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ACUTE ADULT BURN RESUSCITATION

Evidence Based Medicine Guideline

Primary Author: Dominick Curry, PharmD; Susan Smith, PhD, APRN-BC
Co-Authors: Howard Smith, MD; Timothy Smith, MD
Editors: Michael L. Cheatham MD, Chadwick Smith MD
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SUMMARY
Acute major burns are serious life-threatening conditions. Burn shock is the intravascular volume depletion and resultant tissue and organ malperfusion that occurs after burns involving 20% total body surface area (TBSA) or more. The patient's optimal chance for survival and meaningful recovery depends upon appropriate airway management, fluid resuscitation, and timely burn care.

RECOMMENDATIONS

- **Level 1**
  - None
- **Level 2**
  - Estimate initial fluid requirement at 2 mL/kg/% TBSA burn administered over the first 24 hours
    - Electrical burn injuries should be estimated at 4 mL/kg/% TBSA burn
    - Divide the 24-hour total by 16 to calculate the initial fluid rate
    - Titrate fluid resuscitation to maintain a urinary output of at least 30-50 mL/hr
  - Avoid the use of hypertonic saline
- **Level 3**
  - Assess patients 8- and 12-hours post-injury to identify the need for colloid rescue
    - If the patient has met their 24-hour fluid requirement at 8 hours (or 1.5 x 24-hour requirement at 12 hours), initiate colloid rescue (see algorithm):
      - 5% albumin (1/3 current fluid rate) + Lactated Ringer's (2/3 current fluid rate)
      - Do not initiate albumin prior to 8 hours from injury
  - Avoid over sedation. Consider non-narcotic analgesics such as ketorolac, ibuprofen, or ketamine (see Ketamine for Analgesia guideline)
  - High-dose ascorbic acid infusion is no longer recommended as an adjunct to fluid resuscitation
  - **Fluid boluses should be administered for hypotension only**.
  - Target the following resuscitation endpoints in the first 24 hours post-burn injury:
    - Monitor arterial lactate q 4 hours until < 2 mmol/L
    - Adjust fluid rate by 1/3 of current rate (up or down) each hour that target urine output is not achieved
    - Check daily creatinine kinase levels in electrical injury or rhabdomyolysis patients until < 2500 mcg/L
    - Monitor hemoglobin to ensure that it is not trending upward suggestive of hypovolemia

INTRODUCTION

Numerous formulas have been developed to guide fluid resuscitation for the burn-injured patient. Despite extensive research, no ideal formula has been identified and most seriously burned patients continue to be over-resuscitated. There is general agreement within the burn surgery community that both the Parkland and modified Brooke formulas

LEVEL OF RECOMMENDATION DEFINITIONS

- **Level 1:** 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.

have been most effective, although most burn centers have abandoned the use of colloid therapy beginning with the second 24 hours of resuscitation as was originally recommended by these two formulas.

Due to the lack of evidence to support any specific formula as the gold standard, the American Burn Association (ABA) Consensus Panel has proposed 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 of crystalloid per %TBSA burn per kg body weight over the first 24 hours is an appropriate guideline for initial resuscitation

The central goal is "'preservation of vital organ function at the least physiologic cost and the least number of complications" (1). While strong, evidence-based recommendations for burn injury resuscitation do not exist, close monitoring of markers of both tissue perfusion (e.g., lactate and base deficit) and organ dysfunction (e.g., serum creatinine for acute renal injury and PaO_2/FiO_2 for acute lung injury) play a major role in directing any burn resuscitation efforts.

LITERATURE REVIEW

Volume Repletion

There is no perfect method to monitor and ensure adequate tissue perfusion and volume resuscitation. However, several principles should be considered. Shock following burn injury is a combination of both hypovolemic and distributive shock. In addition to Starling forces, influence of the endothelial glycocalyx on vascular permeability and intracellular volume distribution, as regulated by the systemic inflammatory response plays a vital role in overall fluid requirements. The endothelial glycocalyx is potentially impaired by crystalloids and exhibits a positive response to colloid administration in experimental models (2). The emphasis should be on avoiding excessive fluid administration that can cause patient harm. There appears to be reluctance by clinicians to decrease fluid administration rates even when urinary output exceeds 1 ml/kg/hr. There are many complications associated with over-resuscitation including abdominal compartment syndrome, extremity compartment syndrome, and increased nosocomial infections. Patients receiving >250 ml/kg have significantly increased mortality compared to those who receive less than 250 ml/kg. This has become known as the "Ivy Index" (3). Contributing factors resulting in increased, and potentially excessive, fluid administration include delayed resuscitation, inhalation injury, concomitant trauma, electrical injury, alcohol and narcotic use prior to the injury, excessive opioid administration, inadequate monitoring, inaccurate estimation of the patient's TBSA burn, and excessive fluid administration in the prehospital setting (3-5).

