Use of Negative Pressure Wound Therapy During Aeromedical Evacuation of Patients With Combat-Related Blast Injuries

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The purpose of the study was to evaluate safety and feasibility of negative pressure wound therapy (NPWT) during aeromedical evacuation from a combat zone to a regional treatment center. A retrospective review of patients who received NPWT during aeromedical evacuation from Iraq or Afghanistan to Landstuhl Regional Medical Center (LRMC) was performed. Data were collected describing mechanism of injury; anatomic site of NPWT application; number of sites per patient; date and time of NPWT application; date, time, and wound condition on arrival and inspection at LRMC; and complications encountered during aeromedical evacuation. Broad definitions of complications were employed. Any reported malfunction of NPWT devices or need to reinforce NPWT dressings was abstracted. Presence of tissue under the dressing requiring debridement was defined as a minor complication. Major complications were defined as wound sepsis with systemic manifestations. A total of 218 patients who had received NPWT for 298 wounds (1.37 per patient) during aeromedical evacuation were identified. Most wounds were due to high-energy blast or ballistic mechanisms. Average time from NPWT application to removal was 53 hours (range, 18–133 ± 22 hours). Complications occurred at 14% of NPWT sites and in 19% of patients receiving NPWT. Most recorded complications were minor (95%). Two patients who arrived at LRMC with fever and evidence of wound sepsis improved rapidly after additional operative debridement. In no case was failure of the NPWT device in flight specifically implicated in the genesis of a recorded complication. In-flight device problems were identified in seven cases. Four of these could not be repaired in flight and were clamped. Complications were not increased in this cohort. Use of NPWT during aeromedical evacuation appears safe and feasible in a large cohort of patients with high-energy injuries. Complications were consistent with severity of injury and not related to failure of NPWT. (Journal of Surgical Orthopaedic Advances 19(1):44–48, 2010)

Key words: aeromedical evacuation, extremity blast injury, negative pressure wound therapy, wound management

Negative pressure wound therapy (NPWT) has become recognized as a valuable adjunct in the management severe soft tissue wounds secondary to high-energy injuries (1–3). Advantages of NPWT (V.A.C. Therapy, KCI Licensing, Inc., San Antonio, TX) as compared with conventional wound management techniques include a decreased frequency of dressing changes, promotion of a granulation bed, facilitation of wound drainage, edema control, and avoidance of exposure of the wound to unsterile environments (4).

Severe soft tissue wounds frequently result from high-velocity gunshot wounds and explosive blasts. These two injury mechanisms account for 96% of combat wounds sustained in Operation Iraqi Freedom (Iraq) (OIF) and

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Operation Enduring Freedom (Afghanistan) (OEF) (5). Sequential treatment of these injuries typically includes initial operative debridement within the theater of combat operations followed by rapid aeromedical evacuation to a higher level facility outside of the combat area (6).

Use of NPWT during aeromedical transport potentially simplifies wound management en route and improves wound care relative to standard wet-to-dry dressing application. Anecdotal reports, however, suggest that difficulties maintaining NPWT dressings during flight may lead to loss of the negative pressure environment and secondary wound complications (R. C. Andersen, personal communication). Some of these complications were allegedly associated with significant morbidity, yet none of these anecdotes has been formally reported in the literature to our knowledge. Conversely, undocumented experience suggests that NPWT has been used effectively and without complication in a large number of aeromedical transports from Balad, Iraq and Bagram, Afghanistan to Landstuhl Regional Medical Center (LRMC) (Landstuhl, Germany) (E. T. Powell, personal communication).

The purpose of this retrospective study was to assess the safety and efficacy of NPWT during aeromedical evacuation by examining the medical records of patients transported from the theater of combat operations in the Global War on Terrorism (GWOT) to LRMC. If NPWT can safely and effectively be employed in a military environment, there is potential for its application in civilian settings in the context of transporting patients with high-energy open extremity trauma and other complex wounds from smaller local hospitals to trauma centers or tertiary care facilities.

Methods

The study protocol was reviewed by the Walter Reed Army Medical Center Institutional Review Board (IRB) as per a memorandum of agreement with LRMC. Approval was obtained to review the medical records for US military members transferred to LRMC from the US Central Command (CENTCOM) area of responsibility (AOR) if NPWT was employed during aeromedical transport. Foreign nationals, civilian US contractors, and other NATO military personnel were excluded from the review per Department of Defense policy.

