Chapter 9

Burns

Introduction

Natural childhood curiosity and lack of supervision frequently combine to make thermal injuries a major cause of morbidity and mortality in the pediatric patient. Whether accidental or intentional, the most frequent etiologies are flame and scalding. Many factors contribute to the significant differences in the pathophysiology and treatment of burn injuries in children, including diminished thickness of skin and subcutaneous tissue, immaturity of immune and organ systems, difficulty establishing and maintaining intravenous (IV) access, pain management, and the psychological ramifications of hospitalization, parental separation, physical disability, and disfigurement.

- General considerations
  - Most burns occur in the home
  - Scalding is the most common etiology
  - Flame burns cause the highest incidence of full-thickness injuries and are associated with the highest morbidity and mortality
  - Metabolic responses are as follows:
    - Increased protein catabolism
    - Gluconeogenesis and hyperglycemia
    - Decreased insulin responsiveness
    - Increased plasma catecholamines (especially norepinephrine)
    - Increased heat production (basal metabolic rate)
- Pathophysiological considerations
  - Children's increased surface-area-to-body-weight ratio results in increased evaporative water loss
  - Decreased skin thickness and decreased insulating fat results in increased heat loss
- Point-of-injury care
  - Key steps in the first aid of pediatric burn patients:

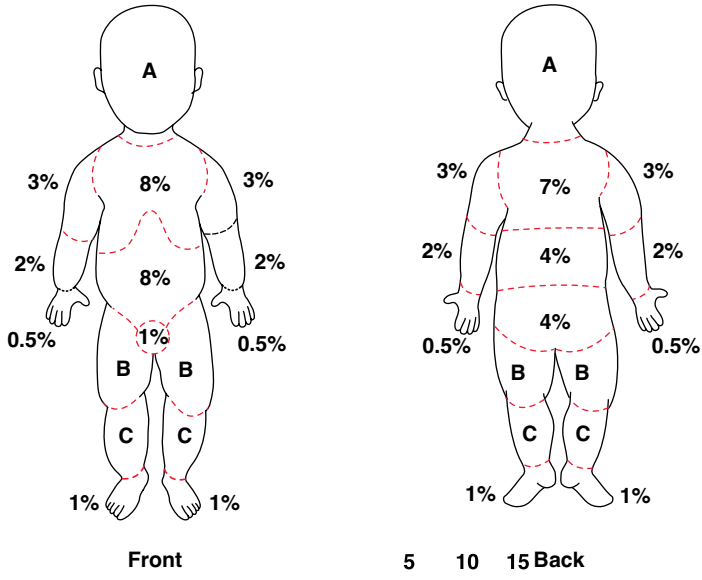
        - Fire: stop the burning process
        - Chemical: remove contaminated clothing; lavage with copious quantities of water
        - Electrical: remove the patient from contact with the electrical current
        - Ensure airway patency
        - Prevent hypothermia
            - Cover the patient with a clean, dry sheet or thermal blanket
            - Increase room temperature
            - Provide warm IV fluids
        - Establish IV or intraosseous access and begin fluid resuscitation with Ringer's lactate
    - Conduct primary survey ("ABCDE")
        - Airway
        - Breathing
        - Circulation
        - Disability
        - Exposure/environmental control
    - Conduct secondary survey to uncover other injuries
        - History ("AMPLE")
            - Allergies
            - Medications
            - Past illnesses
            - Last meal
            - Events/environment
    - Perform head-to-toe physical examination
    - Examine every orifice
    - Conduct a complete neurological examination
    - Run special diagnostic tests as needed
    - Reevaluate
- Initial treatment
    - Administer supplemental oxygen
    - Place nasogastric tubes in all patients with burns > 15% body surface area (BSA) due to the high incidence of intestinal ileus
    - Place a Foley catheter
    - Monitor with electrocardiogram and pulse oximeter
    - Check hourly vital signs, monitor fluid input and output

