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ORIGINAL ARTICLE

Various Purposes of Negative Pressure Wound Therapy in Severe Burn Treatment: a Short Case Series Analysis

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Abstract

The purposes for performing negative pressure wound therapy (NPWT) in severe burns are diverse, but few reports comprehensively discussing its indications and methods have been published. We included patients with a ≥30% total burn area. There were 4 patients, and a total of 9 NPWT were performed. The therapy sites were the upper extremity ($n = 2$), the elbow ($n = 1$), the dorsum of the hand ($n = 5$), and the knee ($n = 1$). The purposes of the therapy were bridge-to-skin grafting ($n = 5$), dressing the artificial dermis ($n = 1$), therapy for bolstering the autograft ($n = 1$), bridge-to-flap surgery ($n = 1$), and covering the flap ($n = 1$). The devices used were bedside wall suction ($n = 5$) and dedicated device ($n = 3$). Therapy was converted to wall aspiration after use of the dedicated device in 1 case. NPWT is an effective option in severe burn treatment. For each purpose, it is necessary to consider the device used, negative pressure setting, starting date, frequency of dressing changes, and period of therapy. NPWT in severe burns also has the advantage of prioritizing life-prolonging treatment. If strict control of negative pressure is required, a dedicated device should be used rather than wall suction.

Keywords Burn · Flap surgery · Negative pressure wound therapy · Skin graft

Introduction

Negative pressure wound therapy (NPWT) is a treatment that reduces inflammatory exudate and promotes the formation of granulation tissue by the application of negative pressure to the wound. NPWT was previously used for open wounds, but its application is expanding to include suture wounds, skin grafts, and skin flaps. NPWT is used for the treatment of various injuries including chronic wounds [1] and acute trauma [2]. In recent years, the number of reports on the use of NPWT for burns has been increasing [3, 4]. However, the purposes for using NPWT in severe burns are diverse, and few reports comprehensively discussing its indications and methods have been published. Here, we describe our experience with NPWT for severe burns at our hospital.

Patients and Methods

This was a case series study. We included patients with a ≥30% total burn area who underwent NPWT at our hospital between September 2020 and September 2022. In a single patient, each therapy was considered as 1 therapy for a different site and purpose of use. There were 4 patients, and a total of 9 NPWT were performed. Using the medical records and clinical photographs, we investigated each patient's age, total burn surface area (TBSA), outcome, NPWT site, burn surface area (BSA) where NPWT was performed, purpose in using NPWT, device used, negative pressure setting, NPWT start date, frequency of dressing changes, period during which NPWT was performed, local outcome, and treatment after NPWT.

Results

Three patients were discharged with good outcomes, but 1 patient died of multiple organ failure. The NPWT sites were the upper extremity (upper arm to forearm) ($n = 2$), the elbow ($n = 1$), the dorsum of the hand ($n = 5$), and the knee ($n = 1$). The average (min, max) BSA where NPWT

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was performed was 2.2 (0, 7) %. The purposes of NPWT were bridge-to-skin grafting ($n = 5$), dressing the artificial dermis ($n = 1$), therapy for bolstering the autograft ($n = 1$), bridge-to-flap surgery ($n = 1$), and covering the flap ($n = 1$). Bedside wall suction was performed using the YOX DISPO S-701 (Koike Medical, Tokyo, Japan) ($n = 5$), the RENASYS NPWT system (Smith & Nephew, London, UK) ($n = 2$), or the VAC system (KCI, TX, USA) ($n = 1$). Therapy was converted to wall suction after use of the VAC system in 1 case. The negative pressure setting was −10 to −20 kPa for wall suction and −50 to −100 $mmHg^2$ for the RENASYS and VAC systems. NPWT was started on average (min, max) 36.9 (14, 108) days after injury. The average (min, max) duration of NPWT was 16.1 (5, 35) days, and the dressing was changed every 3 to 7 days in patients who underwent NPWT for 8 days or more. Regarding the local outcome and treatment after NPWT, 2 patients received sheet skin grafts after the burn borders were demarcated. Two patients received mesh skin grafting, and 1 patient, flap surgery, after good granulation was obtained. One therapy for fixation of the skin graft resulted in good engraftment. In 1 therapy for fixation of the artificial dermis, the artificial dermis failed to engraft, and the therapy was switched to ointment therapy. In 1 therapy, NPWT was continued without granulation, although it was possible to maintain a moist environment (Table 1).

