ROLE OF CYCLIC NEGATIVE PRESSURE WOUND THERAPY IN THERMAL BURNS PATIENT

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(Received 13th June 2025; revised 05th October 2025; accepted 20th October 2025)

Abstract. This article provides an in-depth examination of the evolution of Negative Pressure Wound Therapy (NPWT), with a particular focus on the cyclic mode, which offers a compelling alternative to continuous and intermittent NPWT. The cyclic NPWT system operates by maintaining sub-atmospheric pressure while oscillating between preset levels, never reaching zero, thereby enhancing local blood circulation and oxygenation at the wound site. The authors assert that this therapy provides superior microcirculation improvements compared to other NPWT methods, with the added benefit of being less painful for patients than the intermittent mode. A critical analysis of this approach highlights the transformative potential of cyclic NPWT in managing both acute and chronic wounds. The article positions cyclic NPWT as a more patient-friendly option that retains the efficacy of traditional intermittent NPWT without the discomfort associated with pressure fluctuations. These advantages are particularly significant for patients requiring long-term wound care, as the reduced pain and enhanced healing could improve patient compliance and overall outcomes. However, while promising, the research calls for further studies to validate the clinical superiority of cyclic NPWT in various settings. Long-term research is essential to assess its impact on granulation tissue formation, wound closure, and overall healing. The article also highlights limitations in current NPWT devices, emphasizing the need for more accessible and cost-effective solutions to optimize patient care in diverse healthcare environments. In conclusion, this study contributes significantly to the field of wound care, suggesting that cyclic NPWT could become a cornerstone of modern wound healing practices by combining pain reduction with enhanced efficacy. Further clinical evidence and technological advancements are necessary to fully realize it’s potential.
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. 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 (Argenta and Morykwas, 1997; Morykwas et al., 1997). 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. 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

eISSN: 2785-8243
https://doi.org/10.55197/qjmhs.v4i6.176

zero in the cyclic mode. So, it continuously creates certain pressure gradient that oscillates between −125 mmHg and the preset sub atmospheric pressure. The cycle runs based on the changes in sub atmospheric pressure, not time, and thus its frequency reflects the wound volume.

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) (Glass and Nanchahal, 2012). 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. There are three types of NPWT: (1) Continuous NPWT- the continuous mode constantly applies a sub-atmospheric pressure of −125 mmHg. (2) 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. (3) 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.

Materials and Methods

The study focuses on the clinical application of Cyclical Negative Pressure Wound Therapy (CRONPWT) in the treatment of thermal burns. The patient, a 37-year-old male with bilateral gluteal region burns (*Figure 1*), received multiple functional regenerative therapy dressings, incorporating scaffold technology in conjunction with CRONPWT, following debridement (*Figure 2* and *Figure 3*). Cyclical NPWT differs from other forms by maintaining sub-atmospheric pressure oscillating between preset levels without reaching zero, thereby enhancing microcirculation and oxygenation at the wound site. This therapy has shown to be less painful compared to traditional intermittent modes, thus improving patient compliance during the healing process. The application of CRONPWT, with five therapy sessions administered post-debridement, aimed to stimulate tissue regeneration, optimize wound perfusion, and ultimately accelerate recovery.

eISSN: 2785-8243
https://doi.org/10.55197/qjmhs.v4i6.176

Figure 1. *Wound time of admission.*

Figure 2. *Raw area after debridement.*

Figure 3. *After applying CRONPWT.*

The materials and methods involved in this study reflect a structured approach to wound care, integrating advanced therapeutic technologies. The use of scaffold-based regenerative therapy provides a supportive matrix for cell migration, tissue formation, and angiogenesis, thus promoting faster healing in burn injuries. Scaffold technology used in conjunction with CRONPWT offers an ideal environment for cell proliferation and collagen synthesis, essential for burn wound healing. The cyclical application of NPWT allows for a dynamic pressure gradient that optimizes local tissue oxygenation and vascularization, crucial for healing thermal burns. The technique's ability to oscillate pressure levels enables increased local blood flow and enhances the formation of granulation tissue, a key factor in wound healing. The process has been carefully monitored, with *Figure 2* and *Figure 3* showing the progression from raw post-debridement tissue to an improved wound site post-therapy.

