Burns

Burns are tissue injuries resulting from direct contact with hot liquids, gases, or surfaces; caustic chemicals; electricity; or radiation. Most commonly, the skin is injured, which compromises its function as a barrier to injury and infection and as a regulator of body temperature, fluid loss, and sensation.

ASSESSMENT AND MANAGEMENT OF BURN INJURIES

Assessment

The mechanism of injury identified by the patient or witnesses helps to direct the assessment. Burns sustained in a closed environment, such as a structure fire, often produce inhalation injury in addition to thermal trauma. Explosions can cause barometric injury to the lungs and may cause blunt trauma. Burn source, duration of exposure, time of injury, and environment are documented carefully.

Associated injuries may be present in the burn patient and can result from explosions, falls, or jumping in escape attempts. Fractures, abdominal organ injury, pulmonary contusion, and pneumothorax sometimes occur.

Patient age has a major effect on outcome, with infants and elderly patients being at highest risk. Inpatient, outpatient, or burn unit management decisions also are influenced by patient age. Elderly patients often have diminished organ system reserve and comorbid medical problems that place them at increased risk.

State of health

Preexisting medical problems affecting management should be noted, including allergies, medications, hypertension, and diabetes mellitus. A careful review of systems should be obtained, with particular attention paid to cardiac.

Physical examination

Airway assessment and support have the highest priority. Supraglottic tissue edema progresses over the first 12 hours and can obstruct the airway rapidly. The larynx protects subglottic tissue from direct thermal injury but not from injury due to inhaled toxic gases. Inhalation injury should be suspected if the patient was burned in an enclosed structure or explosion. Physical signs include hoarseness, stridor, facial burns, singed facial hair, expectoration of carbonaceous sputum, or presence of carbon in the oropharynx. Direct laryngoscopy is useful in equivocal cases but should not delay expeditious endotracheal intubation with a large-bore tube based on clinical indications. Bronchoscopy is particularly helpful in diagnosing inhalation injury in patients with clinically silent airway injuries, in facilitating difficult intubations, and in predicting the onset of adult respiratory distress syndrome .

Breathing is evaluated for effort, depth of respiration, and auscultation of breath sounds. Wheezing or rales suggest either inhalation injury or aspiration of gastric contents. Circumferential deep burn of the thorax can restrict inspiration, necessitating escharotomies in the anterior axillary lines bilaterally. Carboxyhemoglobin levels >10% indicate inhalation injury (in nonsmokers). Levels >30% are associated with mental status changes, and those >60% are not compatible with survival.

Circulation is assessed for the presence of shock (rapid, weak, or absent pulse) and tissue perfusion. Signs of impairment in central perfusion include cyanosis, agitation, and reduced mentation. Intravascular volume shifts to the interstitial compartment, coupled with exudative and evaporative water loss from the burn injury, can reduce circulating blood volume rapidly. Full-thickness circumferential extremity or neck burns require escharotomy if circulation distal to the injury is impaired. Escharotomies are rarely needed within the first 6 hours of injury.

Remove all clothing to halt continued burn from melted synthetic compounds or chemicals and to assess the full extent of body-surface involvement in the initial examination. Irrigate injuries with water or saline to remove harmful residues. Remove jewelry (particularly rings) to prevent injury resulting from increasing tissue edema.

Depth of burn

Table 1 Treatment algorithm for the three clinically important burn depthsa

Burn depth[b]	Level of injury	Clinical features	Treatment	Usual result
Superficial partial-thickness	Papillary dermis	Blisters Erythema Capillary refill Intact pain sensation	Tetanus prophylaxis Cleaning (e.g., with chlorhexidine gluconate) Topical agent (e.g., 1% silver sulfadiazine) Sterile gauze dressing[c] Physical therapy Splints as necessary	Epithelialization in 21 days Hypertrophic scar rare Return of full function
Deep partial-thickness	Reticular dermis	Blisters Pale white or yellow color Absent pain sensation	As for superficial partial-thickness burns Early surgical excision and skin grafting an option	Epithelialization in 60 days in the absence of surgery Hypertrophic scar common Earlier return of function with surgical therapy
Full thickness	Subcutaneous fat, fascia, muscle, or bone	Blisters may be absent Leathery, in classic, wrinkled appearance over bony prominences No capillary refill Thrombosed subcutaneous vessels may be visible Absent pain sensation	As for superficial partial-thickness burns Wound excision and grafting at earliest feasible time	Functional limitation more frequent Hypertrophic scar mainly at graft margins

[a]Epidermal (first-degree) burns present clinically with cutaneous erythema, pain, and tenderness; they resolve rapidly and generally require only symptomatic treatment.
[b]No clinically useful objective method of measuring burn depth exists; classification depends on clinical judgment.
[c]Sterile gauze dressings are frequently omitted on the face and neck.

