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# Fluid Resuscitation in Burns: 2 cc, 3 cc, or 4 cc?

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**Abstract**

**Purpose of Review** A variety of burn resuscitation formulas, each with varying volumes and types of fluid being given, have been developed. The recommended fluid rate in these formulas ranges from 2 to 4 mL/kg/%total body surface area (TBSA), which could lead to variability among practitioners. As such, the purpose of this study is to evaluate which starting fluid rate is optimal for burn resuscitation.

**Recent Findings** Multiple small trials have shown that a lower starting intravenous fluid rate yields no difference with respect to ventilator days, mortality, or renal failure. However, the preponderance of smaller studies precludes definitive conclusions. Larger, prospective, randomized trials are needed in a variety of aspects of burn resuscitation.

**Summary** In this review, we describe the history of burn resuscitation, summarize the data on fluid rates for burn resuscitation, discuss adjuncts to burn resuscitation, and highlight future research directions for burn care.

**Keywords** Burn resuscitation · Parkland formula · Modified Brooke formula · Fluid rate · Resuscitation endpoints · Outcomes

## Introduction

Burn injury remains a major source of mortality and morbidity in the USA. It is estimated that 486,000 people sought medical attention for burns in 2016, with about 40,000 admissions related to burn injury [1]. The idea of burn resuscitation dates back well over 60 years. Multiple formulas for burn resuscitation have been described, using various combinations of normal saline (NS), lactated Ringer's solution (LR), and colloid. Table 1 lists some of the more popular resuscitation regimens. Evans formula in 1952 was the first to recognize and incorporate total body surface area (TBSA) burn [2]. The Brooke formula was first developed in 1953 by Reiss et al. [7]. This was described as 1.5 mL/kg/%TBSA of LR plus 0.5 mL/kg/%TBSA of colloid and 2 L of 5% dextrose in water solution [7, 8], but was later modified to 2 mL/kg/% TBSA of LR without colloid (reserved for after 24 h post injury) and deemed the modified Brooke formula [2, 8]. At the higher end of the spectrum was the Parkland formula, which was proposed in 1968 by Baxter and Shires [8, 9]. This formula described resuscitation with 4 mL/kg/%TBSA with half given in the first 8 h and the rest over the next 16 h [2, 9]. Baxter subsequently published that most burn patients could be adequately resuscitated with fluid in the range of 3.7–4.3 mL/kg/%TBSA burn [8, 10••]. However, there still remains a controversy about the most effective method.

The American Burn Association guideline recommends 2–4 mL/kg/%TBSA burn [3]. Even within this range, there is little consensus on the initial starting rate. The debate about fluid volume hinges on the fine balance between under-resuscitation and over-resuscitation. Under-resuscitation may lead to complications such as acute kidney injury (AKI), organ failure, and death [3, 10••, 11••]. On the other hand, over-resuscitation may play a role in the development of intra-abdominal hypertension (IAH), abdominal compartment syndrome (ACS), and pulmonary edema [3, 12–14]. Complications such as limb and ocular compartment syndrome, conversion of the burn wound to deeper thickness, and increased ventilator requirements have also been described [11••, 12, 13]. Ivy et al. recommended bladder pressure monitoring after infusion of more than 250 mL/kg during

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**Table 1** Commonly described burn resuscitation formulas [2, 3, 4•, 5•, 6]

| | Crystalloid | Colloid | 5% Dextrose |
|---|---|---|---|
| Body-Weight Burn Budget 1947 | 1-4 L LR & 1200 mL 0.5NS | 7.5% body weight | 1500-5000 mL |
| Evans 1952 | 1 mL/kg/%TBSA burn of NS | 1 mL/kg/%TBSA burn | 2000 mL |
| Brooke 1953 | 1.5 mL/kg/%TBSA burn of LR | 0.5 mL/kg/%TBSA burn | 2000 mL |
| Parkland 1968 | 4 mL/kg/%TBSA burn of LR | None | None |
| Modified Brooke 1979 | 2 mL/kg/%TBSA burn of LR | None | None |

LR= lactated Ringers solution; NS= normal saline; TBSA= Total Body Surface Area

acute resuscitation [15]. In 10 patients, 7 developed IAH while 2 developed ACS requiring decompressive laparotomy. Both of these patients had 80% TBSA burn. Unfortunately, if decompressive laparotomy is performed for ACS in burn patients, mortality is approximately 90% [12]. Of note, it was observed that patients with delayed resuscitation, inhalation injury, full-thickness injuries, or high-voltage electrical injury required increased fluid volumes [3, 10••].

