The Versatility of Negative Pressure Wound Therapy with Reticulated Open Cell Foam for Soft Tissue Management After Severe Musculoskeletal Trauma

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Summary: This review serves to outline the current and evolving usages of negative pressure wound therapy with reticulated open cell foam (NPWT/ROCF) as delivered by V.A.C.® Therapy (KCI, San Antonio, TX) as an adjunctive treatment modality for optimal management of wounds associated with high energy musculoskeletal trauma.

Key Words: NPWT/ROCF, VAC, VAC Therapy

INTRODUCTION

Negative pressure wound therapy with reticulated open cell foam (NPWT/ROCF) as delivered by V.A.C.® Therapy (KCI, San Antonio, TX) is a beneficial adjunctive treatment modality for soft tissue management after high-energy musculoskeletal trauma. NPWT/ROCF has ideally complemented the existing surgical armamentarium for optimal care of both traumatic and tenuous surgical wounds. Although NPWT/ROCF usage was initially prescribed for the treatment of chronic wounds, clinical uses have expanded to improve soft tissue conditions associated with acute severe musculoskeletal trauma.

Definitive clinical uses for NPWT/ROCF for severe musculoskeletal injury are currently evolving. This technique, however, is currently accepted in practice for the interval or definitive treatment of open musculoskeletal wounds. NPWT/ROCF is frequently employed for temporary coverage of complex wounds when immediate primary closure is not achievable or advisable. This therapy system will "prepare" an orthopaedic wound before definitive soft tissue coverage or is alternatively used to expedite the process of healing by secondary intention as a bridge to closure.

Although NPWT/ROCF application is simple, the effects provided to a compromised soft tissue envelope are profound. Subatmospheric pressure applied through a reticulated open cell foam promotes optimal soft tissue health. The negative pressure device evacuates excessive interstitial fluid from the wound bed providing edema control. Decreased soft tissue swelling encourages essential inflow and outflow bringing oxygen and nutrition to the wound bed while clearing inhibitory factors. Furthermore, the uniform mechanical stress applied to the wound encourages dynamic tissue formation by stimulating regenerative cells to proliferate. This accounts for the rapid formation of healthy granulation tissue noted when this technique is used on wounds treated by secondary intention.

The aim of this article is to review the current and potential usages of NPWT/ROCF for soft tissue management after severe musculoskeletal trauma. Successful care of soft tissue injury after high-energy trauma is integral to optimize outcomes and avoid complications. NPWT/ROCF has a proven record as an adjunctive technique for acute and chronic musculoskeletal wounds. NPWT/ROCF is also used on fasciotomy sites and over wounds that have received skin grafts. However, novel usages for NPWT/ROCF are currently under investigation including application for high-risk surgical wounds which have been closed by primary intention.

ACUTE TRAUMATIC MUSCULOSKELETAL WOUNDS

Blunt and penetrating high-energy musculoskeletal trauma is by definition associated with varying degrees of compromise to the soft tissue envelope. Optimal care of the soft tissue injury is often correlated with successful outcomes and decreased complications. Thus, modern orthopaedic trauma treatment protocols focus on respect for the soft tissue trauma which universally accompanies these injuries.

Protocols for managing open musculoskeletal wounds have recently used negative pressure wound therapy as an adjunctive strategy. Certainly, this technology has become popular for wound management, but it must be emphasized that standard operative wound care must precede NPWT/ROCF usage. Mandatory practice requires meticulous debridement and irrigation of traumatic musculoskeletal wounds. Soft tissue lesions secondary to high-energy trauma are always associated with varying degrees of irreversible damage to the tissues. The zone of injury must be defined and all nonviable tissues sharply excised. After formal debridement, NPWT/ROCF is an ideal postoperative dressing to improve the local wound environment.

The simplicity and effectiveness of NPWT/ROCF have led to the widespread usage of this technique for temporary...
coverage of complex musculoskeletal wounds (Fig. 1). Wound health is promoted by the subatmospheric pressure applied through the open cell foam adjacent to the wound bed. Edema fluid drawn from the wound is conveniently collected in a closed canister attached to a negative pressure–producing device.

The bio-occlusive dressing is less labor intensive as compared with traditional wound care techniques. Typically, the dressing is applied in the operating room after wound inspection and debridement. It is changed every 2–3 days until the wound matures. Based on the size of the wound and degree of tissue loss, the decision is then made to perform delayed primary closure, skin grafting, or more advanced coverage techniques.

