Vacuum-Assisted Wound Closure (VAC Therapy) for the Management of Patients With High-Energy Soft Tissue Injuries

Dolfi Herscovici, Jr, DO, Roy W. Sanders, MD, Julia M. Scaduto, ARNP, Anthony Infante, DO, and Thomas DiPasquale, DO

Objective: To evaluate the results of a vacuum-assisted closure device in patients presenting with open high-energy soft tissue injuries.

Design: Consecutive nonrandomized clinical study.

Setting/Participants: From August 1999 through October 2000, 21 patients, with 21 high-energy soft tissue wounds (6 tibial, 10 ankle, and 5 with wounds of the forearm, elbow, femur, pelvis, and a below-knee stump) were treated with a vacuum-assisted closure device at a Level 1 trauma center.

Intervention: A negative atmospheric pressure device used for the management of complex open injuries. Infected wounds had dressings changed every 48 hours, whereas all others had dressings changed every 72 to 96 hours.

Main Outcome Measurements: The duration of vacuum-assisted closure use, final wound closure outcome, costs versus standard dressing changes or free flaps, and a list of all complications were recorded. All patients were followed for 6 months postcoverage.

Results: Patients averaged 4.1 sponge changes, 77% performed at bedside, with the device used an average of 19.3 days. Twelve wounds (57%) required either no further treatment or a split-thickness skin graft, and 9 (43%) required a free tissue transfer.

Conclusions: The vacuum-assisted closure appears to be a viable adjunct for the treatment of open high-energy injuries. Application can be performed as a bedside procedure but additional soft tissue reconstruction may be needed for definitive coverage. This device does not replace the need for formal debridement of necrotic tissue, but it may avoid the need for a free tissue transfer in some patients with large traumatic wounds.

Key Words: fractures, wounds, vacuum-assisted closure

(*J Orthop Trauma* 2003;17:683–688)

Accepted for publication September 8, 2003.

From the Orthopaedic Trauma Service, Tampa General Hospital, Tampa Florida.

No financial support of this project has occurred. The authors have received nothing of value.

The device that is the subject of this manuscript is FDA approved.

Reprints: Dolfi Herscovici, Jr, DO, Florida Orthopaedic Institute, 13020 N. Telecom Parkway, Temple Terrace, FL 33637 (e-mail: fixbones@aol.com).

INTRODUCTION

The management of high-energy open fractures requires both skeletal stability and adequate soft tissue coverage. Although the goal is to debride all nonviable tissue, this can produce significant soft-tissue defects precluding healing through primary closures, delayed primary closures, or through secondary intention.[1] To aid in these difficult closures, various surgical methods have been developed to obtain coverage. These include closure devices,[2] skin grafts, local rotation flaps, and myocutaneous or fasciocutaneous tissue transfers. Although skin grafts are readily obtainable, they are dependent on the vascularity of its recipient bed and may be contraindicated when exposed bone, cartilage, tendons, or surgical implants exist.[3] In these cases, a local rotation flap may be needed. When the soft tissue defect prevents local coverage, free tissue transfers are usually required but the transfer may produce donor site morbidity[4–6] and require late revisions due to the size of the muscle flap.[7] In extremely large defects, more than one flap may be required to obtain adequate coverage.[8]

Although nonoperative modalities, such as hyperbaric oxygen,[9] have been used to enhance wound coverage, these devices may not be available to all patients and may not be adequate for use in patients presenting with high-energy injuries due to edema, retraction of the skin and soft tissue, wound size, or loss of available local coverage. Attempts have been made to identify an alternative treatment of wound management in these patients. Initially developed in the early 1990s, for the management of large, chronically, infected wounds that could not be closed in extremely debilitated patients,[10] the use of vacuum-assisted closure (VAC) has been more recently used in the treatment of traumatic wounds. The purpose of this study is to describe the indications and evaluate the results of our initial use of this therapy[11] for the management of patients presenting with high-energy soft tissue injuries.

