Initial Assessment and Fluid Resuscitation of Burn Patients

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KEYWORDS
- Burns
- Inhalation injury
- Resuscitation

KEY POINTS
- The management priorities (ABCs) for burn patients are the same as for other types of patients, but their application reflects the unique features of thermal injury.
- The goal of fluid resuscitation is to maintain end-organ perfusion at the lowest possible physiologic cost, which requires meticulous attention to detail, frequent reassessment, and a strategy to manage both fluid resuscitation and the resultant edema.
- The initial assessment and resuscitation of a patient with burns of greater than 20% total body surface area is the first in a long series of steps, which includes critical care, wound healing, and rehabilitation.

INTRODUCTION

For the physician or surgeon practicing outside the confines of a burn center, initial assessment and fluid resuscitation will encompass most of his or her exposure to patients with severe burns. The importance of this phase of care should not be underestimated. Successful management during the first 24 hours post-burn sets the stage for successful wound closure and survival, whereas errors in initial management may be unsalvageable. The purpose of this article is to highlight what needs to be done for a patient with life-threatening thermal injuries on arrival in the Emergency Department or Trauma Center and during the first 24 hours after injury in the intensive care unit, while

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awaiting transfer to the regional Burn Center. Pearls, pitfalls, and recent evidence will be addressed.

**INITIAL ASSESSMENT**

**Referral Criteria**

This article focuses on life-threatening injuries. The first step in management of a burn patient is to determine whether the patient presents with a big problem or a small problem. To be sure, even small burns may be incapacitating, to include, for example, burns of the hand. However, indicators of major (potentially life-threatening) injuries include the following. These patients merit rapid referral to a burn center:

- Large burn: greater than 10% of the total body surface area (TBSA). Shock sets in at about 20% TBSA and can occur at 10% to 20% TBSA in medically fragile patients.
- Inhalation injury.
- Associated mechanical trauma: initial stabilization of such patients at the Trauma Center, followed by transfer to the Burn Center, may be appropriate if the mechanical injury is the more life-threatening problem.

Although patients with lesser degrees of injury may be candidates for outpatient management, the following categories of patients may have functionally or cosmetically complicated injuries and merit referral to a burn center:

- Burn on specific areas: face, hands, feet, perineum, genitalia, major joint
- Full-thickness (third-degree) burns of any size

Patients with special types of injuries who merit burn center referral include:

- Electric
- Chemical
- Lightning

Finally, special types of patients who merit referral include:

- Children (who should be transferred to a facility equipped and staffed appropriately)
- Preexisting medical problems
- Special social, emotional, or rehabilitative needs

The Burn Center Referral guidelines from the American Burn Association mentioned above are intended to encourage early, frequent, and detailed communication between referring hospitals and the regional burn center. Regional trauma systems should establish a means to facilitate such communication.

**History**

An accurate history should be obtained from the patient, the next of kin, other witnesses, and/or Emergency Medical Services. A history of the injury and its aftermath will help identify factors that may influence care (and may play an important role in those cases that come to legal attention). The following questions should be addressed:

- Cause and mechanism of injury
- Date and time of injury
- For electric injury: voltage
- For chemical agents: identify; obtain Safety Data Sheet (formerly, Material Safety Data Sheet); prehospital decontamination
Mechanical trauma: falls; motor vehicle accidents (MVAs), explosions
Loss of consciousness
Smoke or toxic gases
Potential for child or elder abuse
Prehospital vital signs and procedures

Primary Survey

The principles in emergency burn care (ABCs) are the same, but there are unique characteristics that mandate special attention. The need for cervical spine control depends on the mechanism. MVAs, high-voltage electric injuries, falls, and jumping from a building are examples of higher-risk scenarios.

