https://doi.org/10.48047/AFJBS.6.15.2024.6364-6374

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

INDIGENOUSLY PREPARED CONTINUOUS NEGATIVE PRESSURE WOUND DRESSING: EFFECTIVE AND ECONOMIC APPROACH IN MANAGEMENT OF OPEN WOUNDS IN THE INDIAN SCENARIO

Dr. Ankit Pathak[1]; Dr. Naveen Chauhan[2], Dr.Dhirendra Pratap Singh[3], Dr. Albert Dsouza[4], Dr Pranav Kapoor[5], Dr Aditya Musaddi[5]

[1]Senior Resident; Department of Orthopedics, School of Medical Science and Research, Sharda University, Greater Noida, Uttar Pradesh, India.

[2]Assistant Professor; Department of Orthopedics, School of Medical Science and Research, Sharda University, Greater Noida, Uttar Pradesh, India.

[3]Assistant Professor; Department of Orthopedics, KSG Medical College, Bulandshahr , Uttar Pradesh, India

[4]Associate Professor; Department of Orthopedics, School of Medical Science and Research, Sharda University, Greater Noida, Uttar Pradesh, India.

[5]Post Graduate Resident; Department of Orthopedics, School of Medical Science and Research, Sharda University, Greater Noida, Uttar Pradesh, India.

Corresponding author: Dr. Albert Dsouza

Volume 6, Issue 15, Sep 2024

Received: 15 July 2024

Accepted: 25 Aug 2024

Published: 05 Sep 2024

doi: 10.48047/AFJBS.6.15.2024.6364-6374

Abstract

Background: Open wound management, despite various advancements still poses a difficult therapeutic challenge. With increased morbidity and prolonged hospital stay, the financial burden incurred by such patient's causes significant emotional strain on the family and relatives. Negative pressure wound dressing (NPWD) with its benefits has revolutionized wound care management, but its high cost, availability and procurement in our country poses a significant challenge to an already financially weak patient. Our study was carried out to determine the efficacy and cost effectiveness of our indigenous NPWD using easily available local materials. **Material and methods:** A prospective interventional study was carried out on 20 patients in our institution who met the inclusion criteria. All patients' wounds were thoroughly debrided and serial applications of our indigenous NPWD was applied and their results were studied. **Results**: Study group included 13 males and 7 females. 25 % of wounds were caused due to trauma. Number of dressings required ranged from 2-7 with an average of 3 .45 dressing before wound closure with a mean duration of NPWD applied for 9.5 days. The mean wound size prior to NPWD was 24.75 which significantly reduced to 19.35(p=0.027). The mean wound bed score at baseline was 9.5 which significantly improved to 13.5 at the end of 30 days. (p=0.012) The duration of hospital stay ranged from 10- 30 days with an average duration of 14.64 days. Wound closure was achieved by split thickness skin graft and secondary suturing once healthy granulation tissue was seen. Skin maceration was seen in 3 wounds for which reapplication of NPWD were delayed by 2-3 days. The average cost of each NPWD was approximately 350- 400 INR for our patients.

Conclusions: Our study indicates that our indigenous NPWD is an easy to apply and economical construct, utilizing locally easily available resources, providing at par and comparable results to commercially available NPWD with good patient compliance and significant reduction in his financial burden in all strata of patients in the Indian scenario.

Keywords: *wound care, open wounds, infected wounds, NPWD, VAC*

INTRODUCTION

The incidence of high velocity trauma is on the upward rise owing to the rapid urbanization and increased vehicular traffic resulting in increased motor vehicle and road traffic accidents. As a consequence, open fractures with large skin defects are quite common. Despite numerous evolvements in wound care, management of open wounds still remains a surgical challenge with high infection rates.[1]

Infected wounds management is particularly difficult, causing pain, increased morbidity, prolonged treatment, increased complications and high cost of treatment. Such wounds need to multiple debridements and repeated dressings before they are free of infection and can be definitely covered. This process entails increased pain and suffering to the patient, increases cost and prolonged hospital stay which causes significant emotional and financial strain on patient and his relatives.[2,3]

