Journal of Plastic, Reconstructive & Aesthetic Surgery (2010) **63**, 174–179

ELSEVIER

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

The paradox of negative pressure wound therapy — in vitro studies☆

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Received 9 April 2008; accepted 10 August 2008

KEYWORDS
Negative-pressure wound therapy;
Topical negative pressure;
Vacuum dressings;
Suction dressings;
VAC;
Tissue pressure

Summary Negative-pressure wound therapy (NPWT) has revolutionised wound care. Yet, it is still not understood how hypobaric tissue pressure accelerates wound healing. There is very little reported on the relevant physics of any substance subjected to suction in this manner. The common assumption is that applying suction to a substance is likely to result in a reduction of pressure in that substance. Although more than 250 research articles have been published on NPWT, there are little data verifying whether suction increases or decreases the pressure of the substance it is applied to. Clarifying this basic question of physics is the first step in understanding the mechanism of action of these dressings.

In this study, pressure changes were recorded in soft plasticene and processed meat, using an intracranial tissue pressure microsensor. Circumferential, non-circumferential and cavity NPWT dressings were applied, and pressure changes within the underlying substance were recorded at different suction pressures. Pressures were also measured at 1 cm, 2 cm and 3 cm from the NPWT placed in a cavity.

In all three types of NPWT dressings, the underlying substance pressure was increased (hyperbaric) as suction pressure increased. Although there was a substantial pressure increase at 1 cm, the rise in pressure at the 2-cm and 3-cm intervals was minimal.

Substance pressure beneath all types of NPWT dressing is hyperbaric in inanimate substances. Higher suction pressures generate greater substance pressures; however, the increased pressure rapidly dissipates as the distance from the dressing is increased. The findings of this study on inanimate objects suggest that we may need to review our current

☆ Presented in part at the 37th Annual Congress of South African Society for Surgery to the Hand, Durban, South Africa, 4–5 September 2006. Awarded Best Scientific Paper.
Presented in full at the 50th Anniversary Congress of the Association of Plastic and Reconstructive Surgeons of Southern Africa, Drakensberg, South Africa, 22–26 October 2006. Awarded Best Basic Science Paper.
Presented in full at the summer meeting of the British Association of Plastic, Reconstructive and Aesthetic Surgeons, Deauville, France, 4–6 July 2007.

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1748-6815/$ - see front matter
doi:10.1016/j.bjps.2008.08.037

perception of the physics underlying NPWT dressings. Further research of this type on living tissues is warranted.

Negative-pressure wound therapy (NPWT) has been hailed by some as the greatest advance in wound care since antimicrobial therapy. Its uses have expanded dramatically since it was popularised in 1997 by Morykwas and Argenta[1,2] and encompass many different disciplines. It can be used in chronic wounds of different aetiologies,[2] as well as acute wounds secondary to trauma[3] or burns.[4] It has also been useful in anchoring skin grafts and has been shown to increase graft take.[5] General surgeons have often used it on open abdomens,[6] whilst thoracic surgeons have found it useful for sternal sepsis.[7] It has been found to decrease oedema and bacterial load, increase vascularity and granulation tissue and thereby accelerate wound healing.[1]

Yet, to date, the mechanism of the action of NPWT remains unknown. Many of the proposed theories are based on work suggesting that on application of an NPWT dressing, tissue pressure is immediately decreased, resulting in dilation of capillaries,[8,9] removal of oedema, angioneogenesis and, ultimately, an accelerated and increased production of granulation tissue.[2,10] Although it can be conceived that the tissue pressure beneath a pore of the foam may be hypobaric, this does not necessarily mean that the overall tissue pressure generated by the NPWT dressing is hypobaric too. This net tissue pressure is the actual pressure that affects perfusion to the wound. Although work on substance pressures has been done by German researchers,[11] there is no study in the English literature that has measured substance pressure beneath NPWT dressings to confirm the assumption that NPWT dressings result in decreased underlying tissue pressures. Furthermore, whether substance pressure beneath a circumferential NPWT dressing is different from that beneath a non-circumferential NPWT dressing has never been evaluated. Moreover, an NPWT dressing placed inside a cavity may generate different substance pressures compared to either of the aforementioned two types of dressings. Indeed, it may be possible that, regardless of the type of NPWT dressing used, the net pressure in the underlying substance will always remain equal to atmospheric pressure once the foam has completely collapsed.

The objective of this study was to determine the effects of NPWT dressings on underlying substance pressures. Three foam configurations were tested, namely circumferential, non-circumferential and foam placed inside a cavity (cavity dressing). The effects of different suction pressures were also investigated.

Methods

Substance pressures were measured using an intracranial tissue pressure microsensor (Codman/Johnson and Johnson Professional Inc., USA), which makes use of a strain gauge transducer (Figure 1). It measures both positive and negative pressures in gas and liquids or any compliant substances, for example, soft tissue. Negative pressure was created using a portable suction pump with an accurate pressure gauge (Schuco, USA). In a pilot study, it was found that conventional foam resulted in similar substance pressure effects to the commercially available, reticulated, open-cell foam (Kinetic Concepts Inc., USA), and therefore this foam was used in this study. All experiments were repeated 5 times, and the means of these values were calculated.

Circumferential NPWT dressings

In order to simulate a limb, a large sausage was skewered onto a pen (which would represent the underlying bone). Using the supplied placement cannula, the pressure transducer was carefully placed in the substance of the sausage (Figure 2). The transducer was placed about 5 cm from the puncture site (at one end of the sausage) and care was taken not to allow the transducer to be in continuity with the cavity created by the pen or the outer atmosphere. This would allow for true measurement of substance pressure alone. Rather than wrap the foam slab around the sausage, the sausage was loosely sandwiched between two separate slabs of foam. This was to create a circumferential NPWT dressing that would not constrict the sausage and thereby create a mechanical increase in substance pressure, which is unrelated to the changes due to the differential pressures. A portion of the sausage was left protruding from the foam, and the adherent occlusive dressing was stuck directly onto this portion of the sausage, allowing a part of the sausage to be excluded from the NPWT dressing, that is, exposed to normal atmospheric pressure (Figure 3) in the same way that a limb would not be entirely covered by a circumferential NPWT dressing. The transducer was

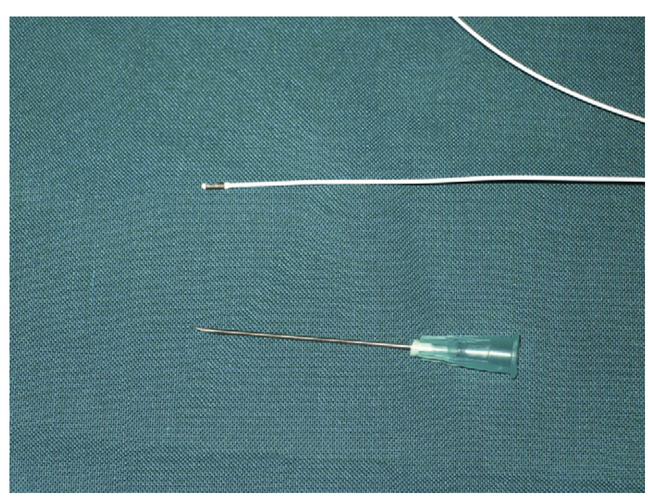

Figure 1 Intracranial pressure microsensor with a standard 21-gauge needle for size comparison.