Burn Care for Children

Robert L. Sheridan, MD*

**Burn Service, Boston Shriners Hospital for Children; Division of Burns, Massachusetts General Hospital; and Department of Surgery, Harvard Medical School, Boston, MA*

Education Gap

Burn injuries are common in children. Management of these injuries and their consequences will be part of most busy general pediatric practices. Although most burns in children are small and can be managed with care provided in the outpatient setting, there is a significant number of children with more serious burn injuries whose acute and long-term management will involve a collaboration between the regional burn program and the child's pediatrician. An understanding of the practice of outpatient small burn care is important. Also useful is a grasp of the concepts of inpatient burn care and long-term burn aftercare.

Objectives

After completing this article, readers should be able to:

1. Understand the local and systemic physiologic changes caused by burns so that they can best understand therapeutic options.
2. Describe the essential components of outpatient care of small burns.
3. Grasp the essential components of inpatient care of more serious burns.
4. Develop an awareness that long-term physical and emotional outcomes can be enhanced through participation in burn aftercare programs that include scar management, burn-specific physical and occupational therapy, ready access to burn reconstruction, emotional counseling, and family and peer support.
5. Have an awareness of the nonburn conditions commonly treated in burn units.

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INTRODUCTION

The first objective of this review is to familiarize the reader with the local and systemic changes caused by burns and relate these to the immediate and long-term practical needs of children who have experienced such injuries. The second objective is to familiarize the reader with how burn care is organized and how general pediatric practices and hospitals can collaborate with regional burn programs to provide quality care of burns and burnlike conditions for children.

Epidemiology and Etiology

Burns are common injuries caused by a variety of etiologic mechanisms. Both incidence and mechanism vary with age and socioeconomic status. In developed countries, infants and toddlers are particularly vulnerable, most commonly injured by scalding in bath and kitchen incidents (Fig 1). In low-income countries, incidence and severity tend to be higher because of fewer mandated electrical safety precautions and more primitive living and cooking conditions. (1)(2) Around open fires, young children are particularly at risk for accidental burn injury.

Prevention

Efforts to reduce burn incidence have had mixed success. (3) Product safety regulations have included flame-retardant sleepwear, fire-safe cigarettes, hot water heater temperature set caps, and mandatory hard-wired smoke detectors. A large number and variety of public education programs have also been championed. Despite these legislative efforts, much work remains to be done to craft a broadly effective burn prevention strategy. Individual family counseling in conjunction with well-child pediatric visits may be most effective (Table 1).

Organization of Care

From a health system perspective, available data support the contention that burns are most cost-effectively managed in dedicated burn centers rather than in general hospitals, (4) with improved survival in higher-volume centers. (5) Itemized in Table 2, the American Burn Association burn center transfer criteria have been widely disseminated and largely implemented in the United States. (6) From the perspective of the individual patient with severe and/or large burns, a highly organized process of burn management is ideal. This process can be described with 4 clinical phases: evaluation and resuscitation, initial excision and closure, definitive wound closure, and rehabilitation-reconstruction. (7)

PHYSIOLOGY OF BURN INJURY

Burn wounds trigger stereotypical local and systemic physiologic aberrations that increase in intensity with wound size and depth. Systemic changes are minimal when total burn size is small, meaning less than approximately 10% of the body surface. As burns become larger, systemic effects can become very significant.

