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**Original Research Article**

# Negative pressure wound therapy: eleven-year experience at a tertiary care hospital

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## ABSTRACT

**Background:** Management of complicated wounds is a reconstructive challenge. A reconstructive surgeon has to be ready to face new challenges every day. Negative pressure wound therapy has revolutionized the management of complex wounds. We are presenting our experience with this wound care modality in the past 11 years.
**Methods:** It was a prospective study conducted from January 2006 to December 2016 on patients having wounds of varied etiologies, who consented to participate in this study. Custom made low cost NPWT was used till definitive wound closure.
**Results:** A total of 568 patients consented to participate in the study during these 11 years. No major complications were seen. Most of these were males (60.73%) in their 3rd and 4th decade. Trauma was the leading cause of wounds in 38.14%, followed by diabetic foot wounds in 21.5%. Ankle and foot was the most common site of wounds (30.92%) followed by leg (24.01%). A total of 322 small, 218 medium and 97 large size dressings were used. Most of the patients improved with the NPWT. No major complications were seen.
**Conclusions:** NPWT is safe, effective and has proved to be revolutionary in managing difficult wounds. With the use of customized low cost NPWT the benefit can be extended to underprivileged population in under developed nations too.

**Keywords:** NPWT, Reconstruction, Wounds

## INTRODUCTION

The management of difficult wounds has been the seminal force that led to development of plastic and reconstructive surgery as a specialty. Wounds of patients in need of reconstructive surgery are frequently large with extensive soft tissue loss caused by degloving injuries, infection, dehiscence, donor site defects after reconstruction of invasive tumors, or full-thickness ulceration in pressure sores. These situations leave patient in debilitating circumstances with wound that entail labour intensive treatment In the past 30 years, we have entered into an era where patients are living longer with more complex systemic pathology and subjected to more extensive surgical procedures. The number of patients with chronic non-healing wounds and wound complications continue to increase, stressing physicians, hospital, and economic resources. In this population, the aim often becomes not closure, but control of the wound to maximize patient comfort, minimize complications, increase survival, as well as to control cost and hospitalization time.

In the recent past, there has been a surge in the research for the management of non-healing wounds by both surgical and non-surgical methods. Among the new methods, negative pressure wound therapy which was introduced in 1997 by Argenta and Morykwas has gained acceptance for management of various types of wounds e.g. decubitus ulcers, diabetic foot ulcers, varicose ulcers, burn wounds, post fasciotomy wounds, post cardiac surgery deep sternal infections, acute traumatic wounds, skin and soft tissue defects resulting from free or pedicle flap harvest, negative pressure wound therapy has also been used as skin graft dressing of wounds in complex anatomical regions.[1,2]

## METHODS

The study was conducted in the department of Plastic and Reconstructive Surgery, SKIMS, Srinagar, India from January 2006 to December 2016. Patients with wounds were treated with custom made low cost negative pressure wound therapy.

Custom made NPWT dressing was used in all patients which included following materials:

- Open cell polyurethane foam with pore size of 400 to 600 micron and thickness of half inch. it was procured from the seller as 3 feet by 6 feet sheets. This Polyurethane foam was cut to the desired sizes and sterilized with autoclave.
- Transparent adhesive drape (Incise drape/Iodrape) of different sizes were used (depending on the size of wound)
- Connecting tubing (length depending on the requirement)
- Sterilized canisters for collection of effluent.

Wall suction available in the wards was used to provide the negative pressure.

### *Steps for applying the custom made NPWT*

In all the wounds (Figure 1) to be treated with NPWT, the first step was debridement of the necrotic tissue. Adequate hemostasis was achieved, culture swab for microbiology was taken.

**Figure 1: Post traumatic wound over the dorsum of left foot.**

Sterilized polyurethane foam was cut to match the shape and size of the wound and is placed over the wound (Figure 2). Transparent adhesive drape of proper size was applied over the wound which was already covered with the foam (Figure 3). The incise drape should cover more than 5 centimeters beyond the wound margin.

