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The application of negative pressure wound therapy in orthopedics: current concepts

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Summary

We conducted a literature review to better understand the correct application and indications of negative pressure wound therapy (NPWT) in orthopedics and traumatology. A literature search was conducted on PubMed and all articles in English, Spanish, and Italian were included. Relevant articles, references, data, and relevant findings were identified, reviewed, extracted, and accepted by consensus of at least 66% of the researchers. Relevant articles were discussed by the research group. NPWT has several beneficial effects on the wound that contribute to the maintenance of a favorable biochemical and cellular environment, to the formation of granulation tissue and to faster healing. NWPT can be useful in the treatment of septic wounds after initial debridement surgery and removal of the septic foci, and in necrotizing fasciitis in the presence of gas gangrene, venous or pressure ulcers. NPWT can also be used "for prophylactic purposes" (incisional NPWT) in patients with risk factors for skin dehiscence and with a high risk of wound drainage in the post-operative period and after prosthetic surgery or internal fixation to protect the surgical scar. However, the available evidence is mostly unclear. The appropriate use of NPWT seems to reduce the number of dressing changes in complex wounds, reduce hospitalization times, and offer greater comfort to the patient; when applied on surgical incisions, it may reduce the risk of delayed healing and the risk of infections.

Key words: negative pressure wound therapy, vacuum assisted closure therapy, wound healing, osteomyelitis, periprosthetic joint infection

Introduction

The term negative pressure wound therapy (NPWT) refers to a controlled negative/sub-atmospheric pressure system topically applied on a wound to improve its healing [1]. It is also commonly referred to with the term vacuum-assisted closure (VAC) therapy.

NPWT was introduced in the early 1990s in Germany for treatment of exposed fractures [2]. Later, Argenta and Morykwas described its use for the treatment of ulcerative lesions, and with echo-Doppler demonstrated its NPWT effectiveness in increasing blood flow around the wound. Moreover, the authors reported rapid formation of granulation tissue and reduction of bacterial load [3]. Since its introduction, several studies have compared NPWT with conventional dressing methods, reporting improved wound healing rate and time [4-12], especially in general surgery. The promising effects of NPWT in complex wound healing led to a broadening of its indications [1]. We conducted a literature review to better understand the correct application and indications of NPWT in orthopedics and traumatology.

Materials and methods

During a preliminary meeting, the research group posed three fundamental questions that can guide the orthopedic in the management of complex wound issues using NPWT in orthopedics and traumatology: (1) How to appropriately use NPWT?; (2) What is the current knowledge of NPWT in orthopedics and traumatology?; and (3) What are the future perspectives of NPWT in orthopedics and traumatology? To answer these questions, a PubMed search was conducted by three independent researchers using as keywords: "negative pressure wound therapy", "orthopedics", "osteomyelitis", "open fractures"; "traumatology"; "prophylaxis", and "periprosthetic joint infections".

The literature research was conducted only on PubMed considering that 90% of high-quality studies can be retrieved from this database as reported by Rollin et al. [13]. Therefore, searching on PubMed should be considered cost-effective and a practitioner can efficiently retrieve the majority of the literature on a given topic [13,14].
All articles in English, Spanish, and Italian were included. References of the included articles were also reviewed. Relevant articles were identified by consensus of at least 2 of 3 researchers. Data from the studies included were extracted, and relevant findings were discussed by the research group and accepted if a consensus was obtained between at least 66.6% of researchers.

Discussion

1) How to appropriately use NPWT?