Study patients were initially identified by review of a log book that was prospectively maintained for all patients admitted to LRMC for whom a NPWT machine was requested. In situations in which the log book information was incomplete, original medical billing invoices were reviewed. Patients transferred from Iraq or Afghanistan to LRMC between October 1, 2006 and September 30, 2007 with NPWT applied during transportation were included in the analysis.

Patients were excluded from analysis if NPWT was used solely as a dressing for an open abdominal or thoracic wound. These patients were excluded because there was substantial variability in the types of dressings applied. In addition, the purpose of the therapy was primarily for management of an open body cavity as opposed to the use of NPWT for traumatic soft tissue wounds.

Charts were reviewed to determine time, specific combat zone treatment facility, and anatomic location for the initial application of NPWT in the theater of combat operations. The presence or absence of problems with NPWT during transport from the combat hospital to LRMC, condition of the NPWT wound on arrival at LRMC, time from arrival at LRMC to formal wound inspection with removal of NPWT dressing, hospital location of NPWT removal (operating room vs. other), and any wound complications noted at time of NPWT dressing removal were also recorded.

Wound condition was recorded individually for patients with NPWT dressings applied at different body sites. If NPWT was applied to multiple sites within the same portion of an extremity or if the dressing communicated between more than one portion of an extremity, only one site application was reported. Time of NPWT dressing application or removal was frequently not recorded. When not specified, the surgery "stop" time for the operative procedure in which the dressing was applied was used as a proxy for time of dressing application and the surgery "start" time was used as a proxy for time of removal at LRMC. Times were abstracted from operative records, anesthesia records, and time of note entry into a medical record.

A typical wound care scenario involved initial surgical debridement of the wounds at a combat support hospital. Associated fractures were managed using external fixation or damage control orthopaedics (7). Wounds were covered with a NPWT dressing which was placed to suction using either a standard hospital-based suction pump (V.A.C. ATS Therapy System, KCI Licensing, Inc., San Antonio, TX) or a portable suction unit (V.A.C. Freedom Therapy System, KCI Licensing, Inc., San Antonio, TX). If standard hospital-based pump was used, it was changed to a portable system prior to aeromedical evacuation to LRMC. The patient was then evacuated to Ramstein AFB, Germany. After deplaning, patients were transported to LRMC where an initial triage evaluation was performed.

The timing of NPWT dressing replacement or removal was made by the admitting surgeon at LRMC. This decision was based on the time since the last operative debridement of the wound, the appearance of the wound dressing and surrounding tissues to include an assessment of how well the NPWT dressing was functioning, and the presence of other body system injuries that might require operative assessment and management. If patients required

anesthesia for management of an injury separate from that for which the NPWT device was being used, the NPWT dressing was typically changed at that time also.

Condition of the wounds at the time of NPWT dressing change was abstracted from operative notes, nursing notes, and progress notes. When no information about the condition of the wound at the time of initial dressing change was available, the absence of information was recorded. Wound complications were defined in a very inclusive manner so that the safety of NPWT in long-distance aeromedical evacuation would not be overstated. Any evidence of underlying wound necrosis, infection, or tissue devitalization requiring further surgical debridement was considered a wound complication regardless of its association with the use of NPWT. Major complications included associated wound sepsis, substantial necrosis, or need for major additional debridement and also were identified without regard for the degree to which the complication may have been associated with the NPWT dressing.

Results

NPWT pumps were requested for 271 patients prior to their arrival at LRMC based on information from the aeromedical evacuation system. Thirteen patients were excluded from the review because they were evacuated from locations other than Iraq or Afghanistan, they sustained non-combat-related injuries, or they were not classified as US military personnel. NPWT was applied solely for the management of open abdomens in 27 cases. In seven cases, there was no evidence that NPWT was employed at any time prior to arrival of the patient at LRMC, and in an additional six cases, information was insufficient to estimate time of NPWT application in the theater of combat operations or time of removal at LRMC. The remaining 218 cases comprised the study population.

Of the 218 patients in the final data set, NPWT was used to manage 298 separate wound sites for an average of 1.37 wound sites per patient. Forty-two complications were identified in 41 patients (14% of wounds, 19% of patients). Forty of these complications were classified as minor based on study definitions and were managed without apparent long-term consequence to the patient. Two patients who arrived at LRMC with fever and evidence of wound sepsis (major complications) improved after additional operative debridement.

