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Negative Pressure Wound Therapy

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Continuing Education Activity

Negative pressure wound therapy (NPWT) aims to optimize the physiology involved in wound healing by applying sub-atmospheric pressure to help reduce inflammatory exudate and promote granulation tissue. It is primarily utilized to treat complex wounds which are non-healing or at risk of non-healing, such as diabetic foot ulcers or skin grafts. All medical personnel can implement NPWT; however, specific training and a sufficient level of expertise must be obtained prior to application. This activity outlines the background information and practical application of NPWT and explains the role of the healthcare team in managing patients who undergo NPWT.

Objectives:

- Describe the anatomy and physiology behind negative pressure wound therapy.
- Identify the indications and contraindications of negative pressure wound therapy.
- Summarize how to apply a negative pressure wound dressing to appropriate wounds.
- Explain the clinical significance of negative pressure wound therapy.

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Introduction

Negative pressure wound therapy (NPWT) is a broad term used to describe a unique and versatile system that aids the optimization of wound healing through the application of sub-atmospheric pressure to help reduce inflammatory exudate and promote granulation tissue. It can be utilized to manage acute and chronic wounds, ranging from open fasciotomy wounds and diabetic foot ulcers to closed surgical incisions.

NPWT has undergone a significant evolution since the first modern-day recorded application of this concept in the 19 century.[1] The most recent iteration of NPWT is courtesy of Argenta and Morykwas, who demonstrated its efficacy in their paper published in 1997. This type of NPWT system comprises a porous foam dressing upon which continuous or intermittent suction is applied through an electronically powered suction device to achieve a sub-atmospheric pressure of 125mmHg below ambient pressure.[2]

The system has seen widespread uptake and is now implemented routinely for open wounds, such as open fractures, fasciotomies, ulcers, and infected wounds. Termed Vacuum-Assisted Closure (often abbreviated to “VAC”), this system is only effective if applied correctly by trained individuals. It is usually performed in the operating room, given the fact that the wounds usually require debridement and a washout in a sterile environment.

More modern iterations of this system now offer advanced options to enhance the delivery of the NPWT, such as a range of pressure settings from -40mmHg to -200mmHg, which can be tailored for different types of wounds. The material from which the foam is derived is either polyurethane (PU) (black) or polyvinyl alcohol (PVA) (white).[3] Additionally, disposable wound VACs, either battery operated or purely mechanic suction, are available for use and typically used for smaller wounds.

In more recent years, NPWT has also been adapted for the adjunctive treatment of closed wounds, such as closed surgical incisions and skin grafts.[4] This aims to reduce edema and seroma formation, prevents surgical dihisence in high-risk incision sites, and promote granulation to encourage healing. While the available evidence shows equivocal results for wound healing, this wound management system has seen a widespread implementation for closed wounds prone to dehiscence or infection secondary to exudate and localized inflammation.[5]

An emergent adaptation of NPWT is using fluid instillation in conjunction with NPWT to enhance the therapy delivered. This comprises the direct administration of saline or antibiotic-containing solution into the wound bed, followed by a period of time ranging from ten to twenty minutes to allow for the distribution of the solution throughout the wound. Negative pressure is then applied at 125mmHg below atmospheric pressure for a sustained duration of up to six hours, after which the fluid instillation recurs.[6]

NPWT provides an impactful and exciting development in wound care, with different clinical applications. This article explains the mechanism of NWPT along with the indications, contraindications, and practical approaches to this advanced wound care modality.

Anatomy and Physiology

The skin is a laminated structure, comprising (from superficial to deep) the epidermis, dermis, and hypodermis, which is also referred to as the subcutaneous or fatty tissue layer. The epidermis is further subdivided into (from superficial to deep) stratum corneum, stratum lucidum, stratum granulosum, stratum spinosum, and stratum basale. Each layer has its unique structure and cellular composition, contributing to its characteristic function within the epidermis.[7] These microscopic processes, in turn, contribute to the macroscopic processes involved in the continual daily maintenance of skin, including wound healing.

