Vacuum-assisted closure (VAC) is a noninvasive, active wound management system that subjects a wound bed to subatmospheric pressure within a closed environment. Within this closed, negative-pressure environment, VAC therapy removes fluid from the extravascular space, improves circulation, and enhances the proliferation of granulation tissue.1-4 This article describes the necessary equipment for, and method of applying, VAC therapy; reviews the mechanism of action and benefits; and describes contraindications and complications.

**Equipment and Application**

Basic wound care principles must be followed before VAC therapy is initiated. Proper debridement of devitalized tissue is essential to eliminate any potential nidus for bacterial growth and to allow successful wound closure after VAC therapy.4 Incomplete wound debridement before the application of VAC therapy may result in the proliferation of granulation tissue over necrotic tissue, delaying wound healing and promoting abscess formation.1-4 VAC therapy is applicable for the treatment of several wound types (BOX 1).

A VAC system consists of several essential elements: sterile open-cell polyurethane foam (pore size: 400 to 600 µm), plastic egress tubes, occlusive plastic adhesive film, suction tubing, a collection reservoir, and an adjustable suction pump capable of intermittent or continuous negative pressures ranging from –50 to –200 mm Hg. These components are commercially available (Kinetic Concepts, Inc. [KCI], San Antonio, TX; Smith and Nephew, London, England). Additional supplies that we have found useful in applying VAC therapy include a skin stapler, adhesive paste, and adhesive spray (TABLE 1). Patients are hospitalized for the duration of VAC therapy (usually 3 to 7 days) and require frequent monitoring.

An airtight seal is essential to maintain continuous negative pressure and prevent desiccation of the underlying tissue.1 In dogs and cats, the hair on the skin adjacent to the wound must be clipped to facilitate
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creation of this seal. The foam should be cut to conform to the shape of the wound and placed, fully expanded, directly within the wound so that it is in contact with the entire wound surface, especially the deep margins1,2,4 (FIGURE 1). A plastic, fenestrated egress tube or polyvinyl (red rubber) catheter (10 to 14 Fr) with several additional 2- to 3-mm fenestrations is then tunneled into a hole cut into the foam or placed between two pieces of foam. To avoid pressure necrosis in tissue adjacent to the fenestrations, the egress tube should not be in direct contact with the wound bed. When the foam and plastic tubing are in place, the foam can be secured to the wound margins using skin staples (FIGURE 1).

To establish an airtight seal, we have found it helpful to apply adhesive spray and a ring of adhesive paste to the skin surrounding the wound before covering the foam and tubing with the adhesive plastic film. The film should extend several centimeters beyond the wound margins (FIGURE 1). The egress suction tube is attached to standard suction tubing and a collection reservoir, which is in turn connected to the vacuum pump with additional suction tubing.

We use and recommend continuous suction. The continuous negative-pressure setting most commonly used during VAC therapy is –125 mm Hg.1,6 Initial animal studies showed improved blood flow and granulation tissue formation with intermittent suction (5 minutes on, 2 minutes off)2; however, human patients reported more discomfort when suction was applied intermittently than when it was continuous.1 In our experience, veterinary patients tolerate continuous suction well and do not require pain medication specifically for VAC therapy.

When VAC therapy is used postoperatively over a closed incision to prevent seroma and edema formation, a lower negative-pressure setting of –50 mm Hg has been advocated.4 When VAC therapy is used in this manner, the foam can be cut and placed directly over the incision or, if the incision is on a limb, wrapped around the circumference of the limb. If the foam is wrapped circumferentially around a limb, it is essential to cover the entire limb distal to the incision, including the paw, with the foam to prevent a tourniquet effect.

When suction is applied, the foam should visibly collapse within the wound and take on a “raisin” appearance beneath the adhesive film (FIGURE 1). The KCI and Smith and Nephew negative-pressure wound care units are equipped with alarm systems to detect air leakage. If one of these pumps is not being used, the appearance and texture of the foam must be checked frequently to ensure that there is no loss of suction. If the airtight seal is lost, measures must be taken to restore the vacuum immediately.

Indications for VAC Therapy

- Large, open, contaminated wounds
- Skin avulsions
- Degloving injuries
- Abdominal and thoracic wounds (e.g., laparotomy surgical sites, open thoracic wounds)
- Surgical dehiscence
- Chronic nonhealing wounds
- Prevention of postoperative seroma and edema
- Bolster for skin grafts
- Myofascial compartment syndrome

Our experience with the use of VAC therapy for these indications will be detailed in a companion article in March 2010.
The frequency of VAC bandage changes depends on the characteristics of the wound. VAC bandages are typically changed every 48 to 72 hours, although initial management of traumatic or highly contaminated wounds may require the bandage to be changed every 24 hours to allow adequate debridement. Culture and sensitivity testing and administration of appropriate antibiotic therapy are indicated for infected wounds. If VAC bandages are left in place for more than 4 to 5 days, granulation tissue may grow into the pores of the open-cell foam, requiring surgical removal of the foam bandage.

