

Negative pressure wound therapy: clinical utility

Heidi Sandoz

Accelerate CIC, Mile End
Hospital, London, UK

Abstract: Negative pressure wound therapy (NPWT), also known as topical negative pressure therapy, has been increasingly used in health care for the management of a wide variety of wounds over the last 2–3 decades. It is an advanced therapy that can be helpful to accelerate wound healing in both acute and chronic wounds by delivering negative pressure (suction) to the wound bed. More recent advancements in the application of NPWT have provided clinicians with wider choices of utilization. There are now devices available that can deliver irrigation to the wound bed, be used for closed surgical incisions, or are disposable and highly portable. Systematic reviews considering NPWT have been published previously. These usually focus on one wound group or device and fail to offer practical clinical guidance due to the scrutiny offered to the evidence via a systematic review process. Here, an overview of the history of NPWT, the varieties of device available, their wide clinical application, and the evidence to support its use are explored in a pragmatic way.

Keywords: negative pressure, wound, incision, healing, pain

History of negative pressure wound therapy

In 1989, Chariker et al¹ published a paper describing a wound dressing technique using gauze filler, drains, and continuous closed (possibly wall or portable) suction to assist wound healing and exudate management. Papers had been published earlier than this describing similar techniques^{2–6} using a syringe and catheter,² water seal drainage bottles,² or glass chambers.^{4,5} In 1997, Argenta and Morykwas published two papers^{7,8} describing their technique delivering the same treatment using a foam wound filler and pump, called vacuum-assisted closure (VAC) therapy. Over the next 9 years, possibly due to patents and robust marketing strategies, VAC[®] therapy (distributed by KCI Medical) became the only available product to deliver negative pressure wound therapy (NPWT) worldwide.

In 2006, Blue Sky Medical⁹ successfully challenged some of the patents held by KCI Medical and Wake Forest University, and opened up the market to alternative modes of delivering NPWT. Since that time, several manufacturers have brought competitively priced products to the market, some of which have also had patent battles in the courts with KCI Medical and Wake Forest University.¹⁰

How does NPWT work?

Through the use of a wound filler contact material (foam, gauze, or drain), negative pressure is applied directly to the wound bed using an electrically, battery, or mechanically

Correspondence: Heidi Sandoz
Accelerate CIC, Mile End
Hospital, Bancroft Road,
London E1 4DG London, UK
Tel +44 208 223 8331
Fax +44 208 223 8863
Email heidi.sandoz@nhs.net

powered pump. An airtight vacuum seal is required in order to achieve this. The level of negative pressure delivered to the wound may vary dependent upon manufacturer, wound type, and wound filler. Early research undertaken by Morykwas et al⁸ demonstrated improved blood flow to the wound with negative pressures set at higher levels. This has been both supported¹¹ and disputed¹² in later studies.

The benefits of using NPWT include enhanced healing,^{13–15} management of exudate,^{14,15} reduced dressing changes compared with other dressings,¹⁶ reduced nurse time,¹⁷ reduced costs,¹³ and improved quality of life.¹³ Wound healing is thought to be assisted by provision of a moist environment, interstitial fluid removal, exudate removal and therefore rebalance of cytological disturbances,^{14,15} enhancing granulation tissue formation via mechanical stress,^{8,15} and promoting angiogenesis¹⁴ and enhanced tissue perfusion.^{14,15,18}

Others have reported fluctuations in blood flow according to distance from the wound edge and the level of negative pressure applied to the wound.^{11,19,20} This may be a useful finding to consider when using NPWT on wounds with compromised vascularity, such as in patients with diabetic foot or lower limb arterial disease where caution may be required with use if reperfusion is diminished.²⁰ Claims by Morykwas et al⁸ of a reduction in bacterial count have not been further supported by research.^{14,15}

When can NPWT be used?

NPWT is suitable for use in all but a few wounds (including closed surgical or grafted wounds) and requires caution in others^{21,22} (Table 1). There is evidence of NPWT being used with good clinical effect in a wide variety of wounds and clinical situations (Table 2).

Adverse events

As with anything in health care, the benefits of a therapy need to be balanced with any risks. There are several adverse events reported with regard to the use of NPWT, including retention of foam dressing in the wound tissue,²² perforation of blood vessels,^{22,44} cardiac rupture,⁴⁵ and retention of liner dressings.⁴⁶ Clinicians need to be both aware and mindful of the risks of these events and ensure that the patient has been fully informed.

