Review Article | Odisha Journal Of Orthopaedics and Trauma| January 2020 | 01: 41-45

Negative pressure wound therapy... A healing touch approach to difficult wounds in orthopedic practice... A systematic review

Bikram Kar[1], Buddhadeb Nayak[1], Harshal Sakale[1], Alok C Agrawal[1]

Abstract

The routine use of Negative Pressure Wound Therapy (NPWT) in big and complex wounds has gained the momentum over the past couple of years .In addition to surgical debridement for treating tissue defects around open fractures and chronic non healing ulcers, contaminated wounds in orthopaedic trauma, open fractures with soft tissue defects, its usage is frequently seen with increasing evidence to aid closed incisions having high risk of wound breakdown. Also the evidence for its use on skin grafts is now well established.

This review will analyze the available literature in order to summarize the current understanding of NPWT in terms of its mechanism of action, its applications, complications, contraindications and its future. Research on the application of NPWT in treating chronic non-healing wounds has largely taken the form of case studies, single-center studies, non-randomized controlled trials, with few randomized controlled trials (RCTs). Our aim is to summarize the current and emerging indications for negative pressure wound therapy in Orthopaedic trauma and the existing evidence for its use.

Keywords: Negative pressure wound therapy, Open fractures, Trauma, Wound management.

Introduction

The use of negative-pressure wound therapy has also been described initially in the treatment of acute war related wounds, Negative pressure wound therapy (NPWT), also known as topical negative pressure, Vacuum assisted closure (VAC) has now become an important adjuvant therapy for the treatment of many types of wounds. In all sub-specialities Surgeons and physicians have adopted NPWT into their practices. In patients with traumatic, post surgical, diabetic, and peripheral vascular disease-associated wounds, NPWT has become an important tool in the management of lower extremity soft tissue injury. This article reviews the background, currently understood mechanisms of action, indications, contraindications, complications, advantages, disadvantages and techniques in the use of VAC which has become an important adjuvant for managing, closing, and preparing wounds for skin grafting. This system rapidly debrides contaminated wounds, reduces edema, decreases wound size, and induces granulation tissue. Wounds are then treated by delayed primary closure, or skin grafting, may be with local flap coverage.

NPWT

In NPWT, initially the wound is filled with a porous material such as gauze or foam, that behaves as a pressure transmitter across the wound. Above the porous material, a drainage port is then attached and the wound is sealed with an adhesive film dressing. The drainage port is connected to a controlled vacuum pump which maintains negative pressure, usually ranging from -50 to -150 mmHg [1,2]. The pressure can be applied in a continuous, intermittent, or variable mode, with the continuous type being the most frequently used. In the variable mode, the suction level changes but is never turned off, whereas in the intermittent mode the pressure is switched on and off throughout the course of treatment.

The specific interface material that contacts the wound surface affects the biological response of the system. The most commonly used material is a reticulated open-pore polyurethane (PU) foam that forms a structure resembling a three-dimensional net. This lattice configuration allows the vacuum to be distributed evenly throughout the foam and improves the drainage of fluid and serosanguinous collections.

[1]?Department of Orthopaedics, SCB Medical College, Cuttack, Odisha India.

Address of Correspondence
Dr. Buddhadeb Nayak,
SCB Medical College, Cuttack, Odisha India.
E-mail: buddhadeb9188@gmail.com

VAC-Foam

In practice, routinely three foam types are being used in the VAC systems. Black polyurethane ether (VAC GranuFoam, KCI) is the most commonly used foam, and black polyurethane ester (VAC VeraFlow, KCI) is used in instillation systems. The white polyvinyl alcohol (VAC WhiteFoam, KCI) foam has very small pore sizes and is used to protect critical structures without inducing micro-deformations which is an important mechanism of its action.

Gauze-based system

Usage of gauze in NPWT is based on the Chariker-Jeter method of application, which uses a moistened antimicrobial gauze (AMD; Covidien, Hampshire, United Kingdom) as a wound interface, along with 80 mmHg of negative pressure and a silicone drain [3]. In one retrospective study with a mixed group of patients with challenging wounds, gauze used as a wound filler material was found to achieve reductions in wound size and volume comparable with published data from polyurethane foam-based systems [4].

parts of NPWT

1. A special pump is used to apply negative pressure
2. Track pad with suction tubing connects to a canister to collect the fluid drainage.
3. A thin clear occlusive dressing seals over the wound.
4. Special foam padding is placed on or within the wound.