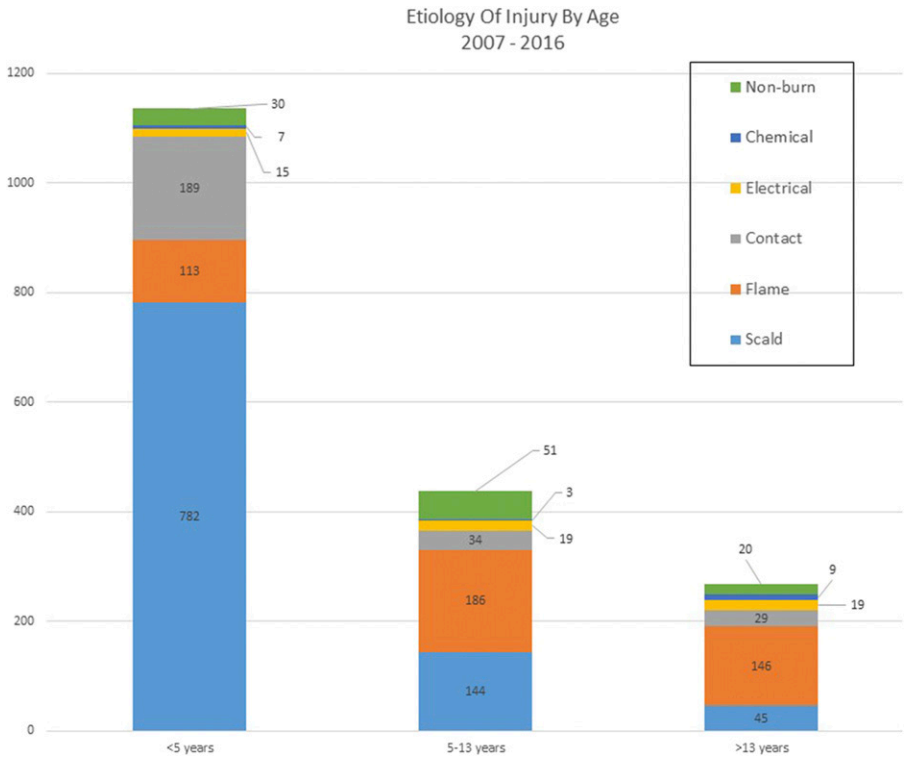


Figure 1. Age group versus mechanism of injury—Boston Shriners burn admissions over a 10-year period (2007–2016). In developed countries, infants and toddlers are particularly vulnerable to burn injury, most commonly by scalding in bath and kitchen incidents.

TABLE 1. **Selected Elements of Burn Prevention Counseling**

• Do not let cooking appliance electric cords hang off a counter.
• Do not leave hot beverages or foods unattended or near the edge of a table where a curious child can reach them.
• Keep hot beverages away from children and do not have a child sit in your lap while you drink a hot beverage.
• Teach older children how to safely remove hot food from a microwave or stove top.
• Minimize use of front burners on stoves so curious children cannot pull down pots of hot liquid.
• When carrying hot foods in the kitchen, ensure children are not in the path of movement.
• Test bathwater and shower temperature with your hand for 30 seconds.
• Never leave children unattended in the bath or shower.
• Adjust water heater so that the hottest temperature at the faucet is <120°F.
• Avoid leaving unattended pots on a stove.
• Keep children away from fireplace and wood stove doors with appropriate guards.
• Install smoke detectors on every floor of a dwelling and test them monthly. They are ideally hard-wired with battery backup. Batteries should be replaced at least annually on a schedule.
• Practice home fire drills and make sure children know how to exit the house and where to meet outdoors.
• Keep fire extinguishers in the kitchen, in the furnace room, and near a fireplace.
• Teach children to exit the house low to the floor if there is smoke in a room.
• Obtain a safety ladder if your home has a second story.
• Teach children who live in tall buildings not to use the elevator during a fire.
• Teach your children to "stop, drop, and roll" if clothing is on fire.
• Avoid smoking indoors.
• Minimize storage of flammable liquids and keep them away from areas where children can play and away from any ignition sources.
• Minimize use of extension cords.
• Keep matches and lighters where they will not be available to children.
• Avoid use of fireworks.

Local Response

In addition to direct coagulation of skin and subcutaneous fat, the local response to burn includes microvascular vasoconstriction and thrombosis in peripheral unburned tissue (8). This microvascular injury with secondary capillary thrombosis and necrosis explains, in part, the common clinical observation that burns appear to deepen in the days after initial evaluation. The degree to which progressive necrosis will occur is difficult to predict in individual patients. However, the process is thought to be exacerbated by long periods of hypotension, hypothermia, and wound infection. (9) This is an important consideration during the initial evaluation of children with extensive partial-thickness (second-degree) burns. Several devices designed to facilitate earlier determination of the likelihood that a burn will heal have been tested, but none have proved accurate or simple enough to be universally adopted. (10)

