# 6 In Patients with Traumatic Extremity Wounds Is Negative Pressure Wound Therapy Superior as Compared to Standard Dressing Changes?

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## Introduction

The global negative pressure wound therapy (NPWT) market size is expected to reach 2.74 billion dollars by 2026, displaying a compound annual growth rate of 5.1% during that time [1]. This economic surge in NPWT is paralleled in the clinical and academic world with more than 400 manuscripts in circulation on this wound care therapy [2]. Since its approval by the Food and Drug Administration (FDA) in 1997, NPWT has progressively gained acceptance as an option for treatment of traumatic superficial and deep soft tissue defects, open extremity fractures, and damage control laparotomy wounds [3]. From a physiologic standpoint, it is believed to create a moist environment, augment blood flow, stimulate cell proliferation, aid in thermoregulation, and induce angiogenesis through microdeformation [4, 5]. In turn, NPWT should theoretically augment wound healing, promote tissue coverage of exposed bone or hardware, minimize hematoma formation, and potentially decrease the complexity of future reconstructive surgery. Interestingly, multiple meta-analyses suggest that the evidence supporting NPWT is low quality and stems from poorly designed studies [2, 5, 6]. Therefore, the aim of this chapter is to determine if patients with traumatic extremity wounds benefit from NPWT as compared to standard dressings regarding wound outcomes, hospital length of stay, infectious sequelae, and quality of life outcomes (Table 6.1).

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**Table 6.1** Description of research strategy using PICO format

| Criteria | Determinants |
|---|---|
| Population | Patients with traumatic extremity wounds |
| Intervention | Negative pressure wound therapy |
| Comparison | Traditional wound dressings (i.e., moist-to-dry gauze) |
| Outcome(s) | Wound healing; hospital length of stay; infectious complications; quality of life |

## Search Strategy

The literature evaluation was performed by searching PubMed, Google Scholar, Science Direct, and OVID databases for the following terms: "negative pressure wound therapy," "NPWT," "vacuum-assisted wound closure," or "VAC" in conjunction with "trauma" or "traumatic." Searches were limited to studies published after 1997 (the year the FDA approved the clinical use of NPWT), manuscripts written in English, and studies that specifically evaluated NPWT in traumatic extremity wounds. Titles and abstracts of resultant studies were reviewed for relevance; if the abstract did not yield sufficient information, the full article was examined for suitability. Additionally, if a selected publication included pertinent data from a previous study, that original study was also retrieved and analyzed for inclusion. All studies meeting the above criteria were then fully reviewed by the authors.

## Results

### The Advent of Negative Pressure Wound Therapy

In 1997, Müllner et al. published a 3-year prospective evaluation of 45 patients who had sustained traumatic lower extremity soft tissue defects. After bony stabilization, wound debridement, and application of a NPWT device, 84% of patients demonstrated a reduction in wound dimensions. The authors asserted that this shrinkage was afforded by NPWT and would ultimately hasten healing times and curtail infections [7]. In the same year, Argenta and Morykwas published their experience with a NPWT device created by Kinetics Concept, Inc. (KCI®) called a vacuum-assisted wound closure (V.A.C.) device. They observed the fastest granulation in the 31 acute traumatic wounds in comparison to patients with pressure ulcers, venous stasis ulcers, and subacute lesions [8]. The authors attributed this augmented healing to the device's ability to remove interstitial fluid, increase tissue vascularity, and decrease bacterial colonization [8]. Although these two series are hampered by a lack of randomization, a clearly defined exclusion criteria, and external validation, they still introduced a therapy that could promote a wound bed amenable to downstream closure techniques [8].

