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Critical Care Update

Burn Care: Resuscitation and Respiratory Care

Mithun R. Suresh, MD, David J. Dries, MSE, MD

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Fluid resuscitation is the foundation of immediate burn care. Despite this, the optimal type, timing, and amount of fluid for burn shock remains inadequately investigated. Early burn resuscitation formulas included a variety of colloids that were later associated with significant infectious complications.

The commonly used Parkland and modified Brooke formulas for identifying appropriate amounts of resuscitation with lactated Ringer solution have remained unchanged since their introduction in the 1970s. In the first 24 hours after burn, the Parkland formula calls for 4 mL/kg crystalloid per percentage of the total body surface area (% TBSA) and the modified Brooke formula for 2 mL/kg/% TBSA. An increasingly recognized concern is that many patients are found to receive considerably more resuscitation fluid than predicted by the formula. This phenomenon was termed "fluid creep" by Pruitt in 2000, and excessive resuscitation has emerged as a significant problem in contemporary burn care.

Numerous reports document that many patients with major burns exceed the predicted amount of acute resuscitation fluid. In a 2007 study of patients with major burns, fluid in excess of the predicted volume was accompanied by increased odds of pneumonia, bloodstream infections, acute respiratory distress syndrome (ARDS), multiorgan failure, and death. Another major complication directly attributable to over-resuscitation in patients is compartment syndrome of the abdomen or extremities resulting from massive edema in both burned and unburned tissue. Large-volume fluid resuscitation in patients with major burns increases the risk of intra-abdominal hypertension and consequent abdominal compartment syndrome (ACS). Generally, ACS is encountered in patients with burns of 50% TBSA or more, often with coincident inhalation injury. ACS can significantly worsen the prognosis of burn patients.

The primary goal of resuscitation is to restore and preserve tissue perfusion. Colloids by virtue of their oncotic properties may better maintain intravascular volume than crystalloids and reduce the fluid volume demands. Nonetheless, the question of whether colloids can improve outcomes in burn shock resuscitation remains unclear. In an international survey of burn shock resuscitation practices, approximately half of the respondents administered colloid during the first 24 hours. The colloids predominantly used were purified albumin and fresh frozen plasma. Albumin is the predominant protein in fresh frozen plasma, accounting for more than 75% of its colloid osmotic pressure. The use of albumin in burned patients was first described more than 70 years ago among combat casualties of Pearl Harbor. Despite clinical use in burns for decades, the optimal timing, dose, and patient population for albumin use remain unclear. Contemporary evidence suggests that albumin may improve outcomes of burn shock resuscitation. However, the scope and quality of current evidence are limited.

Hourly urine output appears to be the most commonly used end point to guide titration of resuscitation fluids. The most recent practice guidelines of the American Burn Association recommend that fluid infusion be titrated to achieve urine output of .5 to 1.0 mL/kg/h. As a resuscitation end point, urine output is practical and works well in many circumstances, but it is imperfect. Correlation between urine output and various hemodynamic variables or measures of oxygen delivery or tissue perfusion is poor. Furthermore, optimum hourly urine output has never been accurately defined. A permissive oliguria approach has been suggested as appropriate. However, in inexperienced hands, urine output may be prone to misuse and misinterpretation, particularly in the presence of intra-abdominal hypertension or ACS where oliguria may be caused by diminished renal perfusion rather than hypovolemia. This may lead to erroneous administration of additional fluid creating a vicious cycle involving edema formation, rising intra-abdominal pressure, and oliguria.

Elevated serum lactate and arterial base deficit during acute burn resuscitation are recognized as markers of global poor perfusion and uncompensated shock and predictors of subsequent organ dysfunction and death. Rapid correction of these indices appears to be associated with improved survival. The use of devices to monitor skin perfusion or gastric mucosal pH has not been proven to be advantageous in guidance for burn resuscitation. Similarly, the use of invasively derived variables as obtained from the pulmonary artery catheter to guide acute burn resuscitation has largely disappeared because earlier

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studies found that this approach led to the administration of excessive volumes of fluid. Newer less invasive monitoring approaches including transpulmonary thermodilution may be used to measure cardiac output and determine volumetric measures of preload such as the global end diastolic volume and intrathoracic blood volume as well as extravascular lung water. This approach allows arterial waveform pulse contour analysis to yield real-time continuous measures of cardiac output, stroke volume, stroke volume variation, pulse pressure, and pulse pressure variation.

