

WHAT'S NEW IN INTENSIVE CARE



What is new in burn shock resuscitation?

Kathryn Puxty^{1*}  and Francois Dépret² on behalf of The ESICM Trauma, Emergency Medicine Section

© 2025 Springer-Verlag GmbH Germany, part of Springer Nature

Burn injuries involving a significant total body surface area (TBSA) produce a negative interstitial pressure, concomitant tissue edema, and hypovolemia, collectively termed burn shock. Initial resuscitation is a critical intervention, typically initiated when TBSA involvement is $\geq 20\%$. Insufficient resuscitation leads to tissue hypoperfusion, burn wound progression, and excess mortality [1]. Conversely, over-resuscitation contributes to complications such as abdominal and extremity compartment syndromes, pulmonary edema, prolonged mechanical ventilation and excess mortality [2].

From resuscitation formulas to individualized fluid titration

Resuscitation formulas were developed to predict expected fluid requirements of the burn victim during the first 24 h post-injury. The Parkland formula remains the most widely used recommending 4 mL/kg/%TBSA of balanced crystalloids [3]. Despite this strategy, the patient often remains in a controlled hypovolemic state until 18–24 h post-injury signaled by an increase in lactate and renin [4]. However, many patients receive fluid volumes significantly in excess of Parkland and there is increasing concern that this may cause harm. The modified Brooke formula, which prescribes 2 mL/kg/%TBSA in the first 24 h, is an alternative approach endorsed by professional bodies and leads to an overall reduction in fluid administration when used as an initial rate although many patients still receive volumes in excess of their predicted requirement [5]. Due to significant variability in individual patient fluid volume requirements (influenced by

mechanism of burn injury, presence of smoke inhalation, prehospital cardiac arrest, and escharotomy), fixed-volume resuscitation targets should only be used to establish the initial flow rate, before progressing to dynamic goal-directed fluid titration [6].

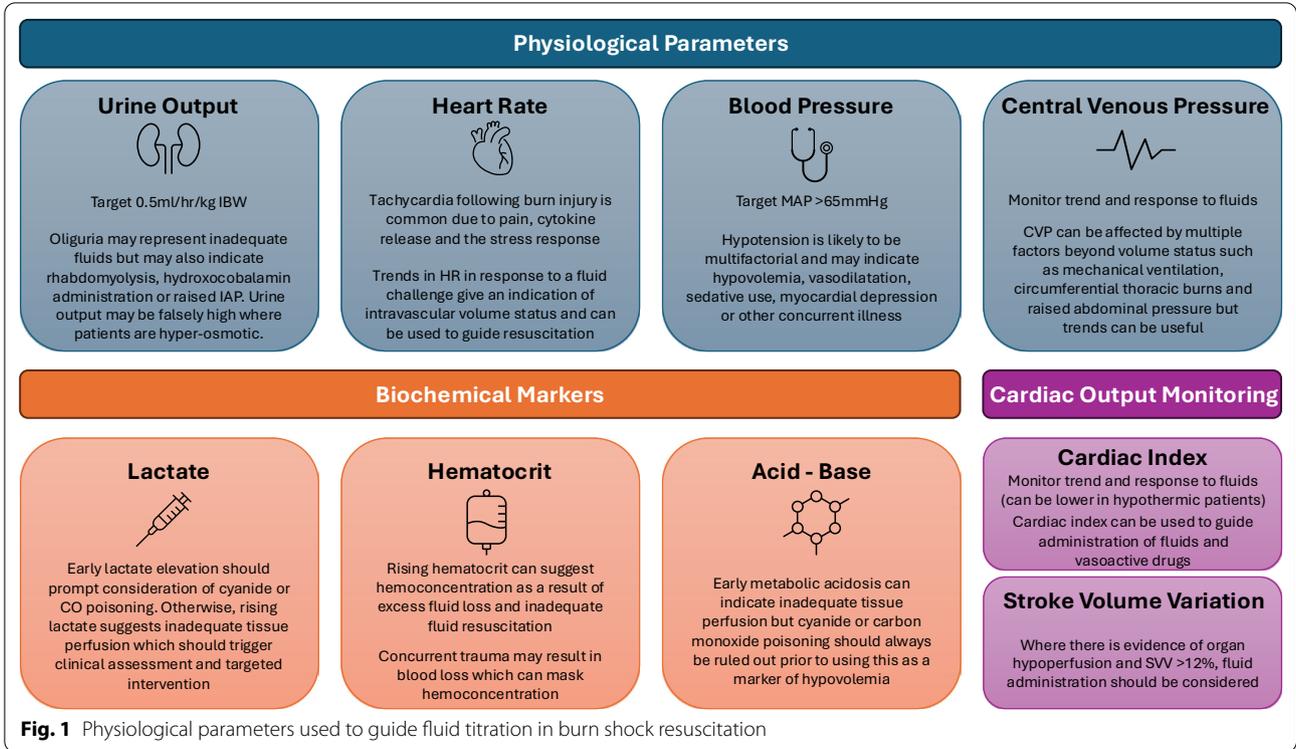
The initial aim of burn shock resuscitation is not to achieve euolemia (as a degree of hypovolemia is expected and should be tolerated), but rather ensure adequate organ perfusion. Urine output remains the most common endpoint to assess resuscitation adequacy, targeting 0.5 mL/kg/hour (ideal body weight) [6]. Failure to meet this, or excess urine production, should prompt clinical reassessment and hourly adjustment of fluid delivery rates. It is important to note that using urine output as an indicator of adequate perfusion is not without problems. Multiple factors independent of fluid status can lead to oliguria in the burn-injured patient including cytokine response, rhabdomyolysis, and neurohormonal activation [7]. Raised intra-abdominal pressure (IAP) secondary to fluid overload can also reduce urine output, with further fluid administration worsening the scenario. Conversely, a rapid drop in plasma albumin concentration following capillary leak can lead to a misleading diuresis due to the drop in intravascular oncotic pressure, as can hyperosmolar states such as hyperglycemia or ethanol intoxication. In a young patient without pre-existing kidney disease, a low urine output is likely to be due to hypovolemia in the first hours following the burn injury. The persistence of oliguria despite restoration of adequate perfusion markers, a mean arterial pressure > 65 mmHg, and the absence of fluid responsiveness with an increasing central venous pressure (CVP) after fluid challenges should lead the clinician to reconsider further fluid resuscitation and look for cardiac dysfunction to avoid over-resuscitation and fluid overload. Additional markers, including serum lactate, hematocrit, and acid–base status, offer valuable adjunctive data pertaining to volume status and adequacy of organ perfusion,