Over the next several years, multiple experiences with NPWT were published. In 2001, DeFranzo et al. shared a series of 49 traumatic lower extremity wounds managed with the V.A.C. device. The authors noted less tissue edema, faster granulation tissue coverage over bone and hardware, and less wound surface area when using NPWT [9]. Two years later, Herscovici and associates published a 21-patient series of high-energy soft tissue injuries treated with V.A.C. therapy. They suggested that V.A.C. therapy does not replace the need for débridement of necrotic tissue but is a viable clinical tool for traumatic injuries that can be safely performed at bedside (~75% of sponge changes) [10]. Although descriptive in nature and limited by lack of control groups, these studies proved instrumental for supporting wound care during Operation Iraqi Freedom. Within a year of the war's inception, NPWT was approved as an adjunct to wound care and documented in the US Department of Defense's Handbook of Emergency War Surgery (2004) [11].

After many grueling months of changing wet-to-moist dressings twice daily for traumatic combat-related injuries, field and hospital personnel began to utilize NPWT given the longer period of time in between sponge changes [12]. Within a 6-month period, NPWT for extremity wounds increased from 46% to more than 90%. However, NPWT was not immediately used during combat transport due to flight team inexperience with equipment and potential environmental issues. Nevertheless, in July 2006, KCI's V.A.C. Freedom device was approved for aeromedical transport use by the Air Mobility Command US Air Force given its unwavering performance in high altitudes, temperature extremes, and during rapid decompression [12]. Fang et al. prospectively observed 30 patients with combat-related wounds in 2008 who were treated with this V.A.C. Freedom device. All patients in their cohort had a V.A.C. placed at a ground facility and were then flown to a destination; all individuals arrived with a functional system having sustained no in-flight complications. Fang et al. believed NPWT could safely and feasibly be expanded to aeromedical evacuation [13].

## Impact on Wound Healing

NPWT rapidly infiltrated the armamentarium of the trauma surgeon regardless of evidence substantiating its efficacy [3, 5, 14, 15]. This phenomenon occurred likely because NPWT is easily learned, appealing to patients, and applicable to a large number of scenarios [16]. Not surprisingly, from 2001 to 2007, Medicare payments for NPWT and associated equipment increased almost 600% from 24 million to 164 million dollars [17]. One of the original theorized benefits of NPWT was that it decreased the need for complex flap coverage in lower extremity fractures with soft tissue defects [15, 18]. For example, Dedmond and colleagues evaluated the role of NPWT on wound closure in adults with type III open tibial shaft fractures. In this 2006 retrospective review of 50 patients treated with NPWT after bony fixation, 24 (48%) patients had fractures that historically would have required a rotational flap or free tissue transfer. However, only 14 (28%) patients required these specific operative interventions while the remaining 10 (20%) were able to undergo delayed primary closure, split-thickness skin grafting, or routine epithelialization presumably because of NPWT [19].

In a smaller series, the same authors examined 15 children with open type III tibial shaft treated with NPWT. They again found a 50% reduction in the need for free tissue transfers and rotational muscle flaps for wound coverage in patients treated with NPWT compared to historical controls [20]. Liu and associates retrospectively reviewed 103 patients with lower extremity trauma over an 8-year period. Prior to a planned free flap coverage, NPWT was used in 78 patients and moist gauze was used in 25 patients [21]. Patients treated with NPWT had significantly lower rates of flap take-back and flap thrombosis; however, the NPWT group received significantly more wound debridements prior to flap coverage. The authors proposed that NPWT aids in wound coverage in patients destined for flap surgery but does not prevent postoperative complications [21].

Some of the first prospective randomized trials examining NPWT were performed by Stannard et al. in 2006 [22]. Their first study enrolled 44 patients with traumatic injuries who required surgical intervention and who demonstrated postoperative drainage for at least 5 days after surgery. In this "draining hematoma" cohorts, 31 patients received standard treatment and 13 patients received NPWT. The standard therapy drained for an additional 3.1 days while the NPWT drained for only 1.6 days longer ($p = 0.03$). The second study enrolled 44 patients who had undergone surgical repair of calcaneal, pilon, or tibial plateau fractures. Twenty-four patients had a regular dressing placed atop their surgical incision and 20 patients had NPWT applied to their incision. Drainage occurred for 4.8 days in the standard dressing group but only for 1.8 days in the NPWT group ($p = 0.02$) [22]. The authors concluded that wounds heal faster (based on wound drainage) using NPWT. Unlike many previous studies, these authors recognized that their investigation was limited by its small sample size [22, 23].

