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Original Research Article

Outcome analysis of vacuum assisted closure application in open fractures of long bones

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ABSTRACT

Background: We performed a prospective analysis to compare the efficacy of the vacuum assisted closure (VAC therapy) and conventional cotton gauze dressing of wounds.
Methods: The study was conducted from July 2014 to June 2016 on patients admitted from emergency department or presenting in the outpatient department of the hospital. Necrotic tissues were debrided before applying VAC therapy. Dressings were changed every 3 or 4 days. For standard wound therapy, debridement followed by daily dressings was done. All patients were reconstructed with SSG/FLAP coverage after the granulation tissue was sufficient. Two groups of 10 each compared prospectively. Data were collected for age, sex, time needed for sufficient granulation tissue for coverage, length of hospital stay, no of debridements for VAC application and conventional gauze dressings.
Results: Time needed to have a good granulation tissue sufficient for coverage, length of stay in hospital, and no of debridements were significantly less in VAC group. No major complication occurred that was directly attributable to treatment.
Conclusions: Vacuum assisted wound therapy was found to facilitate the rapid formation of healthy granulation tissue on open musculoskeletal injuries, shortens hospital stay and minimize secondary soft tissue defect coverage procedures.

Keywords: Conventional dressings, Vacuum-assisted closure, Wound closure, Debridement

INTRODUCTION

Open fractures are injuries in which skin and soft tissue are disrupted and the underlying bone is exposed to the external environment. This leads to contamination by micro-organisms that can cause deep and superficial infection. The management of severe open fractures of the lower leg remains a major challenge in surgery, and adequate treatment of the concomitant soft tissue injury is of the highest priority, since it determines the fate and outcome of bone and extremity.[1,2] In the past, open wound treatment of fractures or osteosynthesis followed by flap coverage was often associated with loss of the extremity.[3] Wound healing is a complex and dynamic process that includes an immediate sequence of cell migration leading to repair and closure. This sequence begins with removal of debris, control of infection, clearance of inflammation, angiogenesis, deposition of granulation tissue, contraction, remodelling of the connective tissue matrix, and maturation. Impaired vascularity, devitalised tissue and loss of skeletal stability are all factors leading to increased susceptibility to infection after open fracture.

Delayed wound healing is a significant health problem. In addition to the pain and suffering, failure of the wound to heal also imposes social and financial burdens. Although non-operative modalities, such as hyperbaric oxygen, have been used to enhance wound coverage, these devices may not be available to all patients and may not be adequate for use in patients presenting with high-energy injuries due to edema, retraction of the skin and soft tissue, wound size, or loss of available local coverage. Attempts have been made to identify an alternative treatment of wound management in these patients. The use of sub-atmospheric pressure devices, available commercially as VAC devices, has been shown to be an effective way to accelerate healing of various wounds.[4-7] Initially developed in the early 1990s, for the management of large, chronically infected wounds that could not be closed in extremely debilitated patients, the use of vacuum-assisted closure (VAC) has been more recently used in the treatment of traumatic wounds.[8]

For simple wounds, gauze works as an inexpensive and simple product that absorbs exudate and keeps wound clean and covered. An alternative method that has been started to be extensively used in recent years is VAC (vacuum assisted closure) therapy systems. It is observed that local blood circulation is increased after VAC with intermittent 125 mmHg negative pressure effect. The management of open wounds are variable and costly, challenging, lengthy hospital stays or home care requiring skilled nursing, costing the health system heavily. Increased speed of wounds healing could result in reduced hospitalization and rapid return of function. A method that improves the wound healing process could seriously reduce the risk of amputation, infection, and length of hospital stay and result in an annual savings of healthcare cost. The VAC treatment has significantly increased wound closure rates and decreased morbidity and health costs for patients.

The purpose of this study is to evaluate the results of this therapy for the management of patients presenting with open musculoskeletal injuries.

METHODS

The study was conducted on 20 patients in the Department of Orthopaedics, Sir Sunderlal Hospital, I.M.S., B.H.U. over a period of 16 months, after obtaining the permission from institutional ethical committee and taking informed and written consents from the patients. The study was conducted from July 2014 to June 2016 on patients admitted from emergency department or presenting in the out-patient department of the hospital.