*Correspondence: kathryn.puxty@glasgow.ac.uk

¹ University of Glasgow, Glasgow, UK

Full author information is available at the end of the article

The members of The ESICM Trauma, Emergency Medicine Section are listed in acknowledgements section.



and no single parameter should be used in isolation (Fig. 1).

Many protocols are described to guide fluid rate adjustment. Close targeting of urine output with hourly adjustment to infusion volumes based on the previous output is a common theme across protocols. Additional recommendations on hemodynamic monitoring to target specific indices (cardiac index and stroke volume variation) may lead to the overall administration of less fluid but studies are small with limited outcome measures [5]. Most protocols advocate for holistic patient assessment with consideration of all clinical and laboratory variables without the requirement for additional invasive monitoring [5]. Computer-based decision support systems are also available to assist the bedside clinician titrate fluid resuscitation, although meaningful outcome analysis from this approach remains untested [8].

The complex hemodynamic evolution of the patient with burn shock transitions from hypovolemic to distributive shock over the initial 24–48 h and often includes intercurrent cardiac dysfunction [9]. Advances in hemodynamic monitoring technologies, such as pulse contour analysis, ultrasound-based assessments, and bioimpedance devices, may assist with titration of appropriate support. The widespread

use of these modalities is limited by cost, training requirements, and, most importantly, lack of definitive evidence supporting their use to improve outcomes [5].

Choice of fluids

The optimal fluid type for burn resuscitation remains a subject of debate. No burn-specific randomized studies are available comparing balanced crystalloids to saline. Given the large quantities of fluid administered in burn patients and the increased risk of metabolic complications attributed to saline (such as hyperchloremic acidosis and acute kidney injury), it seems appropriate to propose balanced crystalloids as first-line solutions. Care should be given when large volumes of Ringers lactate are administered, as hyperlactatemia without acidemia can result, complicating clinical assessment [10]. With plasmalyte administration, calcium levels should be monitored to detect and supplement the onset of hypocalcaemia [11].