More recently in 2018, Älgå et al. published the results of a pragmatic, randomized controlled superiority trial performed at two civilian medical centers in Jordan and Iraq [24]. During this 3-year study, 174 patients were enrolled after sustaining a conflict-related extremity wound no more than 72 h prior to presentation. In comparison to standard gauze dressings, NPWT offered no significant benefit in rates of wound closure, limb amputation, sepsis, or bleeding [24]. The authors questioned how NPWT technology became introduced, particularly in resource-limited conflict settings, without scientific support for its efficacy [24–26]. Results from this rigorous study support our recommendation on NPWT and wound healing (Table 6.2).

**Table 6.2** NPWT and wound healing recommendation

| Statement | Level of evidence |
|---|---|
| NPWT does not improve wound healing, timing of closure, nor need for flap coverage compared to conventional dressings. | A |

## Effect on Hospital Length of Stay

Potentially as an extrapolation of the results from the tissue flap literature, many surgeons began to speculate that NPWT could offer shorter inpatient hospitalizations. Shilt et al. retrospectively examined 31 children with soft tissue wounds from lawnmower injuries; 16 received V.A.C. therapy and 15 were treated with traditional dressings [27]. While there was a trend toward fewer revision amputations and an improvement in function following treatment, they did not identify a shorter length of stay. In fact, children receiving NPWT had a mean length of stay of 16.8 days compared to a 10.2-day hospitalization in the traditional treatment group ($p = 0.04$). The authors argue that, at the time of their study, V.A.C. therapy was not yet approved for home use, thus necessitating hospitalization [27]. Arti et al. prospectively randomized 90 patients in Iran with open fracture wounds to NPWT or conventional wound dressings. The NPWT group exhibited an average 1.5-day shorter hospital length of stay (9.7 vs 11.2 days, $p = 0.01$) compared to the conventional dressing group [28]. This study's results are encouraging because of its prospective randomization; however, the authors do not account for important confounding variables such as patient comorbidity, initial wound severity, or concomitant injury profile.

Kaplan and colleagues also examined the impact of NPWT on hospital length of stay in their 2009 retrospective review [29]. They specifically compared wounds that were treated early (≤2 days of admission; $n = 518$) and wounds treated late (≥ 3 days, $n = 1000$). The early group had significantly shorter inpatient hospitalizations (10.4 vs 20.6 days; $p < 0.0001$), shorter intensive care unit stays (5.3 vs 12.4 days; $p < 0.0001$), and shorter duration of NPWT (5.1 vs 6.0 days; $p = 0.049$). Although this study was well-powered, the inclusion criteria were very broad [29]. They enrolled patients with upper or lower extremity trauma, acute abdominal trauma, cardiovascular-related trauma or surgical wounds, or if they had undergone a sternotomy, fasciotomy, or flap or graft procedure [29]. Furthermore, they did not compare NPWT to standard dressings but rather analyzed the timing of NPWT initiation. Because of the flawed methodology utilized and limitations discussed, we cannot definitively state that NPWT use leads to a decreased hospital length of stay (Table 6.3).