The beneficial effects on the wound have been demonstrated by the reduction of wound area, which is related to the stimulation of angiogenesis, constant aspiration and mechanical cleaning of small debris and necrotic tissue, removal of protease-containing fluids, reduction of interstitial edema with improvement of microcirculation, and increase in blood flow and oxygenation [1,3,15,16]. All these conditions contribute to a favorable biochemical and cellular environment and formation of granulation tissue and therefore to faster wound healing (Fig. 1).
From a technical point of view, the system is characterized by a vacuum generator, a fluid collection container (canister), a wound filler material, and a wound sealing material [1]. The

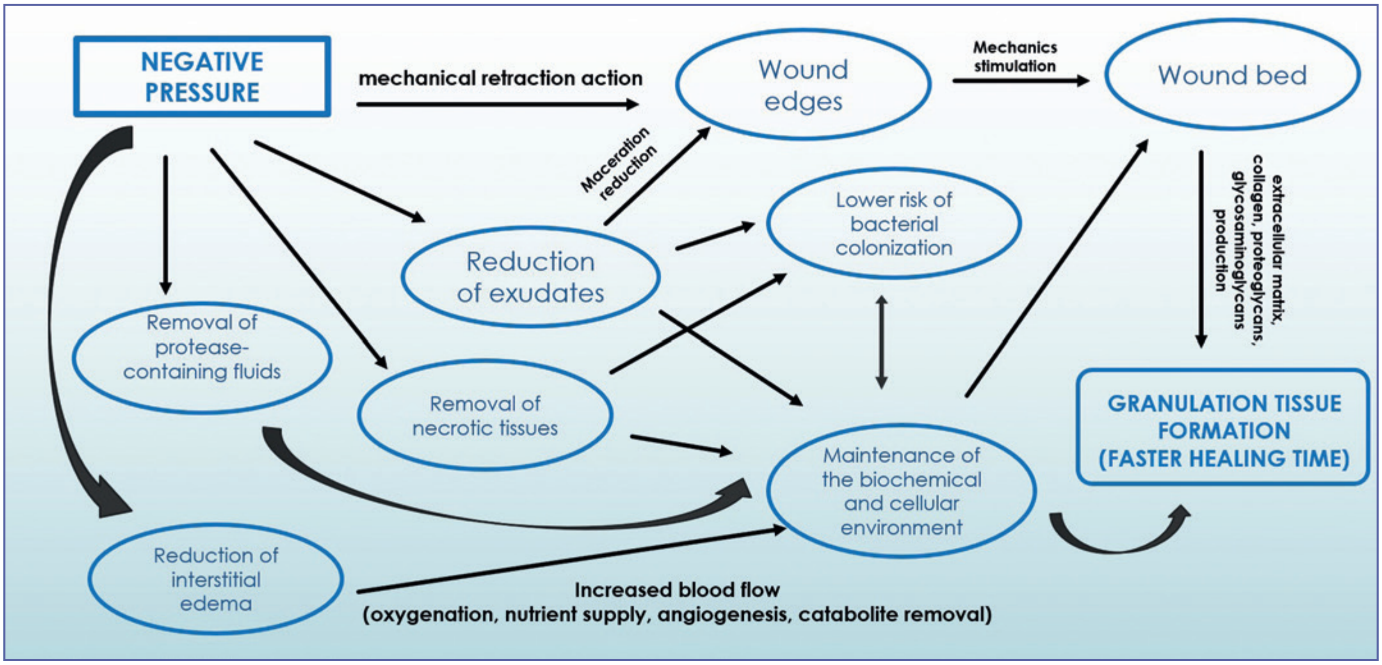

Figure 1. NPWT: mechanism of action.

