Experience With Wound VAC and Delayed Primary Closure of Contaminated Soft Tissue Injuries in Iraq

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Background: **Wartime missile injuries are frequently high-energy wounds that devitalize and contaminate tissue, with high risk for infection and wound complications. Debridement, irrigation, and closure by secondary intention are fundamental principles for the management of these injuries. However, closure by secondary intention was impractical in Iraqi patients. Therefore, wounds were closed definitively before discharge in all Iraqi patients treated for such injures at our hospital. A novel wound management protocol was developed to facilitate this practice, and patient outcomes were tracked. This article describes that protocol and discusses the outcomes in a series of 88 wounds managed with it.**

Methods: **High-energy injuries were treated with rapid aggressive debridement and pulsatile lavage, then covered with negative pressure (vacuum-assisted closure [VAC]) dressings. Patients underwent serial operative irrigation and debridement until wounds appeared clean to gross inspection, at which time they were closed primarily. Patient treatment and outcome data were recorded in a prospectively updated database.**

Results: **Treatment and outcomes data from September 2004 through May 2005 were analyzed retrospectively. There were 88 high-energy soft tissue wounds identified in 77 patients. Surprisingly, for this cohort of patients the wound infection rate was 0% and the overall wound complication rate was 0%.**

Conclusion: **This series of 88 cases is the first report of the use of a negative pressure dressing (wound VAC) as part of the definitive management of high-energy soft tissue wounds in a deployed wartime environment. Our experience with these patients suggests that conventional wound management doctrine may be improved with the wound VAC, resulting in earlier more reliable primary closure of wartime injuries.**

Key Words: **Wound VAC, Delayed primary closure, High-energy soft tissue injury, Iraq, War wounds, Contaminated, Contaminated wounds, Wound management, Military trauma.**

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The 332nd Air Force Theater Hospital (AFTH) is a multispecialty military trauma center in Balad, Iraq. Staffed by a rotating contingent of Air Force physicians, this hospital treats injured United States military members, Iraqi security forces, civilians, contractors, and captured insurgents received from locations throughout Iraq. These patients frequently present with severe soft tissue injuries from high-energy projectiles (Fig. 1).

A combination of factors make the high-energy wounds seen at the 332nd AFTH highly susceptible to infection. The cavitation effect of high-energy projectiles produces a significant volume of devitalized tissue. In addition, these wounds are all contaminated by dirt, shrapnel, and pieces of the victim's environment (clothing, seat cushions, etc.) driven into the wound. Difficulties in evacuation from the scene to the hospital often result in delays of 1 to 6 hours before definitive treatment, with such patients arriving hypotensive and hypothermic at our facility.

The early military medical teams at this hospital treated high-energy missile wounds with irrigation, debridement, and closure by secondary intention, as per established military medical doctrine.[1] American troops were evacuated from the theater of operations, and indigenous patients were treated at our facility during a prolonged convalescence with bedside saline gauze dressing changes. This resulted in a wound infection rate in the indigenous patient population as high as 80% (Jenkins DH. Col. USAF MC, Director of Trauma Systems, CENTCOM, January 2005, personal communication).

Several unanticipated factors in Iraq prompted us to adapt our wound care plan for our indigenous patients, closing all wounds before discharge. The Iraqi hospitals lacked the resources to perform the requisite wound care, and there were no skilled nursing facilities. The Iraqi medical system could accept the transfer of only one or two of our patients each week, and many of the transfers returned rapidly to us with complications. Home health care service did not exist, and it was often impossible for our patients to obtain supplies or medications on the local economy. For this reason, we could not discharge our Iraqi patients with open wounds.