All patients above 18 years of age with open musculoskeletal injuries in extremities that required coverage procedures were included in the study. However, patients with pre-existing osteomyelitis, neurovascular deficit, diabetes, malignancy and peripheral vascular disease were excluded from the study.

The patients were prospective lyrandomized into one of the two treatment groups receiving either the vacuum assisted closure therapy or standard saline-wet-to-moist wound care.

Participation in the study did not deviate from the standard care of the acute wound. All patients for wound management were subjected to

- Standard radiological assessment of the injured limb,
- Routine haematological investigation, for example, complete blood count, ESR, blood sugar, HIV, HCV and HbsAg, gram stain and culture,
- All patients were supplemented with standard nutritional supplements, including zinc and multivitamin daily.

Vacuum assisted wound therapy procedure

Materials used

The application of topical negative pressure moist dressings needs the following materials. They include

- Synthetic hydrocolloid sheet
- Vacuum suction apparatus
- Transparent semi permeable adhesive membrane sheet

Wound preparation

A culture swab for microbiology was taken before wound irrigation with normal saline. Necrotic tissues were surgically removed (surgical debridement), and adequate hemostasis was achieved.

Placement of foam

Sterile, open-pore foam (35 ppi density and 33 mm thick) dressing was gently placed into the wound cavity which provide an even distribution of negative pressure over the entire wound bed to aid in wound healing.

Sealing with drapes

The site was then sealed with an adhesive drape covering the foam and tubing and at least three to five centimeters of surrounding healthy tissue to ensure a seal.

The application of negative pressure

Controlled pressure was uniformly applied to all tissues on the inner surface of the wound. The pump delivers an intermittent negative pressure of 125 mmHg. The cycle was of seven minutes in which pump was on for five minutes and off for two minutes. The dressings were changed on the fourth day.

Saline-wet-to-moist group procedure

Any dressings from the wound was removed and discarded. A culture swab for microbiology was taken before wound irrigation with normal saline. Surface slough or necrotic tissue was surgically removed (surgical debridement), and adequate hemostasis was achieved. Daily dressings by conventional methods, that is, cleaning with hydrogen peroxide and normal saline and dressing the wound with providone iodine (5%) and saline-soaked gauze was done and wound examined daily.

Method of use

Steps 1-5 demonstrate the technique for vacuum assisted closure:

Step 1

The foam dressing is cut to the approximate size of the wound with scissors and placed gently into position.

Step 2

The perforated drain tube is then located on top of the foam and a second piece of foam placed over the top. For shallower wounds, a single piece of foam may be used and the drainage tube is inserted inside it.

Step 3

The foam, together with the first few inches of the drainage tube and the surrounding area of healthy skin, is then covered with the adhesive transparent membrane supplied. At this stage it is important to ensure that the membrane forms a good seal both with the skin and the drainage tube.

Step 4

The distal end of the drain is connected to the VAC unit, which is programmed to produce the required level of pressure.

Step 5

Fluid within the wound is taken up by the foam and transported into the disposable container within the main vacuum unit.

The wounds were also evaluated by plastic surgeon on day 1 and on day 8 to assess the nature of surgical procedure that to be adopted to cover the wound.

Antibiotics

The antibiotic was started on admission and continued depending on the wound status minimum 7 post-op days. Amino-glycoside was also added in type IIIA & IIIB.

V.A.C. therapy precautions

Acute bleeding, patients on anticoagulants, or difficult wound homeostasis. Ensure all vessels are adequately protected with overlying fascia, tissue, or other protective barrier. Monitoring and progression of wound healing and weekly wound measurements

Signs of healing as following

Oozing of blood as granulation occurs, wound bed becomes red, gradual decrease in wound drainage, decrease in dimensions of wound. Average length of treatment is 3-4 weeks

Termination of V.A.C. therapy

Adequate granulation base achieved allowing for split-thickness skin graft flap closure.

RESULTS

Mean patient age was 48 years (range, 18 to 60 years).

Table 1: Age distribution of patients.

Age (years)	No. of patients	Percentage (%)
18-20	02	10
21-30	07	35
31-40	05	25
41-50	04	20
51-60	02	10
Total	20	100

Table 2: Type of treatement methods.