Some traumatic wounds, however, are best managed with healing by secondary intention. NPWT/ROCF is used to promote the efficient production of granulation tissue to expedite the healing process. Wounds treated in this manner will require multiple dressing changes. In selected cases, continued wound maintenance can be performed in the outpatient setting. Patients can be discharged with home nursing assistance and the portable NPWT/ROCF device. Close outpatient monitoring continues until uneventful wound healing is achieved.

Herscovici et al13 demonstrated the safety and efficacy of NPWT/ROCF for adjunctive care of complex musculoskeletal wounds secondary to high-energy trauma. No complications related to NPWT/ROCF were reported in 21 cases. Furthermore, NPWT/ROCF reportedly decreased the need for complex soft tissue reconstructive procedures to obtain wound coverage.

**OPEN FRACTURE**

Soft tissue management is a priority for limb salvage strategies after open fracture. Even acute stabilization of the bony injury is designed to stop the cycle of injury to the soft tissue sleeve. Serial debridements are often required to establish a stable healthy wound bed before definitive soft tissue reconstructive procedures.

NPWT/ROCF has played an integral role in providing interval coverage of open fracture wounds. The NPWT/ROCF dressing can be used to cover muscle, tendon, bone, and/or orthopaedic implants.14,15 The wound remains “sealed” while the patient is on the ward. Protection of the wound from hospital-acquired bacteria is essential to avoid septic complication from nosocomial infection.16

NPWT/ROCF treatment avoids the pressure of “fix and flap” principles.17,18 Often serial debridements are necessary to obtain a wound bed suitable for definitive coverage. Complicated coverage procedures over open fractures require planning and availability of a plastic surgeon skilled in soft tissue reconstructive surgery.19 Furthermore, severe open tibia fracture often occurs in the polytrauma patient. A staged approach is often favored in the acute setting to decrease initial surgical burden.20,21 A negative pressure dressing provides coverage of the wound while the patient is stabilized. NPWT/ROCF is used between serial debridements and before definitive soft tissue and bone reconstruction.

Dedmond et al22 studied the efficacy of NPWT/ROCF treatment for temporary coverage of Gustilo–Anderson Grade

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**FIGURE 1.** A 22-year-old construction worker s/p accident with bulldozer involving primarily the posterior leg (A). Patient with sensate plantar foot. After choosing limb salvage, the full extent of his massive soft tissue injury was appreciated after extending the traumatic laceration (B). Three serial debridements were performed with the NPWT/ROCF used as the postoperative dressing. Posterior neurovascular structures were covered with adaptac before foam placement. NPWT/ROCF was used until a healthy wound bed evident. The patient subsequently received a skin graft. Skin graft survival on this complex irregular wound was facilitated by NPWT/ROCF dressing. At 1 year, the patient is satisfied with overall result. He does not use any walking aids except an AFO to compensate for his deficient posterior musculature (C).
open tibia fractures. The authors reported a 20% deep infection rate which they noted was comparable to historical controls using conventional wound care. The authors experience, however, was similar to the report from Tampa and Parrett et al suggesting that NPWT/ROCF usage decreased the need for either rotational or free flap reconstructive surgeries.

Although standard NPWT/ROCF technology will often suffice for most open fracture wounds, current research is investigating modifications of the existing technique to decrease septic complication especially in contaminated wounds. Silver impregnated foam (V.A.C. GranuFoam Silver Dressing) can be used to add antimicrobial coverage locally. Alternatively, antibiotic beads can be placed deep to the foam to boost antibiotic concentration locally.

FASCIOTOMY WOUNDS

Vigilance in diagnosis and surgical treatment of compartment syndrome is integral to preserve function and viability of limbs subjected to severe trauma. Urgent fasciotomy is indicated upon diagnosis. It is recommended that extensile incisions are performed along with complete fascial release. The skin should never be closed acutely. The patient is typically brought back to the operating room theater 24-48 hours later for second-look debridement. In most cases, delayed primary closure or split-thickness skin grafting is performed after the fasciotomy sites are stable.

The NPWT/ROCF dressing is a popular temporary coverage strategy for fasciotomy wounds. By definition, the muscular envelope is massively swollen. The subatmospheric pressure applied to the wound relieves the edematous musculature of excessive fluid. Additionally, the bio-occlusive dressing potentially minimizes secondary bacterial colonization of these open wounds.

In fasciotomy wounds amenable to delayed primary closure, it is usually necessary to apply gentle tension to the wound margins to prevent skin retraction. The “crossed rubber band” technique can be employed (Fig. 2). A NPWT/ROCF foam is manicured to the geometry of the fasciotomy site. Crossed rubber bands are then stapled to the skin edge over the foam. The bio-occlusive seal is then applied followed by the negative pressure–producing device.