The high infection rate and labor-intensive nature of the previous management strategy compelled Air Force surgical teams at Balad to adopt a more rigorous approach to wound management. Bedside dressing changes were eliminated in favor of mandatory interval wound examina-

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Fig. 1. *The entry portal for the 332nd Air Force Theater Hospital in Balad, Iraq.*

tion, re-debridement, and dressing changes in the cleaner environment of the operating room. Liberal use of the negative pressure dressing (Wound VAC, Kinetic Concepts International, San Antonio, Tex.) facilitated this practice while keeping the wound bed covered and protected from the hospital environment. As we gained experience with this treatment, we noticed that our patients had a much lower incidence of wound complications and their wounds were amenable to closure sooner than expected.

METHODS

All patients treated at the 332nd AFTH were entered prospectively into a patient database maintained daily by staff surgeons. This registry functioned as the inpatient medical record and included each patient's date of injury, nature of injuries, date and description of operations performed, and daily progress, including wound complications, infections, and overall patient condition.

Because American patients were rapidly evacuated and thus not available for follow up, we identified a subset of Iraqi patients with high-energy soft tissue injuries who were representative of our experience with the wound vacuum-assisted closure (VAC) in the wartime environment. All had sustained missile injuries to soft tissues as a result of improvised explosive devices (IEDs) or small arms fire. To restrict our evaluation to those patients managed by our protocol, we limited our analysis to patients treated exclusively at our facility, eliminating patients who had initiated treatment at other medical units and then transferred to us for further care (Table 1).

All wounds were operated on within 24 hours of injury. Each wound bed was sharply debrided to viable-appearing bleeding tissue with meticulous hemostasis. The wound was then lavaged with at least 3L sterile normal (0.9%) saline solution using pulsatile jet irrigation. (SurgiLav Plus, Stryker Instruments, Kalamazoo, Mich.). Wound beds were covered with

Table 1 Patient Inclusion Criteria

- One or more high-energy soft tissue injuries
- Injuries judged survivable at patient presentation
- Patient presented first to 332nd AFTH for definitive treatment (no transfers for complications from other facilities)
- Patient presented within 24 hr of wounding
- Received definitive wound management (delayed primary closure, flap rotation, or split thickness skin graft) before discharge
- Available for follow-up appointment 7–14 days postdischarge

VAC sponge dressings and set to -125 mm Hg continuous pressure (VAC Acute TRAC System, KCI). The negative pressure dressing was left in place for 2 to 4 days, as dictated by the patient's need for additional surgery and operating room availability. Each VAC dressing change was accomplished by a staff surgeon in the operating room under sterile conditions, with additional lavage and debridement as necessary. No wounds in this series had to be taken back for early re-debridement because of wound infection or patient sepsis. No patients had to be returned to the operating room for bleeding complications.

When a wound bed appeared clean and viable to gross inspection, the wound was definitively closed by delayed primary closure, flap mobilization, or split-thickness skin grafting. The VAC system was also used postoperatively for 3 to 5 days over skin grafts, then removed at the bedside to assess graft take. Granulation tissue was not a prerequisite for wound closure. The closed wounds were then examined daily during rounds for signs of infection or other local complications. Patients were not discharged from hospital until the closed wounds were clean and dry with good skin graft incorporation. All patients were scheduled for follow-up in our outpatient clinic for 1 to 2 weeks after discharge for wound checks and suture or staple removal. At these appointments wounds were assessed and any wound healing complications were noted in the registry (Fig. 2).

RESULTS

Retrospective examination of the data in our patient registry yielded a total of 88 wounds in 77 Iraqi patients who met the criteria described previously. All patients survived their hospital stay and were discharged with closed wounds. The registry was used to provide data regarding wounding mechanism, location of injury, and wound dimensions, when available. Each patient's length of hospital stay, number of operations, and time from injury until wound closure were also extracted (Fig. 3; Table 2).