Modifications to traditional VAC therapy have been introduced to treat highly infected wounds or wounds with resistant infections, including silver-impregnated foam (V.A.C. Granufoam Silver Dressing, KCI) and a system that combines negative-pressure wound therapy and antibiotic instillation (V.A.C. Instill, KCI). Early results of the use of these systems in highly infected wounds are promising, although no studies of their use have been conducted in dogs.

In dogs and cats, bandages can usually be changed with patients under heavy sedation. If VAC therapy is used for long periods of time and multiple bandage changes are performed, the plastic adhesive film can be incised directly over the foam, which can then be removed through the fenestration in the film. Leaving the margins of the original film adhered to the skin reduces skin irritation and minimizes the discomfort experienced during bandage changes by avoiding pulling the film away from the skin. New adhesive film sheets are then placed over the previously applied bandage.

### TABLE 1 Components Recommended for Application of VAC Therapy and Approximate Price

<table>
<thead>
<tr>
<th>Component</th>
<th>Costa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterile open-cell polyurethane foam (pore size: 400–600 µm)</td>
<td>$8.00/8″ × 12″ sheet</td>
</tr>
<tr>
<td>Plastic egress tube</td>
<td>$8.75</td>
</tr>
<tr>
<td>Occlusive plastic adhesive film</td>
<td>$23.25</td>
</tr>
<tr>
<td>Skin staples</td>
<td>$23.00</td>
</tr>
<tr>
<td>Adhesive spray</td>
<td>$3.75</td>
</tr>
<tr>
<td>Adhesive paste</td>
<td>$22.95</td>
</tr>
<tr>
<td>Suction tubing and collection reservoir</td>
<td>$20.00</td>
</tr>
<tr>
<td>Suction pump capable of continuous negative pressure</td>
<td>$54.00</td>
</tr>
</tbody>
</table>

Essential items are in bold.

Prices listed are based on costs charged to clients at the University of Florida Veterinary Medical Center.

This cost is not billed to clients because one container can be used for approximately 20 patients.

This is a daily fee assessed for continuous suction through either central suction or a VAC machine.

VAC therapy is used for long periods of time and multiple bandage changes are performed, the plastic adhesive film can be incised directly over the foam, which can then be removed through the fenestration in the film. Leaving the margins of the original film adhered to the skin reduces skin irritation and minimizes the discomfort experienced during bandage changes by avoiding pulling the film away from the skin. New adhesive film sheets are then placed over the previously applied bandage.

### Beneficial Effects and Mechanism of Action

The uniform negative pressure applied to the wound bed by VAC therapy has several beneficial effects, including decreased interstitial edema, increased tissue blood flow, accelerated granulation tissue formation, increased bacterial clearance, and hastened wound closure. VAC therapy enhances the formation of granulation tissue by increasing capillary blood flow velocity, stimulating endothelial cell proliferation and angiogenesis, narrowing endothelial spaces, and restoring capillary basement membrane integrity. Decreased capillary permeability results in reduced edema formation, and the closed, negative-pressure system removes excess interstitial fluid, resulting in decreased local interstitial pressure and restoration of blood flow to previously collapsed vessels.

An additional mechanism by which VAC therapy increases granulation tissue formation is through mechanical stresses exerted on the wound environment. VAC therapy mechanically stimulates cells by exerting tensile forces on the surrounding tissues. The concept that tissues respond to applied forces has long been recognized in relation to bone physiology (Wolff’s law) and is the basis of the Ilizarov technique for distraction osteogenesis. In wounds treated with VAC therapy, the cytoskeleton of cells exposed to subatmospheric pressure is altered, resulting in the release of intracellular second messengers and upregulation of cell proliferation. VAC therapy is also postulated to increase granulation tissue formation through the removal of substances (e.g., degradative enzymes, proteases, collage-nases) that negatively affect wound healing.

The ability of VAC therapy to enhance bacterial clearance has been debated. Initial animal studies comparing the bacterial clearance of VAC therapy with that of daily saline wet-
to-dry bandages showed a drop in quantitative bacterial counts in VAC-treated wounds and a peak in bacterial counts in the control group by day 5. However, clinical studies evaluating wounds treated with VAC therapy in human patients have failed to show a significant reduction in total bacterial counts. Irrespective of whether bacterial numbers are reduced, VAC therapy is able to improve a wound's resistance to bacterial overgrowth through the creation of a healthier wound environment. VAC therapy is not, however, a substitute for proper wound management, and wounds must be appropriately debrided before VAC therapy application.

**FIGURE 1**

Method of VAC bandage application.

(A) A large thermal burn on the dorsum of an adult boxer.

(B) One week after injury, the eschar has been debrided, leaving a large open wound. Polyurethane open-cell foam is placed within the wound.

(C) The margins of the wound are advanced and secured to the foam using skin staples. A polyvinyl catheter has been tunneled into the foam and exits the foam at the upper left wound margin. This catheter is connected to standard suction tubing, which is then connected to a collection reservoir and suction pump.

(D) A ring of adhesive paste has been placed around the wound margins, the foam and surrounding skin have been sprayed with adhesive spray, and adhesive film has been placed over the foam and surrounding skin. Negative pressure (~125 mm Hg) has been applied to the bandage, and the foam has contracted beneath the film, taking on a raisin-like appearance and texture.

