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The Role of Tumescent Technique in Stabilizing Hemodynamics During Early Surgery in Patients with Extensive Severe Burns

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Abstract

Abstract: Objective: To investigate the clinical efficacy of the tumescent technique in early-stage surgery for patients with extensive critical burns. Methods: A retrospective cohort study was conducted on 27 patients with extensive burns who met the inclusion criteria from June 2019 to November 2022. Among them, 14 patients admitted from June 2021 to November 2022 who underwent hemostasis via tumescent solution injection were designated as the tumescent group; 13 patients admitted from June 2019 to November 2021 who underwent tourniquet hemostasis were designated as the tourniquet group. The operation time, blood loss, preoperative planned transfusion volume, actual transfusion volume, preoperative and postoperative hemoglobin levels, intraoperative and postoperative blood pressure and heart rate, postoperative skin graft survival rate, and other related indicators were compared between the two groups to observe the clinical effects. Results: No statistically significant difference in preoperative planned transfusion volume was observed between the two groups ($P>0.05$). The actual transfusion volume in the tumescent group was significantly lower than that in the tourniquet group ($P<0.05$). The intraoperative blood loss and operation time in the tumescent group were significantly less than those in the tourniquet group ($P<0.05$). No significant differences in preoperative and postoperative hemoglobin levels were found between the two groups ($P>0.05$). The postoperative skin graft survival rate in the tumescent group was slightly higher than that in the tourniquet group ($P<0.05$). The intraoperative vital signs of patients in the tumescent group were more stable than those in the tourniquet group ($P<0.05$). Conclusion: The tumescent technique in early-stage surgery for patients with extensive critical burns can reduce intraoperative blood loss, shorten operation time, improve postoperative skin graft survival rate, and simultaneously ensure intraoperative hemodynamic stability, demonstrating favorable clinical efficacy.

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Full Text

The Role of Tumescent Technique in Stabilizing Hemodynamics During Early Surgery for Massively Burned Patients

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Abstract

Objective: To investigate the clinical efficacy of tumescent technique in early surgical management of massively burned patients.

Methods: A retrospective cohort study was conducted on 27 patients with extensive burns admitted between June 2019 and November 2022 who met the inclusion criteria. Among them, 14 patients admitted from June 2021 to November 2022 received intraoperative injection of tumescent fluid for hemostasis (tumescent group), while 13 patients admitted from June 2019 to November 2021 underwent tourniquet hemostasis (tourniquet group). The two groups were compared regarding operative time, blood loss, planned versus actual blood transfusion volumes, preoperative and postoperative hemoglobin levels, intraoperative and postoperative blood pressure and heart rate, postoperative skin graft survival rate, and other relevant indicators.

Results: No statistically significant difference was observed in preoperative planned transfusion volume between the two groups ($P > 0.05$). However, the tumescent group had significantly lower actual transfusion volume compared to the tourniquet group ($P < 0.05$). Intraoperative blood loss and operative time were also significantly reduced in the tumescent group ($P < 0.05$). Preoperative and postoperative hemoglobin levels showed no significant differences in either group ($P > 0.05$). The skin graft survival rate was slightly higher in the tumescent group compared to the tourniquet group, with a statistically significant difference ($P < 0.05$). Additionally, intraoperative vital signs remained more stable in the tumescent group ($P < 0.05$).

Conclusion: Tumescent technique in early surgery for massively burned patients reduces intraoperative blood loss, shortens operative time, improves postoperative skin graft survival, and maintains stable intraoperative hemodynamics, demonstrating favorable clinical efficacy.

Keywords: tumescent technique; burn; surgical operation; intraoperative application; blood loss; hemodynamics; clinical effect

Introduction

The primary challenges in managing massively burned patients involve stabilizing hemodynamics, preserving blood perfusion to vital organs, and performing early debridement of necrotic tissue with effective wound coverage. Appropriate early treatment significantly influences patient outcomes [1]. Based on our experience in rescuing massively burned patients, deep partial-thickness burns often progress due to inadequate tissue perfusion, edema, and infection. Consequently, we perform early tangential excision on both deep partial-thickness and superficial full-thickness burns simultaneously. However, hemodynamic fluctuations caused by intraoperative blood loss, fluid shifts, and surgical manipulation also critically affect prognosis [2].

Therefore, we introduced tumescent technique into early tangential excision procedures for massive burns to reduce intraoperative blood and fluid loss while maintaining hemodynamic stability. We compared this approach with conventional tourniquet hemostasis, with results reported below.