None of the patients in the series experienced acute in-hospital wound complications and all left with clean closed wounds. No patient with wounds closed by skin grafting had to be re-grafted because of poor graft "take". However, three patients had to return to the operating room prematurely to replace wound VAC dressings that had lost their seals and

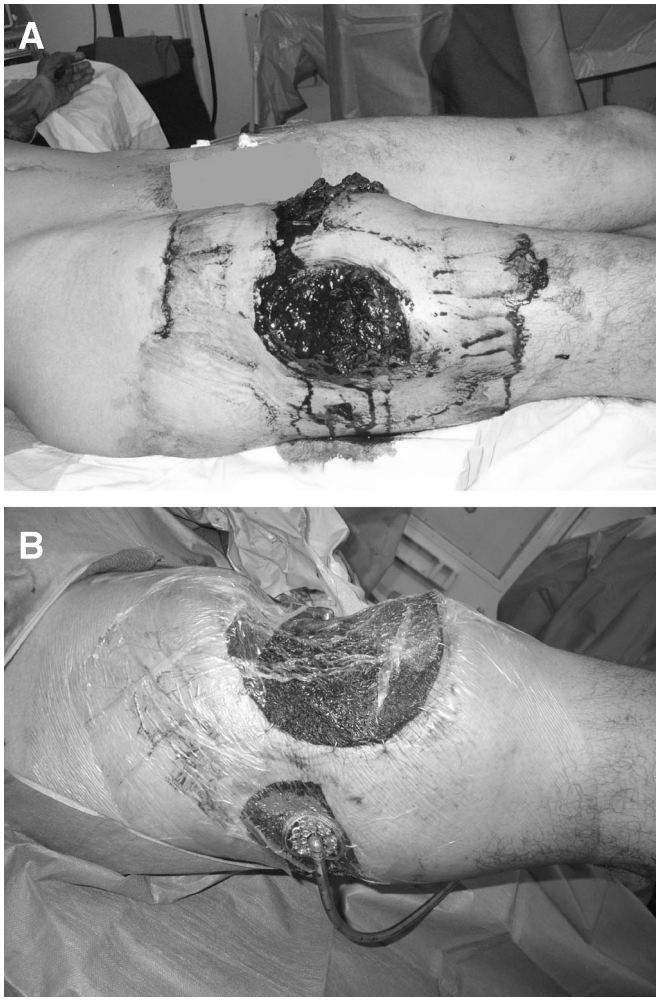

Fig. 2. *(A) Assault rifle injury to thigh before initial debridement and irrigation. (B) Same wound after wide debridement and pulsatile lavage, with VAC dressing applied. Exploration revealed no significant vascular injury or fracture.*

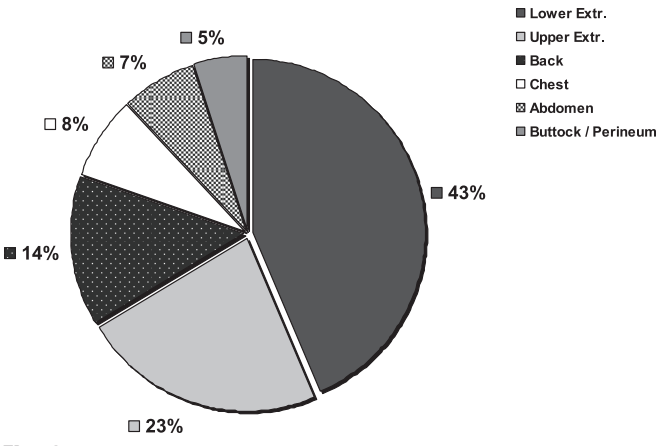

Fig. 3. *Pie chart depiction of the anatomic distribution of 88 soft tissue injuries managed as described in the manuscript.*

Table 2 **Characteristics of High-Energy Soft Tissue Wounds Treated at 332nd AFTH**

Size of 31 wounds	
Maximum	160 cm^2
Minimum	12 cm^2
Median	32 cm^2
Mean	45.3 cm^2
SD	30.6 cm^2
Cause of injury in 88 wounds	
Blast (IED/RPG)	55 (63%)
Small arms	33 (37%)
Anatomic region injured in 88 wounds	
Lower extremity	39 (44%)
Upper extremity	20 (23%)
Back	12 (14%)
Chest	7 (8%)
Abdomen	6 (7%)
Buttock/perineum	4 (5%)