For the past several decades, crystalloid fluid resuscitation in the burn patient has been administered according to either the Parkland or modified Brooke formulas. Use of these formulas, however, places the patient at risk for over-resuscitation. 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 increased risk for critical edema of airway and periphery, blood stream infection, pneumonia, multisystem organ failure, adult respiratory distress syndrome, abdominal compartment syndrome, and death (5,6).

Since the Parkland formula was developed, the narcotic dosages employed during resuscitation have increased significantly. These medications decrease normal catecholamine effects resulting in vasodilation. 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 patient outcomes (8).

There is no single clear parameter to guide the adequacy for 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), hemoglobin, serial lactate, base deficit, and/or creatinine kinase levels. Despite use of a variety of invasive monitoring devices, urine output remains the "gold standard" parameter for assessing adequacy of resuscitation. The trend in these parameters over time helps ensure appropriate resuscitation and it is important to see that they are approaching normal values within the first 24 hours post-burn injury (5).

Use of colloids

Colloid use during resuscitation dates back many decades but fell out of favor in the 1970's after being attributed to cause excessive edema and related complications. This resulted in crystalloid-only resuscitation, leading to "over-

resuscitation." The pendulum had now returned to the inclusion of colloid administration, primarily as a "rescue" option for perceived inadequate response to resuscitative fluid administration (2).

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 increased capillary permeability. According to the American Burn Association (ABA), colloid-containing fluids can be considered 12-24 hours post-injury (9). However, studies exist supporting colloid use as early as 8 hours post-injury, such as the Galveston protocol, with colloid replacement considered if serum albumin less than or equal to 2.5 g/dl (5). In addition to timing, exact dose and appropriate patient selection remain up for debate (9). There remains a paucity of higher level and recent evidence endorsing the administration of albumin during initial burn resuscitation. Eljajek et al. performed a meta-analysis of four randomized studies that evaluated colloid resuscitation demonstrating a decrease in overall fluid requirements, but no reduction in mortality (10). Navickis et al. conducted a meta-analysis evaluating the effects of albumin in burn shock resuscitation on morbidity and mortality in 8 trials (4 randomized and 4 non-randomized). Albumin led to a non-significant reduction in mortality overall. However, following the exclusion of 2 trials which significantly increased overall heterogeneity of the total population due to unadjusted higher baseline mortality in the albumin groups, mortality was significantly lower in the albumin group. Furthermore, patients receiving albumin in the first 24 hours experienced significantly less incidence of compartment syndrome (9).

