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Negative Pressure Wound Therapy: A Review of Current Practical Applications & Complications

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Abstract: Negative pressure wound therapy is arguably one of the most important advances in wound healing to date. It has been widely researched and accepted in the medical community for its efficacy with healing neuropathic diabetic ulcerations. New applications for negative pressure wound therapy continue to be introduced. These new applications include coverage of open trauma, primarily closed surgical incisions, and instillation of irrigant fluid.

Key words: NPWT, VAC, Negative, Pressure, Wound, Therapy, Instillation

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Negative pressure wound therapy (NPWT) is a wound healing modality that delivers continuous or intermittent sub-atmospheric pressure to a wound in order to assist with healing and decrease bioburden. This pressure is maintained using any number of commercially available specialized pumps with a sealed dressing which consists of open-celled foam and adhesive semi-permeable drape.[1] This powerful adjuvant therapy has widely been utilized in medicine for its benefit in wound healing and limb salvage. NPWT decreases overall complication rates including but not limited to incidence of infection, re-operation, and time to healing.

History & Mechanism of Action

NPWT was initially introduced in 1995 by Argenta and Morykwas on the premise that sub-atmospheric pressure provided some benefit to wounds.[2] It is not well understood why NPWT is so effective, however, there are three commonly accepted mechanisms by which it is believed to work. One theory suggests sub-atmospheric pressure provides micromechanical stress to underlying cells which causes release of intracellular messenger signals which induce cell proliferation and matrix molecule synthesis.[3] It has also been proposed that sub-atmospheric pressure removes residual space in the interstitium and wicks away drainage thus reducing edema. Additionally, it has been reported that negative pressure increases blood flow to area of insult/injury due to increased capillary permeability.[2] Since the initial introduction of NPWT numerous studies have been performed and various new applications outside of the diabetic foot have been explored.

NPWT in the Diabetic Foot

There is little dispute regarding the benefits of properly administered NPWT on neuropathic diabetic ulcerations. One landmark study performed by Armstrong et al has outlined these benefits. The purpose of the study was to evaluate at efficacy of

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NPWT as an adjuvant to healing diabetic amputations. It was designed as a 16 week prospective randomized controlled trial which was performed at 18 different clinical sites. A total of 162 patients were included who were confirmed to have diabetes complicated by peripheral neuropathy, adequate circulation, and optimized nutritional status for healing. Subjects were randomized and treated either with standard wound therapy or NPWT with dressing changes every 48 hours. A third party vendor was used to measure wound sizes independent of practitioners involved in order to limit bias. The results obtained by Armstrong et al showed that more patients (56%) treated with NPWT healed during the course of study versus the control group (39%). Additionally, the mean time to achieve granulation was faster than the control group (mean 56 days vs. 77 days p=0.002). The results of this randomized controlled trial allowed the authors conclude NPWT is a safe and effective treatment modality with a higher proportion of wounds healed and at a faster healing rate.[1]

In another article by Vassallo et al, the authors sought to compare the efficacy of NPWT as compared to standard calcium alginate dressing for treatment of neuropathic diabetic foot ulcerations. This study included 30 patients with 15 patients in each treatment group. They found that NPWT was 3.2 times more effective at reducing wound area and 3.78 times more effective at reducing depth of wounds when compared to calcium alginate dressing (P=0.001).[4]

Closed Incision NPWT

The application of NPWT over primarily closed surgical incisions is a relatively new development. It has been proposed that the benefits seen in diabetic foot ulcers may help with healing of high risk surgical incisions. Typically, incisional NPWT involves a semi-permeable drape bordered around a closed surgical incision followed by non-adherent dressing, open cell foam, and another semi-permeable drape. There are several commercially available systems which are specifically designed for primarily closed surgical incisions. These systems are typically disposable, have specialized drapes, and deliver sub-atmospheric pressure over a set period of time during the postoperative phase.[5]

Total ankle arthroplasty (TAA) has become increasingly popular in recent years, and is often associated with wound healing complications. Matsumoto et al performed and retrospective cohort study on 74 patients in which they looked at the effect of NWPT on wound healing after anterior approach TAA. In this particular study, experimental subjects were treated with disposable units which delivered 6 days of NPWT at -80 mmHg versus a control group which received a standard dry dressing. The authors found a 24% incidence of wound complications in control versus 3% in the experimental group (P=0.004). They concluded that NPWT offers decreased incidence of complication in these high-risk surgical incisions.[6]

Similarly, in a study by Pachowsky et al the effects of NPWT on postop healing were also analyzed. In this prospective randomized controlled trial, the authors used ultrasound imaging to measure seroma formation on postop days 5 and 10 in a total of 19 enrolled patients. The control group received standard dry wound coverage and the experimental group received NPWT delivered at continuous -125 mmHg. They found that 90% of patients in the control group and 44% of patients in the experimental group developed postop seroma (P=0.021). Based on these results, the authors concluded that there was a significant decrease in seroma formation and observed overall improved wound healing in patients treated with NPWT over a primarily closed surgical incision.[7]

In addition to elective surgical cases, the utility of NPWT has also been studied in high-risk lower extremity trauma. Stannard et al conducted such a study to determine whether prophylactic NPWT was a beneficial adjunct to decrease infection rate after ORIF of lower extremity fractures. This study was designed as randomized prospective multicenter trial of 249 patients who sustained tibial plateau, pilon, and calcaneal fractures. The authors found that the incidence of infection in the control group (19%) was statistically higher than that of the experimental group (10%) (P=0.049). The mean time of NPWT duration was 2.5 days at a cost of approximately $500 to the institutions. They concluded that the relative risk of developing an infection without incisional NPWT was 1.9 times higher than patients treated with a standard surgical dressing.[8] Based on these studies, it is evident that NPWT offers significant benefit when applied to primarily closed surgical incisions.

