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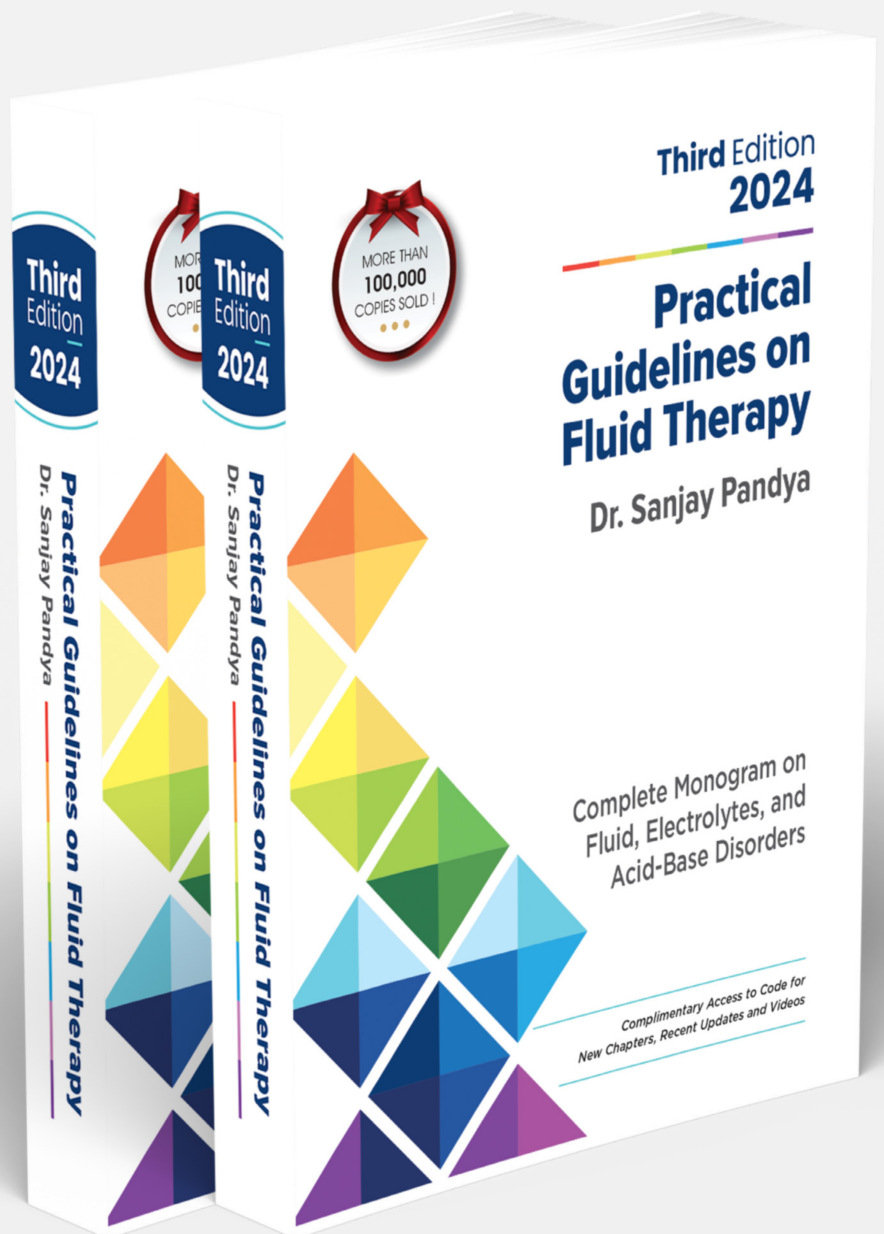
# Chapter 46:

## Burns



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# 46 Burns



Fluid management in burns is a crucial aspect of burn care as it significantly impacts patient outcomes, particularly in severe cases where larger volumes of IV fluids must be administered within the first hours, exceeding the needs of other trauma patients [1].

However, it is a complex and controversial topic, as no one-size-fits-all approach can be universally applied to every clinical scenario. Therefore, it is essential to have a comprehensive understanding of fluid therapy in order to make proper decisions regarding the selection, volume, and administration of fluids from the array of available fluid regimens.