(E) Approximately 6 weeks after the original injury, the wound is closed and healing appropriately. This wound required approximately 10 days of VAC therapy.
Another advantage associated with the use of VAC therapy is the acceleration of wound closure.\textsuperscript{17} The mechanical forces and improved granulation tissue formation hasten wound contraction, resulting in earlier closure.\textsuperscript{17} The reduction in time needed to achieve a healthy wound bed, along with the need for fewer bandage changes under sedation, may offer cost savings for VAC therapy compared with conventional dressings that must be changed once or twice daily.\textsuperscript{17}

**Complications and Contraindications**

Complications associated with VAC therapy tend to be minor and easily managed. In our experience, the most common complication is the loss of the airtight seal, which can often be corrected by adding an additional layer of adhesive film. Local dermatitis associated with the bandage is also common but tends to be self-limiting. A significant complication resulted from leaving a VAC therapy dressing in place for 5 days. Granulation tissue grew into the pores in the open-cell foam and necessitated surgical excision of the foam to completely remove the polyurethane fibers.

Few complications have been reported in human patients undergoing VAC therapy.\textsuperscript{5} The most common complication is mild skin irritation from contact with the foam.\textsuperscript{1,4} Two cases of toxic shock syndrome associated with VAC therapy use have been reported.\textsuperscript{18} Additionally, chronic complications may result from pieces of foam being left within the wound.\textsuperscript{5} VAC therapy should be used with caution in hemodynamically unstable patients because large volumes of fluid can be removed during treatment.\textsuperscript{3,4}

There are several contraindications to VAC therapy. The VAC system has a limited ability to debride wounds, and it will not remove devitalized or necrotic tissue. Thus, VAC therapy should not be used in lieu of proper surgical debridement.\textsuperscript{1,4} The treatment of osteomyelitis with the VAC system alone is also contraindicated.\textsuperscript{4,19}

The VAC therapy system should not be used in wounds contaminated with malignant neoplastic cells because the application of the VAC therapy bandage will likely increase blood flow and stimulate cellular proliferation within the wound bed.\textsuperscript{1,4} Finally, care should be taken when placing VAC therapy dressings near exposed arteries and veins. It is possible for the foam to erode through exposed vessels, resulting in extensive blood loss.\textsuperscript{4,5} Similarly, VAC therapy dressings should be used with caution in patients with coagulopathies or active bleeding.\textsuperscript{4,5}

**Conclusion**

VAC therapy increases local blood flow and enhances granulation tissue formation in wounds, accelerates wound contraction, and removes excessive fluid from wounds. After adequate debridement, VAC therapy can be applied to a wide variety of wounds.
1. Debridement of devitalized tissue in a wound is essential before initiation of VAC therapy for what reason?
   a. A potential complication of VAC therapy is further devitalization of tissue.
   b. Granulation tissue may form over necrotic tissue, delaying wound healing.
   c. VAC therapy is contraindicated in contaminated or infected wounds.
   d. It is not essential to eliminate devitalized tissue because one of the benefits of VAC therapy is wound debridement.

2. Which of the following is not required for a VAC bandage?
   a. open-cell polyurethane foam
   b. plastic adhesive drape
   c. suction pump
   d. closed-cell antimicrobial-impregnated foam

3. Tissue desiccation during VAC therapy is prevented by
   a. maintaining an airtight seal.
   b. soaking the foam in physiologic saline.
   c. applying a colloid gel to the wound bed.
   d. using a pressure setting between –50 and –75 mm Hg.

4. Which pressure setting is most commonly used during VAC therapy?
   a. 125 mm Hg
   b. 75 mm Hg
   c. –50 mm Hg
   d. –125 mm Hg

5. Intermittent negative-pressure cycles of 5 minutes on and 2 minutes off result in the greatest increase in blood flow; however, continuous suction is most commonly used because it
   a. minimizes patient discomfort.
   b. is less labor intensive.
   c. more reliably maintains an airtight seal.
   d. removes more bacteria.

6. How often should VAC bandages be changed?
   a. every 12 hours
   b. every 24 to 72 hours
   c. every 4 to 5 days
   d. once a week

7. VAC therapy has been shown to enhance granulation tissue formation
   a. only when applied intermittently.
   b. by stimulating endothelial cell proliferation and angiogenesis.
   c. by increasing capillary permeability.
   d. by clearing bacteria from the wound.

8. Which is not a reported benefit of VAC therapy?
   a. removal of degradative products
   b. nonsurgical debridement of gross contamination
   c. need for fewer bandage changes compared with wet-to-dry bandages
   d. reduction of interstitial fluid

9. Which is a reported complication of VAC therapy?
   a. local dermatitis
   b. ingrowth of granulation tissue into foam
   c. fluid volume depletion
   d. all of the above

10. VAC therapy would be contraindicated for
    a. a degloving injury with exposed tendons.
    b. exposed orthopedic implants.
    c. an intraabdominal wound.
    d. a neoplastic wound.
References