Modes of delivery of NPWT

Since 2005, the variety of commercially available pumps delivering NPWT has expanded. Consideration of how NPWT is delivered can be divided into two categories for ease of explanation, ie, type of wound contact material used to ensure negative pressure is in contact with the wound bed and the type of pump used to deliver the negative pressure.

Wound contact material

NPWT requires a contact material to enable the negative pressure or suction from the pump to reach the wound bed. Currently, using commercially available products, this is most commonly achieved by using one (or a combination) of the following: antimicrobial gauze wound filler, foam wound filler, drains, flat dressings for incisional/superficial wounds, and exposed bowel dressings.

Selecting which contact material is used may be dependent on the available supplier and contract within the local clinical area. Much of the clinical evidence available prior to 2005 focuses on the use of foam with the KCI Medical VAC therapy pumps. However, since that time, the use of gauze filler has increased, prompting both the production

Table 1 Wounds where NPWT is contraindicated or caution with use is needed

Contraindicated wounds	Rationale	Use with caution	Rationale
Wounds involving untreated osteomyelitis	If the wound closes over an underlying osteomyelitis there is a risk the wound will recur	Wounds with visible fistula	Isolate fistula to prevent further deterioration
Wounds exposing blood vessels, nerves, anastomotic sites or organs, or with an unexplored fistula	Risk of rupture to blood vessel, anastomotic site, or organ; risk of nerve damage; risk of further deterioration of fistula	Wounds with exposed bone or tendon	Isolate bone or tendon from direct pressure by protecting with a liner dressing to prevent drying out
Wounds including open joint capsules	Risk of drainage of synovial fluid	Clotting disorder or anticoagulant use	Risk of bleeding
Skin malignancy and excised skin malignancy except for palliation	Risk of exacerbation of growth of malignant cells	Compromised microvascular blood flow to the wound bed	Risk of further compromise of vascular supply
Wounds with necrotic tissue, debride first	NPWT will not facilitate debridement of necrotic tissue		

Abbreviation: NPWT, negative pressure wound therapy.

Table 2 Published papers utilizing NPWT for a wide variety of wound types

Reference	Wound type	Paper type
Baharestani ²³	Neonatal and pediatric population	A retrospective case study of 24 children aged between 14 days and 18 years
Butter et al ²⁴ Binet et al ²⁵	Pediatric population Giant omphalocele management	Retrospective case review Case study report of three babies aged 11 days to 5 months
Yu et al ²⁶	Post-sternotomy mediastinitis	Systematic review
Gupta and Ichioka ²⁷	Pressure ulcers	Literature review and case studies
Ousey et al ²⁸	Spinal wounds	Systematic review
Davies et al ²⁹	Exposed brain	Letter reporting single case study
Falagas et al ³⁰	Sternal wound infections	Meta-analysis
Gupta ³¹	Skin graft	Literature review
Llanos et al ³²		Randomized controlled trial
Sziklavari et al ³³	Pleural empyema	Retrospective case study review
Vuerstaek et al ³⁴	Chronic leg ulcers	Randomized controlled trial
Jeffery ³⁵	Severe military lower limb trauma	Case studies
Penn-Barwell et al ³⁶	Combat wounds	Retrospective case review
Noble-Bell and Forbes ³⁷	Diabetic foot ulcer	Systematic review
Roberts et al ³⁸	Open abdomen	Systematic review
Molnar et al ³⁹	Burns	Single case studies
Gonzalez Alana et al ⁴⁰	Burns	Single case studies
Stannard et al ⁴¹	Closed incisional wounds	Literature review and case studies
Masden et al ⁴²		Randomized controlled trial
Suzuki et al ⁴³	Surgically closed wounds in open fractures	Retrospective review

of a best practice statement⁴⁷ and studies comparing gauze with foam.^{48–50} It has been demonstrated that gauze filler achieves the same clinical outcomes^{48,50} whilst reducing pain for the patient at dressing change,^{50,51} saving nursing time, and reducing costs.⁵⁰

In a bid to find a cheaper wound contact filler, Tuncel et al⁵² have described similar effects using a sterilized, store-bought loofah sponge when compared with foam and gauze in *in vivo* studies of acute wounds in rabbits. Perez et al⁵³ also describe creating a “homemade” system to deliver negative pressure in Haiti, where funding for the commercially available systems is not available. They used the foam from a surgical hand scrub brush as the wound contact material. Both groups reported effective clinical outcomes.