Fasciotomy sites that will require coverage with a split-thickness skin graft are prepared using the NPWT/ROCF device. The subatmospheric pressure applied to the wound assists in coating the muscular tissues with a thin layer of vascular granulation tissue. This local milieu is ideal for accepting skin grafts.

Benefits of NPWT/ROCF applied to fasciotomy wounds have been demonstrated clinically. Yang et al determined that NPWT/ROCF usage results in more timely delayed closure or skin grafting of fasciotomy wounds. Comparing 34 patients with leg fasciotomy treated with NPWT/ROCF versus controls managed with conventional dressings, time to definitive coverage was significantly less. The NPWT/ROCF cohort was either closed or skin grafted at an average of 7 versus 16 days for the control group. Potential implications include shorter hospital stays and decreased risk of nosocomial infection in the NPWT/ROCF group.

SKIN GRAFTS

Wounds accompanying severe musculoskeletal trauma often require split-thickness skin grafting alone or in conjunction with either local or free flap coverage. Although harvest and application of skin grafts are straightforward, attention to detail is of utmost importance to maximize graft survival. Incorporation is encouraged by intimate contact between the wound bed and the graft. Excessive motion at the graft–wound interface needs to be minimized. Prevention of hematoma or seroma under the graft is necessary. Also, dry conditions and infection lead to poor results after skin grafting.
A negative pressure dressing over the skin graft site accomplishes the requirements to maximize success. The technique is simple in application and efficacious for the recipient and the donor site. After securing the harvested skin to the wound bed, an occlusive dressing is secured. The NPWT/ROCF foam is then applied followed by the bio-occlusive seal and suction device. The dressing is typically removed at 3–5 days postoperatively, and graft survival is evident in a vast majority of cases.

The application of NPWT/ROCF over the graft creates an optimized milieu for skin incorporation. Negative pressure applied over the wound prevents the accumulation of excessive fluid under the graft and promotes apposition of the graft to the recipient bed. Neovascularization of the graft is encouraged via the mechanical stress applied to the wound bed. Furthermore, the occlusive dressing creates a moist environment and seals the site from contamination.

As compared with the standard bolster dressing, NPWT/ROCF is heralded for use in difficult skin graft sites. Many musculoskeletal wounds have a complex geometry in anatomic sites subject to excessive motion. Maintaining adherence of the skin graft to these sites is often difficult with standard dressing protocols. Often the anatomic site needs to be immobilized to minimize motion.

Negative pressure dressings conform to the complex geometry present in many musculoskeletal wounds. Skin grafts applied to these locations are “splinted” by the collapsed foam. Adjunctive immobilization of these sites is often not necessary. Furthermore, portable negative pressure units allow selected patients to proceed with a more rapid rehabilitation protocol and earlier hospital discharge.

Several clinical studies have validated the use of negative pressure therapy over split-thickness skin graft sites. Schneider et al used a NPWT/ROCF dressing to cover over 100 difficult wounds with a greater than 98% success rate. Scherer et al compared the rate of graft failures using NPWT/ROCF versus the traditional bolster dressing. The authors reported a need for repeat skin grafting in only 3% of the NPWT/ROCF cohort compared with 19% in the bolster dressing group. Moisidis et al determined that skin graft quality was superior with a negative pressure dressing compared with traditional techniques.

### TENUOUS SURGICAL WOUNDS

Failure of surgical wounds after fracture care has historically plagued bone reconstruction efforts after severe musculoskeletal trauma involving the lower extremities. Wound problems such as edge necrosis, dehiscence, or persistent drainage are often precursors to septic complication. Infamous skeletal injury patterns prone to wound problems are well documented such as high-energy fractures of the tibial plateau, tibial plafond, and calcaneus.

A paradigm shift has occurred as a result of unacceptable infection rates reported after acute reconstruction of high-energy lower extremity injuries. Respect for the soft tissue envelope is standard practice with staged protocols recommended. Although decreased rates of wound problems are reported after delayed reconstruction, adjunctive strategies to encourage primary wound healing are under investigation.

Use of NPWT/ROCF over these difficult surgical wounds is one such modality which may decrease the rate of wound-related complications after severe lower extremity musculoskeletal trauma (Fig. 3). NPWT/ROCF is applied over the closed (but loosely reapproximated) wound in an effort to promote primary wound healing while actively evacuating any drainage or edema. The mechanical stress (stabilization) applied to the wound positively influences the healing by primary intention. Furthermore, the wound is “sealed” under sterile conditions in the operating room before transfer to the ward which potentially decreases contamination and simplifies postsurgical care.