Table 3 **Treatment Outcomes (n = 88 wounds)**

Length of hospitalization	
Maximum	21 days
Minimum	3 days
Mean	7.45 days
SD	2.53 days
Number of operations to closed wounds	
Minimum	2
Maximum	5
Mean	2.16
SD	0.65
Time from injury to wound closure	
Minimum	2 days
Maximum	14 days
Mean	4.24 days
SD	1.77 days
Wound complications	
Wound infections	0 (0%)
Seromas	0 (0%)
Hematomas	0 (0%)
Dehiscences	0 (0%)

Other wound complications: 0 (0%).

would not hold vacuum. These patients each had complicated extremity wounds, one with an external fixator, and in each case it was possible to apply a new dressing and obtain a reliable seal over the wound. During outpatient follow-up no wound complications were identified (Table 3).

DISCUSSION

Penetrating missile injuries sustained during military operations and terrorist attacks are high-energy injuries that produce extensive tissue destruction. In this series, the projectiles resulted from explosive devices and assault rifles. Civilian trauma articles often categorize explosive shrapnel as low energy missiles: an incorrect description for the injuries produced by the Iraq insurgency. The explosive devices used in Iraq are significantly more powerful than those described previously. They are usually stationary traps or vehi-

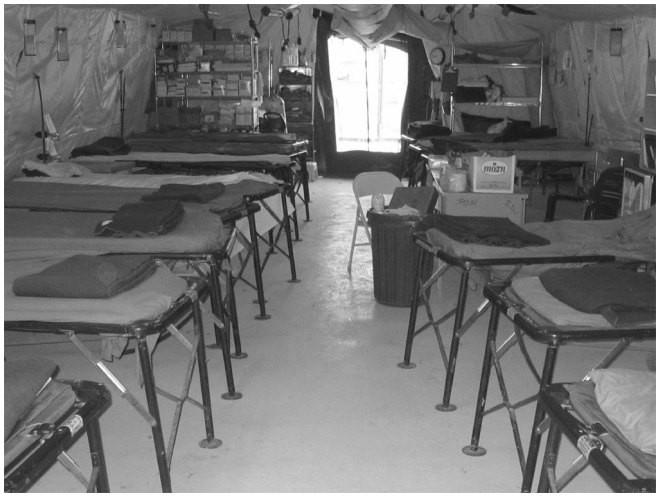

Fig. 4. *A photograph of an inpatient surgical ward at the 332nd AFTH.*

cles packed with large quantities of high explosive, rather than the explosive vest of a suicide bomber. The shrapnel from these explosions can travel at up to 27,000 feet per second, and sometimes penetrates the sides of armored personnel carriers. The victims at close proximity to these attacks now often survive, possibly because of the improved body armor fielded by US and Iraqi troops.

Wound infection frequently results if these high-energy wounds are managed incorrectly (Jenkins DH. Col. USAF MC, Director of Trauma Systems, CENTCOM, January 2005, personal communication). The technique of initial wound management for similar civilian trauma has been well described in the literature. Wide debridement and pulsatile lavage are essential to reduce the load of contamination and necrotic tissue in the wound and facilitate later wound closure.[2,3] Military doctrine evolved from a strong respect for this propensity to infection, and categorically forbids closure of these wounds.[1]

Wound closure by secondary intention was not suitable for our Iraqi patients for several reasons. Patients were housed in open ward tents, each containing 10 to 14 patients and staffed by a single nurse and a medical technician. Although climate controlled, these tents were not sealed to the outside environment, and flies, dust and rain leaks were frequently observed (Fig. 4). Saline gauze dressing changes under such conditions would have exposed wounds to environmental contamination and would have been prohibitively labor intensive.

Local medical care was not available for these patients. The indigenous hospitals were already over-crowded and only accepted one or two patient transfers per week. Home health care was nonexistent, and wound care supplies were not available as a result of the local economy. Several patients were discharged or transferred to local medical care with favorable granulating wounds early on in our experience, and most of these returned rapidly with complications.

