ORIGINAL RESEARCH

A Modified Negative Pressure Wound Therapy Reduces the Occurrence of Tension Blisters Around Negative Pressure Dressings

Tao Ning, MD; Huihui Guo, MD; Qiwei Song, MD; Siwei Mei, MD; Hao Wang, MD; Haiyang Yu, MD

ABSTRACT

Background • To date, there is no effective solution for preventing the formation of blisters around negative-pressure wound dressings. In this study, we aim to address this problem and identify techniques to improve the negative-pressure drainage technique.

Methods • A total of 129 patients from 2021.11 to 2022.11 who were previously treated in Fuyang People's Hospital were included in this retrospective analysis. All patients had negative-pressure drainage dressings applied to their wounds after undergoing thorough wound debridement. The patients were divided into the following groups: a traditional treatment group and a modified treatment group. The traditional treatment group comprised 60 patients who received negative-pressure wound therapy (NPWT) and a modified treatment group comprised 69 patients who received NPWT plus Vaseline gauze. The dressing coverage area, wound location, incidence of blisters around the dressing 3 days after NPWT, wound infection rate, and length of hospitalization were recorded. The incidence of blisters, wound infection rate, and wound location in the 2 groups were included as the categorical data and were compared using a chi-squared test. The dressing coverage area and length of hospitalization in the 2 groups were included as the quantitative data and were compared using an independent samples *t* test or with the Mann-Whitney test if the data were abnormally distributed.

Results • The incidence rates of blisters in the traditional and modified treatment groups were 33.3% (20/60) and 13.0% (9/69), respectively, displaying a statistically significant difference ($\chi^2 = 7.581$, $P = .006$). The infection rates of the 2 groups were 38.3% (23/60) and 20.3% (14/69), respectively, showing a statistically significant difference ($\chi^2 = 5.108$; $P = .024$). The lengths of hospitalization in the 2 groups were 26.05 ± 14.74 days and 18.17 ± 7.54 days, respectively, showing a statistically significant difference ($t = 3.892$; $P = .000$). The dressing coverage areas were 150 cm^2 (88.75 cm^2, 600 cm^2) and 150 cm^2 (124 cm^2, 600 cm^2), respectively, showing no statistical difference ($P = .759$).

Conclusion • Modified NPWT can effectively reduce the incidence of blisters, length of hospitalization, and infection rate of patients. (*Altern Ther Health Med.* 2023;29(8):540-544).

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BACKGROUND

In 1992, Fleischmann et al. first developed the negative-pressure drainage technique and applied it to open fracture wounds, demonstrating an excellent curative effect.[1] The negative pressure wound therapy (NPWT) system, which has been widely used in recent years, is regarded as a revolutionary wound protection device that can promote the rapid formation of granulation tissue and increase blood flow and bacterial clearance, thus eliminating obstacles to cell proliferation and repair, accelerating the healing of shallow and deep wounds, and effectively reducing the infection rate, amputation rate, wound healing time, and length of hospitalization.[2,3] Due to multiple factors, such as multiple systemic injuries, wound infection, or severe contamination of the wound surface, the soft tissues in a wound are usually not able to be treated on time. Negative-pressure drainage technology has replaced conventional dressings and can effectively treat open wounds.[4] Wound healing is a complex, dynamic process supported by a myriad of cellular events that must be tightly coordinated to efficiently repair damaged tissue.

Ruptured blister, iatrogenic, and dissecting pseudo-aneurysms pose challenges for cerebrovascular surgeons. However, iatrogenic blisters are a common and easily overlooked complication in NPWT. Once ruptured, blisters are susceptible to rapid contamination by common skin flora, such as

Figure 1. The mechanism of formation of blisters. **A.** Formation of shearing forces between the hardened dressing and the skin. **B.** Use of Vaseline gauze around the negative pressure wound therapy dressing edge to disperse the shearing forces.