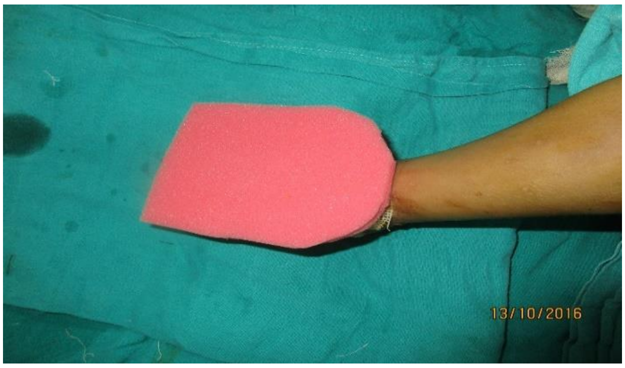


**Figure 2: Application of autoclaved medium density open cell polyurethrane foam following wound debridement.**

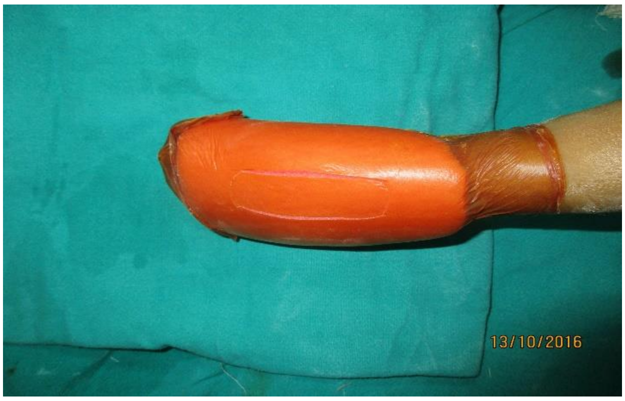


**Figure 3: Cutting a rectangle in the centre of the applied iodrape.**

For connecting the tubing, 4x7 centimeter defect was made in the centre of the adhesive drape (Figure 4). Over this defect the drainage tube (Figure 5) covered with small piece of polyurethane foam (Figure 6) was placed.

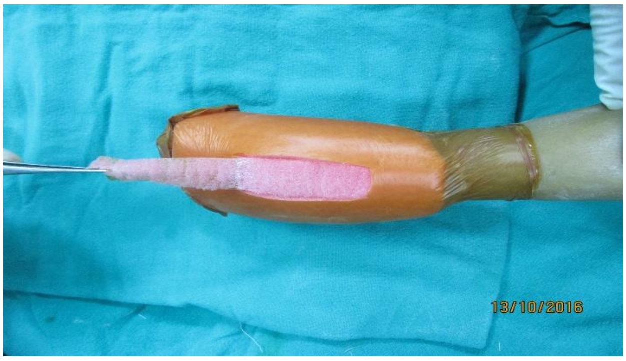


**Figure 4: Removal of this rectangle area of iodrape to expose the underlying foam.**

This defect was sealed with piece of adhesive drape (Figure 7) converting the open wound into a closed system which is open through the tubing only. The end of the drainage tube was connected to canister in the wall suction using a connecting tube and the suction is regulated between 50 to 150 mm of Hg (Figure 8).


**Figure 5: Placement of a fenestrated tube over the foam.**


**Figure 6: Additional piece of foam used to cover the tube.**


**Figure 7: Iodrape used to cover the whole assembly converting it into a closed wound open to exterior through the tube only.**

Wound dressing was changed after every 3 to 4 days unless there was leakage in the dressing until healthy granulations covered the wound (Figure 9). Only in cases where NPWT was used in stabilizing the skin graft, dressing was changed after 4 days and in these cases the graft was first covered with the tulle gauze and then the foam was applied over it.