The NPWT system

- Draws fluid from the wound, decreases edema.
- Allows the wound to shrink in.
- Encourages new granulation tissue to proliferate.
- Both foam and gauze have been shown to be equally effective at wound contraction and stimulation of blood flow at the wound edge [5]. Foam has been shown to provide rapid granulation, but this can be offset by in-growth with potential to disturb the epithelialization process and also be painful when the foam is changed [6-9].

Primary mechanisms

NPWT is thought to promote wound healing via four primary mechanisms: (1) fluid removal; (2) macro-deformation; (3)micro-deformation; and (4) alteration of the wound environment.

Fluid removal:

By removing fluid, the compression forces acting on the microvasculature allow increased blood flow and perfusion of the tissue [10]. The adhesive film dressing covering the wound is semipermeable and hence allows some air to enter the system preventing a fluid lock and enabling continuous fluid removal.

Macro-deformation:

Macrodeformation, or wound shrinkage, occurs when suction is applied to the foam causing pore collapse. This results in deformational forces being exerted on the wound edges, which draws them together. Macrodeformation can also induce compressive forces such as when these devices are used circumferentially on extremities [11,12]. Studies in a porcine model showed that suction of 125 mmHg can decrease the volume of a PU foam by approximately 80% resulting in a significant shrinkage of the wound [13,14].

Micro-deformation:

Microdeformation is the mechanical changes which occur on the microscopic scale when suction is applied to the porous material resulting in an undulated wound surface. Via the extracellular cell matrix (ECM), mechanical forces, which include compression and tension from the foam, shear and hydrostatic forces from the extracellular fluid, and the effect of gravity, are transmitted throughout the tissue shear forces which affect the cytoskeleton and activate a signaling cascade, similarly upregulates granulation tissue formation and, hence, enhances wound healing [15-17]. Besides that, microdeformation is believed to stimulate angiogenesis on the the wound bed [1]. The details have been described in the secondary effects of NPWT. Localized hypoxia produced by Microdeformation also results in an increase in local vascularity.

Alteration of the wound environment: Continuous evacuation of fluid along with proteins and electrolytes may stabilize osmotic and oncotic gradients at the wound surface. A warm wound environment [10] is produced by the insulating action of foam and drape. The semipermeable nature of drape helps in maintaining a sterile, moist environment by reducing wound contamination with microorganisms and also minimizes evaporation of water from the wound.

These four primary mechanisms of NPWT affect various wound healing processes including neurogenesis, hemostasis, angiogenesis, modulation of inflammation, cellular proliferation, differentiation, and migration, granulation formation, and alterations in bioburden.

MDWT has been related to upregulation of neurotrophin nerve growth factor, substance-P, and calcitonin gene-related peptide [18]. There occurs a transient elevation Epinephrine and norepinephrine, which is followed by a slower but more long-lasting elevation of substance P and neuropeptide- Y. Neuropeptides are believed to be key homeostatic factors in the skin which play a role in the secondary effects of NPWT. The extent of neurogenesis has been directly linked to the level of microdeformation. In addition, intermittent suction results in greater neurogenesis than continuous MDWT. MDWT treatment of chronic wounds results in increased micro vessel density. Microdeformation causes temporary hypoperfusion to the wound edge resulting in localized hypoxia of the tissues, subsequent upregulation of hypoxia-inducible factor-1α and in turn increased VEGF expression which ultimately leads to increased angiogenesis [19]. Similar results to angiogenic response stimulation have been replicated in in vitro studies using intermittent MDWT. Furthermore, in vivo studies in patients have shown a difference between the initial and final stages of wound healing. Initially MDWT results in upregulation of angiogenin-2 (Ang-2) expression and downregulation of angiogenin-1 (Ang-1) expression, hence leading to decreased ratios of Ang-1/Ang-2. This favors destabilization and regression of micro vessels leading to increased angiogenesis. In contrast, in the latter stages, Ang-1 is increased and the ratio of Ang-1/Ang-2 also increases. There occurs a Phosphorylation of tyrosine kinase receptor-2, which enhances micro vessel stabilization and promoting micro vessel maturation.

