Negative Pressure Wound Therapy for Burns

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KEYWORDS

• Negative pressure wound therapy • Burns • Skin graft • VAC

KEY POINTS

- The use of NPWT is associated with improved outcomes in a wide variety of complex wounds. Existing data support certain uses of NPWT for burn care, although studies are limited.
- Studies on the use of NPWT for acute burns suggest that NPWT may have a role in reducing edema and pain, and a positive effect on tissue perfusion and re-epithelialization.
- Of all potential applications of NPWT in burn care, using NPWT as a skin graft bolster dressing has the most supportive data. Other potential applications include management of extent of injury in acute burns, preparation of wound beds for skin grafting, and dressing skin graft donor sites. The use of modified NPWT dressings has shown promise in treating large burns.
- More scientific and clinical studies are needed to fully understand the mechanism of action, optimal method, and ideal applications for NPWT in burn patients.

INTRODUCTION

Negative pressure wound therapy (NPWT) has been used in the treatment of acute and chronic wounds for almost 20 years and is now widely used around the world. Although further research is required to specifically validate many of these treatments and to determine cost-effectiveness, existing data support the use of NPWT for certain aspects of burn care. Of all potential applications of NPWT in burn care, using NPWT as a skin graft bolster dressing has the most supportive data. Other potential applications include using NPWT to limit the extent of injury in acute burn wounds, as a bridge to skin grafting, and as a dressing for skin graft donor sites. This article reviews the literature based on application and describes our center's experience with extra-large (XL) NPWT dressings for large burns.

CLINICAL EVIDENCE ACCORDING TO INDICATION/APPLICATION

Management of Acute Burns with Negative Pressure Wound Therapy

The application of NPWT in the acute management of burn wounds was studied in hand burns by Kamolz and colleagues.[1] The goal when treating a burn acutely is to create a healing environment that protects against fluid losses, infection, and most importantly prevents further progression of the burn wound. Kamolz and colleagues[1] tested whether NPWT is better at this than conventional silver sulfadiazine cream in patients with bilateral partial-thickness hand burns who presented within 6 hours. Seven patients were used in this study with the conventional silver sulfadiazine treatment being used on the less severely burned hand. The primary outcome measure was perfusion to the

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injured skin as measured by indocyanine green angiography. The authors reported that perfusion was significantly improved on Day 3 in the burn wounds treated by NPWT. They also noted reduced edema and decreased progression of the burn wound on clinical examination of the NPWT-treated sites. Although this study was small (seven patients, 14 hands), it suggests that NPWT may have a role in preventing burn progression by improving microcirculation in the reversible zone of stasis.[1]

Beyond altering the microenvironment of the acute burn wound, NPWT may also be useful in the broader context of managing acutely ill burn patients. Banwell and Musgrave[2] have suggested that burns be treated in the acute phase with NPWT and that it is of particular benefit in clinically unstable patients for two reasons. First, full coverage of the burn (which might include complex operative procedures) may be delayed if patients are receiving treatment in intensive care. Second, it may be difficult to change dressings frequently in unstable patients, and NPWT can dramatically reduce the frequency of dressing changes. Thus, in addition to the direct benefits of limiting inflammatory injury in the microenvironment of the burn, NPWT can serve as a practical temporizing measure to achieve control of large wounds until patients become physiologically stable.

A prospective, randomized trial is needed to examine the effectiveness of NPWT in preventing progression of burn wounds, and its cost-effectiveness in management of acute burn wounds in critically ill patients.

Negative Pressure Wound Therapy as a Bridge to Skin Grafting

After the acute phase of burn injury and resuscitation, the second step is excision of devitalized tissue and coverage with skin grafts, when possible. The success of skin grafts depends on several factors, including the quality of the recipient wound bed. A well-vascularized bed with a low degree of bacterial colonization maximizes the probability of skin graft take. As such, NPWT use has been suggested as a method to prepare a wound to accept a skin graft. Although there are no good data on the use of NPWT in the preparation of burn wounds, there have been favorable studies looking at other types of open wounds. In addition to several retrospective studies,[3,4] a prospective randomized trial by Saaiq and colleagues[5] reported using NPWT versus wet-to-dry saline gauze to prepare traumatic wound sites for tie-over bolster skin grafting 10 days after debridement. The authors found that the patients treated with NPWT had a higher skin graft take and shorter hospital stays.