The timing and role of albumin administration remain under investigation. Studies indicate that the routine use of albumin reduces the total volume of resuscitation fluids and improves urine output [12]. With the greatest benefits observed in those with more extensive injury, many clinicians now incorporate albumin into their fluid

resuscitation plan in patients with large TBSA or escalating fluid needs [5]. Results of an ongoing randomized controlled trial, the ABRUPT 2 trial (NCT04356859), are eagerly awaited. However, evidence for other colloids, such as fresh frozen plasma, remains insufficient to support routine use beyond concomitant hemorrhagic shock, and current guidelines recommend awaiting RCTs before being incorporated into routine clinical practice [5].

Adjunctive therapies in burn shock

An appropriate dressing should be applied immediately to the burn wound to reduce evaporative fluid losses. In addition, early wound debridement and grafting has recently been promoted for the positive impact on wound healing, risk of sepsis and mortality [13] (NCT02940171). With earlier surgical intervention, fluid shifts might be anticipated; however, the overall impact on systemic inflammation and fluid leak may conversely lead to improvements in burn shock.

Recent investigations have explored pharmacologic adjuncts to reduce fluid requirements and modulate the systemic inflammatory response. Early vasopressors, particularly norepinephrine are increasingly considered in patients with vasodilatory shock, where they may support perfusion while mitigating excessive fluid administration [14]. In addition to addressing the vasoplegia experienced in burn shock, noradrenaline increases venous return and subsequently cardiac output in patients that are adequately resuscitated, and may avoid excess administration of fluids. Potential benefits and harms have yet to be fully studied, and the current evidence base limits any recommendation on the timing of vasopressor initiation. Where there is persistent hypotension following adequate fluid resuscitation, norepinephrine should be considered. In cases of low stroke volume without fluid responsiveness and high CVP, an echocardiography should be performed to evaluate cardiac function and the initiation of an inotrope may be more appropriate.

High-dose vitamin C has gained interest due to its antioxidant and endothelial-stabilizing properties. Preliminary evidence suggests it may reduce fluid requirements and potentially improve survival [15]. However, data in sepsis suggest potential harm; therefore, definitive conclusions in severe burn injury await the results of large-scale randomized trials such as the VICTORY study (NCT04138394).

Ongoing challenges and future directions

Despite advances in protocols and monitoring, several challenges persist. Uncertainty continues regarding the optimal endpoints of fluid resuscitation particularly with regards to the role of technology and novel monitoring

tools. The integration of artificial intelligence to guide burn resuscitation is an evolving field that may lead to improvements in avoiding under- or over-resuscitation. The precise role and timing of vasopressors remain ambiguous, and future work to inform practice would be welcomed by the clinical community. Predictive biomarkers such as dipeptidyl-peptidase 3 have shown promise at identifying patients at greater risk of cardiovascular failure [9], but how these markers can be used to inform management remains unclear. Finally, we must recognize that the burden of severe burn injury falls disproportionately on low- and middle-income countries, and strategies for improving management in resource-limited settings will likely lead to the greatest benefit on a global scale.

Conclusion

Fluid resuscitation remains a fundamental intervention in the management of severe burn injury. Evolving understanding has driven a paradigm shift toward individualized, goal-directed strategies, with increasing emphasis on avoiding both under- and over-resuscitation. However, robust evidence remains scarce. Further research is essential to establish best practices, validate emerging therapies and management strategies, and ultimately improve outcomes.

Author details

¹ University of Glasgow, Glasgow, UK. ² Hopital Saint-Louis, Paris, France.

Acknowledgements

Members of the ESICM Trauma and Emergency Section Burns subgroup contributed to the authorship of this manuscript and include; Kathryn Puxty (University of Glasgow, UK), Francois Depret (Hopital Saint-Louis, France), Matthias Hänggi (University Hospital Zurich, Switzerland), Christopher McGovern (Glasgow Royal Infirmary, UK), Olivier Pantet (Lausanne University Hospital, Switzerland), Folke Sjöberg (Linköping University Hospital, Sweden), Ignacio Martin-Loeches (Trinity College Dublin, Ireland), Kevin Roedel (University Medical Centre Hamburg, Germany), Clément Hoffmann (Percy Military Teaching Hospital, France), Lia Paton (Glasgow Royal Infirmary, UK), Martin Dünser (Kepler University Hospital, Austria), Nadia Depetris (Città della Salute e della Scienza di Torino, Italy), Brendan Sloan (Pinderfields Hospital, UK), José A. Lórente (Hospital Universitario de Getafe, Madrid, Spain), Sabri Soussi (University of Toronto, Canada), Ascanio Tridente (Manchester Metropolitan University, UK), Kyrillos Nassim (Nasser Institute Hospital for Research and Treatment, Egypt), Madiha Hashmi (Ziauddin University, Pakistan), Matthieu Dumont (Bordeaux University Hospital, France).

