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Indications, complications, and outcomes associated with subdermal plexus skin flap procedures in dogs and cats: 92 cases (2000–2017)

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OBJECTIVE

To describe indications, complications, and outcomes associated with subdermal plexus skin flap (SPSF) procedures in dogs and cats.

ANIMALS

53 dogs and 20 cats that received SPSFs for reconstruction of skin defects from 2000 to 2017.

PROCEDURES

Medical record data were collected and summarized regarding patient signalment, indication for the SPSF procedure, type and location of SPSF, complications, and outcome.

RESULTS

92 SPSF procedures (64 in dogs and 28 in cats) were included. Indications for the procedures included tumor excision ($n = 37$ [40%]), acute wound (14 [15%]) or chronic wound (28 [30%]) reconstruction, surgical scar revision (7 [8%]), and other reasons (6 [7%]). Types of SPSFs included advancement (31 [34%]), axillary fold (20 [22%]), inguinal fold (20 [22%]), rotation (16 [17%]), transposition (3 [3%]), and distant direct (2 [2%]). Complications were noted for 47 (51%) procedures at a mean \pm SD of 6.9 ± 4.0 days after surgery and were classified as minor (34 [37%]) or major (13 [14%]). Outcome was considered excellent for 44 (48%) procedures, good for 33 (36%), fair for 13 (14%), and poor for 2 (2%).

CONCLUSIONS AND CLINICAL RELEVANCE

Results suggested that approximately half of SPSF procedures in dogs and cats can be expected to be followed by a complication, occurring at a mean of 1 week after surgery, and yet with appropriate management of these complications, a good to excellent outcome was possible. Owners should be counseled about the likely need for additional visits and costs associated with treatment of postoperative complications. (*J Am Vet Med Assoc* 2019;255:933–938)

Subdermal plexus skin flaps, also known as local or random pattern flaps, may be used to reconstruct skin defects in dogs and cats when primary closure is not possible. Relatively simple to perform, an SPSF procedure may be preferred when a choice exists between that and a more advanced reconstructive technique, such as axial pattern flap or free-skin graft procedures. Unlike axial pattern flaps, SPSFs do not contain a specific or named direct cutaneous artery and instead derive their blood supply from the terminal branches of cutaneous trunci vessels in the subdermal plexus, which run from the base of the flap. However, in some anatomic areas, the wider the base of the SPSF, the greater the chance of accidentally incorporating part of an adjacent direct cutaneous artery.^{1,2}

Subdermal plexus skin flaps can be classified according to their location relative to the skin deficit

and method of transfer, such as advancement, rotation, transposition, axillary fold, and inguinal fold flaps.^{1–3} Distant direct SPSFs can also be created and are most commonly used to cover skin deficits on the proximal and middle aspects of a limb.^{2,4}

Because dogs and cats generally have loose skin, SPSFs are commonly available and used; nevertheless, little information has been published regarding indications, complications, and outcomes associated with SPSF procedures, and the limited available information is based on studies involving small numbers of animals or case reports. For example, in a study⁵ involving dogs that received an SPSF to close the skin deficit created by tumor excision, no difference in flap survival rate was identified between dogs in which nonabsorbable suture was used ($n = 10$) and those in which nonabsorbable suture and cyanoacrylate adhesive were used (5). The mean flap survival rate for the 2 groups was 85%. In another study,⁶ axillary and inguinal fold flaps were used in 6 dogs and 2 cats. Two of the 6 dogs had complications, and all patients had a successful outcome. A case series⁴ of

ABBREVIATIONS

SPSF Subdermal plexus skin flap

distant direct SPSF procedures performed at 5 institutions revealed a 95% flap survival rate for 12 of 14 animals (10 dogs and 4 cats), and infection and dehiscence were the most common complications.

To the authors' knowledge, no large-scale study has been performed on the use of SPSFs in cats and dogs or the use and outcome of SPSFs for the reconstruction of acute or chronic wounds, as opposed to the reconstruction of surgical wounds following tumor excision. The aim of the study reported here was to describe the indications, complications, and outcomes associated with various types of SPSFs used to reconstruct skin deficits of various causes in a large number of dogs and cats.

