

Cyclical Negative Pressure Wound Therapy: A Review

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Abstract

Over the past decades, the application of “negative pressure” has evolved to a cornerstone in the treatment of acute and chronic wounds in almost all specialties. Continuous Intermittent, cyclic are the three types of Negative pressure Wound Therapy (NPWT). The cyclic NPWT system is similar to the intermittent mode in terms of using the same maximal sub atmospheric pressure, but the pressure never reaches zero in the cyclic mode. Cyclic application of “negative pressure” results in a superior local enhancement of cutaneous microcirculation with regards to blood flow and consecutive tissue oxygenation. In this article, cyclic NPWT was compared with other NPWT.

Keywords: Negative pressure wound therapy; Cyclic; Wound.

INTRODUCTION

Since the introduction of the negative pressure wound therapy (NPWT) system by Morykwas and Argenta, it has been applied to a number of wounds and has become an influential and effective technique for healing simple and complex wounds. The conventional NPWT system adopts either ‘intermittent’ or ‘continuous’ mode.

While the continuous mode constantly applies a sub-atmospheric pressure of -125 mmHg, the

intermittent mode creates a sub-atmospheric pressure of -125 mmHg for 5 minutes and a 2-minute resting phase of 0 mmHg (Figure 1, left).

In experiments performed on animal models, the intermittent mode showed increased perfusion level and formation of granulation tissue in the wound area compared with the continuous mode.^{1,2} Despite the effectiveness of intermittent mode in wound healing, it has been avoided in clinical application because of the pain occurring every few minutes during the initiation phase of the system to reach -125 mmHg. Thus, ‘cyclic’ mode would minimize the pain while maintaining the superior efficacy of the intermittent mode (Figure 1, right).

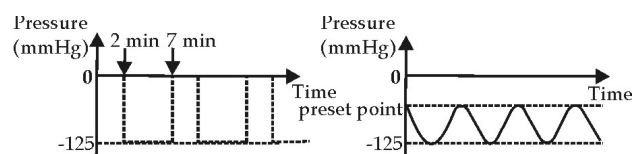


Fig. 1: Scheme of negative pressure wound therapy (NPWT) modes. The conventional intermittent mode (left) The cyclic mode (right).

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BACKGROUND

Over the past decades, the application of “negative pressure” has evolved to a cornerstone in the treatment of acute and chronic wounds in almost all specialties. Various available synonyms reflect the past developments and current applications of the technique involving, amongst others, “Vacuum assisted closure” (VAC), “Negative Pressure Wound Therapy” (NPWT), “closed incision Negative Pressure Therapy” (ciNPT), or “Negative Pressure Wound Therapy with instillation” (NPWTi).³ All but ciNPT are used for treatment of open wounds and exert the known beneficial effects of “negative pressure” therapy on wound healing, i.e., sufficient temporary wound closure, promotion of wound bed granulation, mechanical contraction and stabilization of wound margins, and efficient reduction of bacterial load. Wound bed perfusion represents another key factor in wound healing. Effects of “negative pressure” on wound bed perfusion have lately been widely discussed. Results from different research groups have partly shown diverging results which could seriously question the hypothesis of an enhancement of local and adjacent wound bed perfusion due to application of a negative pressure dressing.^{4,5} Actual doubt was risen based on the physically driven understanding of a compression of underlying tissues through application of a negative pressure dressing, particularly, on the capillary network that is subjected to surface pressure. Consecutively, occlusion of microvessels would result in a diminished rather than enhanced capillary blood flow, causing local hypoxia and, probably, ischemia. Moreover, the utilization of an otherwise broadly used technique for perfusion analysis, laser-dopplervelocimetry, was questioned to be flawed due to the impact of “pressure artifacts”⁶, therefore resulting in a false positive sign of an enhancement in perfusion underneath an applied NPWT dressing.

On the contrary, current research regarding perfusion alterations due to ciNPT and the application of negative pressure wound therapy over closed incisions found that blood flow and consecutive tissue oxygenation acutely improved upon treatment.⁷⁻⁹ Additionally, NPWT was also successfully applied in free tissue transfer, with a reduction of postoperative tissue damage instead of an increment.¹⁰ No adverse effects of negative pressure were found. In a previous analysis, we used continuous laser dopplerflowmetry combined with white light spectroscopy for a comprehensive real time analysis of microcirculatory changes under

an NPWT dressing.⁸ Application of an intermittent negative pressure resulted in a stepwise increase in local tissue perfusion with a consecutive enhancement of tissue oxygen saturation.

