“Low Cost" Negative Pressure Wound Therapy for Acute and Chronic Wounds Healing - About 3 Cases

Nazim SIFI (sifinazimjamil@gmail.com)
Centre Hospitalier Alpes Léman: Centre Hospitalier Alpes Leman  https://orcid.org/0000-0002-5218-1443

Ryad BOUGUENNA
EPH Béni Abbès

Lamia KACI
EPH Béni Abbès

Research article

Keywords: Acute wound, Chronic wound, Negative pressure wound therapy, NPWT, Vacuum assisted closure, VAC

DOI: https://doi.org/10.21203/rs.3.rs-586783/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background: Negative pressure wound therapy (NPWT) is an alternative to standard treatment of acute wounds (such as traumatic or post-operative wounds) but also in that of chronic wounds (such as ulcers or stage 3 and 4 pressure ulcers). However, the exorbitant cost of VAC (vacuum assisted closure) devices for our limited resources health facilities, and their unavailability led us to opt for a "low cost" solution using wall suction and disposable materials readily available in all surgical departments.

Materials and methods: After surgical debridement in 3 patients with both acute and chronic lesions evolving in septic environment, we replaced polyurethane foam by that from surgical scrub brushes, the tubing and its suction port by nasogastric tube, the hydrocolloid for the protection of wound edges by tulle gras (vaseline gauze), the adhesive film ensuring sealing by an incise drape, and the therapy unit by wall suction and exudates collection bottle. We cut up the foam to make it correspond to the wound, in size and depth, and then, using straight forceps, we create a tunnel in it, large enough to allow the introduction of the nasogastric tube. We then carefully place the foam in the wound. After that, we proceed to application of incise drape to cover foam dressing and connect the end of the probe to wall suction system via suction bottle. Therapy is initiated by setting vacuum gauge to a continuously delivered negative pressure of -125 mmHg.

Results: The size of all wounds reduced considerably and rapidly with the installation of budding granulation tissue which appeared as early as the first dressing change enabling subsequently the best possible conditions for directed healing or coverage procedures (skin graft or flaps). The healing was obtained for all our patients.

Conclusions: In this "low cost" NPWT, the negative pressure produced by wall vacuum promotes effective management of acute and chronic wounds, including complex ones, by rapidly "producing" good quality granulation leading to healing, while reducing the cost of therapy, the number of dressings and the length of hospital stay.

Trial registration: Retrospectively registered

Background:

The idea of using negative pressure (NP) to assist wound healing is not new. In the 1970s, pioneering Russian surgeons were already applying the principle of a vacuum chamber placed above the wound. And even if the widespread use of this technique in many surgical specialties is due to the commercial development of many innovative devices, the fact remains that the principle of its use goes back further. In 1986, Kostiuchenok et al. demonstrated, in a study of 116 patients, the superiority of NP dressing for infected wounds after surgical debridement compared to surgical debridement alone. Three years later, Chariker and Jeter published a method of NP dressing connecting wall suction via a drain to moist gauze pads covered with adhesive film, allowing a thin and dense granulation tissue. It was only in the early 90's that Fleischman et al. successfully applied this new negative pressure wound therapy (NPWT) to 15
patients with open fractures using foam dressing for an extended period of time in order to promote granulation and healing. It was Morykwas and Argenta [1, 2] who eventually popularized the technique using a combined system of open-cell polyurethane foam and negative pressure applied in a controlled manner. The granulation tissue obtained through this new approach was thicker and more ventilated, but the financial costs of acquisition and operation of this device were higher, making it inaccessible to low-income countries. Working in a remote and limited resources hospital, access to such medical devices is not always easy task to manage (7,500 USD per unit and 75 USD for each dressing change) [3]. Therefore, we opted for a “low-cost” but yet effective alternative which requires both wall suction as described in the original technique but using a foam whose properties are similar to polyurethane or polyvinyl alcohol foams used in more modern devices. This adaptation allows us to set up a genuine care protocol for wounds, including complex ones, by supporting with NPWT the entire healing process up to the epidermization phase.

Materials And Methods:

We report the case of 3 patients with acute and chronic wounds evolving in a septic context. The informed consent of these patients was obtained orally after an explanation of the procedure and postoperative care, and the technique was then performed in accordance with the principles of the Declaration of Helsinki.

Case n°1 (Fig. 3): A 22-year-old man presented late after having been treated by a bonesetter following a crushing injury of his right ankle. A “too tight” traditional immobilization device was made which led to the formation of a voluminous purulent collection of the medial surface of his right ankle and with a large cutaneous necrosis, subcutaneous detachment and significant inflammatory signs.

Case n°2 (Fig. 4): A 27-year-old paraplegic female patient admitted for the management of stage 4 sacral pressure ulcer constituting deep ulceration with muscle and bone involvement and multiple areas of necrosis.