**Airway** management focuses on early intubation of patients with the following indications: large burn size (≥40% TBSA); symptomatic inhalation injury; or burns of face, oral cavity, or oropharynx, which appear to threaten the airway. There are 3 types of inhalation injury: injuries of the upper airway, injuries of the lower airways and lung parenchyma, and the systemic effects of toxic gases. They often overlap. Even patients without inhalation injury may develop massive facial edema during the resuscitation process (first 48 hours post-burn), thus the 40% TBSA criterion. Symptoms of airway injury may include hoarseness, stridor, cough, carbonaceous sputum, or increased work of breathing. Examine the mouth: look inside; evaluate and reevaluate; and intubate patients prophylactically instead of waiting till symptoms are severe or the airway is lost. Be prepared for hemodynamic instability during induction of hypovolemic burn patients. Ketamine (along with a low-dose benzodiazepine) is often well-tolerated in this setting. The endotracheal tube must be well-secured after intubation, using cotton umbilical tape (ties) placed circumferentially around the head and neck or a similar apparatus. Patients with inhalation injury are at high risk of loss of airway due to obstruction by casts and mucous material. Frequent pulmonary toilet is required to prevent this. Extubation should be postponed (in most patients) until edema begins to subside and the patient is able to breathe around the tube.

**Breathing** management includes obtaining an admission radiograph of the chest and assessing the adequacy of ventilation. A normal chest radiograph does not rule out inhalation injury. Immediate surgical intervention may be required for patients with circumferential full-thickness burns of the anterolateral torso. In the "thoracic eschar syndrome", edema builds up under inelastic eschar during the resuscitation period, gradually constricting chest excursion and causing increased peak airway pressure, followed by respiratory arrest. The treatment is rapid bedside thoracic escharotomy (Fig. 1), which should result in immediate restoration of chest compliance. The technique of escharotomy (whether in the chest or the extremities) includes incision all the way through the full thickness of the skin, such that the 2 sides of incised skin separate sufficiently. Incision all the way to the investing fascia, or into muscle, is rarely required.

Aside from the airway problems mentioned earlier, inhalation injury has several deleterious effects on lung physiology. Rapid onset of acute respiratory distress syndrome (ARDS) is unusual. Rather, hypoxemia after smoke inhalation most often reflects ventilation-perfusion (V/Q) mismatch. Small airways are damaged, causing both a decrease in alveolar ventilation and an increase in blood flow to affected areas. Small airway damage also causes bronchospasm and bronchorrhea, which serve only to worsen V/Q mismatch. Inflammation, sloughing of mucosa, release of exudate into the airways, and formation of obstructing casts lead to alveolar collapse. This immune failure, and damage to the mucociliary apparatus, predispose to bacterial colonization and pneumonia.
Mechanical ventilation with positive end-expiratory pressure may be required to support oxygenation and ventilation in these patients. Although low-tidal-volume ventilation (according to the ARDSnet guidelines) is reasonable to reduce the risk of ventilator-induced lung injury, it does not address the small-airway pathophysiology described earlier. For this reason, the authors prefer high-frequency percussive ventilation (Volumetric Diffusive Respiration, VDR-4, Percussionaire, Sandpoint, ID) for patients with inhalation injury. In a recent randomized controlled trial of VDR-4 versus low-tidal-volume ventilation in burn patients, Chung and colleagues demonstrated that VDR-4 ventilation was more successful, as measured by the number of patients who required rescue to another mode of ventilation because of hypoxemic or hypercarbic respiratory failure.