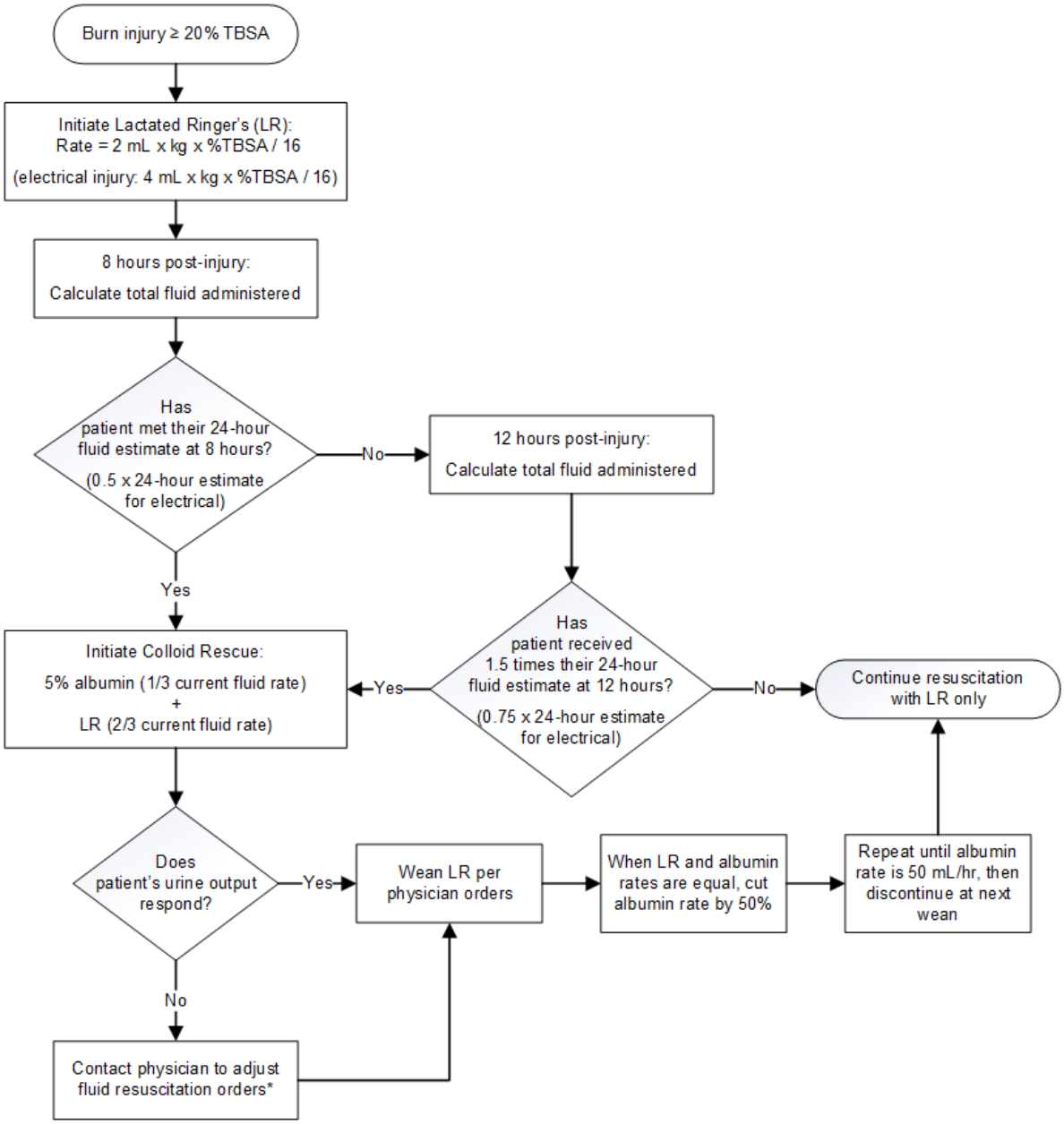
Cartotto et al. recommended "colloid rescue" for those patients who exceeded the Parkland formula calculation by more than 1.5 times or 6 ml/kg/%TBSA. Similar protocols were instituted at the University of Utah and by the U.S. military. One colloid rescue formula commonly utilized is 1/3 of the current fluid rate given as albumin + 2/3 of the current fluid rate given as Lactated Ringer's solution (10). This formula has been shown by multiple studies to decrease fluid requirements without any associated increase in mortality or renal failure (5,8-13).

Human albumin and fresh frozen plasma (FFP) are the most selected and most investigated colloids, though selection has been debated for nearly 60 years. Albumin remains the most widely preferred. In a retrospective review, Comish et al. published their findings using both 5% and 25% albumin initiated in patients with initiation based on urine output less than 0.5 ml/kg/hour for three consecutive hours. A one-time dose of 25% albumin was initiated as part of the overall resuscitation for non-crystalloid responders, administered between 8-13 hours, with additional 5% albumin given as a rescue dose. Results supported overall lower fluid volume administration and no increase in complication rates (12).

