus skin flap was used to close the remaining defect. In all three dogs, the wounds eventually healed after revision surgery. The rate of revision surgery is similar to the revision rate of 13% reported for the genicular axial pattern flap (Emmerson *et al.*, 2019), but lower than the rate of revision surgery of 31% reported by Field *et al.* (2015) for various axial pattern flaps. Higher revision rates were reported for the caudal auricular axial pattern flap (50%, Proot *et al.* 2019) and the thoracodorsal axial pattern flap (60%, Aper & Smeak 2003).

Use of the superficial brachial axial pattern flap allowed wide excision and clean histological margins to be obtained in 12 out of 15 dogs (80%) of the dogs treated for neoplasia in this study. The large skin defects created by wide surgical excision of these neoplasms may not have been amenable to simpler skin reconstruction methods.

The limitations of this study are inherent to its retrospective nature. The description of complications and flap outcome is based on the review of medical records, and the surgical technique, postoperative management and management of complications were not standardised. Despite these limitations, this study reports the largest series of dogs

treated with a superficial brachial axial pattern flap to cover skin defects of the antebrachium. Although surgeons and owners should be aware that the rate of complications is high, the majority of these complications appeared minor and could be managed without additional surgery, and all wounds healed in the end.

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### **Figure legends:**

Figure 1. Photographs on dog 8 showing a soft tissue sarcoma on the proximal antebrachium preoperatively (A) and elevation of the superficial brachial axial pattern flap (B).

Figure 2: Photographs of dog 9 showing partial distal flap necrosis (A), which was treated with revision surgery (wound debridement and closure). Panel B shows the appearance of the wound 2 months after initial surgery.

Figure 3: Photographs of dog 10 showing the appearance of the wound 4 days after surgery (A), and partial dehiscence of the axial pattern flap one week after initial surgery (B).

Table 1: Clinical features and flap outcome for the 16 dogs that underwent skin reconstruction using the superficial brachial axial pattern flap.

Table 2: Summary of outcome and complications.