- Obtain chest radiographs of all intubated patients and those with suspected inhalation injury
- Initial laboratory tests include:
  - Complete blood count (CBC)
  - Electrolytes
  - Blood urea nitrogen (BUN)/creatinine
  - Blood glucose
  - Urinalysis
  - Blood type and screen
  - Consider checking arterial blood gases and carboxyhemoglobin (inhalation injury)
- Keep the patient warm by infusing warm IV fluids, elevating room temperatures, and minimizing patient exposure
- Administer tetanus immunization
- Stress ulcer prophylaxis
- Systemic antibiotics are not indicated except for treating proven infection

- Determining burn depth
  - First degree
    - Involves the epidermis only (eg, sunburn)
    - Erythematous, painful, no blisters
    - Not included in calculation of BSA
  - Second degree ("partial thickness")
    - Superficial partial thickness
      - Involves injury to the epidermis and superficial dermis
      - Erythematous, painful, and characterized by intact or ruptured blisters
      - Heals spontaneously within 1–2 weeks, usually with minimal scarring
    - Deep partial thickness
      - Involves injury to the epidermis and deeper layers of the dermis, but some viable dermis remains
      - Whiter and less erythematous as the depth into the dermis increases; may appear mottled
    - Epidermal appendages (hair follicles, sweat and sebaceous glands) serve as the source of regenerating epidermal cells following a burn, as well as a source of bacterial contamination

- Third degree ("full-thickness")
  - Involves epidermis and full thickness of the dermis; these burns always require skin grafting
  - Painless because the nerve endings are destroyed
  - Whitish-gray and waxy to black, leathery appearance, dermal elements (hair, capillaries, nerves) are destroyed
  - Distinguishing between deep partial-thickness burns and full-thickness burns may initially be difficult
    - Deep partial-thickness burns often require 3–4 weeks to heal
    - The degree of scarring is related to the length of time needed for reepithelialization; deep partial-thickness burns that take longer than 3 weeks to heal should be excised and grafted to mitigate against hypertrophic scarring and improve long-term cosmesis
- Fourth degree
  - Involves destruction of epidermis, full-thickness of the dermis, and subdermal structures (eg, muscle, bone, or tendon)
  - Typically associated with electrical burns

- Estimating burn surface area
  - The pediatric modification of the adult rule of nines takes into account that a child's head size is relatively larger, compared to the torso and extremities, than an adult's; the increased ratio of the surface area of the head to the total BSA decreases as age increases
  - The palm of a child's hand approximates 1% BSA; this estimation can be useful for calculating splotchy patterned burns
  - A modified Lund and Browder chart can be used for calculations in children < 10 years old (Figures 9-1 and 9-2)
- Inhalation injury
  - Always suspect inhalation injury when a burn occurs in a closed space
  - Physical findings
    - Singed nasal hair and eyebrows
    - Carbonaceous sputum
    - Increased carboxyhemoglobin



Area	Age 0	1y	5y	10y	15y	Adult
A = half of head	9½	8½	6½	5½	4½	3½
B = half of one thigh	2¾	4¼	4	4½	4½	4¾
C = half of one leg	2½	2½	2¾	3	3¼	3½

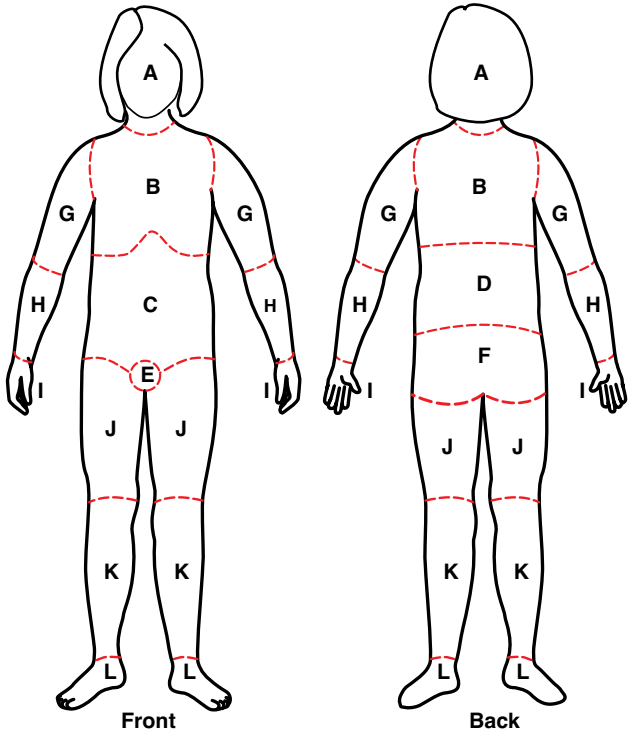
Figure 9-1. Modified Lund and Browder chart for estimating burn severity in infants.