## IMPORTANCE OF FLUID MANAGEMENT

Effective, optimal, and timely fluid management is crucial for resuscitation in burn patients because:

- Severe hypovolemia and hypotension in severe burns can lead to life-threatening shock or shock-induced renal failure [2].
- Delayed or insufficient fluid resuscitation is associated with higher mortality [3].
- Severe hypotension and suboptimal fluid resuscitation cause rapid conversion of viable but ischemic

deep-dermal burn to non-viable full-thickness burn, leading to greater mortality [4].

- Acute loss of protein (especially in the first 24 hours) due to leaky capillaries in the burned tissue causes hypoproteinemia, which accentuates edema formation in the burn as well as non-burn areas. Proper fluid therapy is essential for its prevention.
- Over-aggressive fluid therapy is harmful as it can lead to fluid creep and other complications [3, 5].

## CAUSES OF HYPOTENSION

Causes of hypovolemia and hypotension in burns are multifactorial, including extensive loss of plasma from damaged blood vessels, increased capillary permeability, fluid shifts into the interstitial space, and loss of albumin and other proteins [6]. Additionally, the release of inflammatory mediators can lead to vasodilation and reduced systemic vascular resistance [7]Decreased cardiac output, which occurs in the early postinjury phase, also contributes to hypotension [8]. The combination of these factors can result in inadequate circulating blood volume and impaired tissue perfusion in burn patients.

## GOALS

Providing timely and effective fluid resuscitation in burns is vital because a delay of more than 2 hours post-burn injury is associated with higher complications and mortality [4]. The objectives of proper fluid therapy in burns are:

- To restore and maintain adequate intravascular volume, optimize tissue perfusion, and improve oxygenation.
- To replace lost fluids, prevent complications such as hypovolemic shock and organ dysfunction, and correct electrolyte imbalances.
- To preserve heat-injured but viable soft tissue.
- To avoid the detrimental effects of over-resuscitation and associated complications like fluid creep.

## INDICATIONS OF IV FLUIDS ADMINISTRATION

Common indications of intravenous fluid administration in burns are [9, 10]:

- Adults with more than 15–20% nonsuperficial burns.
- Children with more than 10% burns.
- Electric burns with hemochromogens in the urine.
- Patients at the extremes of age or elderly patients with preexisting cardiac or pulmonary disease, where the compensatory response to even minor hypovolemia is reduced.

**Estimation of burn area:** The "Rule of Nines" in burns is the most popular and quick method to estimate the percentage of total body surface area (TBSA) affected by burns: Head and neck (9%), each upper limb (front and back) (9% each, total 18%), anterior trunk (18%), posterior trunk (18%), each lower limb (front and back) (18% each, total 36%), and perineum (1%). The "Rule of Nines" provides a rough estimation but may not be precise for irregularly distributed burns or specific areas like the hands, feet, or face.

## PLANNING FLUID THERAPY ON DIFFERENT POST-BURN DAYS

During the different stages of burns, the body undergoes varying degrees of fluid loss, resulting in the need for different volumes of fluids. Understanding the distinct pathophysiology during each stage is crucial for designing appropriate treatment strategies on different post-burn days.

For a basic understanding, fluid therapy in burns is broadly categorized into three phases:

A. Initial 24 hours
B. During the first 24–48 hours
C. Fluid therapy after 48 hours

## A. INITIAL FLUID RESUSCITATION

During this period, the inflammatory response triggered by a burn injury results in increased capillary permeability and damaged blood vessels, leading to significant fluid loss from the blood vessels into the surrounding tissues. The leakage of fluid rich in sodium and proteins from the intravascular compartment into the interstitial spaces of the burn area contributes to the formation of edema. Hence, it is crucial to promptly and cautiously initiate IV fluid resuscitation during the initial phase to replace lost fluid, maintain blood pressure, and minimize edema formation.

Fluid therapy in burns is tailored based on factors such as the extent and degree of burn injury, hemodynamic status, coexisting morbid conditions, body weight, age, preexisting medical conditions, burn location, and time since the burn injury. To ensure adequate and effective fluid resuscitation during the initial phase of burns, it is crucial to establish appropriate vascular access, select the suitable replacement fluid, accurately determine the required fluid volume through proper calculations, and decide on the optimal rate of fluid administration.

### Vascular access

Establishing vascular access is crucial for the timely and effective administration of large amounts of IV fluids, but it can be challenging in burn patients due to technical issues such as edema [11]. Commonly employed options for IV fluid administration include the reliable insertion of large bore IV in peripheral veins, with the utilization of vessels underlying burned skin if necessary. In cases where peripheral intravenous access is unavailable, alternatives such as tunneled central venous catheterization, central line placement, or the use of intraosseous access in emergent situations can be considered.