Case n°3 (Fig. 5): A 58-year-old woman with insulin-dependent diabetes presenting ulceration of the dorsal surface of her right foot with loss of substance and purulent infiltration towards the superomedial part and towards the 2nd toe.

As a first step, all patients underwent flattening with surgical debridement, cleaning, excision of devitalized or necrotic tissues, elimination of fibrin, abundant irrigation using saline solution and an antibiotic therapy adapted to the results of bacteriological findings. Debridement, which is a capital step, must be meticulous and repeated at each dressing change if necessary. In order to use our "low cost" technique (Fig. 1), we replaced polyurethane foam by that from surgical scrub brushes, the tubing and its suction port by nasogastric tube or bronchial suction tube No.14, 16 or 18, the hydrocolloid for the protection of wound edges by tulle gras (vaseline gauze), the adhesive film ensuring sealing by an incise drape, and the therapy unit by wall suction and exudates collection bottle. We start our installation by protecting the surrounding skin using strips of tulle gras. Afterwards, we cut up the foam to make it
correspond to the wound, in size and depth (Fig. 2A), and then, using straight forceps, we create a tunnel in it, large enough to allow the introduction of the nasogastric tube (Fig. 2B-2C). We then carefully place the foam in the wound without covering healthy skin but exceeding wound surface by about 1 cm (Fig. 2E). After that, we proceed to careful application of incise drape to cover foam dressing, while respecting an additional edge of 5 cm or more if necessary in order to make it airtight (Fig. 2F). In our female patient with sacral pressure ulcer, we created a "foam bridge" by connecting different pieces of foam together so we can shift tubing positioning to a location that makes it easier for us to connect the suction pipe with (Fig. 4C). It should be noted that noble nerve, ligament or tendon structures must be protected by interposing an interface between them and the foam (Fig. 2D). In our case, the interface was tulle gras. All that remains is to connect the end of the probe to wall suction system via suction bottle where serous fluid will be collected. Therapy is initiated by setting vacuum gauge to a continuously delivered negative pressure of -125 mmHg (Fig. 1B). We authorized a maximum of 1 hour of suction interruption per day for ambulation, wash and fulfilment of needs. The dressing is changed every 72 hours. Wounds were carefully cleaned with saline solution during each dressing change, and a mechanical debridement using a curette was performed during the first dressings in order to minimize bacterial load by eliminating biofilm. All our patients benefited from this therapy for 3 weeks, which represents a total of 5 dressing changes.

Results:
The size of all wounds reduced considerably and rapidly with the installation of budding granulation tissue which appeared as early as the first dressing change. Granulation tissue was clean, bright red, well vascularized, bleeding on contact, ventilated, without fibrin or exudates. This granulation tissue offered good conditions for directed healing for the first case, and allowed us to proceed with a secondary coverage using gluteus maximus flap for sacral pressure ulcer and skin graft for diabetic foot ulceration. It should be noted for the latter case that thanks to NPWT, exposed toe extensor tendons kept their physiological appearance, hydration, white color and were not subject to drying out or necrosis. Both patients who underwent secondary coverage were also put on NPWT immediately after surgery for 5 days, which promoted faster healing. No pain was reported neither during therapy hours nor during dressing changes for which the application of a little saline solution was sufficient to achieve smooth removal. The only notable disadvantage of this "low cost" NPWT adaptation was the limitation of patient movement due to the device connection to wall suction.