Wound healing is divided into acute and chronic phases. An acute injury to the skin initially induces a proinflammatory cascade comprising hemostasis followed by inflammation. This involves neutrophils and various cytokines and occurs over the first seven days after the injury. The inflammation then slowly begins to settle into the proliferative and re-epithelialization phases of wound healing. This commences with angiogenesis and reinnervation involving endothelial cells and fibroblasts, which leads to the cardinal element of wound healing: the formation of healthy granulation tissue.[8]

As granulation tissue begins to form, a shift towards the final stage of wound healing occurs, known as the remodeling phase, to restore the epithelium of the skin. This phase can last for anywhere between 12 to 24 months and involves collagen deposition, mediated by growth factors such as fibroblast growth factor and epidermal growth factor, to form a cross-linked matrix.[9][10]

Contrastingly, a chronic wound comprises a skin lesion that has failed to heal within the expected timescale of a normal wound. It is thought that stasis in the inflammatory phase of wound healing is the most common characteristic of these wounds and indicates a frank dysregulation of normal processes. Usually, there is a causative proponent, such as repetitive tissue stress, or an ongoing inflammatory trigger such as microbial infection.[11]

The archetypal pathological process implicated in chronic wounds entails protease-induced extracellular matrix destruction, infiltration of proinflammatory cytokines, and attenuated growth factor signaling. This, in combination with excessive fibrous tissue deposition, such as collagen and fibronectin, ultimately creates a vicious cycle that propagates inflammation and prevents any progression to the proliferative phase. The cardinal microscopic findings in

chronic wound tissue are macrophages, excessive granulation tissue, and fibrosis. Eventually, this leads to excessive scar formation and poor skin compliance.

NPWT aims to optimize the physiology involved in wound healing through various processes, many of which have thus far only been studied in an in-vitro laboratory setting. However, the known principal mechanisms are macro deformation, micro deformation, excess fluid removal, and equilibration of the wound microenvironment. It is useful to appreciate the mechanism of action of NPWT as a continuum of multiple contributory factors as opposed to standalone, hypothetical occurrences.

First, wound shrinkage is incurred by directly applying 125 mmHg of sub-atmospheric pressure to the foam. This mechanical process is called macro deformation, which can reportedly reduce wound space by approximately 80%. Second, suction through the pores in the foam invokes mechanical stress on the wound surface, which causes microscopic ripples to form along the wound edge due to increased tissue tension. This process is known as micro deformation and promotes normal cellular proliferation, migration, differentiation, and angiogenesis due to induced hypoxia causing the release of vascular endothelial growth factors. Third, the negative pressure directly transports excess inflammatory exudate away from the wound site, alleviating wound bed tissue compression and helping to restore microvascular circulation. Lastly, removing excess extracellular fluid helps establish a normal oncotic and osmotic pressure gradient through the extrication of excess proteins and electrolytes. Other adjunctive processes include increased endothelial and epithelial cell migration, as well as keratinocytes. In addition to the thermal insulation of the wound afforded by the sealed NPWT dressing, all these individual mechanisms exert positive effects on the wound tissue and encourage healthy tissue formation to propagate normal wound healing.[12]

Indications

Negative pressure wound therapy is primarily utilized to treat complex wounds which are non-healing or at risk of non-healing. These can be broadly categorized into acute and chronic wounds. NPWT is indicated for acute wounds when the wound cannot be closed by primary intention due to the risk of infection, active infection, skin tension, or swelling.[13]

Traumatic wounds such as open fractures or open lacerations are some of the most commonly observed acute wounds. Other traumatic wounds can include degloving injuries and burns, which cause partial thickness skin loss. The majority of these wounds are at high risk of infection due to contamination from exposure to the surrounding environment. Primary closure or skin grafting of such a wound in the acute setting would simply entrap the microorganisms in the soft tissue and lead to abscess formation. Additionally, retention of devitalized tissue would lead to necrosis and further tissue loss. Therefore, the successful adjunctive use of NPWT relies on a thorough surgical debridement and washout of the wound to promote healthy granulation tissue and encourage wound apposition.

NPWT would also be indicated for dehisced wounds, which can be acute or chronic wounds and often refractory to primary closure. This is because NPWT provides an interim measure to protect the wound bed and enable the resuscitation of the skin, which thereby increases the chances of subsequent successful wound closure. Similarly, NPWT can help cultivate a healthy wound bed to ameliorate the successful uptake of a skin graft for the same reasons.