Information about the condition of the NPWT dressing during flight was annotated in the medical records in 155 cases. NPWT mechanical device or other problems were identified in seven cases. In four of these seven cases, the NPWT system was not reparable during transport and the suction tubing from the dressing to the pump machine was clamped during a large portion of the transport time. One minor wound complication was identified among these seven patients at the time of wound inspection at LRMC for an incidence of 14% as opposed to an overall incidence of 19% (NS) for the overall study population. Determining the exact amount of time that the tubing remained clamped for any individual patient was not possible because these times were not generally recorded in flight.

The mean time from NPWT dressing application in a combat hospital within the CENTCOM AOR to dressing removal at LRMC was 53 hours (range, 18–133 hours; standard deviation, ±22 hours). Of this time, the average time from NPWT dressing application in the AOR to arrival of the patient as LRMC was 30 hours and the average time from arrival of the patient at LRMC to removal of the NPWT dressing was 24 hours.

In nine cases, problems with the NPWT dressing were identified at the initial examination upon arrival at LRMC. Six cases related to improper functioning of the suction apparatus. Four of these six cases resulted from leaks in the dressing leading to an inability of the system to maintain adequate negative pressure. Of the remaining three cases, two problems were related to the thrombus preventing proper suction and one was related to high-volume fluid drainage output from the wound. In one additional case, the dressing was intact but did not appear to have been connected to suction en route. In all but one case, the NPWT dressing was left in place until a formal dressing change was performed in the operating room. The average time from arrival of the patient at LRMC to removal of the dressing in the operating room for these nine patients was not significantly different from that for the overall study population (24 ± 17 hours vs. 24 ± 15 hours). The single instance when the dressing was removed immediately upon arrival involved high-volume fluid output of fluid from a flank wound. The urologist performing the initial evaluation was concerned that the NPWT was contributing to a leak from a ureteral injury.

In three of these nine cases, a problem was identified with the wound at the time of initial dressing removal and inspection. In two of these cases, ongoing bleeding discovered within the zone of injury was successfully addressed at surgery. The third related to necrotic tissue at the base of the wound requiring additional operative debridement. In none of these cases was there evidence of wound sepsis or systemic evidence of infection secondary to the traumatic wound.

Discussion

This review supports the premise that NPWT can safely be utilized during aeromedical transport when supported by aeromedical flight crews with basic familiarization in the monitoring of NPWT dressings and utilizing a NPWT device designed for portability and in-flight use.

This was accomplished for patient evacuations from the CENTCOM AOR without a substantial incidence of complications identified upon arrival at LRMC. The length of time that the device remained in place between time of application in the AOR until its removal time in the operating room at LRMC ranged from 18 hours to 141 hours with an average time of 53 hours in the current series. Prior studies evaluating the use of the device in hospital environments suggest that the device can be left in place safely without need for opening the wound and changing the dressing for 72 hours (1).

Since 2004, NPWT has been utilized as a standard therapy for contaminated soft tissue wounds sustained by the indigenous Iraqi population at Joint Base Balad, Iraq. The paucity of local health care resources led to the practice of surgical debridement, NPWT, and delayed primary closure of soft tissues wounds to expedite discharge from inpatient care. No wound infections or other complications were associated with 88 patients treated in this fashion and initially reported by Leininger et al. (8). Early efforts to treat US military members in an analogous manner was hindered by the lack of a flight-approved commercial NPWT until the V.A.C. Freedom System was certified airworthy. An inventory of these pumps was then acquired by the US Air Force for patient movements between the CENTCOM AOR and LRMC. LRMC is the receiving facility for US military members aeromedically evacuated from the CENTCOM AOR. Patients are re-evaluated and treated at LRMC until they are able to return to combat duty or are repatriated to the United States.

During the time period of this review, no patients were evacuated from LRMC to the Continental United States (CONUS) with NPWT employed per local policy. Instead, patients with wounds treated with NPWT while at LRMC were closed or converted to another modality prior to air evacuation to CONUS.

The results of this study should not be interpreted to support use of NPWT in less monitored transport environments. Further study is indicated to establish the safety and efficacy of the use of NPWT during commercial flights or during prolonged ground transportation. We are unaware of any data thus far evaluating this type of use. The potential danger in all situations is that the NPWT dressing could fail resulting in establishment of a closed, anaerobic environment that could lead to rapid development of necrotizing infection with associated sepsis. For this reason, manufacturer's guidelines recommend that V.A.C. Therapy dressings should never be left in wounds for more than 2 hours without negative pressure. The current series describes the use of the device on 218 occasions over the course of 12 months for transport of injured patients from Iraq and Afghanistan to LRMC in an aircraft specially staffed for aeromedical evacuation. Its use on a more occasional basis in other types of aircraft or in ground transportation vehicles by crews less familiar with its operation may not be associated with the same clinical safety profile or results.