Where bowel is exposed within either an intentionally laid open or a dehiscence abdominal wound,⁵⁴ a specialized membrane liner dressing is used in combination with either foam or gauze to prevent fistulation of the bowel. Fistula formation has been reported in 7% of patients where NPWT has been used over an open abdomen.⁵⁴

There is an absence of clinical comparative trials with regard to channel drains. However, a channel drain can be used for a tracking sinus wound of considerable depth or length. The narrow lumen of a channel drain can be inserted into sinuses with or without gauze to help facilitate closure of the sinus. The origin of the sinus should be explored⁴⁷ prior to commencing NPWT via scan, ultrasound, magnetic resonance imaging, or computed tomography. This can help eliminate a deeper source for the sinus origin that may need to be resolved prior to attempting closure.

Pump type

There are currently several commercially available pumps on the market. Rather than discuss them by manufacturer, they are described here via functionality.

Traditional negative pressure delivery

These pumps can be used with gauze and/or foam filler, and may be either cumbersome or smaller and portable, commonly using a carry bag. The canisters in use with these pumps will usually hold from 300 mL to 1,000 mL of wound exudate. They are electrically powered and have a battery backup.

Disposable negative pressure pumps

These are sized to be hand-held, and are battery^{55–58} or mechanically powered.^{59,60} They may use a dressing or a canister to hold exudate. These are disposed of once therapy or dressing life is over.

Negative pressure pumps for surgical incision wounds

There are two commercially available pumps^{58,61,62} that use flat absorbent dressings for use directly over closed surgical wounds. These are small and easily carried pumps, and are disposable once the dressing life has expired or therapy is completed. It is not clear in the literature whether these devices reduce the incidence of surgical site dehiscence and infection. Stannard et al⁶³ were early authors describing the use of NPWT to prevent surgical incision dehiscence and infection in patients with orthopedic trauma wounds. Their small randomized study was inconclusive. Some later

studies have also yielded similar findings.^{42,61} However, larger randomized studies since have found that use of incisional NPWT has reduced infection and dehiscence rates.^{64,65}

Irrigation negative pressure pump

There are two commercially available irrigation pumps reported in the literature^{66–70} that can intermittently deliver irrigation fluids to the wound with negative pressure. Various instillation fluids have been described, including insulin,⁶⁹ antibiotics,⁶⁶ Dakin's solution,⁶⁸ and polyhexamethylene biguanide.^{71,72} This technique of instilling fluids into the wound whilst intermittently delivering negative pressure has been described previously.^{73,74} The main outcome for this mode of delivery is prevention or eradication of infection, and it has been shown to be useful for osteomyelitis⁷² and to improve retention rates of infected orthopedic implants.⁷¹ A recent international consensus guideline on the use of instillation therapy offers recommendations as to suitable wound types and instillation fluids.⁷⁵

Adapted or “home-made” systems

Several authors have described using the hospital central suction system^{32,53,76} to apply negative pressure to wounds. The cost savings in comparison with a commercial pump system are favorably portrayed.

Clinical effectiveness of NPWT

It could be argued that NPWT sees the highest number of randomized clinical trials, systematic reviews, and consensus best practice guidelines in publication than any other wound treatment modality. NPWT has been clinically evaluated and compared with other wound treatments, one NPWT wound contact material has been compared with another, the costs of delivering NPWT have been analyzed, and patient-centered outcomes such as pain have also been considered. Meta-analyzing the different controlled trials can be difficult due to the heterogeneity of the wound types studied. The methodology of some of the randomized clinical trials can be criticized; often power, blinding issues, potential bias, and randomization systems are not discussed. As such, three of four Cochrane reviews^{74,77–79} have been unable to recommend the use of NPWT over any other treatment modality. The fourth⁸⁰ suggests that when used with the diabetic foot ulcer patient, there may be a benefit to healing and reduced risk of further amputation. However, they do recommend caution when considering the results because of the risk of bias around adequate blinding. In a recent BMJ rapid response, Tovey and Bero⁸¹ quote: “Few now support the view that the

