13 Burn Management

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A 50-year-old male patient with history of alcohol abuse was admitted to the emergency department with burns while sleeping in a closed room. On arrival, he was conscious and oriented with cold, clammy extremities and feeble pulse. Blood pressure was 80/50 mmHg. He had 60% burns involving face, torso, and extremities. Over the right lower limb, there were circumferential burns and swelling with absent pulsations. There was hoarseness of voice with production of sooty sputum. Chest radiograph was normal.

The mortality and morbidity of burn patients have improved due to improvement in the care over the past few decades. Local burn wound care and long term systemic, social and psychological care need to be addressed. The removal of deep wounds and biological closure helps to attenuate the development of wound sepsis. The care of the burn patient requires very advanced critical care, preferably in the burn unit.

First Day

Step 1: Initial Assessment and Resuscitation

All burn patients should be approached as a polytrauma patient. All severe burn injury that is complicated by major trauma or inhalational injury, chemical burns, high-voltage electrical burns, and in adults deep burns covering more than 20% of body surface area should be managed in a dedicated burn unit.

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Airway

- The airway is assessed first by asking the name of the patient and listening to hoarseness, which signifies upper airway burn.
- One hundred percent oxygen is administered, and oxygen saturation is monitored using pulse oximetry. Beware of falsely high saturation due to high carboxyhemoglobin levels in cases of carbon monoxide intoxication due to inhalation injury. Confirm oxygenation by measuring true oxyhemoglobin in blood gas analysis with a CO-oximeter which also measures carboxyhemoglobin levels.
- Wheezing, tachypnea, stridor, and hoarseness indicate impending airway obstruction due to an inhalation injury or edema, and immediate treatment is required.
- If the patient is not breathing or has labored respiration or signs of obstruction, clear the airway by oral/nasal suction followed by orotracheal intubation with in-line stabilization of the neck if an injury to the cervical spine is a consideration.
- Risk of upper airway obstruction increases with the following:
  - Inhalation burns—carbonaceous sputum, singed nasal hairs
  - All patients with deep burns of more than 35–40% TBSA (total burn surface area)
  - Burns involving face, neck, and upper torso
- Intubate early if progressive airway edema is suspected in cases of extensive burns or if the patient has signs of airway obstruction.
- Early intubation is also performed if the patient requires prolonged transport. Properly securing airway is of utmost importance in these patients.
- Awake fiberoptic intubation should be performed in difficult cases.

Breathing

- Breathing problem may be due to smoke inhalation injury, deep circumferential chest burn, or associated chest injury.
- Carbon monoxide (CO) is a by-product of incomplete combustion. Its intoxication is diagnosed by carboxyhemoglobin levels:
  - Less than 10% is normal.
  - More than 40% is severe.
- Treatment for carbon monoxide intoxication is to remove source and give 100% oxygen. Hyperbaric oxygen is also used to treat this condition. Patients with smoke inhalation injury often present with hoarseness, wheezing, carbonaceous sputum, facial burns, and singed nasal vibrissae.
- We should also consider the possibility of cyanide toxicity and keep a low threshold for initiating treatment. It is diagnosed by depressed level of consciousness, which may also be caused by carbon monoxide, traumatic shock, or head injury, in addition to potential cyanide toxicity. A serum lactate measurement and $EtCO_2$

monitoring may provide useful information as cyanide toxicity may cause lactic acidosis and a compensatory drop in $EtCO_2$. Antidotal treatment of cyanide poisoning involves three strategies: binding of cyanide, induction of methemoglobinemia, and use of sulfur donors. The combination of sodium thiosulfate and hydroxocobalamin has provided successful treatment of severe poisoning. At some places, the Cyanide Antidote Kit is also used if hydroxocobalamin is not available. This kit includes amyl nitrite and sodium nitrite to induce methemoglobinemia, and sodium thiosulfate to act as a sulfur donor.

