# Protocolized Resuscitation of Burn Patients

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**KEYWORDS**

- Fluid resuscitation • Burns • Decision making—Computer-Assisted
- Decision support systems - Clinical

**KEY POINTS**

- Fluid resuscitation of patients with burn shock requires careful hourly titration (up or down) of fluid infusion rates. Over-resuscitation has become more common (fluid creep).
- Patients who receive greater than 250 mL/kg during the first 24 hours following burn injury are at risk of abdominal compartment syndrome (ACS) and other complications. ACS in burn patients is highly lethal despite decompressive laparotomy.
- Paper-based flow sheets and clinical practice guidelines for burn resuscitation are associated with improved outcomes.
- Computerized decision support tools have been developed to assist providers during the resuscitation process.

## INTRODUCTION

The concept of formulas, algorithms, and protocols for the fluid resuscitation of severely injured burn patients is not new, but recent advances in information technology have enabled development of computerized versions of these methods. This article reviews these techniques and proposes a framework for evaluating them.

An understanding of the pathophysiology of burn shock as involving the loss of plasma-like fluid from the intravascular space into the interstitium led to the use of

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plasma for fluid resuscitation.[1] Following the Cocoanut Grove fire of 1942, fluid resuscitation formulas were proposed and widely adopted that used varying concentrations of plasma and crystalloid solutions during the first 24 to 48 hours following burn injury.[2] There was a gradual movement away from plasma over the ensuing years.[3] This reflected the observation that hypovolemic shock causes an extracellular fluid deficit,[4] and created a focus on correcting this deficit with crystalloid solutions.[5] During the 1960s, researchers at the Brooke and Parkland hospitals in Texas developed formulas which used only lactated Ringer's (LR) solution, and no plasma, for the first 24 hours following burn injury.[5,6] The modified Brooke formula (which estimates the first 24-hour volume as LR solution, 2 mL/kg/total body surface area burned [TBSA], with half of this delivered over the first 8 hours) and the Parkland formula (similar to Brooke but 4 mL/kg/TBSA) are the most commonly used formulas for resuscitation of adult burn patients today.[7] Albumin replaced plasma in most resuscitation regimens and was used primarily during the second 24 hours, at a dose of 0.3 to 0.5 mL/kg/TBSA for the day.[8] Subsequently, the utility of colloid solutions before the 24th hour in selected patients reemerged (early albumin), especially in those in whom early resuscitation performance indicated a risk of large-volume resuscitation.[9–11]

Formulas for the resuscitation of burn patients are widely accepted. However, slavish adherence to a formula without adjustment of the fluid infusion rate based on physiologic response is to be condemned. A burn resuscitation formula provides a starting point; the patient's care is then tailored in response to therapy. This can be viewed as a basic example of personalized medicine.[12] For many patients, the volumes infused are greater than those predicted by the formula, be it the Parkland, Brooke, or some other formula.[13,14]

In the absence of any randomized controlled trials of burn resuscitation formulas, a retrospective study was performed by Chung and colleagues[15] in combat casualties, some of whom were started at 2, and some at 4 mL/kg/TBSA. This study showed that fluid begets more fluid: if one starts resuscitation at the rate predicted by the 2 mL/kg/TBSA formula, then the actual infusion volume approximates 4 mL/kg/TBSA by the end of the 24-hour period. If one starts at the rate predicted by the 4 mL/kg/TBSA formula, then the actual infusion volume approximates 6 mL/kg/TBSA. A possible explanation for this is that the microvasculature is more sensitive to hydrostatic pressure gradients during the initial hours following burn injury. In other words, extra fluid infused under a high-volume strategy during the early hours following burn injury is simply lost.[16] Another explanation is that excessive crystalloid therapy damages the glycocalyx, which is known to maintain normal capillary permeability.[17] Furthermore, burn resuscitation with LR solution has been shown to wash components of the glycocalyx out of the microcirculation.[18]

How exactly to adjust the fluid infusion rate based on physiologic response has constituted the art of fluid resuscitation. The main indicator of the adequacy of resuscitation in burn patients remains the hourly urine output (UO).[19] The reasons for using hourly UO are that it is easily measured (once a Foley catheter has been placed), it reflects glomerular filtration rate and renal blood flow, and it is a surrogate for end organ perfusion and an indirect correlate of cardiac output. The target range for UO in burn resuscitation is 30 to 50 mL per hour in adults, or 0.5 to 1.0 mL/kg/h. Recently, some burn experts have argued for a lower target of 0.25 to 0.5 mL/kg/h, in an attempt to counter the trend toward over-resuscitation (R. Sheridan, MD, personal communication, 2016). Changes in infusion rate are made about once an hour. This means that the fluid infusion rate should be increased if the UO is less than the target, and decreased if the UO is greater than the target. In practice, the recent literature suggests that clinicians are more likely to increase the infusion rate than they are to decrease it, and