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Clinical Study on Early Conservative Tangential Excision Combined with Xenogeneic Dermal Grafting for the Treatment of Extensive Critical Burns

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Article

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Abstract

Objective

To investigate the effects of performing conservative tangential excision during the early shock phase (12 to 24 hours post-burn) combined with the application of xenogeneic dermal grafts on hemodynamic stability, inflammatory response, and clinical outcomes in patients with extensive critical burns. The aim is to provide a new strategy for the early treatment of critical burns.

Methods

Twenty-two patients with extensive burns (Total Body Surface Area, TBSA, ranging from 50% to 90%) admitted to the Burn Department of our hospital between December 2019 and June 2025 were selected. All patients underwent conservative tangential excision surgery within 12 to 24 hours post-burn, with careful preservation of interstitial tissue during the procedure. Postoperatively, the wounds were covered with xenogeneic dermis. Hemoglobin, blood lactate levels, and B-type Natriuretic Peptide (BNP) were monitored and compared preoperatively and postoperatively. The total fluid resuscitation volume at 24 and 48 hours post-burn, as well as the levels of inflammatory cytokines (including Tumor Necrosis Factor-alpha [TNF-α], Interleukin-6 [IL-6], and Procalcitonin [PCT]), were also recorded. Additionally, outcome indicators such as complication rates, wound healing rate, total number of surgeries, and length of hospital stay were documented.

Results

A significant difference was observed in hemoglobin levels between pre-operative and post-operative measurements ($P < 0.05$), with post-operative hemoglobin stabilizing at a higher level of (156.43 ± 25.60) g/L. The fluid resuscitation volumes for the first 24 hours and 48 hours were (5195.95 ± 1758.06) ml and (9279.52 ± 2698.76) ml, respectively, both significantly lower than the estimated volumes calculated using conventional formulas ($P < 0.05$). Blood lactate levels decreased to (2.70 ± 0.95) mmol/L on the first postoperative day. BNP increased on the fourth day after operation, and decreased after reaching a peak of 571.80 (208.70, 772.40) pg / mL on the sixth day. Compared to preoperative levels, white blood cell count and IL-10 showed a clear downward trend postoperatively, IL-6 peaked at 3 days after surgery and then decreased; PCT levels reached their highest point on the first postoperative day and then decreased; TNF-α levels exhibited minor fluctuations within the normal range. By three weeks postoperatively, the spontaneous wound healing rate reached (44.5 ± 22.15)%, and the infection rate was 9.1%. No cases of systemic sepsis, Multiple Organ Dysfunction Syndrome (MODS), or mortality occurred during the study period. The average number of surgeries per patient was (3.35 ± 1.81), and the average length of hospital stay was (53.9 ± 26.7) days.

Conclusion

Performing conservative tangential excision combined with xenogeneic dermal grafting during the early burn shock phase can effectively maintain hemodynamic stability, significantly reduce systemic inflammatory response and metabolic disturbances, lower the incidence of infection, decrease the number of required surgeries, and shorten the hospital stay. This strategy represents a safe and effective early intervention protocol for the treatment of extensive critical burns.

Introduction

Burns represent one of the most severe traumatic injuries worldwide, particularly in developing countries, where industrial accidents and domestic fires contribute to high incidence rates. According to epidemiological data, China reports approximately 10 million burn cases annually, with mortality rates reaching 14.21% in severe burns (TBSA >50%), primarily attributed to systemic complications such as multiple organ dysfunction syndrome (MODS), sepsis, and systemic inflammatory response syndrome (SIRS) [1]. In recent years, significant advancements have been achieved in critical burn care within China, including the Third Military Medical University fluid resuscitation formula, microskin grafting techniques, and allogeneic skin interposition grafting [2], which have markedly improved patient survival rates. However, therapeutic challenges persist, encompassing precise fluid resuscitation management, systemic absorption of burn toxins (e.g, lipopolysaccharides and HMGB1), sustained release of inflammatory mediators (TNF-α, IL-6), and severe infections [3–5]. These factors collectively contribute to the complexity and high-risk nature of treating critically burned patients.