- Hoarseness
- Wheezing
- Bronchorrhea
- Altered mental status

◦ Diagnosis: bronchoscopy

◦ Indications for intubation
- Compromised upper airway patency
- Need for ventilatory support as manifested by poor gas exchange or increased work of breathing, or compromised mental status (Glasgow Coma Scale score ≤ 8)

◦ Carbon monoxide toxicity
- Leading cause of death in patients with inhalation injury



Area	Age 1y	5y	10y	15y
A = half of head and neck	8½	6½	5½	4½
B = half of chest	7	7	7	7
C = abdomen (front)	6	6	6	6
D = abdomen (back)	5	5	5	5
E = perineum	1	1	1	1
F = buttocks	5	5	5	5
G = half of arm	2½	2½	2½	2½
H = half of forearm	2	1½	2	2
I = half of hand	1½	2	1½	1½
J = half of thigh	3	4	4	4½
K = half of leg	2½	4	3	3
L = half of foot	1½	1½	1½	1½

Figure 9-2. Modified Lund and Browder chart for estimating burn severity in children.

    - Carboxyhemoglobin levels:
        - < 20%: no symptoms
        - 20%–30%: headache, nausea
        - 30%–40%: altered mental status
        - 40%–60%: unconsciousness
        - > 60%: death
    - Should be suspected with persistent metabolic acidosis, despite adequate volume resuscitation
    - 100% oxygen should be administered via a high-flow, nonrebreathing mask to all patients suspected of having inhalation injury
- Guidelines for hospitalization or transfer
    - Second- or third-degree burns > 10% BSA in patients < 10 years old
    - Third-degree burns > 5% BSA
    - Full- or partial-thickness burns involving the face, eyes, ears, perineum, hands, or feet
    - Inhalation injuries
    - Electrical injuries
    - Chemical injuries (especially involving white phosphorus)
- Fluid resuscitation
    - Children with burns > 15% BSA require formal IV fluid resuscitation
    - An indwelling urinary catheter is required to accurately measure the adequacy of resuscitation
    - Avoid fluid boluses unless the patient presents with hypotension secondary to hypovolemia
    - Calculating resuscitation requirements:
        - First 24 hours (modified Parkland formula): total 24-hour volume = 3 cc/kg/%BSA burn Ringer lactate
            - Half of this volume is infused over the first 8 hours (calculated from the time of burning, not from when the patient actually arrives at the treatment facility)
            - The remaining half of the calculated 24-hour volume is infused over the next 16 hours
            - These calculations are only an initial estimate; the fluid rate is reassessed every hour and titrated as appropriate to achieve an hourly urine output of 1 cc/kg/h in toddlers, and 2 cc/kg/h in infants
            - Children < 30 kg should be administered D_5¼ normal

saline (NS) at a standard maintenance rate in addition to their calculated resuscitation requirement
- 24–48 hours after burn
  - At the 24th hour, discontinue Ringer lactate and infuse 5% dextrose in water (D_5W) at half the rate of the previous 16 hours
  - For burns > 30% BSA, infuse 5% albumin at a rate of 0.5 cc/kg/% BSA burn for 24 hours
- After 48 hours
  - Diuresis will usually commence at this time
  - Administer D_5W or $D_5¼$ NS at a maintenance rate
  - Estimate evaporative losses at 1–2 cc/kg/%BSA/day and replace with D_5W in addition to maintenance fluid to avoid hypernatremia
  - Monitor daily body weight, daily "ins and outs," urine-specific gravity, serum electrolytes, BUN/creatinine, and CBC
  - **NOTE**: it is critically important that BSA determination and resuscitation fluid calculations are accurate, and that ins and outs are recorded every 30–60 minutes on a burn resuscitation flow sheet