Negative pressure wound dressing (NPWD) is novel and time-tested treatment modality in management of compound injuries and can be used as alternative to conventional wound management techniques. NPWD was first introduced in clinical practice in the early 90's and since then has been widely used, once FDA approval was obtained in 1995. [4] Various studies have extensively studied NPWD, its effects and its advantages.[5-8]As it promotes wound healing by faster granulation tissue formation, the need for multiple dressing as well as a definitive wound closure operations is sometimes abated. Since the need for repeated dressings is reduced, this reduces treatment cost and decreases the staff workload.[5-8]
In a developing country like India, the health care system is wrought with multiple issues related to public health and it deliverance. A vast majority of our population is rural or have a below poverty line (BPL) profile and rely entirely on public healthcare system for medical aid. With an overburdened healthcare infrastructure and deficient manpower, finance was, is and will always remain a major deterrent in such patients who have difficult wounds and require prolonged care with specialized equipment. [9]

Despite the proven benefits of NPWD, such patient will not able to afford conventional NPWD system which cost approximately 7000–15,000 rupees per week on a hire basis, putting it out of the reach of a common Indian patient. There is also a question of availability of such dressing in rural centers.[10] Hence, considering the above scenario, it becomes imperative for healthcare providers develop better and faster wound healing techniques that utilizes low cost easily available resources that will work faster than conventional techniques to produce similar if not better results. Our study was undertaken to determine the efficacy and cost-effectiveness of our indigenous NPWD utilizing easily available local materials in a hospital or low resource centers.

MATERIALS AND METHODS

The present prospective interventional study was conducted on 20 patients of the Orthopedics department, School of Medical science and Research, Sharda Hospital from Jan 2021 - Dec 2022. Patients included in the study were patients with post traumatic wounds, post-operative wounds with dehiscence, post debridement degloving wounds and wounds with delayed healing. Excluded patients were patients with severe anemia, malignancy, immune compromised status and underlying osteomyelitis of bone. Written informed consent from all patients was taken. All patients underwent athorough debrima followed by serial applications of our indigenous NPWD.

RESOURSES NEEDED TO CONSTRUCT NPWD WITH COST -

Our indigenous NPWD was prepared using the following components –

A) Locally available foam of minimum 2 cm thickness which was sterilized using ETO. -cost 30 INR approximately (Figure 1b)
B) A suction tube of French Gauge (FG) 16. Easily available and cheap. -cost 48 INR. approximately (Figure 1e)
C) Pre-sterile IOBAN dressing- when cut according to wound size, costs 300 INR per patient approximately
D) A vacuum system – we use our bedside centralized hospital suction system to create the vacuum. (Figure 1g)
E)

PREPERATION AND APPLICATION OF NPWD –

Foam is cut using sterile scissors to the size and shape of the wound (Figure 1c). This was inserted into the wound cavity to sufficiently cover the entire wound bed, yet not encroaching on the peri wound margins, thereby preventing skin maceration. A size 16FG suction catheter with multiple small fenestrations (Figure 1d) in its distal part was placed in the substance of the foam from its edge to the center of the foam such that the fenestrated part of the tube was embedded in the foam (Figure 1f).

The construct is then covered with IOBAN drape in such a manner so as to cover at least 3-5 centimeters of skin circumferentially around the wound and encompassing the tube to create a perfect seal. This isolates the wound and creates a vacuum which transfers sub atmospheric pressure to the wound surface (figure 1h).

Care was taken that no foam particles would get entrapped into the wound cavity. The suction tube was connected to centralized hospital suction unit at a negative pressure of 125-150 mm Hg. Shrinkage of the sponge and dressing confirmed the integrity of the NPWD and the vacuum generated.The dressing was changed every 48-72 hours.

This frequency of dressing varied according to individual wound size and type and volume of exudates. Pressure was reduced if the patient experienced increased pain or bleeding and increased if the patient wound had high wound exudate. The suction was kept on for 22-23 hours and kept off for 1-2 hours.

Wound was inspected 48 hours after the first dressing application. Tissue integrity was checked during every change of dressing. If the skin edges showed maceration, then the next dressing was done after 12-24 hours to allow the skin to get back to normal state. After wound contracture and healthy-looking granulation was formed, wound coverage was achieved either by secondary closure or split thickness skin grafting.

Figure 1:

			
Figure 1a- Open Wound.	Figure 1b- Locally available foam	Figure 1c- Foam Size estimation, base on wound dimensions.	Figure 1d - Making of smalls cuts in the foam.
			
Figure 1e- Suction tube.	Figure 1f- Suction tube insertion.	Figure 1g- Suction tube attached to vacuum machine.	Figure 1h- Application of IOBAN dressing and confimation of seal by shrinkage of IOBAN.