Current international burn care guidelines recommend early escharectomy within 48–72 hours post-injury to remove necrotic tissue, mitigate inflammatory mediator release, reduce hospitalization duration, and lower mortality rates [6–7]. However, in patients with extensive burns (TBSA >50%), conventional escharectomy is associated with significant intraoperative blood loss (0.8 mL/cm²), necessitating large-volume transfusions to avoid hemodynamic instability[8]. The optimal timing for escharectomy remains controversial: shock-phase surgery (within 24 hours post-burn) may limit systemic absorption of burn toxins but carries a higher risk of exacerbating shock [9], whereas delayed surgery (4–7 days post-injury) offers hemodynamic stability but allows inflammatory mediators to enter circulation, increasing susceptibility to SIRS and MODS [10]. Recent studies suggest that surgery within 24 hours reduces blood loss, yet this benefit may be offset by higher risks of conventional surgical complications [11].

To address this clinical dilemma, this study proposes a conservative tangential excision combined with xenogeneic dermal coverage during the early shock phase (12–24 hours post-burn), aiming to balance hemodynamic stability with the benefits of early debridement. The conservative tangential excision preserves viable intermediate tissue and partial reticular dermis, minimizing intraoperative blood loss and systemic circulatory stress. Meanwhile, xenogeneic dermal grafts act as a biological barrier, reducing fluid/protein leakage, suppressing bacterial colonization, and lowering infection risks. Through clinical data analysis, this study evaluates the impact of this strategy on hemodynamics, inflammatory responses, and clinical outcomes in critically ill patients with extensive burns (TBSA >50%), providing novel theoretical and practical insights for early severe burn management.

1 Materials and Methods

1.1 Patient Data

This study was a retrospective analysis involving 22 patients with extensive burns admitted to the Department of Burns of our hospital from December 2019 to June 2025. The patients ranged in age from 4 to 82 years (mean age 45.6 ± 20.3 years), with total body surface area (TBSA) burned ranging from 50% to 90% (mean 65.4% ± 15.2%), burn index > 40, and all had deep partial-thickness to full-thickness burn wounds. Among them, 10 cases had mild to moderate inhalation injury. Inclusion criteria: (1) TBSA ≥ 50%; (2) deep partial-thickness to full-thickness burns; (3) admission and fluid resuscitation within 12 hours post-injury. Exclusion criteria: (1) delayed fluid resuscitation (> 12 hours post-injury); (2) severe comorbidities (e.g. heart failure, liver or kidney dysfunction); (3) combined injuries (e.g. fractures, traumatic brain injury). Written informed consent was obtained from all patients or their legal guardians, and the study protocol was approved by the hospital's ethics committee.

1.2 Treatment Methods

1.2.1 Fluid Resuscitation: The Third Military Medical University fluid resuscitation formula [2] was used to calculate the fluid volume based on the patient's body weight and total body surface area (TBSA). The total fluid volume for the first 24 hours was calculated as 1.5 mL/kg/%TBSA (colloid: crystalloid ratio = 1:2) + 2000 mL (basal water requirement). The infusion rate was dynamically adjusted according to urine output (target range: 0.5–1.0 mL/kg/h) and hemodynamic parameters.

1.2.2 Timing of Surgery: Surgical intervention should be performed within 12–24 hours post-burn, provided that hemodynamic stability was achieved, defined as mean arterial pressure (MAP) > 65 mmHg and urine output > 0.5 mL/kg/h.

