Elderly patients are at increased risk for burns that are caused by hot liquid or by flame, often in kitchen accidents. Young children are also at higher risk for burn injury. Up to 20% of burns in young children involve abuse or neglect.

Physiological Changes and Clinical Implications

Burns over about 20% of the body surface trigger a sequence of fairly predictable physiological changes\(^3\) that have important implications for ongoing care (Table 3). The “ebb phase” is a period of hours to a few days after injury in which there is a relative hypodynamic state and diffuse capillary leak. The basic biological factors driving these changes are poorly understood, but they are best addressed with individualized fluid resuscitation. In successfully resuscitated patients, a “flow phase” follows, which is a protracted period of high cardiac output, low peripheral vascular tone, fever, and muscle catabolism.\(^4\) These changes increase with burn size and depth and are best addressed with individualized nutritional support.\(^5\)

The diffuse capillary leak syndrome is relatively unique to patients suffering large burns and is believed to be secondary to wound-released mediators and neurohormonal changes following injury. Formulas have been developed over the past few decades that attempt to predict resuscitation volume requirements based on body weight or surface area and burn size. However, multiple other variables affect resuscitation requirements, including time from injury to resuscitation, the presence of inhalation injury, and the depth and ease of liquid and vapor water loss through the wound. No formula exists that can accurately predict volume requirements in all patients.\(^6\) Given the morbidity associated with overresuscitation and underresuscitation, burn resuscitation should be guided by hourly...
**Table 1. The American Burn Association Burn Center Transfer Criteria**

1. Partial thickness burns greater than 10% total body surface area.
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints.
3. Third-degree burns in any age group.
4. Electrical burns, including lightning injury.
5. Chemical burns.
6. Inhalation injury.
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.
8. Any patient with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient may be initially stabilized in a trauma center before being transferred to a burn unit. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
9. Burned children in hospitals without qualified personnel or equipment for the care of children.
10. Burn injury in patients who will require special social, emotional, or rehabilitative intervention.

**Table 2. Phases of Burn Care**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Time Course</th>
<th>Major Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial evaluation and resuscitation</td>
<td>0-72 hours</td>
<td>Individualized fluid resuscitation and complete evaluation of injuries</td>
</tr>
<tr>
<td>Initial wound excision and biological closure</td>
<td>Days 1-7</td>
<td>Accurate wound assessment with hemostatic and minimally ablative wound excision</td>
</tr>
<tr>
<td>Definitive wound closure</td>
<td>Days 7-30</td>
<td>Replacement of temporary wound membranes with autograft and closure of high-complexity wounds</td>
</tr>
<tr>
<td>Rehabilitation, reconstruction, and reintegration</td>
<td>Day 1 to discharge</td>
<td>Initially to maintain range and strength with subsequent strengthening and emotional recovery</td>
</tr>
</tbody>
</table>

**Table 3. Predictable Physiological Changes in Burn Patients**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Major Physiological Changes</th>
<th>Clinical Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0-3: resuscitation period</td>
<td>Diffuse capillary leak; hypodynamic circulation</td>
<td>Individualized fluid resuscitation is needed.</td>
</tr>
<tr>
<td>Day 3 to bulk wound closure: postresuscitation period</td>
<td>Hyperdynamic hypermetabolic state with muscle catabolism</td>
<td>Deep wounds must be excised and closed to reduce sepsis; nutritional support is important.</td>
</tr>
<tr>
<td>Bulk wound closure to 2 years after injury</td>
<td>Gradually tapering hypermetabolic physiology</td>
<td>Accurate nutritional repletion is needed for up to 2 years.</td>
</tr>
</tbody>
</table>

Re-evaluation of resuscitation endpoints; formulas only help to determine initial volume infusion rates and to roughly predict overall requirements. In patients who are successfully resuscitated, capillary integrity improves 18 to 24 hours after injury, and volume requirements abruptly decline. Subsequently, a diffuse inflammatory state evolves that is characterized by a hyperdynamic circulation, fever, and massively increased protein catabolism.⁷
Initial Evaluation of Patients with Large Burns

Oftentimes, the initial evaluation and management of burn patients have not been completed prior to their transport to the ICU. For all patients arriving to the ICU with significant burns, clinicians should consider the probability of multiple trauma and incomplete initial evaluation. Their evaluation should follow the primary through tertiary survey format of the American College of Surgeons Committee on Trauma, Advanced Trauma Life Support Course.

