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Original Article

Effect of vacuum sealing drainage plus skin grafting on deep burns and analysis of risk factors for postoperative infection

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Abstract: Objective: To analyze the effect of vacuum sealing drainage (VSD) plus skin grafting on deep burns and the risk factors of postoperative infection. Methods: A retrospective analysis was conducted on 124 patients with deep burns who were admitted to the Taizhou People's Hospital from February 2019 to February 2021. The 55 patients who underwent traditional dressing change therapy plus second-stage skin grafting became the control group. The remaining 69 patients treated with first stage VSD plus second-stage skin grafting became the observation group. Wound healing time, hospital stay, postoperative infection, wound closure success rate, pain degree, and scar hyperplasia were recorded and compared between the two groups. Logistic regression was used to analyze the risk factors of postoperative infection in patients. Results: Compared with the control group, the observation group had a shorter time of wound healing and hospital stay, lower postoperative wound infection rate and lung infection rate, higher success rate of wound closure, lower pain degree scores on the 7th day after the operation, and less scar hyperplasia (all P<0.05). Logistic regression analysis revealed that burn degree, treatment plan, proportion of burn area, and wound healing time were the factors affecting postoperative infection in patients. Conclusion: VSD plus skin grafting have significant effects on deep burns. This combined treatment reduced the occurrence of the wound infection, relieved pain, shortened the healing time and hospitalization time, and reduced the proliferation of scars in the later stage.

Keywords: Vacuum sealing drainage (VSD), skin grafting, deep burn, wound repair, postoperative infection, risk factors

Introduction

A burn is a common accidental injury in daily life that can be divided into I-III degrees determined by the amount of skin damage. Degrees II and III burns are deep burns that damages all layers of the skin [1]. Degree III burns, known as eschar burns, affects all layers of the skin and even muscle tissues [2]. Severe infections occur during treatment because deep tissue damage can develop, bringing challenges and difficulties to clinical treatment and delaying wound healing [3]. Many wounds are difficult to heal without surgical treatment, leaving a great impact on the patient's physiological and mental status [4].

The treatment for patients with severe burns was divided into two stages. The first stage was mainly to heal the wounds. The second stage was skin grafting [5]. The traditional clinical treatment for burns is to remove the necrotic tissue and perform skin grafting. After surgery, frequent dressing changes were used to remove the secretions from the wound to keep the wound clean and dry. This promoted the survival of the skin graft and wound healing [6]. Patients with a wound infection were often assessed with unsatisfactory healing effects. The dressing change process was painful or even unaffordable for some patients because of the long treatment cycle and high expense [7, 8]. With the investigation of burns in recent years, the treatment method has gradually developed into traditional debridement skin grafting supplemented by biological dressing coverage to promote wound healing [9]. Necrotic tissue can remain on the wound surface after debridement. The liquefaction and shedding of the necrotic tissue can result in an accumulation of pus in the dressing. This increased the depth of the wound, resulting in delayed or even difficult wound healing. Vacuum sealing drainage (VSD) is a new technology for the treatment of complex burn wounds with a main feature of promoting the discharge of burn wound secretions. This ensures that the wound is always dry and facilitates the growth of wound granulation tissue [10]. Previous research found that VSD combined with second-stage skin grafting repaired skin and soft tissue defects caused by car accidents [11]. Directly performing skin grafting after first-stage debridement or not, remains controversial.

We aimed to analyze the effect of VSD plus skin grafting on deep burns (degree II or III) in the present study, and to explore the risk factors for postoperative infection in patients, to provide a reference for clinical treatments.

Materials and methods

A retrospective analysis was conducted on 124 patients with deep burns who were admitted to the Taizhou People's Hospital from February 2019 to February 2021. The 55 patients who underwent traditional dressing change therapy plus second-stage skin grafting became the control group. The remaining 69 patients treated with first stage VSD plus second-stage skin grafting became the observation group. All patients signed an informed consent for the surgery and were informed about the study. This study was approved by the Medical Ethics Committee of Taizhou People's Hospital (TZRY-LL-AF/SQ-014-2.0).

Inclusion criteria

Inclusion criteria: Patients who met the diagnostic criteria and treatment guidelines for burn infections published in 2012 [12]; patients who were diagnosed with degree II-III burns; patients whose burn area was less than 15% of the body surface; patients with complete clinical data.