Negative Pressure Wound Therapy as a Bolster Dressing for Autografts

Scherer and colleagues[6] reported the results of a retrospective study where traditional skin graft securing methods were compared with NPWT in a variety of wounds, 50% of which were burns. A subgroup analysis of the burn wounds showed a decreased graft failure rate in the NPWT group (0% vs 19%).[6]

A randomized, double-blind control trial compared the total area of skin graft loss for skin wounds (of which more than half were burns) in grafts secured with conventional methods and NPWT.[7] The authors reported a median graft loss of 0.0 cm^2 (range, 0.0–11.8 cm^2) for the NPWT group, whereas the control group median graft loss was 4.5 cm^2 (range, 0.0–5.2 cm^2; $P = .001$). The patients treated with NPWT also had significantly shorter hospital stays.

A prospective randomized control trial by Petkar and colleagues[8] of 30 burn patients compared the graft take in 21 burn wounds receiving NPWT on the split-thickness skin graft (STSG) and 19 burn wounds receiving conventional compression dressings on the STSG. They found that mean graft take was higher in the NPWT group than in the control group (96.7% vs 87.5%; $P<.001$). Most studies have not examined the use of NPWT as a bolster in exclusively burn patients. However, the previously mentioned studies all report that NPWT likely improves graft take but at a higher financial cost.

Negative Pressure Wound Therapy as a Dressing to Integrate Bilaminate Dermal Substitutes

NPWT may have a role in the integration of a bilaminate dermal substitute in a burn site, such as Integra® (Integra LifeSciences Corporation, Plainsboro, NJ). Jeschke and colleagues[9] compared the use of conventional compression dressings versus NPWT with fibrin glue changed every 4 days to secure a bilaminate dermal substitute. Once the dermal substitute had fully vascularized, an STSG was placed and the STSG take rate as a percentage of total area of dermal substitute placement was recorded. The STSG take rate was significantly higher in the NPWT plus fibrin glue group compared with conventional pressure dressings (98% vs 78%; $P<.003$) with a shorter time to definitive coverage (10 days vs 24 days;

$P<.002$). It is worth noting that because fibrin glue was used alongside NPWT, one cannot separate any beneficial effect of the NPWT from that of the fibrin glue.

A retrospective study by Molnar and colleagues[10] examined bilaminate dermal substitute revascularization and staged skin graft take rate with use of NPWT for securing both coverage procedures. They performed procedures on patients with exposed bone, joint, tendon, or bowel, who would have otherwise required more extensive reconstructive procedures. The authors reported a 96% Integra® revascularization rate, 93% STSG take rate, and mean of 7.25 days from dermal substitute placement to skin grafting.[11–14] These studies suggest that NPWT may improve the rate of vascularization of bilaminate dermal substitutes thereby reducing the delay before skin grafting and improving eventual skin graft take.

Negative Pressure Wound Therapy as a Skin Graft Donor Site Dressing

Many burn patients require an STSG to treat their wounds. The STSG donor site is often painful and messy. Many burn surgeons still treat donor sites with some form of dry dressing; however, multiple studies suggest that a moist wound environment is preferable for donor site wound healing.[15–17] It is possible that NPWT may have a role in helping the donor site re-epithelialize faster. In our experience, the main advantage of NPWT for donor sites is that it removes wound exudate, allowing for quantification and a more stable dressing that does not move, make a mess, smell, or fall off easily. We have also found that patients seem to have less pain, perhaps because of the immobility and lack of shear associated with the dressing.

Genecov and colleagues[18] looked at the rates of skin graft re-epithelialization in 10 patients who served as their own control subjects. Two donor sites were used on each patient with one donor site being covered with occlusive dressings without negative pressure and one site being covered with NPWT. On postoperative day 7, analysis of the keratinocyte layer from punch biopsies confirmed accelerated re-epithelialization in the NPWT group in 70% of patients, equivalent rates in 20%, and delayed re-epithelialization in 10%. Statistical analysis confirmed faster re-epithelialization in the NPWT group ($P<.013$). The data from this experiment suggest that NPWT could help the donor site re-epithelialize faster within the first 7 days after graft harvest.