**Figure 8: Tube connected to wall mounted suction and NPWT activated.**


**Figure 9: Healthy granulating wound fit to be grafted.**

## RESULTS

Negative pressure wound therapy was used in 589 cases with 661 total number of wounds. 21 patients (3.17%) refused to continue with the treatment and were excluded from the study. Total number of patients managed in these eleven years in the department of Plastic and Reconstructive Surgery with the custom made NPWT was 568, out of which 69 (12.14%) patients had two wounds each. Most of these were male (60.73%). Table 1 shows the age distribution of the cases. Most of these cases were in the third and fourth decade; youngest patient was three years old whereas the oldest was 86 years old.

A total of 637 wounds were managed with NPWT. Table 2 shows the causes for which the NPWT was used. Traumatic wounds were the most common among these. In 83 cases the NPWT was used to stabilize the split thickness graft over the wound. Thirty-seven cases of 2$^{nd}$ degree burn were managed with this technique whereas the NPWT was used in 137 diabetic feet also.

**Table 1: Age distribution of patients.**

| Age (years) | No. of patients | Percentage |
|---|---|---|
| 0-10 | 16 | 2.81 |
| 11-20 | 46 | 8.09 |
| 21-30 | 168 | 29.57 |
| 31-40 | 129 | 22.71 |
| 41-50 | 86 | 15.14 |
| 51-60 | 67 | 11.79 |
| 61-70 | 47 | 8.27 |
| 71-80 | 34 | 5.98 |
| 81-90 | 9 | 1.58 |

**Table 2: Etiology of wounds and indications of NPWT.**

| Reason for application of NPWT | No. of wounds | Percentage |
|---|---|---|
| Traumatic wounds | 243 | 38.14 |
| Diabetic foot | 137 | 21.50 |
| Nacrotizing fasciitis/infective wounds | 79 | 12.40 |
| Fasciotomy wounds | 32 | 5.02 |
| Burn wounds | 37 | 5.80 |
| Bed sores | 26 | 4.08 |
| As split thickness skin graft dressing | 83 | 13.02 |

The NPWT was used in most of the areas in the body. Most commonly it was used in foot and ankle area followed by the leg. It was also used in scalp, upper limb, abdomen and chest wall. Table 3 shows the distribution of the body areas where the NPWT was used.

**Table 3: Site of wounds.**

| Site of wound | No. of wounds | Percentage |
|---|---|---|
| Ankle and foot | 197 | 30.92 |
| Leg | 153 | 24.01 |
| Thigh/knee | 33 | 5.18 |
| Sacral area | 17 | 2.66 |
| Gluteal/ischeal /trochantric area | 19 | 2.98 |
| Iliac crest | 3 | 0.47 |
| Scalp | 19 | 2.98 |
| lumbar area | 11 | 1.72 |
| Hand | 56 | 8.79 |
| Arm and forearm | 69 | 10.83 |
| Chest wall | 21 | 3.29 |
| perinium | 13 | 2.04 |
| Abdominal wall | 26 | 4.08 |

The wounds were categorized into three types depending on the size of dressing required (Table 4). The number of dressing changes required till definitive wound closure is shown in Table 5.

**Table 4: Categorization of wounds on the basis of size of dressing required.**

| Dressing type | Dressing size in cms | Number of wounds | Percentage |
|---|---|---|---|
| Small | 10x7.5 | 322 | 50.55 |
| Medium | 18x12.5 | 218 | 34.22 |
| Large | 26x15 | 97 | 15.23 |

Most of the patients improved with the NPWT. Out of 243 wounds due to trauma, 33 (13.58%) wounds healed by secondary intention whereas 189 (77.77%) wounds were covered with healthy granulation tissue and were grafted with split thickness skin graft (Figure 10). Even though the wounds in rest of 21 (8.64%) cases improved but they still required flap cover.

