International Journal of
Science Inventions Today
www.ijsit.com
ISSN 2319-5436
Review Article

AN OVERVIEW ON THE ROLE OF NEGATIVE PRESSURE WOUND THERAPY (NPWT) AS DAMAGE CONTROL MEASURE IN ACUTE AND CHRONIC WOUNDS

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ABSTRACT

Negative pressure wound therapy (NPWT) is often called topical negative pressure or by the trade name Vacuum assisted closure (VAC) is a technique that uses negative pressure applied to wounds of diverse etiology to promote wound healing. The concept of damage control orthopedics (DCO) is a strategy that focuses on managing orthopedic injuries in polytrauma patients who are in an unsuitable physiological state. In this review we have collectively studied the available current clinical literature to evaluate the role of NPWT in extensive soft tissue trauma and how it can benefit in damage control surgery (DCS).

Keywords: Negative pressure wound therapy (NPWT), vacuum assisted closure (VAC), chronic wounds, sub atmospheric pressure, suction pump

INTRODUCTION

Many wounds are difficult to heal, despite medical and nursing care. They may result from complications of an underlying disease, like diabetes; or from surgery, constant pressure, trauma, or burns. Chronic wounds are more often found in elderly people and in those with immunologic or chronic diseases. Chronic wounds may lead to impaired quality of life and functioning, to amputation, or even to death. The prevalence of chronic ulcers is difficult to ascertain. It varies by condition and complications due to the condition that caused the ulcer. There are, however, some data on condition-specific prevalence rates; for example, of patients with diabetes, 15% are thought to have foot ulcers at some time during their lives. The approximate community care cost of treating leg ulcers, without reference to cause, has been estimated at upward of $100 million per year. Surgically created wounds can also become chronic, especially if they become infected. For example, the reported incidence of sternal wound infections after median sternotomy is 1% to 5%. Abdominal surgery also creates large open wounds. Because it is sometimes necessary to leave these wounds open and allow them to heal on their own (secondary intention), some may become infected and be difficult to heal. Current best practice for the treatment of ulcers and other chronic wounds includes debridement (the removal of dead or contaminated tissue), which can be surgical, mechanical, or chemical; bacterial balance; and moisture balance. Treating the cause, ensuring good nutrition, and preventing primary infection also help wounds to heal. Saline or wet-to-moist dressings are reported as traditional or conventional therapy in the literature, although they typically are not the first line of treatment in Ontario. Modern moist interactive dressings are foams, calcium alginates, hydrogels, hydrocolloids, and films. Topical antibacterial agents—antiseptics, topical antibiotics, and newer antimicrobial dressings—are used to treat infection. Current evidence-based indications for the use of negative pressure on wound healing are broad and include chronic, acute, traumatic, subacute and dehisced wounds, partial-thickness burns, ulcers (such as diabetic or pressure), flaps and grafts[[1-6] . The rationale behind the use of sub atmospheric pressure for wound healing is based upon a wide array of mechanisms that ultimately result in wound contraction, mechanical stimulation of epithelial growth, and prevention of fluid collection, drainage and bacterial growth[7, 8]

Historical background:

The use of suction or negative pressure to remove exudates or haematoma has a long history going back to ancient times [9]. The author can recall during the 1960s being instructed in a form of assisted wound drainage. A perforated rubber tube was fitted and sealed with sleek tape into the wound and was attached to portable Roberts suction pump. The concept of trying to make a sealed suction unit has appeared in the literature for nearly 40 years [10] In 1970, matilda reported on studies that looked at 1193 wounds over a 5 years period- using suction drainage. Improved rates of wound healing were noted particularly for genitor-urinary, breast, thyroid wounds and hematomas. Miller and Brown (2005) in their literature review describe step-by–step the early work done in Russia during the 1970s and discussed that work as it appeared in English

during the 1980s. The translated work became known as the 'Kremlin Papers' by western writers (Miller and Lowery, 2005). The work described how surgeons used rigid domes over difficult-to-heal wounds to create sub-atmospheric pressure. The work showed that NPWT reduced wounds bacterial count, improved healing time and promoted white cell and fibroblast proliferation within the wound.

The Procedure:

