“Homemade” Negative Pressure Wound Therapy: Treatment of Complex Wounds Under Challenging Conditions

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Abstract: Background. Complex wounds pose a challenge to the surgeons regarding coverage and reconstruction. Negative pressure wound therapy (NPWT) has become a widely accepted technology for managing such wounds. Despite the case reports suggesting excellent outcomes of commercially available NPWT systems, there is paucity of randomized, controlled trials. Homemade alternatives can be of great use in hospitals with limited resources if they are found to be effective for managing complex wounds. Objective. To determine the effectiveness of “homemade” NPWT for coverage of challenging and difficult wounds of different regions of the body with limited options for reconstruction. Methods. Forty-four patients with 51 complex wounds involving different parts of body were included in the study. After initial debridement, the patients were treated with NPWT to obtain a healthy granulating wound bed that could be covered with simple reconstruction (ie, skin graft). Results. The average number of dressing changes was 2.9 and the average duration from start of therapy until the wound was ready for coverage was 13 days. Forty-seven wounds were skin grafted and 3 wounds were covered with local turnover flaps. One post sternotomy wound healed by secondary intention. Conclusion. This simple “homemade” NPWT system is an effective technique for treating challenging wounds on various parts of the body.

Management of complex wounds of different areas of the body has been the cornerstone of reconstructive surgery since its inception. Most of such wounds have exposed bones, tendons, or vital structures in the presence of limited reconstructive options, which present a significant challenge to plastic surgeons. Salvaging severely traumatized limbs, managing post sternotomy wounds with exposed vital structures or treating post radiotherapy chest wounds can be quite difficult when the options are limited. Regarding lower limb reconstruction, soft tissue defects of the heel, ankle, and lower leg are difficult to cover most of the time, and it remains a challenge to seek safer options with less morbidity. There are many possible reconstructive options, including skin grafts, local flaps, distant flaps, and
free tissue transfer, but their usage is limited and problems exist in these regions. Soft tissue coverage is often difficult to obtain with mutilated hand trauma when multiple tissues like bone, tendons, or nerves are involved. Free tissue transfer has been established as a good tool for coverage of large, complicated wounds of the extremities, but when free flaps are contraindicated or they fail, management of such wounds presents a formidable task. Moreover, they require a microvascular team and equipment and the procedure is lengthy. Fleischmann et al introduced a new technique in 1993 describing the use of subatmospheric pressure to promote healing of wounds with open fractures resulting in efficient cleaning and conditioning of wound and marked granulation tissue. In 1995, a negative pressure wound therapy (NPWT) system, also known as vacuum-assisted closure (V.A.C™ Therapy, KCI, San Antonio, TX), became commercially available and achieved good performance outcomes sought after for negative pressure dressings. Since its introduction, it has rapidly evolved into a widely accepted treatment for acute and chronic wounds. This could result in a shift of clinical practice with a trend down the reconstructive ladder, as observed by Parrett et al, who observed fewer free flaps and more delayed closures and skin grafts with the use of NPWT.

There are, however, limitations of V.A.C, which preclude its universal adoption in appropriate clinical settings. The most significant include high cost of treatment, decreased patient mobility, and prolonged hospital admission. In an attempt to seek cost-effective, inexpensive alternatives to V.A.C, Shalom et al devised a homemade NPWT system, which they found to produce comparable results to the more expensive V.A.C system. In the authors’ setting, cost of treatment is a major concern, as the hospital cannot provide such expensive equipment for treatment of individual patients. Based on the same principles, the authors have been using a simple alternative to provide a controlled negative pressure environment for the wounds and have found it to be effective. By implementing this therapy, the authors have been able to convert complex soft tissue defects to healthy granulating wounds that easily accept skin grafts or local flaps.

Methods
This study was a descriptive case series conducted at the Federal Postgraduate Medical Institute, Sheikh Zayed Hospital (Lahore, Pakistan) over a 2-year period (January 2007–December 2008) that included 44 patients with 51 complex wounds or soft tissue defects of different areas of the body (eg, lower limbs, hands, and chest). Wounds from the lower limb were considered to be challenging if they had exposed bones or tendons and if there were multiple wounds on the same limb precluding locoregional flaps, or major injuries of the chest, abdomen, or head and neck region, contraindicating lengthy and risky free tissue transfer procedures. Similarly, patients with diabetes and concomitant severe peripheral neuropathy or vasculopathy or poor general health, which made them unfit for major surgery, were also included. Mutilated hands (usually a result of crush injury) with loss of 50% or more of the skin making locoregional flap transfer impossible, were the criterion for upper extremity wounds. The chest wounds included were those in which flaps had failed for breast cancer reconstruction or post sternotomy wounds. Patients with generalized sepsis, malignant disease, exposed vessels, and those who refused the NPWT treatment after appropriate counseling were excluded from the study. Patients gave informed consent prior to including their data in the research. Patients demographic data such as age, sex, wound site and size, exposure of bone or tendons, number of NPWT dressings applied, and duration of the treatment until the wound was ready for temporary or permanent coverage of the wound were recorded.