MATERIALS AND METHODS

The VAC device (Kinetic Concepts, Inc., San Antonio, TX) is a subatmospheric pressure device that uses a medical-grade reticulated polyurethane ether sterile foam dressing, which contains an embedded noncollapsible evacuation tube. The pore size of the sponge is 400 to 600 μm, which has been

shown to maximize tissue ingrowth,[12] and the tube contains side ports to allow communication of its lumen to all the spaces in the foam. The sponge comes in four different sizes: small (7.5 cm × 10 cm), medium (12.5 cm × 17.5 cm), large (15 cm × 25 cm), and extra-large (37.5 cm × 62.5 cm) and can be trimmed and shaped to contact all wound surfaces allowing equal distribution of the subatmospheric pressure to all surfaces in contact with the sponge. A smaller sponge, also with a noncollapsible tube, is available primarily for the management of superficial wounds and shallow chronic ulcers. This saline-soaked soft-foam dressing, with pore sizes ranging from 0.2 to 1 mm, is available in 2 sizes, 7.5cm × 10 cm and 10 cm × 15 cm (Fig. 1A).

To create an airtight seal, an adhesive drape is applied over the sponge extending at least 5 cm beyond the wound margins onto adjacent intact skin. The tubing is then connected to a collection canister, which is in turn connected to an adjustable vacuum pump (Fig. 1B). The pump pressure can be adjusted between 50 to 125 mm Hg and can be used in two different modes, intermittent or continuous. Once the pump is turned on, the pressure it produces causes the sponge to collapse onto the wound[10,13] (Fig. 1C).

From August 1999 through October 2000, 21 consecutive patients with high-energy soft tissue injuries that required coverage procedures beyond split thickness skin grafting were treated using a VAC device. The primary indication for this device was an attempt to avoid a local or free-tissue transfer. The sole purpose of this pilot study was to evaluate the results of VAC use. No attempt was made to exclude patients because of age or pre-existing medical condition. All bone and joint injuries were treated according to standard protocols that are well documented in the literature (individual treatments are not described in this paper as they are not the focus of this study). The study cohort consisted of 12 males and 9 females with an average age of 45.9 years (range 16–83). The mechanisms of injury consisted of five wounds resulting from falls, eight secondary to motor vehicle accidents, three resulting from motorcycle accidents, four in pedestrians struck by car, and one as a result of a sporting accident. Six patients had tibial injuries, with wound sizes averaging 73 cm^2 (range 5–261), and 10 patients had ankle or foot injuries with wounds averaging 38 cm^2 (range 8–52). The remaining five patients had wounds involving the elbow, forearm, femur (above-knee amputation), acetabular fracture, and a traumatic below-knee stump approximating 60, 65, 156, 264, and 400 cm^2, respectively.

The clinical management of all patients consisted of a complete and thorough debridement of all nonviable tissue in the operating room. The VAC device was applied at the end of each surgical debridement until the wound was clean and without further necrotic tissue, as determined by the operating surgeon. Once clean, surgical debridements were discontinued and VAC sponges were changed at the bedside every 72 hours. All patients were treated with a continuous pressure of 125 mm Hg applied to their wounds, which was selected based on the descriptions and use of this device by other authors.[11,13–17] Evaluations of the treatment included the duration of VAC use, final wound closure outcome, costs for use versus standard dressing changes or free flaps, and a list of all complications. All patients were followed for a minimum of 6 months after definitive soft tissue coverage to verify healing and or complications.