Negative Pressure Wound Therapy as an Integrated Dressing for Large Burns

Given the multiple uses for NPWT in managing a variety of burn wounds at different phases of healing, it is possible that an integrated large NPWT dressing could be useful in treating limbs and large areas of mixed burn wounds. Chong and colleagues[19] reported sandwiching limbs in large polyurethane dressings with a thin strip of sponge placed in dependent position in an approach called the “total body wrap.” This technique uses the negative pressure to encourage re-epithelialization in skin graft donor sites while removing inflammatory exudate and reducing exposure to pathogens. The authors concluded that this technique could be used to promote healing and improve comfort and care in a severely burned patient, although no objective measures were recorded.

THE BRIGHAM AND WOMEN’S HOSPITAL EXPERIENCE

In the burn unit at the Brigham and Women’s Hospital we have been using large NPWT dressings to treat patients with burn wounds greater than 15% total body surface area (TBSA) on a regular basis.[20] Our methods are different from those described by Chong and colleagues.[19] We apply microporous silver-impregnated foam with a silicone contact layer over donor sites and STSG recipient sites (Mepilex Ag®, Molnlycke, Gothenburg, Sweden). Both areas are then covered with similarly contoured conventional NPWT sponge (V.A.C. GranuFoam, KCI, San Antonio, TX; and/or Ioban, 3M, St. Paul, MN) and a seal is obtained using a suction pad (Sensa T.R.A.C. Pad, KCI). We have found that this combination of dressings works well on all wound types, including burned skin, open wounds, donor sites, recipient sites, and (most importantly) intact skin. Therefore, it is not necessary to tailor the dressing to each type of wound, with special bridges over intact skin. Instead, the entire extremity or body area can be covered in this two-layered dressing and covered with an occlusive dressing to obtain a seal (**Fig. 1**), greatly simplifying the dressing application process (and reducing operating room time).

Similar to Chong and colleagues,[19] to cover limbs we sandwich the limb between large sheets of occlusive dressing. Wall suction is applied just before the most difficult area to obtain a seal is covered, thereby assuring a seal immediately after occlusive dressing application. Areas prone to moisture or sheer forces (eg, nonexcised burn tissue, the perineum) have a double layer of occlusive dressing applied and secured in place by sutures or

Fig. 1. Modified technique of NPWT applied to an STSG recipient site on the right arm (*A*), then covered with an occlusive dressing to obtain a seal (*B*), showing skin graft take after NPWT is removed (*C*).

staples (**Fig. 2**). Suction pads are applied in the most dependent areas, with one pump used per arm, two pumps per leg, and two pumps for the chest or back (**Fig. 3**). Pressure is applied at −125 mm Hg continuously, going down to −50 mm Hg on Day 1 to 3 for physical therapy at the discretion of the attending burn surgeon.

There is a steep but not very long learning curve to become adept in the application of large NPWT dressings and obtaining a proper seal that will hold for 5 to 7 days. Critical technical points are as follows:

1. Use a modified dressing (as described) that is effective over multiple wound types and intact skin, thus eliminating the need to contour dressings.
2. Wrap extremities circumferentially and obtain seal by sandwiching large occlusive dressings, or using an extremity bag and proximal seal when the hands/feet are involved.
3. Save the hardest part until last. Apply wall suction before placement of the last piece of occlusive dressing, so a seal is immediately obtained.
4. Use double layers, staples, running sutures, ostomy paste, and so forth and be creative in figuring out how to obtain seal in difficult areas, because you will want to use this dressing for all burns when you see the results.