**Table 6.3** NPWT and hospital length of stay recommendation

| Statement | Level of evidence |
|---|---|
| Use of NPWT may be associated with a decreased inpatient hospital length of stay; however, this recommendation does not account for inpatient days spent awaiting outpatient therapy approval by an insurance company. | B |

## Influence on Infectious Complications

A large portion of NPWT research seeks to identify a reduction in infectious complications through the use of this wound therapy. Rezzadeh and associates retrospectively reviewed 32 patients with type III open tibial fractures [30]. The patients were divided into three groups based on time elapsed between injury and definitive reconstruction: acute (≤ 6 days; $n = 8$), subacute (≥ 7 days to <42 days; $n = 16$), and chronic (≥ 42 days; $n = 8$). Each time category was then divided into patients receiving NPWT and traditional wet-to-dry gauze dressings. They noted lower rates of surgical site infections in the NPWT acute group ($p = 0.007$), lower rates of osteomyelitis in the NPWT subacute group ($p = 0.02$), and lower rates of osteomyelitis ($p = 0.04$) and nonunion ($p = 0.002$) in the NPWT chronic group [30]. The authors argue that NPWT in patients with open lower extremity fractures reduces complications associated with limb salvage surgery and serves as a temporizing measure before flap surgery. These sweeping conclusions are substantially limited by the overall study sample size, which were often rendered after comparing two patients with NPWT to six patients with wet-to-dry gauze (i.e., acute group).

In another investigation by Stannard et al., 58 patients with severe lower extremity open fractures were prospectively randomized to NPWT ($n = 35$) or standard wound therapy ($n = 23$) following initial wound irrigation and debridement [31]. The authors concluded that NPWT reduces overall infection rates because only two patients (9%) treated with NPWT developed infections compared to seven patients (20%) in the control group. However, the authors cautioned that there was no significant difference between infection rates when complications were stratified by timing (acute or late) [31]. They also failed to strictly define what constituted an infection in their study.

In a similarly designed investigation set in India, Virani et al. prospectively evaluated 93 patients with open tibial fractures who were randomized to NPWT ($n = 43$) or standard dressings ($n = 50$). They found a significantly lower percentage of overall infections (acute infections and osteomyelitis) in the NPWT group compared to the control group (4.6% vs 22%, $p < 0.05$). The authors stated that NPWT is beneficial in preventing acute infections and osteomyelitis in open fractures, yet they fail to address that there was no difference among individual rates of acute infection and rates of osteomyelitis between groups. Furthermore, the authors briefly mention that some patients in the analysis presented more than 48 h after injury and had not received antibiotics during that time. They also disclose that, of the 11 patients developing osteomyelitis, seven were smokers and three were diabetics but do not specify to which treatment group they belonged. Additionally, they excluded wounds that dehisced after primary closure and did not explain the antibiotic protocol for their study [32]. These limitations considerably lower this study's level of evidence.

In 2019, Hahn and associates prospectively randomized 65 patients with open, contaminated lower extremity wounds from trauma to conventional NPWT or silver

**Table 6.4** NPWT and infectious complications recommendation

| Statement | Level of evidence |
|---|---|
| Infectious wound complications are no different between NPWT and conventional dressings. The addition of silver to NPWT may decrease bacterial counts of *S. aureus* species. | B |

impregnated NPWT [33]. The authors obtained serial bacterial cultures from wounds over 4 weeks from the wounds and detected a significant reduction in Methicillin-resistant *Staphylococcus aureus* (MRSA) colonization in the silver impregnated NPWT wounds. These findings correlated with previous animal research performed by Stinner et al. in 2011 [34]. Complex extremity wounds in goats were inoculated with *Pseudomonas aeruginosa* or *Staphylococcus aureus*, debrided 6 h after inoculation, and treated with silver impregnated gauze combined with NPWT. After 6 days, the wounds inoculated with *P. aeruginosa* had similar bacterial counts between the treatment and control group. For wounds with *S. aureus*, the bacterial count in the wounds treated with NPWT and silver contained much less bacteria than the regular NPWT (25% and 115%, $p = 0.001$) [34]. While the addition of silver to NPWT appears to effectively reduce bacterial counts in contaminated wounds, overall infectious complications are not significantly improved with this treatment modality (Table 6.4).

