ACUTE BURN RESUSCITATION

SUMMARY

Acute major burns are serious life-threatening conditions. Burn shock is the intravascular volume depletion and resultant tissue and organ malperfusion that occurs following burns involving 20% of the total body surface area (TBSA) or more. The patient's optimal chance for survival and a meaningful recovery depends upon appropriate fluid resuscitation, airway management, and appropriate, timely burn care. This guideline provides a template for the initial resuscitation of patients with acute major burn injury involving greater than 20% TBSA.

RECOMMENDATIONS

- **Level 1**
  - None
- **Level 2**
  - Estimate initial fluid requirements with the "Consensus formula" (2 mL/kg/%TBSA burned).
  - Vitamin C infusion is not recommended as an adjunct to fluid resuscitation.
  - Avoid the use of hypertonic saline.
- **Level 3**
  - If the patient requires > 6 mL/kg/TBSA in the first 12 hours, or develops oliguria or hypotension, consider colloid rescue
    - 5% albumin at 1/3 Parkland rate (4 mL/kg/%TBSA burned) + Lactated Ringers at 2/3 Parkland rate.
  - Avoid oversedation. Consider non-narcotic analgesia such as ketorolac, ibuprofen, or ketamine.
  - Resuscitation endpoints in the first 24 hours post-burn injury:
    - Monitor arterial lactate q 4 hours until normalized (< 2 mmol/L)
    - Maintain urine output at 30-50 mL/hr
    - In electrical injury or rhabdomyolysis patients, serial creatinine kinase levels should be checked daily until < 2500 mcg/L
    - Monitor hemoglobin to ensure that it is not trending upward
  - Fresh frozen plasma may be used as an alternative to albumin.

INTRODUCTION

Numerous formulas have been developed since the 1940s specifically designed to provide optimal fluid resuscitation for the burn-injured patient. Despite extensive research, no ideal resuscitation strategy has been found. Most seriously burned patients continue to be over-resuscitated. There is a general agreement within the burn surgery community that both the Parkland and modified Brooke formulas have been most effective, though most institutions have abandoned limiting the use of colloid therapy to the second 24 hours after the injury as was originally recommended by these formulas.

EVIDENCE DEFINITIONS

- **Class I:** Prospective randomized controlled trial.
- **Class II:** Prospective clinical study or retrospective analysis of reliable data. Includes observational, cohort, prevalence, or case control studies.
- **Class III:** Retrospective study. Includes database or registry reviews, large series of case reports, expert opinion.
- **Technology assessment:** A technology study which does not lend itself to classification in the above-mentioned format. Devices are evaluated in terms of their accuracy, reliability, therapeutic potential, or cost effectiveness.

LEVEL OF RECOMMENDATION DEFINITIONS

- **Level 1:** Convincingly justifiable based on available scientific information alone. Usually based on Class I data or strong Class II evidence if randomized testing is inappropriate. Conversely, low quality or contradictory Class I data may be insufficient to support a Level I recommendation.
- **Level 2:** Reasonably justifiable based on available scientific evidence and strongly supported by expert opinion. Usually supported by Class II data or a preponderance of Class III evidence.
- **Level 3:** Supported by available data, but scientific evidence is lacking. Generally supported by Class III data. Useful for educational purposes and in guiding future clinical research.

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Common Burn Fluid Resuscitation Formulas

Parkland Formula	4 mL Lactated Ringer's solution per % TBSA per kg body weight • Administer ½ of the calculated volume in the first 8 hours post-burn injury • Administer remaining ½ of the calculated volume in the following 16 hours
Modified Brooke Formula	First 24 hours: • 2 mL Lactated Ringer's solution per % TBSA per kg body weight • Administer ½ of the calculated volume in the first 8 hours post-burn injury • Administer remaining ½ of the calculated volume in the following 16 hours Second 24 hours: • 0.3-0.5 mL 5% albumin per % TBSA per kg body weight + D_5W to maintain urinary output
Consensus Formula	2-4 mL Lactated Ringer's solution per % TBSA per kg body weight • Administer ½ of the calculated volume in the first 8 hours post-burn injury • Administer remaining ½ of the calculated volume in the following 16 hours

Due to the lack of evidence to support any specific formula as the gold standard, the American Burn Association (ABA) Consensus Panel has established recommendations which provide a framework for treatment and clinical quality outcomes. Though there remains a lack of Level 1 evidence, the panel established the following "consensus" recommendations (1):

- Fluid resuscitation occurs during the first 72 hours after injury.
- Fluid resuscitation should be initiated for burns greater than or equal to 20% TBSA.
- Although no standardized regimen has been established by evidence, 2-4 ml/kg/%TBSA is generally accepted for initial fluid resuscitation.