A critical point of the primary survey of burn patients is evaluation and control of the airway. Unique considerations include the fact that progressive mucosal edema may compromise airway patency over the first few postinjury hours. This is especially true of young children. Edema of the tongue, face, neck, and airway can make intubation progressively more challenging. Inhalation injury may be associated with early upper airway edema and bronchospasm but rarely early failure of gas exchange. If intubation is indicated and is done before significant edema has developed, direct laryngoscopy is generally safe and effective. If the patient’s airway is already swollen, it may be prudent to obtain help and have airway adjuncts immediately available, such as a flexible bronchoscope and surgical airway equipment and personnel. Once the position of the endotracheal tube is confirmed, properly securing the tube is critical, since reintubation of a patient with a swollen face may be very difficult. A harness system using umbilical ties has proven effective, but other methods of tube security are available. Establishing reliable vascular access is another important early priority. In many patients, this is best achieved with central cannulation.

Once urgent priorities have been addressed, a thoughtful and thorough secondary survey should be conducted. This is especially true for patients with large burns who may have been transported over significant distances without a careful and complete evaluation. It is common for important issues to first be discovered during examination on arrival in the ICU. Several burn-specific additions to the trauma secondary survey are itemized in Table 4.

Fluid Resuscitation

For perhaps as long as 1 to 3 hours after an extensive burn, patients experience little derangement in intravascular volume, which explains the common observation that in the first hours after even massive injuries, patients can be quite alert. As wound-released mediators are absorbed into the systemic circulation, and as stress- and pain-triggered hormonal release occurs, a diffuse loss of capillary integrity occurs that results in the extravasation of fluids, electrolytes, and even moderate-sized colloid molecules. For reasons still unclear, this leak abates between 18 and 24 hours later in patients who have been well resuscitated. An increased leak can be seen in those whose resuscitations are delayed, thought to be due to the systemic release of reactive oxygen species formed upon reperfusion of marginally perfused tissues. Increased leak and increased fluid requirements are also common in patients with very deep burns or inhalation injury.

A plethora of burn resuscitation formulas have been promulgated over the past 50 years. Their recommendations for individual patients rarely coincide, and it is unusual for a tightly monitored resuscitation to follow a given formula. The best resuscitations are individualized to the specific patient’s needs and adjusted hourly based on resuscitation endpoints (Table 5). A reasonable starting consensus formula is outlined in Table 6. Patients vary widely in their needs based on duration of preresuscitation hypoperfusion, extent and vapor transmission characteristics of wounds, presence of inhalation injury, coincident nonburn trauma, and individual inflammatory response to tissue injury. Frequent monitoring and titration of fluid resuscitation are essential for a good outcome. The use of colloid in burn resuscitation is an area of active debate, and most current practitioners advocate the use of colloid earlier than most classic formulas. The author’s routine fluid resuscitation practice reflects this evolution and is outlined in Table 7.
### Table 4. Elements of the Burn-Specific Secondary Survey

<table>
<thead>
<tr>
<th>Element</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td>1. Important points include the mechanism of injury, closed space exposure, extrication time, delay in seeking attention, fluid given during transport, and prior illnesses and injuries.</td>
</tr>
</tbody>
</table>
| HEENT       | 1. The globes should be examined and the corneal epithelium stained with fluorescein before adnexal swelling makes examination difficult.  
2. Adnexal swelling provides excellent coverage and protection of the globe during the first days after injury. Tarsorrhaphy is virtually never indicated acutely.  
3. Corneal epithelial loss can be overt, giving a clouded appearance to the cornea, but is more often subtle, requiring fluorescein staining for documentation. Topical ophthalmic antibiotics constitute optimal initial treatment.  
4. Signs of airway involvement include perioral and intraoral burns or carbonaceous material and progressive hoarseness.  
5. Hot liquid can be aspirated in conjunction with a facial scald injury and result in acute airway compromise requiring urgent intubation.  
6. Endotracheal tube security is crucial. An umbilical tape harness often is safer than adhesive tape if the face is burned.                                                                                                                                                                                                                                                                                                       |
| Neck        | 1. The radiographic evaluation is driven by the mechanism of injury.  
2. Rarely, in patients with very deep circumferential neck burns, escharotomies are needed to facilitate venous drainage of the head.                                                                                                                                                                                                                                                                                                                                                      |
| Cardiac     | 1. The cardiac rhythm should be monitored for 24-72 hours in patients with high-voltage electrical injury.  
2. Although elderly patients may develop transient atrial fibrillation if modestly overresuscitated, significant dysrhythmias are unusual if intravascular volume and oxygenation are adequately supported.  
3. Patients with coronary disease may suffer myocardial infarction due to the hemodynamic stress associated with the injury and should be appropriately monitored.                                                                                                                                                                                                 |
| Pulmonary   | 1. Chest escharotomies should be performed when needed to ensure that inflating pressures are <40 cm H₂O.  
2. Severe inhalation injury may lead to sloughing of endobronchial mucosa and thick bronchial secretions that can occlude the endotracheal tube; be prepared for sudden endotracheal tube occlusions.                                                                                                                                                                                                                                                        |
| Vascular    | 1. The perfusion of burned extremities should be serially monitored. Indications for escharotomy include decreasing temperature, increasing consistency, slowed capillary refill, and diminished Doppler flow in digital vessels.  
2. Fasciotomy is indicated after electrical or deep thermal injury when distal flow is compromised on clinical examination. Compartment pressures can be helpful, but clinically worrisome extremities should be decompressed regardless of compartment pressure readings.                                                                                                                                                                                                                                       |
| Abdomen     | 1. Nasogastric tubes should be placed in the patient prior to air transport in unpressurized helicopters.  
2. An inappropriate resuscitative volume requirement may be a sign of an occult intra-abdominal injury.  
3. Torso escharotomies may be required to facilitate ventilation in the presence of deep circumferential abdominal wall burns.  
4. Ulcer prophylaxis is indicated in all patients with serious burns.                                                                                                                                                                                                                                                                                                                            |
| Genitourinary | 1. Bladder catheterization facilitates using urinary output as a resuscitation endpoint and is appropriate in all who require a fluid resuscitation.  
2. Ensure that the foreskin is reduced over the bladder catheter after insertion, as progressive swelling may otherwise result in paraphimosis.                                                                                                                                                                                                                                                                                          |
| Neurological | 1. An early neurological evaluation is important, as the patient’s sensorium is often progressively compromised by medication or hemodynamic instability during the hours after injury.  
2. This may require computed tomography scanning in patients with a mechanism of injury consistent with head trauma.  
3. Patients who require neuromuscular blockade for transport should also receive adequate sedation and analgesia.                                                                                                                                                                                                                                                                                                         |
### Table 4. Elements of the Burn-Specific Secondary Survey (continued)