- Diagnosis of Inhalational injury is often established by the use of bronchoscopy, which reveals early inflammatory changes such as erythema, edema, ulceration, sloughing of mucosa, and prominent vasculature in addition to infraglottic soot. Management of inhalation injury is directed at maintaining open airways and maximizing gas exchange.
- Bronchodilators can be useful when bronchospasm is present. Corticosteroids, however, should be avoided as they are associated with an increased risk of bacterial infection.
- A patient who is able to cough with a patent airway can clear secretions very effectively, and efforts should be made to treat the patient without mechanical ventilation.
- If respiratory failure is imminent, intubation is instituted early, and frequent chest physiotherapy and suctioning are performed to maintain pulmonary hygiene.
- Frequent bronchoscopies may be needed to clear inspissated secretions.
- In addition to the preceding measures, adequate humidification and appropriate treatment for bronchospasm is indicated.
- These patients should be ventilated as per ARDSnet protocol with low tidal volume (6 mL/kg ideal body weight). Try to keep the plateau pressure below 30 cm H_2O. Deep circumferential chest burn may limit chest wall mobility, so a higher plateau pressure up to 40 cm H_2O may be tolerated.
- Frequent escharotomies may improve breathing and airway pressures.

Circulation

- Obtain IV access anywhere possible and start giving fluids:
  - Unburned areas are preferred.
  - Burned areas are acceptable.
  - Central access is obtained if expertise available.
  - Cutdowns.
- Perform resuscitation in burn shock (first 24 h):
  - Massive capillary leak occurs after major burns.
  - Fluids shift from intravascular space to interstitial space.
  - Fluid requirement increases with greater severity of burn (larger percent total body surface area(TBSA), increased depth, inhalation injury, associated injuries)

Table 13.1 Resuscitation formulae

Formula	Crystalloid volume	Colloid volume	5% dextrose or plain water by the nasogastric tube
Parkland	4 mL/kg/% TBSA burn	None	None
Brooke	1.5 mL/kg/% TBSA burn	0.5 mL/kg/% TBSA burn	2.0 L
Galveston (pediatric)	5000 mL/m^2 burned + 1500 mL/m^2 total	None	None

TBSA total body surface area

- IV fluid rate depends on physiologic response and goals:
  - Sensorium—comfortable, arousable.
  - Base deficit—less than 2.
  - Goal for adults—urine output of 0.5 mL/kg/h.
  - Goal for children—urine output of 1 mL/kg/h; if urine output is below these levels, increase fluid rate.
  - Preferred fluid—lactated Ringer's solution as it is isotonic, cheap, and easily stored.
  - Resuscitation formulae—resuscitation formulae are just a guide for initiating resuscitation (Table 13.1).

Parkland formula is most commonly used for fluid calculation:

- Give half of the calculated volume in the first 8 h (from the time of injury).
- Give the other half in the next 16 h.
- Warning: Despite the formula suggesting decrease the fluid rate to half at 8 h, the fluid rate should be gradually reduced throughout the resuscitation to maintain the targeted urine output.

Resuscitation Endpoint

When maintenance rate is reached (approximately 24 h), change fluids to D5/NS with 20 mEq KCl at the maintenance level:

- Maintenance fluid rate = basal requirements + evaporative losses
- Basal fluid rate
  - Adult basal fluid rate = 1500 mL × body surface area (BSA) (for 24 h)
  - Pediatric basal fluid rate (<20 kg) = 2000 mL × BSA (for 24 h)
- Evaporative fluid loss
  - Adult evaporative fluid loss (mL/h) = (25 + percent TBSA burn) × BSA
  - Pediatric evaporative fluid loss (<20 kg) (mL/h) = (35 + percent TBSA burn) × BSA

Role of Albumin

- There is generally a profound hypoproteinemia following the initial resuscitation, and addition of intravenous albumin generally favours recruitment of interstitial fluid. Overall, no improvement in mortality has been noticed with albumin administration although complications are lowered by albumin compared with crystalloid in burn patients.

Role of Blood Transfusion

- Hemoconcentration occurs during the first several hours immediately following a severe burn and transfusions are generally unnecessary. Thereafter, bone marrow function is depressed and transfusions may be needed. Although, blood transfusions in severe burn injuries is associated with increased mortality but transfusion of two units of packed red blood cells can be given if the hemoglobin falls below 8 g/dL provided no high risk of acute coronary syndrome. Threshold for transfusion should be 10 g/dL for patients at risk for acute coronary syndrome.