At the time of each wound dressing, photographs of the wound were taken using a smartphone with wide angle and telephoto camera. Prior to taking the photograph, the wound was cleansed to remove loose necrotic tissue, slough and debris. Photographs were taken with a clear background. Photographs were taken in the daytime without flashlights. Distance of around 1.5–2 feet was maintained between the wound and the camera. Photographs were taken at the right angle to the wound. The photographs were taken by a single observer, and interpretation was done by the same assessor. Wound assessment was done using the revised Photographic Wound Bed Score.[11]

Wound bed score[11]: It is a classification system that scores the following parameters-

- Healing edges (wound edge effect)
- Presence of Escher
- Greatest wound depth/granulation tissue
- Amount of exudate

- Edema
- Peri-wound dermatitis
- Peri-wound callus and or fibrosis and
- Pink/red wound bed.

Each parameter receives a score from 0(worst score) to 2(best score), and all the parameter scores are added for a total score. Each wound can have a maximum score of 16 (the best score possible), to a minimum score of 0(the worst score possible)

Statistical Analysis:
The findings of the study participants were collected in an excel sheet and analyzed using Graphpad Prism Software. The non-categorical variable like gender distribution was analyzed using Chi Square test. Categorical Variables like pre-operative wound size and Wound Bed Score were mentioned in mean ±SD and compared pre and post intervention using Paired T test.

OBSERVATIONS AND RESULTS:
The study group consisted of 20 patients which included 13 males and 7 females (figure 2). The mean age of participants was 25.54 ± 12.30 years and ranged from 18 to 64 years. We observed no significant difference in the gender distribution amongst our study participant (p=0.549)
The most common etiology of wounds was trauma and were 25%.
No of required dressing ranged from 2- 7 with an average of 3.45 ±1.20 dressing before wound closure with a mean duration of NPWD of 9.5±4.57 days.
The Mean size of wound at baseline was 24.75 ±10.21 which significantly reduced to 19.35 ±9.62 cm (p=0.027).
The mean wound bed score at baseline was 9.5 ± 1.36 which significantly improved to 13.5± 1.19 at the end of 30 days. (p=0.012)
Duration of hospital stay ranged from 10-30 days with an average duration of 14.64±2.05 days
All wounds showed clean healthy granulation tissue and reduction of wound depth and were finally covered with split thickness skin graft (SSG) or by secondary suturing.
Skin edge maceration were seen in 3 wounds in which reapplication of the NPWD was delayed by 2-3 days. There were no other complications associated with NPWD other than technical issues related to tube blockage and loss of seal which required reapplication.