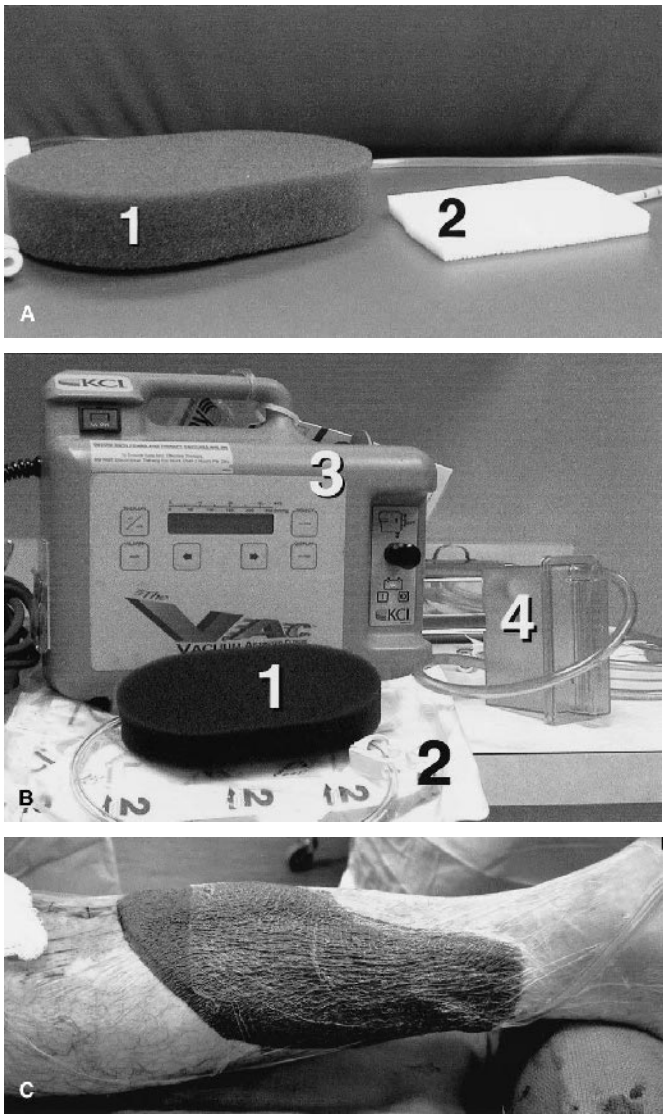

FIGURE 1. A, Comparison of the two sponges; regular sponge (1) is on the left and the smaller foam sponge (2), used for the management of shallow wounds and chronic ulcers, is on the right. B, VAC supplies demonstrating the sponge (1) lying on the drapes (2), the pump (3) behind it, and the collection canister (4) is to the right. C, VAC sponge applied demonstrating collapse over the wound. Note that the drapes exceed the margins of the wound (sponge is cut to the exact size of the wound). Patient is seen in Figure 3.

RESULTS

Follow-up was available on all wounds. Wounds averaged 4.1 sponge changes (range 2–16), with 77% of these performed at bedside, before definitive coverage was obtained. The device was used for an average of 19.3 days (range 5–84). Twelve wounds (57%) avoided the need for further treatment. Five additional wounds were treated to completion requiring only a split-thickness skin graft, The use of a free tissue transfer was required in only 9 (43%) wounds.

There were only two soft tissue complications in this series; one minor and one major, and neither was related to the use of the VAC. The first was due to a partial loss of the split thickness skin graft, requiring revision skin grafting. The second was a failure of the free tissue transfer requiring a revision. Both revisions healed uneventfully. In evaluating the economics of soft tissue closures, three methods were compared: the VAC, wet-to-dry dressings, and the application of a free tissue transfer. Using our trauma registry, wounds and sites that were similar were identified. Treatments were then evaluated. We found 19 wounds that required 20 days with wet-to dry dressings, along with 7 separate wounds that required a free tissue transfer. The total costs for application of the wet-to-dry dressings were calculated as the charges for the dressing supplies plus the fees incurred by the nursing personnel, for dressings changed three times per day. This method of closure resulted in an average cost of $100 per day. For the 21 patients who used the VAC, the charges were calculated as the cost for the sponges and the collection canisters, the rental use of the vacuum pump, and the cost of nursing personnel changing the sponges 3 times a week. The cost for use of the VAC averaged $103 per day. It must be noted that neither method included surgical fees or hospitalization costs. Thus, at an average of 20 days, the cost averaged $2000. In contrast to these two forms of nonoperative management, in the 7 wounds requiring a free tissue transfer, the surgical fee (Medicare rates) alone averaged $6,000.