Exclusion criteria: Patients who refused to tolerate the treatment and did not undergo the surgery; patients with any severe systemic infections; patients with tumors or congenital organ dysfunction; patients who were pregnant.

Treatment plan

Patients in the CG were treated with first-stage traditional dressing change therapy plus second-stage skin grafting. After regular examinations, patients were first treated with pre-debridement in the infected wounds. Iodophor, hydrogen peroxide, and normal saline were used to rinse the wound repeatedly to remove foreign bodies, necrotic, and infected inactivated tissues. When the blood supply of the distal limb of the patient was affected, incision and decompression was performed to avoid limb ischemic necrosis. Debridement and dressing changes were performed daily. Skin grafting was performed based on the fresh granulation tissue at the burnt site. The wound was excised to the normal tissue. An electrosurgical knife was used to cover the wound with a blade-thick to medium-thick skin sheet. The wounded area was pressed and wrapped with multiple layers of dressing.

For patients in the OG, first stage VSD plus second-stage skin grafting were performed. The eschar was removed within 72 hours after admission. Routine debridement and wound hemostasis were performed. Symptomatic treatment including infusion, anti-shock, and anti-infection was provided as needed. After routine anesthesia, the burn wound was cleaned. When the burn was on an extremity, a tourniquet was applied to the injured extremity to stop the bleeding. After the removal of necrotic and inactivated tissue, the bleeding was completely stopped by electrocoagulation. In the process of debridement, the vitality of the tissue was evaluated. Debridement maximized the preservation of active tissue and prevented excessive debridement. After sutured, the wound was covered with negative pressure material, sealed with a transparent film, connected with a tee tube, and attached with a vacuum drainage device at a pressure of 0.03 MPa. The negative pressure material was observed to collapse showing it was suitable for unobstructed drainage. After VSD, continuous or intermittent lavage was performed depending on the wound condition. VSD was removed after continuous drainage for 7 days The necrotic tissue was thoroughly cleaned again and skin grafting was performed for the CG. If no fresh granulation tissue grew after 7 days, VSD treatment was continued until the muscularis tissue was healthy.

Table 1. Baseline data

Factors	Control Group (n = 55)	Observation Group (n = 69)	P
Age			0.205
≥35 years old	31	31	
<35 years old	24	38	
Sex			0.422
Male	35	39	
Female	20	30	
Burnt Location			0.904
Limbs	38	50	
Torso	13	15	
Head and Face	4	4	
Burnt Degree			0.581
II degree	43	51	
III degree	12	18	
Cause of injury			0.778
Thermal Burn	38	48	
Chemical Burn	3	5	
Electrical Burn	13	13	
Radiation Burn	1	3	
Percentage of burnt area (%)	10.84±2.36	10.92±2.33	

The two groups were treated with excision of the scab to remove the necrotic tissue, and the wound was repaired after the operation. The autologous skin piece (thickness 0.25 mm) was cut with a Meek electric dermatome (Humeca, Netherlands), laid flat on a sterilized board, and soaked in normal saline for 0.5 h. The skin piece was pasted on a specific cork plate and was cut vertically and horizontally to form a suitable size. Specific glue was evenly sprayed on the epidermis of the micro skin piece, and it was pasted on the polyamide crepe de chine tulle. After 5-8 minutes, microskins were fully expanded by forming an equal distance between the skin pieces. The microskins were soaked in normal saline, directly transplanted to the wound surface, and wrapped with sterile dressings.

Outcome measures

Main outcome measures: Wound healing time, hospital stay, postoperative infection, and the success rate of wound closure were compared between the two groups after treatment. Logistic regression was used to analyze the risk factors for postoperative infection and to construct a regression model.

Secondary outcome measures: The pain degree of patients was scored according to the visual analog scale (VAS) [13], with a full score of 10 points. A higher score meant more severe pain. Patients were reexamined 1 year after the operation for the degree of scar hyperplasia. This was divided into 4 levels: none, with no scar hyperplasia on the wound surface; mild, with a light red scar, but without pain or other discomfort; moderate, with a light red scar, mild pain, and discomfort; and severe, with a dark red scar in firm texture, obvious pain, and discomfort. The clinical data of the two groups of patients were compared.