### Choice of replacement fluid

The mainstays for initial fluid resuscitation in burns include the use of crystalloids like Ringer's lactate, normal saline, and PlasmaLyte, and colloids like albumin and hydroxyethyl starch. The selection of these fluids is individualized based on factors such as the severity of the burn, hemodynamic status, and response to therapy.

#### 1. Crystalloid resuscitation

For initial fluid resuscitation in burns, the primary options are crystalloids such as Ringer's lactate, normal saline, and PlasmaLyte.

**a. Ringer's lactate:** Crystalloid solution Ringer's lactate (RL) is the recommended first-line intravenous fluid for initial fluid resuscitation in burns [9, 10, 12]. The preference for RL over normal saline is based on several reasons, which are as follows:

- RL is a balanced crystalloid solution that closely resembles plasma electrolyte composition, enabling the administration of large volumes without causing electrolyte imbalances.
- With a high sodium concentration of 130 mEq/L, RL effectively replaces the significant amount of sodium and water lost from the intravascular

space into the interstitial spaces of the burn area, correcting hypotension.

- RL is free of glucose, so it does not carry the risk of hyperglycemia and associated problems even when rapidly infused in large volumes.
- RL's conversion of lactate into bicarbonate helps correct metabolic acidosis commonly seen in burn patients.
- Using RL instead of normal saline for initial fluid resuscitation in burns prevents the risk of hyperchloremic acidosis associated with large volumes of normal saline.

**b. Normal saline:** Normal saline is an isotonic crystalloid solution that is widely available, inexpensive, and compatible with most medications. However, due to its 50% higher chloride concentration than plasma (154 mEq/L vs. 100 mEq/L), administering normal saline in large volumes can result in dilutional hyperchloremic acidosis, which makes it less favorable for initial fluid resuscitation in burns [3, 13]. Furthermore, normal saline lacks electrolytes such as potassium or calcium.

**c. PlasmaLyte:** PlasmaLyte, a newer balanced crystalloid solution similar to RL, is gaining popularity for its use in critically ill patients, including those with burn injuries [14]. Its utilization as the primary crystalloid solution for large burns is increasing due to its favorable characteristics, including a composition closer to plasma than RL and lactate as a bicarbonate precursor that can be metabolized even in patients with shock [15, 16]. However, the limited use of this fluid in burns is attributed to its high cost and the lack of evidence demonstrating its superiority over other fluids in burn management [17].

## 2. Colloid resuscitation

Colloids like albumin and fresh frozen plasma are commonly used, while hydroxyethyl starch and gelatins are avoided. The role of colloids in the initial resuscitation of burns is controversial, as their use is typically considered an adjunct to crystalloids rather than a primary choice of fluid. The limited utilization of colloids is primarily attributed to their higher cost and the absence of survival benefits [3, 18].

Capillary leakage is maximum within the initial 8 hours after the burn and persists for subsequent 24–48 hours [19]. Consequently, the use of colloids for resuscitation is generally avoided during the initial 8–12 hours, as it has minimal effect on intravascular retention due to the significantly high protein leakage [12, 20]. Furthermore, the use of colloids within 12 hours of a burn injury may have detrimental effects, as it can potentially worsen alveolar exudative inflammation [21].

However, judicious administration of colloids after 12–18 hours provides advantages, such as a reduction in the overall fluid volume requirement, a significant decrease in fluid load, and a minimized risk of "fluid creep" and edema formation [5, 18, 22].

**a. Human albumin:** Human albumin, the most widely used colloid, is recommended as an adjunct to crystalloid resuscitation in patients with severe burns and shock, particularly after the initial 12 to 18 hours [21]. Its major benefit lies in reducing the total volume requirement of crystalloid in burn patients during the early period, thereby reducing the risk of fluid overload and fluid creep [1, 23–28]. The use of albumin is suggested in patients with severe burns who have serum albumin concentrations below 30 gm/L [21] and a projected fluid volume requirement exceeding 6 mL/kg/%TBSA in 24 hours [29]. Notably, albumin administration decreases the occurrence of compartment syndrome, improves outcomes, and reduces mortality rates in patients undergoing burn shock resuscitation [25, 30].