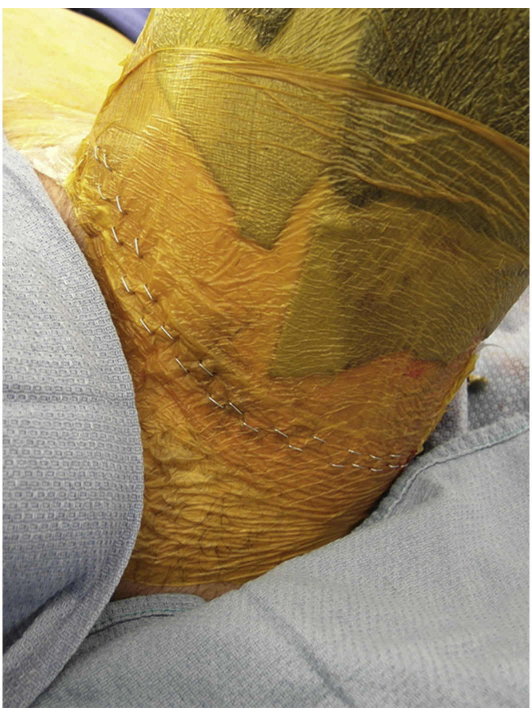

Fig. 2. Application of modified technique of NPWT to the groin area: in this case two layers of occlusive dressing and two rows of staples facilitate the maintenance of a seal to overcome shear forces and moisture.

A useful function of NPWT is monitoring fluid output from the wounds (which can also be predicted, as discussed later). With large NPWT dressings, fluid output is high. When it exceeds 3 L/d, we have chosen to replace it 1:1 with lactated Ringers solution. Electrolytes are checked twice daily and corrected. We prefer our technique to that of Chong and colleagues[19] because we believe graft fixation, exudate removal, and wound healing are improved by applying an NPWT sponge over the entire wound bed.

Perhaps the most important clinical benefit of using large NPWT dressings is that the surgeons and nurses in our unit have noted a dramatic decrease in pain and anxiety compared with traditional dressings that require more frequent changes. Our nurses uniformly love the dressing. Because it controls exudate, the dressings are not changed daily, which is a great reduction in tedious work and results in less patient anxiety and pain associated with such dressing changes. Many patients have little pain following surgery, but increased pain after the dressing is removed at 5 to 7 days. It is possible that NPWT is modifying the inflammatory response that modulates pain perception, or that the lack of motion and sheer minimizes pain. Future studies on NPWT for burns should incorporate pain as an outcome measure.