Systemic Response

The systemic response to a burn results from the body's response to a complex array of changes and insults, which can include neurohormonal changes, fluid loss, hypoproteinemia, and hypotension. (11) In children with large burns, the systemic response to burns can manifest as high fever and multi-organ dysfunction without infection. During the first 1 to 2 days after a larger injury, a hypodynamic state with decreased cardiac output and metabolic rate is common. (12) Subsequently, hypermetabolic physiology follows, with rising energy expenditure and cardiac output. This response is proportional to burn size, peaking at about twice the normal metabolic rate in

TABLE 2. **American Burn Association Burn Center Transfer Criteria**

• Second- and third-degree burns >10% TBSA in patients <10 or >50 y of age.
• Second- and third-degree burns >20% TBSA in other age groups.
• Second- and third-degree burns that involve the face, hands, feet, genitalia, perineum, and major joints.
• Third-degree burns >5% TBSA in any age group.
• Electrical burns, including lightning injury.
• Chemical burns.
• Inhalation injury.
• Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.
• Any patients 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 treated initially in a trauma center until stable before being transferred to a burn center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
• Hospitals without qualified personnel or equipment for the care of children should transfer children with burns to a burn center with these capabilities.
• Burn injury in patients who will require special social/emotional and/or long-term rehabilitative support, including cases involving suspected child abuse, substance abuse.

TBSA=total body surface area.
(Based on American Burn Association burn center referral criteria available at at http://ameriburn.org/wp-content/uploads/2017/05/burncenterreferralcriteria.pdf.)

children with burns involving more than half of the body surface. (13) This later response has important nutritional implications, including enhanced gluconeogenesis, insulin resistance, and increased protein breakdown. (14) A variety of pharmacologic agents have been used in clinical trials to reduce the impact of increased metabolism after large burns, including insulinlike growth factor, growth hormone, anabolic steroids, nonsteroidal anti-inflammatory agents, and β-antagonists. (15) All of these substances will improve protein catabolism, particularly anabolic steroids, but in most well-nourished children, sufficient nutritional support is adequate to address these changes. (16)

Unique Anatomical and Physiologic Concerns

Several important points regarding pediatric anatomy and physiology relevant to the treatment of burns are worth noting. (17) The small diameter of the child's airway makes occlusion by edema more likely, mandating more liberal use of prophylactic intubation, as indicated for head and neck swelling in the presence of stridor or retractions. Endotracheal tube security is of paramount importance. The trachea is shorter and more susceptible to right mainstem bronchial intubation. Young infants may have less mature renal concentrating ability and thereby require somewhat more fluid per unit body weight than older children (18); however, overreplacement of fluid may lead to fluid overload, so careful monitoring is advised. Hypotonic fluids are best avoided initially because seizures may occur in young children secondary to acute hyponatremia. For a given body weight, children have higher energy needs than adults and can quickly become catabolic, so early nutritional support is advisable. Children have a relatively large surface area to mass ratio, making them more susceptible to hypothermia, a constant consideration during early care. Similar to the elderly, infants and toddlers have relatively thin skin, making burns more likely to be full-thickness and donor sites more difficult to harvest and heal. Vascular access is more challenging in children as a result of their smaller blood vessels. Growing young children will frequently require revision of an initially good surgical result because burns and skin grafts often do not keep pace with skeletal growth. This mandates close long-term follow-up, rehabilitation therapy, and staged surgical revisions. Members of the child's extended family and school play a central role in injury recovery for children, so family and social support should be a part of recovery planning. (19)

INITIAL EVALUATION AND IMMEDIATE MANAGEMENT

Regardless of injury severity and mechanism, children with burns should be initially evaluated in an organized manner that includes primary and secondary surveys as outlined in the Advanced Burn Life Support course of the American Burn Association (20) and the Advanced Trauma Life Support approach of the American College of Surgeons. (21)

Primary Survey

The integrity of the airway is the highest-priority issue. Not all children who experience inhalation injury will require intubation. However, if they show signs of hoarseness, stridor, or progressive facial edema, intubation may be advisable, especially in smaller children. Ensuring that the endotracheal tube is secure is important and can be done with a variety of techniques, including a tie-harness. Uncuffed endotracheal tubes are ideally avoided because problematic air leaks can occur if respiratory failure develops and higher inflating pressures are required. (22) Secure vascular access should be obtained before long distance transport of children with major burns. If peripheral or central venous access is difficult, intraosseous access may be a good option. Short-term placement of intravenous or intraosseous lines through burn wounds is acceptable if required initially.