- Managing minor burns
  - The goals of treatment are to minimize the problems of pain, superficial infections, wound drainage, and prolonged convalescence
  - Small burns may initially be covered by a cloth cooled with saline solution
  - Ice should never be applied directly to a burn
  - Intact blisters should be left unbroken unless they are at flexion creases; ruptured vesicles should be debrided, and the area cleansed gently
  - Partial-thickness injuries may be treated with 1% silver sulfadiazine or by application of a fine-mesh gauze impregnated with petroleum jelly
  - Alternatively, second-degree burns may be covered with a biologic or synthetic dressing (polyurethane film or hydrocolloid semiopen dressing) without a topical antibiotic
  - Tetanus immunization should be given as indicated by immunization history

- Nonsteroidal antiinflammatory agents may reduce pain
- If the patient has evidence of group A streptococcal disease, give penicillin (50,000 units/kg/24h q6h oral or IV) to prevent colonization of the burn

- Burn wound care
  - Provide adequate IV (**not** intramuscular or subcutaneous) analgesics or conscious sedation for wound debridement and dressing changes
  - Devitalized skin, foreign bodies, and ruptured blisters should be debrided
  - Cleanse wounds with surgical soap
  - Apply topical agents bid
    - 1% silver sulfadiazine (may cause neutropenia)
    - 10% mafenide acetate (carbonic anhydrase inhibitor that may cause metabolic acidosis and compensatory hyperventilation)
    - 0.5% silver nitrate (may cause decreased serum sodium, resulting in seizures, methemoglobinemia, and indelible black staining)
  - Silver-impregnated dressings may be changed every 48 hours, rinsed, and reapplied on the same patient
  - Treat facial burns with antibiotic ointment to avoid ocular irritation
  - Treat burns to the external ear with mafenide cream
  - Artificial skin substitutes may be used to treat partial-thickness burns and have the advantage of eliminating the painful twice-daily dressing changes associated with standard dressings
  - Circumferential burns of extremities
    - The eschar of circumferential full-thickness and deep partial-thickness burns may result in vascular compromise as resuscitation proceeds
    - All extremities at risk should be monitored with hourly Doppler pulse checks
    - Extremity escharotomy is indicated for clinical symptoms of ischemia ("5-Ps": pain, pallor, paresthesias, paralysis, pulselessness)
    - Treatment: emergent escharotomy, preferably performed at the bedside using electrocautery

        - Because the nerve endings have been destroyed, no anesthesia is required
        - Incise the eschar longitudinally through the medial and lateral aspects of the extremity down to the subcutaneous fat, which should bulge into the wound if adequately incised
        - Arterial pulse should immediately return
    - Failure to adequately apply compartmental decompression will necessitate a fasciotomy
  - Circumferential chest wall burns
    - A child's respiratory efforts may become rapidly exhausted by the edema and restriction of a circumferential chest wall burn
    - Decreased compliance may impair oxygenation and ventilation, which are indications for chest wall escharotomy, performed by incising the chest along the anterior axillary lines bilaterally, extending onto the abdomen, with transverse bridging incisions across the chest
- Surgical treatment of burns
  - Early excision and grafting is effective in decreasing morbidity and improving the mortality rate of full-thickness burns
  - The goal should be to excise the wound within the first week following injury
  - Preoperatively, patients must be hemodynamically stable and be in optimal acid–base, fluid, and electrolyte balance
  - Adequate blood products must be available before excision and grafting can be considered
  - A prophylactic dose of a first-generation cephalosporin antibiotic may be used
  - It is extremely important to maintain the patient's body temperature at all times
    - Raising the temperature of the operating room is the most effective way to achieve this
    - On-table patient warming devices can also be used
  - Tangentially excise burn eschar down to viable tissue using a dermatome or freehand knife
  - Harvest meshed autografts from donor sites