## Role in Quality of Life

Recently, NPWT has been examined with respect to patient-centered outcomes like quality of life, disability, and pain. In 2018, Costa and colleagues published the results of a United Kingdom Major Trauma Network multicenter, randomized trial comparing NPWT to standard wound care at 24 different centers [25]. Among 460 patients with a severe, open fracture of the lower limb, 88% completed the trial. Analysis demonstrated no significant difference in the quality of life or disability scores between the treatments [25]. Nearly identical results were reached by Ondieki et al. who compared NPWT to routine gauze dressings in patients with acute traumatic wounds. They found no significant difference in subjective pain scores during dressing changes as well as no difference in time to full wound granulation, reduction in wound surface area, or infection rates [35].

Costa et al. performed another multicenter randomized trial including 1548 patients who underwent surgery for a traumatic lower limb fracture [26]. They compared incisional NPWT to traditional wound dressings and demonstrated no difference between groups regarding disability scores, health-related quality of life, surgical scarring, or chronic pain at 3- and 6-months [26]. The amalgam of these contemporary, well-powered scientific studies provides considerable evidence that NPWT is not superior to traditional wound care for traumatic open extremity fractures (Table 6.5).

**Table 6.5** NPWT and quality of life recommendation

| Statement | Level of evidence |
|---|---|
| NPWT does not offer an improvement in quality of life compared to conventional dressings. | A |

## Recommendations Based on the Data

A recent Cochrane systematic review based on the available scientific literature determined that NPWT does not lead to superior wound healing rates in traumatic open fractures compared to standard therapy. The review further notes insufficient evidence to determine the impact of NPWT on infection, wound closure, quality of life, and pain in open fractures [36]. Despite these findings, NPWT paradoxically remains lauded for increasing limb salvage and function as well as promoting faster wound closure than conventional dressings [11, 37, 38]. Indeed, NPWT may be another instance where enthusiasm for an innovative technology outshines scientific evidence and providers do not remember the adage, “new is not always better.”

## Summary of Recommendations

- NPWT does not improve wound healing, timing of closure, nor need for flap coverage compared to conventional dressings.
- Use of NPWT may be associated with a decreased inpatient hospital length of stay; however, this recommendation does not account for inpatient days spent awaiting outpatient therapy approval by an insurance company.
- Infectious wound complications are no different between NPWT and conventional dressings. The addition of silver to NPWT may decrease bacterial counts of *S. aureus* species.
- NPWT does not offer an improvement in quality of life compared to conventional dressings.

## A Personal View of the Data

Despite a relatively limited amount of literature regarding its efficacy, NPWT has become an important tool used for the care of complex traumatic wounds. Combining its ubiquitous availability with provider ingenuity and experience, the care of many patients has potentially improved over the last 20 years because of NPWT. Indeed, NPWT likely has facilitated better control of wound output, less frequent need for dressing changes, and better pain control. However, these benefits are not necessarily substantiated in the scientific literature.

In our opinion, it is critically important to observe the standard principles of early excision of devitalized tissue, wide drainage, and rapid, efficient resuscitation.

For example, in patients with traumatic amputations, it is our practice to perform immediate operative debridement, open packing, and early re-exploration to reassess the extent of soft tissue damage. In our experience, the second inspection generally reveals further soft tissue injury that was not readily apparent at the first operation and occasionally leads to more tissue loss. Premature NPWT application before adequate debridement has the potential to delay the recognition of wounds that require further operative intervention. In our opinion, it is only after this second and thorough debridement that NPWT should be considered.

After this careful review, the literature surrounding NPWT is inadequate to answer many of the questions about this wound treatment paradigm. While there are pockets of relatively convincing evidence on long-term outcomes related to NPWT, there is a dearth of sound data that NPWT improves care in the acute setting. Indeed, like many innovations that have emerged in the care of trauma patients, the widespread implementation of NPWT has advanced quicker than the available evidence substantiating its efficacy. Accordingly, this field warrants further robust investigation as in certain situations, it likely has the potential to benefit trauma patients.

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