In addition to evaluating the effectiveness of CRONPWT, this study also explores its comparative advantages over other NPWT methods, particularly in terms of pain reduction and enhanced healing outcomes. Clinical evidence suggests that the cyclic pressure mode improves wound microcirculation without causing the painful spikes associated with intermittent pressure modes. By avoiding complete pressure relief, CRONPWT maintains an optimal pressure gradient that supports tissue regeneration and reduces the risk of ischemia. Previous studies on NPWT in burn wounds have shown that enhanced perfusion leads to faster wound closure and better overall outcomes. The five CRONPWT applications in this study resulted in improved wound conditions, as evidenced by the photographs (*Figure 2* and *Figure 3*), suggesting that the cyclic mode is an effective and less painful option for burn wound management. This method, although promising, requires further investigation to fully establish its long-term benefits and applicability in a broader range of wound types.

Results and Discussion

Cyclical NPWT is useful in improving the wound healing of burns in patient as we have seen in this study (*Figure 4*). 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 (Borgquist et al., 2010; Kairinos et al., 2009). 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-doppler velocimetry, was questioned to be flawed due to the impact of “pressure-artifacts” (Kairinos et al., 2014), 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 (Müller-Seubert et al., 2021; Muenchow et al., 2019; Sogorski et al., 2018). Additionally, NPWT was also successfully applied in free tissue transfer, with a reduction of postoperative tissue damage instead of an increment (Eisenhardt et al., 2012). No adverse effects of negative pressure were found. In a previous analysis, we used continuous laser-doppler flowmetry combined with white-light spectroscopy for a comprehensive real-time analysis of microcirculatory changes under an NPWT dressing (Sogorski et al., 2018). Application of an intermittent negative pressure resulted in a stepwise increase in local tissue perfusion with a consecutive enhancement of tissue oxygen saturation.

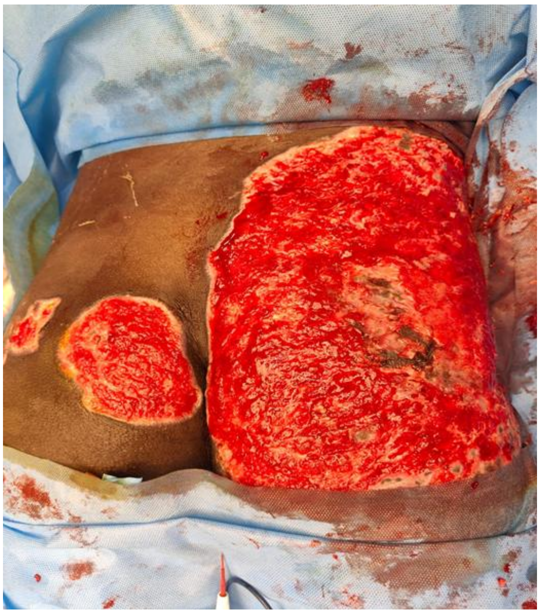

Figure 4. *Wound after the CRONPWT Treatment.*

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. (2011), in which discontinuous applications were rarely reported. 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 (Lee et al., 2015). 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 (Shore, 2000; Fagrell, 1985). 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 (Mahy et al., 1995). Overall, the mechanisms of cutaneous vascular response to certain stimuli are complex,

eISSN: 2785-8243
https://doi.org/10.55197/qjmhs.v4i6.176

especially concerning vasodilation and improvement of local flow (Wong and Hollowed, 2017). 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 (Glass et al., 2014; Wilkin, 1986). 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 (Sogorski et al., 2021; Kolbenschlag et al., 2017). 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.

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). 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: (1) Less painful when compared to intermittent NPWT. (2) Superior effects on local and remote cutaneous perfusion in the cyclic type compared to others. Disadvantage of cyclic NPWT: (1) Requires expansive devices to fluctuate between sub atmospheric pressure. (2) To perform cyclic NPWT in classic suction device is cumbersome. 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 (Borgquist et al., 2011).

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.

Acknowledgement

This research is self-funded.

Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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