vacuum generator creates the suction pressure of variable intensity which is electrically powered. The suction pressure ranges between -50 and -150 mmHg, with an optimum of -125 mmHg [1,17-21]. However, a lower pressure is recommended in patients with vascular disorders, ischemic areas, skin transplants, or pain during the treatment [21-26]. The suction can be continuous or intermittent. Continuous suction theoretically offers better wound cleaning, and reduces bacterial proliferation and the risk of secretion leakage [1]. The canister collects all the fluids and secretions. In some of the handiest NPWT devices, the canister is replaced by a highly breathable dressing that favors evaporation rather than the simple collection of material [27]. The filler material can be either polyurethane foam or gauze. The former is most suitable to deep wounds with regular and wet edges and in cases where a high granulation is desired [1,27]. The latter, instead, is especially useful for superficial or irregular wounds, and in case of local ischemia or severe pain [1,27]. The latest generation of fillers available on the market contains also bactericidal substances like silver. The sealing material, which hermetically covers and isolates the wound, can be in polyurethane or hydrocolloid. This latter is particularly useful in case of suffering of the wound edges. The wound is connected to the vacuum generator by a drainage tube. When the vacuum is appropriately generated, collapse of the filler material, mechanical retraction of the wound, and drainage with the collection of secretions from the canister can be observed. To appropriately use the NPWT requires that the filler perfectly follows the geometry of the wound, and the absence of any leakage from the sealing material [1]. NPWT should be applied for at least 22 hours per day. In case of battery failure or insufficient suction for more than 2 hours, the device should be removed, and the dressage reapplied [1,26,27]. Dressings should be changed at least every 48 to 72 hours. In fact, a lower frequency easily results in foam saturation which decreases the effectiveness of treatment while increasing the risk of infection [28]. The canister must be changed when it is full or at least once a week [1,26,27].

In case of infections, the NPWT can be associated with the instillation of substances such as antiseptics and antibiotics inside the wound (NWPTi) [1,27]. These latter systems allow controlled and automatic instillation of a defined fluid quantity, duration, and number of cycles [1,27]. Generally, instillation with a duration between 10 and 30 seconds, represents the first of the three phases, and is followed by a stationary phase that lasts from 5 to 30 minutes after the instillation. The third phase is suction, which lasts about 2-3 hours. The instillation cycle is repeated several times a day depending on the type and pharmacodynamic properties of the instilled substance [1,27].

2) What is the current knowledge of use NPWT in orthopedics and traumatology?

NWPT may be used in several scenarios, including the treatment of septic wounds, necrotizing fasciitis, gas gangrene, and venous or pressure ulcers. In the orthopedic fields it can be used especially in open fractures, infections (including osteomyelitis and periprosthetic joint infections), and fasciotomy [27]. Although the quality of the available literature is mostly poor [29], there are several studies that support the effectiveness of negative pressure therapy in reducing the risk of infection, accelerating the wound healing process, and reducing hospitalization length, at least in open fractures [30-32].

In particular, good outcomes in terms of hospital stay, wound size reduction, wound healing time, and deep infection rate were reported by Kumaar et al. in their randomized controlled trial comparing NPWT with standard dressing in open fractures [33]. A safer delayed free flap repair was reported by Mastumine et al. in their case series of Gustilo IIIb tibial injuries [34]. Liu et al. conducted a systematic review on the use of NPWT in open fractures, reporting that VAC therapy was able to accelerate the wound healing process (in terms of shorter wound coverage time, shorter wound healing time) and reduces the length of stay as well as the rates of infection and amputation. However, NPWT was not demonstrated to be able to act on the need for flap surgery, free flap size, flap failure, and nonunion rate [30]. Similar results were also reported in a recent meta-analysis [31]. However, other reports have questioned the usefulness of NPWT in open fractures [35-37]. For example, the WOLLF randomized controlled trial, conducted on 460 adults with open fractures, failed to identify substantial differences between NPWT and standard dressage at both 12 months and 5 years of follow-up [35,36]. These observations raised some questions of the cost-utility of the routine use of NPWT in open fractures [37]. However, as reported by Zhang et al. in their series of 21 patients, NPWT may be part of an effective protocol for the treatment of osteomyelitis with severe soft tissue impairment [38]. Figure 2 shows the staged application of NPWT in a case of osteomyelitis at our institution.

When using a NPWT there are some contraindications to consider. It should be avoided in case of coagulation disorders, active bleeding of the wound, exposure of organs, vessels, nerves, vascular anastomoses, in the presence of neoplastic tissue in the wound region (except as a palliative measure), or as an alternative for surgical debridement in case of osteomyelitis, or necrotic tissue.

3) What are the future perspectives of NPWT in orthopedics and traumatology?