The dressing used for negative pressure wound therapy starts with sterile open-cell foam that is cut to size and packed into the wound. This foam acts as a type of filter to keep any large particles (such as blood clots or dead, sloughed off tissue) from clogging the vacuum system. Once packed with foam, the wound is covered with an occlusive dressing, typically made of polyurethane. This dressing is clear in color, thin and creates an airtight seal around the wound. A pump is attached to the occlusive dressing and once negative pressure is applied, a vacuum environment is created. The pump can be programmed by a health care professional for strength of suction, amount of time it is to be applied and if it is to be intermittent or continuous. A chamber on the pump collects drainage and moisture is drawn away from the wound site. In wounds that are not deep enough to accommodate the open-cell foam, sterile open weave gauze or other honeycomb dressing textiles can be applied beneath the clear polyurethane film instead. Dressings are changed every three to seven days or as needed. Negative pressure applied can range anywhere from -125 to -75 mmHg depending upon the wound and patient tolerance. Negative pressure wound therapy can be painful, particularly when dressings are changed[11]. Once pressure is applied, most patients report a plateau in pain levels; however, the level of pain greatly depends upon the wound type, location and level of healing. Patients are often treated with pain medications prior to dressing changes and throughout negative pressure wound therapy. A prospective non-blinded study recruited 46 patients with soft tissue defects and infection from January 2010 to May 2014 and randomly divided them into experimental and control groups (n=23). Patients in the experimental group were treated with VSD and antibiotic-loaded bone cement, while the patients in the control group were treated with VSD only. In the experimental group, the wound was healed in 23 cases at 4 weeks postoperatively, of which direct suture was performed in 12 cases, and additional free flap transplantation or skin grafting was performed in 6 cases and 5 cases, respectively. No infection reoccurred in 1-year follow-up. In the control group, the wound was healed in 15 cases at 6 weeks postoperatively, of which direct suture was performed in 8 cases, and additional free flap transplantation or skin grafting was performed in 3 cases and 4 cases, respectively. In the other 8 cases the wound was healed at 8 weeks postoperatively. Infection reoccurred in 3 cases during the follow-up. The experimental group had significantly fewer VSD dressing renewals, shorter time needed until the wound was ready for surgery, shorter duration of antibiotic administration, faster wound healing, and shorter hospital stay than the control group (p<0.01)[12]

Figure: Patient on acceptance (upper left); after serial debridement exposure of the ulnar bone (upper centre); during negative pressure wound therapy (upper right); intra-operative view (lower left); early post-operative (lower right).

Figure: Patient after serial debridement, exposure of tibia (upper left); during circumferential negative pressure wound therapy (NPWT) (upper right); during NPWT, trephanated tibia bone (lower left), before skin grafting (lower centre); early post-operative appearance (lower right).

Who Is a Candidate for Negative Pressure Wound Therapy?

Candidates for negative pressure wound therapy include individuals suffering from:

- Chronic ulcers caused by unrelieved pressure (bedsores), diabetes mellitus, venous insufficiency or arterial insufficiency
- Wounds with copious drainage
- Chronic wounds that have not responded to other treatments
- Acute or surgical wounds at high risk for infection

DISCUSSION

Chronic wounds are wounds that have failed to proceed through the normal process of healing. There are varying etiologies of chronic wounds, which all create a burden upon the health care system. The health care expenditures for chronic wounds have been estimated to be up to $25 billion dollars per year. Common types of chronic wounds include venous insufficiency ulcers, arterial leg ulcers, diabetic foot ulcers, burn victims and pressure ulcers. These wounds can affect a large number of people with varying degrees of severity.[13-16] Venous insufficiency ulcers are a large proportion of chronic wounds as a whole, with over 50% of chronic leg ulcers occurring as a result of a venous etiology. Amputations related to diabetic foot wounds have been associated with high cumulative mortality – up to 70 percent within 10 years from the first amputation due to a diabetic foot ulcer. Annual prevalence of venous insufficiency ulcers in those 65 and older has been estimated to be 1.69 per 100 person-years. The prevalence of pressure ulcers varies between 0.31 to 0.70 percent per year, with increasing incidence with advancing age. Given the aging population the growing incidence of cardiovascular disease, diabetes, and obesity, the prevalence of chronic wounds, and the associated burdens, can only be expected to grow. There are a variety of modalities available for chronic wound treatment, with some targeted toward specific types of wounds, such as compression for venous insufficiency ulcers. Routine wound care may involve any or all of the following: debridement (removal of material from the wound bed to permit healing), wound dressings (including gauzes, films, hydrogels, hydrocolloids, alginates, and foams), barrier products, and topical or systemic antimicrobials. In addition to these various wound dressings and medications, there are other adjunctive treatment modalities, such as skin substitutes, hyperbaric oxygen, and negative pressure wound therapy (NPWT). This last modality is the focus of our review. VSD reduces wound infection and promotes wound healing. Following the debridement of large-area soft tissue defects accompanied by bone exposure in the lower leg, VSD is conducted to transform the open wound into a closed wound and prevent external bacteria from invading the wound surface. Therefore, it eliminates the conditions that favor bacterial culture, inhibits bacterial growth and reproduction, blocks infection spread and toxin absorption, decreases bacterial infection and reproduction levels in the tissue, decreases the wound infection rate, helps the rapid growth of granulation tissues on the wound surface and promotes wound healing.[17]Its use is widespread amongst surgical specialties many of which employ NPWT to varying degrees as part of their

armamentarium against challenging wounds. Its use in orthopedics is diverse and includes the acute traumatic setting as well as chronic troublesome wounds associated with pressure sores and diabetic foot surgery. The strategy of two-stage repair is regarded as a more reliable treatment for soft-tissue defects of the lower leg.[18] . NPWT refers to the application of negative pressure across a wound. The technology emerged in the 1980s and consists of the application of a dressing, usually foam or gauze, on the wound, which is then connected through tubing to a vacuum pump. The area is sealed with an adhesive film and the pump delivers a controlled negative pressure across the wound bed. The Centers for Medicare and Medicaid Services (CMS) defines NPWT as the "application of sub atmospheric pressure to a wound to remove exudates and debris, via an integrated system consisting of a suction pump, separate exudates collection chamber, and dressing, over specific wounds". The aim of NPWT is to facilitate wound healing, promote granulation of the wound bed, and provide a bridge to surgical closure.