Step 2: Take Detailed History

- Allergy
- Medication
- Pregnancy/past illness
- Last meal taken
- Environment (associated injuries)

Step 3: Start Supportive Treatment

- The nasogastric tube (small bore) for gastric decompression and initiating early enteral nutrition
- IV analgesics
- Antacids
- Tetanus prophylaxis

Step 4: Assess Severity

Burn severity is dictated by percent TBSA involvement, depth of burn, age, and associated injuries:

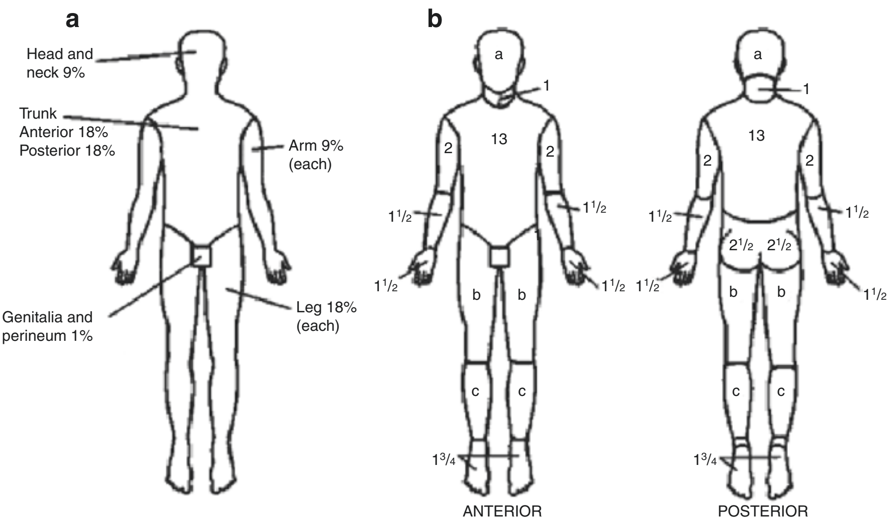
- Burns of 20–25% TBSA require IV fluid resuscitation.
- Burns of 30–40% TBSA may be fatal without treatment.

- In adults, rule of “nines” is used as a rough indicator of percent TBSA (Table 13.2 and Fig. 13.1).
- In children, adjust percents because they have proportionally larger heads (up to 20%) and smaller legs (13% in infants) than adults.
- Lund–Browder diagrams improve the accuracy of the percent TBSA for children.
- Palmar surface of the hand is approximately 1% TBSA helps in estimating percent total body surface area in children affected by burns.
- *Depth of burn injury*

1. Superficial burns (first-degree and superficial second-degree burns):
   - First-degree burns

Table 13.2 Rule of nines for establishing extent of burnt body surface

Anatomic surface	Total body surface (%)
Head and neck	9
Anterior trunk	18
Posterior trunk	18
Arms, including hands	9% each
Legs, including feet	18% each
Genitalia	1



Relative percentage of body surface areas (% BSA) affected by growth

	0 yr	1 yr	5 yr	10 yr	15 yr
a-1/2 of head	9 1/2	8 1/2	6 1/2	5 1/2	4 1/2
b-1/2 of 1 thigh	2 3/4	3 1/4	4	4 1/2	4 1/2
c-1/2 of 1 lower leg	2 1/2	2 1/2	2 3/4	3	3 1/4

Fig. 13.1 (**a**) Rule of “nines” and (**b**) Lund–Browder diagram for estimating extent of burns (Adapted from Artz CP, Moncrief JA. The treatment of burns. 2nd ed. Philadelphia: WB Saunders Company; 1969)