<table>
<thead>
<tr>
<th>Element</th>
<th>Considerations</th>
</tr>
</thead>
</table>
| Extremities | 1. Extremities that are at risk for ischemia, particularly those with circumferential thermal burns or those with electrical injury, should be promptly decompressed by escharotomy and/or fasciotomy when clinical examination reveals increasing consistency, decreasing temperature, and diminished Doppler flow in digital vessels. Limbs at risk should be dressed so they can be frequently examined.  
2. The need for escharotomy usually becomes evident during the early hours of resuscitation. Many escharotomies can be delayed until transport has been effected if transport times will not extend beyond 6 hours after injury.  
3. Burned extremities should be elevated and splinted in a position of function. |
| Wound     | 1. Wounds are often underestimated in depth and overestimated in size on initial examination.  
2. Wounds should be evaluated for size, depth, and the presence of circumferential components.  
3. Burn size varies in relation to patient age. A burn diagram ([Figure 1](#)) is useful for documentation. |
| Laboratory | 1. Arterial blood gas analysis is important when airway compromise or inhalation injury is present.  
2. A normal admission carboxyhemoglobin concentration does not eliminate the possibility of a significant exposure, as the half-life of carboxyhemoglobin is 30-40 minutes in those effectively ventilated with 100% oxygen.  
3. Baseline hemoglobin and electrolytes can be helpful later during resuscitation.  
4. Patients with deep thermal or electrical injuries should undergo urinalysis for occult blood. |
| Radiograph | 1. The radiographic evaluation is driven by the mechanism of injury and the need to document placement of lines and tubes. |
| Electric  | 1. In high-voltage exposures, cardiac rhythm should be monitored for 24 hours.  
2. Low- and intermediate-voltage exposures can cause locally destructive injuries but uncommonly result in systemic sequelae.  
3. After high-voltage exposures, delayed neurological and ocular sequelae can occur, so carefully documented neurological and eye examinations should be completed.  
4. Injured extremities should be serially evaluated for intracompartmental edema and promptly decompressed when it develops.  
5. Bladder catheters should be placed in all patients suffering high-voltage exposure to document the presence or absence of pigmentation. This is treated adequately with volume loading in most patients. |
| Chemical  | 1. Wounds should be irrigated with tap water for at least 30 minutes. The globe should be irrigated with isotonic crystalloid solution.  
2. Blepharospasm may require ocular anesthetic administration for examination and irrigation.  
3. Exposures to hydrofluoric acid may be complicated by life-threatening hypocalcemia, particularly exposures to concentrated or anhydrous solutions. Patients should have serum calcium closely monitored and supplemented. Subeschar injection of 10% calcium gluconate solution is appropriate after exposure to highly concentrated or anhydrous solutions. |
| Tar       | 1. Tar should be initially cooled with tap water irrigation and later removed with a lipophilic solvent.  
2. Wounds are usually quite deep and often require early decompression and later excision. |
| Abuse     | 1. All patients should be screened for abuse as the injury mechanism.  
2. Approximately 20% of burns in young children are reported to state authorities for investigation, but abuse occurs in all age groups. Often this determination is not made until the patient has been admitted to ICU.  
3. The entire team must consider the possibility of abuse and file any suspicious case with appropriate state agencies.  
4. Careful and complete documentation of the circumstances and physical characteristics of the injury is essential.  
5. Photographic documentation is ideal. |
**Figure 1.** A burn diagram