randomized controlled trial is the only meaningful research to guide rational decision-making, or that statistical significance is the only determinant of effectiveness.” When considering effectiveness, the clinician must consider not just the evidence base but also take a broader view incorporating clinician experience and patient preference. When it comes to NPWT, it would seem clinicians continue to utilize this modality in many more advancing ways without what Cochrane can agree is a robust evidence base. As is often the case in medicine, NPWT was created by innovative clinicians who needed to solve a clinical problem. Commercial companies have then produced products that will deliver the innovation to a wider market. Innovative clinicians take these commercial products and adapt them to help solve a clinical problem. And so the cycle goes on. Innovative risk-taking clinicians drive medical advancement which, in turn, feeds the randomized clinical trial to prove the effectiveness of the innovation. However, lack of proof via randomized clinical trial should not then halt the use or advancement of these treatments. Lack of evidence of effect is not the same as evidence of no effect. Policy makers and budget holders need to be mindful of this chicken and egg scenario.

As this is not a systematic review of NPWT,^{13–15,28,37,49,61} it highlights only some of the studies that have claimed to demonstrate clinical effectiveness and/or cost-effectiveness of NPWT, without critiquing the methodology that might challenge their findings.

Reduction in wound size

NPWT using a foam contact layer has been shown to reduce open wound size and volume to a statistically significant degree when compared with alternative treatment modalities.^{53,76,82–86} However, in contrast, Braakenburg et al⁸⁷ reported no statistical significance when compared with what they describe as modern dressings (hydrocolloid, alginate, acetic acid, and EUSOL [Edinburgh University Solution of Lime]) except within the patient population with cardiovascular disease and/or diabetes.

Cost-effectiveness

Where cost-effectiveness has been evaluated, it has been demonstrated that NPWT is more cost-effective than alternatives.^{13,88} However, the costs are balanced by a reduced number of dressing changes and nurse time required to change the dressings.¹³ To a finance director, the cost of NPWT can seem extremely high. As such, it is important to understand how reduced healing time can impact on the overall costs involved when negotiating for the use of

NPWT in times of austerity. The larger portion of the cost-effectiveness papers consider KCI Medical VAC therapy as the product of comparison. More recently, the costs of using a gauze-based system have been compared favorably with KCI Medical VAC therapy.⁵⁰

Foam versus gauze filler

Studies comparing effectiveness between gauze-based and foam-based NPWT have considered the difference in healing rates,⁵⁰ pain at dressing change,^{50,51} contraction,^{89,90} scar tissue depth,⁹¹ tissue formation^{91,92} and deformation,⁹² and microvasculature effect.^{19,92}

It would seem that there is very little difference in clinical outcomes between the two types of contact media. However, it has been demonstrated that less force is required to remove the gauze medium,^{92,93} which may go some way to explaining the finding that patients report higher pain levels^{50,51} when using foam, which can allow tissue ingrowth.⁹³ It has also been shown that the granulation tissue forming under foam is thicker with increased scarring.⁹³ Plastic surgeons have identified this as a cause of frailer skin grafting, and as such, some have switched to using gauze to prepare a wound for skin grafting.⁹³

Level of negative pressure

The level of negative pressure required will vary according to the manufacturer's instructions, the contact material used, and patient acceptability, but is usually between -50 mmHg and -200 mmHg. For instance, gauze requires a much lower negative pressure to collapse and conform to the wound bed than a denser foam.

Initial studies⁸ considering the level of negative pressure required to be effective suggested that 125 mmHg resulted in optimal blood flow. However, later studies have not been able to achieve consensus with regard to level of pressure and what effect this has on blood flow.¹¹ Very often the level of pressure selected is guided by the manufacturer. Clinicians may decide to set pressures lower to reduce pain or higher to expedite exudate removal.²¹

Effect of wound liners on pressure

One study considered the effect that a wound liner contact layer may have on the level of pressure delivered to the wound bed.⁹⁴ Three liners were evaluated on healthy skin, and so conclusions as to translation when using on the wounds themselves need to be drawn with caution. However, what can be concluded is that the use of Jelonet[®] (Smith and Nephew) adversely affects the negative pressure, thereby

rendering its use impractical where negative pressures need to be achieved, but is potentially useful where structures, such as fistulas, bone, or vascular grafts, may need to be isolated from negative pressure.