First-degree burns are limited to the epidermis. The skin is painful and red. There are no blisters. These burns should heal spontaneously in 3 to 4 days.

Second-degree burns, which are subdivided into superficial or deep partial-thickness, are limited to the dermal layers of the skin. ***Superficial partial-***

thickness burns involve the papillary dermis. They appear red, warm, edematous, and blistered, often with denuded, moist, mottled red or pink epithelium. The injured tissue is very painful, especially when exposed to air. Such burns frequently arise from brief contact with hot surfaces, liquids, flames, or chemicals. ***Deep second-degree burns*** involve the reticular dermis and thus can damage some dermal appendages (e.g., nerves, sweat glands, or hair follicles). Hence, such burns can be less sensitive, or hairs may be easily plucked out of areas with deep partial-thickness burns. Still, the only definitive method of differentiating superficial and deep partial-thickness burns is by length of time to heal. Superficial burns heal in <2 weeks; deep ones require at least 3 weeks. Further, any partial-thickness burn can convert to full-thickness injury over time, especially if early fluid resuscitation is inadequate.

Full-thickness (third- or fourth-degree) burns involve all layers of the skin and some subcutaneous tissue. ***In third-degree burns,*** all the skin appendages, including hair follicles and sweat and sebaceous glands, and sensory fibers for touch, pain, temperature, and pressure are destroyed. This results in an initially painless, insensate dry surface that may appear either white and leathery or charred and cracked, with exposure of underlying fat. ***Fourth-degree burns*** also involve fascia, muscle, and bone. They often result from prolonged contact with thermal sources or high electrical current. ***All full-thickness burns are managed surgically, and immediate burn expertise should be sought.***

Percentage of BSA estimation

Small areas: palm of patient's hand equals 1% of BSA.

Large areas: rule of nines. Regions of the body approximating 9% are shown in Table 1. Note that infants and babies have a proportionally greater percentage of BSA in the head and neck region and less in the lower extremities compared with adults.

Table1 Rule of nines estimation of percentage of body surface area

		Trunk		Extremity		
	Head and neck	Anterior	Posterior	Upper	Lower	Genital
Adult	9	18	18	9	18	1
Infant	18	18	18	9	14	1

Management

Emergency room

Resuscitation. A surgical consultation is initiated for all patients with major injury.Oxygen should be provided to patients with all but the most minor injuries. A 100% oxygen high-humidity face mask for those with possible inhalation injury assists the patient's expectoration from dry airways and treats carbon monoxide poisoning. Others can benefit from 2 to 6 L oxygen via nasal cannula.

Intravenous access. All patients with 20% BSA burns require intravenous fluids. A 16-gauge or larger peripheral venous access should be started immediately to provide circulatory volume support. Peripheral access in the upper extremities is preferred over central venous access because of the risk of catheter-related infection. An intravenous catheter may be placed through the burn if other suitable sites are unavailable. Avoid lower-extremity catheters, if possible, to prevent phlebitic complications.

Increased capillary permeability in injured tissue results in edema and evaporative losses. Evaporative cooling results in heat loss, and hypothermia may result. Acute metabolic acidosis usually is secondary to inadequate fluid resuscitation. Persistent metabolic acidosis also can result from anaerobic metabolism secondary to carbon monoxide binding to cellular cytochrome.

Modified Parkland formula. The estimated crystalloid requirement for the first 24 hours after injury is calculated based on patient weight and BSA burn percentage. Lactated Ringer solution volume in the first 24 hours = 4ml per 1% BSA (second-, third-, and fourth-degree burns only) per 1 kg body weight(4*%BSA burn*Body weight in Kg). One-half of the calculated volume is given in the first 8 hours after injury, and the remaining volume is infused over the next 16 hours. Fluid resuscitation calculations are based on the time of injury, not the time when the patient is evaluated. Prehospital intravenous hydration is subtracted from the total volume estimate. It should be emphasized that formulas are only estimates, and more or less fluid may be required to maintain adequate tissue perfusion as measured by rate of urine output. Patients with inhalational injury, associated mechanical trauma, electrical injury, escharotomies, or delayed resuscitation require more fluid than that based on the formula alone. Further, for children weighing less than 30 kg, 5% dextrose (D5) in ¼ normal saline maintenance fluids should supplement the Parkland formula to compensate for ongoing evaporative losses. Patient body weight is determined early after the burn as a baseline measurement for fluid calculations and as a daily reference for fluid management.