Age groups	No. of patients	Conventional dressing		VAC therapy	
		No.	%	No.	%
18-20	02	01	05	01	05
21-30	07	04	20	03	15
31-40	05	02	10	03	15
41-50	04	01	05	03	15
51-60	02	02	10	00	00
Total	20	10	50	10	50

According to Gustilo and Anderson classification, out of 20 patients, 12 patients had grade IIIA injury, 8 had grade IIIB injury.

All patients had suffered acute trauma. Road traffic accident was found to be most common cause with 16 (80%) patients, followed by physical assault in 2 (10%) patients and 2 (10%) patients had a sport injury.

Decrease in wound size: There was significant decrease in wound size from day zero to day eight in VAC group in comparison to saline-wet-to-moist group. A decrease in size of 10 to 19.9 mm was seen in 46.66% of patients of VAC group and only 6.66% in control group.

There was significant decrease in the expenditure, length of hospital stay, number of debridement of the wound and infection rate.

Table 3: Sex distribution of patients.

Sex	No. of patients	Percentage (%)
Male	14	70
Female	06	30
Total	20	100

Table 4: Type of fractures.

Type of fracture	No. of patients	Percentage (%)
IIIA	12	60
IIIB	08	40
Total	20	100

Table 5: Type of injury.

Mode of injury	No. of patients	Percentage (%)
RTA	16	80
Physical assault	02	10
Sports injury	02	10
Total	20	100

Table 6: Soft tissue coverage procedures.

Procedure	Conventional gauxe saline dressing	VAC therapy
Primary closure	00	01
Split skin graft	06	06
Fasciocutaneous flap	00	00
Musculocutaneous flap	04	03
Secondary closure	00	01

VAC therapy can be regarded as a method that combines the benefit of both open and closed treatment and adheres to DeBakey's principles of being short, safe, and simple. It was observed to promote wound healing. VAC therapy is not the answer for all wounds; however, it can make a significant difference in many cases.

Patient satisfaction in terms of time taken for wound closure, number of antibiotics used, treatment related complications and outcome was better in first group compared to second Group and overall resource utilization was more in second group.

Case 1: 36 yrs/F, 2 years old case of open fracture shaft tibia and fibula at junction of mid and distal 1/3rd with wound of 7 x 5 cm over antero-medial aspect of leg. Close reduction and internal fixation with TIN done on same day and debridement of wound done and VAC applied for 2 weeks and then wound coverage with split skin grafting done. Patient was asymptomatic for 1 year and presented with discharging sinus from distal locking site. Removal of implant done 1month back.

Figure 1: At the time of admission.

Figure 2: Debridement of wound done and VAC applied.

Figure 3: After 5 days of VAC application.

Figure 4: After wound coverage with SSG.

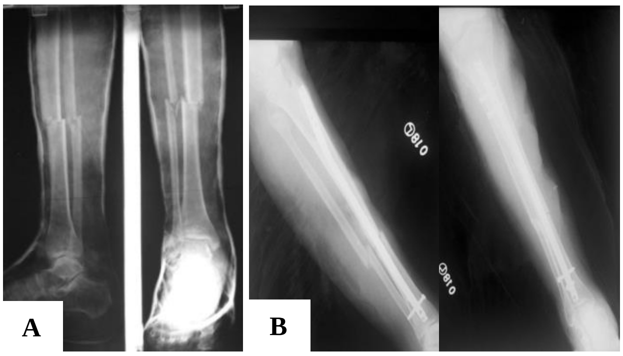

Figure 5: A=Pre op X-ray; B=Post op day 1.

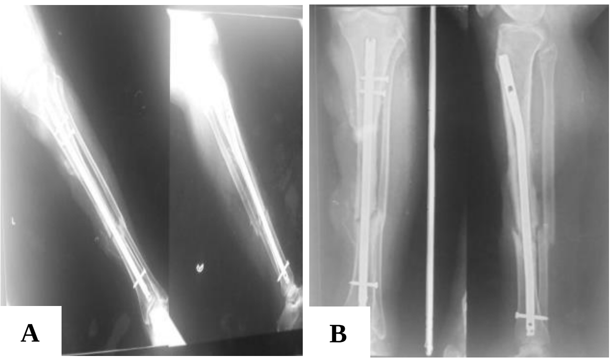

Figure 6 (A and B): Follow up 4 months 7 months follow up.