Secondary Survey

An organized secondary survey facilitates cataloging all aspects of a child's injuries, minimizing the potential for delayed care of injuries missed by an initial cursory examination. (23) The secondary survey includes a review and clarification of the mechanism of injury, a careful head-to-toe physical examination, and radiographs as directed by history and examination findings. Child abuse or neglect should be considered when presentation for care is delayed or the reported injury mechanism is not consistent with the physical findings. Some wound patterns are particularly concerning, such as those including flexor sparing and wounds consistent with immersion or contact (Fig 2). Hospital admission is advisable regardless of injury severity in such situations. A nonjudgmental history and a careful burn diagram are important components of documentation. Wound photography is particularly useful. (24)

Initial Evaluation of the Wound

In most children who present with a burn injury, the wound is their central problem, and an accurate determination of wound size and depth is the cornerstone of therapeutic decision making. Generally speaking, first-degree burns

Figure 2. Abuse or neglect must always be considered during the initial evaluation. This burn pattern demonstrates flexor sparing of the popliteal fossa, concerning for possible immersion injury.

are dry and painful, second-degree burns are moist and painful, third-degree burns are dry and insensate, and fourth-degree burns demonstrate injury to underlying muscle and bone (Fig 3). Burn depth is difficult to ascertain accurately on early examination. It is often underestimated initially because the full extent of skin necrosis may take a few days to manifest (Fig 4). Deciding whether a wound will need surgery can be a difficult and important decision when caring for young children with mixed-depth burns. Because body proportions change with age, evaluation of burn size should include use of anthropometric diagrams such as the Lund-Browder diagram (Fig 5). The area of irregular nonconfluent burns can be estimated knowing that the palmar surface of a child's hand is approximately 1% of their body surface area. (25) It is particularly important to note burns that encircle or nearly encircle an extremity or the entire torso because monitoring distal to the burn for turgor and perfusion is often prudent.

Initial Care of the Wound

Initial wound evaluation and debridement can be uncomfortable and scary for young children, who may require distraction in addition to analgesic and anxiolytic medications. Ketamine sedation can be particularly useful in children with larger wounds. (26) Unduly prolonged wound exposure should be avoided to minimize stress, desiccation, and wound contamination. Tetanus immune status should be ensured, especially if wounds are large or contaminated.

Decompression Procedures

In tissues confined by inelastic circumferential eschar or muscle compartments, progressive soft-tissue edema can