Additional indications include skin breakdown due to ulceration secondary to multiple etiologies and closed wounds such as surgical incisions, including skin flaps and grafts.[14]

Contraindications

A thorough wound assessment must be carried out before applying negative pressure wound therapy to ensure no harm to the patient is incurred. For instance, any exposed vasculature or organ surfaces should immediately preclude

the use of NPWT due to the serious risk of exsanguination secondary to erosive forces. Non-enteric and unexplored fistulae are also contraindicated due to a similar mechanism of excessive fluid extraction which can lead to dehydration and electrolyte imbalance.[12]

Any necrotic tissue or eschar present in the wound bed, such as in full-thickness burns, can exacerbate non-healing and risk the further spread of necrosis. If either of these issues is identified, the wound requires further intervention or an alternative dressing should be considered.

The presence of underlying malignancy also contraindicates the use of NPWT due to the hypothetical possibility of tumor propagation and metastasis.[15] This should therefore be treated prior to the application of NPWT. Similarly, active osteomyelitis should ideally be treated before NPWT use, although there have been instances described in the literature where this has not been the case without incurring any further damage to the wound.[16]

Equipment

The following equipment is required:

1. Alcoholic chlorhexidine (2% chlorhexidine in 70% isopropyl alcohol) or betadine (7.5% povidone-iodine) preparation
2. Sterile drapes
3. Sterile small fragment orthopedic surgical instrument tray OR sterile standard wound care surgical instrument tray
4. 0.9% sodium chloride x 3 to 6 liters
5. Sterile gauze
6. Non-paraffinized, coated polyester net
7. NPWT pack:
    1. Specialized negative pressure adhesive dressing (closed wounds)
    2. Specialized pre-cut or unprepared foam dressing (open wounds)
    3. Transparent adhesive sealant tape
    4. NPWT suction device

Personnel

All medical personnel can implement negative pressure wound therapy, including physicians, podiatrists, wound care specialists, nurses, nurse practitioners, and physician assistants. However, specific training and a sufficient level of expertise must be obtained before the independent application of any NPWT dressings. This is due to the complex nature of the wounds, which may be refractory to other methods of wound management and therefore prone to further complications if the procedure is performed incorrectly.

Closed wounds are usually dressed either on a hospital floor or clinic by trained healthcare personnel. If the closed wound results from a surgically closed incision or a skin graft, the initial NPWT should be applied in the operating room (OR) by the operating surgeon or surgical scrub nurse. On the other hand, open wounds warrant surgical management at the first stage in the OR. Accordingly, one to two surgeons and an experienced surgical scrub nurse will be necessary throughout the procedure. Once the initial management in the OR has been completed, subsequent NPWT dressing changes can be performed on the ward or in a clinic-based environment by appropriately trained healthcare personnel.

In complex polytrauma cases, an intensive care facility may be considered.

Preparation

Closed wounds can be managed inside or outside of the OR, depending on the nature of the wound. In either case, the equipment is prepared in a sterile field. The wound site is cleaned with an alcoholic chlorhexidine preparation (if not already surgically prepared in the OR) and allowed to air dry before applying the NPWT dressing.

Open wounds require admittance to the OR for initial management and therefore necessitate the pre-operative completion of a written consent form along with patient safety checklists. The consent process should include a discussion about the indications, benefits, and risks of the procedure, with an assurance to tailor each risk to the individual patient in accordance with the Montgomery principles of consent.[17] The equipment is prepared in a sterile field in the OR by the surgical scrub nurse.

The open wound is first sterilized using alcoholic chlorhexidine and then surrounded by a sterile field using sterile drapes as per standard surgical preparation protocols. Once a sterile field has been established, the wound bed itself requires careful preparation before applying the VAC device. This is because any necrotic or infected tissue which remains will impair wound healing through the compromised blood supply and colonization of bacteria.

Thorough debridement of infected or necrotic tissue should be carried out (only indicated at the first application of the VAC device unless further necrosis is identified), followed by a washout of the wound with a copious volume of 0.9% sodium chloride. Following wound bed preparation, the wound should be dried with sterile gauze and protected with a sterile, atraumatic, non-adhesive wound contact layer. Current practice favors a non-paraffinized, coated polyester net. [18]

Technique or Treatment

The patient should be positioned to suitably expose their wound site and the area may be draped off.

