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Role of Vacuum-assisted closure therapy in the management of chronic wounds

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Abstract
Vacuum-assisted closure (VAC) therapy is a relatively new concept described in the literature that increases wound-healing capacity. The aim is to investigate the effect of vacuum-assisted closure therapy on wound healing and granulation tissue formation and hence shortening of the wound bed preparation time, reduction in duration of hospital admission, and reduction in the necessity for dressing change or for debridement. Sixty-eight patients with chronic wounds were randomized to initial treatment with vacuum-assisted closure or conventional dressings. Depending upon the condition of the wound, it was debrided and dressing changed. The rate of granulation tissue production was determined by measuring the reduction in wound volume over time. The primary endpoint was a granulated wound or preparation for wound coverage techniques. The mean wound size before treatment was 26.52 cm^2 and 15.84 cm^2 in VAC therapy and conventional dressing group respectively. Similarly, the mean wound size after treatment was 13.35 cm^2 and 14.38 cm^2 in VAC therapy and conventional dressing group respectively. The duration of treatment was 14.71 days and 23.38 days with % of wound size reduction 49.66% and 9.21% in VAC therapy and conventional dressing group respectively were statistically significant. The application of controlled levels of negative pressure has been shown to accelerate debridement and promote healing in chronic wounds. It also provides a sterile, more controlled resting environment to large exudating wound surfaces.

Keywords: chronic wound, granulation tissue, vacuum-assisted wound closure.

Introduction

Acute and chronic wounds affect at least 1% of the population and represent a significant risk factor for hospitalization, amputation, sepsis, and death. About 2% of the population in the course of a lifetime will develop a chronic wound, with a mortality rate of approximately 2.5% from the wound.

Wound healing is a dynamic process of three overlapping phases: inflammation, proliferative phase with granulation tissue formation and epithelialization, and tissue remodeling [1, 2]. Inflammation lasts several days in the acute healing wound but persists in the chronic wound [3, 4, 5]. It is driven by pro-inflammatory cytokines, the prolonged and overactive neutrophil response leads to increased protease activity, mainly matrix metalloproteinase [6, 7].

In conventional wound therapy, the wound is covered with wound dressings consisting of various materials (e.g., gauze, hydrocolloids, and alginate) which can be used either dry or alter moistening. Conventional wound therapy is subject to a very wide range of variations. There is no generally valid uniform standard [8, 9]. Dressings are usually changed once or several times daily.

The current conventional modalities of treatment of wounds are time-consuming, expensive, and only moderately successful. It also requires specialized wound care systems. This is especially so in cases of chronic wounds. By following the currently available protocols, about 50% of ulcers will heal in 4 months, about 20% do not heal in less than 2 years, and about 8% do not even heal after 5 years [10]. Furthermore, various studies reported a recurrence rate after wound healing with non-operative techniques of up to 57% after 1 year [11].

The technique of applying negative pressure to a wound to assist in healing has been in use since the 1950s, and the practice has continued to evolve and gain in popularity. The technique has been given several other names: negative-pressure wound therapy, vacuum-sealing techniques, sealed surface wound suction, sub-atmospheric pressure therapy, and vacuum-pack technique [12].

In VAC therapy, a sub-atmospheric pressure dressing is used to convert an open wound into a controlled closed wound [13]. VAC has been extremely successful in the treatment of acute and chronic wounds [14, 15]. Although this form of therapy is being used for various Wound types, one of the primary indications remains the treatment of chronic wounds [16].

VAC therapy is a sophisticated development of a standard surgical procedure, the use of vacuum-assisted drainage to remove blood or serous fluid from a wound or operation site. In essence, the technique is very simple. A piece of foam with an open-cell structure is introduced into the wound and a wound drain with lateral perforations is laid on top of it. The entire area is then covered with a transparent adhesive membrane, which is firmly secured to the healthy skin around the wound margin.