1.2.3 Surgical Technique: Under general anesthesia, necrotic tissue was excised from the extremities, chest, abdomen, and back using an electric dermatome or roller knife, while preserving viable intermediate-zone tissue, deep dermal reticular layer, and minimal residual necrotic tissue. The intraoperative debridement criteria were as follows: (1) for deep partial-thickness burns, tangential excision was performed until minimal oozing hemorrhage was observed; (2) for full-thickness burns, debridement continued until scattered punctate bleeding points appeared. Circumferential deep burns undergo conservative tangential excision to achieve decompression and relieve tissue pressure [12]. Due to anatomical considerations, no debridement was performed on the head, neck, perineum, or toes. The wound surface was repeatedly irrigated with 3% hydrogen peroxide and 37°C warm saline to remove residual necrotic tissue debris, followed by coverage with xenogeneic dermis (Jiangsu U-Young Biotechnology Co., Ltd., thickness 0.3–0.5 mm, acellular dermal matrix type A). Postoperatively, the wounds were dressed and immobilized, with the first dressing change performed on day 7 to assess wound healing and xenogeneic dermis adherence.

1.2.4 Intraoperative and postoperative management: During surgery, fluid resuscitation was continued according to the planned protocol, with an infusion volume of 500–1000 ml. Hemodynamic parameters

were monitored, and urine output was maintained at 0.5–1.0 mL/kg/h. The surgical procedure lasted 60–90 minutes. Postoperatively, broad-spectrum antibiotics were administered to prevent infection, early enteral nutrition support was initiated, and analgesic and sedative treatments were provided when necessary.

1.3 Observation Indicators

1.3.1 Hemodynamics and Blood Lactate: Preoperative and postoperative hemoglobin levels, fluid infusion volumes during the first 24 and 48 hours compared with formula-based resuscitation targets, as well as changes in BNP and blood lactate levels before and after surgery.

1.3.2 Inflammatory Markers: Preoperative and postoperative (day 3, day 10) levels of TNF-α, IL-6, and IL-10 were measured. Additionally, procalcitonin (PCT) and white blood cell count (WBC) were assessed preoperatively and on postoperative days 1, 4, 6, and 9.

1.3.3 Prognostic indicators: The rate of spontaneous wound healing at 3 weeks, the infection rate (defined as positive wound culture and systemic septic symptoms), the incidence of multiple organ dysfunction syndrome (MODS) during the disease course, mortality rate, number of operations (including subsequent skin grafting or debridement surgeries), and length of hospital stay.

1.4 Statistical Methods

Data analysis was performed using SPSS 22.0 software. Normally distributed continuous variables were expressed as mean ± standard deviation ($\bar{x} \pm s$) and analyzed using paired t-tests after Shapiro-Wilk normality testing; categorical data were presented as percentages. Non-normally distributed data were reported as median (interquartile range) and analyzed with non-parametric tests (Mann-Whitney U test for between-group comparisons, Wilcoxon signed-rank test for paired comparisons). Comparisons among multiple time points were performed using the Friedman test. A P-value < 0.05 was considered statistically significant.

2 Results

2.1 Hemodynamic parameters

The study group exhibited statistically significant differences in hemoglobin levels before and after surgery (postoperative levels stabilized at 156.43 ± 25.60g/L, Table 1), despite no intraoperative blood transfusion. The fluid infusion volume in the first 24 hours was 5195.95 ± 1758.06 mL, which was significantly lower than the formula-calculated volume of 8735.36 ± 2729.43 mL ($P < 0.05$); the infusion volume in the first 48 hours was 9279.52 ± 2698.76 mL, also significantly lower than the formula-calculated volume of 14103.04 ± 4094.14 mL (Table 2). Blood lactate decreased markedly on postoperative day 1 to 2.70 ± 0.95 mmol/L (Table 3). BNP increased on postoperative day 4, peaked on day 6 at 571.8 (208.7, 772.4) pg/mL, and then declined (Table 4).

