Case Description—A 9-month-old domestic shorthair cat was evaluated after being struck by a car.
Clinical Findings—The cat had a fractured tibia and avulsion of the tail base. Motor and deep pain sensation were absent from the tail. The fractured tibia was repaired 2 days after the trauma. On the third day, the cat developed tachypnea, dyspnea, high serum urea nitrogen and total bilirubin concentrations, epistaxis, persistent hypotension, and oliguria. The cat recovered with supportive care but developed extensive necrosis of the skin on the dorsum by 9 days after the initial trauma.
Treatment and Outcome—The skin was debrided from the caudal portion of the scapula to the anus and down each pelvic limb to the level of the distal portion of the femur. The tail was amputated. Wet-to-dry bandages were applied to the wound for 3 days. Approximately 50% of the wound underwent delayed primary closure, and the remainder was managed with vacuum-assisted closure. A healthy granulation bed was quickly established. Vacuum-assisted closure was also applied after graft application. Graft acceptance was 100%, and use of the vacuum-assisted closure bandage was not associated with the complications associated with the traditional bandage.
Clinical Relevance—Vacuum-assisted closure is a useful, easily applicable technique for open and grafted wounds, even when wounds are in challenging anatomic locations. (J Am Vet Med Assoc 2007;230:1669–1673)

A 9-month-old 5.2-kg (11.5-lb) neutered male domestic shorthair cat was evaluated at the Veterinary Specialty and Emergency Center shortly after being hit by a car. On initial examination, rectal temperature was 36.3°C (97.4°F), heart rate was 230 beats/min, and respiratory rate was 40 breaths/min with a mild increase in effort. The cat was recumbent but had motor movement in both pelvic limbs. A closed right tibial fracture was palpable. Motor movement and deep pain sensation to the tail, as well as anal tone, were absent. Urinary continence was not initially evaluated because of placement of an indwelling urinary catheter to assess urinary output.

Initial treatment for stabilization included administration of a crystalloid solution (14 mL/kg [6.4 mL/lb], IV), buprenorphine (0.01 mg/kg [0.005 mg/lb], IV), dexamethasone sodium phosphate (0.3 mg/kg [0.14 mg/lb], IV), and heat support. Heat was supplied via a warm water blanket and circulator with a thin cover between the blanket and patient. A serum biochemical panel and measurements of electrolytes, PCV, and total solids were performed. Abnormalities included hypoalbuminemia (1.9 g/dL; reference range, 2.2 to 4.0 g/dL), hypoglycemia (2.7 g/dL; reference range, 2.8 to 5.1 g/dL), low total protein (4.6 g/dL; reference range, 5.7 to 8.9 g/dL), hyperphosphatemia (8.5 mg/dL; reference range, 3.1 to 7.5 mg/dL), and hyperglycemia (322.9 mg/dL; reference range, 76 to 145 mg/dL). Packed cell volume was 29% (reference range, 30% to 47%). Radiography revealed evidence of hemoglobinuria.

Two days after admission, the cat was premedicated with buprenorphine (0.01 mg/kg, IV) and glycopyrrolate (0.005 mg/kg [0.002 mg/lb], SC), anesthesia was induced with propofol (3.8 mg/kg [1.73 mg/lb], IV) and diazepam (0.2 mg/kg [0.09 mg/lb], IV) administered at induction. The cat was positioned in right lateral recumbency on a warm water blanket and circulator. The tibial fracture was repaired with an intra-...
medullary pin and full cerclage wires. A splint was placed after surgery. The cat was administered fluids IV, hydromorphone (0.1 mg/kg, IV, q 4 to 6 h), ticarcillin disodium and clavulanate potassium (19.3 mg/kg [8.8 mg/lb], IV, q 8 h), famotidine (0.5 mg/kg [0.23 mg/lb], IV, q 24 h), and meloxicam. The postoperative PCV was 15%, so a second transfusion of stored whole blood (11.5 mL/kg [5.3 mL/lb], IV) was administered after a crossmatch was performed. All variables, including heart rate, respiratory rate, and temperature, remained stable during administration of the blood transfusion. After the transfusion, PCV increased to 30%.

The following day, 18 hours after the second blood transfusion, the cat had signs of depression and developed unilateral epistaxis, tachypnea, and dyspnea. Thoracic radiography did not reveal abnormalities. A serum biochemical panel revealed high activity of alanine aminotransferase (317 U/L; reference range, 12 to 130 U/L) and concentrations of total bilirubin (6.98 mg/dL; reference range, 0 to 0.9 mg/dL) and BUN (73.7 mg/dL; reference range, 16 to 36 mg/dL); serum potassium concentration was low (2.9 mmol/L; reference range, 3.4 to 5.6 mmol/L). Although prothrombin time and activated partial thromboplastin time were not measured, venipuncture sites subjectively bled longer than expected. Despite administration of appropriate volumes of crystalloid and colloid fluids, hypotension and oliguria developed. Twenty-four hours after the last transfusion, PCV decreased to 20%. The cat’s clinical signs were considered consistent with either a severe delayed transfusion reaction or systemic inflammatory response syndrome with multi-organ dysfunction syndrome.