When the exposed end of the drain tube is connected to a vacuum source, fluid is drawn from the wound through the foam into a reservoir for subsequent disposal. The plastic membrane prevents the ingress of air and allows a partial vacuum to form within the wound, reducing its volume and facilitating the removal of fluid. The foam ensures that the entire surface area of the wound is uniformly exposed to this negative pressure effect, prevents occlusion of the perforations in the drain by contact with the base or edges of the wound, and eliminates the theoretical possibility of localized areas of high pressure and resultant tissue necrosis [17].

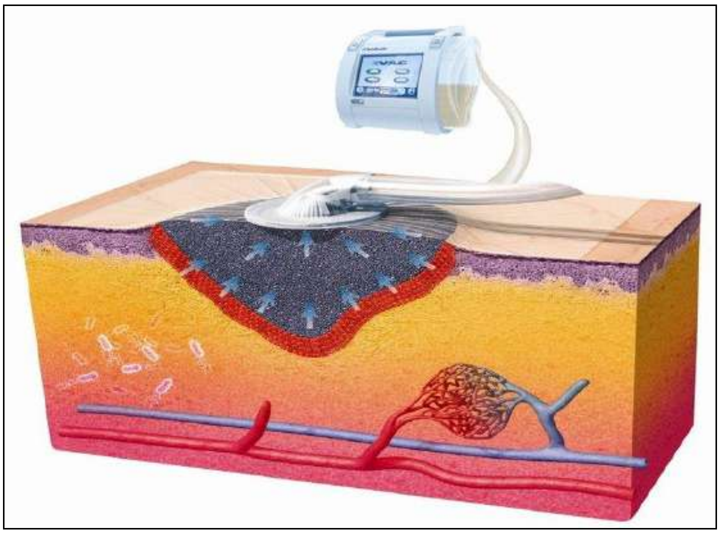

Fig 1: The figure shows the foam dressing fitted into the wound that helps to provide the necessary mechanisms to promote granulation tissue formation [18].

The application of VAC therapy has been shown to alter the expression of apoptosis-related proteins and genes, including Bcl-2, NGF/NGf mRNA, C-myc, and C-Jun, to promote healing. It has since been proposed that the application of sub-atmospheric pressure produces mechanical deformation or stress within the tissue resulting in protein and matrix molecule synthesis and enhanced angiogenesis [19]. Additionally, mechanical deformation of cells is thought to result in protein and matrix molecule synthesis, which increases the rate of cell proliferation. Changing the external forces may be a more efficient way to stimulate angiogenesis and granulation tissue formation [20]. VAC therapy induces mechanical stress, and a pressure gradient between the wound and the surrounding tissue may force blood to the wound, increase blood flow velocity, dilate capillaries and open up the capillary beds [21]. Mechanical forces and increased blood flow are known to affect the cytoskeleton in vascular cells and stimulate endothelial proliferation, capillary budding, and angiogenesis [22].

VAC therapy has profoundly changed the clinical approach to wound healing and patients with chronic wounds, including patients with pressure ulcers, long-term dehisced wounds, venous stasis ulcers, vascular and diabetic ulcers, and a wide variety of miscellaneous long-standing wounds [23, 24]. Many of these patients are debilitated, nonsurgical candidates or individuals who have previously failed multiple surgical procedures. In the past, such patients would have required prolonged hospitalization and a myriad of treatments. Dressing changes are minimized with vacuum-assisted closure, and the overall cost for wound treatment is controlled. The addition of the ambulatory vacuum-assisted closure device has greatly improved the quality of life for many of these patients [25]. The vacuum-assisted closure device is used until the chronic wound has healed or stabilized and co-morbidities are controlled. Definitive reconstruction with skin grafts, flaps, or biomaterials is then selectively performed [25]." Hospitalization time and expenses are significantly reduced [26,27]. The aim of the study is to investigate the benefits of VAC therapy on chronic wound healing as compared to conventional dressing.