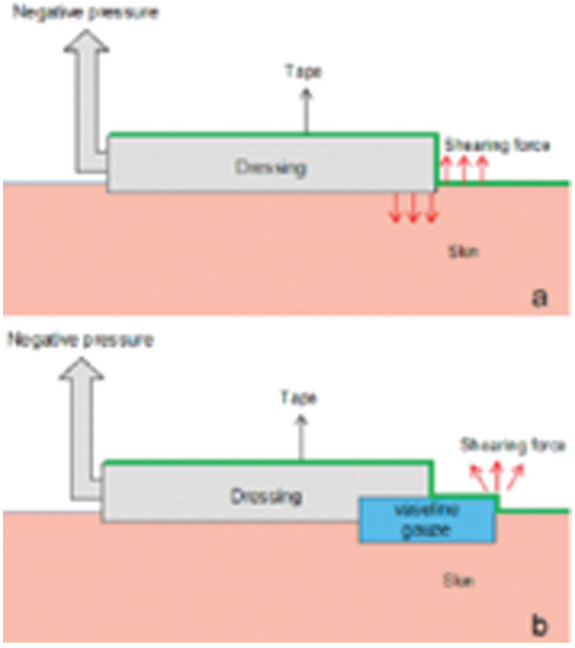

Table 1. Demographics of patients with wounds

Group	Age ($x \pm s$)	Gender		Wound size, M (p25,p75)
		Male	Female	
Traditional	50.63 ± 17.02	38	22	150 (88.75, 600)
Modified	53.75 ± 18.58	36	33	150 (124, 600)
t value	-0.989			
χ^2		1.634		
Z value				0.306
P value	.325	.201		0.759

Table 2. Wound sites of patients

Group	Wound site							Fisher's Exact Test
	Thigh	Calf	Foot and ankle	Forearm	Upper arm	Hand and wrist	Other	
Traditional	11	11	26	4	1	6	1	0.670
Modified	12	18	31	3	2	2	1	

Staphylococcus epidermidis and Staphylococcus aureus.[5] Strebel et al.[6] identified 7 positive cultures of the blister fluid from 64 patients with fractures. Howell et al.[7] described the formation of blisters around negative pressure drainage dressings after total knee arthroplasty. They observed that the positions of blisters at the edge of the dressing were linear, and the blisters mostly occurred on normal skin. Thus, they suggested that the friction between the dressing foam and the tape, which led to the separation of the epidermis and dermis, was the main cause of blister formation.[7-9] However, in their study, they did not provide a reliable solution for overcoming this problem. We also observed similar blister formation in patients with soft tissue defects in the extremities. To this end, we investigated the mechanism of blister formation by considering multiple factors and identified corresponding preventive measures.

After a negative pressure drainage dressing is connected to a negative pressure device, the dressing hardens and generates shearing forces on the skin, causing an imbalance in the osmotic pressure on both sides of the skin. Moreover, due to the swelling of the tissues, the liquid moves from a low permeability zone to a high permeability zone,[5,10,11] which results in the formation of blisters. This study aimed to detect the influence of modified negative pressure wound therapy on the occurrence of tension blisters around negative pressure dressings.

PATIENTS AND METHODS

Patients

The patients included in this study belonged to a retrospective case series from the Fuyang People's Hospital from November 2021 to November 2022. The following inclusion criteria were applied: 1) patients with skin and soft tissue defects who experienced difficulty with wound healing and 2) patients who underwent skin grafting to the wound and NPWT. The following exclusion criteria were applied: (1) patients with severe cardiopulmonary disease and intolerance to surgery and (2) patients with edema caused by other medical factors such as severe hypoalbuminemia.

A total of 129 patients and 129 healthy volunteers from September 2020 to November 2021 were included in this study. The patients comprised 74 males and 55 females aged from 4 to 77 years. The patients were divided into the traditional treatment group and the modified treatment group. There was no statistical difference regarding age, gender, wound area, or wound location between the 2 groups (Tables 1 and 2).

METHODS

Sample size

The sample size was calculated by statistical data.

Selection criteria

The RCT studies were collected in this study to compare the influence of modified negative pressure wound therapy on the occurrence of tension blisters around negative pressure dressings.

Procedure

Antibiotics were applied to the patients 30 min before surgery to prevent wound infection. According to the patient's wound locations, appropriate anesthesia methods and positions were used. Each wound was washed with liquid soap and then washed 3 times with hydrogen peroxide solution and a copious amount of normal saline solution (>3000 ml). To prevent infection, the wound was debrided from the superficial to deep tissues to remove as much deactivated and contaminated/infected soft tissue as possible, except for vital blood vessels and nerves. Free bones and necrotic tendons were completely removed, and soft tissues, such as the periosteum and fascia, were preserved as much as possible. After debridement, the wound was washed repeatedly with hydrogen peroxide, iodophor, and sterile saline.

To prevent wound infection, an irrigation tube was placed in the wound. The wound was covered with NPWT dressing, sealed with a semi-permeable membrane, and connected to a negative-pressure suction device (with the standard negative pressure of 125 mmHg). All surgical procedures were performed by the same senior surgeon. All patients were informed of the surgical plan and signed a consent form before surgery. The wounds were covered with a traditional NPWT dressing in the traditional treatment group and with a traditional NPWT dressing combined with a double layer of Vaseline gauze in the modified treatment group. The dressing exceeded the size of the wound by at least 2 cm around the edge. This study was approved by the Ethics Committee of Fuyang People's Hospital.