Incisional NPWT (INPWT) can be used “for prophylactic purposes” on several occasions, especially in high risk patients (diabetes, glucocorticoid therapy, very elderly, revision surgery) [39-42]. Several studies support this kind of approach. In particular, a meta-analysis conducted by Ailaney et al. supported the efficacy of INPWT in revision total hip arthroplasty, decreasing hospital stay and reoperation rates [39]. Similar results were also reported by DeCarbo et al. in ankle replacement and calcaneal fractures [43]. Moreover, in a randomized controlled trial on over 263 extremity fractures a reduction in the infec-

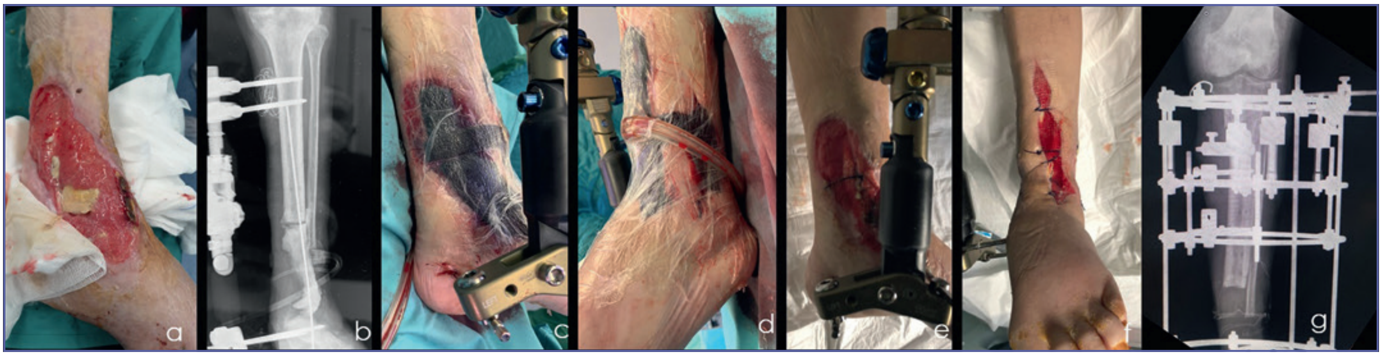

Figure 2. Clinical case of a female with a distal tibia osteomyelitis. A) clinical picture prior to surgical treatment. The patient was scheduled for bridging therapy based on wide debridement, application of an external fixator; B) and NPWTi (VAC Veraflo™, 3M, Milan, Italy); C-D) after three weeks, the soft tissues significatively improved and the patient underwent a bone transport using an Ilizarov external fixator (G).

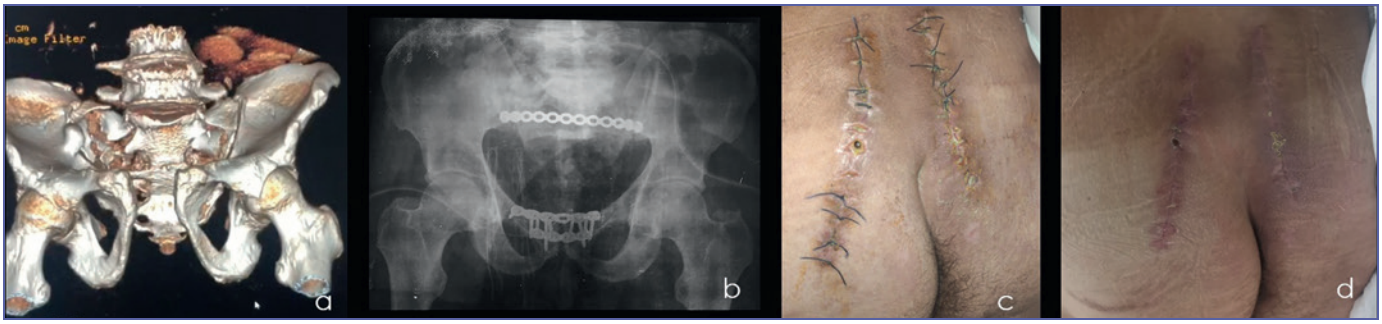

Figure 3. Male with a pelvic fracture (A) treated with plate and screws (B). At two weeks after the surgery a wound dehiscence was observed (C) and an INPWT (Prevena™, 3M, Milan, Italy) was applied. In (D) clinics after 2 weeks of application.