Colloid-containing solutions are best held for intravenous therapy until after the first 24 hours postburn. The role of albumin therapy in resuscitation has been reviewed recently, and one conclusion is that it should be used with great caution. If given to patients with inhalation injury early in resuscitation, albumin may move into the interstitium and may increase pulmonary complications. By 24 hours, capillary leak diminishes. For patients with >30% BSA burn, a one-time bolus of 5% albumin solution (0.3 to 0.5 mL/kg per 1% of BSA) should be infused to restore plasma oncotic pressure. Otherwise, replace insensible losses with D5W in adults or D5 in normal saline in children weighing 30 kg. Such fluids replace evaporative losses and mitigate the hypernatremia after resuscitation.

A Foley catheter is used to monitor hourly urine production as an index of adequate tissue perfusion. In the absence of underlying renal disease, a minimum urine production rate of 1 mL/kg per hour in children (weighing 30 kg) and 0.5 mL/kg per hour in adults is the guideline for adequate intravenous infusion. **To minimize edema, consider reducing intravenous hydration if urine output exceeds 1.5 mL/kg per hour in adult patients.**

Nasogastric tube insertion with low intermittent suction is performed if patients are intubated or develop nausea, vomiting, and abdominal distention consistent with adynamic ileus. Virtually all patients with >25% BSA burns have an adynamic ileus.

Escharotomy may be necessary in full-thickness circumferential burns of the neck, torso, or extremities when increasing tissue edema impairs peripheral circulation or when chest involvement restricts respiratory efforts. Full-thickness incisions through (but no deeper than) the insensate burn eschar provide immediate relief. Longitudinal escharotomies are performed on the lateral or medial aspect of the extremities and the anterior axillary lines of the chest, where indicated . Usually, they are done at the bedside and require no anesthesia. However, if the digits were burned so severely that desiccation results, midlateral escharotomies have minimal benefit. *Escharotomies are rarely required within the first 6 hours after injury. Indications for escharotomy rest on clinical grounds. Traditionally, to aid in assessing peripheral circulation, the documentation of palpable peripheral pulse or the presence of a Doppler signal has been used. However, studies have indicated that correlation of intramuscular pressure with signs and symptoms of extremity compression, including Doppler pulse, was poor. Infrared photo-plethysmograph (PPG or pulse oximetry) has been a useful adjunct in assessing the need of escharotomies. PPG has been correlated with blood flow and direct measurement of compartment pressure.*

Monitors: Continuous pulse oximetry to measure oxygen saturation is useful. One caveat التحذير is that falsely elevated levels can be observed in carbon monoxide poisoning.

Laboratory examination includes a baseline complete blood cell count, type and cross-match, electrolytes and renal indices, human chorionic gonadotropin (in women), arterial carboxyhemoglobin, arterial blood gas, and urinalysis. A toxicology screen and an alcohol level are obtained when suggested by history or mental status examination. A chest x-ray is obtained with the understanding that it rarely reflects early inhalation injury. Additional chest films are obtained should endotracheal intubation or central line placement become necessary. An electrocardiogram is useful initially, particularly in elderly patients or those with electrical burns. Fluid and electrolyte fluxes during resuscitation and later mobilization of third-space edema can result in arrhythmias and interval electrocardiographic changes.

Moist dressings applied to partial-thickness burns provide pain relief from air exposure. Cool water applied to small partial-thickness burns can provide relief but must be avoided in patients with major burns (>25% BSA) and especially in infants groups that are at high risk for hypothermia. Cold water also can cause vasoconstriction and can extend the depth and surface area of injury.

Analgesia is given intravenously every 1 to 2 hours to manage pain but in small doses to guard against hypotension, oversedation, and respiratory depression.

Photographs or diagrams of the BSA involvement and thickness of burns are useful in documenting the injury. They also can facilitate communication between the various members of the team caring for the patient and serve medicolegal purposes in the case of assault or child abuse.