Materials and Methods

Case selection criteria

Electronic medical records at the Queen Mother Hospital for Animals, University of London, were searched to identify dogs and cats that received an SPSF between January 1, 2000, and December 31, 2017, for treatment of a skin defect. Patients receiving a flap that included muscle layers other than the panniculus (eg, a latissimus dorsi myocutaneous advancement flap) or a direct cutaneous artery (ie, an axial pattern flap) were excluded.

Medical records review

For each dog and cat included in the study, information was retrieved from the medical record regarding patient signalment, indication for the SPSF procedure, type and location of SPSF, perioperative management details (including antimicrobial treatment), complications, and outcome. For patients that received multiple SPSFs, the details and outcome of each SPSF procedure were recorded separately.

Chronic wounds were defined as those that had failed previous wound treatments or surgeries before patients were referred to the study hospital for further assessment and surgery. Acute wounds were defined as traumatic wounds in patients evaluated by the hospital's emergency service that had been transferred directly for surgical assessment without failing any previous wound management. Scar revision surgery was considered to have been performed when biopsy results for excised tumors indicated that the margins were not clean, and a second surgery was performed in an attempt to create clean margins.

Complications affecting the SPSF within the postoperative period until the point of discharge from the hospital were recorded, as were any wound complications noted at subsequent visits to the hospital. A complication was classified as major if a second SPSF procedure was required or > 50% of the SPSF underwent necrosis and sloughing (ie, > 50% flap failure). All other complications were classified as minor, including seroma, wound discharge, wound infection treatable with appropriate antimicrobials and wound management, and dehiscence of small portions of the flap successfully managed by second-intention healing, none of which prevented the SPSF from healing successfully.

Such complications also included wounds that required the patient to be sedated for wound debridement and lavage to facilitate successful healing.

Outcome was defined by use of previously reported criteria⁷ as excellent (no complications), good (with complications that required minimal intervention and healed successfully by second intention), fair (with complications that required a second surgery to achieve successful closure), or poor (with complications that required > 1 additional surgical intervention or involved irredeemable sloughing and necrosis of the flap).

SPSF procedures

Patients with wounds were managed until a healthy bed of granulation tissue filled the skin defect before wound reconstruction with an SPSF was attempted. Surgically created skin deficits, such as those created by tumor excision, were closed with an SPSF immediately after creation during the same surgical procedure. All SPSF procedures were performed as described elsewhere.¹⁻⁴

Statistical analysis

Data were analyzed with the aid of statistical software.^a Continuous data (eg, patient age) were evaluated for normality of distribution with the D'Agostino-Pearson normality test; normally distributed data were reported as mean \pm SD, and nonnormally distributed data were reported as median (range). Categorical data were compared between selected groups by means of the χ^2 test or, when a given category was represented by < 5 observations, the Fisher exact test. The null hypothesis for all statistical tests was homogeneity between groups, and values of $P < 0.05$ were considered significant.

Results

Animals

Fifty-three dogs with a mean \pm SD age of 7.0 \pm 3.3 years were included in the study. Dogs were classified as Labrador Retriever (n = 53 [13%]), Boxer (5 [9%]), Cocker Spaniel (4 [8%]), or other breeds (\leq 3 each) or as a mixed-breed dog (4 [8%]). Twenty-three (43%) dogs were neutered females, 14 (26%) were neutered males, 11 (21%) were sexually intact males, and 5 (9%) were sexually intact females. These 53 dogs received 64 SPSFs that met the inclusion criteria: 1 (2%) dog had 4 flaps, 2 (4%) had 3 flaps, 4 (8%) had 2 flaps, and 46 (87%) had 1 flap.

Twenty cats with a median age of 4.5 years (range, 0.5 to 17 years) were also included. Cats were classified as domestic shorthair (n = 16 [80%]) as well as Maine Coon, Siamese, Siamese-cross, and Bengal (1 [5%] each). Ten (50%) cats were neutered males, 8 (40%) were neutered females, 1 (5%) was a sexually intact male, and 1 (5%) was a sexually intact female. These 20 cats received 28 SPSFs that met the inclusion criteria: 2 (10%) cats had 3 flaps, 4 (20%) had 2 flaps, and 14 (70%) had 1 flap.