Bronchospasm usually responds to bronchodilators such as albuterol. However, Enkhbattar and colleagues have demonstrated beneficial effects of nebulized epinephrine, which acts not only by reversing bronchoconstriction but also by reducing bronchial blood flow. Thus, it improves oxygenation by addressing the

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**Fig. 1.** Escharotomy incision sites. Escharotomies are performed through full-thickness burns (eschar), which are circumferential and which constrict either circulation (in the extremities) or respiration (in the chest). The bold lines indicate the importance of including any involved joints in the incisions. There is less soft tissue over the joints, thus greater risk of ischemia due to swelling and greater importance of escharotomy. (Reprinted from Cancio L, Becker H. Burns, blast, lightning, & electrical injuries. In: United States Special Operations Command and Center for Total Access. Special operations forces medical handbook. Jackson (WY): Teton NewMedia; 2001. p. 7.17–7.22.)
problem of V/Q mismatch. A high index of suspicion must be maintained for onset of pneumonia, particularly in those patients who remain intubated past the 72-h mark. Pneumonia in this setting greatly increases morbidity and mortality.\(^7\)

Toxic gases that complicate the management of patients with smoke inhalation injury include carbon monoxide (CO) and cyanide. CO is the colorless, odorless gas released by the incomplete combustion of carbon-containing fuels like wood and fossil fuels. It binds avidly to hemoglobin and in so doing impairs oxygen delivery to tissues. Its effects are most pronounced, therefore, in those tissues most sensitive to hypoxia: the heart and the central nervous system (CNS). Diagnosis requires measurement of the carboxyhemoglobin (COHb) level with a CO-oximeter, since the partial pressure of oxygen in arterial blood (PaO\(_2\)) does not change with CO poisoning. The mainstay of treatment is 100% oxygen until the COHb level is less than 10%. An argument for hyperbaric oxygen treatment up to 24 hours after exposure is that CO also remains bound to cytochromes in the brain, even after it has been cleared from the blood.\(^8\)

Cyanide (HCN) is released by the incomplete combustion of nitrogen-containing materials like silk, nylon, and plastics (eg, polyurethane). Like CO, HCN affects the CNS and the cardiovascular system, producing rapid loss of consciousness. It binds to the terminal cytochrome oxidase of the electron transport chain, interfering with the body’s utilization of oxygen. Thus, patients with HCN poisoning may have lactic acidosis in the presence of an elevated mixed venous saturation of oxygen, and despite adequate volume resuscitation. Unfortunately, it may be difficult to differentiate lactic acidosis due to burn shock, from that due to HCN poisoning, in patients with burns and inhalation injury. No rapid diagnostic test is available. Treatment therefore is based on a presumptive diagnosis. The antidote of choice is high-dose vitamin B12 (hydroxocobalamin, Cyanokit).\(^9\) The mechanism of action for hydroxocobalamin is chelation. Other less-desirable antidotes include sodium thiosulfate, which catalyzes the metabolism of HCN by hepatic rhodanase into sodium thiocyanate, and amyl and sodium nitrite, which oxidize hemoglobin into methemoglobin, another chelator.

**Circulation** management during the primary survey includes obtaining intravenous (IV) access and initiating resuscitation at a reasonable rate. Peripheral, central, and intraosseous routes may be used for access. Lines should be placed through unburned skin if possible, but placement through burned skin may be necessary and is acceptable. Tape alone is not likely to adhere well to burned areas. For transport, then, we recommend that IV lines be sewn or stapled in place. The 2-L initial bolus recommended in the Advanced Trauma Life Support course may, or may not, be needed in burn patients. Instead, we recommend starting burn patients (TBSA >20%) at 500 mL/h for adults, 250 mL/h for children, and 100 mL/h for infants. This dose will then be refined based on burn size and weight measurement (see later discussion). Boluses are usually unnecessary and should be avoided unless the patient is hypotensive or shows other signs of severe hypovolemia. Such needless infusions exacerbate edema formation without causing a long-term improvement in plasma volume. A quick check for palpable pulses in all 4 extremities, and an electrocardiogram for adults, is performed.

**Disability** management includes recording the patient’s level of responsiveness (AVPU), Glasgow Coma Scale score, and ability to move all 4 extremities. Even patients with extensive burns should have a normal mental status on arrival. An abnormal neurologic examination suggests hypoxia or exposure to toxic gases at the fire scene, head or spinal injury, or drug or alcohol use and should be worked up.