The wound VAC system was instrumental in our adaptation of wound care for our Iraqi patients. The basic science of the system has been well elaborated in the plastic surgery literature.[4–6] The sponge dressing connects to a closed suction system and distributes a fixed negative pressure evenly over the wound bed. The physiologic benefits of such a dressing include clearance of wound exudate,[7,8] enhanced granulation from local vasodilation, and mechanical wound contraction because of pressure differential.[9,10]

We believe the most significant benefit was the prolonged protection of the wound from the ward environment. The VAC system isolated the tissue injury, yet still kept it clean and free of exudate. Dressing changes could be accomplished every two or three days, rather than three times per day, allowing us to do them in the cleaner environment of the operating room. Re-debridement and pulsatile lavage could be accomplished simultaneously, under bright illumination with good exposure. The limitations in the collected data make it impossible to attribute the decreased wound infection rate to any inherent properties of the negative pressure dressing, and it may simply be that this decline was a consequence of our more aggressive wound care, which was facilitated by use of the VAC system.

By using the described protocol we were able to attain delayed primary closure of contaminated high-energy wounds without complications. As we gained experience, we were able to decrease the number of operations before wound closure, and shorten hospital stays. However, we still strongly think all high-energy missile wounds should undergo some period of observation before closure, and we discourage wound closure at the first debridement and irrigation. The cavitation and blast effect of the high-energy missile appears to produce a variable and unpredictable zone of relative tissue ischemia, much like the "zone of stasis" classically described in burns. This margin of injured tissue can appear grossly normal at the initial debridement, only to undergo progressive thrombosis and devitalization during the first 24 to 72 hours after injury. The authors have seen apparently clean, viable wound beds require subsequent re-debridement for progressive necrosis during these "second look" operations, and think that primary closure at the first debridement is potentially dangerous for that reason.

One potential limitation of the widespread application of our wound care protocol would be the dependency on wound VAC units and related consumable supplies. The 332nd AFTH at Balad was fortunately not subject to these limitations. As the logistical "hub" of all air transportation for the US military in Iraq, Balad was at the very front of the theater supply line, and had at least 30 working VAC pump units and a large trailer full of VAC dressing change kits. During the period covered in this report, no shortages occurred, and we were able to allocate VAC units to all patients who needed them.

This is the first report of the use of a negative pressure dressing in the management of high-energy penetrating soft tissue injuries in wartime. To date, our experience indicates

that this management strategy permits successful delayed primary wound closure in a field environment. After instituting this method of wound management our hospital infection rate decreased from an anecdotally reported 80% to a documented 0%. Length of patient hospital stay is substantially reduced compared with closure by secondary intention or delayed grafting. Ward nursing care is simplified considerably, freeing over-worked nurses and technicians to attend to other important patient care tasks. Given these outcomes under adverse conditions in the field, it appears reasonable to study the application of the same techniques in the civilian setting.

Clearly, this large case series is limited because of its observational and descriptive nature. The pace of military and medical operations in theater limited research activities, and a controlled prospective clinical trial was beyond the scope of our abilities during the deployment. Although it seems reasonable to presume that the good outcomes noted in the Iraqi patients should be translatable to other patient populations, further study is obviously needed. It is also important to recognize that the data presented in this article are relevant only to the study period and the pace of operations in theater during the time of the review. The experience reported here is that of an established trauma center operating in a mature theater of operations during the insurgency, and will therefore differ from earlier reports during the active invasion phase at the initiation of Operation Iraqi Freedom II. Finally, mid and long-term follow-up for wound complications was impossible, given the security environment and geographic dispersion of our patients after hospital discharge.

Despite these limitations, we think it is important to document and communicate our experience as it stands at this time. The promising results observed in our series warrant more rigorous investigation with prospective controlled clinical trials. With continuation and critical review of our soft-tissue injury registry, we are optimistic that we will be able to change in-theater strategies and refine our training methods at home to improve the outcome of these potentially debilitating injuries.

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