Materials and Methods

1.1 Clinical Data

A retrospective cohort study was conducted on 27 patients with extensive burns (burn area > 50%) admitted between June 2019 and November 2022. All patients received anti-infection therapy and fluid resuscitation during the shock phase, followed by early surgical intervention after hemodynamic stabilization. The tumescent group comprised 14 patients admitted from June 2021 to November 2022 who received tumescent fluid injection for hemostasis. The tourniquet group included 13 patients admitted from June 2019 to November 2021 who underwent tourniquet hemostasis.

Inclusion criteria: (1) Admission within 24 hours post-burn; (2) Initial surgical site limited to limbs, including both lower extremities or both lower extremities plus one upper extremity; (3) Surgery performed 3-5 days after stable recovery from shock phase, with operative area covering 30%-40% of body surface (deep partial-thickness to superficial full-thickness burns).

Baseline characteristics: The tumescent group (n=14) had a mean age of 35.60 ± 18.59 years (8 males, 6 females), mean burn area of 61.20 ± 13.09%, mean full-thickness burn area of 35.40 ± 10.30%, and mean operative area of 34.52 ± 3.56%. The tourniquet group (n=13) had a mean age of 37.38 ± 15.21 years (7 males, 6 females), mean burn area of 66.58 ± 16.62%, mean full-thickness burn area of 38.75 ± 9.50%, and mean operative area of 35.46 ± 3.80%. No statistically significant differences were found between groups in gender, age, burn area, or operative area ($P > 0.05$), making them comparable.

Exclusion criteria: Cases with full-thickness burns extending through subcutaneous fat to deeper structures.

1.2 Tumescent Solution Preparation

The tumescent solution consisted of 1 ml of 1:1000 epinephrine added to 1000 ml of normal saline. Approximately 100 ml of tumescent fluid was injected per 1% of operative area.

1.3.2 Surgical Procedure

After successful general anesthesia and standard sterile preparation, the tumescent group received subcutaneous injection of tumescent fluid into the superficial fascial layer using a medical peristaltic pump (MP300-TH152) connected to a 5 ml syringe needle. The injection continued until the burned skin became firm and turgid. Tangential excision was then performed with a dermatome: for deep partial-thickness burns until a porcelain-white appearance or healthy white reticular fibers were visible; for superficial full-thickness burns until bright yellow, glossy healthy fat tissue was exposed. The wound surface showed tumescent fluid exudation with minimal bleeding. Larger vessel bleeding was controlled with electrocautery when necessary. The wound was then irrigated alternately with hydrogen peroxide and normal saline before grafting.

In the tourniquet group, tourniquets were applied routinely to limbs. Tangential excision was performed with a dermatome using a combined excision technique. The excision depth for deep partial-thickness burns matched the tumescent group, while superficial full-thickness burns were excised to the deep fascial layer. Larger vessel stumps were coagulated with electrocautery. The tourniquet was released intermittently to achieve complete hemostasis while minimizing blood pressure impact (observations showed that releasing a tourniquet from a unilateral lower extremity could decrease blood pressure by 10-20 mmHg). The wound was irrigated alternately with hydrogen peroxide and normal saline before grafting.

Donor sites were injected with tumescent fluid before harvesting skin with a powered dermatome. Skin grafts were trimmed to approximately 0.5 cm × 0.5 cm pieces or prepared as Meek micrografts. In the tumescent group, grafts were applied to full-thickness burn areas and covered with xenogeneic acellular dermal matrix, while deep partial-thickness areas received only xenogeneic acellular dermal matrix coverage. The tourniquet group received identical wound coverage. All grafted areas were covered with antimicrobial dressings and sterile gauze for pressure dressing and fixation. Donor sites were covered with petrolatum gauze and sterile gauze pressure dressing.

If patients developed unstable vital signs or sudden hypotension during surgery, the procedure was halted for fluid resuscitation and vasopressor administration until stabilization. Patients who could not be stabilized intraoperatively were transferred to the intensive care unit for further management.

1.3.3 Postoperative Management

Donor site outer dressings were removed on postoperative day 2, retaining the petrolatum gauze, then covered with concentrated povidone-iodine gauze and thin layer dressing. On postoperative day 3, outer dressings were removed for semi-exposure therapy. Grafted areas were opened on postoperative days 3-4 for routine dressing changes.

1.4 Observation Indicators

The following parameters were compared between groups: intraoperative blood loss, planned preoperative transfusion volume, actual transfusion volume, preoperative and postoperative hemoglobin, operative time, intraoperative and postoperative blood pressure and heart rate, and postoperative skin graft survival rate.

Blood loss was calculated using the 24-hour dynamic hemoglobin method [3], based on the standard that transfusing 1 unit of whole blood (200 ml) increases hemoglobin by 5 g/L in a 60 kg patient with normal blood volume. The formula was: Blood loss = (Preoperative Hb - Postoperative Hb) (g/L) × 200/5 + Transfusion volume (ml).