**Exposure and environmental control** are particularly important in patients with extensive burns, who lose the ability to thermoregulate, and thus are at high risk of
hypothermia. The use of wet linens to cool burn wounds is particularly hazardous and should be condemned. (We recognize that limited cooling of small surface areas is a reasonable first aid, but it must be limited in both extent and duration.) The entire body should be examined (front and back). All clothes and jewelry should be removed; edema formation in the fingers can cause ischemia if rings are left in place.

**Secondary Survey**

During the secondary survey, the patient should be carefully reexamined for nonburn trauma. Nonburn injuries, which may be life-threatening, are easy to miss if one focuses solely on the burns. A Foley catheter should be placed for fluid resuscitation monitoring, and a nasogastric tube should be placed for gastric decompression. Laboratory analyses and appropriate imaging studies are performed.

**FLUID RESUSCITATION**

Fluid resuscitation and edema management are the most important tasks during the first 24 to 48 hours post-burn, after initial assessment has been completed. Historically, 13% of casualties died within the first 48 hours of failure of resuscitation. More recently, abdominal compartment syndrome (ACS) as a consequence of fluid overload has been identified as a major complication of overzealous resuscitation efforts. Close hourly attention to careful titration of fluid resuscitation is required to avoid this and other “resuscitation morbidities”.

The first step in resuscitation is careful burn-size calculation. The burn size can be rapidly estimated with the Rule of Nines. However, it is distressing that burn size is often overestimated by as much as 2 by referring hospitals. To refine this initial estimate, the authors use the Lund-Browder chart (Fig. 2) and the Rule of Hands (the patient’s hand represents 1% of the patient’s body surface area).

The second step is to initiate fluid resuscitation by means of a formula. The fluid most commonly used for burn shock resuscitation is lactated Ringer’s (LR) solution. There are 2 traditional formulas for adult burn resuscitation. The modified Brooke formula (MBF) estimates the volume needs as 2 mL/kg/TBSA burned, with half of this given over the first 8 hours and half over the second 16 hours. For example, a 70-kg patient with 40% burns would receive $2 \times 70 \times 40 = 5600$ mL over the first 24 hours. Half of this should be given over the first 8 hours: $5600 \text{ mL}/2 = 2800$ mL. The initial rate is $2800 \text{ mL}/8 \text{ h} = 350 \text{ mL/h}$. The Parkland formula (PF) estimates the volume needs as 4 mL/kg/TBSA burned. A similar calculation yields a starting rate of 700 mL/h.

There have been no randomized controlled trials comparing the 2 formulas. The American Burn Association “consensus” formula states that burn resuscitation should be started based on 2 to 4 mL/kg/TBSA. A similar recommendation was made to deployed providers during the recent conflicts in Iraq and Afghanistan. A retrospective review of this experience demonstrated that some patients were resuscitated based on the 2 mL/kg/TBSA prediction and others on the 4 mL/kg/TBSA prediction. The actual volumes received were greater in both groups, thus the conclusion that “fluid begets more fluid” and an implicit conclusion in favor of the MBF.

To simplify calculations, Chung and colleagues developed the ISR Rule of Tens for Adults. The starting rate is given by TBSA/10. In the example given earlier, this would be $40 \times 10 = 400 \text{ mL/h}$. It can be seen that the Rule of Tens estimate is most often in between the MBF and PF estimates.