Early irrigation and debridement are performed using normal saline and sterile instruments to remove all loose epidermal skin layers, followed by the application of topical antimicrobial agents and sterile dressings. In general, it is safe to leave blisters intact because they permit healing in a sterile environment and offer some protection to the underlying dermis. Once they are ruptured, or if the bullae are large (>2 cm) and thin-walled, debridement is indicated to prevent infection. If the burns resulted from liquid chemical exposure, they are irrigated continuously for 20 to 30 minutes. Dry chemicals are removed from the skin before irrigation to prevent them from dissolving into solution and causing further injury. Corneal burns of the eye require continuous irrigation for several hours and immediate ophthalmologic consultation.

Topical antimicrobial agents are the mainstay of burn management. The most common organisms complicating the burn injury are Staphylococcus aureus, Pseudomonas aeruginosa, Enterococcus species, Enterobacteria, group A streptococci, and Candida albicans. Systemic antibiotics are not administered prophylactically but are reserved for documented infection. Bacterial proliferation may occur underneath the eschar at the viable-nonviable interface, resulting in subeschar suppuration and separation of the eschar. Microorganisms can invade the underlying tissue, producing invasive burn wound sepsis. The risk of invasive infection is higher in patients with multiorgan failure or burns >30% BSA to total BSA. When the identity of the specific organism is established, antibiotic therapy is targeted to that organism. It may be useful on occasion to diagnose invasive infection. The technique requires a 500-mg biopsy of suspicious eschar and underlying unburned tissue. The presence of microorganisms in viable tissue confirms the diagnosis. The number of microorganisms in viable tissue correlates with mortality. Treatment requires infected eschar excision and appropriate topical/systemic antibiotic therapy.

Silver sulfadiazine (e.g., Silvadene) is the most commonly used agent because it is not irritating and has the fewest adverse side effects, the worst being a transient leukopenia in the first 1 to 3 days. It is formulated as a cream, which helps to minimize evaporative water and heat loss and thus diminishes caloric requirements. It is contraindicated in patients with glucose 6-phosphatase deficiency.

Mafenide acetate (Sulfamylon) is bacteriostatic and has better Gram-negative (particularly against P. aeruginosa) and anaerobic coverage as well as deeper eschar penetration. Further, burns over avascular cartilage, such as the ear, are ideal for mafenide acetate therapy. However, it is painful and readily absorbed systemically; it can also lead to metabolic hyperchloremic acidosis by inhibiting carbonic anhydrase.

Polymyxin B sulfate (Polysporin) is tolerated well on facial burns and does not discolor skin, as silver sulfadiazine sometimes can.

Silver nitrate has lost favor because of the severe electrolyte abnormalities resulting from Na^+, K^+, and Cl^- leaching الترشيح from the wound and because it readily stains skin and clothing. However, for patients with a sulfa allergy, it is a reasonable choice, provided that electrolytes are closely monitored.

Tetanus prophylaxis should be administered as tetanus toxoid, 0.5 mL intramuscularly, if the last booster dose was more than 5 years before the injury. If immunization status is unknown, human tetanus immunoglobulin 250 to 500 units, should be administered intramuscularly using a syringe and injection site different from those used for tetanus toxoid administration.

Critical care issues with burns: Such issues include burn wound infection, pneumonia, sepsis, ileus, Curling ulcer (gastroduodenal), acalculous cholecystitis, and superior mesenteric artery syndrome.

Stress ulcer prophylaxis (e.g., H_2 blockers, antacids, or omeprazole) should be provided for patients who have major burns and can receive nothing by mouth, especially those with coagulopathy.

Deep venous thrombosis and thromboembolic complications were considered to be rare in burn patients, even when their protracted immobility, hypercoagulability, and common need for femoral central venous access were taken into account. There is currently no consensus on the advisability of routine prophylaxis, but some type is increasingly being prescribed for adult burn patients during prolonged critical illness.

Glucose monitoring is also of paramount importance. Glucose control has been associated with a reduced incidence of infectious complications and enhanced survival.

Sepsis: Recent studies are now available suggesting that recombinant activated protein C (r-APC) may have some benefit in select patients with systemic sepsis and sudden organ failure.

Outpatient: Only minor first-degree or partial-thickness injuries should be considered for outpatient management. Whether to use outpatient management depends on many factors, including patient reliability, opportunity for follow-up, and accessibility to health professionals. Surgical consultation is recommended at the time of initial evaluation in all but the most minor injuries.

Dressings are often managed by the patient when the injury is easily accessible. Home health nursing is a useful adjunct when self-application is suboptimal or wounds are in early healing stages, requiring close follow-up. Silver sulfadiazine is often applied as a light coating, followed by sterile dressings once or twice daily.