Closed wounds are covered with a specialized adhesive dressing, the edges of which are reinforced with wide strips of transparent adhesive sealant tape to create a firm, airtight seal around the dressing. This is the single most essential part of any of the NPWT, as, without an adequate seal, the sub-atmospheric pressure cannot be achieved, and therapy will not be delivered.

Open wounds are covered with a specialized porous foam dressing, which is cut by hand to the exact dimensions of the wound unless it is available in a pre-cut formulation. The foam dressing must cover the whole wound, ideally in a single piece; if the wound is too large, multiple pieces may be utilized to gain adequate coverage. It is essential to document the number of pieces utilized, as this is important for when the dressing is changed to avoid retaining any pieces of foam inside the wound bed.

The foam dressing is covered in turn by large strips of transparent adhesive sealant tape to create a firm, airtight seal around the foam dressing. Depending on the VAC system to hand, a suction drain tube is either placed over the foam dressing before applying the transparent adhesive sealant tape or applied as part of a separate adhesive dressing that is placed on top of the transparent adhesive sealant tape.

Upon completion of the wound dressing, the NPWT suction device should be connected to the suction drain tube to test successful therapy delivery, which is indicated by an electronic signal on the suction device. [19]

Complications

Aside from complications incurred by the contraindicated use of NPWT, the most common complications associated with NPWT are pain, bleeding, infection, and foam retention, which, in turn, can cause an infection. A common mechanical complication is unsuccessful therapy delivery due to loss of suction. This can be due to several possible

causes. The most frequent cause is an inadequate seal around the wound dressing, whereby the transparent adhesive sealant tape has either been misapplied or has come off due to poor contact with the underlying skin. This should be remedied as soon as possible to avoid any delay in the delivery of therapy. Other causes can be the incorrect placement of the suction drain tube, loss of battery power, blockage of the suction drain tube, or a full NPWT suction device.

Other complications can include a hypersensitivity reaction to the dressing materials, further damage to the wound through negative pressure erosion or necrosis, and intra-operative complications, such as damage to surrounding nerves, blood vessels, and soft tissue. If skin breakdown occurs or there is localized pain around the site of the negative pressure, topical emollient therapy can be used, or an alternative non-adherent dressing can be applied under the transparent adhesive sealant tape to reduce skin tension. If any discoloration or duskiness of the wound bed or wound edges are identified, then suction should initially be reduced. If this persists or worsens, then the device should be switched off.[12]

It is also important to remain vigilant for dehydration secondary to extracellular fluid loss through the NPWT suction drain. Intravenous maintenance fluid should be considered to mitigate this risk.

Clinical Significance

When performed correctly by trained healthcare professionals, negative pressure wound therapy is a high-yield, adjunctive therapy for managing complex wounds, resulting in improved wound healing and restoration of dermal integrity in affected patients. It has widespread clinical applications across a myriad of specialties, including vascular, orthopedic, and plastic surgery, along with dermatology, endocrinology, and tissue viability. The type of wound involved determines the length of therapy and the intended healing process; thus, it can vary significantly between patients.[12]

Enhancing Healthcare Team Outcomes

Negative pressure wound therapy forms a cornerstone of advanced wound care and demonstrates excellent utility for complex acute and chronic wounds.[12] However, this procedure must be carried out correctly by appropriately trained personnel for optimal efficacy. Members of the healthcare team who wish to utilize NPWT must obtain the appropriate knowledge prior to applying negative pressure wound therapy and be familiar with the anatomy, physiology, indications, and contraindications associated with this wound care modality.

One of the many advantages of NPWT is that once sufficient expertise is attained, this form of wound care can be implemented by multiple healthcare team members, including physicians, nurses, nurse practitioners, and physician assistants. A caveat to this is that this procedure is carried out by the operating surgeon when performed in the operating room. However, it is important to consider that this endeavor in itself requires a multidisciplinary approach, with the anesthesiologist, surgical scrub nurse, and operating room practitioners all providing their respective essential expertise.

Finally, as mentioned before, NPWT can be utilized by various specialties, including dermatology, podiatry, plastic surgery, trauma, and orthopedic surgery, general surgery, vascular surgery, and endocrinology. Therefore, it is imperative to consider the wider healthcare team involved in this process and how each member can positively impact patient care. Good communication and an appreciation of each team member's roles can significantly enhance patient care. [Level 5]

Review Questions

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