    - Damage above the basal layer of epidermis.
    - Dry, red, painful ("sunburn").
  - Second-degree burns
    - Damage into dermis.
    - Skin adnexa (hair follicles, oil glands, etc.) remain intact.
    - Heal by reepithelialization from skin adnexa.
    - The deeper the second-degree burn, the slower the healing (fewer adnexa for reepithelialization).
    - Moist, red, blanching, blisters, extremely painful.
    - Superficial burns heal by reepithelialization and usually do not scar if healed within 2 weeks.
2. Deep burns (deep second-degree to fourth-degree burns):
  - Deep second-degree burns (deep partial thickness)
    - Damage to deeper dermis
    - Less moist, less blanching, less pain
    - Heal by scar deposition, contraction, and limited reepithelialization
  - Third-degree burns (full thickness)
    - Entire thickness of skin destroyed (into fat)
    - Any color (white, black, red, brown), dry, less painful (dermal plexus of nerves destroyed)
    - Heal by contraction and scar deposition (no epithelium left in middle of wound)
  - Fourth-degree burns
    - Burn into muscle, tendon, and bone.
    - Need specialized care.
    - Deep burns usually need skin grafts to optimize results and lead to hypertrophic (raised) scars if not grafted.

Age

- Mortality for any given burn size increases with age.
- Children/young adults can survive massive burns.
- Children require more fluid per TBSA burns.
- The elderly may die from small (<15% TBSA) burns.

Associated injuries

- Other trauma increases severity of injury.

Use of alcohol or drugs

- It makes assessment of the patient more difficult.

Role of antibiotics

- It can be started later on when signs/symptoms of infection are present.

Step 5: Burn Wound Care and Control of Infection

Burn wound care: Current therapy for burn wounds can be divided into the following three stages: assessment, management, and rehabilitation:

- Once the extent and depth of the wounds have been assessed and the wounds are thoroughly cleaned and debrided, each wound should be dressed with an appropriate covering that serves three functions. First, it protects the damaged epithelium. Second, the dressing should be occlusive to reduce evaporative heat loss. Third, the dressing should provide comfort over the painful wound.
- The choice of dressing should be individualized based on the characteristics of the treated wound:
- First-degree wounds are minor with minimal loss of barrier function. These wounds require no dressing and are treated with topical agents to decrease pain and keep the skin moist.
- Second-degree wounds can be treated by daily dressing changes with an antibiotic ointment such as silver sulfadiazine covered with several layers of gauze under elastic wraps. Alternatively, the wounds can be covered with a temporary biologic or synthetic covering to close the wound. These coverings eventually slough as the wound reepithelializes underneath.
- Deep second- and third-degree burns will not heal in a timely fashion without autografting. These burned tissues serve as a nidus for inflammation and infection that can lead to death of the patient. Early excision and grafting of these wounds is preferred in terms of survival, less blood loss, and decreased length of hospitalization.
- Early excision should be reserved for third-degree wounds typically caused by flame. A deep second-degree burn can appear clinically to be a third-degree wound at 24–48 h after injury, particularly if it has been treated with topical antimicrobials that combine with wound drainage to form a pseudoeschar.
- Escharotomy: Excision and grafting is generally performed between 6 and 24 h after the injury. With circumferential deep second- and third-degree burns to an extremity, peripheral circulation to the limb can be compromised. The entire constricting eschar must be incised to relieve the obstruction to blood flow. Increased pressures in the underlying musculofascial compartments are treated with standard fasciotomies to avoid compartment syndrome.
- Control of infection: Decreasing invasive infections in the burn wound is due to early excision and closure and the timely and effective use of antimicrobials. The antimicrobials that are used can be divided into those given topically and those given systemically. Topical antibiotic includes 11% mafenide acetate, 1% silver sulfadiazine, polymyxin B, neomycin, bacitracin, and mupirocin:
  - Mafenide acetate has a broad spectrum of activity, particularly for Pseudomonas and Enterococcus species. Mafenide sulfate is typically reserved for small full-thickness injuries and ear burns to prevent chondritis.
  - Silver sulfadiazine, the most frequently used topical agent, has a broad spectrum of activity from its silver and sulphur moieties that cover Gram-positive