## Fluid Resuscitation Rates

Multiple studies have examined fluid infusion rates during burn resuscitation. Chung et al. compared patients with > 20% TBSA burn resuscitated by the modified Brooke formula (31 patients) with those resuscitated by Parkland formula (21 patents) [16]. The target urine output (UOP) was 30–50 mL/h (hr). Those in the modified Brooke group received less fluid overall in the first 24 h (16.9 ± 6.0 L) compared with those in the Parkland group (25.0 ± 11.1 L, $p = 0.003$). They estimated that patients in the modified Brooke group were resuscitated with 3.8 ± 1.2 mL/kg/%TBSA compared with the Parkland group 5.9 ± 1.1 mL/kg/%TBSA ($p < 0.0001$). The Ivy index (250 mL/kg) was exceeded more frequently in the Parkland group compared with the modified Brooke group (57% vs. 29%, respectively, $p = 0.043$). Despite the overall decreased total fluids in the modified Brooke group, there were no significant differences in incidence of acute lung injury (ALI), acute respiratory distress syndrome (ARDS), AKI, ventilator-free days, intensive care unit (ICU) days, hospital days, ACS, or mortality. Exceeding the Ivy index (250 mL/kg) was an independent predictor of mortality. Of note, the use of albumin was not significantly different between the two groups. As such, the authors concluded that "the modified Brooke formula resulted in significantly less 24-hour volume without resulting in higher morbidity or mortality" [16]. Despite less fluid being given in the modified Brooke group, both groups were associated with fluids greater than predicted. The Parkland group fell above the recommended 2–4 mL/kg/%TBSA.

Blumetti et al. also observed fluid administration in excess of that predicted by the Parkland formula [8]. Using an endpoint of UOP, they defined adequate resuscitation as UOP of 0.5–1.0 mL/kg/h while over-resuscitation was defined as UOP > 1.0 mL/kg/h. Interestingly, of the 483 patients, only 43% were appropriately resuscitated. Almost half of the study cohort (48%) was over-resuscitated, while the remaining 9% were under-resuscitated. The mean fluids given between the two groups were similar (5.8 ± 2.3 mL/kg/% TBSA for adequately resuscitated vs. 6.1 ± 2.7 mL/kg/%TBSA for over-resuscitated, $p = 0.188$), as was the rate of colloid use. Both groups had similar length of stay (LOS), ventilator days, complication rates, and survival rates. It should be noted that although complication rates were not different, they were still high at 79.5% and 82.4%, respectively. In fact, they found that the median volume of fluids given for burns greater than 40% TBSA often exceeded the Ivy index. Overall, in those who were adequately resuscitated, only 13.8% of patients received resuscitation within Parkland formula parameters. This is similar to the findings of Cartotto et al. who also found that only 13% of patient resuscitations fell within Parkland formula guidelines [13]. Both of these findings are contrary to initial publications by Baxter, which stated that only 12% of patients required more fluid than what was expected based on the Parkland formula, implying that 88% would fall within the predicted volumes [8, 13]. In fact, Cartotto et al. had 84% of patients exceeding the 4.3 mL/kg/%TBSA predicted [13].

As mentioned, Cartotto et al. showed that patients often required more fluid than predicted by the Parkland formula [13]. In their series of 31 patients, the 24-h resuscitation volume was 6.7 ± 2.8 mL/kg/%TBSA, which is greater than predicted ($p = 0.001$) and exceeded the estimated volume in 84% of patients. Although not achieving statistical significance, those with increased fluid rates had more ventilator days, lower minimum $PaO_2/FiO_2$ ratios during resuscitation, more frequent abdominal compartment syndrome, and higher mortality. Those who died tended to have higher resuscitation volumes (8.1 ± 3.3 mL/kg/%TBSA vs. 5.9 ± 2.3 mL/kg/%TBSA in survivors, $p = 0.03$). Of note, there were no cases of acute renal failure in either group.