The Rule of Tens works only for adults; for patients less than 40 kg, weight must be taken into account. There is a variety of pediatric burn resuscitation formulas. The pediatric MBF is 3 mL/kg/TBSA burned. Children may in addition require a fluid such as
Burn diagram based on the Lund-Browder chart. The user sketches the extent of burn using a red pencil for full-thickness burns and a blue pencil for partial-thickness burns. Then, he or she estimates the proportion of each body part that is burned and fills in the chart. For example, a burn of one-half of the head of an adult would occupy one-half of 7%, thus 3.5% of the TBSA. This enables a more accurate tabulation of burn size than does the Rule of Nines. (Courtesy of US Army Burn Center, Fort Sam Houston, TX.)
5% dextrose in one-half normal saline (D5\textsuperscript{1/2}NS) at a weight-based rate appropriate for maintenance. This requirement is particularly important for smaller children with smaller burns. This maintenance fluid is given in addition to the resuscitation fluid. Unlike the resuscitation fluid, the maintenance fluid is not titrated hourly (see later discussion). If dextrose is not given in the maintenance fluid, then blood glucose levels should be monitored as these patients have limited stores of glycogen and can become hypoglycemic.

Patients with high-voltage electric injury (>1000 V) who present with gross myoglobinuria represent a special case of fluid resuscitation.\textsuperscript{16} Here, the target goal for the urine output (UO) is increased to 70 to 100 mL/h for adults, to prevent deposition of myoglobin in the renal tubules. Adjuncts such as mannitol and/or sodium bicarbonate may also be required. Electric injury patients with persistent gross myoglobinuria or with evidence of extremity compartment syndrome on physical examination are candidates for urgent fasciotomy and muscle debridement.

The third step is to monitor and titrate fluid resuscitation. The resuscitation formulas provide only a starting rate. The infusion rate must be adjusted hourly based on physiologic response. The single most important indicator of the adequacy of resuscitation is the UO. The LR rate should be titrated hourly (up or down by about 20% each time) to achieve a target UO of 30 to 50 mL/h in adults, 0.5 to 1 mL/h in children, and 1 to 2 mL/h in infants. An hourly flow sheet should be filled out.\textsuperscript{17} Providers must maintain hourly awareness of the total volume infused (in mL/kg) during the first 24 hours post-burn, because patients who receive more than 250 mL/kg during this period are at higher risk of ACS.\textsuperscript{18} Once ACS occurs in burn patients, and decompressive laparotomy is performed, mortality rates approach 90%. Because of the importance of avoiding complications like ACS, the authors developed and fielded a burn resuscitation decision support system to help providers titrate fluid infusion during burn resuscitation (Burn Navigator, Arcos Medical, Galveston, TX). Use of this computer program was associated with a decrease in infused volumes and a higher success rate in achieving UO goals.\textsuperscript{19}

Other indices that should be monitored (eg, every 6 hours) during resuscitation include indicators of volume status and perfusion such as base deficit, lactate, central venous pressure, bladder pressure (especially if the infused mL/kg approaches 250 mL/kg), and ScvO\textsubscript{2}.

**The Difficult Resuscitation**

It is important to recognize when fluid resuscitation is not going well. This may be manifested by any of the following:

- Repeated episodes of low UO despite increasing fluid infusion rates
- Repeated episodes of hypotension and/or a vasoactive pressor requirement
- Worsening base deficit, for example, less than $-6.0$
- Total fluid infused greater than 200 mL/kg, that is, approaching 250 mL/kg

In these patients, the following maneuvers should be rapidly considered:

- Reassess the ABCs
- Look for missed mechanical trauma, that is, bleeding
- Measure bladder pressure, evaluate for ACS
- Reassess cardiac function and volume status, for example, via echocardiography
- Avoid overresuscitation; do not give more than 2000 mL/h or 1500 mL/h sustained
- Consider starting a continuous infusion of albumin 5% or plasma
- Consider use of vasopressors (vasopressin, norepinephrine) to support blood pressure, and/or inotropes to support cardiac function
- Consider adjuncts: high-dose vitamin C; continuous renal replacement therapy (CRRT); plasmapheresis

In some resuscitation regimens such as the MBF, a continuous infusion of 5% albumin is given on post-burn day 2 (24–48 hours post-burn). The dose for this is given in Table 1.20 Five percent albumin is often used before the 24th post-burn hour in the care of patients who do not respond in the usual way to LR resuscitation. When this is done, the infusion is continued until the 48th post-burn hour and then weaned off. Saffle and colleagues21 described an algorithm for the salvage use of albumin, which uses this concept.

