Use of vacuum-assisted closure to maintain viability of a skin flap in a dog

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Case Description—A 4-year-old sexually intact male Labrador Retriever–Poodle mix was admitted to the hospital for treatment of a wound in the left thoracic region. The wound had been debrided and primary closure had been performed by the referring veterinarian 4 days previously.

Clinical Findings—The dog had a 20-cm-long wound covered by a large flap of skin that extended caudally from the scapula over the left side of the thorax. A 3-cm defect was evident at the cranioventral aspect of the wound, from which purulent material was being discharged. The skin flap was necrotic, and the skin surrounding the flap was bruised. Signs of pain were elicited when the wound and surrounding region were palpated. Other findings, including those of thoracic radiography, were unremarkable.

Treatment and Outcome—The wound was debrided, and vacuum-assisted closure (VAC) was initiated for 3 days until a healthy bed of granulation tissue developed. A reconstructive procedure was performed with a rotation flap 3 days after VAC dressing removal. The VAC process was reinitiated 2 days following reconstruction because of an apparent failing of the skin flap viability. After 5 days of VAC, the flap had markedly improved in color and consistency and VAC was discontinued. Successful healing of the flap occurred without the need for debridement or additional intervention.

Clinical Relevance—Use of VAC led to a good overall outcome for the dog, with complete healing achieved. Additional evaluation of this technique for salvaging failing skin flaps is warranted in dogs, particularly considering that no reliable method for flap salvage in veterinary species has been reported to date. (J Am Vet Med Assoc 2013;243:863–868)

A 4-year-old sexually intact male Labrador Retriever–Poodle mix, weighing 25.9 kg (57.0 lb), was evaluated following a traumatic injury to the left thoracic region. When initially evaluated by the referring veterinarian, the dog had a 20-cm wound covered by a large flap of skin that extended caudally from the scapula over the left side of the thorax. The dog was anesthetized, the wound debrided, and the flap of skin sutured to close the wound over a Penrose drain. Progressive discoloration of the flap of skin was noticed over the next 3 days, which prompted referral.

On evaluation of the dog at the Queen Mother Hospital for Animals, a 3-cm defect was evident at the cranioventral aspect of the wound, from which purulent material was being discharged. The flap of skin was black and hard, consistent with necrotic tissue, and the skin surrounding the flap of skin was bruised (Figure 1). Signs of pain were elicited on palpation of the wound and surrounding region. Results of physical examination, blood gas and electrolyte analysis, PCV and blood total protein measurement, and thoracic radiography were all unremarkable.

The dog was anesthetized, and the entire flap of necrotic skin excised with debridement of the underlying tissue. Lacerations in the latissimus dorsi and external abdominal oblique muscles and branches of the brachial plexus were seen. The branches of the brachial plexus were covered by apposing overlying subcutaneous tissue with simple interrupted sutures. A swab specimen for bacterial culture was obtained from the wound bed, administration of amoxicillin–clavulanic acid (20 mg/kg [9.1 mg/lb], IV) was initiated, and the area was thoroughly lavaged. Primary wound closure was not possible because of excessive tension and contamination.

A VAC system was used to aid wound decontamination and formation of granulation tissue. The VAC dressing was placed into the wound bed with a sterile piece of open-cell polyurethane. Adhesive spray followed by a sterile adhesive dressing was applied over the polyurethane and onto the surrounding skin to hold the dressing in place. A stab incision was made in the adhesive dressing to attach the adhesive port for the VAC machine, which was subsequently switched on and set at –100 mm Hg. The thorax was bandaged to include the suction line of the VAC machine by use of a soft bandage, wrapping, and cohesive dressing.

The VAC dressing was removed 3 days after application, at which time a healthy bed of granulation tissue was observed (Figure 2). The wound was lavaged with sterile saline (0.9% NaCl) solution, skin stretchers were applied cranial and caudal to the wound with cyanoacrylate glue and hook-and-loop fasteners, and the entire region was bandaged. Bacterial culture yielded scant mixed growth of Staphylococcus pseudinterme-


dius, Escherichia coli of 2 colony types, and Enterococcus spp. One E coli isolate was resistant to potentiated amoxicillin, whereas all isolates were susceptible to trimethoprim-sulfonamide. Consequently, the antimicrobial administered was changed to trimethoprim-sulfonamide (15 mg/kg [6.8 mg/lb], PO, q 12 h).