Table 1
Comparison of Hemoglobin Levels Before and After Surgery (Mean ± SD, n = 22)

Indicator	Mean ± SD	Minimum	Maximum	P Value
Preoperative hemoglobin (g/L)	194.76 ± 23.96	134	224	< 0.001 (preoperative vs. postoperative)
Postoperative hemoglobin(g/L)	156.43 ± 25.60	93	203	—

Table 2
Comparison of Actual and Formula-Based Fluid Infusion Volumes at 24h and 48h (Mean ± SD, n = 22)

indicator	Mean ± SD(ml)	Min	Max	P-Value(Actual vs. Formula, Paired t-test)
24h Actual infusion	5195.95 ± 1758.06	1950	7750	< 0.001
24h Formula Infusion	8735.36 ± 2729.43	3020	14000	—
48h Actual Infusion	9279.52 ± 2698.76	3175	14000	< 0.001
48h Formula Infusion	14103.04 ± 4094.14	5530	22000	—

Table 3
Blood lactate levels before and after surgery (mean ± SD, n = 22)

Time Point	Preoperative	Postoperative Day 1	Postoperative Day 2	Postoperative Day 4
Lactate(mmol/L)	4.40 ± 2.64	2.70 ± 0.95 a	1.86 ± 0.78a	1.28 ± 0.39 a
a: P<0.01 vs □□□				

Table 4
BNP levels before and after surgery (Md (P25, P75), n = 22)

Time Point	Preoperative	Postop Day 1	Postop Day 2	Postop Day 4	Postop Day 6	Postop Day 9
BNP (pg/ml)	45.6 (20.6,79.9)	81.3 (37.3,104.7)	99.6 (41.1,348.6)	433.8 (252.4,778.1)	571.8 (208.7,772.4)	143.7 (86.1,314.0)

2.2 Infection and Inflammatory Marker Indicators

White blood cell (WBC) counts showed a decreasing trend before and after surgery but gradually increased by postoperative day 6. Procalcitonin (PCT) peaked on the first postoperative day and subsequently declined. IL-6 reached its highest level at postoperative day 3 before decreasing, while IL-10 exhibited a significant downward trend before and after surgery. TNF-α fluctuated slightly within the normal range (see Tables 5 and 6).

Table 5
WBC (×10⁹/L) and PCT (ng/mL) at Different Time Points (Md (P25, P75), n = 22)

Infection Indicator	Preoperative	Postop Day 1	Postop Day 4	Postop Day 6	Postop Day 9
WBC	22.8(16.9,31.2)	16.2(14.0,22.6)	8.2(7.2,12.5)	12.0(8.7,14.4)	16.5(13.3,23.9)
PCT	0.27(0.06, 4.29)	1.75(0.40,4.20)	1.09(0.29,1.79)	0.88(0.30,1.40)	0.51(0.33,0.88)

Table 6
Cytokine Levels at Different Time Points (Md (P25, P75), n = 22)

Cytokine(pg/mL)	Preoperative	Postop Day 3	Postop Day 10
IL-6	55.16(22.95, 151.34)	73.57(62.58, 113.83)	25.57 (16.76, 51.51)
IL-10	9.79 (6.00, 15.28)	4.32 (3.20, 7.86)	4.35 (1.98, 6.39)
TNF-α	1.20 (0.53, 2.02)	1.00 (0.41, 1.71)	1.42 (0.53, 2.20)

2.3 Clinical Prognostic Indicators

The area of spontaneous wound healing within three weeks accounted for 44.5 ± 22.15% of the total burn area. Only 2 cases (9.1%) developed localized wound infections, which were successfully managed with antibiotic therapy and wound dressing changes. No cases of systemic sepsis, multiple organ dysfunction syndrome (MODS), or mortality were observed. The mean number of surgical interventions was 3.35 ± 1.81, with an average hospitalization duration of 53.9 ± 26.7 days (Table 7).