Statistical analysis

SPSS 22.0 was used for data analysis. GraphPad Prism 8 was used for plotting figures. Logistic regression was applied to evaluate the risk factors for postoperative infection. The receiver operating characteristic (ROC) curve was employed to evaluate the effectiveness of indicators affecting the postoperative infection. The enumeration data between the two groups were tested by χ^2 test. The inter-group comparison of measurement data (mean ± standard deviation) was performed using the student t test. Multiple time-point data were analyzed by repeated measures ANOVA, denoted by F, and Bonferroni post-hoc tests were performed. The rank data were tested by the value sum test, denoted by Z. A difference of P<0.05 was statistically different.

Results

Comparison of baseline data

No statistical difference was observed between the CG and the OG in terms of age, sex, burnt area, burnt location, burnt degree, and cause of injury (**Table 1**, P>0.05).

Comparison of wound healing time and hospitalization time between the two groups

Compared with the OG, patients in the CG had a much longer wound healing time and length of hospital stay (**Figure 1**, P<0.001).

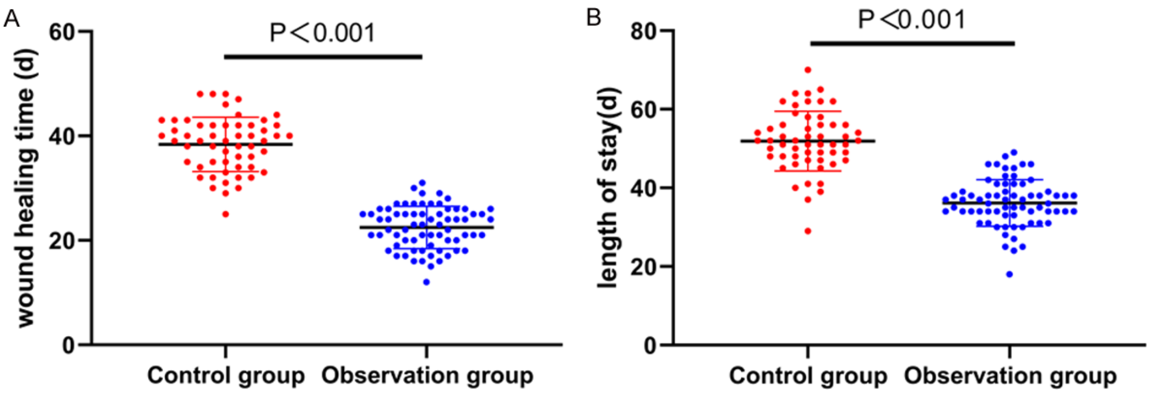

Figure 1. Comparison of wound healing time and hospitalization time. A. The wound healing time. B. Length of hospital stay after treatment.

Table 2. Statistics of postoperative infection and closure success rate

Items	Postoperative Infection Site		Total Infection Rate	Wound Closure Success Rate
	Wound Infection	Lung Infection		
Control Group (n = 55)	8	5	13 (23.64)	29 (52.73)
Observation Group (n = 69)	2	1	3 (4.35)	55 (79.71)
χ^2	5.600	3.881	10.132	10.197
P	0.018	0.048	0.002	0.001

Table 3. Comparison of VAS score

Time	Before Surgery	1st Postoperative Day	7th Postoperative Day
Control Group (n = 55)	7.97±0.80	7.83±0.81	6.16±1.06^{a,b}
Observation Group (n = 69)	7.97±0.74	7.63±0.78	3.84±0.88^{a,b}
t	1.119	1.316	15.265
P	0.792	0.567	<0.001

Note: Visual analogue scale (VAS), ^{a} means P<0.05 compared with preoperative, ^{b} means P<0.05 compared with the first day after operation.

Comparison of postoperative infection and closure success rates

The risk of postoperative infection in the CG was higher than that of the OG. The success rate of closure was lower in the CG than that in the OG (**Table 2**, P<0.05).

Comparison of VAS scores of patients before and after surgery

VAS scores of the patients before the surgery, on the 1st day after skin grafting, and on the 7th day after the surgery of both groups were recorded and compared to assess postoperative pain. No difference was observed in VAS scores before the operation and on the 1st day after the operation between the two groups (P>0.05). On the 7th day of post-operation, the VAS scores decreased in both groups. The 7 d postoperative VAS score of the OG was lower than that of the CG (**Table 3**, P<0.05).