**Table 5.** Resuscitation Endpoints

<table>
<thead>
<tr>
<th>Endpoint</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examination</td>
<td>Warm extremities, full peripheral pulses, soft abdomen</td>
</tr>
<tr>
<td>Sensorium</td>
<td>Comfortable, arousable</td>
</tr>
</tbody>
</table>
| Systolic pressure | Infants: 60-70 mm Hg  
Children: 70 to (90 + (twice age in years)) mm Hg  
Adolescents and adults: 90-120 mmHg |
| Urine output | Infants: 0.5-1 mL/kg/h  
Children and adults: 0.5 mL/kg/h |
| Base deficit | <2                                                                     |
| Lactate level| <2                                                                     |
**Table 6. A Consensus Formula for Starting Resuscitation—The Modified Brooke Formula**

<table>
<thead>
<tr>
<th>First 24 hours</th>
<th>Lactated Ringer’s solution: 2-4 mL/kg/%burn/24 h (first half in first 8 h)</th>
<th>Colloid: none</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults and children &gt;10 kg</td>
<td>Lactated Ringer’s solution: 2-3 mL/kg/%burn/24 h (first half in first 8 h)</td>
<td>Colloid: none</td>
</tr>
<tr>
<td>Children &lt;10 kg</td>
<td>Lactated Ringer’s solution with 5% dextrose: 4 mL/kg/h</td>
<td>Colloid: none</td>
</tr>
</tbody>
</table>

**Second 24 hours**

<table>
<thead>
<tr>
<th>All patients</th>
<th>Crystalloid: To maintain urine output. If silver nitrate is used, sodium leeching will mandate continued isotonic crystalloid. If other topical is used, the free water requirement is significant. Serum sodium should be monitored closely. Nutritional support should begin, ideally by the enteral route.</th>
<th>Colloid (5% albumin in lactated Ringer’s solution):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%-30% burn: none</td>
<td>0%-30% burn: none</td>
</tr>
<tr>
<td></td>
<td>30%-50% burn: 0.3 mL/kg/%burn/24 h</td>
<td>30%-50% burn: 0.3 mL/kg/%burn/24 h</td>
</tr>
<tr>
<td></td>
<td>50%-70% burn: 0.4 mL/kg/%burn/24 h</td>
<td>50%-70% burn: 0.4 mL/kg/%burn/24 h</td>
</tr>
<tr>
<td></td>
<td>&gt;70% burn: 0.5 mL/kg/%burn/24 h</td>
<td>&gt;70% burn: 0.5 mL/kg/%burn/24 h</td>
</tr>
</tbody>
</table>

**Table 7. Author’s Personal Fluid Resuscitation Practice**

<table>
<thead>
<tr>
<th>Burn Size</th>
<th>LR</th>
<th>5% Albumin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial infusions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1%-20%</td>
<td>1.5M</td>
<td>none</td>
</tr>
<tr>
<td>20%-50%</td>
<td>P less 1M</td>
<td>1M</td>
</tr>
<tr>
<td>&gt;50%</td>
<td>P less 2M</td>
<td>2M</td>
</tr>
</tbody>
</table>

Abbreviation: LR, lactated Ringer’s solution; M, calculated maintenance rate; P, Parkland calculation for crystalloid (4 mL/kg/%burn in first 24 hours, half in first 8 postinjury hours—typically 0.25 mL/kg/%burn/h for first 8 hours).

Additional points:
- During first 24 hours, infusion rate is titrated hourly to endpoints noted in Table 5. For the first 24 hours, LR is titrated. At 24 hours, LR and albumin are titrated in tandem. Typically, patients require about 1.5M at 24 hours.
- If patient is a child weighing less than 20 kg, 1M of initial LR is given as D5LR, the remainder as LR.
- If needed, boluses are given as 5% albumin.
- Goal is to be “just on the dry side of euvoemia.”
- Tube feedings can be started at trophic rate during first 24 hours in stable patients with monitored advancement. Tube feeding rate is subtracted from LR rate.