Reconstruction of the wound was performed after 3 days of skin stretching. Small nonviable sections of the left latissimus dorsi muscle were debrided along with most of the granulation bed, and the remainder of the latissimus dorsi muscle was apposed with simple interrupted sutures. A 40-cm rotation flap was marked on the skin extending from the caudoventral edge of the wound in a curve directed caudodorsally. The flap was incised and elevated and further tissue undermining continued as necessary until a tension-free closure could be achieved. A miniature continuous suction drain was placed under the flap so that it exited cranioventrally through a separate stab incision, several centimeters from the surgical wound. A diffusion catheter was placed under the flap so that it exited ventrally. The drain and diffusion catheter were bandaged in place, but the dog still managed to pull out the active-suction wound drain 2 hours after anesthetic recovery. The diffusion catheter was left in place for administration of ropivacaine hydrochloride (1.5 mg/kg [0.68 mg/lb]) every 6 hours for the initial 48 hours after surgery, after which the catheter was removed.

Two days after surgery, evidence of dehiscence was noticed at the cranioventral aspect of the wound. Ten centimeters of the ventral suture line and 15 cm of the cranioventral suture line had dehisced, and a moderate volume of serosanguineous fluid leakage was present. The skin surrounding these areas had marked purple-black discoloration and was cold and hard for a circumference of approximately 3 cm around the suture lines. It had a leathery appearance and was nonpliable, suggestive of early necrosis.

The VAC dressing was reapplied, this time in the hope that it might help maintain viability of the compromised flap. Sponges were cut to length and placed over the suture lines with a 2- to 3-cm overlap circumferentially around the wound edges. The VAC machine was maintained at –100 mm Hg.

Forty-eight hours after the VAC dressing was reapplied, marked improvement was noticed in the appearance of the compromised ventral and cranial aspects of the wound: the color had changed from black to purple-pink, and the temperature and texture of the skin felt consistent with that of the surrounding skin (Figure 3). After an additional 72 hours of VAC, there was further improvement in the appearance of the skin edges, with a decrease in the degree of bruising and edema. The VAC dressing was removed, and the wound was kept covered with a dressing until the skin sutures...
Small animals were removed 3 days later. At that point, the dog was released from the hospital with a small residual open wound, 3 x 1 cm in diameter, from where an eschar had sloughed (Figure 6). The owners were instructed to change the dressing once a day and enforce strict rest until complete skin healing had taken place. Reexaminations were performed by the referring veterinary surgeon. There were delays in healing due to lack of owner compliance in exercise restriction and management, but healing progressed until complete at 6 weeks after release from the hospital, with no requirement for further intervention.

**Discussion**

Vacuum-assisted closure can be performed with various treatment goals in mind, as tailored to the characteristics of individual patients and their wounds. The use of VAC was first described in the human literature in 1995 and now has a wide variety of clinical indications, including repair of fresh or chronic wounds, open abdomens, burns, enterocutaneous fistulae, open fractures, osteomyelitis, and use over skin grafts and flaps. The first report of VAC in the veterinary literature was published in 2007; however, little information is available on the use of VAC in companion animals.

In humans, VAC has been used as a treatment for skin flaps with partial necrosis after debridement of necrotic tissue. Application of VAC is hypothesized to improve the success of skin flaps by reducing wound edema, increasing blood flow, and securing placed flaps onto the recipient wound bed. In a cat, VAC has been reportedly used to prepare a wound for a mesh graft and to cover and secure the graft. To the authors’ knowledge, the use of VAC for salvage of a flap that has started to dehisce or devitalize has not been reported in the veterinary literature.

Vacuum-assisted closure can stimulate granulation tissue formation, reduce edema and interstitial fluid production, reverse tissue expansion, reduce bacterial colonization, and increase dermal perfusion. Tissue growth is known to be stimulated by mechanical forces such as those used in distraction osteogenesis. Mechanical stress has direct effects on cellular activity and angiogenesis, and use of VAC results in application of equally distributed mechanical pressure at the foam-wound interface. The effects of VAC on cellular activity and angiogenesis are not yet fully understood, but stimulation of these is hypothesized as one of the reasons VAC can aid graft uptake. Vacuum-assisted closure also has an effect on dermal perfusion, which may contribute to its usefulness in wound healing. It is likely that the changes in interstitial fluid pressures have an indirect effect on wound perfusion by decompressing small blood vessels. In addition, the mechanical forces exerted on the extracellular matrix will inevitably affect the microvasculature contained within it, and therefore, mechanical stress may be the principal effector. In contrast, direct effects on the dermal vasculature are believed to be mediated through the influence of the negative pressure on vasomotor tone and vasoactive mediators.