Skin graft survival was evaluated using the following criteria [4]: (1) Excellent: dry wound without exudate or inflammation, with nearly complete graft survival; (2) Good: minimal wound exudate with majority graft survival; (3) Fair: moderate wound exudate with mild inflammation and approximately 50% graft survival; (4) Poor: significant wound exudate with severe inflammation. Graft survival rate = (Excellent + Good + Fair cases) / Total cases × 100%.

1.5 Statistical Methods

Data were processed using SPSS 22.0. Normally distributed continuous data were expressed as mean ± standard deviation ($\bar{x} \pm s$) and analyzed using t-tests. Non-normally distributed data were expressed as median (P25, P75) and analyzed using Mann-Whitney U test. Categorical data were expressed as percentages and analyzed using Chi-square test, Bonferroni-corrected Pearson Chi-square test, continuity-corrected Chi-square test, or Fisher's exact test. $P < 0.05$ was considered statistically significant. Graphing was performed using GraphPad Prism 7.

Results

2.1 Comparison of Intraoperative Blood Loss

Intraoperative blood loss was significantly lower in the tumescent group compared to the tourniquet group ($P < 0.05$) .

Table 1 Comparison of intraoperative blood loss between groups M (P75-P25) Blood loss (ml): Tumescent group 600 (685-572.5)* vs. Tourniquet group 1150

(1700-875)

2.2 Comparison of Blood Preparation, Transfusion, and Hemoglobin Levels

Both groups had adequate preoperative blood preparation. The tumescent group showed a significant difference between planned and actual transfusion volume ($t = 4.142$, $P = 0.001$), whereas the tourniquet group showed no significant difference. Postoperative hemoglobin was slightly lower than preoperative levels in the tumescent group ($t = 0.909$, $P = 0.380$), but the difference was not statistically significant. Some cases in the tumescent group even exhibited higher postoperative than preoperative hemoglobin. Similarly, the tourniquet group showed a slight postoperative hemoglobin decrease ($t = 0.561$, $P = 0.585$) without statistical significance, though some cases maintained identical pre- and postoperative levels .

2.3 Comparison of Operative Time

Operative time was significantly shorter in the tumescent group compared to the tourniquet group ($P < 0.05$) .

Table 3 Comparison of operative time between groups ($\bar{x} \pm s$)
Operative time (min): Tumescent group 139.0 ± 31.024 vs. Tourniquet group 157.50 ± 27.027

2.4 Comparison of Intraoperative and Postoperative Vital Signs

Compared to the tourniquet group, the tumescent group demonstrated more stable intraoperative blood pressure. The tourniquet group showed significant blood pressure reduction beginning 45 minutes after surgery initiation. Statistically significant differences in blood pressure were observed at multiple time points: intraoperative 45, 60, 75, 90, 105, 120, 135, 150, 165, and 180 minutes, and postoperative 30, 60, 90, and 120 minutes [FIGURE:1, TABLE:4].

Heart rate in the tourniquet group began increasing at 30 minutes intraoperatively, with statistically significant differences between groups observed at intraoperative 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, and 180 minutes, and postoperative 30, 60, 90, and 120 minutes. The most significant difference occurred at intraoperative 90 minutes ($P < 0.05$) [FIGURE:2, TABLE:5].

2.5 Comparison of Postoperative Skin Graft Survival

Using Fisher's exact test, no statistically significant difference was found in overall graft survival rates between groups ($P > 0.05$). However, the tumescent group achieved a higher survival rate (96.42%) compared to the tourniquet group (92.31%), with an excellent-to-good rate of 89.28% versus 78.57%, respectively .

Table 5 Comparison of skin graft survival rates between groups
Note: Graft survival was assessed at one week postoperatively.

Discussion

In the management of massively burned patients, early fluid resuscitation and anti-shock therapy are crucial, yet timely debridement and effective wound coverage after the shock phase also critically influence prognosis [5]. Most massively burned patients present with deep partial-thickness and superficial full-thickness burns, with only a minority having typical full-thickness or deeper injuries. This study focuses on early surgical management of extensive deep partial-thickness and superficial full-thickness burns. Surgical removal of large amounts of necrotic tissue interrupts continuous release of inflammatory mediators and absorption of burn toxins, representing a vital life-saving intervention [6-7]. However, large operative areas often cause hemodynamic instability due to massive blood loss, fluid shifts, and surgical manipulation, leading to ischemia-reperfusion injury, procedure interruption, and poor graft survival [8]. Reducing intraoperative blood loss can minimize coagulopathy from hemodynamic derangement, preserve limited blood resources, and reduce transfusion-related infection risks [9].