**Critical Care Issues**

A number of issues predictably arise in the burn ICU. Critical care issues tend to crescendo at the time of initial evaluation and resuscitation and then in the immediate postoperative period after major excisions.

**Neurological Issues**

Important neurological issues include reasonable monitoring and control of pain and anxiety as well as prevention of peripheral neuropathies. Poorly controlled pain and anxiety have adverse physiological and psychological consequences and may contribute to the development of post-intensive care syndrome. Burn patients often develop some degree of tolerance to medications used to address these issues, which should be anticipated. The role of nonbenzodiazepine anxiolytics and antidepressants is increasing.
develop in burn patients because of direct thermal damage, compression from compartment syndromes or poorly fitting splints, or the metabolic derangements that these patients experience. Careful positioning of deeply sedated or anesthetized patients will avoid traction and pressure injuries.

**Ocular Issues**
In the weeks following acute injury, progressive contraction of burned eyelids and periorcular skin can result in exposure of the globe. This will cause desiccation of the globe with secondary keratitis, ulceration, and globe-threatening infection. Lubrication of the exposed globe with hourly application of ocular lubricants will often effectively temporize until the contracted lids is surgically released.

**Pulmonary Issues**
A number of important pulmonary issues commonly present in the burn unit. Airway security is a major issue throughout the critical care course. Endotracheal tube security should be regularly verified, and ICU personnel should be trained and equipped to deal with sudden airway emergencies. Urgent reintubation in swollen burn patients can be very challenging.

Inhalation injury is a clinical diagnosis based on a history of closed-space exposure and the presence of singed nasal vibrissae and carbonaceous sputum. Fiberoptic bronchoscopy facilitates diagnosis in equivocal cases and may help document laryngeal edema. The common sequelae associated with inhalation injury include upper airway obstruction, bronchospasm, small airway occlusion, pulmonary infection, and respiratory failure. Upper airway obstruction is anticipated and managed with endotracheal intubation. Bronchospasm (from aerosolized irritants) generally responds to inhaled β₂-adrenergic agonists. Ventilatory strategies should be designed to minimize auto-Positive End Expiratory Pressure. Small airway obstruction occurs as necrotic endobronchial debris is sloughed and clearance of secretions is impaired. Pulmonary toilet and periodic therapeutic bronchoscopy facilitate airway hygiene. Pulmonary infection develops in 30% to 50% of patients with inhalation injury. Differentiating between pneumonia and tracheobronchitis (purulent infection of the denuded tracheobronchial tree) is often difficult but generally of little practical consequence. A patient with purulent sputum, fever, and impaired gas exchange should be treated with antibiotics according to the results of cultures. Empiric coverage should depend on time since injury, with community acquired organisms requiring coverage immediately after injury and hospital acquired gram negative and positive organisms emerging as common pathogens subsequently. Pulmonary toilet is particularly important in these patients, who have denuded airways and impaired mucociliary clearance. Fortunately, respiratory failure is fairly uncommon in patients with uncomplicated inhalation injury. It is best managed with routine pressure and volume-limited support. Some patients, especially those with extensive burns, may develop acute respiratory distress syndrome (ARDS) and should be managed with the strategies developed by the ARDS Network.

**Carbon Monoxide Exposure**
Carbon monoxide (CO) exposure is common in patients injured in structural fires. Impaired mental status in such patients can occur from a combination of CO poisoning, anoxia, drugs, intoxicants, and hypotension. Carboxyhemoglobin levels decrease rapidly after ventilation with 100% oxygen. Hyperbaric oxygen has been proposed as a means of improving the prognosis of patients with serious CO exposures, but its use remains controversial, and it is not always clear which patients are suffering primarily from CO poisoning and would potentially benefit from hyperbaric treatment.

Carbon monoxide avidly binds and inactivates heme-containing enzymes such as hemoglobin and the cytochromes, which are involved in oxygen delivery and consumption, respectively. The formation of carboxyhemoglobin results in an acute physiological anemia, much like an isovolemic hemodilution. A carboxyhemoglobin concentration of 50% is physiologically similar to a 50% isovolemic hemodilution. The routine occurrence of unconsciousness at this level
of carboxyhemoglobin suggests that other mechanisms may be involved in the pathophysiological process of CO injury. Potentially, CO binding to the cytochrome system in the mitochondria, interfering with oxygen utilization, is as toxic as CO binding to hemoglobin. For unknown reasons, between 5% and 20% of patients with serious CO exposures have been reported to develop delayed neurological sequelae, although this figure is debated.