**b. Fresh frozen plasma (FFP):** Natural colloids like human albumin and fresh frozen plasma are widely prescribed [31] and advocated in major burns [1, 19]. The use of FFP in burn resuscitation remains controversial, but recent literature suggests a growing trend of using FFP as a potential adjunct to crystalloids and as an alternative to albumin in severe burns because [32–35]:

- FFP effectively reduces the large amounts of crystalloid fluids required during burn resuscitation [18, 32, 36].
- Its composition is more consistent with the lost body fluid [21].
- FFP improves clotting factors and hemostasis and has a longer shelf life compared to albumin [37].
- FFP exerts a protective effect on the endothelium in burns by preventing the disruption of the endothelial glycocalyx, thus reducing the microvascular leak commonly associated with large burns [33, 38, 39].
- In the first study comparing FFP and albumin recently conducted, patients treated with FFP had significantly lower mortality [40]. However, further studies with larger sample sizes are needed to confirm these findings.
- FFP is preferred over albumin in certain guidelines [21].
- The risk of transfusion-transmitted infections is low due to recent advancements in screening techniques and more rigorous testing [41].
- In many resource-limited countries like India, FFP is preferred due to the limited availability and comparatively high cost of albumin [42]. However, the cost comparison between the two varies across different countries.

**c. Hydroxyethyl starch:** When hydroxyethyl starch (HES) was added to RL in severe burn injury, studies did not find a volume-sparing effect [43], and due to the lack of benefits and the increased risk of mortality, acute kidney injury and coagulopathy associated with HES [44, 45], recommendations strongly advise against its use in burns [46].

**d. Gelatin:** Gelatins are not recommended in burns as they have not shown superiority over crystalloids, and the evidence does not support their safety [1].

## 3. Hypertonic resuscitation fluid

**Physiological considerations:** Due to the distribution of sodium in the extracellular fluid (ECF), the sodium concentration of an IV fluid determines its ability to expand the ECF, including the intravascular volume, which plays a crucial role in maintaining hemodynamic stability. Due to its higher sodium concentration of 513 mEq/L, a smaller volume of 3% hypertonic saline is required for initial resuscitation compared to Ringer's lactate, which has a sodium concentration of 130 mEq/L. The osmolality of 3% hypertonic saline solution, which is significantly higher at 1027 mOsm/kg compared to the normal serum osmolality of around 285 mOsm/kg, creates an osmotic gradient.

**Clinical considerations:** Hypertonic fluid resuscitation is considered an attractive choice as it increases plasma osmolality, shifts water into the intravascular space, reduces intracellular water volume, limits the development of cellular edema, and also reduces the requirements of total resuscitation fluid volume and prevents fluid creep [9, 18]. However, its use should be approached cautiously due to the potential risks of hypernatremia, hyperchloremia, renal failure, and increased mortality rate [9, 47]. Based on current data, the use of hypertonic saline as a safe and viable adjunct to burn resuscitation is not supported [34].

## Formulas used to calculate fluid volume

Numerous formulas have been proposed to calculate the appropriate resuscitative volume, but it is important to remember that these formulas serve as rough guides for predicting initial fluid resuscitation [48]. Subsequent infusion rates should be adjusted hourly based on individual responses rather than blindly following a set regimen.

The Parkland and modified Brooke formulas are the two most widely used and popular formulas for calculation in adults. It is important to note that the 24 hours for resuscitation is calculated from the time of the burn accident and not from the time of admission or initiation of treatment. It is also important to note that this formula provides an initial estimate and may require adjustments based on hourly urine output, the patient's clinical condition, and ongoing assessment of their fluid status.

**1. Parkland formula:** The Parkland formula, also known as the Baxter Formula, was developed in 1968 by Baxter and Shires, and it remains the most frequently used formula for calculating the volume required for burn resuscitation. The estimated requirement of Ringer's lactate for patients with burns in the first 24 hours can be calculated using the widely used Parkland formula as follows [49]:

The Volume Required (ml) =
4 × %TBSA of Burns ×
Body Weight (kg)

For example, if a patient weighs 70 kilograms and has a burn affecting 30% of their TBSA, the fluid requirement in the first 24 hours would be:

Fluid Volume =
4 mL × 30% × 70 kg
= 8,400 mL or 8.4 Liters

Out of the total fluid requirement for the first 24 hours, half is administered within the first 8 hours following the burn injury, while the remaining half is given over the next 16 hours. This initial 50% volume administration within the first 8 hours is necessary to compensate for the maximum capillary leakage and the loss of protein and sodium-rich fluids that occur during this time. As the rate of fluid loss decreases after the initial 8 hours, a smaller volume is needed to meet the ongoing needs.