Cases

Patient A The patient, a 53-year-old woman, doused herself in kerosene and set her clothes on fire, resulting in severe burn wounds. The TBSA was 40%. After the burn area had been reduced with skin grafts for deep burns on the elbow, flap surgery was performed. NPWT was performed 3 times. The first time was for wound bed preparation before skin grafting (therapy 1), the second time was to fix the skin graft (therapy 2), and the third time was performed on the skin flap (therapy 3). At 5 months postinjury, she has an elbow joint extension disorder, but she uses her left hand as a functional limb.

Patient B A 61-year-old woman sustained burn injuries as a result of a fire at her home. The burn sites were the lower limbs, the anterior chest and abdomen, the hands, and the face, and the TBSA was 42%. NWPT were performed three times. The first and second NPWT were performed on the dorsum of the hand. After performing debridement of the third-degree burn on the dorsum of the hand on postinjury day 14, we covered the burn with artificial dermis and provided bolstering with NPWT (therapy 4). However, the artificial dermis failed to engraft, and the tendon was exposed, so a second NPWT was started on postinjury day 24 in preparation for flap surgery (therapy 5) (Fig. 1a, b, c). Dry necrosis of the tendon became apparent, but the surrounding granulation was good (Fig. 1d). On postinjury day 64, the patient underwent reverse radial forearm flap covering and tendon reconstruction with a palmaris longus tendon (Fig. 1e, f, g). Interdigital flap revision was performed, and 9 months after the flap surgery, the patient has functional use of the hand (Fig. 1h). This patient had a patellar exposure and a third NPWT, and third NPWT was performed before skin grafting for patellar exposure (therapy 6).

Patient C A 61-year-old woman sustained burn injuries in a bonfire accident. The burn sites were the head, the face, the anterior chest, the upper limbs, and the back, and the TBSA was 55%. On postinjury days 5 and 8, escharotomy was performed, and artificial dermis was applied. Escharotomy for burns on the dorsum of the hand was also performed, but NPWT was performed instead of primary skin grafting to shorten the operation time and preserve the donor skin (therapy 7). While life-prolonging treatment was being given, trunk skin grafting was prioritized, but the patient died of multiple organ failure on postinjury day 47.

Patient D A 47-year-old man sustained burn injuries when his clothing caught fire while he was working near an aluminum furnace. The burn sites were the chest, the abdomen, the upper limbs including the dorsum of the hand, the lower limbs, and the back, and the TBSA was 68%. Escharotomy was performed on postinjury day 10 for a full-layer burn on the dorsum of both hands (Fig. 2a). NPWT was performed on postinjury day 14 to prioritize skin grafting to the other burn areas (Fig. 2b, c) (therapies 8 and 9). Sheet skin grafting was performed on postinjury day 32 (Fig. 2d, e). The skin grafts took well, and 2 months postoperatively, the patient is continuing rehabilitation (Fig. 2f).

Discussion

NPWT has a wide variety of uses in severe burn treatment. Previously, we reported on the types of applications for NPWT in burn treatment [5] (Fig. 3). In this study, NPWT was used for bridge-to-skin grafting, dressing the artificial dermis, therapy for bolstering the autograft, bridge-to-flap surgery, and covering the flap. We examined the indications and methods for NPWT based on the cases in our hospital.

NPWT as Bridge-to-Skin Grafting (Wound Bed Preparation)

NPWT increases wound blood flow and reduces bacterial counts to prepare the wound bed for the skin graft. The use of NPWT before skin grafting has been reported to improve the survival rate of the skin graft and to reduce the infection