The notion of permissive hypovolemic resuscitation was examined in children with 10–20% TBSA scald burns using a reduced resuscitation approach: fluid resuscitation for a 15% TBSA burn was initiated with fluid rate of 2 mL/kg/%TBSA, 80% maintenance fluid requirements, and the application of biosynthetic dressings [17]. As long as the patients remained well perfused and not acidotic, a urine output goal of 0.5 mL/kg/h was targeted, which is lower than the traditional 1 mL/kg/h used in children [17]. The authors then compared these patients to those prior to this change, as well as patients from surrounding burn centers. They found that median length of stay was shortened to 3 days compared with 7.5 days prior to the change ($p < 0.001$). They also noted a lower percentage of ICU admission after the change and in other burn centers (1.5% vs. 7.7% vs. 13.7%, respectively, $p = 0.005$). There was no difference in the number of patients requiring ventilator support and readmission. They concluded that permissive hypovolemic resuscitation had a positive effect on outcomes as measured by LOS and percent ICU admission. Furthermore, despite lower urine output goals, no patients across all groups had renal dysfunction or significant increase in burn depth.

## Over-resuscitation?

As evidenced by these and other published studies, patients often receive more fluid than predicted. This begs the question: do all of these formulas grossly under-estimate resuscitation requirements or do clinicians inadequately titrate fluids once started? In the previously detailed study by Chung et al., there was a trend for patients resuscitated with the Parkland formula to spend more time over the goal UOP (12 ± 5 h vs. 9 ± 4 h in modified Brooke group, $p = 0.11$) [16]. The mean urine output in the analysis by Cartotto et al. was 1.2 ± 0.6 mL/kg/h [13], also higher than goal UOP. After 8 h of resuscitation, Cartotto et al. had only half of their cohort with decreasing fluid rate and this decrease was by a mean 34%, while the other half had fluids increased by 47% [13]. Both of these studies suggest that patients may have in fact been over-resuscitated with fluids which were not decreased when appropriate. This observation is supported by Cancio et al. who described that despite excessive UOP (UOP > 50 mL/h), fluids were appropriately decreased only 27% of the time [18]. With this in mind, it is not surprising that 62.9% of their cohort received more than 4 mL/kg/%TBSA [18].

The Parkland formula describes giving half the predicted fluid in the first 8 h with the second half being given in the following 16 h [2, 9]. Interestingly, the analysis by Cartotto et al., showed no significant difference in the volume of fluid given compared with expected in the first 8 h, but in the second 8 h, there was almost twice the expected volume given ($p < 0.001$) [13]. This is likely due to the previously mentioned finding that only half of their cohort had fluid rates decreased and when that happened, the decrease was by a mean 34% [13], which was less than the 50% decrease described by the Parkland formula. Alvarado et al. made the observation that the original Parkland formula had a urine output goal of 50 mL/h but in recent years, a lower goal of 30–50 mL/h was used [2]. This higher goal for urine output in the original description could result in the formula over-estimating fluid needs [2], which would then lend way to the "fluid begets fluid" phenomenon. This describes the finding that "a burn resuscitation that is begun at a higher fluid rate, results in more volume given during 24 hours" [16].

In addition to the reluctance to decrease fluids, the phenomenon of over-resuscitation could be affected by a tendency to treat invasive monitors as opposed to urine output, the increased use of opiates and sedatives that may worsen vasodilation, and the higher likelihood to resuscitate burns > 80% TBSA who typically exceed formula calculations [3].

The correct assessment of TBSA burn is important in determining fluid rates. Obesity seems to factor in to resuscitation volumes. In 2015–2016, the estimated prevalence of obesity in the USA was 39.8% [19]. Rosenthal et al. found that the Parkland formula tended to under-estimate fluid requirements in patients who were normal weight and overweight (4 L and 1 L, respectively) [20••]. Conversely, the formula over-estimated fluid requirements in the obese and morbidly obese patients (1 L and 4 L respectively) [20••]. This over-estimation was avoided if ideal body weight was used instead. They concluded that using actual body weight could lead to over-resuscitation in obese and morbidly obese patients. They suggested that use of ideal body weight with computerized decision support system may provide a more reasonable starting point [20••]. This over-estimation of fluid requirements in these patient populations could be related to observed changes in TBSA distribution attributed to body habitus. Livingston et al. proposed that there is under-estimation of the trunk and leg surface area, and over-estimation of the arm and head surface area with increasing obesity [14]. For the obese adult, the authors recommended a "rule of fives" instead of the more accepted "rule of nines" to estimate TBSA burn. This estimated each arm as 5%, each leg as 20% (5% × 4), and trunk as 50% (5% × 10) [14]. Of note, the groin remains 1% and the head is 2% [14].