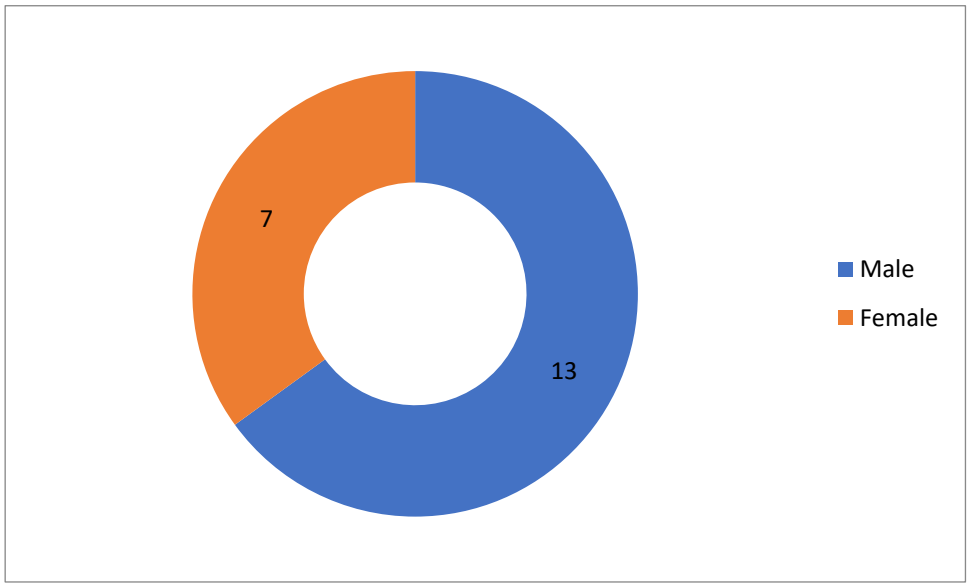

Figure 2: Gender distribution

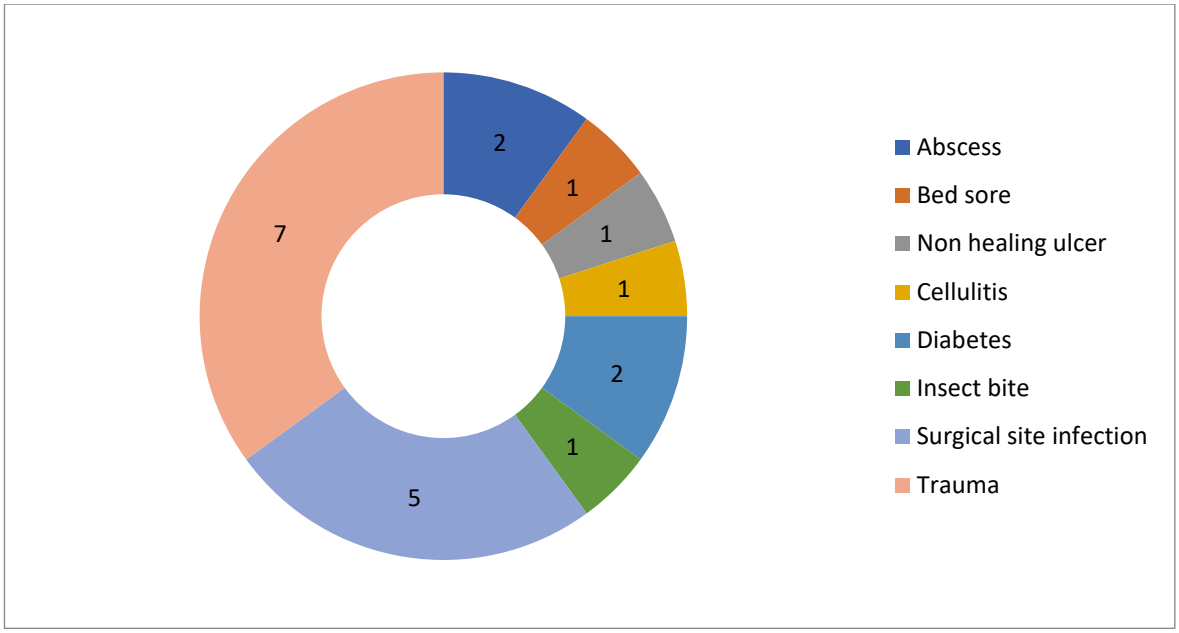

Figure 3: Etiology distribution

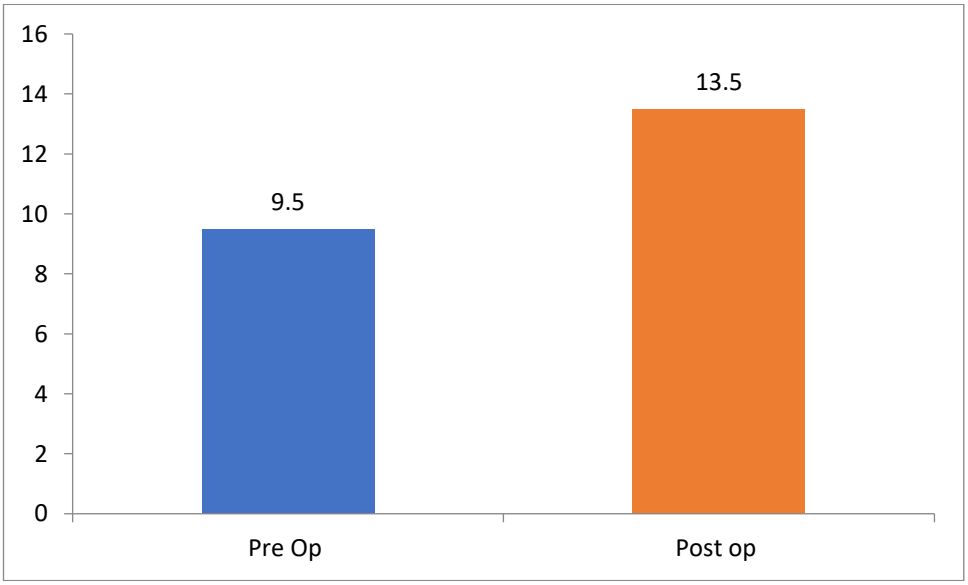

Figure 4: preoperative & post operative mean wound bed score

Figure 5: Serial photograph of knee wound following NPWD

CASE 1 (figure 5) - A 36-year male sustained a 7cm x 7cm laceration over the left knee following a RTA and presented 2 days later. (Figure 5a) He underwent a surgical debridement in the operation theatre. Post debridement the patella surface was exposed hence 3millimeter drill holes were made on its surface (figure 5b) and subsequently NPWD was applied to the wound. NPWD was removed after 3 days and wound photographed and measured (figure 5c). Then serial NPWD's was applied to the wound (figure 5d, 5e,5f and 5g) till healthy granulation tissue covered the exposed surface of the patella and there was shrinkage of the wound size. (Figure 5h). Finally, split skin thickness graft was done on the healthy wound bed (figure 5i)