Patients with significant CO exposure can be managed with 100% normobaric oxygen for 6 hours or with hyperbaric oxygen administered in a monoplace (single patient) or multiplace (multiple patient) chamber. If overt neurological impairment or a high carboxyhemoglobin level is documented, then hyperbaric oxygen treatment may be warranted if it can be administered safely. Hyperbaric oxygen treatment regimens vary, but an exposure at 3 atmospheres of 100% oxygen for 90 minutes, with 3 ten-minute “air breaks,” is typical. An air break refers to the breathing of pressurized room air rather than pressurized oxygen, which decreases the incidence of seizures from acute oxygen toxicity. Because treatment is generally in a monoplace chamber, unstable patients are not good candidates. Other relative contraindications are wheezing and air trapping, which increase the risk of pneumothorax, and high fever, which increases the risk of seizures. Six hours of 100% normobaric oxygen is a generally accepted alternative. Prior to placement in the chamber, endotracheal tube balloons should be filled with saline to avoid balloon compression and associated air leaks. Myringotomies are required in intubated patients or those who cannot follow instructions to keep the Eustachian tubes open.

Cyanide is often detectable in patients extricated from structural fires but is rarely severe enough to justify the risk of treatment with amyl nitrate and sodium thiosulfate. Unexplained acidosis is the hallmark of significant cyanide exposure. Treatment of such patients is controversial and tends to be program specific. Consultation with the receiving unit is warranted when possible.

Gastrointestinal Issues
To the degree that they experience splanchnic hypoperfusion early in resuscitation, burn patients have an ulcer diathesis (“Curling’s ulcer”). Burn patients who require resuscitation should be treated with empirical histamine receptor blockers, proton pump inhibitors, or antacids until they are hemodynamically stable and tolerating tube feedings. Ileus is often an early sign of sepsis, so the sudden development of ileus should prompt a search for a septic focus. Acalculous cholecystitis is not uncommon and can be addressed percutaneously in many cases.²¹

Nutritional Support
Burn patients have predictable, protracted needs for supplemental protein and calories. This support should be carefully managed to avoid the consequences of over- and underfeeding.²² Tube feedings at a trophic rate can often be started during resuscitation. Initial use of an intragastric sump tube will facilitate monitoring of tolerance. Parenteral nutrition is used if tube feedings are not tolerated for the first few days.²³ Highly catabolic burn patients tolerate prolonged periods of fasting very poorly, especially children. Nutritional targets are debated, but consensus holds that protein needs are about 2.5 g/kg/d and caloric goals are between 1.5 and 1.7 times the calculated basal metabolic rate, or 1.3 to 1.5 times the measured resting energy expenditure.²⁴ Nutritional support needs to be titrated to nutritional endpoints during a lengthy burn hospitalization. Regular physical examination, quality of wound healing, nitrogen balance, and indirect calorimetry are all useful in this regard.²⁵

Infectious Disease Issues
The best way to avoid wound sepsis is through prompt excision of necrotic material with immediate closure of resulting wounds. Topical agents and membranes are only an adjunct to slow bacterial growth in the presence of necrotic material. Several topical agents and wound membranes are in common use (Table 8). Infection may occur beneath wound membranes if wound debridement is incomplete.
Physiological consequences of burn injury include the routine occurrence of moderate fever, which is not necessarily a sign of infection.\(^{26}\) When unexpected fever occurs, clinicians should perform a physical examination, inspect wounds for signs of infection, obtain any indicated laboratory tests and radiographs, and order cultures of blood, urine, and sputum. If the patient appears unstable, empirical broad-spectrum coverage is reasonable pending return of culture data. This is sometimes a tough judgment call, balancing the morbidity of untreated infection against the morbidity of antibiotic overuse.\(^{27}\) If no infectious focus is identified and cultures remain negative, antibiotics should be stopped. It is critically important that deteriorating burn patients be evaluated for occult foci of infection to allow prompt treatment prior to the development of systemic sepsis.\(^{28}\)

Finally, the importance of vigilant infection control practices cannot be overemphasized. Burn patients have a fairly high rate of harboring...
resistant bacterial species. Outbreaks with such organisms are best avoided by strict application of universal precautions.