A multicenter, prospective observational study involving 21 centers from the United Stated and Canada, studied patterns of albumin administration. Results supported that albumin was administered most to older patients with higher TBSAs, more full-thickness burns, older age and inhalation injuries. Eight-five percent of patients received albumin by 24 hours after their injuries. Albumin was initiated at 15.3 ± 8.4 hours after injury, with 64% receiving 5% Albumin only, 16% with 25% Albumin and 19% receiving a combination of both. FFP administration was not included. Outcomes for the albumin population were worse overall with lower survival rate, longer ventilator days and length of stays and more renal compromise. These findings may speak to the severity of the population receiving albumin and have led to a prospective trial comparing crystalloid and albumin burn resuscitation (14).

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 chart review for severely burned patients who underwent burn shock resuscitation with the West Penn or Slater Formula (15). FFP was initiated at 75 mL/kg body weight + 2 L Lactated Ringer's solution over 24 hours with titration of FFP to achieve urine output 0.5-1.0 mL/kg/hr for 48 hours or until the patient was completely resuscitated. Among 18 patients studied, one developed TRALI (5.5%). Wiktor et al. prospectively studied FFP administration versus crystalloid alone in 56 patients. In 40 of those patients, FFP was administered at a mean of 7 hours, improving urine output to 0.44 ml/kg/hr with no serious FFP-related complications reported (16). 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.

Colloid Rescue



*If urine output does not respond to initial colloid rescue, increase current total fluid (LR + albumin) by 1/3 of the total hourly rate. Break the total fluid amount into 1/3 albumin 5% + 2/3 LR.

Please note that additional parameters such as (increasing) hemoglobin, elevated lactic acid, elevated intraabdominal pressures, need for continuous renal replacement therapy (CRRT) or hemodynamic instability may result in deviation from this guideline and require provider notification.

Use of Vasopressors

Patients with severe burns may remain hypotensive and require vasoactive medications despite aggressive fluid resuscitation. However, their use is associated with significant negative outcomes and should only be used as a last resort. The reasons some burn patients require vasopressors are unclear. One study analyzed burn patients requiring vasopressors within the first 48 hours of fluid resuscitation (12). On average, those requiring vasopressors were older (55 vs. 42 years, p=0.03), had greater involvement of full-thickness burns (38% vs. 15% p=0.006), and had higher revised Baux scores (regression analysis of data including age, %TBSA, and inhalation injury). 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 1.5-fold increase in Lactated Ringer's infusion requirement in the first 24 hours, a 2.5-fold greater mortality, and a dialysis rate of 10% vs. 0% (17).

Hypertonic Saline

In 1995, Huang et al. performed a trial comparing 65 patients resuscitated with hypertonic saline (290 mEq/L) vs. 148 patients resuscitated with Lactated Ringer's solution (18). Among patients resuscitated with hypertonic saline, mortality was significantly higher (54% vs. 27%, p<0.001) as was the 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 in 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 1.25 mL/kg/%TBSA less fluid than those receiving Lactated Ringer's (p<0.001), but hypertonic saline did not reduce the total resuscitation volume required.

Renal Replacement Therapy (RRT)

RTT is used to treat severe acute kidney injury, acidosis, severe electrolyte abnormalities, intractable fluid overload, and/or complications of uremia. CRRT 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). There is one multicenter study evaluating RRT practice and outcomes for severe burn patients treated at United States burn centers (8 centers, 171 patients, four years). On average, treated patients had sustained burns involving 38 ± 26% TBSA and injury severity scores of 27 ± 21. Most patients were treated with continuous venovenous hemofiltration at a mean delivered rate of 37 ± 19 (ml/kg/hour) and treatment lasted 13 ± 24 days. Most of the patients in the study were placed on RRT 'early' (without having met the above triggers for initiation). Overall, in-hospital mortality was 50% which is similar to other critically ill populations who are treated with RRT. Ninety percent of the study patients who survived and were discharged from the hospital had recovered renal function without need for further RRT by 6 months post-discharge (19).

Ascorbic Acid

High-dose ascorbic acid (HDAA) administration during acute burn resuscitation gained popularity because of evidence suggesting that its use reduced fluid administration during the critical first 24 hours. Further studies have failed to corroborate this finding, however. Moreover, HDAA use has not been shown to decrease ventilator days, decrease ventilator-associated pneumonia, or mortality, but is associated with an increased risk for acute renal failure and oxalate nephropathy (20-23). Further, HDAA infusions confound point of care glucose measurements interfering with hyperglycemic control. As a result, HDAA infusions are no longer recommended at this institution.

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