With intensive care, the cat had steady systemic improvement. By 3 days after surgery, the fever was resolved. After removal of the urinary catheter, the cat had voluntary urinations with incomplete bladder emptying. Nine days after the initial trauma and 7 days after repair of the tibial fracture, the cat again developed increased rectal temperature ranging from 39.5°C to 39.9°C (103.1°F to 103.8°F). The following day, the skin over the entire dorsum of the body, from the scapulae to the tail base, began developing signs of necrosis. The area was clipped and cleaned for daily monitoring of the site.

On day 17, the full extent of necrosis of the skin was evident, and the cat was anesthetized via the described protocol. The necrotic skin was excised, leaving a defect from the caudal portion of the scapulae to the perineal area and extending down the lateral aspect of each pelvic limb to the level of the proximal portion of the femur. The surviving centimeter of skin surrounding the anus was tacked into place. The tail was amputated at the time of surgery. A bacterial culture of the wound bed was obtained after skin debridement.

The wound was covered with wet-to-dry bandages that were changed daily for 3 days. On the fourth day after skin debridement, the cat was again anesthetized. One millimeter of the wound edges was removed, and the skin along the lateral portion of the thorax and abdomen was undermined and advanced with walking sutures to progressively bring the skin edges together. Approximately 50% of the skin defect was closed primarily, leaving a defect 12 X 18 cm encompassing an area from the cranial aspect of the ilial wings to the anus and laterally down each thigh (Figure 1). This wound was subsequently managed with vacuum-assisted closure.

With the cat in sternal recumbency, a sterile piece of open-cell polyurethane foam was trimmed to the shape of the wound, overlapping the skin by several millime-
ters. This overlap allowed for a small amount of shrinkage in the foam once the vacuum was applied. Several small openings were cut in a 10-F polyvinyl catheter. A tunnel was created through the middle of the foam through which the catheter was inserted. The catheter was positioned to extend the entire length of the foam, making sure that the last hole cut in the catheter did not extend beyond the foam. An adhesive paste was applied along the skin approximately 0.5 cm from the wound edges in areas where it was thought a vacuum-tight seal might be difficult to obtain. The sterile foam was placed directly on the wound and a sterile adhesive dressing was applied in a cranial to caudal direction covering the entire foam and 4 cm of the surrounding skin to create an airtight seal (Figure 2). Holes were cut in the adhesive drape to uncover the anus and prepuce. The vacuum was connected to the exiting end of the red rubber catheter, and 125 mm Hg of continuous subatmospheric pressure was applied to the wound. Suction was provided by a vacuum system and adjusted with a suction regulator. The dressing was carefully examined, and locations of any audible leaks were covered with pieces of adhesive dressing.

The cat was maintained on 125 mm Hg of continuous suction. The polyvinyl catheter exiting the sponge dressing was attached to a collection canister via standard suction tubing. A second suction tube connected the collection container to the suction wall unit. The volume of fluid suctioned from the wound was measured daily. Approximately 30 mL of a transudate was collected per day during the first 2 days of use of the VAC bandage, after which the fluid volume decreased. The bacterial culture yielded heavy growth of Enterobacter cloacae, scant growth of a γ (nonhemolytic) Streptococcus sp, and growth of a Clostridium sp. Intravenous administration of antimicrobials performed on the basis of these culture results included cefazolin (25 mg/kg [11.4 mg/lb], q 8 h) and enrofloxacin (5 mg/kg [2.3 mg/lb], q 24 h). The bandage was frequently checked for audible leaks and repaired as needed.

Following published recommendations, the bandage was changed every 48 hours by cutting out the sponge through the dressing and applying new sterile foam. Healthy granulation tissue was evident within 48 hours, and the skin edges had adhered down to the underlying tissue. Edema in the right pelvic limb, which had been mild before application of the bandage, worsened with the vacuum-assisted bandage in place, and the limb remained moderately edematous during treatment with VAC. The rectal mucosa also began to slightly prolapse. By the time of the second bandage change, a 2-cm area of the primary closure that was not under VAC had dehisced and was draining serosanguinous fluid. A second sponge was cut to fit an area 2 cm larger in diameter than the wound opening and was inserted under the skin. Both of the sponges were attached into the same suction tubing via a 3-way adapter.