Objective

The objective of this study is to investigate the safety and effectiveness of negative-pressure wound therapy use in the treatment of patients with compound fractures, non healing chronic wounds, diabetic ulcerations, resistant bed sores.

Methods

Randomized controlled trials and larger studies have been published studying the clinical benefits of NPWT in orthopaedic trauma setting as well as in many surgical cases. This allows clinicians such as those in the International Negative Pressure Wound Therapy Expert Panel (NPWT-EP), who have met annually since 2009, to establish an international consensus that allows the formulation of clinical guidelines.

Encourages new healthy tissue growth and blood vessels to form We searched the following electronic databases to identify reports of relevant randomized clinical trials: the Cochrane Wounds Group Specialized Register (searched 11 November 2011); the Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library 2011, Issue 4); Database of Abstracts of Reviews of Effects (The Cochrane Library 2011, Issue 4); Ovid MEDLINE (2005 to October Week 4 2011); Ovid MEDLINE (In-Process & Other Non-Indexed Citations 8 November 2011); Ovid EMBASE (2009 to 2011 Week 44); and EBSCO CINAHL (1982 to 04 November 2011). One trial (87 participants) compared a commercial negative pressure device (VAC® KCI, San Antonio, Texas) with a negative pressure system developed in the hospital (GSUC). The wound complication rate was lower in the GSUC group (VAC® 3/42; GSUC 0/45); the RR was 0.13 (95% CI 0.01 to 2.51). The mean cost to supply equipment for VAC® therapy was USD 96.51/day compared to USD 4.22/day for the GSUC therapy (P = 0.01). Labour costs for dressing changes were similar. Pain intensity score was also reported to be lower in the GSUC group when compared with the VAC® group (p = 0.02). Indications for the use of negative pressure wound therapy (NPWT) have included including the use on clean, closed incisions and skin grafts. Joan Webster et al concluded that there is no evidence for the effectiveness of NPWT on complete healing of wounds expected to heal by primary intention. There are clear cost benefits when non-commercial systems are used to create the negative pressure required for wound therapy, with no apparent reduction in clinical outcome. Pain levels are also rated lower when hospital systems are compared with their commercial counterparts. The high incidence of blisters occurring when NPWT is used following orthopaedic surgery suggests that the therapy should be limited until safety in this population is established.

Malmsjö M et al [20] Negative-pressure wound therapy using gauze or open-cell polyurethane foam: similar early effects on pressure transduction and tissue contraction in an experimental porcine wound model.

The experimental study designed by them shows that gauze and foam are equally effective at delivering negative pressure and creating mechanical deformation of the wound.

Diabetic foot wounds, particularly those secondary to amputation, are very complex and difficult to treat.

David G Armstrong, et al [21] have done a amulticenter, randomized controlled trial on Negative pressure wound therapy after partial diabetic foot amputation. They have investigated whether negative pressure wound therapy (NPWT) improves the proportion and rate of wound healing after partial foot amputation in patients with diabetes and found that; More patients healed in the NPWT group than in the control group (43 [56%] Vs 33 [39%], p=0•040). The rateof wound healing, based on the time to complete closure, was faster in the NPWT group than in controls (p=0•005).

The rate of granulation tissue formation, based on the time to 76–100% formation in the wound bed, was faster in the NPWT group than in controls (p=0•002). The frequency and severity of adverse events (of which the most common was wound infection) were similar in both treatment groups.

Retrospective clinical evaluation of gauze-based negative pressure wound therapy PE Campbell, GS Smith…et al [4] have demonstrated that Negative pressure wound therapy (NPWT) is an established modality in the treatment of challenging wounds. However, most existing clinical evidence is derived from the use of open-cell polyurethane foam at– 125 mmHg. Alternative negative pressure systems are becoming available, which use gauze at a pressure of 80 mmHg which is more or less similar to the effectiveness of polyurethane foam , but excitingly cost effective .

MW Kaufman et al [7] published their article stating that the management of chronic, nonhealing, draining wounds is challenging for the wound continence nurse and other health care providers involved in skin integrity care. Vacuum-assisted closure (VAC) therapy has proven cost efficient, safe, and effective as a treatment modality in wound care.