Table 1 Summary of patient information

Therapy no.	1	2	3	4	5	6	7	8	9
Patient	A			B			C	D	
Age, y	53			61			73	47	
Total burn surface area	40%			42%			55%	68%	
Outcome	Survival			Survival			Death	Survival	
NPWT site	Upper limb		Elbow	Dorsum of hand		Knee	Dorsum of hand	Dorsum of right hand	Dorsum of left hand
NPWT burn surface area	7%		0%	1%		0.5%	1%	1%	1%
Purpose of NPWT	Bridge-to-skin grafting	Bolster dressing for autograft	NPWT over flap	Dressing for artificial dermis	Bridge-to-flap surgery	Bridge-to-skin grafting	Bridge-to-skin grafting	Bridge-to-skin grafting	
Device used	Wall suction	RENASYS	RENASYS	VAC	VAC→wall suction	Wall suction	Wall suction	Wall suction	
Negative pressure setting	20 kPa	100 mmHg	80 mmHg	50–75 mmHg	50–75 mmHg→10–15 kPa	20 kPa	20 kPa	20 kPa	
NPWT start date (postinjury day)	45	52	108	14	24	53	8	14	
Frequency of dressing changes	None	None	None	Every 4 days	Every 3–4 days	Every 3–4 days	Every7days	Every 3–4 days	
NPWT period (days)	7	5	7	8	26	35	21	18	
Local outcome	Good granulation	Engraftment	Disappearance of exudate	Artificial dermis loss	Demarcation	Good granulation	Maintenance of moist environment	Demarcation	
Treatment after NPWT	Skin graft	Ointment therapy	None	Ointment therapy	Flap surgery	Skin graft	None	Skin graft	

Fig. 1 **a** Findings at the time of transport to our hospital. **b** We performed escharotomy of the third-degree burn on the dorsum of the hand on postinjury day 14, covered it with artificial dermis, and provided bolstering with NPWT. However, the artificial dermis failed to engraft, and the tendon was exposed. **c** The second NPWT was started on day postinjury day 24 in preparation for flap surgery. **d** Dry necrosis of the tendon became apparent, but the surrounding granulation was good. **e** On postinjury day 64, the patient underwent reverse radial forearm flap covering. **f** Tendon reconstruction with a palmaris longus tendon was performed at that time. **g** Findings at the end of surgery. **h** Interdigital flap revision was performed and the patient has functional use of the hand at 9 months after the flap surgery

Fig. 2 **a** Findings on the right hand at the time of transport to our hospital. **b** Debridement was performed on postinjury day 10 for a full-layer burn on the dorsum of the right hand. **c** NPWT was performed on postinjury day 14 to prioritize skin grafting to the other burn areas. **d** Sheet skin grafting was performed on postinjury day 32. The wound bed at the time of surgery was good. **e** Findings at the end of surgery. **f** The skin graft took well, and the patient is continuing rehabilitation at 2 months postoperatively

rate of not only intractable ulcers but also burns [5]. In therapies 1 and 6, good granulation was obtained by use of NPWT, and good skin engraftment could be obtained. NPWT also serves as a "test of wound bed viability" to determine if the wound bed is suitable for skin grafting [6]. In addition, in severe burns, treatment of localized burns is not the only treatment target, and life-prolonging treatment may be prioritized. NPWT does not exacerbate

Fig. 3 Summary of the clinical application of NPWT in burn treatment

life-threatening conditions and local treatment can be delayed until later [7]. In therapies 8 and 9, waiting and testing of the wound bed with NPWT allowed for planned and reliable use of less donor skin. In therapy 7, the patient died of multiple organ failure during NPWT, but waiting for hand treatment with NPWT allowed the other treatments to be prioritized. We used wall suction because strict negative pressure maintenance and regulation are not essential in NPWT for bridge-to-skin grafts. However, when wall suction is used, a discrepancy may exist between the meter and the actual negative pressure applied to the wound, so care must be taken. In treatment 6, in which bone exposure was observed, NPWT was performed for 5 weeks. However, because normal burn wounds respond well to NPWT, shorter duration of NPWT is usually considered sufficient.

NPWT as a Bolster Dressing for the Autograft

Because NPWT applies uniform pressure to the skin graft even in the presence of a large defect or moving parts, the use of NPWT for skin graft fixation is desirable [8]. Therefore, the use of NPWT for skin graft fixation provides benefits, including increased engraftment rates, decreased reoperation rates, hematoma prevention, and reduced shearing force [9]. In addition, reports have been published of skin grafts, including those on the joints of the upper limbs that no longer require splints when NPWT has been used [10]. In reports of pressure for bolstering skin grafts, the pressures ranged from −25 to −125 mmHg [11–13]. We set the pressure at 100 mmHg and had no loss of the graft nor necrosis due to overpressure. Although the proper amount of pressure remains controversial, it is better to use a dedicated device (such as the VAC or RENASYS) rather than wall suction to maintain a constant pressure for bolstering the dressing.