SPSFs

Indications for SPSF procedures for dogs and cats combined included tumor excision (n = 37 [40%]), acute wound (14 [15%]) or chronic wound (28 [30%]) recon-

struction, surgical scar revision after incomplete tumor removal (7 [8%]), and other reasons (6 [7%]). Other reasons included lip-fold dermatitis (2 [2%]), herpes dermatitis (2 [2%]), corn removal (1 [1%]), and fungal mass removal (1 [1%]). Location of the SPSFs included the torso (43 [47%]), proximal aspect of a limb (29 [32%]), head or face (18 [20%]), and distal aspect of a limb (2 [2%]).

The types of SPSFs used to reconstruct the recipient skin deficit in dogs and cats combined included advancement (n = 31 [34%]), axillary fold (20 [22%]), inguinal fold (20 [22%]), rotation (16 [17%]), transposition (3 [3%]), and distant direct (2 [2%]). Nineteen of the 64 (30%) flaps in dogs were the advancement type (including 1 vulval skin advancement flap), 18 (28%) were the axillary fold type, 12 (29%) were the inguinal fold type, 10 (16%) were the rotation type (including 1 scrotal skin rotation flap performed immediately after castration), 3 (5%) were the transposition type, and 2 (3%) were the distant direct type. In cats, 12 of the 28 (43%) SPSFs were the advancement type, 8 (29%) were the inguinal fold type, 6 (21%) were the rotation type, and 2 (7%) were the axillary fold type (1 of which was also omentalized).

An active suction drain was placed at surgery in 10 of the 92 (11%) flaps and a passive drain in 24 (26%) flaps, according to surgeon preference. For 1 rotation flap, negative-pressure wound therapy was applied for 3 days after surgery to help maintain distal tip viability.

Broad-spectrum antimicrobials (cefuroxime^b or amoxicillin-clavulanic acid^c; 10 mg/kg [22 mg/lb], IV, q 2 h) were administered from the point of anesthetic induction until surgery concluded for 36 (39%) SPSF procedures on the basis of the class and duration of surgery.

Postoperative complications

Postoperative complications were recorded for 47 of the 92 (51%) SPSF procedures, and some procedures resulted in > 1 complication. Data regarding the first signs of a complication were available for 34 SPSF procedures with complications, and the mean \pm SD number of days for a complication to be noted was 6.9 \pm 4.0. Observed complications included dehiscence of the distal wound edge (n = 28 [30%]), seroma (11 [12%]), partial flap failure due to necrosis or sloughing (9 [10%]), infection (8 [9%]), discharge (4 [4%]), ulceration (2 [2%]), and self-trauma (1 [1%]). Ulceration was believed to have occurred in 1 dog because the SPSF was in contact with a canine tooth and in 1 cat because

of herpesvirus infection. Overall, these complications were considered minor for 34 (37%) procedures and major (requiring second surgery or > 50% flap failure) for 13 (14%) procedures.

For the 8 patients with a postoperative infection, amoxicillin-clavulanic acid was administered PO on an empirical basis for 7 to 14 days until results of bacterial culture and antimicrobial susceptibility tests could be obtained, and this course of treatment was completed or changed to an appropriate oral antimicrobial formulation as indicated by the susceptibility test results. The 2 cats with a postoperative infection received the SPSF for treatment of an acute wound, whereas 3 of the 6 dogs with a postoperative infection received the SPSF for treatment of a chronic wound and the remaining 3 were undergoing tumor excision.

In dogs, 35 of the 64 (55%) SPSF procedures resulted in complications, of which 25 (39%) were classified as minor and 10 (16%) as major. In cats, 12 of the 28 (43%) SPSF procedures resulted in complications, of which 9 (32%) were classified as minor and 3 (11%) as major. No significant ($P = 0.51$) difference in overall complication rate was identified between dogs and cats.

Complications and complication rates associated with the different types of, indications for, and locations of SPSFs were summarized for dogs and cats combined (**Tables 1–3**). Inguinal fold flaps, axillary fold flaps, rotation flaps, and 2 distant direct flaps had the highest complication rates, whereas advancement flaps and transposition flaps had the lowest complication rates. The large number of SPSF types and small numbers within some of the groups precluded statistical comparison of complication rates among types of SPSFs. The overall complication rate for SPSFs used to reconstruct acute or chronic wounds was significantly ($P = 0.005$) higher than that for SPSFs used to reconstruct a tumor excision deficit or scar revision deficit. No significant ($P = 0.35$) difference in overall complication rate was identified between flaps used to reconstruct acute wounds and those used to reconstruct chronic wounds.