Echocardiography, especially if immediately available, can help delineate cardiac function and volume status. Most burn shock patients demonstrate decreased cardiac output, increased myocardial contractility, increased systemic vascular resistance, and hypovolemia when studied by echocardiography and/or pulmonary arterial (Swan-Ganz) catheterization.22 Nevertheless, many still respond to vasoactive pressor medications with an improvement in blood pressure and in vital organ perfusion; this may reflect, in part, the presence of what has been called “myocardial depressant factors” during burn shock.23 Thus, if a patient is hypotensive during resuscitation despite aggressive volume loading, the authors commonly assess his/her responsiveness to vasopressin (0.4 u/h in adults) followed by norepinephrine (beginning at 1 mg/min in adults). Close bedside monitoring of these patients is critical, however, to avoid under- or overresuscitation.

High-dose vitamin C (ascorbic acid) has been studied in one single-center randomized controlled trial in Japan.24 The dose is 66 mg/kg/h; prior coordination with the pharmacy is often required to enable a dose of this magnitude to be available. It should be noted that in the trial, ascorbic acid was started soon after admission, not as a salvage therapy after standard resuscitation was failing.

Chung and colleagues25 reported that the survival of adult burn patients with acute renal failure (most often due to sepsis) was increased by the early use of CRRT by means of venovenous hemofiltration, in comparison with those who underwent conservative management by nephrology consultants. A postulated mechanism for this effect is the removal of proinflammatory cytokines. Whether CRRT exerts a beneficial effect during burn shock resuscitation remains to be determined. Plasmapheresis (plasma exchange) has been used at a few centers during difficult fluid resuscitations. It is also postulated to remove proinflammatory cytokines and other mediators. In a retrospective review, Klein and colleagues26 found that plasma exchange, which was begun an average of 17 hours after injury, was associated with a reduction in fluid infusion rates and an improvement in UO.

<table>
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<th>Dosing calculations for 5% albumin infusion</th>
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<td>TBSA (%)</td>
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Example: a 70-kg patient with 40% TBSA burns would receive a volume = 0.3*40*70 = 840 mL. The infusion rate is 840 mL/24 h = 35 mL/h. If albumin is started earlier than 24 hours post-burn, then the same infusion rate is used (ie, in this case 35 mL/h), and the infusion is continued until the 48th hour post-burn.

\(^a\) Volume of albumin to be given over 24 hours = (Dose\(^a\))*(TBSA)* (weight in kg).
New Approaches

Recently, several investigators have questioned the universal applicability of resuscitation regimens based solely on intravenous crystalloids. One approach is to perform enteral resuscitation using a solution such as the World Health Organization’s oral resuscitation solution or an equivalent. This approach may save resources in austere or mass casualty scenarios and may obviate the need for intravenous crystalloids in many patients with burns of less than about 30% TBSA.27

Another approach is to use 5% albumin or fresh frozen plasma as the mainstay of resuscitation starting on admission, rather than at the 24-h point or as a salvage therapy. This approach represents a return to formulas such as the original Brooke formula, which estimated colloid needs as 0.5 mL/kg/TBSA for the first 24 hours and crystalloid needs as 1.5 mL/kg/TBSA.28 In 1971, Pruitt and colleagues29 at the US Army Burn Center reported that varying the dose of colloid infused during the first 24 hours post-burn had no effect on the intravascular blood volume, meaning that the microvasculature is highly permeable to plasma proteins during this period. Furthermore, in 1983, Goodwin and colleagues22 from the same unit reported a randomized controlled trial of crystalloid-based versus colloid-based resuscitation, in which use of colloid was associated with an increase in extravascular lung water and in mortality (although the study was not designed to detect the cause-effect relationship, if any, between colloid use and mortality). However, the paper by Goodwin and colleagues also showed that colloid-based resuscitation achieved earlier restoration of cardiac output at a lower total volume (less than 4 mL/kg/TBSA). If patients at high risk of ACS or large-volume resuscitation could be predicted, it is speculated that institution of colloid-based resuscitation on admission could be lifesaving in this subset of patients. This concept merits further study.