Technique. Simple suction drain tubing with multiple holes was passed through open cell sterilized foam,

**KEYPOINTS**

- When free flaps are contraindicated or they fail, management of such wounds presents a formidable task.
- The authors have been using a simple alternative to provide a controlled negative pressure environment for the wounds and have found it to be effective.

- **Patients treated with this therapy included those with mutilated hands and loss of 50% or more of the skin making locoregional flap transfer impossible. The chest wounds included those with failed flaps for breast cancer reconstruction or post sternotomy wounds.**
- **An intermittent negative pressure (125 mmHg) cycle with 1 hour on and 15 minutes off during the day and continuously on during the night was applied to the wounds.**
which was cut geometrically to fit the wound. A plastic adhesive drape dressing was then placed over the foam in such a way that the drape overlapped the wound margins by 5 cm or more and completely surrounded the drain tubing so that an airtight seal was obtained. The tubing was connected to the wall suction if the patient was admitted in the hospital or to an ordinary suction machine if the patient was considered for home based treatment. In either situation, a continuous and graduated negative pressure was maintained according to the protocol. The fluid was collected in a glass container and calculated. If the collected fluid was in excess of 500 mL per day, it was replaced to the body either orally or intravenously.

**Management protocol.** The patients to be treated with NPWT initially underwent thorough wound debridement to remove all necrotic tissue. Wounds were swabbed and sent for culture and sensitivity testing before the NPWT dressing was applied. In cases of open wounds, absence of pyrexia, and local signs of cellulitis, no empirical antibiotics were administered until the culture and sensitivity results were completed and reviewed. An intermittent negative pressure (125 mmHg) cycle with 1 hour on and 15 minutes off during the day and continuously on during the night was applied to the wounds. The dressings were observed every 6 hours to examine the presence of vacuum and to detect possible leaks. The patients could ambulate during the off period after a nurse disconnected the tubing during the off time period. When the dressing was removed after 4 days, the wounds were washed with normal saline and assessment was made about the wound parameters and presence of granulation tissue. At that time, a decision was made regarding whether to reapply the dressing or to cover the wound, both of which were done on the next available operative day; the wound was dressed with routine saline wet-to-dry gauze dressing in the meantime. If an air leak, local signs of extending cellulitis, or generalized septicemia were evident, the dressing was removed earlier and the wound was reassessed. The patients who were sent home with the device were specially instructed and counseled regarding its use and monitoring protocol. The dressing was changed immediately if a leak was evident.

**Results**

A total of 44 patients with 51 wounds were included in the study. There age ranged from 7 to 76 years with mean age of 39.4. There were 33 males and 11 females.

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**Table 1. Wound locations and management summary.**

<table>
<thead>
<tr>
<th>Wound location</th>
<th>No. wounds</th>
<th>Average no. of NPWT dressings per wound</th>
<th>Average no. of NPWT treatment days</th>
<th>Final procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower limb</td>
<td>39</td>
<td>2.6</td>
<td>11.5</td>
<td>STSG (37) Turn over flap (3)</td>
</tr>
<tr>
<td>Hand</td>
<td>7</td>
<td>2.8</td>
<td>15.0</td>
<td>STSG (7)</td>
</tr>
<tr>
<td>Chest</td>
<td>4</td>
<td>5.5</td>
<td>23.5</td>
<td>STSG (3) Latissimus dorsi flap (1)</td>
</tr>
<tr>
<td>Periauricular</td>
<td>1</td>
<td>4</td>
<td>17.0</td>
<td>STSG (1)</td>
</tr>
</tbody>
</table>

STSG: Split-thickness skin graft.

**Figure 1.** Study group comorbidities.
Figure 2A. Diabetic patient with wound over dorsum of foot and exposed metatarsals.

Figure 2B. Note the appearance of healthy granulation tissue after application of negative pressure therapy.