Using NPWT in clinical practice: decision-making and application tips

When deciding to use NPWT, several considerations are necessary:

- Suitability of the wound for the therapy
- Risk factors and risks of harm by using the device
- Suitability of the patient for the therapy
- Which device and contact medium will best suit the clinician and patient outcomes
- What level of pressure is best for the wound and desired outcomes
- Length of time treatment is expected to be needed
- Who will manage the ongoing dressing changes and in what setting
- Use in the community
- Willingness of patient to receive the treatment.

Most wounds are suitable for the use of NPWT, taking into consideration the aforementioned contraindications. Rather than considering suitability of use by wound type, it is more reasonable to consider suitability by wound conditions. For instance, a wound with an exposed blood vessel or necrotic tissue present may be contraindicated unless the vessel can be safely protected or the necrotic tissue can be debrided. A wound too close to a functioning anus may lead to challenges gaining a secure seal, rendering NPWT impractical to use.

Of course, the wound belongs to a person, whose ability to cope with the pump and therapy also needs to be taken into consideration.²¹ Some questions to consider prior to commencing therapy are:

- How mobile is this person and will the pump restrict their mobility?
- How heavy will the pump be for them to carry?
- Will the therapy be used in a hospital setting or in the patient's residential setting?
- Are there any safety issues that need to be considered, for instance, trip hazards, poor vision, hearing problems, and frail or elderly living alone?
- How readily will the individual cope with any alarms and will they be able to follow processes to resolve these?
- Where pumps are owned or rented by individual organizations, how will the pump be returned to that organization when therapy is discontinued?

1. Foam or gauze filler must not come into contact with intact skin, because skin can be damaged by negative pressure contact
2. Intact skin must be lined with film dressing if foam/gauze needs to extend onto it, to prevent damage
3. Each piece of foam or gauze must be in contact with another where more than one piece is used to ensure continued application of negative pressure throughout the wound/wounds. Record the number of pieces used
4. An airtight seal is created using a film dressing. This can be enhanced using adhesive gel strips or stoma paste
5. Prior to application of new foam/gauze, ensure any liner contact materials and remnants of foam or gauze are fully removed from the wound bed to prevent ingrowth of fibers
6. Where more than one wound is receiving the therapy, they can be joined together by bridging from one to another. Ensure non-wounded skin in between each wound is protected from contact with the foam or gauze

Figure 1 Practical tips for safe and effective application of negative pressure wound therapy.

- Does the patient have cognition and are they willing to comply with the therapy?
- How painful is the wound and dressing change? Where dressing changes are painful, nitrous oxide may reduce this, but this would need to be administered in the hospital setting as very often this is not available in the community setting.

Dressing changes will be undertaken 2–4 times per week dependent upon the contact dressing used, manufacturer guidance, exudate levels, and patient preferences.

Transition of care from the hospital to the community setting with NPWT in place requires good communication between organizations. Very often, a tissue viability nurse from each organization will be involved in this transition. Papers describing processes to aid this transition have been published previously.^{17,95} Accepting NPWT for use in the community setting can expedite earlier discharge from hospital and reduce the number of community nursing visits for dressing changes, both of which reduce the costs of overall care for patients with wounds that can be managed with NPWT.¹⁷

Tips for successful dressings

In order for NPWT to effectively accelerate wound healing it requires good contact with the wound bed and a vacuum

1. Where foam or gauze has been used with minimal beneficial effect, try switching to the alternative
2. Where foam is adhering to newly growing granulation tissue and/or causing pain on removal, switch to gauze
3. Where shaping and sculpting the foam filler may be time-consuming, consider using gauze
4. Where narrow tracks or sinuses exist, consider using gauze or a channel drain
5. Where mobility is important to the patient, for instance in a young working person, consider using a smaller disposable device

Figure 2 Selecting the wound filler and pump.

achieved by sealing the dressing from air leaks. There are a number of other considerations to ensure safety during therapy use (Figure 1).

Wound filler and pump selection

The selection of type of wound filler and pump may be based on several considerations (Figure 2). In some organizations, this may be limited to which system is available for use.

Conclusion

NPWT is a widely utilized treatment for many different wound types. Despite the quality of trial methodology depreciating statistically significant findings, NPWT has been shown to be effective in accelerating wound healing and reducing treatment costs. Advances in the development of NPWT products are providing clinicians with an expanding choice of therapeutic modalities to use. Further research is needed to demonstrate the effectiveness of NPWT when used to prevent surgical incision dehiscence and infection.

Disclosure

The author reports no conflicts of interest in this work.

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