Table 7
Prognostic indicators (n = 22)

Spontaneous wound healing rate at 3 weeks (Mean ± SD)	Positive wound culture (n)	Sepsis (n)	MODS incidence (n)	Mortality (n)	Number of surgeries (Mean ± SD)	Hospital stay duration (Mean ± SD, days)
44.5 ± 22.15	2	0	0	0	3.35 ± 1.81	53.9 ± 26.7

3 Discussion

Patients with extensive burns (TBSA > 50%) face multiple challenges during the shock phase, including extensive tissue edema induced by fluid resuscitation due to increased capillary permeability [13], persistent release of inflammatory mediators (e.g., TNF-α, IL-6) from necrotic tissue [14], hemodynamic disturbances caused by significant bleeding during early surgical intervention [15], and intraoperative misjudgment of the wound leading to loss of healthy tissue [16]. These factors collectively increase the complexity of treatment and the risk of mortality. According to statistics, 55% of deaths in patients with severe burns occur within the first 72 hours post-injury, primarily associated with shock and systemic inflammatory response syndrome (SIRS) [17]. Therefore, early treatment for critically ill patients with extensive burns is of

paramount importance; however, there is currently no unified standard regarding the timing, method, or extent of surgery, either domestically or internationally.

Several studies have shown that wound excision within three days post-injury significantly reduces the risk of infection and mortality [18–19]; however, other studies have suggested that early surgery, particularly during the shock phase, may fail to improve prognosis due to complications arising from massive bleeding and excessive invasive manipulation [20]. The reason for this discrepancy lies in the considerable variability in the specific timing, surgical methods, and extent of early surgery, leading to inconsistent conclusions across studies. The present study proposes a strategy of conservative tangential excision combined with xenogeneic dermal coverage during the early shock phase (12–24 hours post-injury), aiming to balance hemodynamic stability with the benefits of early debridement, maximize the blockade of inflammatory mediator release, reduce the risk of complications, and provide a new approach for the standardized treatment of extensive severe burns.

Conventional escharectomy requires complete removal of necrotic tissue down to healthy tissue, resulting in substantial intraoperative blood loss (approximately 1 mL/cm²), with an average blood transfusion volume exceeding 2000 mL in patients with extensive burns [6]. In this study, a strategy of conservative tangential excision was implemented in patients with burns covering ≥ 50% TBSA during the early shock phase (12–24 hours post-injury), a time when vascular leakage and tissue edema have generally peaked and the boundary between necrotic and healthy tissue becomes distinct, facilitating precise tangential excision [21]; moreover, vasoconstrictive substances such as thromboxane B_2 and catecholamines are markedly elevated early after burn injury, with vasopressin levels increasing up to fivefold and thromboxane B_2 levels reaching as high as 86 times the normal value, factors that contribute to reduced blood loss during surgery performed in the early shock phase without exacerbating hemodynamic instability [22]. Furthermore, conservative tangential excision removes only definitively necrotic tissue while preserving marginally viable tissue and a small amount of necrotic tissue, thereby significantly minimizing surgical injury to deeper healthy tissue and blood vessels and resulting in extremely low intraoperative blood loss. In addition, conservative tangential excision during the early shock phase maximizes the preservation of viable tissue, promotes the drainage of exudate, and enhances drug penetration, which is more conducive to the management of burn shock, consistent with the findings of Wang et al. [23]. Although there was a difference in hemoglobin levels before and after surgery, hemoglobin remained essentially stable at the upper limit of the normal range; the postoperative decrease in hemoglobin was not only related to the minimal intraoperative blood loss but also to ongoing fluid resuscitation during the procedure. We also found that the fluid infusion volumes at 24 and 48 hours post-burn were significantly lower than the formula-predicted volumes ($P < 0.05$), and on postoperative day 2, blood lactate decreased to 1.86 ± 0.78 mmol/L, indicating that conservative tangential excision ensured adequate tissue and organ perfusion while effectively reducing hemodynamic burden and avoiding the risks associated with over-resuscitation [24]. Meanwhile, monitoring of ventricular function via BNP levels showed an increase on postoperative day 4, peaking on day 6 and then declining, which is entirely consistent with the pathophysiological process of the post-burn resorptive phase, and no signs of cardiac dysfunction were observed during the treatment course.

