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Positive cumulative fluid balance at 72h is associated with adverse outcomes following acute pediatric thermal injury

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ABSTRACT

Objective: To determine the association between fluid resuscitation volume following pediatric burn injury and impact on outcomes.
Methods: A retrospective chart review of pediatric patients (0-18 years) sustaining ≥15% TBSA burn, admitted to an American Burn Association verified pediatric burn center from 2010 to 2015.
Results: Twenty-seven patients met inclusion criteria and had complete data available for analysis. Fifteen (56%) patients received greater than 6 ml/kg/total body surface area burn in first 24 h and twelve (44%) patients received less than 6 ml/kg/percent total body surface area burn in first 24 h. There were no differences between groups in median number of mechanical ventilator days (4 vs 8, p=0.96), intensive care unit length of stay (10 vs 13.5, p=0.75), or hospital length of stay (37 vs 37.5, p=0.56). Secondary analysis revealed that patients with a higher mean *cumulative* fluid overload (>253 ml/kg, n=16) had larger burn size, higher injury severity scores, and were more likely to receive mechanical ventilation and invasive support devices. Controlling for burn size, odds of longer PICU length of stay and duration of mechanical ventilation were 20.33 [95% CI (1.7–235.6) p=0.02] and 27.9 [95% CI (2.1–364.7) p=0.01], respectively, among patients with a high cumulative fluid overload on day 3 compared to low cumulative fluid overload.
Conclusions: Resuscitation volume in the first 24 h was not associated with adverse outcomes. Persistent cumulative fluid overload at day 3 and beyond was independently associated with adverse outcomes.

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1. Introduction

Fluid resuscitation remains the cornerstone of treatment following thermal injury. However, fluid resuscitation often exceeds consensus formula estimates and has been associated with adverse outcomes. The term "fluid creep" has been used to describe the phenomenon of fluid resuscitation well beyond that which was predicted in the first 24h following thermal injury [1]. Multifactorial in nature, fluid creep has been attributed to a reluctance to use colloid, hesitation to reduce intravenous fluid rates in the face of adequate urine output, pursuit of goal directed therapies, use of continuous opiate infusions, and the inability of the Parkland formula to accurately estimate fluid resuscitation for large burns [1,2].

Potential sequelae of cumulative fluid overload include respiratory failure, prolonged endotracheal intubation, extremity and abdominal compartment syndrome. Prior studies have demonstrated the association between volume delivery in the first 24h after thermal injury and the development of pneumonia, bloodstream infections, adult respiratory distress syndrome (ARDS), multi-organ dysfunction and death [3]. In adults, limiting fluid administration in the first 24h to less than 6ml/kg/%total body surface area burn (TBSA) has been associated with a reduced incidence of abdominal compartment syndrome [4].

Children may be at even higher risk of fluid overload than their adult counterparts [2], however the impact of over-resuscitation in the first 24h on outcomes remains poorly described in pediatric burn injury. In a retrospective single-center study, pediatric resuscitations were notable for greater differences between calculated and delivered fluid volumes than adults [2]. The frequent uses of fluid boluses by prehospital providers as well as the hesitancy to reduce fluid rates in children were cited as possible contributors to additional volume delivery in the first 24h [2]. The significance of such findings should be considered in the broader context of thermally injured pediatric patients whose increased ratio of body surface area (BSA) to weight might predispose them to resuscitation errors. Additionally, the unique anatomy of the pediatric airway may place them at high risk of upper airway obstruction benefiting from intubation and subsequent mechanical ventilation [5]. Prior studies have supported the link between larger burn size and younger age and the need for mechanical ventilation [5–7]. However, the specific contribution of 24-h fluid resuscitation volume and cumulative fluid balance beyond the first 24h to adverse outcomes in burned children remains unclear.

We therefore designed a retrospective study to test the hypothesis that compared to children who received less fluid, those who received greater than 6ml/kg/%TBSA in the first 24h were more likely to have worse outcomes including longer length of mechanical ventilation (MV), pediatric intensive care unit (PICU) length of stay (PLOS) and hospital length of stay (HLOS). Recognizing that positive fluid balance in children with critical illness has been associated with prolonged mechanical ventilation, PLOS, and HLOS [8], we performed secondary analyses to examine the impact of cumulative fluid overload on outcomes.

2. Methods

2.1. Data source and patient population

This retrospective study was conducted at an American Burn Association (ABA) verified pediatric burn center. All patients admitted to the PICU from April 2010 to October 2015 with acute thermal injury of at least 15% TBSA were eligible for inclusion. All patients were resuscitated via the modified Parkland formula. Children who arrived at our facility greater than 24h after thermal injury and those who died within 24h were excluded.

2.2. Resuscitation protocol

Our standard resuscitation protocol uses the modified Parkland formula with estimated fluid volume in the first 24h to be 3ml/kg/%TBSA. Patients with suspected/confirmed inhalational injury or >30% full thickness burn receive 4ml/kg/%TBSA for the first 24h. Hourly intravenous fluid (IVF) adjustments are made according to hourly urine output (UOP) with a targeted urine output goal. Colloid therapy (5% albumin) and vasoactive use in the first 24h was standardized during protocol augmentation in February 2015, however UOP remained the primary resuscitation endpoint and continued to dictate hourly intravenous fluid adjustments. Beyond the first 24h, resuscitation was not standardized. Any further resuscitation was determined as clinically indicated by a multi-disciplinary team comprised of critical care medicine and burn surgery.

2.3. Study design

In our primary analysis patients receiving greater than 6ml/kg/%TBSA in the first 24h were placed in the high fluid group (HFG). We chose 6ml/kg/%TBSA based on prior data demonstrating a reduced incidence of abdominal compartment syndrome via implementation of difficult fluid resuscitation guidelines for resuscitations expected to exceed this threshold [4,9]. Therefore, in our *primary analysis*, patients were compared based on whether they received greater than 6ml/kg/%TBSA (HFG) or if they received less than 6ml/kg/%TBSA (low fluid group (LFG)). The primary outcomes were length of mechanical ventilation, PLOS, and HLOS.

We also performed an exploratory *secondary analysis* to better understand the impact of positive fluid balance beyond 24h on outcomes. In this analysis, our goal was two-fold — first, to determine the day on which patients with good outcomes began to diverge significantly from those with poor outcomes with respect to fluid balance. Second, using values from the day identified in the first step, to determine whether patients with high cumulative fluid overload (HcFO) have worse outcomes compared with patients with low cumulative fluid overload (LcFO). Choice of day and definitions of high/low cumulative fluid overload were driven by statistical analysis, as described below.

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