The effect of VAC on the vascularity of wounds is not yet fully understood. In a wound model in pigs, the effects of negative pressure dressings on blood flow were quantified with needle laser Doppler flowmetry, where it was found that subatmospheric pressures of –125 mm Hg resulted in a 4-fold increase in blood flow. Increasing pressures to –400 mm Hg across the wounds.
actually decreased blood flow in these wounds.\textsuperscript{2} The human literature contains reports\textsuperscript{20,21} of the use of VAC contributing to major hemorrhage in affected patients, and it has been recommended that the sponge should not be placed over major vascular structures (and that visceral organs should be protected) because it can adhere to these and cause tearing of the outer layers, resulting in substantial bleeding or exsanguination.\textsuperscript{20,21} Given these previous reports, the location and nature of the wound in the dog of the present report, and visual identification of branches from the brachial plexus during original surgical debridement, the pressure of the VAC used in the dog was maintained at \textendash100 mm Hg rather than at the commonly used pressure of \textendash125 mm Hg. In addition, the branches of the brachial plexus were covered through the apposition of overlying subcutaneous tissue to ensure the branches were not in contact with the VAC dressing. For the second application of VAC, we continued to use a setting of \textendash100 mm Hg because this setting has been recommended when VAC is used over skin flaps in humans.\textsuperscript{21}

Infection is known to impede wound healing and was a problem in the dog of the present report. A lower number of bacteria have been identified in wounds treated with VAC (vs dressings moistened with saline solution),\textsuperscript{2} which may have played a role in the successful result following application of VAC in the dog. In another study,\textsuperscript{24} the cellular content of the foam from VAC dressings was evaluated, revealing high counts of neutrophilic granulocytes and T cells, particularly CD4+ cells. The results suggested the implanted foam was an attractive habitat for leukocytes.\textsuperscript{24}

Although a flap was used in the dog of this report and not a graft, the 2 are similar in terms of the local wound environment needed for successful dermal integration. The optimal conditions for graft and flap integration are promoting drainage, inhibiting infection, and ensuring firm fixation of the graft to its bed, all of which VAC has been shown to do.\textsuperscript{2,13,20} There was moderate fluid production from the flap, and removal of this fluid would have increased dermal perfusion and reduced the risk of bacterial colonization. Use of negative pressure dressings for grafts has led to survival rates > 90% in affected humans.\textsuperscript{25}

The second application of VAC in the dog was intended to increase dermal perfusion and maintain flap viability. Substantial improvement was noticed in the apparent viability of the flap within \textasciitilde48 hours after VAC dressing application, with no need for debridement. The areas of nonviable tissue seen just prior to placement of the VAC dressing healed with the exception of a small area (approx 3 × 1 cm in diameter) where an eschar had developed and sloughed. The resultant exposed area was left to heal by secondary intention. Although application of VAC over necrotic tissue is not recommended,\textsuperscript{21} most of the compromised flap returned to its preinjured condition, perhaps because of the quick application of VAC.

Although the reported advantages of VAC, including an increase in dermal perfusion, removal of excess fluid, and elimination of dead space, were all exploited in the dog of this report, one of the reported benefits of the technique was potentially overlooked. The VAC dressing was removed once a healthy bed of granulation tissue had formed, and skin stretchers were applied in the hope that they would increase skin elasticity and facilitate final reconstruction of the wound. However, continued use of VAC might have helped to increase the elasticity of the skin, as has been reported for human abdominal wounds in which a centripetal effect has been observed.\textsuperscript{27} Such increased elasticity might have reduced the risk of flap dehiscence.

Although the authors recognize the limitations of physical inspection of skin flaps as a means of assessing their viability, little evidence exists for more objective methods of assessing flap viability or successful reintegration. Reported techniques for measuring microcirculation include laser Doppler flowmetry, optical spectroscopy, indocyanine green fluorescence angiography, measuring trancutaneous \textit{P}<sub>O</sub><textsubscript>2</textsubscript>, vital capillaroscopy, pho- toplethysmography, thermography, isotope clearance, dermofluorometry, and dermofluorography and measurements with radioactively labeled corpuscular blood components.\textsuperscript{28–31} All of these tests have disadvantages, including the need for specialized equipment, high financial cost, unreliability, and high operator demands. In a clinical setting, therefore, the most commonly used method for assessing skin viability is subjective assessment through evaluation of the temperature, color, and texture of the skin. These variables were assessed in the dog and interpreted in combination with clinical experience to draw conclusions as to the viability of the flap and its progression.