Materials and Methods

This is a prospective hospital-based study conducted in the Department of General Surgery, Manipal Teaching Hospital from September 2020 to December 2021. The sample size is sixty-eight. They were randomly assigned to VAC therapy or conventional wound management after the consent. The technique is very simple. Simple instruments like surgical suction apparatus, suction tubes, and adhesive tapes are used. A piece of foam with an open-cell structure is introduced into the wound and a wound drain with lateral perforations is laid on top of it. The entire area is then covered with a transparent adhesive membrane, which is firmly secured to the healthy skin around the wound margin. The exposed end of the drain tube is connected to a vacuum source and fluid is drained from the wound through the foam into a reservoir for subsequent disposal. Depending upon the condition of the wound, the wound was debrided and the dressing was changed periodically. Frequent change of OT dressing was done to allow more regular wound inspection and cleansing to avoid infection. The rate of granulation tissue production under negative pressure was determined by measuring the reduction in wound volume over time. The management of the patient's wound in this manner did not hinder the mobility, as the patient was instructed to disconnect the tubing from the wall unit if the patient wished to mobilize or use the toilet or shower. The tubing was simply plugged with a stopper during mobilization.

Inclusion criteria:
1. Any age
2. Any sex
3. Diabetic wounds
4. Pressure ulcers
5. Dehisced wounds
6. Chronic ulcers
7. Venous ulcers

Exclusion criteria:
1. Malignancy in the wound
2. Fistulas to organs or body cavities
3. Exposed blood vessels
4. Coagulation disorder
5. Necrotic tissue in eschar
6. Osteomyelitis
7. Refusal by patient

The optimum level of pressure applied was between 100-125 mmHg and applied intermittently every 2 hours for 15 minutes. The size of the wound was measured regularly as and when dressing was changed. Statistical analysis was done by using a - test to compare between areas of wounds before and after treatment with VAC therapy; and the duration of treatment required in both study groups.

Results
A total number of 68 patients were enrolled according to the inclusion criteria. 37 patients were in the control group who underwent conventional dressing and 31 in VAC dressing. There were 44 males and 24 females in the study. The average age was 55.84 years in the control group and 58.55 years in the case group. The demography of the study is depicted in Table no.1

Table 1: Sex distribution in VAC dressing and Conventional Dressing

Sex	VAC Dressing		Conventional Dressing	
	Number (n=31)	Percentage	Number (n=37)	Percentage
Male	20	64.51	24	64.86
Female	11	35.48	13	35.13

While comparing hemoglobin, serum albumin, RBS, and total count level between the two groups, the difference was not statistically significant for VAC therapy and the Conventional Dressing group.
The causes of the wound were traumatic, diabetic wound, decubitus ulcer, a venous ulcer, arterial ulcer, necrotizing fasciitis
Wound swab CS at the time of admission was positive in 14 cases (45.16%% in VAC therapy; 37.857% In conventional dressing group) each in both the study groups. The organisms grown were E. coli, Staphylococcus aureus, and Pseudomonas aeruginosa among the VAC therapy group; and *Klebsiella*, *E. coli*, and *Staphylococcus aureus* among the conventional dressing group. Wound swab C/S before the definitive treatment was negative in all the cases of both study groups.

Change in the wound Size before and after treatment with VAC therapy and conventional dressing group
The mean wound size before treatment was 26.52 cm^2 and 15.84 cm^2 in VAC therapy and conventional dressing group respectively. Similarly, the mean wound size after treatment was 13.35 cm^2 and 14.38 cm^2 in VAC therapy and conventional dressing group respectively. The duration of treatment was 14.71 days and 23.38 days with % of wound size reduction 49.66% and 9.21% in VAC therapy and conventional dressing group respectively were statistically significant.

Table 2: Comparison of the duration of treatment (End days) between the two study groups

Variables	Mean	SD	n	t-value	P-value	CI
Case	14.71	8.001	31	3.607	0.001	3.867-13.47
Control	23.38	11.717	37			

There were no complications found related to the treatment in both the study groups. The only significant shortcomings noted were skin irritations from the adhesive covering the skin.