organisms, most Gram-negative organisms, and some fungi. It is painless upon application, has a high patient acceptance, and is easy to use.
- Petroleum-based antimicrobial ointments with polymyxin B, neomycin, and bacitracin are clear on application, are painless, and allow for observation of the wound. These agents are commonly used for the treatment of facial burns, graft sites, healing donor sites, and small partial-thickness burns.
- Mupirocin has improved activity against Gram-positive bacteria, particularly methicillin-resistant Staphylococcus aureus, and selected Gram-negative bacteria.
- Nystatin in the powder form can be applied to wounds to control fungal growth, and nystatin powder can be combined with topical agents such as polymyxin B to decrease colonization of both bacteria and fungi.
- Available agents for application as a soak include 0.5% silver nitrate solution, 0.5% sodium hypochlorite, 5% acetic acid, and 5% mafenide acetate solution.
- The use of perioperative systemic antimicrobials also has a role in decreasing sepsis in the burn wound until it is healed. Common organisms that must be considered when choosing a broad-spectrum perioperative regimen include S. aureus and Pseudomonas species, which are prevalent in wounds. After massive burns, gut flora are often found in the wounds mandating coverage of these species as well.

Step 6: Fluid of Choice on the Second Day

- Five percent dextrose in one-half isotonic saline (i.e., 0.45% sodium chloride). 20 mEq of potassium chloride should be added to each liter of fluid.

Step 7: Supportive Treatment—Nutrition

- Nutritional support is best accomplished by early enteral nutrition that can abate the hypermetabolic response to a burn. Therefore, duodenal or jejunal tube feeding should be commenced as early as within the first 6 h after burn if gastric feed is not possible due to ileus.
- The caloric and protein requirements are needed to gain weight and achieve nitrogen balance. It is estimated as 25 kcal/kg plus 40 kcal/% TBSA burn for 24 h (Table 13.3). Protein needs are approximately 2.5 g/kg. Estimation of 24-h urinary urea nitrogen for calculating nitrogen balance should be obtained (see Chap. 43, Vol. 1 on nutrition).

Table 13.3 Curreri formula for estimating caloric requirements for adult burn patients

Age	Formulas
6–60 years	25 kcal/kg/day + 40 kcal/% burn/day
>60 years	25 kcal/kg/day + 65 kcal/% burn/day

Table 13.4 Formulae for estimating caloric requirements for pediatric burn patients

Age	Formulas
0–1 years	2100 kcal/m^2 TBSA/day + 1000 kcal/m^2 TBSA burn/day
1–11 years	1800 kcal/m^2 TBSA/day + 1300 kcal/m^2 TBSA burn/day
12–18 years	1500 kcal/m^2 TBSA/day + 1500 kcal/m^2 TBSA burn/day

Shriners Hospitals for Children at Galveston, Texas

The pediatric formulae have been derived from retrospective analyses of dietary intake, which is associated with maintenance of average body weight over hospital stay (Table 13.4).

Ulcer prophylaxis and deep venous thrombosis prophylaxis should be started along with the rest of the management unless there are contraindications.

Step 8: Manage Complications

Successful management of burns involves management of predicted complications like Sepsis, ARDS and Renal failure.

Suggested Reading

Bacomo FK, Chung KK. A primer on burn resuscitation. J Emerg Trauma Shock. 2011;4:109. *Over-resuscitation, otherwise known as "fluid creep", has emerged as one of the most important problems during the initial phases of burn care over the past decade. To avoid the complications of over-resuscitation, careful hourly titration of fluid rates based on compilation of various clinical end points by a bedside provider is vital. The aim of this review is to provide a practical approach to the resuscitation of severely burned patients*

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Satahoo SS, Parikh PP. Are burn patients really at risk for thrombotic events? J Burn Care Res. 2015;36(1):100–4. *This study seeks to estimate the true rate of DVT in burn patients, and to evaluate possible risk factors to its development*

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Wise R, Jacobs J. Incidence and prognosis of intra-abdominal hypertension and abdominal compartment syndrome in severely burned patients: Pilot study and review of the literature. Anaesthesiol Intensive Ther. 2016;48(2):95–109. *A review of IAH associated with burn injury. IAH and ACS have a relatively high incidence in burn patients compared to other groups of critically ill patients. The percentage of TBSA burned correlates with the mean IAP. The combination of positive (daily and cumulative) fluid balance, high IAP, high EVLWI and low APP suggest a poor outcome. Non-surgical interventions appear to improve end-organ function. Non-resolution of IAH is related to a worse outcome*