NPWT as a Bolster Dressing for Artificial Dermis

Artificial dermis may be considered when tendons or bones are exposed and no suitable wound bed is available for skin grafting. In addition, burn wounds to which artificial dermis is applied improve the engraftment rate as well as the quality of postoperative scars. NPWT has been reported to be used for fixation of artificial dermis. The advantage of using NPWT is that it reduces the time to skin graft by the promotion of early matrix formation [14, 15]. In therapy 4, NPWT was performed for this purpose, but the artificial dermis did not engraft. A certain level of wound bed viability is necessary for engraftment of artificial dermis, and the lack of viability in therapy 4 is thought to be the cause of the nonengraftment. When applying artificial dermis to burn wounds with exposed tendons or bones, the area of the exposed tendon or bone and surrounding tissue viability should be considered.

Bridge-to-Flap Surgery

The use of NPWT as the dressing while waiting for flap surgery is becoming common in severe extremity trauma. NPWT before flap surgery is expected to reduce edema, control the exudate, and protect against external contamination [16]. In the treatment of burns, skin flap surgery is often required for deep burns that expose tendons and bones [17, 18]. The duration of NPWT use varies with the waiting period for flap surgery. In therapy 5, NPWT were performed for 26 days before the flap surgery. It is possible to avoid flap surgery by performing NPWT for a long period of time and promoting granulation formation [7], but excessive expectations should be avoided, and NPWT should be considered a temporary bridge [16].

NPWT Over Flap

NPWT for local flaps reportedly improves flap blood flow and prevents edema [19]. Also, NPWT has been used for free flaps (skin containing), and early postoperative application has been suggested to minimize edema, rest the flap, reduce exudate from under the flap, and prevent venous congestion [20]. In therapy 3, NPWT was performed to reduce persistent exudate. It was previously reported that there is no issue even if NPWT is used on the flap starting the day of surgery [20], but in this case, NPWT was started 20 days after surgery. The RENASYS system was used to maintain constant pressure and to avoid overcompression of the flap. The foam was placed only on the edge of the flap, and the pressure was adjusted while allowing the color tone of the flap to be observed. Furthermore, it has also been reported that flap surgery and skin grafting are performed at the same time and NPWT is used for the dressing [21]. This method

uses a combination of NPWT as an overflap and a skin graft bolster and is thought to be useful when both deep burns that require flap surgery and shallow burns that allow skin grafting coexist.

Others

Although not performed in this study, NPWT can reportedly prevent injury progression when applied to burn wounds in the early stage of the injury [22]. NPWT was also used for the donor site for the purpose of promoting epithelialization [23]. Although the patient had generalized burns, NPWT was used on all 4 extremities. This is thought to be because the extremities are easier than the trunk to seal in burn treatment. In this study, the dorsum of the hand was the site most frequently treated with NPWT, with 3 cases and 5 treatments. Full-body burns are often accompanied by burns on the hands [24]. The treatment of hand burns does not contribute much to the reduction of the TBA and requires a certain amount of donor skin and operation time, so it is often not possible to operate at the best timing. While we should strive to treat the hand at the optimal time, NPWT to the hand for bridging skin grafts and flap surgery is a realistic option for hands with severe burns.

Limitations

The main limitation of this study is that it was a single-center study. In addition, only 4 cases were reported, and long-term follow-up was not possible. Furthermore, the cost of treatment was not investigated.

Conclusion

Negative pressure wound therapy is an effective option in severe burn treatment. NPWT allows for wound bed preparation, covering with skin grafts and artificial dermis, and management before and after flap surgery. The use of NPWT in severe burns also has the advantage of prioritizing life-prolonging treatment. If strict control of negative pressure is required, a dedicated device should be used rather than wall suction.

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Author Contribution All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Junya Oshima. The first draft of the manuscript was written by Junya Oshima, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declarations

Ethical Approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the ethics committee of the University of Tsukuba (no. R03-202).

Consent to Participate Informed consent was obtained from the participants included in this study.

Consent for Publication The authors affirm that the human research participants of this study provided informed consent for publication of the images shown in Figs. 1 and 2.

Competing Interests The authors declare no competing interests.

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