End result of 137 diabetic wounds was also similar. Wound closure was seen in 23 (16.78%) cases whereas skin grafting was needed in 97 (70.80%). In rest of 15 (10.94%) wounds though marked improvement in the wound condition was noticed but still needed flap cover. In 2 (1.46%) patients there was no improvement seen and needed amputation. Most of the wounds (53) with infective pathology also needed skin grafting whereas 19 healed by secondary intention. Only 8 needed skin flap cover. None of the fasciotomy wound needed flap cover. Twenty-four (75%) fasciotomy wounds needed skin grafting whereas 8 (25%) healed by secondary intention and did not require any further procedure. All but three burn wounds healed without the need for skin grafting. Fourteen (53.84) bedsore wounds healed without need for further procedure whereas 6 (23.07%) wounds needed skin grafts and rest of 6 (23%) wounds needed flap for closure.

**Figure 10: Well taken stable graft.**

Complications were observed in some patients. Out of 589 cases, 21 did not cooperate because the wall suction limited their movement so were excluded from the study. Thirty-six (6.33%) patients experienced discomfort/pain upon application of the negative pressure which was relieved by decreasing the negative pressure and by analgesics. Pain on removal of dressing was the main complaint by the patients which was significant in 164 (28.87%) patients and was tackled by instillation of 0.5% lidocaine into the dressing 15 to 20 minutes before removal of the dressing. Maceration of surrounding skin was seen in 64 (11.26%) patients. Excessive bleeding requiring to stop the negative pressure therapy was seen in 6 (1.05%) patients and in none of these patients blowout of vessel was seen, all these patients were managed by compressive dressing and antibiotics before starting the negative pressure therapy again.

**Table 5: Number of dressing changes required.**

| No. of dressing changes needed | No. of wounds | Percentage |
|---|---|---|
| 1 | 85 | 13.34 |
| 2 | 47 | 7.37 |
| 3 | 96 | 15.07 |
| 4 | 143 | 22.44 |
| 5 | 115 | 18.05 |
| 6 | 54 | 8.47 |
| 7 | 46 | 7.22 |
| 8 | 23 | 3.61 |
| 9 | 17 | 2.66 |
| 10 | 11 | 1.72 |

## DISCUSSION

Wound healing is a complex process and involves complex interaction between the reticuloendothelial and immune systems and is influenced by a number of internal and external factors. In the recent past, a number of newer modalities for enhancing the process of wound healing like hyperbaric oxygen therapy, growth factors, skin substitutes and newer dressings have been used but no other newer modality has gained more popularity than the negative pressure wound therapy (NPWT).[3-5] NPWT dressing is specialized dressing comprising of open cell foam covered with occlusive dressing and this dressing is connected to negative pressure system through tubing. The purpose of the open cell polyurethane foam is only to conduct the negative pressure at the wound surface whereas the occlusive dressing is used to convert open wound to a closed system.[1] Role of the dressing used in the NPWT is only to provide controlled sub atmospheric pressure at the wound site and the dressing of NPWT itself has no intrinsic property to accelerate the healing process.

In vitro studies of NPWT therapy have demonstrated fibroblast migration, increased proliferation through mitosis and the creation of a micro-environment that promotes granulation tissue formation.[6-12] In an experimental study conducted on rabbits, it was found that NPWT increased the blood circulation in the wounds by increasing the capillary calibre and blood volume and by stimulating angiogenesis. Further, it narrowed endothelial spaces and restored the integrity of capillary basement membranes causing a decrease in the permeability of blood vessels and wound oedema by removing excessive fluid from the wound bed.[6] An increased rate of granulation tissue formation was also shown to occur with NPWT application.