## Endpoints of Resuscitation

The most commonly described endpoint of resuscitation is urine output. The goals described are 30–50 mL/h in adults, 0.5–1.0 mL/kg/h in children, and 1–2 mL/kg/h in infants [4•, 12, 18, 20••]. A urine output goal of 0.5–1.0 mL/kg/h for adults has also been used [3, 8, 13]. Walker et al. advised caution when using urine output as a measure of resuscitation in children [17], since oliguria may persist for 48–72 h or longer after the burn, even when intravascular volume has been completely replenished [21]. This is likely related to a surge in antidiuretic hormone (ADH) secretion that is stimulated by the stress of the injury rather than its effect on fluid balance [21]. Furthermore, urine output can be affected by renal insufficiency, cardiac insufficiency, rhabdomyolysis, and diuretics (glucose, alcohol, vitamin C, and intravenous contrast) [22•].

Urine output as a marker of resuscitation hinges on the well-accepted paradigm that "urine output is a surrogate for renal blood flow and therefore cardiac output" [2]. However, Kuwa et al. found that renal cortical blood flow correlated poorly with urine output ($n = 48$, $r^2 = 0.252$) but correlated well with power Doppler ultrasound image intensity analysis of the renal cortex ($n = 48$, $r^2 = 0.696$) in an animal model [23]. As such, the authors concluded that ultrasound image intensity is superior to urine output and could be used as a marker of renal blood flow during resuscitation [23]. Other potential endpoints that have been described include base deficit, lactic acid level, hemoglobin or hematocrit, central venous pressure, bladder pressure, and venous oxygen level [12, 22•].

## Additional Fluid Considerations

The use of colloids, including fresh frozen plasma (FFP), hetastarch, or albumin [5•] has been reported. It is believed that colloids reduce total fluid needed [10••] by increasing oncotic pressure. However, the effectiveness and timing of use is controversial. Some recommend that colloid is best used after 12–18 h as routine therapy or rescue treatment of fluid creep [10••].

Chung et al. suggested using albumin if the projected 24 h resuscitation would exceed 6 mL/kg/%TBSA near the 12-h mark [16]. Albumin's efficacy in resuscitation is based on the theory that large inflammatory-induced gaps between endothelial cells lead to increased capillary permeability with leakage of proteins and fluid into the interstitial space [5•, 24•]. The leak is greatest within the first 8 h post burn but can persist for 24–48 h post burn [5•, 20••, 24•]. Additionally, crystalloid resuscitation can dilute plasma proteins, leading to further extravascular leak of fluid and edema formation [3]. After approximately 6–12 h, capillary permeability of unburned skin appears to return to normal [5•], thereby reducing the capillary leak. The use of colloids can maintain an osmotic gradient that limits fluid flux and edema accumulation beginning about 8–12 h after injury [3, 11••]. Albumin was associated with reductions in resuscitation volumes, weight gain, IAH, and base deficit in several studies [11••]. Historically, the use of albumin in resuscitation has decreased due to findings of increased lung water by the end of the first week [3, 11••], which was thought to play a role in increased ventilator requirements. However, a more recent meta-analysis found that albumin was associated with significantly reduced mortality (pooled OR, 0.34; 0.19–0.58; $p < 0.001$) [25••]. In fact, albumin infusion was accompanied by reduced odds of respiratory complications, renal dysfunction, need for escharotomy or fasciotomy, tissue necrosis, sepsis, cardiovascular complications, edema, hypoproteinemia, local infection, and gastrointestinal and central nervous system complications [25••].

Fresh frozen plasma (FFP) is another alternative to albumin. An analysis by Du et al. evaluated lactated Ringer's solution (LR), hypertonic saline solution (HPT), or fresh frozen plasma (FFP) in three groups of ten patients each with statistically similar age and burn size [26]. There was no statistically significant difference in mean urine output but the FFP group received less fluid. The mean volume of infused fluids was 4.8 mL/kg/%TBSA for LR vs. 3.16 mL/kg/%TBSA for HPT vs. 2.68 mL/kg/%TBSA for FFP. The difference in infusion rates between the FFP group and the LR group was statistically significant ($p < 0.01$). All patients gained weight with resuscitation. The median percentage weight gain at the end of the first day was 10.69%, 7.88%, and 2.38%, respectively ($p < 0.01$). They concluded that FFP is a reasonable alternative to crystalloid resuscitation [26]. However, these benefits need to be weighed against the cost as it is almost twice as expensive as albumin, as well as the potential risk of disease transmission and transfusion-related acute lung injury (TRALI) associated with this blood product [26].