The calculated fluid should be administered as a continuous infusion at a constant flow rate, as administering a large amount of intravenous fluid in bolus form can result in increased edema, while slower infusion rates can lead to hemodynamic instability [50].

**2. Modified Brooke formula:** The modified Brooke formula provides a lower total volume for fluid resuscitation, aiming to prevent "fluid creep" or excessive fluid administration. The formula is as follows:

The Volume Required (ml) =
2 × %TBSA of Burns ×
Body Weight (kg)

**3. American Burn Association guideline:** According to the American Burn Association (2008) recommendation, the initial rate of crystalloid fluid resuscitation in the first 24 hours post-burn is estimated to be 2–4 mL/kg/% TBSA [9]. This guideline is derived from the modified Brooke and Parkland formulas, which are widely used and accepted for burn resuscitation.

**4. WHO formula for mass burn casualties:** In 2021, the World Health Organization Technical Working Group on Burns (WHO TWGB) recommended an initial fluid rate of 100 mL/kg/24 h, either orally or intravenously, as a resuscitation formula for burns beyond 20% TBSA (total body surface area), which is suitable for resource-limited situations [51]. This formula offers the advantages of simplicity, usability, and safety for primary management, including transfers, while reducing the risk of early complications, particularly in situations such as mass burn casualties when immediate expertise is not readily available [52].

**Altered fluid requirement in patients with burns:** Patients who typically require a large resuscitation fluid volume include those with full-thickness burns, high voltage electric injury, inhalation injury, and those who need escharotomy, whereas obese burn patients generally have lower requirements for resuscitation fluid volumes.

## Volume overload and fluid creep

Several reports have documented a high incidence of receiving more resuscitation fluid than predicted, leading to volume overload when utilizing the Parkland formula for calculating fluid requirements [48, 53–55].

Fluid creep in burns refers to the inadvertent accumulation of excessive fluid in the body due to overly aggressive fluid resuscitation, which can result in complications such as tissue edema, compartment syndromes, infections, pneumonia, acute respiratory distress syndrome (ARDS), respiratory failure, acute kidney injury (AKI), increased need for renal replacement therapy (RRT), multiorgan failure, and even death [5, 55–58].

Several factors contribute to the development of fluid creep, including the overestimation of burn size, errors in judgment due to a lack of experience, overly enthusiastic or inattentive resuscitation practices, failure to recognize the need for colloids to conserve crystalloid administration in large volumes, inadequate monitoring of urine output, and inability to adjust fluid administration based on individual patient response [59].

To prevent fluid creep, several measures can be employed, including:

- Following an early fluid restriction regimen [29, 57, 60].
- Administering colloids such as albumin or fresh frozen plasma alongside crystalloids in cases with high fluid requirements, aiming to reduce overall fluid needs and minimize the risk of fluid creep [5, 18, 22, 26, 61].
- Avoid routine use of fluid boluses to correct hypotension.
- Implementing permissive hypoperfusion, a safe and well-tolerated strategy in studies involving adults and children [60, 62].
- Close clinical monitoring, including hourly urine volume assessment and making timely fluid volume adjustments as necessary.

## Blood transfusion

Patients with severe thermal burns may uncommonly require a blood transfusion to correct anemia, which can result from associated traumatic injury, blood loss during surgical procedures, decreased red blood cell production, increased red blood cell destruction, and iatrogenic blood testing [63, 64]. Implementing a restrictive transfusion strategy with a red blood cell transfusion threshold of 7 gm/dL is well tolerated, markedly reduces transfusion volume, and helps prevent numerous complications associated with aggressive transfusion [64–66]. Patients should receive blood transfusions one unit at a time unless they are hemodynamically unstable or actively bleeding, and before administering a second unit, reassessment of the patient is necessary [63].

## B. SUBSEQUENT FLUID THERAPY

### (During the first 24–48 Hours)

During the first 24–48 hours following burns, it is common for the patient's body weight to increase by 5–15% of their pre-injury level due to fluid retention [67]. The goal of fluid management during this stage is to ensure sufficient fluid administration to maintain hemodynamic stability while restricting the total volume of administered fluids to achieve euvolemia and avoid fluid overload and fluid creep.