DISCUSSION

The VAC was originally developed for use in extremely debilitated patients who presented with large, infected, chronic wounds that were deemed unsalvageable.[10] The ability to obtain eventual soft tissue coverage in these patients was attributed to a number of different factors. First, because of the pressure acting on the sponge, the interstitial fluids that accumulated in these wounds were evacuated. These fluids have been found to contain inhibitory factors that suppress the formation of fibroblasts, vascular endothelial cells, and keratinocytes that are prominent in wound healing.[10,11,15,18–21] Secondly, the evacuation of these fluids eliminates the formation of any superficial purulence and slime that is known to occur in open wounds.[10] This enhances wound healing by reducing the potential for anaerobic colonization; decreasing bacterial counts to less than 10^3 per gram of tissue.[14,17,22,23] Third, studies demonstrated that an applied negative pressure allowed arterioles to dilate, increasing blood flow to the area, which produced a proliferation of wound granulation tissue. This has been shown to occur as a result of a decrease in the capillary afterload, which then promotes better inflow.[10,17] Lastly is the effect of applying a mechanical force to the surrounding soft tissues (Fig. 2). Unlike sutures or tension devices,[2] the VAC can exert a uniform force on each individual point on the edge of wound drawing it toward the center of the defect by mechanically stretching the cells when negative pressure is applied.[17] This allows the VAC to move distensible soft tissue, similar to expanders, toward the center of the wound, thereby decreasing the actual size of the wound.[14]

This study represents our initial use of the VAC system. Because we were unsure of its potential, we limited its use to that of a salvage procedure in patients who presented with high-energy soft tissue injuries, who were either awaiting coverage or who were being staged for standard soft tissue techniques. Although the VAC system consistently promoted the formation of granulation tissue and avoided daily dressing changes, formal surgical debridement of necrotic tissue was required. The authors believe that mechanical debridements with secondary evaluations are essential for the management of these injuries. In wounds that are too large, too much time may be required to obtain adequate coverage with the VAC system (Fig. 3). In these cases, a free tissue transfer may be necessary. An unanswered question regarding use of the VAC system remains: how long can one use the VAC before a flap is required? Although the answer is unknown, previous studies have noted that some form of adjunctive soft tissue procedure was needed to obtain a successful wound closure, in the presence of massive traumatic wounds.[10,14,16]

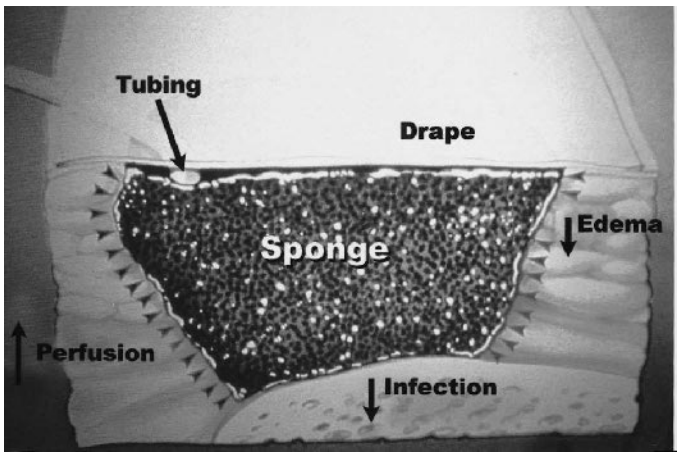

FIGURE 2. Artist rendition of the VAC sponge as it is applied to a bony wound. Note that it decreases edema and infection by evacuating superficial purulence and slime. The vacuum created draws the wound edges to the center and also increases local perfusion to the wound resulting in an increase in the production of granulation tissue.

FIGURE 3. A, 76-year-old non–insulin-dependent male with a history of hypertension and coronary artery disease who presented after a motor vehicle accident with a 3B open tibial fracture. The fracture was managed with an IM device but due to medical problems the patient was unable to be returned to the operating room at 48–72-hour intervals. Appearance of the wound at Day 3, ankle is to the right. B, Sponges were changed at bedside in the ICU every 3–4 days. Note the extensive granulation observed over the distal 4/5 of the exposed bone at Day 15. C, Patient achieved medically stability on Day 22 and underwent the placement of a free lateral arm flap. Appearance of leg at 5 months posttrauma.