Improvement procedures

The following improvement procedures were undertaken: (1) After thorough debridement of the wound, an NPWT dressing was used to cover the wound surface, exceeding the wound margin by about 2 cm (Figure 2A). (2) A 2-cm-wide Vaseline gauze was placed under the edge of the NPWT dressing (Figure 2B). (3) A semipermeable membrane was used to seal the NPWT dressing, which was then connected to a negative-pressure device (Figure 2C). (4) The negative pressure was maintained at 125 mmHg during the operation (Figure 2D).

Observation indicators

Indicators, including the wound location, NPWT coverage area, the incidence of blisters around the dressing 3 days after NPWT, wound infection rate, and length of hospitalization were recorded and compared between the 2 groups. The wound infection rate was measured with the index of bacterial culture of wound exudates after the NPWT dressing was removed.

Statistical methods

The SPSS v. 26.0 (IBM Corp., Armonk, NY, USA) software was used to process the data. Quantitative variables are expressed as means and standard deviations. Abnormally distributed data are expressed as medians (quartiles). An independent samples *t* test was used to compare the age, NPWT coverage area, and length of hospitalization between the 2 groups. A chi-squared test was used to compare categorical variables, including gender, wound location, incidence of blisters, and infection rates; for those abnormally distributed categorical variables, the Mann-Whitney test was used for the comparison. The Kolmogorov-Smirnov test was used for the comparison of quantitative variables. Levene's test was used for the calculation of the equality of variances. A value of $P < .05$ denotes statistical significance.

RESULT

The incidence of blisters around the dressings in the two groups

Of the 129 patients, 29 developed tension blisters in their wounds, including 20 in the traditional treatment group (60 patients) and 9 in the modified treatment group (69 patients).

Figure 2. Improvement procedures of modified negative pressure wound therapy.

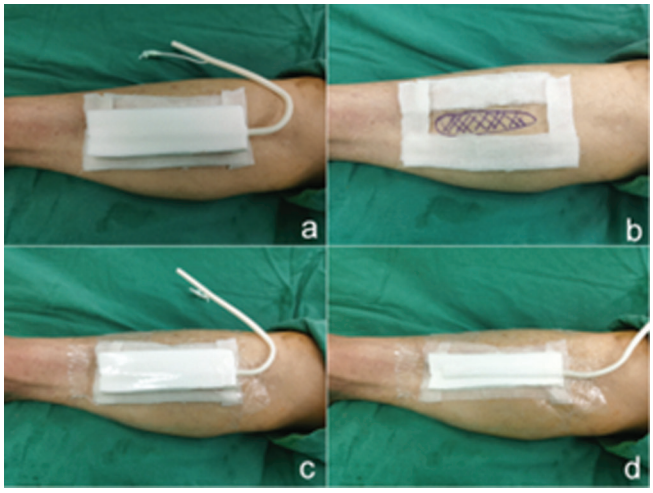

Table 3. Complications and duration of hospital stay in traditional and modified treatment groups

Group	Cases (n)	Blister formmation n (%)	Overall wound infection n (%)	Duration of hospital stay
Traditional	60	20 (33.3%)	23 (38.3%)	26.05 ± 14.74
Modified	69	9 (13.0%)	14 (20.3%)	18.17 ± 7.54
t value				3.892
χ^2		7.581	5.108	
P value		.006	.024	.000

Figure 3. Case presentation of the 2 treatment groups

As a result, the use of the modified NPWT (i.e., the addition of Vaseline gauze) reduced the incidence of blisters from 33.3% in the traditional treatment group to 13.0% in the modified treatment group.

Wound infection rate

The infection rates of the traditional and modified treatment groups were 38.3% and 20.3%, respectively. The infection rate in the traditional treatment group was higher than that in the modified treatment group, and there was a statistically significant difference between the 2 groups ($P = .024$; Table 3).

NPWT dressing coverage area

The mean dressing coverage areas in the traditional treatment group were 150 cm^2 (88.75, 600), while those in the

modified treatment groups were 150 cm^2 (124, 600), with no significant difference (P = .759 between the 2 groups observed.

Length of hospitalization

The lengths of hospitalization were 26.05 ± 14.74 and 18.17 ± 7.54 days in the traditional and modified treatment groups, respectively, with a statistically significant difference (P < .001).