Rehabilitation Issues
Rehabilitation efforts should begin as early as possible in patients with significant burns, including during periods of critical illness. This can begin with twice-daily passive ranging of all joints and static antideformity positioning. These efforts will go a long way toward preventing otherwise inevitable contractures (Table 9). Physical and occupational therapists should be informed of the sequence of planned operations and the modifications of therapy that these imply. Therapists should be encouraged to range patients under anesthesia in conjunction with planned operations and to fabricate custom splints in the operating room, particularly in children, who often poorly tolerate these activities when awake. Addressing these issues during the period of critical illness greatly enhances the rate of recovery when wounds are closed.29

Intraoperative Issues
Burn patients must undergo staged excision and closure of their wounds even if they are critically ill. Oftentimes this is the only way to move patients out of a critically ill state. Close communication between the ICU and operating room teams is essential. Operating rooms must be kept warm to minimize the occurrence of hypothermia in exposed burn patients, as this will cause coagulopathy and increased bleeding. The surgical and anesthesia teams must be in constant communication throughout the operative event to balance the physiologic stress to the patient of a long operation against the benefits to be gained. In patients with large burns, it is often possible to achieve the ultimate surgical objective in staged procedures rather than a single operation. Planning cases so they can be truncated in the face of unstable physiology without compromising the overall objective is an important part of case planning. Periodic intraoperative collaborative patient assessment should be done to ensure that patients are physiologically stable throughout the operative event and opportunities for smooth staging are not missed.

Special Considerations
Burn units combine wound care, general and plastic surgery, and critical care expertise. This combination of resources is useful for a number

<table>
<thead>
<tr>
<th>Burn Area</th>
<th>Common Contracture</th>
<th>Splinting and Positioning Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>Flexion</td>
<td>Daily ranging and extension splinting and conformers, split mattress</td>
</tr>
<tr>
<td>Shoulder</td>
<td>Adduction</td>
<td>Daily ranging and abduction splinting with axillary splints or troughs</td>
</tr>
<tr>
<td>Elbow</td>
<td>Flexion and extension</td>
<td>Daily ranging and alternating extension and flexion splints</td>
</tr>
<tr>
<td>Wrist</td>
<td>Flexion and extension</td>
<td>Daily ranging and splinting in functional position (20°E of extension)</td>
</tr>
<tr>
<td>Metacarpophalangeal joints</td>
<td>Extension</td>
<td>Daily ranging and splinting in functional position (metacarpophalangeal joints at 70-90°E with IP joints in extension)</td>
</tr>
<tr>
<td>Hips</td>
<td>Flexion</td>
<td>Daily ranging and extension splints and prone positioning (if tolerated)</td>
</tr>
<tr>
<td>Knees</td>
<td>Flexion</td>
<td>Daily ranging and knee splints and knee immobilizers</td>
</tr>
<tr>
<td>Ankles</td>
<td>Extension</td>
<td>Daily ranging and neutral splints</td>
</tr>
<tr>
<td>Metatarsophalangeal joints</td>
<td>Extension</td>
<td>Daily ranging and splinting in functional position, rocker bottom shoes</td>
</tr>
</tbody>
</table>
of nonburn injuries and medical illnesses, and nonburn patients are often referred to burn units. Important points of critical care of such patients are mentioned next.

**Electrical Injury**
Patients exposed to low (approximately 0-220 V) and intermediate (approximately 220-1,000 V) voltages may have severe local wounds but rarely suffer systemic consequences. Those exposed to high voltages (>1,000 V) commonly suffer compartment syndromes, myocardial injury, fractures of the long bones and axial spine, and free pigment in the plasma that may cause renal failure if not promptly cleared. Patients suffering high-voltage electrical injury should undergo cardiac monitoring, serial examination for compartment syndromes, examination and/or radiographic clearance of the spine, and examination of the urine for myoglobin. Fluid resuscitation initially is based on burn size, but this generally does not correlate well with deep tissue injury, so resuscitations need to be closely monitored and adjusted. Muscle compartments at risk should be frequently monitored by serial physical examinations. Fasciotomy should be performed when an evolving compartment syndrome is suspected. Wounds are debrided and closed with a combination of skin grafts and flaps.

**Tar Injury**
Hot thermoplastic road materials are the source of occupational injury. These highly viscous materials are heated to between 300°F and 700°F. Wounds caused by these materials should be immediately cooled by tap water irrigation. Resuscitation is based on burn size and then monitored. Wounds are dressed in a lipophilic solvent and then debrided, excised, and grafted. The underlying wounds are generally quite deep.

**Cold Injury**
Soft tissue necrosis from cold injury is due to small vessel thrombosis and is generally managed conservatively until the extent of irreversible soft tissue necrosis is clear, which may require several days. Patients who present with body parts that do not reperfuse after thawing, and who have had an ischemia time less than 24 hours, may benefit from early thrombolytic therapy. When injuries are definitely demarcated, surgical debridement, excision and reconstruction, or closure is carried out if needed; lesser injuries often heal without need for surgery. Cold-injured patients may manifest consequences of systemic hypothermia, which should be managed accordingly.