Resection of musculoskeletal tumors may result in large soft tissue defects that cannot be closed primarily and require prolonged dressing changes and complex surgical interventions for wound coverage. Jacob Bickels et al [8] retrospectively reviewed 23 patients with such defects treated with a vacuum-assistedwound closure system and compared the outcome of these patients with a control group. The study group included 15 women and 8 men who had their wounds located at the back (two), pelvic girdle (eleven), thigh (eight), and leg (two). Treatment included sealed wound coverage with poly-urethane foam and overlying tape connected to a vacuum pump. The use of vacuum-assisted wound closure facilitates wound healing and primary wound closure in patients who have a large soft tissue defect after resection of a musculoskeletal tumor.

Shirakawa M1, Isseroff RR [9] also concluded that Topical negative pressure devices have been used effectively in a number of different types of wounds, including chronic wounds. They are believed to hasten wound healing by (a) maintaining a moist environment, (b) removing wound exudates, (c) increasing local blood flow, (d) increasing granulation tissue formation, (e) applying mechanical pressure to promote wound closure, and (f) reducing bacterial loads in the wound. Multiple non randomized, non-controlled studies have reported that the use of these devices results in faster healing times and more successful closures. Five small randomized, controlled trials have also shown favorable outcomes with the use of topical negative pressure devices compared with conventional treatment.

N. Kairinos, et al [22] enquired whether negative-pressure wound therapy reduce or increase the pressure of wound tissues? This question has never been addressed by a study on living tissues. Their study was to evaluate the nature of tissue pressure changes in relation to negative-pressure wound therapy.

In their study, three negative-pressure wound therapy dressing configurations were evaluated - circumferential, non circumferential, and those within a cavity - on 15 human wounds, with five wounds in each category. Tissue pressure changes were recorded (using a strain gauge sensor) for each 75-mmHg increment in suction, up to 450 mmHg. In the circumferential and noncircumferential groups, tissue pressure was also measured over a 48-hour period at a set suction pressure of 125 mmHg (n = 10).

In all three groups, mean tissue pressure increased proportionately to the amount of suction applied ($p < 0.0005$). Mean tissue pressure increments resulting from the circumferential dressings were significantly higher than those resulting from the non circumferential ($p < 0.0005$) or cavity group ($p < 0.0005$); however, there was no significant difference between the latter two groups ($p = 0.269$). Over the 48-hour period, there was a significant mean reduction in the (increased) tissue pressure ($p < 0.04$ for circumferential and $p < 0.0005$ for non circumferential), but in only three of 10 cases did this reduce to pressures less than those before dressing application.

They concluded that: Negative-pressure wound therapy increases tissue pressure proportionately to the amount of suction, although this becomes less pronounced over 48 hours. This suggests that negative-pressure wound therapy dressings should be used with caution on tissues with compromised perfusion, particularly when they are circumferential.

Conclusion

In a number of orthopaedic trauma related wounds, NPWT behaves an attractive alternative to standard dressings. It acts as a sealant against contamination and reduces the number of dressing changes. It also causes a significant reduction in the rate of infection. Routine NWPT practice should always include regular wound re-evaluation with debridement and irrigation as required. With increasing adoption of NPWT and some good evidence for its efficacy, research centers may now not be willing to subject patients to standard dressings as control groups for trials.

In recent years, there are some extended indications, with some encouraging early results from the use of NPWT on post-traumatic surgical incisions, burn wounds, and skin grafts. Although various types of systems are being practiced in different centers, principle remains same and efficacy also remain similar. Further studies are, however, still required in a number of areas such as the duration of therapy, the effect on antibiotic concentration, and the effect on the type of dressing subjected to NWPT; for example silver impregnated, or gauze versus sponge.