Comparison of scar hyperplasia between the two groups

The degree of scar hyperplasia in the two groups was compared. It was found that the degree of scar hyperplasia in the CG was higher than that in the OG (**Table 4**, P<0.05).

Analysis of risk factors for postoperative infection and construction of risk assessment model

To identify risk factors for postoperative infection, patients were grouped into an infected group (n = 16) and an uninfected group (n = 108) according to their infection status. Clinical data of these two groups were statistically analyzed through univariately analysis. Differences

Table 4. Degree of scar hyperplasia

Degree	Severe	Moderate	Mild	None
Control Group (n = 55)	12	38	4	1
Observation Group (n = 69)	5	29	33	2
Z		-4.777		
P		<0.001		

Table 5. Univariate analysis

Factors	Infected Group (n = 16)	Uninfected Group (n = 108)	P
Age			0.032
≥35 years old	12	50	
<35 years old	4	58	
Sex			0.805
Male	10	64	
Female	6	44	
Burnt Location			0.968
Limbs	10	65	
Torso	4	27	
Head and Face	2	16	
Burnt Degree			0.001
II degree	7	87	
III degree	9	21	
Cause of injury			0.904
Thermal Burn	11	75	
Chemical Burn	1	7	
Electrical Burn	3	23	
Radiation Burn	1	3	
Treatment Plan			0.002
Conventional Treatment	13	42	
VSD	3	66	
Percentage of burnt area (%)	13.20±0.99	10.54±2.28	<0.001
Wound healing time (d)	37.87±6.39	28.46±8.94	<0.001
Length of hospital stay (d)	52.31±8.91	41.56±9.88	<0.001

Note: vacuum sealing drainage (VSD).

between the two groups included age, burnt degree, burnt area, wound healing time, hospitalization time, and treatment plan (**Table 5**, P<0.05). Values were assigned to differing data (**Table 6**). Through multivariate logistic regression analysis, we found that burnt degree, treatment plan, proportion of the burnt area, and wound healing time were the factors that affected postoperative infection (**Table 7**, P < 0.05). To determine the value of burnt degree, treatment plan, proportion of the burnt area, and wound healing time in the occurrence of postoperative infection, we established a risk prediction equation logit(p) = -24.986 + (-2.799 × burn degree) + (2.833 × treatment plan) + (1.041 × burn area ratio) + (0.198 × wound healing time). We applied Hosmer-Lemeshow test to assess the goodness of fit of the regression equation (P = 0.942). The established model was used to determine the area under the ROC curve for postoperative infection (0.963). This was significantly higher than the individual prediction curve area of each indicator (**Figure 2**; **Table 8**), suggesting that this was an ideal risk prediction model.

Typical case of two treatment options

In the observation group, there was a 42-year-old woman who suffered from burns on her hands, with deep burns accounting for 7%. She was admitted to the hospital 30 minutes after the injury. After admission, general treatments such as debridement, anti-infection, and fluid replacement were provided. VSD treatment was carried out within 3 d. After routine anesthesia, the burn wound was cleaned. Skin grafting was performed after the condition was stable. On the 2nd day after the operation, it was found that the wound exuded more, and the external dressing was changed. The dressing was changed every 2 d, and the patient survived (**Figure 3A**).

In the control group, a 37 year old male had burns on his hands, with deep burns accounting for 5% of the total. He was admitted to the hospital 30 minutes after the injury. After admission, general treatments such as debridement, anti-infection, and fluid replacement were provided. Skin grafting was performed after the condition was stable (**Figure 3B**).

Table 6. Assignment

Factors	Evaluation
Age	≥35 years old = 1, <35 years old = 0
Burnt Degree	Depth II degree = 1, III degree = 0
Treatment Plan	Conventional Treatment = 1, VSD = 0
Percentage of burnt area (%)	Belonging to continuous variables using raw data
Wound healing time (d)	Belonging to continuous variables using raw data
Length of hospital stay (d)	Belonging to continuous variables using raw data

Table 7. Multivariate analysis

Factors	β	SE	χ^2	P	OR	95% CI	
						Floor Level	Upper Limit
Age	-2.395	1.405	2.908	0.088	0.091	0.006	1.430
Burnt Degree	-2.799	1.396	4.020	0.045	0.061	0.004	0.939
Treatment Plan	2.833	1.208	5.502	0.019	16.993	1.593	181.25
Percentage of burnt area (%)	1.041	0.388	7.203	0.007	2.831	1.324	6.054
Wound healing time (d)	0.198	0.068	8.541	0.003	1.220	1.068	1.393
Length of hospital stay (d)	0.099	0.053	3.421	0.064	1.104	0.994	1.226