Some important tips should be considered when using this device. First, this technique is primarily designed to prepare the wound bed. Because it provides debridement of some local necrotic tissues and decreases local inflammatory mediators,[16] the result may be a proliferation of granulation tissue. This may not avoid the need for other soft tissue procedures but may result in less extensive surgical techniques being performed to obtain adequate coverage, which was demonstrated in 12 patients in this study. Second, this device may provide an option for the management of otherwise nonsalvageable wounds in patients deemed medically unstable, while avoiding surgical or anesthetic risks (Fig. 3). Third, caution should be used when applying the sponge. To avoid maceration of the skin edges, the sponge should only be applied to the wound.[24] In irregular wounds, where trimming the sponge to size may not be possible, small strips of the adhesive drape should first be cut and applied along all of the edges of the wound (framing). The sponge can then be applied without concern that it has exceeded the edges of the wound. Finally, after each debridement, the VAC should be reapplied. This will help to decrease colonization by providing a constant evacuation of the superficial purulence and slime that develops in open wounds while awaiting the need for further surgical procedures, which may be as or more effective than constructing pouches filled with antibiotic beads.[25]

In evaluating costs, the VAC appeared to equal other nonoperative treatment modalities, despite the fact that for this series of patients, the overall cost was higher than other forms of treatment. This occurred because at the time of this study, a Medicare code for use of this device was not yet available. This produced an inability to obtain approval from insurers, which resulted in a prolonged in-hospital use of the V.A.C because our skilled units and home care institutions could not provide this service. However, a recent Medicare billing code has been provided that now allows patients to be discharged and have sponge changes performed at outside facilities or at home. This should result in a reduction for the cost of VAC use.

In completing the discussion for the use of this device, three separate problems have not been addressed in this paper: the frequency of dressing changes, the use of the VAC in patients who have external fixation devices, and the feasibility of bone grafting patients who were treated to completion with this device. In addressing the timing of sponge changes, we currently change them every 3 days in noninfected wounds, and 2 days, in conjunction with debridements if needed, for infected wounds. Upon discharge, we have noted that our home health services prefer a cycle of Monday-Wednesday-Friday. The use of this protocol appears to be well tolerated by the patients and falls into the limits used by other authors.[10,11,13–17] As to applying the sponges around external fixation devices, we have found that the technique of applying small strips around the pins or wires, similar to the use in the management of irregular wounds, can be successful. If this is not possible, the device now comes with Y-connectors, which may allow the placement of two sponges around the pins to obtain better coverage. Finally, with respect to the problem of a delayed bone graft after VAC application, we have found that bone grafting via incisions placed directly through the wound site do not appear to be compromise either the wound or the grafting. Further analysis of this technique is being evaluated at the present time.

In conclusion, the VAC appears to be a viable adjunct for the treatment of high-energy injuries. Application of this device can be performed as a bedside procedure after the initial debridement and aids in the management of wound preparation for a future soft tissue procedure or as a definitive method of treatment. Although traditional soft tissue reconstructions may still be required to obtain adequate coverage, the use of this device appears to decrease their need overall.

