Introduction
Over the past decade there has been a dramatic increase in the use of negative pressure wound therapy (NPWT). This advanced technology has revolutionised care for many patients with chronic and acute wounds\(^1,2\). Widespread adoption of NPWT over the past 15 years has been driven largely through favourable clinical experience rather than randomised clinical studies or thorough scientific knowledge. However, it now seems that understanding the mechanism by which negative pressure affects the wound bed may allow the clinician to choose the right dressings and pressure settings for NPWT to obtain optimal effects with minimal complications.

What is NPWT?
In 1989, Chariker described a gauze-based negative pressure drainage therapy for healing wounds\(^3\). Previous use of gauze-based NPWT in the Soviet Union has been described by Miller\(^4\). Negative pressure therapy for the treatment of wounds was popularised by Argenta and Morykwas in 1997, who described the use of subatmospheric pressure through an open-pore structure polyurethane foam to expedite wound healing and laid the foundations for a scientific understanding of the therapy\(^5,6\).

Today, NPWT is used for the clinical treatment of many wound types\(^1\), including orthopaedic trauma\(^7\), soft tissue trauma\(^8\), skin grafts\(^9\), pressure ulcers\(^10\), venous leg ulcers\(^11\), diabetic foot ulcers\(^12\), burns\(^13\), surgical infections\(^14\), and management of other major surgical wounds\(^15,16,17\).

NPWT uses a closed drainage system to apply controlled suction (vacuum) to a wound bed. The wound is first filled with a wound filler (gauze or foam) to allow pressure to be distributed evenly to the wound bed. The wound is then sealed with an adhesive plastic drape and the drain is connected to a vacuum pump. Wound fluid is sucked out through the drain and collected in a canister.

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areas of the tissue where the NPWT effect is desired.

**Wound contact layer**
A non-adherent wound contact layer is placed underneath the wound filler when the clinician anticipates complications. A wound contact layer may be placed over vulnerable structures, but also over the wound bed itself since it is believed to protect from ingrowth of granulation tissue into the wound filler. Wound bed tissue has been shown to grow into foam, but not into gauze. The complications associated with ingrowth into foam are as follows:

- pain during dressing changes as the ingrown tissue is torn away from the wound. Pain often needs to be treated vigorously.
- wound bed disruption and mechanical tissue damage as foam is torn from the wound bed during dressing changes.
- pieces of foam may become stuck in the wound bed and, if left in the wound, will act as foreign bodies that may hinder wound healing.

**What evidence exists for the use of these different wound interfaces?**
To date, the scientific evidence on the biological effect of NPWT on the wound bed has concentrated on the use of either polyurethane foam or gauze as wound fillers. It must be remembered that in clinical practice, foam for NPWT is likely to be combined with a non-adherent wound contact layer. Even though it is well known that negative pressure is transduced through commonly used wound contact layers, studies that formally examine the effects of a combined foam and non-adherent contact layer on the wound bed and granulation tissue formation are still not available.

**How do we choose an appropriate interface dressing?**
Paglinawan et al demonstrated that the use of either gauze or foam result in increased granulation tissue formation. In a case series, the rate of wound healing under NPWT using gauze was similar to that for foam. However, studies are now emerging showing that the amount and character of granulation tissue formed may differ between the two dressings. The use of foam as a wound interface in NPWT produces thick, hypertrophic granulation tissue. Gauze under NPWT results in less thick but dense granulation tissue.

**Foam as interface**
The thick granulation tissue generated under foam during NPWT may sometimes be advantageous. However, it may also lead to problems such as fibrosis, which may result in scarring and subsequent contractures as the wound heals.

Foam may be a good choice when treating wounds that benefit from thick granulation tissue and where scarring does not pose a problem, for example in fasciotomy wounds in upper or lower limb compartment syndrome where contraction is beneficial. In acute wounds with large tissue loss, foam may be a bridging therapy that contracts the tissue so that the wound edges are pulled together.

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**Figure 1 NPWT dressings**
The wound interface may be either a wound filler, typically comprising foam (A and B) or gauze (C) or a non-adherent wound contact layer that is placed underneath the foam (B) to protect vulnerable structures or hinder ingrowth of granulation tissue into the wound filler.
We know from preclinical studies that the maximum biological effects on the wound edges, in terms of wound contraction, regional blood flow, and the formation of granulation tissue, are achieved at -80 mmHg. In addition, clinical studies have shown that negative pressure levels below -125 mmHg have resulted in excellent wound healing. A series of clinical cases found that wound healing was similar when using -125 mmHg and -75 mmHg.

What pressure may be used if there is pain or a risk of ischaemia?