Discussion:
The appearance of NPWT was a genuine revolution in the management of acute wounds such as traumatic or post-operative wounds but also in that of chronic wounds such as ulcers or pressure ulcers [4]. Through a mechanical action linked to the application of controlled sub-atmospheric pressure on wound bed, associated with drainage and maintenance in moist environment, it enables the elimination of exudates, minimizes the risk of infection, regulates the inflammatory reaction and promotes the
budding of quality granulation tissue. NPWT systems are adjuvants to healing certain traumatic or surgical wounds with high risk of complications or certain chronic wounds that do not heal at first intention [5]. They boost the physiological healing process until granulation tissue is obtained, leading to directed healing or secondary coverage surgery. NPWT thus reduces the number of dressing changes, the cost of therapy and the length of hospital stay and places the patient in both physical and psychological comfort to complete the healing process. Its indications concern all loss of substances, acute hollow wounds (post-traumatic, surgical, with or without infection) and chronic hollow wounds (leg ulcer, diabetic foot ulcer, stage 3 and 4 pressure ulcers), exuding wounds, 2nd degree burns, before and after skin graft surgery. Its contraindications are mainly represented by malignant wounds, areas of necrosis before their debridement, untreated osteomyelitis, unexplored fistula, exposed blood vessels, pyoderma gangrenosum, uncooperative or agitated patient, patient with hemostasis problems or on anticoagulant therapy. NPWT appears to be a complete solution with multiple virtues: it preserves a moist and warm environment favorable to granulation, ensures effective protection of bone and tendons, prevents cross infections by ensuring airtight separation from external environment, drains serous fluids and prevents their stagnation, thereby achieving bacterial load reduction [6]. It also mobilizes interstitial fluid and reduces tissue edema improving blood flow [7]. All this contributes to the elimination of harmful components such as cytokines and proteases [8, 9], the stimulation of neoangiogenesis process (in particular by increased concentration of local interleukin-8 and vascular endothelial growth factor [10]), promotes cell migration and proliferation, thus leading to the formation of well-vascularized granulation tissue. At the cellular level, negative pressure induced microdeformations by elongation cause a change in ionic concentration and permeability of the cell membrane [11], stimulate metabolic activity (in particular that of cell growth and immune defense factors), induce increased mitosis, fibroblast migration and formation of expanding extracellular matrix [12]. Negative pressure also leads to contraction of wound edges (macrodeformations) and mechanical stimulation of wound basement. In our patients, NPWT enabled us to obtain granulation tissue from the 1st dressing, performed on D4, which is a very short time given the nature of lesions and their septic nature. Regarding the optimal negative pressure to be applied, studies have defined it at -125 mmHg, with a blood flow multiplied by 4 at this pressure. If the pressure is higher than this value, there is a risk of capillaries distortion and blood flow reduction. Recent studies involving animals have suggested that − 80 mmHg is the optimal pressure for wound contraction, microdeformation, reduction of tissue edema which induces positive effects on blood flow, and that beyond this value the therapeutic effect continues but without any additional benefit other than on the elimination of exudate. Other research has suggested that with pressures as low as -40 mmHg, therapeutic benefits are still reported [13]. Samant et al. [14] in a comparative study of 100 patients used the same device that we employed with foam, nasogastric tube and wall suction device. They conclude that NPWT shows better healing compared to conventional management with the advantage of being reproducible and at lower cost. In a systematic review of the literature and a meta-analysis published in 2019, Kim et al. [15] observed in the management of open tibial fractures a lower rate of soft tissue infection, nonunion, flap necrosis and flap revision in NPWT group compared to conventional dressing group. NPWT should be considered as a temporary technique intended to reduce healing time and lead the wound under the best possible conditions to secondary coverage procedure by skin graft or flap or to
directed healing. In our diabetic patient with ulceration of the dorsal surface of her foot and exposed extensor tendons, NPWT enabled us to cover part of these tendons with healthy granulation tissue constituting a favorable basement for the reception of our skin graft. It has also been used immediately after skin graft surgery by setting vacuum pressure gauge to -75 mmHg, in continuous suction, in order to stabilize the graft, avoid shearing movements and secure its engraftment. Clinical benefits of NPWT in the management of diabetic foot complications, especially wounds after amputation, were clearly established in the study of Armstrong et al. with faster budding and healing. As was the case with our patient with sacral pressure ulcer where NPWT promoted reduction of wound size and formation of granulation tissue, enabling us to use gluteus maximus flap under the best possible conditions. Although systematic reviews of international literature contain many methodological shortcomings and significant biases, just as our study may include, particularly due to our small sample, the general trend as well as the reality of our daily practice objectively demonstrate that "low cost" NPWT constitutes a reliable, reproducible, safe, economical solution and an alternative to the purchase of expensive equipments and disposable materials, particularly for health structures in low resource countries.

Conclusion:

In this "low cost" NPWT, the negative pressure produced by wall vacuum promotes effective management of acute and chronic wounds, including complex ones, by rapidly "producing" good quality granulation tissue enabling subsequently the best possible conditions for directed healing or coverage procedures (skin graft or flaps), while reducing the cost of therapy, the number of dressings and the length of hospital stay.

List Of Abbreviations:

NPWT : negative pressure wound therapy
VAC : vaccum assisted closure
NP : negative pressure

Declarations:

Ethics approval and consent to participate

The study was approved by the scientific committee of our establishment.

Consent for publication

The informed consent of all patients was obtained orally after an explanation of the procedure and postoperative care, and the technique was then performed in accordance with the principles of the Declaration of Helsinki.
Availability of data and materials

All data generated or analysed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors declare that they have not received any financial support.

Authors' contributions

SN performed the device placement, the surgeries and wrote the article. RB and LK participated in the surgical interventions and in the post-operative management of the patients. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

References:

1. Morykwas MJ, Argenta LC, Shelton-Brown El, McGuirt W. Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation. Ann Plast Surg. 1997 Jun;38(6):553-62.