One goal of fluid resuscitation is to re-expand the contracted intravascular space in order to restore preload; stroke volume; cardiac output; and, ultimately, oxygen delivery. Fluid responsiveness refers to the ability to increase stroke volume and cardiac index by 10% to 15% after a fluid challenge. Such responsiveness indicates that the patient is on the ascending limb of the Frank-Starling curve, assuming normal ventricular function. Thus, newer transpulmonary thermodilution approaches may help guide burn resuscitation by providing indices reflecting preload and volume responsiveness.

In a recent summary statement, the American Burn Association suggested a number of outcome measures to define quality of care in fluid resuscitation. First is the total 24- and 48-hour resuscitation fluid volume. These parameters reflect the need to adequately resuscitate the patient with the least amount of fluid. The quantity of fluid resuscitation can be measured in comparison with volumes predicted by Brooke or Parkland formulas. A second quality parameter is arterial base deficit and lactate. These metabolic parameters, as noted previously, are readily measured and widely accepted markers of malperfusion. They are objective and easily obtained. Persistent elevation in these markers predicts subsequent organ dysfunction and increased mortality. The effectiveness of resuscitation may be defined by time to normalization of these parameters. Third is the avoidance of acute kidney injury using criteria such as stages of the Risk Injury Failure Loss End Stage or Acute Kidney Injury Network criteria. The quality of resuscitation would be reflected by the demonstration of a low incidence of acute kidney injury. Fourth is the incidence of compartment syndromes. The prevention of limb, abdominal, and ocular compartment syndromes is a crucial marker of resuscitation success because these are important morbidities that result from over-resuscitation. The measurement of pressures may be obtained from all these compartments, and established criteria for the diagnosis of compartment pressure elevation currently exist. High-quality resuscitation is associated with a low incidence of these compartment syndromes. The fifth suggested quality parameter is weight gain. Acute weight gain at 24 and 48 hours reflects acute edema formation, potentially reflecting excessive resuscitation. Sixth is vasopressor requirements. The need for vasopressors based on predefined hemodynamic criteria to support fluid resuscitation is a potential measure of resuscitation quality. An increased requirement for vasoactive drug use suggests incomplete plasma volume re-expansion. Finally, the American Burn Association suggests examination of health-related quality of life in patients receiving resuscitation. No studies to date have addressed late quality of life outcomes. Resuscitation that uses excessive fluid volumes leading to prolonged mechanical ventilation and burn ICU stay or the development of a compartment syndrome could have a significant impact on late quality of life.

Although not often discussed as part of burn resuscitation, the role of transfusion goals in burn management is also worthy of comment. A recently published multicenter randomized prospective trial compared 2 standard transfusion strategies with hemoglobin goals of < 10 g/dL compared with < 7 g/dL in patients with burn injury more than 20% TBSA and found that the restrictive strategy markedly reduced the transfusion volume without significant differences in bloodstream infections, mortality, pneumonia, urinary tract infection, wound infection, hospital or ICU length of stay, organ dysfunction, or wound healing. Treatment groups were comparable in this study conducted in multiple centers over a several year period, and compliance with the study protocol was high with hemoglobin levels carefully maintained in the target range. The findings of this trial confirm and extend the results of the historic Transfusion Requirements in Critical Care trial in which a restrictive transfusion strategy was equally effective as a liberal blood product administration protocol. This observation was confirmed in studies of hip fracture patients, cardiac surgery, and other critical care populations. The restrictive transfusion strategy significantly reduced blood product use compared with the liberal strategy.

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Evaluating the airway is 1 of the most important assessments when encountering burn patients. When smoke and inhaled particles enter the lungs, inflammatory cascades are activated in the bronchi, which subsequently cause sloughing of the respiratory tract mucosa and swelling in the luminal walls. This swelling can be exacerbated by the aggressive fluid resuscitation, and, in severe cases, airway obstruction can occur. Consequently, if airway obstruction is suspected, endotracheal intubation should be performed, and mechanical ventilation should be initiated.

There are several clinical findings that should generate suspicion for inhalation injury. These findings include severe facial burns, hoarseness, carbonaceous sputum, soot in the posterior oropharynx, and hypoxia. Unfortunately, these findings may be subtle or absent. As a result, intubation is often performed in the prehospital setting when there is concern for inhalation injury because an unstable airway during transport can be deadly. However, recent work has advocated for a more conservative approach when determining whether to intubate burn patients. Romanowski et al examined 416 burn patients intubated before their arrival at the burn center or in the emergency department of the burn center. Patients were separated into 2 groups based on the number of ventilator days: 1) 2 or fewer ventilator days (ie, potentially unnecessary intubations) or 2) more than 2 ventilator days. Comparing the 2 groups, more patients were intubated > 2 days (245, 58.9%) compared with ≤ 2 days (171, 40.1%). There were significant differences between the groups in % TBSA burned,