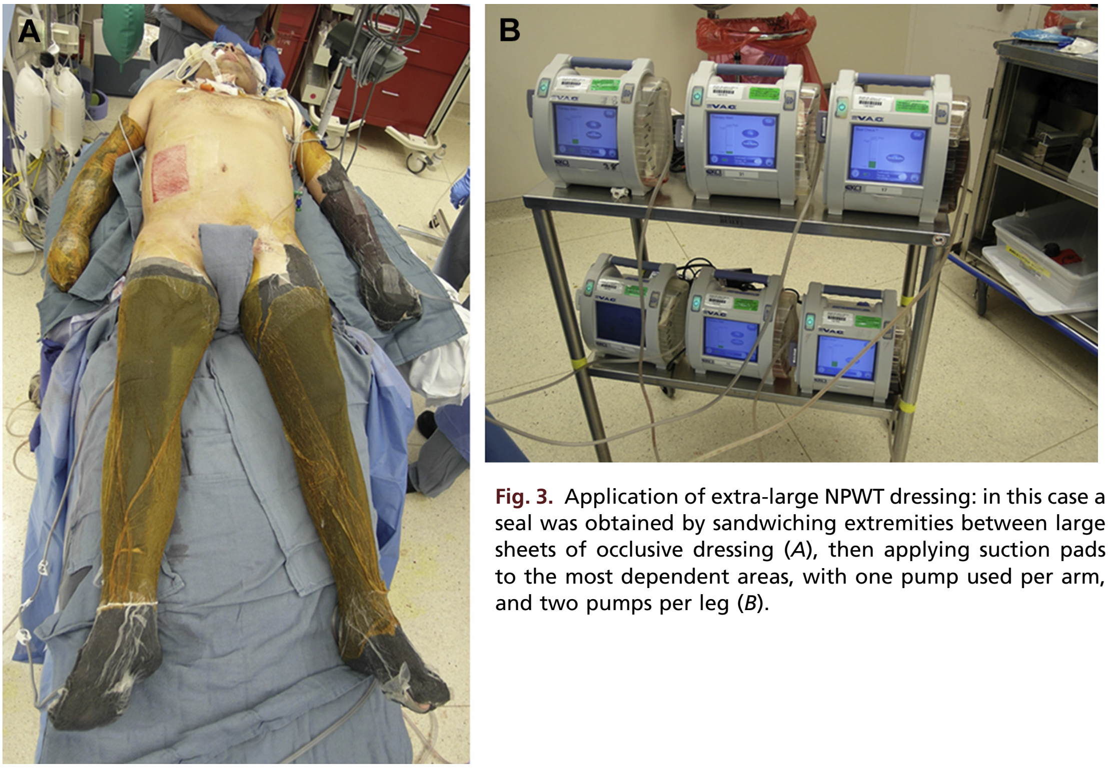

Fig. 3. Application of extra-large NPWT dressing: in this case a seal was obtained by sandwiching extremities between large sheets of occlusive dressing (*A*), then applying suction pads to the most dependent areas, with one pump used per arm, and two pumps per leg (*B*).

A recently published paper based on our early experience with XL NPWT dressings described 12 patients we treated using the aforementioned methods of XL-NPWT burn management (**Fig. 4**).[20] The mean age was 35.5 (median, 28; range, 18–63) with a mean burn size of 29.6% TBSA (median, 25%; range, 15%–60%). Half of the patients we studied had also suffered an inhalation injury, and 11 of the 12 patients required mechanical ventilation for an average of 16.5 days (median, 15; range, 2–40 days). The mean time from injury to grafting was 7.75 days (median, 7.5; range, 2–17 days) and the mean TBSA covered with STSG and NPWT was 35.1% (median, 32%; range, 17%–44%).

The average graft take was 97% (median, 100%; range, 85%–100%) with the STSG donor sites re-epithelializing after an average of 11.25 days (median, 11; range, 10–14 days), although this later information was only from 4 patients. Two patients developed acute kidney injury (AKI) that resolved and one developed a hematoma within 12 hours of surgery. The hematoma was evacuated and the NPWT dressing resealed with no further complications. The length of stay (LOS) for our patients averaged 37.9 days (median, 32.5; range, 19–66) and all 12 of our patients survived without any wound infections. Of interest, two patients had TBSA burns greater than 35% and their LOS were shorter than the ABA Burn Respiratory national averages (39 vs 62 days and 50 vs 68 days, respectively). Patients with smaller burns had variable LOS, chiefly because of social issues. Our sample size is too small to make any conclusions regarding the effect of XL-NPWT on LOS.

Fluid output from the wounds during the first 5 days of grafting averaged 101 $\pm$ 66 mL/% TBSA covered per day. Average output for the donor sites was double that of the recipient site at 132 $\pm$ 83 mL/%TBSA versus 61 $\pm$ 37 mL/%TBSA, respectively. These numbers are used to predict fluid loss from burn wounds covered with NPWT dressings, although measuring actual output is obviously more accurate. Nevertheless, predictions can make the intensive care unit team more prepared to resuscitate such patients in the postoperative period.

Lamke and Liljedahl[21] studied the evaporative water losses from burn wounds and skin graft donor sites reporting that water loss was three times higher from donor sites compared with grafted sites (1.2 vs 0.36 mL/cm^2/d, respectively).