        - Graft thickness varies in pediatric patients
            - Infant: 0.010–0.011 inch
            - Child: 0.012–0.013 inch
            - Teenager: up to 0.015 inch
    - Carefully apply appropriate wound dressings to prevent dislodgment of crucial skin grafts
    - Burn excision results in significant blood loss; the equivalent of 4 units of packed red blood cells (40 cc/kg) should be available for each 10% BSA excision
- Electrical burns
    - Low-voltage injuries result from sources of less than 1,000 volts and include oral injuries from biting electrical cords, outlet injuries from placing objects into wall sockets, and injuries from contacting live wires or indoor appliances
    - High-voltage injuries are caused by sources of more than 1,000 volts and result from contact with a live wire outdoors or from being struck by lightning
        - Children who have sustained high-voltage electrical injury require admission to the hospital with cardiac monitoring, serial electrocardiography, urinalysis, and determination of creatine kinase and urine myoglobin levels
        - If urine is dark, assume myoglobinuria and initiate treatment
            - Increase fluid administration to produce a urine output of 1–2 cc/kg/h
            - If pigment does not clear, administer 1 g/kg of mannitol IV, and add mannitol to IV fluids
            - Treat metabolic acidosis in a normovolemic patient with sodium bicarbonate to alkalize the urine and increase myoglobin solubility
    - Perform appropriate radiographic examinations to exclude concomitant long-bone and spine injuries
    - Myoglobinuria should be treated aggressively with IV hydration, osmotic diuretics, and alkalinization of the urine to avoid renal failure
    - Extremities must be monitored carefully for the development of compartment syndrome, which would necessitate fasciotomy

- The definitive treatment of myoglobinuria is surgical debridement of dead muscle
- Chemical burns
  - The cornerstone of initial management is copious irrigation with water
  - Alkali burns may require several hours of lavage
  - Resuscitate and manage as a thermal burn
- Pain management
  - Pain and anxiety management are critical to the care of burned children
  - Succinylcholine should never be administered to a burn patient because of the risk of hyperkalemia
  - Initially, IV morphine should be used in small amounts and titrated to the child's physiological state
  - Analgesic agents are most effective when given on a regular schedule (rather than as needed)
  - Generous analgesia or conscious sedation should be used before dressing changes and wound debridement or other painful procedures
  - A bowel regimen, including both a stimulant and a stool softener, should be maintained as long as the child is being administered opioid-derived analgesics
  - Benzodiazepines alleviate the many psychological stresses impacting injured children
  - Use diphenhydramine to treat severe pruritis in children with healing second-degree burns
- Nutrition
  - Nutritional support should be started as soon as possible after injury, preferably via the enteral route
  - If patients cannot ingest adequate calories, a nasoduodenal feeding tube should be placed and isoosmolar feedings initiated
  - Estimated protein requirements are 3 g/kg/day
  - The daily caloric requirements of pediatric burn patients can be estimated using the Curreri formula:
    - Age 0–1 years: basic metabolic requirements + 15 kcal/%BSA burn
    - Age 1–3 years: basic metabolic requirements + 25

kcal/%BSA burn
    - Age 4–15 years: basic metabolic requirements + 40 kcal/%BSA burn
- Rehabilitation
    - Burns traversing joints must be treated with passive and active range-of-motion exercises during the healing process
    - Burned extremities should be splinted with the joints in the position of function at night
    - Attention to occupational and physical therapy is necessary to ensure optimal results
    - Burns requiring more than 2 weeks to heal, and all grafted burns, should ideally be treated for 1 year with compression garments that apply approximately 30 mmHg of pressure, which decreases the formation of hypertrophic scars