Case presentation

The thigh skin defects in the traditional treatment group were covered with NPWT dressing after skin grafting (Figure 3A). The NPWT dressing was removed 3 days postoperatively, and blisters were found at the edges of the dressing (Figure 3B). Due to severe trauma, the skin defect of the calf wound after thorough debridement was covered with NPWT dressing, and Vaseline gauze was placed around the edge of the dressing. No blisters were found when the NPWT dressing was removed 3 days after surgery (Figure 3C and Figure 3D).

DISCUSSION

The negative-pressure drainage technique is mainly used for patients whose wounds cannot be healed in the first stage after debridement.[12-14] This technique can effectively cover the wound surface, reduce infection rate, and shorten hospitalization time. However, the negative pressure drainage technique also has many disadvantages, such as the possibility of causing deep wound infection and bleeding and failure of the drainage device.[15] The bioburden of a wound is a continuum from contamination to overt infection. Infection describes the invasion of bacteria into living dermal and subdermal tissue, causing damage to the host. Howell et al.[7] were the first to report the development of blisters around dressings when NPWT was used as an aid to aspirate excess fluid from the wound. However, they did not provide a solution to solve this problem. In the present study, we hypothesized that the formation of blisters around NPWT dressings is due to shearing forces. By increasing the contact area where the dressing contacts the skin, we have developed a convenient and straightforward way to reduce and/or prevent the formation of blisters. In clinical practice, we noticed that blisters were only present at the edge but not at the bottom of NPWT dressings. We proposed the following hypothesis based on this observation: When the NPWT dressing is connected to a negative-pressure device, the air is sucked out and the dressing becomes stiffened; thus, the shearing force is formed at the contact between the dressing edge and the skin, resulting in a pressure imbalance in the soft tissue inside and outside the dressing. The fluid will keep moving to the other side of the wound due to the constant presence of pressure until the pressure on both sides rebalances. Therefore, blisters are only observed at the edges of the dressing.

Based on the hypothesis described above, we have designed a very simple method for preventing the formation of blisters around the dressing by simply inserting a double layer of Vaseline gauze around the dressing edge. Padding with Vaseline gauze at a width of about 2 cm around the edge of the dressing can effectively disperse the shearing force inside and outside the dressing and thus greatly balance the pressure differences on both sides. This study provides an alternative method for preventing blister formation around dressings when NPWT is used for wound treatment.

The negative-pressure value is a core parameter for wound treatment with NPWT. It is very important to choose an appropriate negative-pressure value. It has been reported that -50 mmHg is recommended for the treatment of chronic venous ulcers,[16-17] while -125 mmHg is mostly used for acute trauma wounds.[18] Therefore, in this study, we used a negative pressure of -125 mmHg.

The technique significantly reduced the incidence of blisters from 33.3% in the traditional treatment group to 13.0% in the modified treatment group, which is lower than that reported by Howell et al. Swelling around the wound and subtle differences in dressing materials might also have been responsible for this difference.[19] The infection rates of the traditional and modified treatment groups were 38.3% and 20.3%, respectively, and were statistically different and inconsistent with the reported infection rates, suggesting that the primary wound injury was the underlying cause of wound infection.[19] The lengths of hospitalization of the traditional and modified treatment groups were 26.05 ± 14.74 and 18.17 ± 7.54 days, respectively, representing a statistically significant difference. The ruptured blisters had the right humidity and abundant nutrients, and they lacked immune cells, making them susceptible to infection. Varela et al.[15] suggested that the surgical incision should be made away from the blistered area and that it would be better to wait for the blistered area to re-epithelialize, reporting that this led to a longer hospital stay, which is similar to the result in our study. Based on this conclusion, we proposed an improved NPWT technique to reduce or prevent the formation of blisters around the dressing edge by adding padding below the dressing edge.

To the best of our knowledge, there are few studies to investigate the mechanism of blister formation around NPWT dressings by comparing the clinical data of 2 groups of wound defects. Although this study was simple and effective, it also had the following limitations: (1) The study was retrospective, and (2) the study only recorded and compared the infection at the point in time when the NPWT dressing was removed from the wound surface, without long-term observation and follow-up.

CONCLUSION

We proposed an improved NPWT technique to reduce or prevent the formation of blisters around the dressing edge by adding padding below the dressing edge. In addition, the use of the modified NPWT technique (i.e., the addition of Vaseline gauze) reduced the length of hospitalization significantly.

DATA AVAILABILITY

The data could be obtained by contacting the corresponding author.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

FUNDING

This work was supported by the Bengbu Medical College Project Fund (NO.2020byzd347) Clinical Science Foundation of Anhui Medical University (NO.2022xkj225), and Fuyang city health commission project fund (NO.FY2021-027)

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