Discussion

Large-area burn is a clinically common and serious trauma that damages the skin layers and muscle tissue. It leads to obvious changes in the performance, metabolism, and morphology of the affected area. In severe cases, it can be life-threatening [14, 15]. Clinical treatment for burn patients is mainly through debridement and daily dressing changes to prevent wound infection [16]. There are difficulties in the treatment of deeply burned tissues and exudates. Seeking new treatment options is important clinically.

With the continuous development of medical technology, methods for promoting wound healing have gradually emerged. As a new type of healing and drainage technology in recent years, VSD has played an ideal role in tissue defects caused by trauma, diabetic foot, and venous lower extremity ulcers [17]. Past research has shown [18-20] that VSD technologies have made up for the shortcomings of traditional methods for treating burn patients. A patient's wound can be kept in a closed environment. Exudates and deep necrotic tissue can be continuously suctioned and removed through the negative pressure suction devices. The patient's wound surface can be kept in a moist state. This is beneficial to the growth of the granulation tissue. There is some controversy about whether to directly perform skin grafting after first-stage debridement. Some scholars have pointed out [21] that there was a certain degree of early infection and uneven wound surface in the first stage. This leads to a decrease in the survival rate of the first-stage skin grafting. The second-stage skin grafting was more preferred. In the second-stage skin grafting, the growth of fresh granulation tissue on the burn wound was directly related to the survival of the graft in the later stage. The growth of fresh granulation tissue was more closely related to wound infection [22]. We analyzed the effect of first-stage VSD plus second-stage skin grafting on wound repair among burn patients in this study. We found that the healing time and hospital stay of patients in the OG were shorter than those of the CG. The OG showed lower postoperative infection. The success rate of sealing in the OG was increased, and the pain in patients was relieved. These all indicated that first-stage VSD plus second-stage skin grafting minimized the occurrence of wound infection, enabled the granulation tissue to grow smoothly, and provided favorable conditions for the second-stage transplantation. In the study of Chen et al. [23], it was found that early VSD treatment did not advance the healing time of degree II deep burn wounds. Instead, it improved the healing quality of patients. Our study revealed that VSD was able