An aggressive approach to the use of colloid is embodied in the Western Pennsylvania formula, which uses fresh frozen plasma as the main resuscitation fluid during the first 24 hours.30 Proponents of this approach state that plasma and albumin are not interchangeable; plasma contains procoagulant, anticoagulant, and antiinflammatory factors that are all absent in albumin (SF Miller, MD, personal communication, 2013). It is notable that plasma, not albumin, was the fluid of choice used for burn resuscitation in early formulas such as the original Brooke formula.28 Hepatitis, not efficacy, was the reason plasma was abandoned in the 1950s. Today, this problem has largely been overcome, and the concept that plasma is advantageous merits further study.

If removal of proinflammatory cytokines or control of oxidative stress is a mechanism of action of therapies such as CRRT or high-dose vitamin C, then it is likely that these interventions should be started in high-risk patients as soon as possible after admission, rather than 8 to 12 hours into a difficult resuscitation when it becomes obvious that the patient is failing. Earlier recognition of patients who are at high risk of resuscitation failure or resuscitation-induced morbidity such as ACS would allow us to institute such interventions as early as possible.

SUPPORTIVE CARE

Resuscitation morbidity (RM) is a term used to describe the adverse effects of the large volumes of fluid given during resuscitation. RM may afflict the gastrointestinal (GI) tract, the extremities, the eyes, the airway and lungs (see earlier), and the burn wound. To avoid RM, a fluid resuscitation strategy must be accompanied by an edema management strategy. Edema management encompasses procedures routinely performed during resuscitation to (1) prevent, (2) detect, and (3) treat the effects of RM.
Extremity ischemia is the most common RM problem. Usually, decreased blood flow to burned extremities is a consequence of extremity eschar syndrome. In this syndrome, edema formation beneath tight, inelastic, circumferential, full-thickness burns of an extremity causes decreased venous outflow and then decreased arterial inflow. Extremity eschar syndrome is diagnosed by Doppler flowmetry. Progressive diminution of Doppler arterial flow to a circumferentially burned extremity is an indication for escharotomy. This procedure is performed at the bedside (see Fig. 1). An axial incision is made through the burned skin in the midmedial and midlateral lines of the limb. Care is taken to incise all the way through the burned skin. Restoration of Doppler flow means that the procedure was successful.

In unusual cases, burn patients may develop a true extremity compartment syndrome. High-voltage electric injury, delay in escharotomy, massive fluid resuscitation, or other trauma may cause edema inside the muscle compartments. Increased intracompartmental pressure is diagnostic of compartment syndrome, as in other categories of patients. Escharotomy alone cannot solve this problem; fasciotomy is required.

The risk of both extremity eschar syndrome and extremity compartment syndrome can be reduced by elevation of burned extremities well above the level of the heart throughout the resuscitation period. Hourly pulse checks and examination of the extremities for tightness, with documentation on the flow sheet, is crucial for early diagnosis. Unlike chest escharotomy (see earlier), neither extremity escharotomy nor fasciotomy is an immediate surgical emergency. Thus, they normally should be performed after transfer to the burn center, unless transfer is delayed. The most important consideration in deciding when to perform such procedures is early and frequent communication with the burn center.

The most common ocular problem after thermal injury is corneal injury at the time of burn. These injuries are more common in patients with facial burns and/or inhalation injury. Fluorescein examination and ophthalmology consultation are routinely done on admission in these patients. More ominously, patients with large volume fluid resuscitation and facial edema may develop ocular compartment syndrome. This syndrome is diagnosed by bedside intraocular pressure measurement with a tonometer and is treated by lateral canthotomy and cantholysis.