The central goal is "preservation of vital organ function at the least physiologic cost and the least number of complications" (1). It follows that markers of tissue perfusion (such as lactate and base deficit) and markers of organ dysfunction (such as those for acute renal injury or acute lung injury) in addition to ongoing surveillance of clinical presentation and physical examination, each play a role in managing burn resuscitation efforts.

As a result, there is no single parameter that may be utilized to evaluate the adequacy of fluid resuscitation. Many centers institute a multi-factorial approach looking at several different markers of resuscitation adequacy. These include urinary output (30-50 ml/hr), serial lactate, base deficit, and creatinine kinase levels every 4 hours. The trend in these parameters over time helps ensure appropriate resuscitation and it is important to see them approaching normal values within the first 24 hours post-burn injury (1).

LITERATURE REVIEW

Volume Repletion

There is no perfect method to monitor and ensure adequate tissue perfusion and volume resuscitation. However, several principles should be applied and followed. Shock following burn injury is a combination of both hypovolemic and distributive shock. Crystalloid fluid resuscitation in the burn patient has historically been administered according to either the Parkland or modified Brooke formulas without appreciable change for more than 30 years. Unfortunately, over-resuscitation is an all too common occurrence. In 2000, Pruitt coined the term "fluid creep" suggesting that many patients are being over-resuscitated resulting in secondary complications. Complications from over-resuscitation are well documented in the literature and include blood stream infection, pneumonia, multisystem organ failure, acute respiratory distress syndrome (ARDS), abdominal compartment syndrome, extremity compartment syndrome, and death (2,3). There appears to be a reluctance by clinicians to decrease fluid administration rates even when urinary output exceeds 1 ml/kg/hr. It has been demonstrated that patients receiving >250 ml/kg of fluid resuscitation had a significantly increased risk of abdominal compartment syndrome and mortality compared to those who received less than 250 ml/kg. This has become known as the "Ivy Index" (4). "Fluid creep" has been attributed to excessive opioid administration, inadequate

monitoring, inaccurate estimation of total body surface area and excessive fluid administration in the prehospital setting (4,5).

Compared to when the Parkland formula was developed, more narcotic pain medications are administered. This narcotic use mitigates some of the catecholamine effects and causes vasodilation requiring increased fluid resuscitation volumes to maintain patient vascular preload. While it is essential to control pain, it is also important to not over-sedate patients (6). Nurse driven protocols and hourly communication between nursing staff and burn physicians have been shown to decrease fluid resuscitation volumes and lead to better outcomes (7).

Beyond Volume Repletion

Use of colloids

Human Albumin and fresh frozen plasma are the most commonly selected and most investigated colloids. A 2010 American Burn Association and International Society of Burn Injuries survey revealed that there was equal preference for either fresh frozen plasma or albumin. Large randomized controlled trials examining the use of albumin are lacking. Early administration of albumin is generally felt to be inappropriate due to a potential contribution to edema because of the increased capillary permeability. According to the American Burn Association, colloid-containing fluids can be considered between 12 and 24 hours after injury. However, studies exist supporting colloid consideration as early at 8 hours post injury. In addition to timing, exact dose and appropriate patient selection remain up for debate (8). There remains a paucity of higher level and recent evidence endorsing the administration of albumin during initial burn resuscitation. A recent meta-analysis contained only 4 studies (9). Although less fluid was required when colloid was utilized, no reduction in mortality was realized.

Cartotto et al. recommended “colloid rescue” for those patients who exceeded the Parkland formula calculation by more than 1.5 times or 6 ml/kg/%TBSA (10). Similar protocols were instituted at the University of Utah and by the US military. The colloid rescue formula is 1/3 of the Parkland volume given as albumin + 2/3 of the Parkland rate given as Lactated Ringer’s solution. This formula has been shown in multiple studies to decrease fluid requirements without any associated increase in mortality or renal failure (8,9).