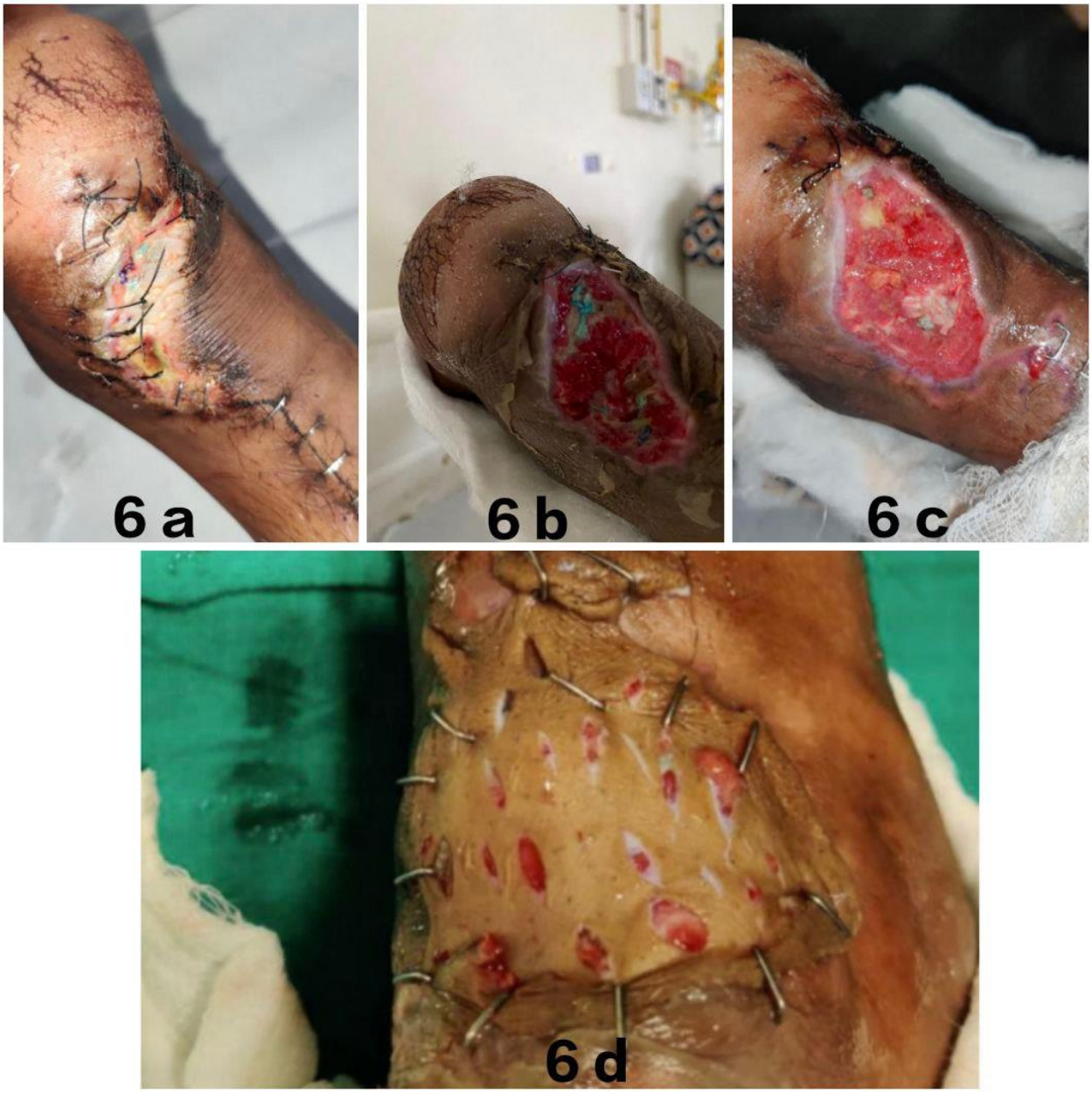

Figure 6: Serial photograph of ankle wound following NPWD

Case 2- (figure 6) A 20-year-old male following Achilles' tendon repair had skin necrosis over operated site (figure 6 a). He underwent a surgical debridement. Post debridement the Achilles tendon was exposed. NPWD was applied to the wound (figure 6 b). following 2 NPWD (figure 6 c) healthy granulation tissue covered the exposed Achilles tendon and there was shrinkage of the wound size. Split skin thickness graft was done (figure 6 d).