Studies have demonstrated that epinephrine tumescent solution, thrombin dressings, and tourniquets effectively reduce mean transfusion requirements per operation and improve graft success rates [10]. Tourniquets can reduce blood loss to 0.49-1.19 ml/cm^2 per 1% body surface area [11]. Pediatric studies show that epinephrine tumescent solution alone reduces surgical blood loss from 3.5-5% to 0.98% per 1% body surface area [12]. Our retrospective study compared hemostatic efficacy and postoperative outcomes between techniques. Intraoperative blood loss was assessed jointly by surgeons and anesthesiologists based on the principle of 50-100 ml blood loss per 1% TBSA during tangential excision, with blood preparation following these guidelines [13]. We found significantly lower intraoperative blood loss in the tumescent group, with both groups receiving less than planned transfusion volumes, confirming that both epinephrine tumescent solution and tourniquets effectively reduce bleeding, with tumescent technique showing superior efficacy. The tumescent group also required significantly less actual transfusion volume postoperatively. These findings align with literature reporting that epinephrine tumescent solution provides hemostasis comparable or superior to tourniquets in limb surgery, while remaining effective in trunk areas where tourniquets cannot be applied [14-16].

Traditional approaches recommend combined tangential and full-thickness excision for deep partial-thickness and superficial full-thickness burns, as the excision plane for deep partial-thickness burns is easily identifiable, while excising superficial full-thickness burns to the deep fascia reduces bleeding and prevents liquefactive necrosis of unhealthy adipose tissue or secondary necrosis of exposed healthy fat, thereby improving graft survival [17]. However, tourniquet use may lead to inadequate excision and poor graft survival due to transplantation onto non-viable tissue [18]. Our study introduced tumescent technique for early debridement of such burns. The tumescent group underwent tangential excision exclusively; tumescent fluid injection facilitated identification of appropriate excision planes for deep partial-thickness burns and helped distinguish healthy from unhealthy fat in superficial full-thickness burns. Precise tangential excision preserved healthy adipose tissue, creating conditions for functional rehabilitation. Both groups achieved >90% graft survival, with the tumescent group showing slightly higher rates. The excellent-to-good rate was 89.28% in the tumescent group versus 78.57% in the tourniquet group, suggesting that the hydrodissection effect of tumescent injection may facilitate more thorough debridement and improve graft quality [19]. Notably, some tumescent group patients exhibited higher postoperative than preoperative hemoglobin, indicating: (1) Potential inaccurate assessment of blood/fluid loss during surgery leading to unnecessary transfusion, as no precise, unified formula exists for calculating burn surgery blood loss; and (2) Slow systemic absorption of tumescent fluid over several hours, which may supplement intraoperative fluid loss and reduce bleeding, potentially causing fluid overload if traditional fluid replacement protocols are followed [20].

Most importantly, this study demonstrated that stable intraoperative blood pressure and heart rate in the tumescent group confer significant advantages for hemodynamic stability during early burn surgery. This stability relates to both mechanical compression from the tumescent fluid and the vasoconstrictive effect of epinephrine [21-23], consistent with our findings of stable hemodynamics in massively burned patients. Conversely, tourniquet release caused blood pressure decline and heart rate acceleration, likely due to reactive hyperemia. Hemodynamic stability in the tumescent group may also relate to fluid resorption. Previous studies indicate approximately 10% of injected tumescent fluid is absorbed [24], requiring healthy subcutaneous adipose tissue for absorption via capillaries and lymphatics. The lymphatic system provides a unidirectional pathway for plasma proteins, excess fluid, and cellular debris from peripheral tissues to circulation, with pressure gradients between interstitial fluid and lymphatic capillaries driving this process [25]. Epinephrine-induced vasoconstriction may prioritize lymphatic absorption, providing volume expansion that balances fluid loss during excision, maintains internal environment stability, and minimizes intraoperative transfusion [26-28]. This explains the significantly lower actual transfusion volume in the tumescent group. Lymphatic resorption of tumescent fluid may also explain the low infection rates observed in injected areas [29]. Wound injection of tumescent fluid rarely caused infection, while slow postoperative exudation provided a moist wound environment conducive to healing and graft survival [30].

Furthermore, significantly shorter operative time in the tumescent group was noted. Comparing surgical techniques revealed that the tourniquet group required 10-15 minutes of compressive dressing after tourniquet release, followed by electrocautery hemostasis, with tourniquet use limited to approximately 1.5-2 hours, necessitating repeated applications for extensive excisions. The tumescent group required preoperative widespread subcutaneous injection, but after excision and electrocautery, no compressive dressing was needed and no extensive oozing occurred during subsequent procedures. Reduced operative time helps minimize intraoperative and postoperative complications in critically ill patients, facilitating recovery [31-32].

In summary, tumescent technique may represent an optimal approach for early surgical management of massively burned patients, providing more stable intraoperative hemodynamics, reducing complications, and promoting comprehensive rehabilitation.

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