Figure 7: 16 Month follow up.

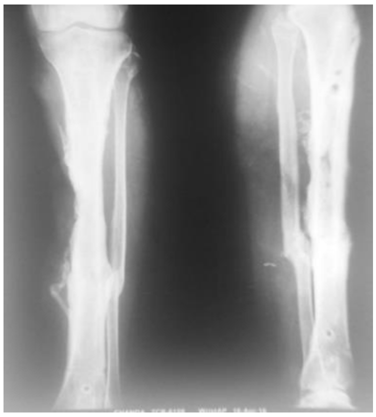

Figure 8: After 2 years implant removed.

DISCUSSION

Apelqvist et al also found a beneficial effect in terms of direct economic cost and resource utilization in patients treated with VAC compared to standard moist wound therapy.[9]

The concept of moist wound dressings which came into vogue in the 1960‟s which revolutionized wound care.[10]

Healing is an intricate, interdependent process that involves complex interactions between cells, the cellular micro environment, biochemical mediators, and extracellular matrix molecules that usually results in a functional restoration of the injured tissue.[11,12]

The goals of wound healing are to minimize blood loss, replace any defect with new tissue (granulation tissue followed by scar tissue) and restore an intact epithelial barrier as rapidly as possible. The rate of wound healing is limited by the available vascular supply and the rate of formation of new capillaries and matrix molecule.[13]

Blood flow increases and bacterial colonization of wound tissues decreases following the application of sub-atmospheric pressure to wounds. Any increase in circulation and oxygenation to compromised or damaged tissue enhances the resistance to infection. One of the recent developments is the application of topical negative pressure (TNP), a concept which emerged in the late 1980s since when several devices have been developed and marketed.[14]

Our study showed that in VAC group after day 4, there were 20% of patients who had no bacterial growth, and on day 8 there were 60% of patients who had no bacterial growth, whereas in saline-wet-to-moist patients only 20% of patients had no bacterial growth on the 8th day. There have been similar studies by Banwell et al and Moryk was et al which showed clearance of bacteria from infected wounds using VAC therapy.

A decrease in size of 10 to 19.9 mm was seen in 46.66% of patients of VAC group and only 6.66% in control group. A decrease in size of more than 25 mm was seen in 13.33% in VAC group.

Our study showed that VAC increases the vascularity and rate of granulation tissue formation compared to standard wound dressing. This is reflected by on average healthier wound conditions, faster healing, increased graft uptake. Another major advantage of vacuum therapy is the reduction of the number of dressings changes to once every 48 h instead of daily dressings as in conventional therapy. The reduction of dressing changes leads to an improved patient compliance as the patient suffers less often pain and inconvenience. In our study we have used a locally constructed VAC device which is very economical to the patient owing more cost-effective than conventional dressing.

Mechanism of action: Despite the early clinical success and widespread empirical introduction of TNP into clinical practice, it is not known exactly how TNP therapy may exert effects on the wound. Several mechanisms have been proposed. TNP is said to increase local blood flow and reduce oedema and bacterial colonisation rates. It is thought to promote closure of the wound by promoting the rapid formation of granulation tissue as well as by mechanical effects on the wound. It concurrently provides a moist wound environment and removes excess wound exudates thus aiding in the creation of the "ideal wound healing environment".[15]

Local blood flow: Morykwas used needle probe laser doppler flowometry to show that sub-atmospheric pressures of 125 mm Hg resulted in a fourfold increase in blood flow using an excisional wound model in pigs. This increase in blood flow has also been shown in human burns.[16] Further higher increases in pressure (>200 mm Hg) were shown to decrease blood flow. There remains confusion as to whether continued pressure leads to an eventual decline in blood flow or a cyclical pattern of blood flow. These direct effects on dermal vasculature are thought to be mediated by influencing vasomotor mediators. However, the indirect effects of mechanical forces exerted on the extracellular matrix inevitably affect the microvasculature contained within it.