The overall complication rates for SPSFs used to reconstruct skin deficits of the torso ($P = 0.02$) and proximal aspect of a limb ($P < 0.001$) were significantly higher than the rate for SPSFs used on the head or face. No significant ($P = 0.14$) difference in overall complication rate was identified between SPSFs used to reconstruct proximal limb versus torso skin defects.

Table 1—Complications associated with 92 SPSF procedures performed in 53 dogs and 20 cats, grouped by type of SPSF.

Type of SPSF	Total complications (n = 47)	Minor complication (n = 34)	Major complication (n = 13)
Advancement (n = 31)	7 (23)	5 (16)	2 (6)
Inguinal fold (n = 20)	13 (65)	9 (45)	4 (10)
Axillary fold (n = 20)	15 (75)	10 (50)	5 (15)
Rotation (n = 16)	9 (56)	9 (56)	0 (0)
Transposition (n = 3)	1 (33)	0 (0)	1 (33)
Distant direct (n = 2)	2 (100)	1 (50)	1 (50)

Data represent number (%) of each type of SPSF with a complication.

Table 2—Complications associated with the SPSF procedures of Table 1, grouped by indication for the SPSF.

Indication for SPSF	Total complications (n = 47)	Minor complication (n = 34)	Major complication (n = 13)
Acute wound (n = 14)	9 (64)	7 (50)	2 (14)
Chronic wound (n = 28)	20 (71)	13 (46)	7 (25)
Tumor excision (n = 37)	11 (30)	9 (24)	2 (5)
Tumor scar revision (n = 7)	5 (71)	3 (43)	2 (29)
Other reason (n = 6)	2 (33)	2 (33)	0 (0)

See Table 1 for key.

Table 3—Complications associated with the SPSF procedures of Table 1, grouped by location of the SPSF.

Location of SPSF	Total complications (n = 47)	Minor complication (n = 34)	Major complication (n = 13)
Torso (n = 43)	22 (51)	16 (37)	6 (14)
Proximal aspect of a limb (n = 29)	20 (69)	14 (48)	6 (21)
Head or face (n = 18)	3 (17)	3 (17)	0 (0)
Distal aspect of a limb (n = 2)	2 (100)	1 (50)	1 (50)

See Table 1 for key.

Outcome

Overall, poor outcomes were recorded for 2 of the 92 (2%) SPSF procedures, a fair outcome for 13 (14%), a good outcome for 33 (36%), and an excellent outcome for 44 (48%). Poor, fair, good, and excellent outcomes were recorded for 2 (3%), 8 (12%), 25 (39%), and 29 (45%) of the 64 SPSFs performed in dogs and 0 (0%), 5 (18%), 8 (29%), and 15 (54%) of the 28 SPSFs performed in cats.

Discussion

To the authors' knowledge, the present study represented the first large retrospective study to characterize the indications, complications, and outcomes associated with different types of SPSFs performed for various reasons in cats and dogs. The most common indications for the SPSF procedures were reconstruction of acute or chronic wounds and reconstruction of deficits created following tumor excision or scar revision, which were similar to those reported for axial pattern flaps⁷⁻⁹ and free-skin grafts.¹⁰⁻¹² Previous studies of SPSF procedures have focused solely on dogs and cats undergoing tumor excision, so it was interesting to note the higher complication rate for SPSFs used to reconstruct acute or chronic wounds, compared with the rate for SPSFs used to reconstruct a tumor excision deficit or a scar revision deficit in the present study. This difference in rates had several possible explanations. Open wounds are generally more difficult to clean and prepare for aseptic surgery than intact skin. Chronic wounds may also have a change in skin flora that could alter wound healing.¹³⁻¹⁵ However, in the present study, clinical signs of postoperative infection were reported for only 8 animals, 3 of which received SPSFs to reconstruct a tumor excision deficit rather than to reconstruct an acute or chronic wound. Another possibility was that differences in wound perfusion existed

or were created during flap elevation for open wounds versus surgically created wounds. It was also likely that the local environment surrounding an open wound (important for wound healing) was more inflamed, even if the wound had been managed well to create a healthy granulation wound bed prior to reconstruction surgery, than that surrounding surgically created wounds.