Antibiotics are not prescribed prophylactically because they allow resistant organisms to multiply. Their use is limited to documented infection of the wounds.

Follow-up usually occurs once or twice a week during the initial healing of partial-thickness burns and split-thickness skin grafts until epithelialization is complete. Thereafter, patients are followed at 1- to 3-month intervals to evaluate and treat scar hypertrophy (application of foam tape or Jobst garments), hyperpigmentation (avoidance of direct sunlight, use of sunscreen), dry skin (unscented lotion massage), pruritus (antihistamines), and rehabilitation potential and therapy (physical, occupational, social, and psychological).

Inpatient: Transfer to a burn center should follow the guidelines of the American Burn Association. These criteria reflect multiple studies showing that age and BSA burn percentage remain the two most important prognostic factors.

- Patients younger than 10 years or older than 50 years sustaining partial- or full-thickness burns to >10% BSA
- Partial- or full-thickness burns to >20% BSA in other age groups
- Specialized regions, including joints, hands, feet, perineum, genitalia, face, eyes, or ears
- Full-thickness burns to >5% BSA
- Significant inhalation, chemical, or electrical injury
- Burns in combination with significant associated mechanical trauma or preexisting medical problems
- Patients requiring specialized rehabilitation, psychological support, or social services (including suspected neglect or child abuse)

Nutrition: The daily estimated metabolic requirement (EMR) can be calculated from the Curreri formula: EMR = [25 kcal /body weight (kg)] + (40 kcal / % BSA). Protein losses from metabolism and burn wound extravasation are replaced by supplying 1.5 to 2.0 g/kg per day. Therapeutic strategies should target prevention of body weight loss of more than 10% of the patient's baseline weight. Losses of more than 10% of lean body mass may lead to impaired immune function and delayed wound healing. Losses of more than 40% lead to imminent mortality.

Enteral feedings are the preferred route when tolerated and can be administered through an enteral feeding tube positioned in the duodenum. For severe burns, early feeding within the first 24 hours has been shown to improve a number of outcome measures, including length of hospital stay. **Overfeeding** may become an issue in patients with a prolonged recovery course. Overfeeding results in hyperglycemia, which has a negative influence on the outcome of septic and critically ill patients Furthermore, the high caloric enteral diet may lead to an impairment of the splanchnic oxygen balance in burned septic patients. The use of the Curreri formula has not been validated in patients with more than 40% BSA burns. Thus, some have encouraged the use of CO_2 gap as a parameter for splanchnic oxygen balance.

Total parenteral nutrition should be initiated after fluid resuscitation only if the patient is unable to tolerate enteral feeding.

Daily vitamin supplementation in adults should include 1.5 g ascorbic acid, 500 mg nicotinamide, 50 mg riboflavin, 50 mg thiamine, and 220 mg zinc. Patients with large burns may remain hypermetabolic for weeks to months after the burn wound is closed; early tapering of nutritional intake in these patients should be avoided.

Wound care

Analgesia and sedation for dressing changes are necessary for major burns. Valium (0.1 mg/kg intramuscularly) plus ketamine (0.5 mg/kg intramuscularly) is one sedative regimen that has been used. Alternatively, in patients with a secure airway (typically intubated), intravenous propofol has the desired effects of ease of titration and quick onset and offset of action. Either of these sedative regimens in concert with narcotic analgesia is well tolerated.

Daily dressing changes: While the wounds are exposed, the surgeon can properly assess the continued demarcation and healing of the injury. Physical therapy with active range of motion is performed at this time, before reapplying splints and dressings.

Debridement of all nonviable tissue should take place using sterile technique and instruments when demarcation occurs. Soft eschar can be abraded lightly, using wet gauze.

Wound healing

Infection is minimized by using topical antimicrobial agents.

Granulation tissue that fails to epithelialize at skin graft sites can be cauterized using an applicator stick tipped with silver nitrate.

Hyperpigmentation is best prevented by avoiding direct sunlight exposure for up to 1 year. When exposure to sunlight is unavoidable, a topical sunblock agent should be used.

Scar hypertrophy is minimized by local tissue compression, tailored Jobst garments, foam sponge, foam tape, silicone gel sheets, and massage regimens.

Pruritus can be palliated with antihistamines. Recently, doxepin, an antidepressant with strong antihistamine properties, has been approved for topical use.

Rehabilitation with ongoing evaluation is provided by occupational and physical therapists.

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