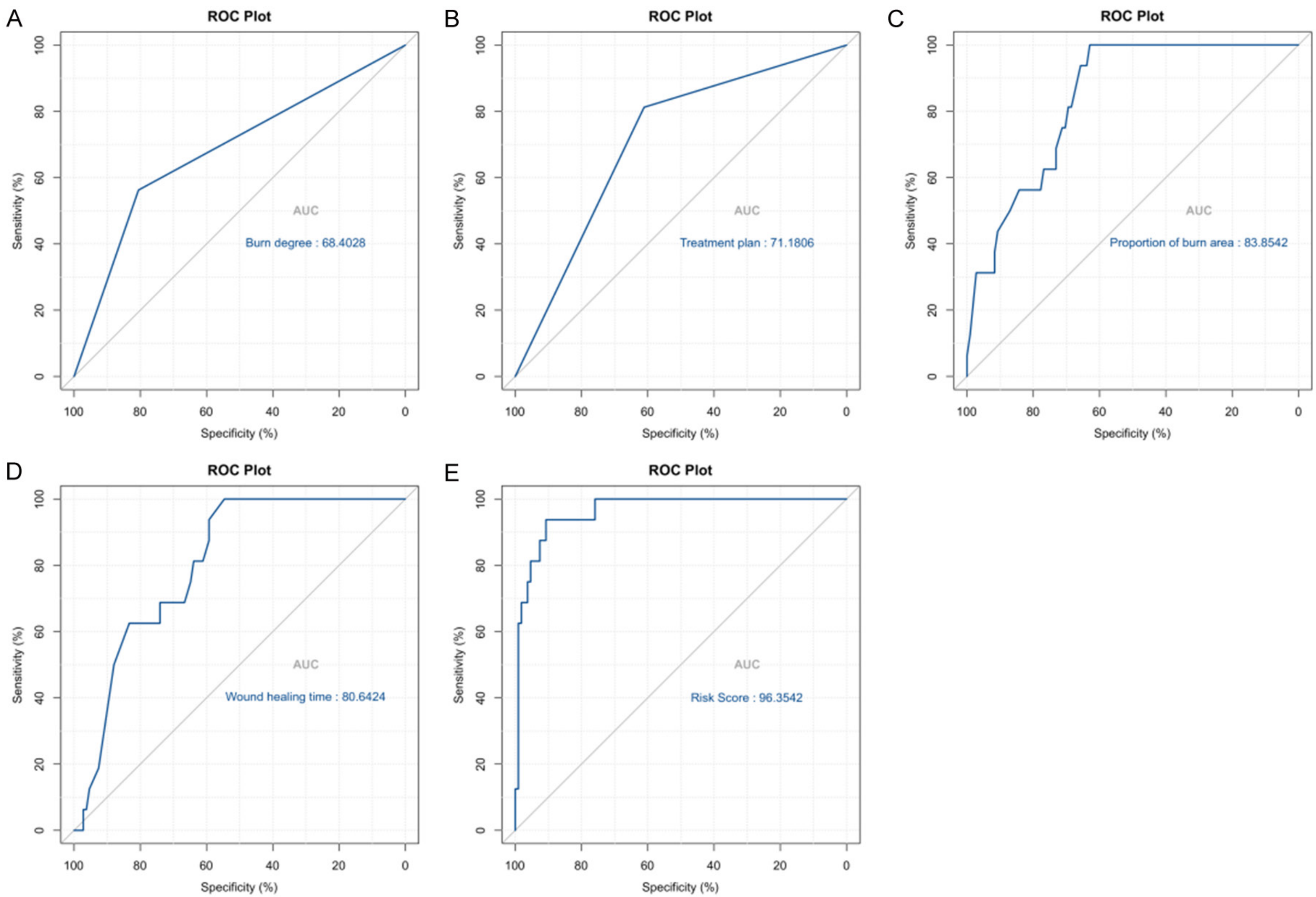

Figure 2. Prediction curve of each index for postoperative infection. A. ROC curve of burn degree for predicting postoperative infection. B. ROC curve of treatment regimen for predicting postoperative infection. C. ROC curve of the proportion of burn area for predicting postoperative infection. D. ROC curve of wound healing time for predicting postoperative infection. E. ROC curve of risk score for predicting postoperative infection. Note: receiver operating characteristic curve (ROC).

Table 8. ROC parameters

Predictive Variables	cut-off	Sensitivity	Specificity	Youden Index	AUC	95% CI
Burn degree	0.50	80.60	56.20	36.80	0.684	0.553~0.815
Treatment plan	0.50	61.10	81.20	42.40	0.711	0.603~0.821
Proportion of burn area	11.45	63.00	100.00	63.00	0.838	0.757~0.920
Wound healing time	26.50	54.60	100.00	54.60	0.806	0.718~0.895
Risk score	2.58	88.00	55.20	88.00	0.963	0.958~1.000