Fifty-one percent of the SPSFs performed in dogs and cats of the study reported here were associated with a minor or major complication, which was lower than the 89% complication rate reported for a large retrospective case series⁷ of axial pattern flap procedures and comparable to the 50% complication rate reported for a large retrospective case series¹⁰ of free-skin graft procedures in dogs and cats. The most common complication (30%) of SPSF procedures in both species of our study was dehiscence of the distal wound edge, which is also the most common complication reported for axial pattern flaps.^{7-9,16,17} Distal SPSF dehiscence is often due to excessive tension on the sutures. Excessive tension can also reduce the lumen size of capillaries in the flap, leading to partial necrosis.¹⁸

Partial flap necrosis was reported as a complication separate from dehiscence in the present study, noted for 10% of the SPSFs. In certain instances, it may be better to create 2 smaller SPSFs rather than 1 larger SPSF to ensure that the flap base is appropriately wide for the flap length it is supporting and to reduce tension on the flap.¹⁸ Despite the 51% overall complication rate, only 14% of SPSF procedures were classified as having a major complication that resulted in > 50% flap failure or required further surgery. The mean time to onset of clinical signs of an SPSF complication was 6.9 days, suggesting that owners of dogs or cats that are discharged from the hospital before this time should be given detailed instructions regarding postoperative care, including a description of the

signs of possible complications and indicating the potential need to return if a complication arises.

Subdermal plexus skin flaps used on the head or face were associated with a lower rate of complications than those used on the proximal aspect of a limb or on the torso in the study reported here. This finding differed from the results of the aforementioned retrospective study⁷ of axial pattern flap procedures in which location of the wound deficit was not identified as an independent risk factor for complications, whereas 4 of the 5 SPSFs that were used to cover deficits on the limbs in a smaller study⁵ involving 15 SPSF procedures failed to achieve 100% viability. The head region has an excellent blood supply, and it may be easier to prevent patients from interfering with wounds in this area versus other areas such as the limbs. Usually, plenty of loose neck skin is available to reduce tension on an SPSF used on the head. We expected that SPSFs used to reconstruct limb deficits might have a higher complication rate than SPSFs used to reconstruct torso deficits because in our experience, the torso has more loose skin available (reducing SPSF tension) than the limbs; however, SPSFs used to cover proximal limb deficits originate from the torso. Skin deficits on the distal portion of a limb require use of a distant SPSF, of which only 2 were performed in the present study and therefore were not included in statistical comparisons, although both procedures were associated with complications. The skin over the limbs has different characteristics than the skin over the torso, so the healing of a torso skin graft over a limb deficit might require more reorganization during the healing process.¹⁸

A large proportion (48%) of SPSFs in the present study were associated with an excellent outcome, meaning no complications were noted and they healed successfully. A good outcome was achieved for another 36% of SPSFs, which healed successfully with minor interventions. The combined rate of good to excellent outcomes (84%) compared favorably with the rate reported for axial pattern flaps (64%)⁷ and free skin grafts (77% success for cats and 38% for dogs).¹⁰ Therefore, our results supported the use of an SPSF whenever a choice exists between use of an SPSF and a more advanced reconstructive technique, such as use of axial pattern flaps or free skin grafts. Subdermal plexus skin flaps are simple to perform and are often chosen as a first-line reconstructive option, regardless of the experience of the veterinarian performing the surgery. Furthermore, use of an SPSF would not usually preclude the use of a more advanced reconstructive technique at a later date.

Advancement and transposition SPSF procedures appeared to result in fewer complications than other types of SPSF procedures in the study reported here, although it was not possible to test this suggestion statistically given the available data. These types of SPSFs may have represented smaller or simpler wound reconstructions than the skin fold flaps and larger rotation flaps. One very large rotation flap described in a case report¹⁹ received negative-pressure wound therapy after surgery, which was deemed helpful in maintaining distal flap viability in the affected dog.