NPWT with Open Trauma

The management of open fractures and degloving injuries often poses a significant surgical challenge. Appropriate surgical timing is critical for the best possible outcomes. Rezzadeh et al studied the effect of NPWT on flap complications and overall outcomes. This study was based timing of soft tissue reconstruction relative to initial injury and implementation of NPWT. In this retrospective study, the charts of 32 patients with Gustilo IIIB and IIIC open tibial fractures were reviewed. The authors looked at length of hospital stay, number of surgeries, flap failure, infection, and nonunion rates. They found that complication rate in NPWT group was lower compared to those patients who received standard wet-to-dry dressings. Additionally, the authors found the highest rate of complications in patients who were operated on >6 weeks after initial injury and receiving wet-to-dry daily dressing changes. The lowest complication rate was found in patients who underwent surgery within 1 week of injury who were bridged with NPWT.[9]

In addition to the Rezzadeh study, Parrett et al conducted a retrospective review of 290 open tib-fib fractures over the course of 12 years. In this study, NPWT was utilized on 61 patients and standard dressing was used on 229 patients experiencing Gustilo grade I, II, and III fractures. The authors found that those patients who received NPWT required less complex plastic surgery, fewer free flaps, more local flaps, delayed primary closure and split thickness skin grafts. Parrett, however, found that the incidence of infection, amputation, non-union, and re-operation rates were not statistically significant between the two groups.[10]

NPWT with Instillation

NPWT with instillation (NPWTi) is a relatively new advancement which combines conventional NPWT with controlled delivery of topical solutions with the intent of decreasing wound biofilm. These solutions are irrigated into a sealed wound bed via separate tubing while the vacuum pump is paused. The solution is then allowed to dwell within the wound for a predetermined amount of time (typically 20 minutes) and the vacuum pump then resumes suction and removes residual fluid from the wound. Very few multicenter randomized prospective clinical trials exist comparing NPWT to NPWT. Currently there are ongoing trials at Georgetown University Hospital to compare NPWT to NPWTi as well as topical solutions.[11, 12]

One study by Lessing et al was performed in order to evaluate rate of graulation tissue in wounds treated with NPWTi. The experiments were carried out in a porcine model with surgically induced wounds. In this particular study: NPWTi, conventional continuous NPWT, and intermittent suction were evaluated. The researchers determined that there was no statistical difference in average granulation tissue among wounds treated with conventional NPWT versus intermittent NPWT at day 7. This study did, however, find that NPWTi using normal saline irrigant resulted in greater reduction in wound area, perimeter, and depth as compared to dry NPWT ($P<0.05$).[13]

There also is little consensus regarding which solution is ideal for irrigation with NPWTi.. A literature review performed by Back et al concluded that use of polyhexanide for the treatment of soft tissue injuries without bone involvement resulted in lower infection rates when compared to povidone-iodine and silver nitrate solutions. They also concluded that purified tap water did not appear to have any disadvantages when compared to sterile saline and 1% povidone-iodine solution.[11]

Complications of NWPT

NPWT is not without complications. These complications include infection, pain, anxiety, bleeding events, and secondary wound formation.[14]

In a prospective randomized controlled trial being carried out by Howell et al needed to be prematurely discontinued due to secondary wound formation. During the course of the study, 63% of the 24 experimental group participants developed blisters at the site of application. The aim of this study was to determine whether NPWT provided benefit after total knee arthroplasty in 60 high-risk surgeries. They compared dry dressing to NPWT and found that time to endpoint (days to dry wound) was about the same in the experimental and control groups (4.3 and 4.1 days respectively).[15]

Collinge et al performed a retrospective study in which they assessed complications related to interruption in NPWT. Of the 123 patients studied, the authors found a 10% complication rate. These complications were related to inadvertent interruption in therapy. These inadvertent interruptions resulted in deterioration of wounds, and additional surgery for debridement, infection, and loss of graft viability ($P<0.05$).[16]

The US Food and Drug Administration also issued an update regarding the complications associated with NPWT in 2011. They report a total of 12 deaths and 174 injuries as a result of NPWT. The most common reported complication was infection related to retention of open cell foam dressing pieced within wounds. They also reported bleeding events in patients on blood thinners, and patients with blood vessel grafts and cautioned the use of NPWT in these patients. [17]

Conclusion

The invention of NPWT is arguably one of the most important advances in wound coverage to date. Some of the more recent advances include instillation of irrigant fluid, application over a closed surgical wound, and application in open trauma. It is a versatile tool with many benefits and some associated risks. There are countless studies which have been conducted that demonstrate the potential benefits of NPWT, but, additional information is required in the emerging field of NPWTi.

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