Intended Uses of Negative Pressure Wound Therapy:

Skin production or wound shrinkage through applied suction: Transmission of force over a specific surface with its varying elasticity will induce tissue stretch and ultimately lead to wound contraction. Lack of oxygen at the wound surface is suggested as the physiological basis for angiogenesis (new blood vessel formation) and granulation tissue growth. To a layperson, this seems like a spectacular answer for wound healing. Based on this information, one begins to wonder how our body could ever heal without negative pressure wound therapy.

Fluid removal and edema reduction: Excess extra vascular fluid buildup has been a well-accepted contravening factor in healing. Removing fluid reduces compression on the blood vessels and improves blood perfusion which promotes the healing process. This intended use of negative pressure wound therapy makes a lot of sense. Similarly, Complete Decongestive Therapy (CDT) is the current standard for controlling edema and healing venous ulcers. This includes manual lymphatic drainage, pneumatic compression, compression bandaging, and diuretics. However, these man-made measures simply deal symptomatically with the issue at large and do not address the root cause, venous reflux disease. In simple terms, vacuum assisted suction compares to putting a pail under a leaking pipe and CDT is like wrapping duct tape around the leak. Minimally invasive venous ablation of the effected superficial veins and perforators shuts off the hose. This is the most direct means of restoring homeostatic venous return and diminishing edema.

Stabilization of the wound environment: Controlling the wound environment and protection of both the surrounding skin and the wound bioburden is an important intervention and intended use of NPWT-that is, if the practitioner is focused only on the wound and not underlying root causes of non-healing.

Additionally, wound infection prevention is also a purported benefit of the cellophane cover used in the application of NPWT. From an infectious disease perspective, it is unclear that NPWT or any dressing prevents infection. All wounds and their surrounding skin are colonized with skin flora, such as *S. epidermitis*, *S. aureus*, Strep species, etc. Colonization is not the same as invasive disease, which may not be avoidable in any open or covered wound, acute or chronic. In fact, the body's intrinsic system in place that prevents invasive disease extending below and around the wound bed is 11 trillion neutrophils made fresh daily that infiltrate and sentry the wound base, engulfing invading bacteria like piranhas. Without first restoring arterial and venous flow, it hardly seems plausible that a suction device would be the preferred antidote to 11 trillion white blood cells or restoration of the arterial and venous circulation. The best dressing that exists and the one that was meant for mankind is an eschar or commonly known as a "scab". There is just no man-made substitute for this biologic wonder, and at no cost to the medical system.

Precautions When Using Negative Pressure Wound Therapy:

In order to be effective, negative pressure wound therapy must be monitored routinely to ensure that:

- The negative pressure seal has not been broken and leaks are at a minimum
- The tubing leading from the wound to the pump is free of kinks
- The drainage chamber is filling correctly and does not need changing
- The area around the wound remains unchanged
- The dressing is clean and not in need of changing

Additionally, a health care professional will evaluate an individual’s overall health to monitor for infection or a worsening condition. Other therapies likely to be used in conjunction with negative pressure wound therapy include:

- Pain management
- Debridement and irrigation of the wound
- Antibiotic therapy
- Nutrition evaluation
- IV fluids or other means of adequate hydration

Complications:

With the potential benefits, there are also potential harms associated with NPWT. Reported adverse effects include pain, retention of foreign bodies from the dressing, bleeding, and infection, death from infection or bleeding, and even complications stemming from power outages, which results in unrecognized interruption

of therapy. In 2011, the U.S. Food and Drug Administration (FDA) issued a safety communication regarding serious complications associated with NPWT systems. Their report included 174 reports of injury and 12 deaths that have occurred since 2007. Of significant concern was the number of events happening in the home setting. Infection was the most common; however, bleeding was the most severe adverse event, and it led to significant morbidity and mortality. As a result, the FDA issued recommendations regarding patient selection, monitoring, contraindications, and risk factors that should be followed by clinicians. Additionally, the FDA endorsed education of the patient and caregivers to improve safety monitoring in the home setting

CONCLUSION

Negative pressure wound therapy (NPWT) is a wound healing modality that intervenes at the proliferation stage of healing and has some good results. Functionally, NPWT is the application of sub atmospheric pressure to a wound bed, open or closed, through foam dressing. These results in decreased interstitial edema reduced bacterial load, the creation of a closed environment, improved circulation and enhanced granulation bed formation. While there's never only one way to treat a wound, I have found that in some cases NPWT is the most efficient path to resolution. Combined cross-leg and free flaps can be useful in management of large soft tissue defect associated with severe lower leg injuries. Faster granulation bed formation means fewer trips to the hospital, fewer bandages changes and often sets the stage for earlier delayed primary closure; however Reliable evidence on the effectiveness of NPWT is scarce. Tentative evidence indicates that the effectiveness of NPWT is at least as good as or better than current local treatment for wounds.

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