Table 1: master chart of 20 patient on which NPWD was done.
(*-cases with skin maceration where duration of hospital stay was extended, SSI- surgical site infection)

S.no	Age	sex	etiology	Approximate size of wound in cm2		Duration of NPWD	Duration of hospital stay	Wound bed score		Secondary Procedure	complication
				Pre op	Post op			pre op	post op		
1	36	male	trauma	49	42	24	30	8	13	Split skin grafting	Nil
2	19	male	SSI	20	16	9	15	10	12	Split skin grafting	NIL
3	20	male	trauma	25	18	12	18	9	12	Split skin grafting	Nil
4	61	male	Diabetic ulcer	30	24	6	11	9	13	Split skin grafting	Nil
5	25	male	trauma	40	35	15	21*	7	14	Split skin grafting	Skin maceration
6	37	female	trauma	36	30	6	11	11	14	Split skin grafting	Nil
7	18	male	SSI	25	20	8	14	10	15	Split skin grafting	Nil
8	21	female	trauma	21	16	10	16	11	15	Secondary suturing	Nil
9	24	male	Abscess	25	16	12	20*	11	14	Secondary suturing	Skin maceration
10	25	male	trauma	30	25	6	12	9	12	Split skin grafting	Nil
11	26	female	SSI	25	16	8	14	10	15	Split skin grafting	Nil
12	27	male	insect bite	8	6	6	10	11	14	Secondary suturing	Nil
13	32	female	trauma	35	30	10	16	8	12	Split skin grafting	Nil
14	62	male	bed Sore	15	10	6	12	10	14	Secondary suturing	Nil
15	34	male	SSI	20	16	12	18	9	15	Split skin grafting	bleeding
16	42	male	Non healing ulcer	25	18	12	20*	7	12	Split skin grafting	Skin maceration
17	45	female	Diabetic ulcer	12	9	6	12	11	14	Split skin grafting	Nil
18	46	male	Cellulitis	16	9	6	11	9	12	Split skin grafting	Nil
19	52	female	SSI	30	25	10	18	10	14	Split skin grafting	Nil
20	64	male	Diabetes	8	6	6	11	10	14	Secondary suturing	Nil

DISCUSSION

Wounds secondary to any etiology is daunting challenge to most surgeons. In untreated or improperly treated cases, infection is the common sequalae resulting in increased suffering and prolonged hospital stay increasing the patient's social and financial burden. Hence, correct and efficient wound management becomes paramount. NPWD therapy has revolutionized the treatment of wounds since its inception in the early ninety's. [1]

Presently the commercially available NPWD systems needs sophisticated equipment in terms of high-end resources and suction apparatus, trained personnel for application and maintenance of dressing which escalates the cost. In our country, the need of the hour is low cost novel wound treatment techniques, as most patients are financially strained and cannot invest in expensive treatment or devices. . The use of NPWD in the Indian studies has not been reported extensively. Only few Indian studies have provided insights by using indigenous NPWT to make it more cost effective so that it can be used in a low resource setting.[5-10]

NPWD was first used in 1991 for patients with diabetic bed sores. In 1992, Fleischmann et al.[4] first described vacuum assisted dressing of wound in 15 patients with open fractures. He found that with the negative pressure wound therapy, there was efficient cleaning and conditioning of wound with marked proliferation of granulation tissue.

Subsequent detailed research have described the use of NPWD and its benefits which included reduction in wound size,[2-4] stimulation of granulation tissue,[2] removal of tissue debris and decreasing wound exudate thereby reducing bacterial proliferation and chance of wound infection. It also decreased interstitial edema[2, 3,5] thereby increasing microcirculation, local blood flow and oxygenation[5]. A few studies using NPWD revealed faster wound healing rates and was considered safe as any other modality of dressing.[5-8]

Studies involving various wound size and types treated with NPWD suggest that overall, the cost of treatment with NPWD is more economical as compared to conventional wound care methods as the frequency of dressing is lessened and fewer reconstructive options are needed.[7-8]

Its use has been extended to a variety of wound types including extensive degloving injuries infected sternotomy wounds[11] and various soft tissue injuries prior to surgical closure, grafting or reconstructive surgery.