The use of high-dose vitamin C (66 mg/kg/h) is also controversial. It has been reported that reactive oxygen species (ROS) play a role in the increased vascular permeability and as such, antioxidant therapy could help to decrease some of this ROS-induced damage [24•]. Theoretically, decreased vascular permeability after antioxidant therapy decreases capillary leak, which leads to decreased fluid requirement [24•]. Vitamin C was shown to decrease fluid requirements and net fluid balance by 30% at 6 h and 50% by 48 h compared with LR alone ($p < 0.05$) in an animal model [27]. Another study found that the 24-h total fluid infusion volume was less when given with vitamin C (control and vitamin C groups were 5.5 ± 3.1 mL/kg/%TBSA and 3.0 ± 1.7 mL/kg/%TBSA, respectively; $p < 0.01$) [28]. The length of mechanical ventilation in the control and vitamin C groups was 21.3 ± 15.6 days and 12.1 ± 8.8 days, respectively ($p < 0.05$) [28]. On the other hand, Lin et al. found no difference in median ventilator days, incidence of ventilator-associated pneumonia, median hospital length of stay, mortality rate, or fluids given (4.6 ± 2.6 mL/kg/%TBSA for vitamin C vs. 4.3 ± 2.5 mL/kg/%TBSA for control group, $p = 0.6$). The vitamin C group did have a significantly higher urine output rate (1.1 mL/kg/h vs. 0.81 mL/kg/h in controls, $p = 0.002$) with no difference in mean day 1 serum creatinine. They concluded that vitamin C may not significantly reduce fluid requirements and may not show improvement in meaningful outcomes [29•]. Both studies were small (Tanaka, 37 patients; Lin, 80 patients). Larger prospective trials are needed to fully evaluate the usefulness of vitamin C in burn resuscitation.

It was previously thought that vitamin C was safe to give in such high doses. Vitamin C is water soluble, so excess can be excreted by the kidneys, reducing toxic accumulation [24•]. However, complications of osmotic diuresis and calcium oxalate nephropathy leading to acute renal failure have been reported [11••, 24•]. In the study by Lin et al., the incidence of acute renal failure requiring dialysis was higher in the vitamin C group at 23% compared with 7% of controls, but this too failed to be statistically significant [29•]. With regard to additional complications, there is false elevation of some point-of-care glucose measurements [11••, 24•] and so care should be taken when adjusting insulin regimens based solely on these measurements.

Hypertonic saline may lead to less fluid given to maintain urine output [3]. Oda et al. compared resuscitation with hypertonic lactated saline (HLS) versus lactated Ringer's solution (LR) in patients with burns 40% TBSA or greater [30]. In the HLS group, less fluid was given to maintain urine output at goal ($3.1 \pm 0.9$ mL/24 h/kg/%TBSA vs. $5.2 \pm 1.2$ mL/24 h/kg/%TBSA in LR group). They also observed that the HLS group had a lower rate of IAH at 14% compared with 50% in the LR group. They concluded that HLS could reduce secondary abdominal compartment syndrome with lower fluid load [30]. In 1995, Huang et al. found that hypertonic saline was associated with less fluid given in the first 24 h compared with LR (3.94 mL/kg/%TBSA vs. 5.25 mL/kg/%TBSA, $p < 0.001$) [31••]. Urine output did not differ between the two groups (1.07 mL/kg/h vs. 1.20 mL/kg/h for LR). However, with hypertonic saline, there was a 4-fold increased incidence of renal failure (40.0% vs. 10.1%, $p < 0.001$) and twice the rate of death (53.8% vs. 26.6%, $p < 0.001$). There were also higher rates of cardiovascular failure, pulmonary failure, and hepatic failure. The authors also reported that despite a slight decrease in volume required in the first 24 h, hypertonic sodium solution resuscitation of burn patients did not reduce the total resuscitation volume required [31••].

The effects of hypertonic saline were examined in a rat model [32•]. It was found that hypertonic saline prevented the deterioration of renal tubules and edema formation [32•]. At 2 h post burn, TNF-$\alpha$ and IL-1$\beta$ were decreased in the hypertonic saline group [32•]. This effect lasted for up to 24 h [32•]. This finding suggests that hypertonic saline may reduce the oxidative stress and inflammation associated with burn injury [32•]. Despite the beneficial results on biochemical markers in an animal model, there were the increased rates of renal failure and death described by Huang et al. in humans, with no difference in urine output. The effect of increased sodium itself may be contributing to the adverse effects. Sodium needs to be monitored closely to prevent renal failure due to severe hypernatremia [3]. However, current data does not support hypertonic saline as a safe, viable adjunct to burn resuscitation.