The bacterial colonization of a wound is a recognized detrimental factor in the multifactorial process of wound healing but it is a matter of debate whether the NPWT increases bacterial colonization or decreases it. While the harmful effects on wound healing are recognized to correspond to a level of $>10^5$ bacteria per gram of tissue, some studies have found tissue bacterial counts to have significantly decreased after four days of application, other studies have shown that bacterial colonization increased significantly with wound NPWT and remained in a range of $10^4$-$10^6$.[7,8] Non-fermentative gram-negative bacilli showed a significant decrease in NPWT treated wounds, whereas Staphylococcus aureus showed a significant increase in NPWT treated wounds. Despite this finding, the beneficial effects of this treatment modality on wound healing were noted in most cases.[9]

Wound surface area reduction was significantly larger in NPWT treated wounds compared to conventionally managed wounds.[10] While close to the wound edge relative hypoperfusion was observed in muscular tissue, the distance from the wound edge to the position at which the blood flow was increased was shorter than that in subcutaneous tissue. The hypoperfused zone was larger at high negative pressures and was especially prominent in subcutaneous tissue. It may be beneficial to tailor the negative pressure used for NPWT therapy according to the wound tissue composition.[10] Studies have shown that when NPWT therapy was terminated, blood flow increased multifold, which may be due to reactive hyperemia. A low negative pressure during treatment may be beneficial, especially in soft tissue, to minimize possible ischemic effects.[11] The application of micromechanical forces through NPWT may be a useful method with which to stimulate wound healing through promotion of cell division, angiogenesis, and local elaboration of growth factors.[12] The application of sub atmospheric pressure alters the cytoskeleton of the cells in the wound bed, triggering a cascade of intracellular signals that increases the rate of cell division and subsequent formation of granulation tissue.[13] The application of the NPWT technique during wound healing increases the expression of the apoptotic modulation-related protein Bcl-2 and affects the expression of NGF/NGFmRNA, which may promote the wound healing process.[14] NPWT promotes healing of chronic wounds through depressing the expressions of MMP-1, 2, 13 mRNA and protein synthesis, depressing the degradations of collagen and gelatine.[15] Studies of NPWT over blood vessels in pigs for 12 hours have shown to enhance an endothelin type A and type B receptor-mediated vasoconstriction. This may be compensated for by a more efficacious endothelium-dependent vasodilatation. In the arteries exposed to

NPWT therapy, spontaneous bleeding, perforation, dissection, or other macroscopic changes were not observed.[16] Subatmospheric pressure created in the wound promotes wound healing through secondary or tertiary intention by preparing the wound bed for closure, reducing oedema, promoting granulation tissue formation, enhancing tissue perfusion and by removing exudates and infectious material. Further the application of a macro strain (centripetal force) draws the wound edges together while a micro strain (forces on the micro circulation) causes cell stretching, increased tissue perfusion, cell mitosis and fibroblast proliferation, thus creating an environment of wound healing at the cellular level.[12]

The use of VAC has been carried out in all age groups including premature neonates with extraordinary soft tissue defects to assist in closing wounds.[17] The youngest patient in present study was a three year old child with post road traffic accident foot defect whereas the oldest was 86 years old with diabetic foot wound. Most of our patients were in 3rd or 4th decade and had wounds mostly due to trauma. It has been used successfully in almost all areas of the body and for many wound types.[18-30] Most of our patients had wounds due to trauma (38.14% of all our patients). The usual causes of trauma in our series were road traffic accidents, fall from height, gunshot injuries, blast victims, assaults. NPWT has been shown to be useful in obtaining wound closure in various types of traumatic injuries including soft tissue defects involving exposed bone, tendon, or hardware.[31-33] The usefulness was also shown in the management of fasciotomies in of our patients which received NPWT followed by closure either by secondary intent or by skin grafting.[34] DeFranzo and colleagues reported a case series that observed NPWT applied to decreased edema of open fractures and decreased circumference of the extremity and size of the wound; 95% of wounds were successfully closed.[34] Other studies have also used NPWT for managing the fasciotomy wounds.[35]

NPWT has been used instead of traditional bolstering methods to provide skin graft fixation. NPWT is initially used in wound bed preparation by reducing wound size as well as improving the amount of granulation tissue available for grafting. Once the graft has been placed, the NPWT dressing distributes negative pressure uniformly over the surface of the fresh graft, immobilizing the graft with less chance of shearing. Shearing forces allow for the formation of fluid collections and seromas, which interrupt the interface between the graft and the prepared vascular bed.