Work has begun to identify the risk of transfusion-related acute lung injury (TRALI) for burn shock resuscitation involving colloid. Jones et al. performed a retrospective study of severely burned patients who underwent burn shock resuscitation with FFP infusion initiated at 75 mL/kg of body weight plus Lactated Ringer’s solution at 2 liters over 24 hours with titration of FFP to achieve urine output 0.5-1.0 mL/kg/hr continued for 48 hours or until the patient was completely resuscitated (11). After exclusion criteria were met, 18 patients were studied, one of whom developed TRALI, a 5.5% incidence. While the risk for development of TRALI exists, the actual occurrence is felt to be low and can be difficult to discern in patients with concomitant inhalation injury.

Use of Vasopressors

Patients with severe burns may remain hypotensive despite aggressive fluid resuscitation and require vasopressors. However, their use is associated with significant negative outcomes and should only be used as a last resort. The reason that some burn patients require vasopressors is unclear and risk factors for burn shock, specifically, have not been extensively studied. One study analyzed a set of burn patients to determine features requiring vasopressors within the first 48 hours of fluid resuscitation. On average, those patients requiring vasopressors were older (54.6 vs. 42.2 years, p=0.032), had greater involvement of full-thickness burns (37.7% vs. 14.5% p=0.006), and had higher revised Baux score (regression analysis of data including age, percent of total body surface area burned, and inhalation injury) (12). In this study, no significant risk was attributable to a comorbidity or home medication, except for those who took dihydropyridine calcium channel blockers (15% vs. 3.3%, p=0.038). Vasopressor use was associated with a need for 1.5 times as much Lactated Ringer’s infusion volume within the first 24 hours, 2.5 times greater mortality, and a requirement of dialysis rate of 10% vs. 0%.

Hypertonic Saline

As mentioned previously, the consensus opinion for fluid resuscitation is to use isotonic crystalloid solution, typically Lactated Ringer's. Another approach is the use of hypertonic saline. In 1995, researchers at University of Alabama at Birmingham selected patients over the course of 8 years and performed a trial comparing outcomes for 65 patients resuscitated with hypertonic saline (290 mEq/L) with those of 148 patients resuscitated with Lactated Ringer's solution. In patients receiving hypertonic saline, mortality rate was significantly higher (54% vs. 27%, $p<0.001$), as was incidence of cardiovascular failure (59% vs. 39%, $p=0.011$), pulmonary failure (68% vs. 38%, $p<0.001$), hepatic failure (69% vs. 36%, $p<0.001$, and renal failure (40% vs. 10%, $p<0.001$). 50% of patients who received hypertonic saline developed organ failure involving three or more systems. Both groups were similar in age, total burn size, and incidence of inhalation injury. During the initial 24 hours of resuscitation, the patients receiving hypertonic saline required about 1.25 mL/kg/%BSA less than those receiving Lactated Ringer's ($p<0.001$) but this approach did not reduce the total resuscitation volume required and resulted in significantly greater morbidity and mortality (13).

Renal Replacement Therapy (RRT)

RTT is used to treat severe acute kidney injury (AKI), metabolic acidosis, severe electrolyte abnormalities, intractable fluid overload, and complications of uremia. Continuous RRT is typically used in hemodynamically unstable patients who cannot tolerate rapid fluid shifts or require ongoing infusions during dialysis (i.e., large-volume fluid administration, vasopressor support, multiple IV medications, or total parenteral nutrition.) Only one multicenter study is available evaluating RRT practice and outcomes in severe burn patients treated at United States burn centers (eight centers, 171 patients, over four years) (14). On average, patients had sustained burns involving 38 ± 26% TBSA with injury severity scores of 27 ± 21. Most patients were treated with continuous venovenous hemofiltration at a mean delivered dose of 37 ± 19 ml/kg/hour and treatment lasted 13 ± 24 days. Most of the patients in the study were placed on RRT "early", that is, without having met the above triggers for initiation. There is mixed evidence regarding whether this is of any benefit. Overall, in-hospital mortality was 50% similar to other critically ill populations who are treated with RRT. 90% of the patients in the study who survived and were discharged from the hospital had recovered renal function without need for further RRT by 6 months post-discharge; 21% required RRT on discharge.

Ascorbic Acid

High Dose Ascorbic Acid (HDAA) administration during acute burn resuscitation gained popularity based upon early studies which suggested that it reduced fluid administration during the critical first 24 hours. This benefit has not been substantiated in subsequent studies however. HDAA use has not been shown to decrease ventilator days, decrease ventilator-associated pneumonia, or mortality, but it does increase the risk for acute renal failure and oxalate nephropathy. Further, it confounds glucose readings on point of care glucometers (15-18).

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