During this stage, although increased capillary permeability persists, it is relatively less pronounced compared to the first 24 hours, potentially leading to a lower volume of fluid loss. Consequently, the total fluid requirements for the second 24 hours are reduced, usually by nearly half compared to the requirements of the first 24 hours, for resuscitation fluid [68]. The volume is adjusted based on the patient's response to resuscitation, closely monitoring parameters such as hourly urine volume and other indicators.

If adequate urine output is maintained for more than 2 hours during the first 24–48 hours, it suggests adequate fluid resuscitation and the patient is gradually switched to maintenance fluid [69]. While calculating the maintenance fluid volume in burns, consider normal maintenance fluid plus evaporative loss from the burned skin. Maintenance fluid can be administered either intravenously, using D5/0.45 NaCl + 20 mEq potassium chloride per liter, or through enteral feeds.

The use of colloids for resuscitation is beneficial at this stage due to the decreased capillary permeability. This decrease in permeability results in reduced loss of colloids from the intravascular compartment into the interstitial spaces, providing two advantages. Firstly, it allows greater intravascular retention, ensuring effective hemodynamic stability. Secondly, it reduces the risk of tissue edema by decreasing protein leakage. Colloids, such as albumin or fresh frozen plasma, can be administered as 20–60% of the calculated plasma volume, which helps reduce fluid requirements and minimize the risk of fluid overload.

## C. FLUID THERAPY AFTER 48 HOURS

During this early post-resuscitation phase (48–72 hours), capillary permeability decreases, resulting in decreased fluid loss. The primary focus shifts from aggressive fluid resuscitation to maintaining a balanced crystalloid status. The volume of fluid required is typically reduced compared to the initial 48 hours, emphasizing the importance of adjusting fluid administration to prevent fluid overload while ensuring proper hydration and electrolyte balance.

After the initial 48 hours of resuscitation, the fluid requirement consists of the sum of normal maintenance requirements, replacement of abnormal evaporative water loss, and continuous loss of plasma.

Fluid therapy is initiated based on the calculated maintenance requirements (100 mL/kg for the first 10 kg, + 50 mL/kg for 10–20 kg, and + 20 mL/kg for >20 kg) and is closely monitored. To calculate the required volume of IV fluid, subtract any orally consumed or NGT-administered fluid from the estimated fluid requirements.The fluid regimen is adjusted according to the patient's response to resuscitation, ongoing fluid losses, and clinical parameters.

## MONITORING

Monitoring the burn patient is an essential component of fluid resuscitation, as no resuscitation formula should be considered a "license" to put the patient on autopilot. Careful and precise monitoring, along with necessary adjustments in the regimen, is vital for achieving adequate fluid resuscitation tailored to each patient's needs. Modalities used to monitor patients with burns can be categorized into clinical monitoring, laboratory tests, noninvasive monitoring, and invasive monitoring.

### Clinical monitoring

The American Burn Association recommends monitoring pulse, blood pressure, urine output, mental status, and oxygen saturation in patients with burns [9].

**Heart rate:** The pulse rate holds limited usefulness but surpasses blood pressure measurement in sensitivity when monitoring fluid therapy [3]. Typically, a pulse rate below 110 to 120 beats per minute in a young adult suggests adequate resuscitation. However, if the heart rate exceeds 140 beats per minute, persistent severe tachycardia may indicate hypovolemia, although it can also arise from untreated pain or agitation [12]. Weak pulses may be attributed to inadequate fluid resuscitation, peripheral edema, or pressure on blood vessels caused by elevated compartment pressures.

**Blood pressure:** Manual blood pressure measurements can be challenging, inaccurate, and potentially misleading in edematous or charred extremities due to the progressive attenuation of auditory blood pressure signals as edema develops beneath the burn wound.

**Sensorium:** Anxiety and restlessness can be early signs of hypovolemia and hypoxia, indicating the need for attention and correction.

**Urine volume:** Accurate measurement and monitoring of urine output are crucial, requiring a urinary catheter in all patients with burns ≥20% TBSA [12]. Hourly measurement of urine output serves as the primary indicator for assessing adequate fluid resuscitation, evaluating tissue perfusion, and guiding timely adjustments in volume administration [70, 71].