References

1. Huang C, Leavitt T, Bayer LR, Orgill DP. Effect of negative pressure wound therapy on wound healing. CurrProbl Surg. 2014;51:301-331.
2. Malmsjö M, Borgquist O. NPWT settings and dressing choices made easy. Wounds International. 2010;1:1-6.
3. Chariker ME, Jeter KF, Tintle TE, Ottsford JE. Effective management of incisional and cutaneous fistulae with closed suction wound drainage. Contemp Surg. 1989;34:59 63.
4. Campbell PE, Smith GS, Smith JM. Retrospective clinical evaluation of gauze-based negative pressure wound therapy. Int Wound J. 2008;5:280-286.
5. Malmsjo M, Ingemansson R, Martin R, Huddelston E. Negative pressure wound therapy using gauze or polyurethane open cell foam: similar early effects on pressure transduction and tissue contraction in an experimental porcine wound model. Wound Repair Regen. 2009;17(2):200–5.
6. Campbell PE, Smith GS, Smith JM. Retrospective clinical evaluation of gauze based negative pressure wound therapy. Int Wound J. 2008;5:280–6.
7. Kaufman M, Pahl D. Vacuum-assisted closure therapy: wound care and nursing implications. Dermatol Nurse. 2003;4:317–25.
8. Bickels J, Kollender Y, Wittig JC , et al. Vacuum-assisted closure after resection of musculoskeletal tumours. ClinOrthopRelat Res. 2005;441:346–50.
9. Shirikawa M, Isseroff R. Topical negative pressure devices. Arch Dermatol. 2005;141(11):144
10. Argenta LC, Morykwas MJ. Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. Ann Plast Surg. 1997;38:563-576; discussion 577
11. Kairinos N, Solomons M, Hudson DA. Negative-pressure wound therapy I: the paradox of negative-pressure wound therapy. PlastReconstr Surg. 2009;123:589-598; discussion 599-600.
12. Kairinos N, Solomons M, Hudson DA. The paradox of negative pressure wound therapy--in vitro studies. J PlastReconstrAesthet Surg. 2010;63:174-179.
13. Scherer SS, Pietramaggiori G, Mathews JC, Prsa MJ, Huang S, Orgill DP. The mechanism of action of the vacuum-assisted closure device. PlastReconstr Surg. 2008;122:786-797]
14. Borgquist O, Ingemansson R, Malmsjö M. The influence of low and high pressure levels during negative-pressure wound therapy on wound contraction and fluid evacuation. PlastReconstr Surg. 2011;127:551-559
15. Lancerotto L, Bayer LR, Orgill DP. Mechanisms of action of microdeformational wound therapy.Semin Cell Dev Biol. 2012;23:987-992. [PubMed] [DOI]
16. Younan G, Ogawa R, Ramirez M, Helm D, Dastouri P, Orgill DP. Analysis of nerve and neuropeptide patterns in vacuum-assisted closure-treated diabetic murine wounds. PlastReconstr Surg. 2010;126:87-96.
17. Armstrong DG, Lavery LA. Diabetic Foot Study Consortium.Negative pressure wound therapy after partial diabetic foot amputation: a multicntre randomized controlled trial. Lancet. 2005; 366(9498):1704
18. Rivilis I, Milkiewicz M, Boyd P, Goldstein J, Brown MD, Egginton

S, Hansen FM, Hudlicka O, Haas TL. Differential involvement of MMP-2 and VEGF during muscle stretch- versus shear stress-induced angiogenesis. Am J Physiol Heart Circ Physiol. 2002;283:H1430-H1438.

19. Quinn TP, Schlueter M, Soifer SJ, Gutierrez JA. Cyclic mechanical stretch induces VEGF and FGF-2 expression in pulmonary vascular smooth muscle cells. Am J Physiol Lung Cell Mol Physiol. 2002; 282:L897-L903.

20. Urschel JD, Scott PG, Williams HT. The effect of mechanical stress on soft and hard tissue repair; a review. Br J Plast Surg. 1988;41:182-186.

21. Orgill DP, Manders EK, Sumpio BE, Lee RC, Attinger CE, Gurtner GC, Ehrlich HP. The mechanisms of action of vacuum assisted closure: more to learn. Surgery. 2009;146:40-51.

22. N. Kairinos, et al Wound Healing Southern Africa, Volume 10 Number 2, Dec 2017, p. 6 – 14.

Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

Kar B, Nayak B, Sakale H, Agrawal A C. | Negative pressure wound therapy… A healing touch approach to difficult wounds in orthopedic practice… A systematic review. | Odisha Journal of Orthopaedics and Trauma | January 2020; 01: 41-45 .