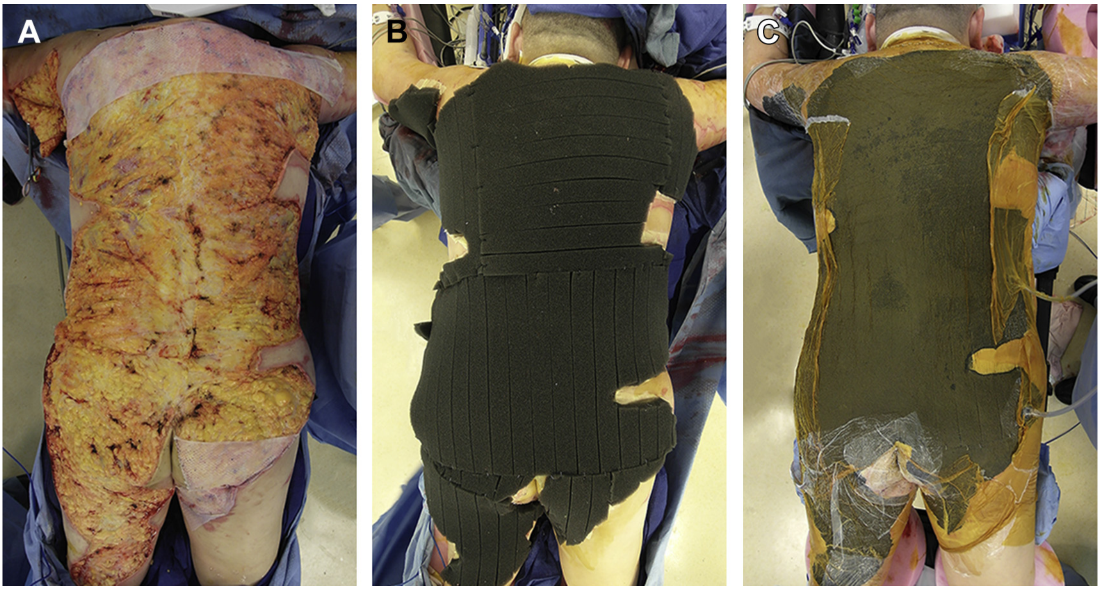

Fig. 4. Application of extra-large NPWT dressing. Large campfire burn of the posterior trunk and buttocks (*A*), covered with xenografts and autografts followed by a microporous nonadherent foam with a silicone contact layer followed by conventional NPWT sponge (*B*). Proximal thighs were then circumferentially wrapped and sealed using an occlusive dressing sandwich technique (*C*) and staples/sutures were used in the perineum. This seal held for 6 days.

The results from our patients followed a similar trend with fluid loss from the donor site being double that of the recipient site. Two of our patients developed AKI; this may have been caused by a lack of experience in using XL-NPWT and an underestimation of fluid loss. On the other end of the fluid resuscitation spectrum, however, none of our patients developed lung edema from overresuscitation and they were able to discontinue manual ventilation earlier than burn patients in other studies, although our study is too small to perform meaningful statistical analysis.[22]

We have found that our modified NPWT dressing is a safe and effective dressing for treating large burn wounds, and a technology-based improvement for patients, nurses, and surgeons alike. Our results regarding graft take are similar to those achieved by Petkar and colleagues[8] with the difference being our burn wounds were much greater than the 10% TBSA burns in their study. Our average healing time of 11.25 days for STSG donor sites corroborates the study by Genecov and colleagues,[18] which showed that NPWT enhanced donor site re-epithelialization.

SUMMARY

Although the literature supporting NPWT for burns is not robust, there is good evidence to support its use as a bolster dressing for skin grafts. Other studies suggest that it may reduce conversion in the zone of stasis, it may improve integration of bilaminate dermal substitutes, and it may improve donor site re-epithelialization. Based on our early experience we have found that a modified NPWT dressing is a safe and effective dressing for large burn wounds because it provides an integrated dressing for management of various wound types in a single burn patient. Our modified NPWT dressing is much easier to apply than traditional NPWT dressings. In addition, accurate measurement of wound exudate helps guide fluid resuscitation and achieve appropriate fluid balance, reducing the risk of pulmonary edema and AKI. Exudate management is a chief advantage of NPWT for burns, resulting in greater ease of use and a stable dressing that requires less work to realize superior outcomes. We also believe that NPWT promotes re-epithelialization, protects against infection, and reduces anxiety and pain. The multiple potential advantages of NPWT for burns converge to make it a compelling dressing.

Having less frequent dressing changes helps reduce the burden on the nursing staff, reduces bacterial colonization, and reduces narcotic requirements. Decreased narcotic requirements and more precise fluid management, with avoidance of fluid overload and subsequent pulmonary edema, may lead to decreased ventilatory support and intensive care unit LOS. Decreased wound colonization may lead to decreased wound infections and decreased infections at other sites that are prone to infection from colonizing bacteria (eg, pneumonia, central line infections). Some disadvantages include cost, time for dressing application, a learning curve for dressing application, and the requirement of an extra trip to the operating room for removal of the dressings. Attention to maintenance of a negative pressure seal before removal of the dressings also requires vigilance and a well-trained nursing staff. On occasion, wall-suction is required.

In balance, we believe that the advantages of NPWT outweigh the disadvantages, and that the potential for improved outcomes and decreased LOS could make it a highly cost-effective dressing.

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