The VAC bandage was maintained for 6 days, after which time the owner chose to take the cat home. The granulation tissue on the primary wound and under the dehisced incision had a healthy cobblestone appearance. The dehisced incision had adhered to the underlying tissue and was no longer draining. A nonadhesive dressing was placed directly over the primary wound, followed by cotton roll, roll gauze, and elastic adhesive tape. The bandage was changed every 3 to 5 days. The bandage slipped down over the anus several times, allowing fecal material to become trapped under the bandage. Because of the configuration of the wound and the limited skin between the rectum and wound bed, a tie-over bandage was not attempted. The wound continued to shrink down, although at a slower rate than while under VAC, resulting in a V-shaped defect of approximately 8 × 12 cm 1 month after cessation of VAC. A small nonhealing wound over devitalized bone on the fifth digit of the right hind foot also became apparent. Bowel and bladder function had returned to normal by this time.

Forty days after the initial skin debridement, a mesh graft was applied following published techniques. Briefly, the graft bed was prepared by removing a 1-mm margin of epithelium along the wound edges and superficially excising the top 1 mm of granulation tissue. A full-thickness graft was created on the lateral aspect of the thoracic wall following a tracing taken of the original wound. Any adherent subcutaneous tissue was removed, and a No. 11 blade was used to cut parallel rows of staggered incisions in the graft. The mesh graft was placed over the wound bed and tacked in place with several sutures. The graft was covered with a VAC bandage (Figure 3). Amputation of the right rear fifth digit was performed at the same time.

Figure 2—Cross-sectional illustration of VAC of a skin wound. Arrows indicate the direction of suction. PF = Open-cell polyurethane foam. PV = Polyvinyl catheter. SD = Sterile dressing. AP = Adhesive paste. WB = Wound bed.

Figure 3—Photograph of a VAC bandage applied over a mesh graft in a cat. See Figure 2 for key.
The graft was maintained for 4 days under VAC with 1 sponge change after 48 hours. Acceptance of the graft was 100%. The cat was released from the hospital with a light wrap applied to the affected area. The bandage encountered the same difficulties as earlier, with slippage resulting in feces being trapped under the bandage and rubbing of the graft resulting in subsequent slowing of healing and eventually wearing away of the graft over the tail base. The bandage was removed after 2 weeks. The owner applied antimicrobial ointment to the area 3 times daily to keep the granulation tissue moist, and healing progressed rapidly.

**Discussion**

Vacuum-assisted closure has become a standard treatment modality for wound management in human medicine since it was first described in 1995. Developed to deal with extremely debilitated patients with chronic wounds, it is now used for patients with acute traumatic wounds, chronic nonhealing wounds, pressure ulcers, degloving injuries, skin grafts and flaps, open abdomens, complex perineal and gynecologic wounds, enterocutaneous fistulas, and skull defects. The technique involves placing open-cell foam in the wound, sealing it with an adhesive drape, and applying subatmospheric pressure to the wound bed. The open-cell foam allows even distribution of suction to the entire wound surface. Vacuum-assisted closure was first used in the cat reported here to promote granulation tissue formation and wound closure. It was applied a second time to provide a negative-pressure dressing for the graft, effectively immobilizing the graft and eliminating any fluid pocketing between the graft and underlying tissue.

Although the exact mechanism of action of VAC remains unknown, it is thought to involve a combination of several factors. The vacuum promotes granulation tissue formation, neovascularization and increased blood flow to the wound, removal of excessive fluid and edema, and a reduction in bacterial counts, all of which promote wound healing. Micro-mechanical forces applied to the wound may also be a key factor for inducing cell proliferation and wound healing. Distraction osteogenesis has long been an accepted method of lengthening bone to correct angular limb deformities and replace segmental bone defects. Cells respond to tension generated in the distraction gap, forming fibrils oriented parallel to the tension vector. Similarly, cells under subatmospheric pressure also are under tension. One report indicates that only cells allowed to stretch can divide and proliferate in response to growth factors. The authors hypothesize that the application of subatmospheric pressure to cells in a wound induces tissue deformation and cell stretch, inducing cell proliferation and angiogenesis.

Vacuum-assisted closure may be performed at a variety of pressures and via continuous or intermittent suction. The greatest increase in blood flow to the wound edges occurs at –125 mm Hg, at which blood flow becomes 4 times baseline values. This pressure has become the standard setting in clinical practice. Intermittent suction is also the mode of choice, resulting in increased granulation tissue formation and blood flow, compared with continuous suction and control values. This option requires a specialized suction unit that can apply timed intermittent suction, however, and such a unit was not available for use in the cat reported here. Nevertheless, continuous suction results in a faster rate of granulation tissue formation, compared with controls.