Practically, the main advantages with NPWD is reduced frequency in dressing changes, reduced need for secondary surgical interventions, it promotes contraction of wound edges, minimizes chances of contamination and reduces hospital stay. This translates into reduced treatment duration and cost, less resource utilization and decreasing the work load of attending staff.[10]

Conventional NPWD machinesavailable in the market cost around 400000–900000 INR and the cost of single dressing is around 5000–10000 INR even on hire. This may not be economically and financially feasible for poor patients having large wounds which require multiple applications of these dressings. To reduce the cost of therapy some modifications have been done by few authors. [12]

Sumedha Chaudhary et al [12] prepared an indigenous NPWD for infected wounds using low-cost resources (transparent adhesive film, Ryle's tube and sterilized foam) amounting to 150-340 INR and reported it as a simple and effective method of application of NPWD which is easy to reproduce, easy to apply and significantly cost effective.

Saurabhi M. Samant et al.[13] used modified vacuum assisted closure (VAC) dressing using sterilized bed foam, transparent adhesive dressing film, Ryle's tube and wall mounted suction apparatus. The total cost of modified VAC dressing for 15 days per patient was 750 INR ($11.16) as compared to a single conventional dressing was 700 INR. ($10.41)

Other Indian authors like Pawan Agarwal et al [14] prepared an indigenous NPWD using locally available materials like orthocling drape (surgiware), abdominal drain (Romsons), Bactigras (Smith and Nephew) and foam sponges at a very cost-effective price of 500 INR, whereas Sumedha Chaudhary et al [12] constructed their indigenous NPWD with an approximate cost of 150-340 INR.

Likewise, we have utilized easily available low-cost components to construct our indigenous NPWD and the cost of each dressing would be approximately 350INR which is very economical and at par with other indigenous designed NPWD constructs which makes it very cost effective and affordable to poor patients.

The optimal application of negative pressure in a NPWD is still debatable. Animal studies have revealed increased granulation tissue formation at 125 mmHg vacuum as compared with low (25 mmHg) and high (500 mmHg) vacuum

suction. Low vacuum pressures cause decreased wound fluid drainage and less deformation of cells whereas high pressures increased mechanical deformation causing localized decrease in perfusion both leading to a low rate of granulation tissue formation. Most literature recommends 125 mm Hg as the standard suction pressure to be used with NPWD systems.[15-18]

Different levels of negative pressure when applied to different types of wounds showed that vacuum pressures should be tailored depending on whether they are acute traumatic or chronic non healing types. The recommendations for the former was 125 mm Hg whereas the latter wound type would require an optimum pressure of 50 mm Hg in intermittent cycles .[4,10,14] We maintained our NPWD at a pressure ranging between100–150 mmHg in a continuous fashion through our centralized hospital suction system with good results in all cases.

The wounds were inspected after 2- 3days of NPWD in all cases and dressing changed if needed until the wound base showed healthy granulation tissue. In our study, all wounds showed healthy granulation tissue with average 3-4 dressings with a definitive wound closure procedure done on average of 10 days of application of NPWD.
The mean wound score before and after application of NPWD was 25.20±10.10 and 10.04 ±1.67 respectively and which was statistically significant (p score <0.001).

No of required dressing ranged from 2- 7 with an average of 3.45 ±1.20 dressing before wound closure This is comparable with other studies which have reported similar results using both conventional NPWD and using indigenous prepared NPWD.[12-14]

Our complications included skin margin macerations which was easily managed and only increased the duration of hospital stay in these patients and no other significant complication were noted because of NPWD. The limiting points of our study were its small number and no group for comparison. All patients were connected to a continuous wall mounted hospital central suction so intermittent suction delivery was not possible and were hence offered to only inpatients of our hospital.

Despite these shortcomings, our indigenous NPWT was found to be an effective adjuvant / good alternative in standard wound care management of difficult wounds with the additional benefit of using low cost easily available resources, easy to apply and maintain providing an emotional and financial boon to such patients in terms of better compliance, reduction in wound size, treatment duration and cost.

CONCLUSIONS

Our study indicated that our indigenous NPWD was at par and produced comparable results to commercially available NPWD dressing at nominal cost.

This has shown to increase patient compliance, decrease morbidity and financial burden on the patients of all strata in the Indian scenario.

Financial support and sponsorship-Nil.
Conflicts of interest-There are no conflicts of interest.