Mechanical stress: The importance of physical forces in TNP therapy is still theoretical, however there is good evidence of the importance of mechanical stress on cellular reproduction and angiogenesis.[17] Increasing mechanical stress in vitro causes an increase in cellular activity, the nature of which varies with the cell type and methodology. Accelerated cell cycling and DNA synthesis have been seen. Experimental evidence from model systems also suggests that mechanical forces can result in increased fibrogenesis in cutaneous wound models.[18,19]

Granulation tissue formation: In Morykwa's studies using porcine dorsal midline excisional full thickness excisional wound models, alginate impressions were taken daily after treatment with TNP. Volume displacement of these casts demonstrated that TNP treated wounds showed increased granulation tissue formation compared with the controls by 63% and 93.4% (continuous and intermittent suction respectively), although it is not known what effect contraction played to change the size of these wounds. This increase in granulation tissue formation has been confirmed by Joseph et al and Fabian et al using rabbit ear studies.[20,21]

Bacterial colonisation: Microbial colonisation of the wound bed is considered as one of the important factors responsible for delay in healing process in chronic wounds. The accumulated oedema fluid acts as a good medium for the proliferation of bacteria at the wound site. The impaired circulation and the resultant reduced local immunity also contribute to this. The microbial infection delays the healing process by a number of mechanisms. The microbes consume oxygen and nutrients from the healing wound environment. Moreover they express certain proteases and enzymes that breakdown cytokines which are necessary the proper progress of healing. Studies have shown that a reduction of bacterial load of a wound improves granulation tissue formation.

Topical negative pressure application is believed to achieve this by removal of accumulated interstitial fluid, improved local circulation and oxygenation and improved local immunity. The increased flow should make greater amounts of oxygen available to neutrophils for the oxidative bursts that kill bacteria.

Oedema reduction and exudate management:

The resulting reduction in oedema is thought to aid in the enhancement of blood and nutrient flow into the wound. However, this removal of exudate (which will include metallo-proteinases and other inflammatory mediators from the wound and oedema from the surrounding tissues encourages nutrient movement into the wound area even if blood flow is not increased.[22,23] Removal of fluid prevents a buildup of inflammatory mediators and encourages diffusion of further nutrients into the wound. This is all beneficial to the healing process especially in the case of chronic wounds where it has been hypothesised that an imbalance of metallo-proteinases can inhibit healing. Anecdotally the volume of wound exudate gathered from acute wounds decreases significantly over the first three to four days signifying a decrease in wound oedema. However, currently there is no quantitative evidence to support an actual reduction in interstitial wound fluid although studies are underway to attempt to evaluate changes in wound fluid constituents under TNP.

Vacuum therapy can be regarded as a method that combines the benefit of both open and closed treatment and adheres to DeBakey's principles of being short, safe, and simple.

There have been similar studies by Joseph et al and Morykwas et al which showed that VAC proved effective in shrinking the widths of wound over time compared to standard wound dressings. Standard wound dressings adhere to devitalized tissue and within four to six hours the gauze can be removed, along with the tissue, as a form of mechanical debridement. This method of wound care has been criticized for removing viable tissue as well as nonviable tissue and being traumatic to granulation tissue and to new epithelial cells.

Further research is needed to increase understanding of the therapeutic effects of VAC therapy to give clinicians stronger arguments to support its use.[24]

CONCLUSION

Vacuum assisted closure therapy appears to be a viable adjunct for the treatment of open musculo-skeletal injuries. Application of sub-atmospheric pressure after the initial debridement to the wounds results in an increase in local functional blood perfusion, an accelerated rate of granulation tissue formation, and decrease in tissue bacterial levels. There is an increasing body of data supporting negative pressure wound therapy as an adjunctive modality at all stages of treatment for Grade IIIB tibia fractures. There is evidence to support negative pressure wound therapy beyond 72 hours without increased infection rates and to support a reduction in flap rates with negative pressure wound therapy Although traditional soft tissue reconstruction may still be required to obtain adequate coverage, the use of this device appears to decrease their need overall. However, negative pressure wound therapy use for Grade IIIB tibia fractures requires extensive additional study.

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