Figure 2C. Granulation tissue is filling up the space between the metatarsals.

Figure 2D. Granulation tissue has almost covered the bones.

Figure 2E. Only a small part of bone is visible in the wound.

Figure 2F. Split skin graft has good take on healthy granulation.
The size of the wounds ranged from 3 cm x 3 cm to 32 cm x 14 cm (average size 11 cm x 6.3 cm). Among the lower limb defects (n = 39), trauma as a result of road traffic accident was the leading cause (n = 30). There were three diabetic foot ulcers, three wounds as a result of bomb blasts, two wounds with chronic osteomyelitis, and one wound resulted from injection abscess in a patient with nephrotic syndrome. Tendons or bone were exposed in 36 lower limb wounds. Among the upper limb wounds, there were four mutilated crushed hands and 3 post infectious wounds in patients with diabetes. Two patients had open sternotomy wounds with exposed pericardium after cardiac bypass surgery and two patients had large wounds of the chest after radiotherapy for breast cancer and failed myocutaneous flaps. One patient who had excision of a carbuncle on the right periauricular area including lower half of the auricle was also treated with NPWT. The exact site of the wounds along with frequency, number of dressing changes, and final procedure are summarized in Table 1. Patient comorbidities are shown in Figure 1.

A marked reduction of tissue edema and evidence of healthy granulation tissue was usually seen after the second dressing application, and most of the wounds were graftable or ready for flap coverage by the third dressing application (Figure 2A–G). The number of dressing changes ranged from 2 to 6 (average 2.9). Total number of treatment days from the first NPWT dressing application to the time the wounds were ready for coverage ranged from 9 to 26 days (average 13 days). The number of dressings, which had to be removed or changed because of leakage, was 12 out of 152 dressings (7.9%). Minor air leaks were observed on 16 occasions, which required complementary draping. The number of wounds covered with split-thickness skin grafts (STSG) was 47, while 3 lower leg wounds with exposed tibia were covered with local turnover flaps. Among the 47 wounds that were grafted, 39 had complete take, and there was partial graft loss in the remaining 8 patients—they were treated with local wound care dressings until their wounds healed completely. One patient with a post-
The sternotomy wound was treated with pedicled latissimus dorsi muscle flap and STSG (Figure 3A–D). This patient developed wound dehiscence at the lower right wound border and was further treated with NPWT until the wound healed completely. All wounds have remained stable after a 4- to 6-month follow up. All turnover flaps survived completely.

**Discussion**

The use of NPWT has been established as a promising new technology in the field of wound healing with multiple applications in a variety of wounds, including those that are difficult to heal. Two main factors are considered to be responsible for the dramatic response seen in the wounds: removal of fluid and mechanical deformation. Removal of fluid decreases edema, which decreases the interstitial pressure resulting in increased blood flow. Mechanical deformation causes a wide variety of molecular responses, including changes in ion concentration, permeability of cell membrane, release of second messengers, and stimulation of molecular pathways increasing the mitotic rate of stretched cells. Recently, Scherer et al, in their experimental model on diabetic mice, concluded that vascular response is related to the polyurethane foam, whereas tissue strain induced by NPWT stimulated cell proliferation. Labler et al found increased concentration of local interleukin-8 and vascular endothelial growth factor, which may accelerate neovascularization. This therapy has now been used successfully to treat chronic and acute wounds, burns, envenomations, infiltrations, sternal wound infections, abdominal wall defects, perineal, urologic, and orthopedic wounds. Despite all these reports of success, a recent systematic review has indicated that there is a paucity of randomized, controlled trials in terms of patient allocation concealment, cost of treatment, and follow up.

Contemporary medicine has not only evolved in terms of technological advancement but also in finding cost effective solutions. Expensive equipment with evolving applications cannot be provided at public hospitals with limited budgets, especially in developing countries. The authors devised our own NPWT system based on the same principles as described by Fleischmann et al and Morykwas et al and have found it to be very effective, especially in the treatment of complex and challenging wounds where other options for reconstruction are limited. The cost of commercially available V.A.C is Rs. 600,000 ($7500) for the unit and Rs. 6000 ($75) for each dressing change. The authors' homemade NPWT costs Rs. 1200 ($15) each for initial application and for subsequent dressing changes. In terms of daily expense, this amounts to $12 for an inpatient and $7 for a patient who is managed on an outpatient basis.

We have used negative pressure dressings to aid coverage of acute and chronic wounds and have found this therapy to be very effective even for treating difficult wounds where options for reconstruction are limited.