Discussion
We have found that negative-pressure therapy seems to honor a significant bent over standard wound care for the treatment of chronic wounds. We found a significant benefit for both changes in wound size and time to prepare the wound bed. Thus, negative-pressure therapy seems more efficient than standard wound care at promoting the healing of chronic wounds.
VAC therapy has been shown to produce a greater reduction in wound dimension than conventional dressings. Eginton et al reported a 49% and 59% reduction in the wound depth and volume, respectively, of 6 VAC-treated diabetic foot ulcers [28]. This was significantly greater than the 7.7% reduction in wound depth and 0.1% reduction in wound volume achieved when the same wounds were treated with moist gauze dressings. The greater reduction in wound dimension had been attributed to the three-dimensional stress that VAC exerted across the whole area of the wound, also known as macro-strain, that drew wound edges inwards in a centripetal fashion, thus shrinking the wound. Similarly, VAC therapy achieved wound healing in 56% Vs. 39% (P=0.04) of patients with a median wound bed preparation time of 42 days' vs 84 days (p-0.02) [28]. The reduction in wound area observed was by 49.66% and 9.21%, during the mean duration of 14.71 days and 23.38 days following VAC therapy and conventional dressings respectively. This decrease in size was statistically significant (p-value<0.001).
Besides reducing wound size, VAC therapy encouraged wound healing by stimulating the formation of granulation tissue. Morykwas et al demonstrated that wounds treated with negative pressure achieved more granulation using either continuous or intermittent pressure than those treated using conventional dressing. A tendency of time needed for wound bed preparation for surgical intervention towards a shorter duration of therapy was found. The wound surface area reduced significantly faster with VAC therapy.
An additional benefit observed was the ability of VAC therapy to alleviate bacterial infection in a wound. In the study performed by Morykwas et al, VAC therapy also achieved a clinically significant reduction in bacterial load of chronic wounds inflicted on a swine model by the fifth day. A similar reduction, however, took l days in untreated control wounds.
In our study, wound culture and sensitivity were found to be positive for microorganisms for all 14 wounds each at the start of both VAC therapy and Conventional dressings. All the

wounds showed clearance of bacterial infection at the end of VAC therapy and conventional dressings before the definitive surgical intervention was undertaken. However, we could not compare the time duration taken for bacterial load clearance between the two study groups.

In our study, the length of time taken to complete VAC therapy ranged from > to 3 days, with an average of 14.71 days. This was much shorter than the average time taken by Armstrong et al of 32.9 days so and Clare et al of 57.4 days.

Complications are being reported in the literature. Toxic shock syndrome following VAC therapy is reported in the literature. There have been explicit reports of sepsis, hypovolemic shock from fluid loss, arterial erosion Deciding and amputation of an extremity". However, in none of these cases of severe adverse events can the possibility be excluded that there was either an individual error in the use of VAC therapy or that the adverse event should not be regarded as a complication or VAC therapy, but rather as an inevitable consequence of the underlying disease. Detached pieces of foam may become walled off as granulation tissue develops around them. Therefore, the use of multiple small sponge fragments should be discouraged. The only significant shortcomings we have noted were skin irritations from the adhesive covering the skin immediately surrounding the wound, decreased patient nobility when the suction was applied, and requirement for wall suction and suction device.

Limitations

We were not able to study the incidence and avoidance of wound recurrence and reduction in the necessity of revision operations; Reduction in mortality rate; improvement or maintenance of the disease-related quality of and avoidance of restrictions in activities of everyday life; and reduction in scar formation and improvement of subjective cosmetic results. It requires a further detailed study on a larger scale to provide better evidence in its day-to-day practice.

Conclusion

In Conclusion, VAC therapy can be used to manage many difficult wounds of several types. Vacuum-assisted closure therapy can be adopted as the standard treatment for wounds. Scientific evidence regarding the mechanisms by which vacuum-assisted closure promotes wound healing has started to emerge.

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