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

3. Gill NA, Hameed A, Sajjad Y, Ahmad Z, Mirza R, MA. "Homemade" negative pressure wound therapy: treatment of complex wounds under challenging conditions. Wounds. 2011;23(4):84-92.

4. Argenta LC, Morykwas MJ, Marks MW, DeFranzo AJ, Molnar JA, David LR. Vacuum-assisted closure: state of clinic art. Plast Reconstr Surg. 2006 Jun;117(7 Suppl):127S-142S.

5. Traitement des plaies par pression négative (TPN) : des utilisations spécifiques et limitées. Haute Autorité de Santé (HAS) 2011.

6. Mouës CM, Vos MC, van den Bemd GJ, Stijnen T, Hovius SE. Bacterial load in relation to vacuum-assisted closure wound therapy: a prospective randomized trial. Wound Repair Regen. 2004;12:11e17.

7. Hunter JE, Teot L, Horch R, Banwell PE. Evidence-based medicine: vacuum-assisted closure in wound care management. Int Wound J. 2007 Sep;4(3):256-69.

8. Banwell PE, Musgrave B. Topical negative pressure therapy: mechanisms and indications. Int Wound J. 2004;1(2):95-106.
9. Scherer SS, Pietramaggiori G, Mathews JC, Prsa MJ, Huang S, Orgill DP. The mechanism of action of the vacuum-assisted closure device. Plast Reconstr Surg. 2008 Sep;122(3):786-97.

10. Labler L, Rancan M, Mica L, Harter L, Mihic-Probst D, Keel M. Vacuum-assisted closure therapy increases local interleukin-8 and vascular endothelial growth factor levels in traumatic wounds. J Trauma. 2009;66(3):749–757.

11. Venturi ML, Attinger CE, Mesbahi AN, Hess CL, Graw KS. Mechanisms and clinical applications of the vacuum-assisted closure (VAC) Device: a review. Am J Clin Dermatol. 2005;6:185.

12. Greene AK, Puder M, Roy R, Arsenault D, Kwei S, Moses MA, Orgill DP. Microdeformational wound therapy: effects on angiogenesis and matrix metalloproteinases in chronic wounds of 3 debilitated patients. Ann Plast Surg. 2006 Apr;56(4):418-22.

13. Malmsjö M, Ingemansson R, Martin R, Huddleston E. Negative-pressure wound therapy using gauze or open-cell polyurethane foam: similar early effects on pressure transduction and tissue contraction in an experimental porcine wound model. Wound Repair Regen. 2009 Mar-Apr;17(2):2005.

14. Samant SM, Sarang Bhakti. Vacuum assisted wound healing: can it prove to be cost-effective? Int Surg J. 2018 Apr;5(4):1358e1364.

15. Kim JH, Lee DH. Negative pressure wound therapy vs. conventional management in open tibia fractures: Systematic review and meta-analysis. Injury. 2019 Oct;50(10):1764-1772.

Figures

**Figure 1**

Elements of the "low cost" negative pressure wound therapy (NPWT): (1) Tulle gras in place of hydrocolloid. (2) Nasogastric tube or bronchial suction tube No. 14, 16 or 18 in place of the suction port and its tubing. (3) Foam from surgical scrub brushes in place of Polyurethane foam. (4) Incise drape in place of adhesive film ensuring sealing. (5) Wall suction gauge connected to exudates collection bottle, set to -125mmHg, in place of therapy unit.

**Figure 2**

Example of applying NPWT device: (A) Cutting the foam according to the wound size and depth. (B) Creating a tunnel in the foam using straight forceps. (C) Introducing the nasogastric tube in the tunnel. (D) Protecting the tendons with tulle gras. (E) Placing the foam in the wound. (F) Applying the incise drape maintaining an airtight seal.

**Figure 3**
(A,B) Purulent collection of the medial surface of the right ankle with a large cutaneous necrosis, subcutaneous detachment and significant inflammatory signs. (C) Appearance after debridement and conventional dressings showing the significant presence of fibrin. (D) Applying NPWT device after another debridement. (E) Budding granulation tissue, without fibrin. (F) Result after directed healing.

Figure 4

(A) Stage 4 sacral pressure ulcer constituting deep ulceration with muscle and bone involvement and multiple areas of necrosis. (B) Appearance after debridement. (C) Applying NPWT device creating a "foam bridge". (D) Reduction in the size of the pressure ulcer and installation of budding granulation tissue, without fibrin. (E) Placing a gluteus maximus flap. (F) Final appearance after healing.

Figure 5

(A) Ulceration of the dorsal surface of the right foot with loss of substance and purulent infiltration towards the superomedial part and towards the 2nd toe. (B) Appearance after debridement, exposed extensor tendons. (C) Applying NPWT device. (D) Installation of budding granulation tissue, without fibrin, covering the tendons. (E) Skin grafting. (F) Healing.