REFERENCES

Atiyeh BS, Ioannovich J, Al-Amm CA, El-Musa KA. Management of acute and chronic open wounds: the importance of moist environment in optimal wound healing. Curr Pharm Biotechnol [Internet]. 2002;3(3):179–95. Available from: http://dx.doi.org/10.2174/1389201023378283

2. Patzakis MJ, Bains RS, Lee J, Shepherd L, Singer G, Ressler R, et al. Prospective, randomized, double-blind study comparing single-agent antibiotic therapy, ciprofloxacin, to combination antibiotic therapy in open fracture wounds. J Orthop Trauma [Internet]. 2000;14(8):529–33. Available from: http://dx.doi.org/10.1097/00005131-200011000-00002

3. Ostermann PA, Seligson D, Henry SL. Local antibiotic therapy for severe open fractures: a review of 1085 consecutive cases. J Bone Joint Surg Br. 1995;77:93–7.

4. Fleischmann W, Strecker W, Bombelli M, Kinzl L. Vacuum sealing as treatment of soft tissue damage in open fractures. Unfallchirurg. 1993;96(9):488–92.

5. Morykwas MJ, Argenta LC, Shelton-Brown EI, McGuirt W. Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation. Ann Plast Surg [Internet]. 1997;38(6):553–62. Available from: http://dx.doi.org/10.1097/00000637-199706000-00001

6. Argenta LC, Morykwas MJ. Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. Ann Plast Surg. 1997;38(6):563–76; discussion 577.

7. Morykwas MJ, Simpson J, Punger K, Argenta A, Kremers L, Argenta J. Vacuum-assisted closure: state of basic research and physiologic foundation. Plast Reconstr Surg [Internet]. 2006;117(7 Suppl):121S-126S. Available from: http://dx.doi.org/10.1097/01.prs.0000225450.12593.12
8. Banwell PE Topical negative pressure therapy in wound care. J Wound Care. 1999;8:79–84.

9. Barik D, Thorat A. Issues of unequal access to public health in India. Front Public Health [Internet]. 2015;3:245. Available from: http://dx.doi.org/10.3389/fpubh.2015.00245
10. Dinakar D, Venkataram A, Santhosh S, Shivaswamy S, Babu R, Segu S. Negative pressure wound therapy: current practice in India. Eur J Plast Surg [Internet]. 2013;36(9):567–72. Available from: http://dx.doi.org/10.1007/s00238-013-0857-9
11. Falanga V, Saap LJ, Ozonoff A. Wound bed score and its correlation with healing of chronic wounds. Dermatol Ther [Internet]. 2006;19(6):383–90. Available from: http://dx.doi.org/10.1111/j.1529-8019.2006.00096.x
12. Chaudhary S, Kumar V, Gandhi P, Koichade M, Mandal S. Low cost, modified negative pressure wound therapy in infected orthopaedic wounds: can it be as effective as its costly counterparts? J Clin Orthop Trauma [Internet]. 2020;11(Suppl 5):S876–82. Available from: http://dx.doi.org/10.1016/j.jcot.2020.07.005
13. Samant SM, Sarang B. Vacuum assisted wound healing: can it prove to be cost- effective? Int Surg J [Internet]. 2018;5(4):1358. Available from: http://dx.doi.org/10.18203/2349-2902.isj20181110
14. Agarwal P, Kukrele R, Sharma D. Vacuum assisted closure (VAC)/negative pressure wound therapy (NPWT) for difficult wounds: A review. J Clin Orthop Trauma [Internet]. 2019;10(5):845–8. Available from: http://dx.doi.org/10.1016/j.jcot.2019.06.015
15. Morykwas MJ, Argenta LC, Shelton-Brown EI, Mcguirt W. Vacuum-assisted closure: a new method for wound control and treatment:animal studieds and basic foundation. Ann Plast Surg. 1997;38:553–62.
16. Borgquist O, Ingemansson R, Malmsjö M. The effect of intermittent and variable negative pressure wound therapy on wound edge microvascular blood flow. Ostomy Wound Manage. 2010;56(3):60–7.
17. Fabian TS, Kaufman HJ, Lett ED, Thomas JB, Rawl DK, Lewis PL, et al. The evaluation of subatmospheric pressure and hyperbaric oxygen in ischemic full-thickness wound healing. Am Surg [Internet]. 2000;66(12):1136–43. Available from: http://dx.doi.org/10.1177/000313480006601209
18. Morykwas MJ, Faler BJ, Pearce DJ, Argenta LC. Effects of varying levels of subatmospheric pressure on the rate of granulation tissue formation in experimental wounds in swine. Ann Plast Surg [Internet]. 2001;47(5):547–51. Available from: http://dx.doi.org/10.1097/00000637-200111000-00013