Skin graft augmentation through the use of negative-pressure wound therapy is also believed to improve graft survival.^{20,21} Locally injected platelet-rich plasma also reportedly increased tissue perfusion and viability of long abdominal wall SPSFs created in an experimental study²² involving 6 Beagles.

No difference in overall complication rate was identified between dogs and cats receiving an SPSF in the present study. In the authors' experience, cats often have more loose skin available than certain breeds of dog; thus, the observed lack of a difference may have been attributable to the surgeons having planned ahead and taken into consideration the skin available in an individual animal such that they harvested only an appropriately sized flap to reconstruct a particular skin deficit.

The present study had important limitations that warrant consideration. Because of the study's retrospective nature, the sample size and completeness and types of data collected could not be controlled, and fewer cats than dogs were included. The surgeries, although conducted at the same institution, were performed by multiple surgeons. Additionally, patients can differ in the amount of loose skin that can be used for SPSFs as well as in terminal blood supply and innervation patterns, and each SPSF is ultimately formed on a case-by-case basis. Multi-institutional prospective studies are therefore recommended, and future research on this topic should include clearly defined surgical guidelines, measurements and photographs of the skin defect, measurements of the flap base and length, estimation of the amount of flap tapering toward the leading edge, and measurement and photographs of the areas of dehiscence left to heal by second intention.

Despite any limitations, findings of the present study suggested that approximately half of SPSF procedures in dogs and cats can be expected to result in a postoperative complication, particularly if the SPSF is used to close a wound or the skin deficit is on the torso or a limb. Complications may be expected to be noted a mean of 1 week after surgery; however, with appropriate management, a good to excellent outcome appears possible. Owners should be counseled about the likely need for additional visits and costs associated with treatment of postoperative complications.

Acknowledgments

The authors declare that there were no conflicts of interest.

Footnotes

- a. GraphPad Prism 7, GraphPad Software Inc, La Jolla, Calif.
- b. Zinacef, GlaxoSmithKline, Brentford, Middlesex, England.
- c. Augmentin, GlaxoSmithKline, Brentford, Middlesex, England.

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From this month's AJVR

Pharmacokinetics of levofloxacin following oral administration of a generic levofloxacin tablet and intravenous administration to dogs

Melanie Madsen et al

OBJECTIVE

To determine the pharmacokinetics of levofloxacin following oral administration of a generic levofloxacin tablet and IV administration to dogs and whether the achieved plasma levofloxacin concentration would be sufficient to treat susceptible bacterial infections.

ANIMALS

6 healthy adult Beagles.

PROCEDURES

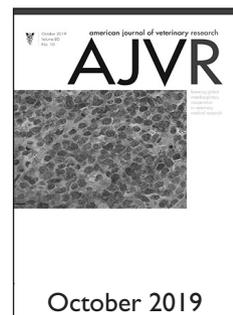
Levofloxacin was administered orally as a generic 250-mg tablet (mean dose, 23.7 mg/kg) or IV as a solution (15 mg/kg) to each dog in a crossover study design, with treatments separated by a minimum 2-day washout period. Blood samples were collected at various points for measurement of plasma levofloxacin concentration via high-pressure liquid chromatography. Pharmacokinetic analysis was performed with compartmental modeling.

RESULTS

After oral administration of the levofloxacin tablet, mean (coefficient of variation) peak plasma concentration was 15.5 µg/mL (23.8%), mean elimination half-life was 5.84 hours (20.0%), and mean bioavailability was 104% (29.0%). After IV administration, mean elimination half-life (coefficient of variation) was 6.23 hours (14.7%), systemic clearance was 145.0 mL/kg/h (22.2%), and volume of distribution was 1.19 L/kg (17.1%).

CONCLUSIONS AND CLINICAL RELEVANCE

In these dogs, levofloxacin was well absorbed when administered orally, and a dose of approximately 25 mg/kg was sufficient to reach pharmacokinetic-pharmacodynamic targets for treating infections with susceptible Enterobacteriaceae (ie, ≤ 0.5 µg/mL) or *Pseudomonas aeruginosa* (ie, ≤ 1 µg/mL) according to clinical breakpoints established by the Clinical and Laboratory Standards Institute. (*Am J Vet Res* 2019;80:957-962)



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