Declarations

Conflicts of interest

KP has no COIs to declare. FD received funding from the French Ministry of Health directly to his institution. Among the members of the ESICM Trauma and Emergency Section Burns subgroup that contributed to the authorship, IML has received consulting fees from Takeda and Biotest as well as Honoraria payments from Grifols. MHashmi is a NIHR Gran holder (NIHR203082). AT and BS are trustees for the British Burns Association.

Ethical approval

Ethical approval was not sought for the writing of this manuscript.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 13 August 2025 Accepted: 25 October 2025

Published: 12 November 2025

References

- Swanson JW, Otto AM, Gibran NS, Klein MB, Kramer CB, Heimbach DM et al (2013) Trajectories to death in patients with burn injury. *J Trauma Acute Care Surg* 74(1):282–288
- Klein MB, Hayden D, Elson C, Nathens AB, Gamelli RL, Gibran NS et al (2007) The association between fluid administration and outcome following major burn: a multicenter study. *Ann Surg* 245(4):622–628
- Greenhalgh DG (2010) Burn resuscitation: the results of the ISBI/ABA survey. *Burns* 36(2):176–182
- Vieweg R, Jaremo M, Steinvall I, Elmasry M, Abdelrahman I, Sjoberg F (2020) Renin signals renal hypoperfusion during Parkland fluid resuscitation of severe burns—a prospective longitudinal cohort study. *Int J Burns Trauma* 10(6):331–337
- Cartotto R, Johnson LS, Savetamal A, Greenhalgh D, Kubasiak JC, Pham TN et al (2024) American Burn Association clinical practice guidelines on burn shock resuscitation. *J Burn Care Res* 45(3):565–589
- Committee IPG, Steering S, Advisory S (2016) ISBI practice guidelines for burn care. *Burns* 42(5):953–1021
- Soussi S, Berger MM, Colpaert K, Dunser MW, Guttormsen AB, Juffermans NP et al (2018) Hemodynamic management of critically ill burn patients: an international survey. *Crit Care* 22(1):194
- Salinas J, Chung KK, Mann EA, Cancio LC, Kramer GC, Serio-Melvin ML et al (2011) Computerized decision support system improves fluid resuscitation following severe burns: an original study. *Crit Care Med* 39(9):2031–2038
- Depret F, Amzallag J, Pollina A, Fayolle-Pivot L, Coutrot M, Chaussard M et al (2020) Circulating dipeptidyl peptidase-3 at admission is associated with circulatory failure, acute kidney injury and death in severely ill burn patients. *Crit Care* 24(1):168
- De Tymowski C, Soussi S, Depret F, Legrand M (2017) On-line plasma lactate concentration monitoring in critically ill patients. *Crit Care* 21(1):151
- Chaussard M, Depret F, Saint-Aubin O, Benyamina M, Coutrot M, Jully M et al (2020) Physiological response to fluid resuscitation with Ringer lactate versus Plasmalyte in critically ill burn patients. *J Appl Physiol* (1985) 128(3):709–714
- Eljaiek R, Heylbroeck C, Dubois MJ (2017) Albumin administration for fluid resuscitation in burn patients: a systematic review and meta-analysis. *Burns* 43(1):17–24
- De La Tejera G, Corona K, Efejuku T, Keys P, Joglar A, Villarreal E et al (2023) Early wound excision within three days decreases risks of wound infection and death in burned patients. *Burns* 49(8):1816–1822
- Soussi S, Depret F, Benyamina M, Legrand M (2018) Early hemodynamic management of critically ill burn patients. *Anesthesiology* 129(3):583–589
- Siddiqi M, Evans T, Guiab K, Capron G, Roberts A, Messer T et al (2022) Vitamin C in the management of burn patients: a systematic review of the risks and benefits. *Am Surg* 88(4):752–757