Use of NPWT dressings for traumatic extremity injury has been postulated to have several advantages relative to the use of regular dressings in the hospital setting (4, 9). Several of these are relevant in the management of complex wounds during interhospital transport. First, since the dressing can remain in place for much longer than a conventional dressing, the need for dressing change in a nonsterile environment is minimized. Patients whose wounds are managed with operative debridement and wet-to-dry dressings typically undergo dressing changes two to three times per day in the intensive care unit or on the hospital ward. This results in exposure of their wounds to an environment that is not as clean as the operating room environment in which the original dressing was applied. Furthermore, part of the rationale for the use of serial wet-to-dry dressing changes in the management of open wounds in general is to prevent bacteria that reside on the dressing from proliferating in the relatively favorable wound environment and to allow gentle debridement of the wound to occur with dressing changes as the dressing desiccates. During prolonged medical transport, serial wet-to-dry dressing changes are often impossible. This potentially increases bacterial load in the dressing if the environment is moist or increases tissue desiccation in a dry environment. Neither situation is desirable, and both are potentially mitigated by the use of NPWT during transport.

Second, fluids in open wounds have been shown to inhibit fibroblast proliferation (10–13). Traditional dressings do not actively remove fluid from the wound base. Negative pressure wound therapy is likely to be effective in limiting the inhibitory effect of chronic wound effluent on fibroblast proliferation and granulation tissue formation.

Finally, the ability to avoid dressing changes in high-energy, soft tissue injuries for up to 72 hours likely improves patient comfort by decreasing the number of times dressing changes are necessary without anesthesia and outside of the operating room and potentially limiting the number of anesthetic events while in the hospital.

We found seven examples of cases in which the suction line from the NPWT device to the machine was clamped throughout a substantial portion of the flight from Joint Base Balad, Iraq, or Bagram AB, Afghanistan, to Ramstein AB, Germany. Given the number of instances in which documentation of in-flight care was either missing or limited, it is probable that NPWT drains were clamped more frequently. Although prolonged clamping of the system likely minimizes any beneficial effect that negative pressure has on the underlying wound (at least during the time that the suction line remains clamped) and creates a

closed anaerobic environment in which bacterial proliferation may be encouraged, there were no apparent devastating consequences. This does not indicate that it is safe to clamp the device in patients during prolonged transports and manufacturer's guidelines recommend that the dressing be left in the wound no more than 2 hours without negative pressure. Instead, this is evidence that better education of transport crews about the NPWT devices and the requirement for ongoing treatment in route is needed. It also suggests that in the context of a system in which NPWT during aeromedical transport is frequently employed, occasional clamping of the suction tubing did not result in measurable untoward outcome.

Certain study weaknesses are inherent in the retrospective design. First, it was assumed that no complications were present when there was no documentation of complication. This premise is likely flawed. However, for complications resulting from the NPWT device during flight, even if documentation was lacking, the results should still have been evident at the time of wound inspection at LRMC. Thus, absence of a higher complication rate as noted at the time of wound inspection or operative debridement suggests that even if there were more failures of the NPWT device to function en route, there were not substantially more resultant infections or wound complications. It is also possible that there were more wound complications that did occur but that they were inadequately documented at the time of the wound inspection or operative debridement at LRMC. If substantial tissue necrosis or purulence was present at the time of the wound inspection or debridement, it is highly likely that surgeons would have documented it. Also in order to minimize such underreporting of wound complications, every mention of tissue requiring additional debridement was considered a complication. The more accurate portrayal of these complications is that they were likely complications of severe combat-related injuries as opposed to complications of the treatment employed.

In summary, these data suggest that NPWT can be employed safely for management of complex wounds during aeromedical evacuation of combat-related blast injuries in the context of sufficient crew training and establishment of a process that mandates early evaluation of patients and wounds upon arrival at the destination. Further study is indicated to ascertain the safety and efficacy of use of NPWT during prolonged ground transport or in civilian aeromedical transport of patients with complex wound injuries.

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