TYPES OF NPWT

- Continuous NPWT- the continuous mode constantly applies a sub-atmospheric pressure of 125 mmHg.
- Intermittent NPWT- the intermittent mode creates a sub-atmospheric pressure of 125 mmHg for 5 minutes and a 2-minute resting phase of 0 mmHg.
- Cyclic NPWT- The cyclic NPWT system is similar to the intermittent mode in terms of using the same maximal sub atmospheric pressure, but the pressure never reaches zero in the cyclic mode. So, it continuously creates certain pressure gradient that oscillates between 125 mmHg and the preset sub atmospheric pressure.

VARIABLES AFFECTED BY NPWT

Cutaneous capillary network can be investigated with regards to blood flow (BF), velocity (VELO), postcapillary oxygen saturation (StO₂), and relative hemoglobin content (rHb).¹¹

Blood Flow (BF)

Regardless of the application of different pressure levels, intervals of suction and cutaneous blood flow below the foam dressing was significantly enhanced in all three types.

Post-capillary Tissue Oxygen Saturation (STO₂)

Corresponding to enhancements in cutaneous BF, STO₂-values steadily increased when suction was active.

Relative Hemoglobin Content (rHb) and Red Blood Cell Velocity (VELO)

Both parameters were significantly altered due to the NPWT stimulus.

Pain/Discomfort

As expected, reported levels of discomfort were nominal. No statistic difference was found in comparison of maximum values between groups ($p > 0.05$).

Surface Pressure

Applied suction caused significant changes in the surface pressure (sp) of the underlying skin.

Remote Effects

Cutaneous microcirculation of the contralateral thigh was also affected by NPWT treatment. It shows virtually a linear increase in BF 90 min in all three types.

Advantage of cyclic NPWT

- Less painful when compared to intermittent NPWT.
- Superior effects on local and remote cutaneous perfusion in the cyclic type compared to others.

Disadvantage of cyclic NPWT

- Requires expansive devices to fluctuate between sub atmospheric pressure.
- To perform cyclic NPWT in classic suction device is cumbersome.

DISCUSSION

Within this preclinical study on acute changes of cutaneous microcirculation under an applied NPWT dressing, we observed a significant increase of local perfusion dynamics with consecutive improvement of tissue oxygen saturation.

Interestingly, all three compared modes of application, continuous, intermittent, and cyclic, resulted in locally enhanced microcirculation of a greater or lesser extent.

In the comparison of different application modes, we observed superior effects on local and remote cutaneous perfusion in the cyclic group.

The continuous mode represented the most common setting in clinical wound care according to a published meta-analysis of Suissa et al. in 2011, in which discontinuous applications were rarely reported.¹²

Notably, continuous treatment represents the generally accepted standard of care despite already available early evidence of superior capabilities of an intermittent NPWT treatment with respect to formation of granulation tissue or angiogenesis. Most likely, this is attributable to the fact that intermittent activation of "negative-pressure," which causes repeated spikes in surface pressure to the wound, is believed to be unpleasing.

Lately, the introduction of the "cyclic-mode"

appears as a promising compromise combining both the satisfaction of patients and superior wound treatment.¹³ Pain levels were generally low in cyclic NPWT.

In human cutaneous microcirculation, resting capillary pressure was reported in a range from 10.5 to 22.5 mmHg or even 41.0 mmHg.^{14,15} Thus, applied surface pressure of 30.0 mmHg via a NPWT dressing could potentially result in an occlusion of cutaneous capillaries. Given the finding that capillary pressure also increases in response to a higher venous pressure, at least a sub-total occlusion of the dermal microvasculature due to the intervention can be assumed.¹⁶ Overall, the mechanisms of cutaneous vascular response to certain stimuli are complex, especially concerning vasodilation and improvement of local flow.¹⁷ Repeated capillary (subtotal) occlusion represents a strong stimulus for the affected tissue. Both post-occlusive reactive hyperemia (PORHA) and increased mechano-humoral transduction to the vascular bed result in alterations of intravascular shear stress and could be accountable for superior effects in the intermittent and, particularly, in the cyclic group.^{18,19} We also assessed changes of cutaneous microcirculation on the contralateral thigh and found stronger effects in the cyclic group. Previous studies on Remote Ischemic Conditioning (RIC), showed alterations in the applied stimulus can influence the triggered improvement of cutaneous perfusion.^{20,21}

Duration of applied pressure, number of repeated cycles, and body site are important variables to optimize the conditioning effect on the improvement of remote microcirculation.

An ideal application of a NPWT dressing must respect the individual circumstances of each patient and treated wounds with respect to comorbidities, location of the wound, and tissue composition.²²

CONCLUSION

Cyclic application of "negative pressure" results in a superior local enhancement of cutaneous microcirculation with regards to blood flow and consecutive tissue oxygenation. Beyond that, repeated alterations between different levels of "negative pressure" due to cyclic application represent a greater stimulus for remote conditioning effects, indicating a superior local interaction with the underlying tissue. Further research is warranted to investigate the correlation between local perfusion enhancements and granulation tissue formation due to cyclic NPWT in humans.

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