Necrotic tissue and subeschar edema fluid following burns are major sources of inflammatory mediators (e.g., TNF-α, IL-6, IL-10) and burn toxins (e.g., LPS, HMGB1), and their sustained release can trigger systemic inflammatory response syndrome (SIRS) and multiple organ dysfunction syndrome (MODS) [25]. As an inducer of acute-phase proteins, IL-6 serum levels closely correlate with burn severity and remain markedly elevated from day 1 to day 4 or even longer post-injury [26]; IL-10 plays an important role in suppressing inflammatory responses, but high IL-10 levels may be associated with sepsis [27]. In this study, we found that IL-6 was markedly elevated preoperatively and decreased after peaking on postoperative day 3; IL-10 showed a clear downward trend preoperatively and on postoperative days 3 and 10; TNF-α fluctuated within the normal range; and procalcitonin (PCT) peaked on postoperative day 1 (possibly related to surgical trauma) and subsequently showed a marked decreasing trend. These findings suggest that conservative tangential excision during the early shock phase not only effectively blocks toxin absorption and the release of pro-inflammatory factors but also regulates the balance of anti-inflammatory cytokines, thereby reducing the risk of SIRS and MODS, which is consistent with the results reported by Zhu et al. [28]. Furthermore, xenogeneic dermal coverage serves as a biological barrier, reducing wound bacterial colonization, with an infection rate of only 9.1% and no cases of systemic infection or MODS, indicating that this strategy effectively controls infection risk. In addition, white blood cell counts showed a decreasing trend postoperatively but gradually increased from postoperative day 6, during which time PCT continued to decline; this phenomenon may be related to early dissolution of the eschar due to a small amount of residual necrotic tissue on the wound surface.

Conservative tangential excision removes most necrotic tissue while avoiding misjudgment of the wound that could lead to loss of healthy tissue, maximally preserves viable tissue, significantly alleviates the inflammatory response, and prevents further deepening of the wound [29], thereby providing a foundation for spontaneous healing of deep second-degree and superficial third-degree burns. In addition, xenogeneic dermal coverage effectively inhibits wound bacterial colonization, reduces infection risk, and promotes wound healing [30]. In this study, the rate of spontaneous wound healing within three weeks was approximately 45%, significantly reducing the need for subsequent skin grafting and conserving autologous skin sources. Furthermore, the mean number of surgical procedures (3.35 ± 1.81) and mean length of hospital stay (53.9 ± 26.7 days) were lower than current international averages [31], indicating that this strategy improves treatment efficiency and reduces the burden on both patients and healthcare systems.

In conclusion, in the treatment of this group of patients with extensive severe burns, no worsening of the condition such as aggravated shock or deepening of the wound was observed following the use of conservative tangential excision combined with xenogeneic skin coverage during the early shock phase. At the same time, this strategy reduced the number of surgical procedures and shortened the hospital stay to a certain extent. However, this study has a small sample size and lacks a randomized controlled design and multicenter clinical investigation, which may introduce certain biases.

Declarations

Ethical Approval and Consent to participate: This article was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (2013 revision) and received approval from the Medical Ethics Committee of Gansu Provincial Hospital (Approval Number: 2025-204). The study protocol was reviewed and deemed compliant with institutional ethical standards. Depending on local standards and legislation, informed consent was obtained from patients and substitute decision-makers.

Consent for publication: All authors have given their consent for publication.

Availability of supporting data: All clinical data relevant to this case are included in the manuscript. Raw data are stored in the electronic health record system of Gansu Provincial Hospital and can be shared for non-commercial research purposes under a data use agreement. Requests should be directed to the author’s email.

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Authors' contributions: Jun Liu: Writing – original draft, Supervision, Resources, Methodology, Investigation, Data curation, Conceptualization. Ruo Nan Lu: Writing – original draft, Resources, Investigation, Data curation, Conceptualization. Hui Wang: Supervision, Investigation, Data curation, Conceptualization. Da Wang: Investigation, Data curation, Conceptualization.

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