The GI tract is also vulnerable to RM. Basic principles of care include nasogastric decompression and ulcer prophylaxis. The timing of enteral nutrition is a controversial practice in burn care. The authors’ goal is to initiate enteral feedings via a nasogastric tube or Dobhoff tube within the first 24 hours post-burn in all patients with TBSA greater than 20%. Increased caution is reasonable for hemodynamically unstable patients. Gastric residuals are monitored as an indicator of GI tract function. ACS is the most extreme manifestation of RM. Careful fluid titration is required to prevent ACS. Monitoring of bladder pressures at least every 6 hours helps detect patients during the early stages of ACS and is advisable whenever the cumulative infused volume exceeds about 200 mL/kg. Patients who develop ACS during burn resuscitation should be considered for paracentesis before decompressive laparotomy, if possible.

Finally, the burn wound is susceptible to RM. Unfortunately, some patients who present with partial thickness burns on the day of burn are found after 2 days to have full-thickness burns. This process, called “conversion” of the burn wound, may be the result of ischemia, inflammation, and/or edema during the resuscitation phase of care. Furthermore, patients who are overresuscitated may, because of massive edema in the wounds, have difficulty with burn wound and skin graft healing. But burn wound care, per se, is not a major priority during the first hours after injury.
Patients should be assessed for tetanus status and treated appropriately. We have found no benefit to prophylactic antibiotics at the time of admission in this patient population.

If a patient cannot be transferred to a burn center within 24 hours of injury, his wounds should be debrided and topical antimicrobial agents should be applied; this should be repeated every 24 hours. The best venue for debridement may be the operating room in many hospitals, because adequate personnel, supplies, and analgesia are available. The approach is aggressive nonsurgical debridement of all nonviable tissue (blisters, dead skin) and foreign material. Chlorhexidine gluconate is the surgical antiseptic of choice for this procedure. After thorough cleansing and debridement, a topical antimicrobial such as silver sulfadiazine or mafenide acetate cream is applied, followed by gauze dressings. A common alternative to creams is silver-impregnated dressings. These dressings can be left in place for 3 to 5 days and are thus ideal for outpatient care. Another alternative is Biobrane. This synthetic skin substitute is ideal for partial thickness burns, such as those caused by scalds. It should not be used for full-thickness burns. In addition, close follow-up is required to detect failure of adherence and/or infection.

TRIAGE AND TRANSFER

As early as possible following arrival, patients who merit referral to a burn center should be identified and communication established with the burn center (see Referral Criteria, mentioned earlier). If a patient’s condition changes or transfer is delayed, ongoing communication based on the topics covered in this article will improve outcome. Common pitfalls of transfer include

- Loss of airway
- Failure to control, titrate, and document fluid resuscitation, leading to over- or underresuscitation
- Hypothermia due to inadequate efforts to maintain warmth

The timing of transfer should be carefully considered. In North America, most burn centers are within a few hours by air or ground, and rapid transfer is the best option. In prolonged transport scenarios, as on the battlefield during the recent conflicts in Iraq and Afghanistan, transfer to a general hospital may take up to 12 hours by air. Optimal management of burn resuscitation is challenging in a burn center but may be impossible in the air. In this case, the ideal timepoint for transport may be 24 hours post-burn, once hemodynamic stability has been achieved but before infection risk begins to escalate. Communication with the burn center is the key to success.

SUMMARY

The initial assessment and resuscitation of a patient with burns of greater than 20% TBSA is the first in a long series of steps, which includes critical care, wound healing, and rehabilitation. Attention to the processes described in this article will set the stage for the steps that follow. The most important concept is that the fluid resuscitation strategy must be accompanied by an edema management strategy to reduce the risk of RM in these patients.

REFERENCES