**Chemical Injury**
Patients can be exposed to a wide variety of chemicals, which in industrial settings are often heated. Clinicians must consider the thermal, local chemical, and systemic chemical effects of these agents. Consultation with poison control centers for guidance regarding systemic effects can be useful. Most agents can be washed off with tap water irrigation for 30 minutes. It is important to protect providers from secondary exposure. Alkaline substances may take longer than 30 minutes to wash off, as they are not as water-soluble as acidic agents or most other chemicals used in industry. When the soapy feel that alkalis usually impart to the gloved finger is gone, or when litmus paper applied to the wound shows a neutral pH, irrigation can be stopped. Concentrated hydrofluoric acid exposure may result in dangerous hypocalcemia, and subeschar injection of 10% calcium gluconate and emergent wound excision may be appropriate. Elemental metals should be covered with oil, and white phosphorus should be covered in saline to prevent secondary ignition. Both agents can react explosively with water.

**Toxic Epidermal Necrolysis**
Toxic epidermal necrolysis is a syndrome that entails a diffuse epidermal-dermal bonding derangement of both cutaneous and visceral epithelial surfaces. Patients commonly present after a drug exposure, but this is not always the case. When the syndrome involves primarily the face, oral mucosa, and eyes and less than 30% of the cutaneous surfaces, it is called Steven-Johnson syndrome. Toxic epidermal necrolysis is similar in presentation to a very large second-degree burn. With good wound care, in most
patients the cutaneous wound will heal without need for surgery. Involvement of mucosa of the lung, gut, and genitourinary tract occurs and often leads to sepsis and organ failures. The disease runs an unpredictable time course but usually is clearly resolving by 3 weeks in most surviving patients.

**Purpura Fulminans**

Purpura fulminans is a complication of sepsis with meningococcus, pneumococcus, or other bacterial species, causing extensive soft tissue necrosis. It has become less common since the meningococcal vaccination became routine. Purpura fulminans is believed to be secondary to a transient protein-C deficiency–related hypercoagulable state that occurs early in the septicemic process, triggering small vessel thrombosis and patchy soft tissue necrosis. These patients present with sepsis-associated organ failures and extensive deep wounds. Both should be managed concurrently, since the wounds are prone to infection if not promptly excised and closed. Early antibiotic treatment and source control are important.

**Soft Tissue Infections**

Patients with soft tissue infections share many characteristics of burn patients. When a soft tissue infection is suspected, patients should be taken to the operating room for exploration of involved muscle compartments with immediate debridement of involved tissue. Operative goals include wide exposure of the infection so that its anatomic extent can be accurately described and its microbiological characteristics can be determined by culture, Gram stain, and biopsy. Debridement under general anesthesia is repeated until infection is controlled. Wounds are later closed with flaps and grafts as appropriate. Broad-spectrum and then focused antibiotics are important adjuncts. Some patients, particularly those with clostridial infection, may benefit from adjunctive hyperbaric oxygen, but prompt surgery is the primary therapeutic modality.

**Combined Burns and Trauma**

Burn care priorities often conflict with orthopedic, neurosurgical, and other trauma priorities. Thoughtful resolution of these differences is an important part of successful management (Table 10).

### Table 10. Conflicting Priorities Presented by Patients With Burn and Polytrauma

<table>
<thead>
<tr>
<th>Area of Conflict</th>
<th>Consensus Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurological: Patients with burns and head injuries must have cerebral edema controlled during resuscitation; pressure monitors increase risk of infection.</td>
<td>A very tightly controlled resuscitation should be conducted, with short-term placement of indicated pressure monitors with antibiotic coverage.</td>
</tr>
<tr>
<td>Chest: Patients with blunt chest injuries and overlying burns may require chest tubes through burned areas, with risk of empyema and difficulty closing the tract.</td>
<td>A long subcutaneous tunnel should be used to decrease trouble closing the tract, and tubes should be removed as soon as possible to decrease risk of empyema.</td>
</tr>
<tr>
<td>Abdomen: Blunt abdominal injuries may be hard to detect if there is an overlying burn. There is a high incidence of wound dehiscence operating through a burned abdominal wall.</td>
<td>Imaging should be used liberally to detect occult injuries. Retention sutures should be routinely used after laparotomy.</td>
</tr>
<tr>
<td>Orthopedic: Optimal management of a fracture may be compromised by an overlying burn.</td>
<td>Most such extremities are best managed with prompt excision and grafting of the wound with external fracture fixation.</td>
</tr>
</tbody>
</table>
Summary
Patients with large burns can present the ICU team with very challenging problems. Wound care and surgical procedures must go on while the team manages sepsis and organ failures. Pain control can be very challenging. Despite this, seriously burned patients can do extremely well in the long term. Skillful critical care is an essential element of patient salvage. Thoughtful and technically skilled critical care not only enhances rates of survival but also directly affects the patient’s ultimate quality of life.

REFERENCES