Moisidis and colleagues compared a standard bolster dressing with a NPWT dressing, although quantitative graft take was similar between the 2 groups, NPWT significantly improved the qualitative appearance of the graft (epithelialization rates and skin grafts were better than those of the control group in 75% and 85% of cases, respectively).[36,37] We also used NPWT over skin grafts in 83 patients with excellent results. The prevalence of pressure sores in hospitalized patients has been reported to be from 14% to 21% over the last decade and the overall annual cost has recently been estimated to be between 5 billion and 8.5 billion dollars.[38] NPWT was used in 26 patients with pressure ulcers. Fourteen (53.84) wounds healed without need for further procedure whereas 6 (23.07%) wounds required skin grafts and rest of the 6 (23%) wounds required flaps for closure. Baharestani and colleagues have also shown that the introduction of NPWT (within 30 days) in the course of the treatment of stage III and stage IV pressure ulcers decreased hospital days of admission.[39] Their study showed that for every day that NPWT is delayed, the patient’s hospital stay increased by 1 day. Other potential benefits of NPWT include ease of use, increased patient comfort, and decreased frequency of dressing changes.

In burns, NPWT may be ideal to induce the physiologic changes necessary for healing to occur and prevent progression; decreased edema on clinical exam and a reduced rate of progression to full-thickness injury with need for skin grafting.[40] While this study only examined 7 patients, it suggests that NPWT can help prevent progression of acute partial-thickness burns by improving the microcirculation in the ‘‘reversible’’ zone of stasis. Other studies have confirmed that NPWT-treated wounds exhibit decreased bacterial counts after 3-4 days of treatment in both animal and human models.[1,7] There is also some experimental evidence that NPWT may reduce the inflammatory infiltrate in both acute and chronic wounds.[2,41,42] Thirty seven burn wounds were treated with NPWT in present series and all but three healed without need for grafting.

One hundred thirty seven diabetic foot wounds were treated with NPWT. Wound closure was seen in 23 (16.78%) cases whereas skin grafting was required in 97 (70.80%). In the rest of 15 (10.94%) wounds though marked improvement in the wound condition was noticed but still required flap cover. In 2 (1.46%) patients there was no improvement and landed up in amputation. Armstrong and Lavery reported that more patients in the NPWT group healed their wounds (defined as 100%re-epithelialization with no drainage) versus the standard group.[43] Rate of healing and of granulation tissue formation was faster in the NPWT group. They found trends toward fewer second amputations. Similar findings were also corroborated by Blume and colleagues[44] in their multicenter RCT. These investigators observed that at 9 months 43.2% of patients with NPWT versus 28.9% of patients receiving advanced moist wound therapy experienced complete wound closure.

Many complications have been documented with the use of NPWT like excessive bleeding, vessel erosion, retained sponge, toxic shock syndrome but in present study we did not have any serious complication.[45-47] We did have bleeding in 6 of our patients but that was managed by removal of NPWT, compression bandage and antibiotics. No case of vessel erosion was seen. Pain on removal of dressing was noticed in 164 cases which was managed by instillation of 0.5% lidocaine into the dressing 15 to 20 minutes before removal of the dressing.

This versatile and effective method of treating wounds has some contraindications and these are exposed vessels and nerves, malignancy, anastomotic sites, untreated osteomyelitis, exposed organs, nonenteric and unexplored fistulas.[49]

## CONCLUSION

NPWT is safe, effective and has proved to be revolutionary in managing difficult wounds. With the use of customized low cost NPWT the benefit can be extended to underprivileged population in under developed nations too.

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