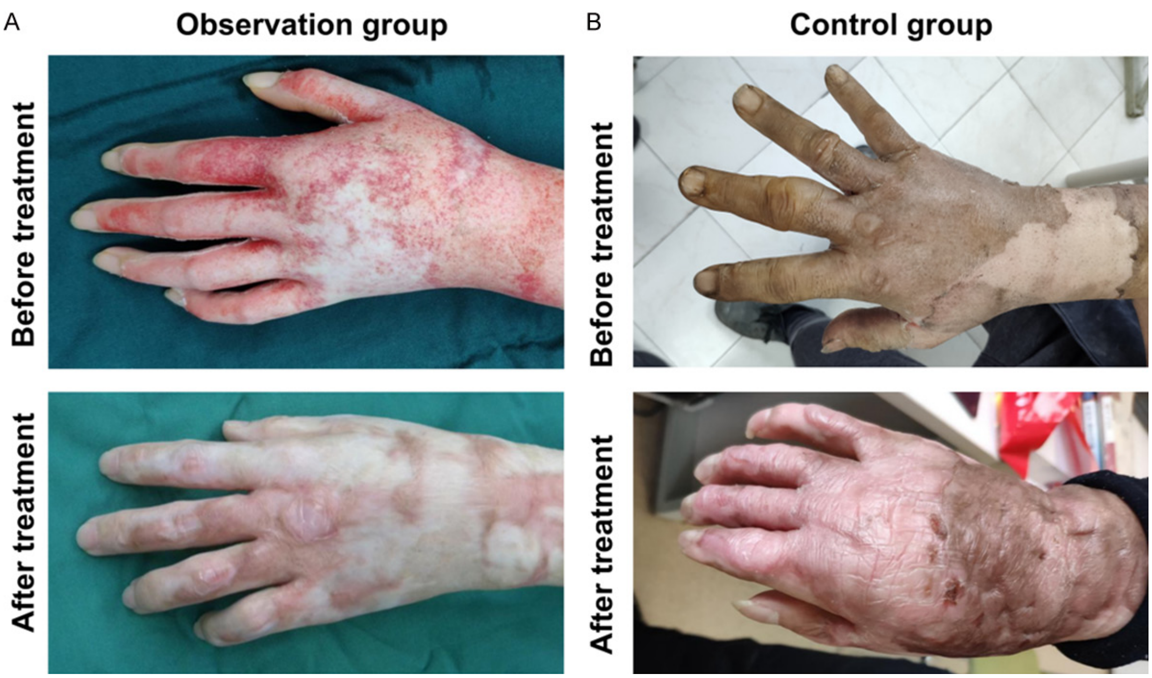

Figure 3. Typical cases treated with the two regimens. A. Comparison of patients in the observation group before and after treatment. B. Comparison of patients in the control group before and after treatment.

to improve the wound healing time of deep burn patients. This can be due to the inconsistency in the burn grades of the samples. We believe that VSD provided a closed and negative pressure environment in the treatment of burn patients. This can keep the growth of pathogens in the wound and accelerate the dissolution rate of fibrin, improving the wound healing speed of patients.

We analyzed the long-term treatment effect of the two regimens on patients. Re-examination records of the two groups after 1 year showed that the degree of scar hyperplasia in the CG was higher than that in the OG. We believe it was because VSD can provide a continuous moist environment for the growth of granulation tissue by keeping the wound in a semi-closed state with good air permeability, promoting the growth process of fresh granulation tissue, and stimulating the proliferation of wound cells, improving the healing effect.

In most cases, the integrity of the patient's skin was destroyed postburn, impairing the antibacterial ability of the burn site and increasing the risk of infection [24]. Once a wound is infected, bacteria and inflammatory cells will accelerate metabolism, deplete nutrients and oxygen, reduce fibroblast metabolism, and slow wound healing [25]. We analyzed the risk factors for postoperative infection in patients at the end of the study. We found that the burnt degree, treatment plan, proportion of the burn area, and wound healing time were influencing factors for postoperative infection. The higher the degree of burn or the larger the burn area, the more likely the patient was to develop infection. Previous studies revealed that infection was the deadliest factor in patients with degree III burns [26]. Studies have reported that the larger the burn area or the more degree III burns, the easier it is to develop sepsis [27]. In the study of Alp et al. [28], it was found that the higher the burn level, the higher the mortality of patients. It is widely acknowledged that slower wound healing time means higher odds for bacterial infection in the wounded area. In this study, we found that first-stage VSD plus second-stage skin grafting were associated with postoperative infections in burn patients. This treatment was a risk factor against postoperative infection in patients. VSD can reduce the wound healing time and hospitalization time. Studies have found that the probability of nosocomial infection during hospitalization was 8% [29], suggesting that VSD treatment reduced the risk of postoperative infections among patients. By establishing a risk model, we found that the area under the ROC curve of the risk model in predicting postoperative infection in patients was >0.95. This suggested that our model was promising for the prediction of postoperative infection.

In this study, we found that VSD treatment was effective in improving wound healing and reducing the risk of postoperative infection among patients. This study was limited. Our study was a retrospective study rather than a prospective study, leading to biased results. The model in this study was not verified in other data. More research is needed to determine the generalization of the model. Long-term follow up was not performed on the patients. It is unclear if VSD treatments have long-term effects. Randomized controlled trials need to be conducted in the future to collect more samples and extend our follow-up time to validate the findings.

In conclusion, VSD plus skin grafting had a significant effect on deep burns. This combined treatment effectively reduced the occurrence of the wound infection, relieved pain, shortened the healing time and hospitalization time, and reduced the proliferation of scars in the later stage.

Disclosure of conflict of interest

None.

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