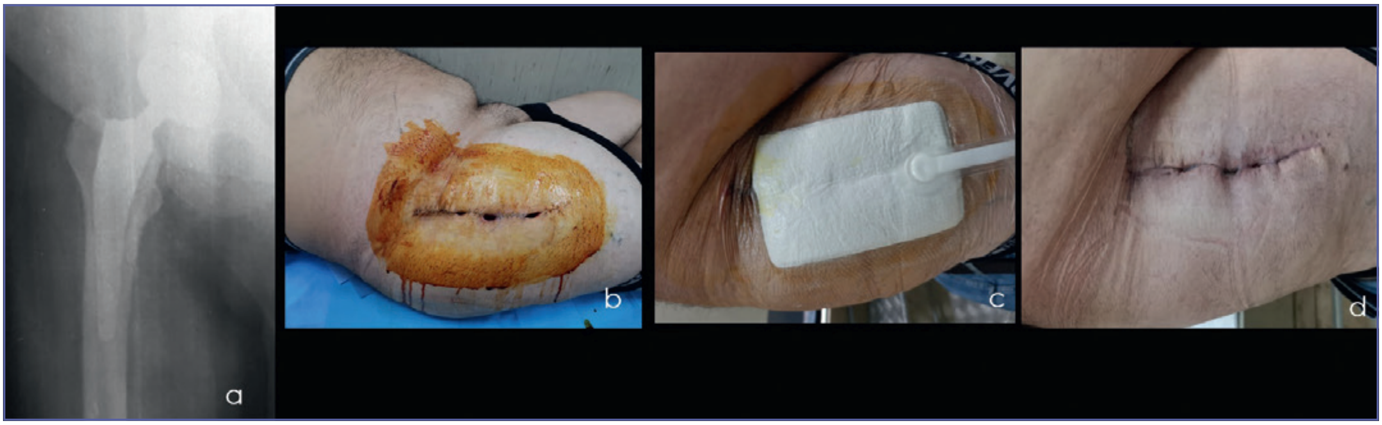

Figure 4. Clinical case of an obese patient with a periprosthetic joint infection who underwent to a one stage revision (A). At three days after the surgery because of a persistent seroma some staples were removed and an INPWT applied (PICO™, Smith&Nephew, London, UK) (C). Clinics at 2 weeks after the application. At 1 year after the surgery the patient still have no clinical or laboratory signs of infection.

tion rate was reported with INPWT compared with traditional dressing [44]. This reduction of surgical site infections with the use of preventive NPWT was also suggested in a recent Cochrane review [8]. The reason for these promising results may be related to the inhibitory effects on bacterial proliferation observable for 48 hours after its application [45].

Conclusions

NPWT is a valuable aid in the management of complex wounds in both acute and chronic phases. It allows to reduce the number of dressing changes, thus decreasing hospitalization time, and offers greater comfort to the patient; applied on surgical incisions it may reduce the risk of delayed healing and the risk of infections, especially in patients with comorbidities. The stratification of the patient's risk, therefore, is fundamental for optimization of the cost-benefit ratio.

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Conflict of interest
The Authors declare no conflict of interest.

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Authors' contributions
GL, GT, ASP: conceived the study; ADC, AB, RP: performed the literature review; ADC, AB, RP, GC: extract data; all Authors analyzed the extracted data; GL, LM: wrote the first draft of the manuscript; all Authors wrote and approved the final draft of the manuscript; GT, ASP: supervised the entire process.

Ethical consideration
As a standard protocol, all patients provided written and informed consent allowing to undergo surgery and to have their data collected for scientific and audit purposes. The present study has been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. According to Italian law, formal ethics approval was not required for this study, as it involved routine tests and clinical evaluations.

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