Measure the hourly volume of urine, calculate the urine output as mL/kg, and adjust the rate of fluid administration in response to the patient's urine output as follows [72]:

- If the urine output is <0.5 mL/kg/h, increase the rate of infusion based on the hourly urine volume. Additionally, considering a fluid challenge with 250 ml of Ringer's lactate in addition to the ongoing fluid may be considered.
- If the urine output is between 0.5 to 1 mL/kg/h, it suggests adequate fluid replacement. Therefore, the fluid infusion should be continued at the same ongoing rate, and reassessment should be done hourly.
- If the urine output is between 1–2 mL/kg/h, the fluid infusion rate should be reduced by 10%, and reassessment should be done hourly.
- If the urine output is >2 mL/kg/h, the fluid infusion rate should be reduced by 20%, and reassessment should be done hourly.

It's important to note that increased urine output can occur in patients undergoing diuretic therapy or with conditions like glycosuria, hypertonic saline infusion, or dextran infusion attributed to the clearance of an osmotic load. However, this elevated urine output does not accurately indicate the patient's volume status and may potentially worsen severely depleted intravascular volume.

## Laboratory tests

The laboratory tests performed for monitoring burns depend on the severity and extent of the burns and typically include complete blood count, electrolyte levels, blood urea nitrogen, creatinine, serum lactate and glucose levels, creatine phosphokinase, and mixed venous blood gas analysis.

Serum lactate level is a commonly used and valuable monitoring tool for hemodynamic resuscitation in patients with burns, as it helps assess tissue perfusion and metabolic status [73]. Estimating serum lactate levels early, upon hospital admission and periodically thereafter, is helpful in assessing the adequacy of tissue perfusion. An increase in serum lactate levels suggests inadequate end-organ perfusion, while a reduction in serum lactate levels after fluid infusion indicates adequate fluid resuscitation in burns [74].

Mixed venous oxygen saturation ($SvO_2$) plays a crucial role in evaluating the patient's respiratory function, and a decrease in $SvO_2$ suggests inadequate end-organ perfusion.

## Noninvasive monitoring

Noninvasive monitoring methods, such as noninvasive blood pressure (NIBP), pulse oximetry, continuous electrocardiogram (ECG) monitoring, ultrasonography, Transthoracic echocardiography, pulse-contour analysis, and transpulmonary thermodilution can be utilized effectively in burns for comprehensive and noninvasive assessment, if available [75–77].

## Invasive monitoring

Invasive monitoring is beneficial for selected high-risk patients with large burns and complex comorbidities, and various techniques used for monitoring include central venous pressure, transesophageal echocardiography, transpulmonary thermodilution, arterial blood pressure, and pulmonary artery catheterization to optimize their management. However, evidence supporting patient outcomes benefits after major burn trauma due to invasive monitoring to guide fluid resuscitation is lacking [78].

# ENDPOINTS OF BURN SHOCK RESUSCITATION

The clinical interpretation of hemodynamic status can be challenging, and there are no single parameters that definitively determine the endpoints of resuscitation in burns. Therefore, simultaneous consideration of various parameters is essential, which may suggest hemodynamic improvement and guide in optimizing fluid administration.

The primary indicators of the adequacy of resuscitation include improvement in mental status (normalization of sensorium), urine output of 0.5 to 1 mL/kg/h without osmotic diuresis, normalization of heart rate and blood pressure (mean arterial blood pressure >70 mm Hg), and a reduction in lactate concentration and base deficit values [79, 80]. Base excess, lactate levels, and their correction rates reliably predict mortality [79].

Patients who are hemodynamically unstable, with coexisting comorbidities such as renal, hepatic, or cardiovascular disease, or elderly persons may need advanced hemodynamic monitoring for better monitoring if available.

# COMPLICATIONS OF FLUID RESUSCITATION

Volume overload and fluid creep are common problems in burns, as discussed.

In addition, large-volume resuscitation can lead to uncommon yet severe complications, which are described below:

- Abdominal compartment syndrome (ACS) is characterized by sustained intra-abdominal pressure (>20 mmHg) and new onset multiorgan dysfunction, including oliguria and decreased pulmonary compliance.
- Extremity compartment syndromes occur when there is an increase in pressure within a closed muscle compartment due to blood accumulation or soft tissue edema, resulting in impaired capillary flow to the enclosed muscle. These syndromes are characterized by clinical signs such as swelling, tightness, muscle pain, pallor, coolness of the distal extremity, and, in severe cases, late loss of pulses.
- Pulmonary complications in burns can manifest as pleural effusions, pulmonary edema, respiratory failure, and prolonged intubation, contributing to significant respiratory challenges.
- Orbital compartment syndrome, a rare yet devastating complication of over-resuscitation, occurs due to a rapid increase in intraocular pressure. It is a surgical emergency characterized by orbital pain, double vision, acute-onset vision loss, and features such as a fixed dilated pupil and ophthalmoplegia.