Vacuum-assisted closure allowed bandage changes to be performed every 48 hours, rather than every 24 hours as required for the wet-to-dry bandages. This meant fewer anesthetic episodes for the patient and less time devoted overall to bandage changes. Previous reports recommend the sponges be changed every 48 to 72 hours, although some authors advocate leaving the sponges on for 3 to 6 days between changes. In certain situations, such as with delicate grafts, this may be advantageous, although this is not recommended for patients with rapid granulation tissue formation because ingrowth of tissue into the sponge may require surgical debridement. In retrospect, the VAC bandage placed over the graft could have first been changed after 3 or 4 days.

Graft survival depends on several factors. Complicating issues, such as graft movement, hematoma or seroma formation, and infection, can all lead to graft failure. Vacuum-assisted closure reduces or eliminates all of these potential problems. The graft in the cat reported here had 100% survival, and problems did not develop until a traditional bandage was placed. Unlike the vacuum bandage, which was firmly adhered to the wound, the padded bandage constantly shifted with the cat’s movements, slowly eroding the graft at pressure points. The localized erosion halted epithelialization of the granulation tissue and required removal of the bandage before the graft had fully covered the defect.

In this case, application of the graft would have ideally occurred at an earlier stage to shorten overall healing time. However, the donor site was part of the skin that was undermined and stretched to allow primary closure of the cranial portion of the wound. In addition, owner consent was not granted until the duration of second intention healing and the need for another surgical procedure to amputate a digit became apparent.

The large area of skin necrosis may have been the result of multiple factors. The tail-pull injury likely resulted in a degree of physiologic degloving with detachment of the skin from the underlying tissues and blood supply. The blood flow to the skin may have been further compromised by the physiologic response to the trauma. Sympathetic stimulation during trauma leads to an increase in circulating catecholamines, which in turn causes vasoconstriction of the peripheral blood vessels and preferential shunting of blood to the brain and heart. Poor cardiac output, decreased arterial oxygen content, anemia, and changes in the complex regulation of microcirculatory blood flow during shock and blood loss further decrease oxygen delivery to the tissues. The resulting anaerobic metabolism as well as local inflammation trigger the production of cytokines and activation of the coagulation cascade. The subsequent transfusion reaction, systemic inflammatory response syndrome, and associated hypotension in the

**References**

days following the initial trauma and surgery added to the overall compromise of the skin.

External sources of heat always raise the concern of iatrogenic thermal burns as a cause of the skin necrosis. Heat was provided several times to the cat in the form of a warm water blanket and circulator. While receiving heat, the cat was positioned in either left or right lateral recumbency, with the exception of preparation of the limb for surgery, for which the cat was positioned in dorsal recumbency. Although the cat had skin necrosis over the lateral aspect of both thighs, the skin over the lateral portion of the abdomen, thorax, and shoulders remained healthy. The cat spent a brief period positioned in dorsal recumbency; however, the entire skin on the dorsum of the cat and the skin around the anus became necrotic. The authors believe that circulatory compromise, rather than a thermal burn, was the cause of the extensive skin necrosis. The devitalized bone in the digit was also believed to be secondary to circulatory compromise to the bone.

The systemic illness the cat developed after surgery was likely the result of a delayed transfusion reaction and the pathophysiologic consequences of severe trauma. In retrospect, although the cat had been stabilized, it was still susceptible to the second systemic stress of general anesthesia and surgery. Partial hemolysis of the blood transfusions contributed to the increase in serum bilirubin concentration, although blood typing and a crossmatch were performed to minimize the risk of a transfusion reaction. Monitoring during the transfusion did not reveal any of the common signs of an acute hemolytic reaction that would have led to discontinuing the blood transfusion or examining the blood for bacterial contamination. Decreased blood flow and oxygen delivery to the liver, anaerobic metabolism, and activation of inflammatory cytokines may have also led to hepatic dysfunction with cholestasis and increases in the activities of liver enzymes.

The complications encountered with VAC treatment were minor and included worsening of preexisting limb edema and mild rectal prolapse. With VAC, any edema, even distal to the site of application, would be expected to resolve with the application of the vacuum. The fractured limb was edematous before application of VAC because of the initial trauma, surgical fixation, and the extensive nature of the skin defect required wrapping the adhesive dressing locally resolved. The second application of VAC did not develop edema during the course of treatment. Upon mobilization of the VAC, the edema improved and eventually resolved. The second application of VAC did not result in edema in either limb. The rectal prolapse was mild and likely occurred secondary to wound contraction during healing because only a small bridge of skin existed between the wound and the rectal mucosa. In a follow-up conversation 14 months after the incident, the owner reported that the rectal prolapse was persistent but mild and causes no clinical problems.

Vacuum-assisted closure has become a cornerstone in wound management in human medicine. It is technically simple and is easily adapted to veterinary medicine with inexpensive equipment. It can be applied in numerous clinical situations and should be considered a viable option in wound care for patients with extensive skin wounds or skin grafts.

References