Despite the many variations of burn resuscitation formulas, there are some who report that after 18–24 h cardiac output and other parameters tend to normalize regardless of resuscitation method implemented [10••].

## The Future of Burn Resuscitation

All of the previously described formulas incorporate intravenous fluid resuscitation. Recent interest has been sparked as to the possibility of oral resuscitation. This would revive some of the work done by Sneve who proposed administration of salt solutions via different modalities including oral, colonic and intravenous routes [2]. In an animal model of 12 swine with 40% TBSA full thickness flame burn, colonic fluid resuscitation with Parkland formula was compared with the intravenous route. The volume given was $86 \pm 18$ mL/kg intravenously versus $89 \pm 14$ mL/kg for the colonic route [33•]. Laboratory and hemodynamic parameters were similar in both groups [33•]. They concluded that in a swine model, colonic resuscitation was equally effective in expanding plasma volumes and restoring hemodynamic stability [33•]. Studies in humans are lacking.

As mentioned, one of the obstacles to adequate burn resuscitation is titration of fluids, with clinicians possibly not decreasing fluids when appropriate. One strategy to reduce fluid creep uses computerized decision support in patients with burns greater than 20%. They found that implementation of computerized decision support led to a small decrease in resuscitation fluid rate, as well as tighter standard deviation of fluid volumes, which could suggest more discipline in titrating fluids. There were lower rates of escharotomies and almost no abdominal compartment syndrome in the computer-support group. There was also no early renal failure in either group. Interestingly, there was commonly a 1–2-h period of anuria between 6 and 10 h post burn in the computer-support group. They learned that this could still be associated with acceptable renal perfusion and could instead reflect kidneys at peak function, i.e., maximal re-absorption of salt and water. The hallmarks of this protocol were goal urine output of 0.5 mL/kg/h with decreasing fluid rate by 10% within the first 10 h followed by 20% for each hour the urine output was above goal. Fluids were not increased until urine output fell below 0.25 mL/kg/h. Finally, lean body mass was used rather than actual weight [22•]. However, no large randomized studies have been done to assess its use.

In addition to computerized decision support, it has been proposed to use hemodynamic monitoring as an endpoint of resuscitation. Paratz et al. performed a systematic review comparing hemodynamic monitoring and hourly urine output. They included 8 empirical articles, 11 descriptive studies, and 1 systematic review. All studies followed the Parkland formula. Hemodynamic monitoring adjuncts examined included intrathoracic blood volume index, pulmonary artery occlusion pressure, cardiac index, stroke volume index, stroke volume variation, and venous oxygen saturation as well as transesophageal echocardiography and tissue oxygenation of skin or gastric mucosa. Upon initial analysis, improved survival was reported for hemodynamic monitoring over hourly urine output (RR 0.58, 95% confidence interval 0.42–0.85, $p < 0.004$). However, when only randomized controlled studies were considered, the effect was no longer significant ($p = 0.19$) [34]. Larger trials are needed to definitively assess the role of hemodynamic endpoints in burn resuscitation.

## Conclusions

Many studies have been done to assess the optimal initial fluid rate in burn resuscitation. These have almost universally shown that more fluid is given than is predicted by the formulas. One possibility is that clinicians do not appropriately decrease fluid rate, leading to fluid creep and the "fluid begets fluid" phenomenon. Unfortunately, since most of the studies are underpowered, it remains difficult to determine an accurate rate for burn resuscitation. With what is known, one possible strategy is to start at a lower fluid rate (2 mL/kg/%TBSA) then titrate to goal urine output (UOP). This should be 30–50 mL/h in adults, 0.5–1.0 mL/kg/h for children, and 1.0–2.0 mL/kg/h in infants. The hourly endpoint of urine output should then be used to titrate fluids by 10% each time to achieve the goals.

While there are mixed promising results with respect to colloid and vitamin C use, and precautionary results with hypertonic saline, additional studies are needed to determine whether these should routinely be incorporated in to burn resuscitations. Enteral resuscitation remains embryonic for major burns.

Computerized decision support modules may help to streamline resuscitations in the future by automating the response to urine output. Regardless of method used, Saffle recommends the development of a protocol that will assist practitioners to "restrict early fluid use, monitor and adjust changing requirements appropriately, and trigger aggressive strategies when predetermined alarm variables are reached" [10••].

## Compliance with Ethical Standards

**Conflict of Interest** Dr. Satahoo has nothing to disclose. Dr. Palmieri has a Department of Defense Grant which is not pertinent to the paper and has no financial conflicts to disclose.

**Human or Animal Studies and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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