## NUTRITION ROUTE AND TIMING

Paying attention to nutrition is crucial in burns because it is a hypermetabolic state characterized by increased catabolism leading to increased caloric and protein requirements, significant loss of protein and micronutrients caused by the compromised skin barrier, and the need for increased energy expenditure to compensate for heat loss through the exposed surface [81]. Timely and adequate nutritional support in burns provides essential nutrients for tissue healing, supports immune function, reduces the risk of infection, minimizes protein catabolism and maintains lean body mass, and promotes wound healing and overall recovery [82]. So, early nutrition should be initiated proactively rather than waiting to address it later.

**Route:** Oral feed, enteral nutrition (EN), and parenteral nutrition (PN) are all viable options for providing nutritional supplementation in burns.

Enteral nutrition is recommended as first-line nutrition support in hemodynamically stable burns patients if oral feeding is not possible or if patients cannot meet the increased nutritional requirements through oral feeding alone. EN is preferred, and PN is not recommended routinely in burns because of adverse effects like overfeeding, impaired immunity, liver failure, and higher mortality [82].

The preferred method for enteral nutrition is nasogastric (NG) tubes, but feeding by nasoduodenal and nasojejunal tubes is indicated in a few patients with delayed gastric emptying.

PN is administered in burn patients only when EN is not feasible, not tolerated (e.g., abdominal distention, high residuals, diarrhea), or is inadequate to meet desired total nutrient requirements [83].

**Timing of nutrition support:** In burn patients, early EN (within 24 hours) is as safe as late EN (after 24 hours) [84], and it is recommended to initiate early EN, preferably within the first 24 hours after a burn injury [83, 85].

The advantages of early enteral nutrition in burns are [85, 86]:

- Protection of the gastrointestinal tract, preventing increased bacterial translocation and reducing the risk of sepsis.
- Enhanced nutrient adequacy, preventing the development of malnutrition and nutrient depletion.
- Reduced rates of complications and infections, shorter hospital stays, lower costs, and decreased morbidity and mortality.

For comprehensive information on nutritional considerations in burns, including energy, protein, carbohydrate, and lipid requirements, as well as the role of glutamine and micronutrients, please refer to the Chapter 56 on "Parenteral Nutrition in Specific Disease".

## OLIGURIA IN BURNS

Oliguria during the resuscitation period (first 48 hours post burns) is commonly due to inadequate resuscitation and is almost never an indicator of acute kidney injury. It should be treated with increased fluid administration, not by fluid restriction or administration of diuretics.

Patients with high voltage electric injuries, deep burns involving muscle, and associated crush injuries are prone to developing rhabdomyolysis and myoglobinuric acute kidney injury, which can lead to oliguria. Weakness, muscular pain, oliguria with dark red to brown urine, and significantly elevated creatine phosphokinase (CPK) levels suggest myoglobinuric acute kidney injury, which may need diuretics.

Urinary output is no longer a reliable indicator to monitor fluid resuscitation once a diuretic has been administered [12]. Diuretics are also required in patients with extensive burns who remain oliguric despite receiving fluid volume far over estimated needs.

## FLUID IN HIGH VOLTAGE ELECTRIC INJURIES

Management of high voltage electric injury is more complex and challenging than standard burn resuscitation due to the potential presence of significant and extensive deep muscle injury that may be hidden beneath normal-looking skin, making it difficult to estimate the severity and extent of burns accurately [87]. Additionally, severe electric injuries can cause damage to deep tissues and muscles, leading to acute kidney injury through rhabdomyolysis-induced precipitation of urinary hemochromogens in the renal tubules.

In such cases, administration of additional fluid is necessary to achieve a high urine flow (0–1.5 ml per kg per hour or 75–100 ml/hour in adults) in order to facilitate the rapid clearance of heme pigments, thus eliminating the need for diuretics and preventing acute kidney injury [12]. As various formulas tend to underestimate the fluid requirements for resuscitation significantly, optimal fluid administration is more accurately guided by monitoring urine output and other clinical, laboratory, and hemodynamic parameters to determine appropriate resuscitation endpoints [87].

If oliguria persists despite adequate hydration, additional measures for diuresis can be employed, such as the use of osmotic diuretics (such as mannitol), loop diuretics (like furosemide), or urine alkalization through sodium bicarbonate titration.

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