Blood flow is known to be decreased in the most superficial layers of the wound bed tissue (0.5cm from the wound edge) and increased in deeper layers of the tissue (2.5cm from the wound edge). The decrease in blood flow is a result of the wound dressing being pushed into and compressing the tissue. In a wound that is not at risk of ischaemia, it is probable that the combination of increased and decreased blood flow is advantageous for the wound healing process. Increased blood flow leads to improved oxygen and nutrient supply to the tissue, as well as improved penetration of antibiotics and the removal of waste products. The reduction in blood flow stimulates angiogenesis, which will promote granulation tissue formation.

If the patient is experiencing pain or if the tissue is poorly vascularised (for example, in diabetic foot ulcers and thin skin transplants), negative pressure may need to be reduced to minimise the risk of ischaemia. A negative pressure of -40 mmHg may be a good choice since we know that this will reduce the risk of ingrowth.

How often should the NPWT dressing be changed?
The frequency of dressing changes required will depend on the type of dressing used but also the wound type. The usual recommendations are to change foam dressings every 48 hours. This is because the foam needs to be changed before ingrowth becomes a problem.

For gauze or a non-adherent wound contact layer, ingrowth is unlikely and dressing changes can probably be less frequent. It is currently recommended that gauze dressings are changed two or three times a week.

What level of negative pressure should be used?

What pressure is the gold standard?
There are currently no detailed clinical guidelines regarding the adjustment of negative pressure levels to suit the individual wound. The most common pressure level used (-125 mmHg) is based on a limited study on pigs carried out in 1997. These high levels of negative pressure can sometimes cause pain and therefore need to be reduced.

Gauze as interface
Gauze is often used because of its conformability and ease of application to large and irregular wounds. Gauze has become popular among some plastic surgeons for wound-bed preparation before grafting. Gauze may also be a good choice when the cosmetic result is of greater importance, or in cases where scar tissue may restrict movement, for example over joints. During NPWT, the wound filler is pushed into the wound and it is suggested that the technique of using gauze under negative pressure can tamponade superficial bleeding.

Gauze is a good wound filler, especially when circumstances are extreme. The use of gauze in NPWT is described by Jeffery et al, 2009, when treating wounds to military personnel caused by landmines and other explosive devices. There are no reported problems with ingrowth of granulation tissue into gauze in NPWT and therefore no wound contact layer is needed. It is important to note that nearly all gauze used in NPWT has been a particular type of cotton gauze (Kerlix AMD), which may provide antimicrobial control since it is impregnated with polyhexamethylene biguanide (PHMB).

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ischaemia while maintaining the wound-healing effects. Even at a negative pressure of -20 mmHg wound healing can be seen; this is probably the lowest pressure that can be used for NPWT. What pressure is best for removing large amounts of exudate? There is seldom any reason to use a negative pressure greater than -80 mmHg, but as the drainage of exudate may be improved at -125 mmHg, this pressure level could be used during the initial treatment of highly exuding wounds.

**Is the choice of negative pressure level affected by the choice of wound interface dressing (foam or gauze)?**
The interactions between pressure and interface are only now beginning to be understood. It is a common misconception that a wound filled with foam should be treated at -125 mmHg and one with gauze should be treated at -80 mmHg. Recent evidence clearly indicates that the level of negative pressure may be tailored depending on the risk of ischaemia and patient pain and that the choice of interface may be based on the desired effects on granulation tissue formation.

Further investigations are needed to explore the true nature of how the wound interface and negative pressure levels affect healing.

**What is the difference between continuous, intermittent and variable negative pressure?**
Continuous negative pressure is currently the most commonly used NPWT setting. The pressure level is kept constant at, for example, -80 mmHg. If the negative pressure is repeatedly switched on and off (for example alternating between 0 and -80 mmHg), this is called intermittent pressure therapy.

Intermittent pressure therapy is not often used clinically as the sudden spiking of negative pressure changes causes the wound filler to expand and contract repeatedly over the granulation tissue, causing pain for the patient.

Variable pressure therapy has been introduced to provide smooth cycling between two different levels of negative pressure (for example -10 and -80 mmHg), thereby maintaining the negative pressure environment throughout the therapy. In preclinical models, both intermittent and variable NPWT have resulted in massive stimulation of granulation tissue formation in the wound bed. This may be a result of both mechanically stimulating the wound bed (a massaging effect) and enhanced blood flow, which may enhance tissue oxygenation and angiogenesis.

**The future use of NPWT**
Although the efficacy of NPWT needs further investigation, this advanced wound care treatment continues to attract the attention of the majority of clinicians involved in caring for patients with wounds. Understanding the role of the wound interface, the level of pressure and its settings is part of the process of optimising the benefits of this treatment modality for patients.

**Summary**
The NPWT setting should be tailored to the individual wound for optimal effects. The type of dressing that is in direct contact with the wound (the wound interface) is important for the outcome. The wound interface may be foam, gauze or a wound contact layer. The negative pressure level and vacuum setting (continuous, intermittent or variable negative pressure) may also be adjusted. Rapid advancement in the field of NPWT is anticipated as new wound fillers are developed and their use explored, and clinical data on different NPWT settings are gathered.

**To cite this publication**

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