The negative pressure in the present study was maintained at 125 mmHg, as has been found to be most effective for increasing blood flow to the wound. DeFranzo et al treated 75 patients with lower limb wounds and changed the dressings every 2 days.
Téot changed dressing every 4 days. Rozen et al used their own NPWT for skin grafts and applied it continuously for 5 to 7 days and reported 100% graft take in chronic ulcers in the presence of comorbidities—what this indicates is that no consensus exists regarding dressing change intervals. In the present study, dressings were changed every 4 days because the authors choose to perform the dressing changes in the theatre under aseptic conditions, mostly via the administration of analgesics, except in patients with large painful wounds that required general anesthesia. This practice has also helped to reduce the number of dressing changes, increase patient comfort and compliance, and reduce overall treatment costs.

Although Argenta et al have discouraged using wall suction stating large controlled volumes might induce wound desiccation, Shalom et al used wall suction successfully for 15 patients with complex wounds. Kiyokawa et al used saline irrigation with continuous negative pressure through a continuous aspirator (Mera Sacume™) after experiencing foam contamination using the V.A.C system. Fenn and Butler® used suction drain bottle and wall suction for abdominoplasty wound dehiscence and achieved successful wound closure. Rozen et al used conventional closed suction drain to apply negative pressure to skin grafts of nine patients. In the present study, both wall suction and an ordinary suction machine (locally manufactured) with controlled negative pressure were used and good results were obtained.

Management of full-thickness lower leg and foot wounds can be quite challenging when treatment options are limited (Figures 4A–C, 5A–C). If the patient has concomitant injuries such as a head or chest injury, reconstruction cannot be prioritized in the acute injury phase. Subatmospheric pressure dressing may extend the acute period and acts as a bridge during the time when major flaps and free tissue transfer procedures are not possible. Most of the patients with lower limb wounds included in the present study also had injuries to the chest, abdomen, or head, or had diabetes, and/or hepatic/renal impairment. For this reason, NPWT provided the opportunity to cover the wound with a minimally invasive technique (ie, skin grafting).

Negative pressure wound therapy has also gained popularity as a reliable and superior strategy for patients with postoperative deep sternal wound infections, as compared to conventional dressings. The authors used NPWT to treat two patients with methicillin-resistant Staphylococcus aureus (MRSA) infected sternotomy wounds after cardiac bypass surgery. In both patients, discharge from the wound decreased significantly and wound cultures were negative for MRSA after 12 days (3 dressing changes). One of those patients was treated with NPWT until their wound healed completely. In the other patient’s case, a pedicled latissimus dorsi muscle flap was utilized to fill the defect after the wound was cleared of MRSA in order to provide well-vascularized tissue to facilitate healing. She developed wound dehiscence at the inferior and right margin of the wound. She was subsequently treated with NPWT until the wound healed completely. Both these patients have well-healed sternotomy wounds without any fistulae or recurrence of infection at 6-month follow up. Although the number of cases in this study is low to compared to others in the

**Key Points**

- “Homemade,” cost effective NPWT has been found to be effective and can be utilized anywhere, especially in resource challenged, third world countries.
literature, the duration of therapy is longer (23 days) compared to the study conducted by Gustafsson et al\(^3\) (3–34 days, median 10 days) who treated 40 consecutive patients with deep sternal wounds.

The true efficacy of NPWT can be established by flawless randomized controlled trials. The paucity of such trials in the literature is due to the varying nature of wounds in different circumstances, involvement of different tissues, and availability of resources at different places. It is difficult to advocate the use of expensive forms of negative pressure therapy; nevertheless, one cannot deny the effectiveness of this treatment modality. Perez et al\(^5\) compared the homemade vacuum system with conventional saline soaked gauze dressing and found that healing of complex wounds was significantly faster with homemade vacuum system as compared to conventional wound care. The main limitation of the present study is the absence of a control cohort treated with commercially available NPWT, so as to establish non-inferiority of the authors’ technique. However, “homemade” solutions like the one presented here can be utilized anywhere, especially in resource challenged, third world countries. The authors recommend such cost effective solutions as the first line of treatment for management of complex wounds under challenging situations.

**Conclusion**

“Homemade” negative pressure therapy is a valuable tool not only for the management of complex wounds, but also a panacea under challenging conditions when options for reconstruction are limited.

**References**


5. Fleischmann W, Strecker W, Bombelli M, Kinzl L. Vacuum sealing as treatment of soft tissue damage in open frac-