The concept of using a negative pressure dressing over difficult surgical wounds was developed at Wake Forest. Early success led other investigators to study the merits of this approach. Gomoll et al coined the term “incisional vacuum-assisted closure therapy (IVAC)” and studied 35 cases reporting no postoperative infections in their heterogeneous yet “at-risk” orthopaedic patients. Stannard et al reported their preliminary results of a prospective randomized study.
using the IVAC for “high-risk” surgical wounds after reconstruction of high-energy tibial plateau, pilon, and calcaneus fractures. The IVAC-treated wounds became “dry” earlier than those managed with conventional postoperative dressings. However, with the small sample size in each cohort, there was no significant difference in rate of deep infection between the IVAC cohort and controls.

As a technical point, IVAC may cause skin maceration over fresh surgical wounds. Techniques to avoid peri-incisional moisture mitigate this phenomenon. The wound can be “framed” to limit the contact area of the foam. It is also recommended to use a lower pressure setting (75 mm Hg) and a nonadhesive yet permeable dressing directly over the wound before foam placement.

**DRAINING POSTOPERATIVE WOUNDS**

Surgical wounds after pelvic and acetabular reconstruction are prone to prolonged drainage. Despite meticulous surgery, often these wounds have significant “dead space” allowing for the accumulation of postoperative hematoma and seroma. Furthermore, these injuries often occur in the polytrauma patient where third spacing of fluid is commonplace. Egress of serosanguinous fluids from the surgical wound interferes with primary wound healing and is often a precursor to deep infection.

The traditional approach to these wounds includes the use of postsurgical drains and soft spica pressure dressings. However, an additional or alternative solution is IVAC. This approach is less labor intensive, improves patient comfort, and creates optimized conditions for uneventful wound healing.

Reddix et al validated the use of IVAC after acetabular surgery by reporting decreased rates of wound-related complications when compared with traditional postoperative wound care. Two hundred and twelve patients treated with an immediate postoperative IVAC were compared with 60 controls at their institution. The rate of deep infection was significantly less in the IVAC cohort (1.4%) compared with controls (6.7%). Furthermore, failure of primary wound healing occurred in only 0.5% of IVAC cases versus 3.3% in controls.

In addition, the IVAC is ideally suited for the obese trauma patient requiring surgical repair of the pelvis and/or acetabulum. This patient population is particularly vulnerable to wound problems and infection. In fact, wound infection rate after acetabular surgery in the obese patient population is 5 times higher than that in controls as reported by Karunakar et al. Reddix et al have demonstrated that IVAC treatment is a promising adjunctive modality for wound care after open reduction internal fixation of acetabular fractures in the morbidly obese patient by reporting a 0% wound or infection rate in 19 consecutive patients.

Even if adjunctive NPWT/ROCF is not chosen initially after operation, this technique is often used on wounds which persistently drain after postoperative day 3. In this scenario, the dressing is used to encourage primary wound healing by acutely decompressing the postoperative seroma. The dressing is changed as needed, and the suture line is inspected. The need for continuing the IVAC can be assessed without taking down the dressing by looking at the tube and its reservoir to assess the amount of drainage accumulated. If the tube has been dry for 24 hours, the IVAC can be replaced with a simple dressing. It should be pointed out that IVAC is not a substitute for surgical evacuation of a hematoma (and surgical control of persistent bleeding) if and when this is indicated. Prolonged NPWT/ROCF for this indication is not a substitute for traditional surgical management.

**CONCLUSIONS**

Negative pressure dressings are a useful adjunctive treatment strategy for managing soft tissue injury associated with severe musculoskeletal trauma. Acute open musculoskeletal wounds, with or without associated fracture, benefit from NPWT/ROCF. This dressing can be used as a temporizing treatment for wounds awaiting complex soft tissue reconstruction or as a definitive strategy for wounds treated by secondary intention. NPWT/ROCF is both efficacious and safe for use over both fasciotomy and skin graft sites. Novel usages of the negative pressure dressing are evolving and may include its role as a dynamic dressing for the “high-risk” surgical wounds.

**REFERENCES**

5. Reddix RN Jr, Langfiit M, Smith T, et al. Microvascular effects of therapeutic topical negative pressure application. *Poster presented at Orthopaedic Trauma Association Annual Meeting: Poster #96; October 18–20, 2007; Boston, MA.*


37. Webb LX. Use of VAC in managing orthopaedic wounds—experience in 191 cases. Presented at the Symposium on Vacuum Assisted Closure and Management of Wounds; June 26, 2000; Hilton Head, SC.


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