Information regarding skin flap survival rates in veterinary medicine is scarce, and few options are available for improving flap survival. In a retrospective study\textsuperscript{32} of the survival of axial pattern skin flaps in 10 dogs, only 3 had complete skin flap survival, with the remaining 7 having various degrees of necrosis in the distal portion of the flap. Six of these failed flaps required further surgical management; however, that study\textsuperscript{32} involved a specific flap design in an anatomic location that is difficult to close. We used a rotation flap, which is believed to be less robust than axial pattern flaps because of the blood supply from the subdermal plexus rather than a direct cutaneous artery, with a surviving area approximately 50% greater than that of subdermal plexus flaps of comparable dimensions,\textsuperscript{33} so an even higher failure rate might have been anticipated. Another perspective is that rotation skip flaps might have a higher survival rate than axial pattern flaps because of their (often) smaller size and comparatively broader base. Until additional evidence is available, no conclusions can be made about the superiority of one approach over the other.

Various methods have been evaluated with the hope of improving skin flap survival rates. Administration of clopidogrel and high-dose acetylsalicylic acid,\textsuperscript{34} topical anti-ischemic agents,\textsuperscript{35} corticosteroids,\textsuperscript{36,37} hypothermic support,\textsuperscript{37} and hyperbaric oxygen\textsuperscript{38,39} have all been tried with varying success. In the absence of established methods to aid with skin flap survival in veterinary patients, we decided to try VAC to increase the likelihood of dermal integration of the skin flap, with success. No major complications were encountered with the use of VAC in the dog. Minor problems initially consisted of an apparent leak in the system, although
the sponge maintained the desired (ie, raisin-like) appearance, indicating that negative pressure was still being applied by the VAC machine. The exact pressure applied to the wound surface under these circumstances was unknown but was presumably less than the −100 mm Hg that was programmed. The location of the wound contributed to these problems given that the axilla was necessarily incorporated into the adhesive dressing, which caused an increase in dressing movement and difficulty with contouring the dressing in this location. As another study of VAC in veterinary species showed, some learning is involved in the application of VAC dressings. The dressing was changed in its entirety at each dressing change in our dog, and with the second dressing change, minor dermatitis was evident in the surrounding skin. Similar problems were encountered in the first 2 dogs evaluated in a study of VAC use in 15 dogs with wounds in the distal portion of the extremities, leading to a change in the bandaging protocol whereby only the adhesive dressing over the open-cell foam was removed. The protocol change solved the problem in the remaining 13 dogs. Not changing the entire dressing would also have decreased the amount of time taken to complete the procedure, with lower cost for materials used.

The reason for initial failure of skin flap integration in the dog of this report remains unknown but was likely multifactorial. Previous infection, injury location (vicinity of the scapula), need for a large flap, and undermining of surrounding skin because of the size of the defect were likely to all have contributed. Detrimental effects of local anesthetic agents on wound healing have been identified through in vitro and in vivo studies involving rats, and potentially, the anesthetic we used could have contributed to dehiscence in the dog. However, another study of lignocaine and bupivacaine on wound healing in rats found no adverse effects of either, compared with wound healing a control group. Bupivacaine and ropivacaine have been used as local anesthetics in humans for diverse reasons, ranging from excisional biopsy of breast lumps to hip and knee arthroplasties. Adverse reactions, including impaired wound healing, were not reported. However, given that we used the VAC technique in 1 dog only and no controlled veterinary studies of use of ropivacaine have been performed in vivo to our knowledge, no conclusion regarding the contribution of the local anesthetic to the dog’s healing can be made. As part of a multimodal analgesia protocol, the diffusion catheter is supported by evidence in the human literature, with several beneficial effects and a low incidence of related complications reported.

To the authors’ knowledge, this is the first report of the use of VAC to salvage a subjectively assessed failing skin flap. The overall outcome was good with complete healing achieved. Vacuum-assisted closure is being used increasingly in humans for skin grafts and flaps. Additional investigation of the use of VAC to salvage failing skin flaps in veterinary medicine is warranted because no consistently reliable method for flap salvage is available.

References