REFERENCES

1. Yaremchuk MJ. Concepts in soft-tissue management. In: Yaremchuk MJ, Burgess AR, Brumback RJ, eds. *Lower Extremity Salvage and Reconstruction. Orthopedic and Plastic Surgical Management.* New York, NY: Elsevier Science Pub, Co., Inc.; 1989:95–106.
2. Narayanan K, Futrell JW, Bentz M, et al. Comparative clinical study of the sure-closure device with conventional wound closure techniques. *Ann Plast Surg*. 1995;35:485–491.
3. Haller JA, Billingham RE. Studies of the origin of the vasculature in free skin grafts. *Ann Surg*. 1967;166:896–901.
4. Geishauser M, Staudenmaier RW, Biemer E. Donor-site morbidity of the segmental rectus abdominis muscle flap. *Br J Plast Surg*. 1998;51:603–607.
5. Salmi A, Touminen R, Tukiainen E, et al. Morbidity of donor and recipient sites after free flap surgery. A prospective study. *Scand J Plast Reconstr Surg Hand*. 1995;29:337–341.
6. Schwabegger A, Ninkovic M, Brenner E, et al. Seroma as a common donor site morbidity after harvesting the latissimus dorsi flap. Observations on cause prevention. *Ann Plast Surg*. 1997;38:594–597.
7. Kelly MB, Searle A. Improving the donor site cosmesis of the latissimus dorsi flap. *Ann Plast Surg*. 1998;41:629–632.
8. Blackwell KE, Buchbinder D, Biller HF, et al. Reconstruction of massive defects in the head and neck. The role of simultaneous distant and regional flaps. *Head Neck*. 1997;19:620–628.
9. Heng MCY. Topical hyperbaric therapy for problem skin wounds. *J Derm Surg Oncol*. 1993;19:784–793.
10. Argenta LC, Morykwas MJ. Vacuum-assisted closure: a new method for wound control and treatment. Clinical experience. *Ann Plast Surg*. 1997; 38:563.
11. Baynham SA, Kohlman P, Katner HP. Treating stage IV pressure ulcers with negative pressure therapy: a case report. *Ostomy Wound Manage*. 1999;45:28–35.
12. Wake MC, Patrick CW, Mikos AG. Pore morphology effects on the fibrovascular tissue growth in porous polymer substrates. *Cell Transplant*. 1994;3:339–343.
13. DeFanzo AJ, Marks MW, Argenta LC, et al. Vacuum-assisted closure for the treatment of degloving injuries. *Plast Reconstr Surg*. 1999;104:2145–2148.
14. DeFranzo AJ, Argenta LC, Marks MW, et al. The use of vacuum-assisted closure therapy for the treatment of lower-extremity wounds with exposed bone. *Plast Reconstr Surg*. 2001;108:1184–1191.
15. Grinnell F, Ho CH, Wysocki A. Degradation of fibronectin and vitronectin in chronic wound fluid. Analysis by cell blotting, immunoblotting, and cell adhesion assays. *J Invest Dermatol*. 1992;98:410–416.
16. Mooney JF, Argenta LC, Marks MW, et al. Treatment of soft tissue defects in pediatric patients using the V.A.C system. *Clin Orthop*. 2000;376: 26–31.

17. Morykwas MJ, Argenta LC, Shelton-Brown EI, et al. Vacuum-assisted closure: a new method for wound control and treatment. Animal studies and basic foundation. *Ann Plast Surg*. 1997;38:553–561.
18. Bucalo B, Eaglstein WH, Falanga V. Inhibition of cell proliferation by chronic wound fluid. *Wound Rep Regen*. 1993;1:181–186.
19. Falanga V. Growth factor and chronic wounds: the need to understand the microenviorment. *J Dermatol*. 1992;19:667–672.
20. Wysocki AB, Grinnell F. Fibronectin profiles in normal and chronic wound fluid. *Lab Invest*. 1993;63:825–831.
21. Wysocki AB, Staiano-Coico L, Grinnell F. Wound fluid from chronic leg ulcers contains elevated levels of metalloproteinases MMP-2 and MMP-9. *J Invest Dermatol*. 1993;101:64–68.
22. Daltrey DC, Rhodes B, Chattwood JG. Investigation into the microflora of healing and non-healing decubitus ulcers. *J Clin Pathol*. 1981;34:701–705.
23. Hunt TK. The physiology of wound healing. *Ann Emerg Med*. 1998;17: 1265–1273.
24. Webb LX, Schmidt U. Wundbehandlung mit der vakuumtherapie. *Unfallchirurg*. 2001;104:918–926.
25. Henry SL, Ostermann PA, Seligson D. The prophylactic use of antibiotic impregnated beads in open fractures. *J Trauma*. 1990;30:1231–1238.