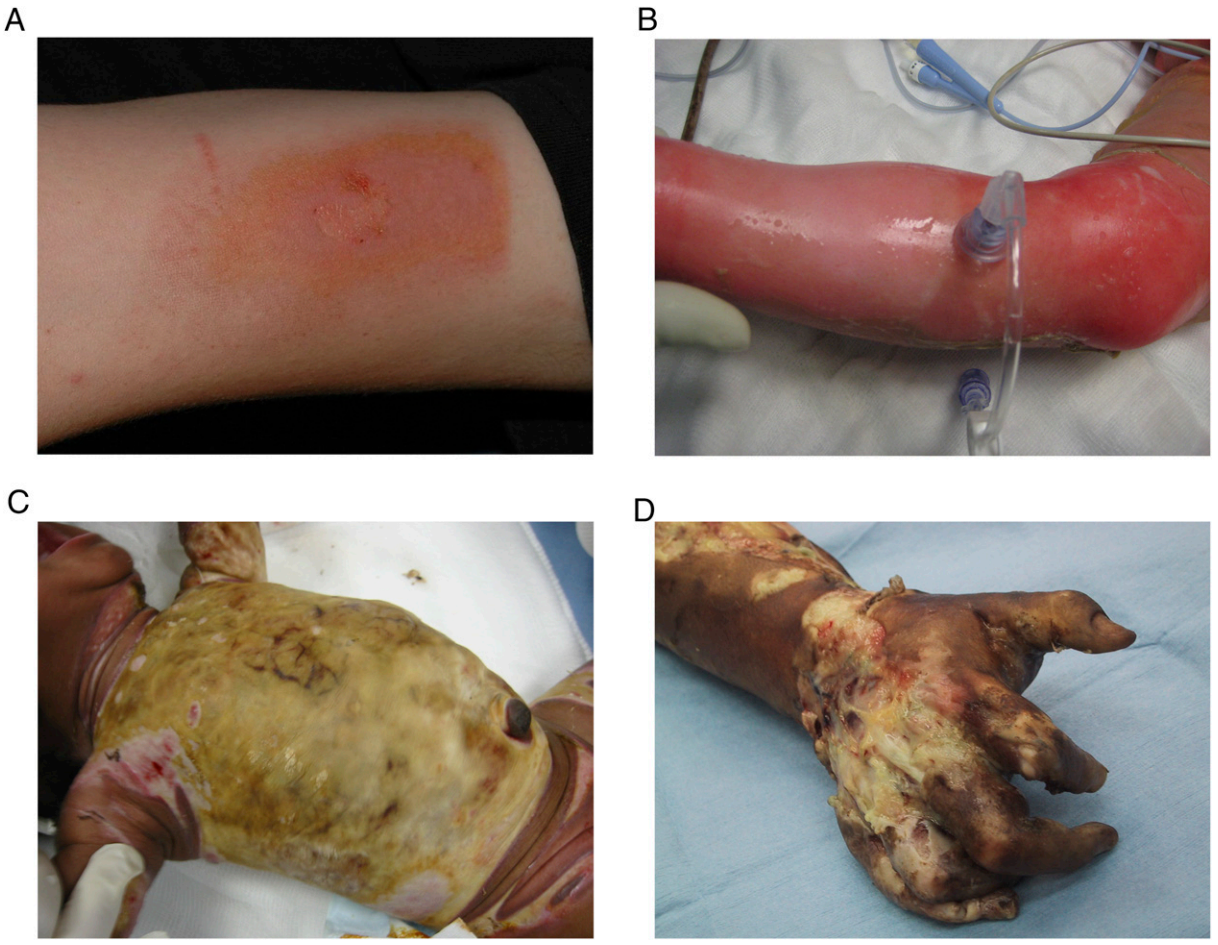


Figure 3. Burn depth can be deceiving on initial examination, but as a general rule, first-degree burns are dry and painful (A), second-degree burns are moist and painful (B), third-degree burns are charred and insensate (C), and fourth-degree burns appear to involve muscle and bone (D). Treatment planning depends in large measure on an initial estimate of burn depth.

drive up pressure, restricting blood flow and causing peripheral nerve ischemia and even muscle necrosis. This can be an issue even when burns are small if they are deep and near-circumferential. Early signs and symptoms of so-called compartment syndrome are easy to miss in children. Identification of extremities at risk for compartment syndrome with frequent focused reassessment will facilitate timely decompression before complications arise. When necessary, torso escharotomies can facilitate ventilation and improve renal perfusion and venous return from the lower body. Escharotomies can often be comfortably performed at the bedside with intravenous sedation using ketamine.

MANAGEMENT OF SMALL BURNS

Most burns in children are small and well managed in the outpatient setting. Even children whose burns have a deeper component who will need grafting may receive the bulk of their care as outpatients, often as a collaborative effort between their primary care pediatrician and regional burn unit. Ideally, there is a seamless interface between the inpatient burn unit and outpatient burn clinic, with nearly continuous access to both an inpatient and outpatient team. (27)(28)

Patient Selection

Careful patient selection will increase the chances that outpatient burn care is successful. Important considerations are listed in Table 3. There should be no concern for concomitant trauma, abuse, or neglect. There should be no concern for evolving airway edema. The burn should not be so severe as to warrant the child receiving a fluid resuscitation or monitoring. The child should not have difficulty drinking fluid. Children who potentially have deeper burns of critical areas such as the face, hands, feet, and genitals may be best managed initially as inpatients until burn depth is clear, pain is well controlled, and

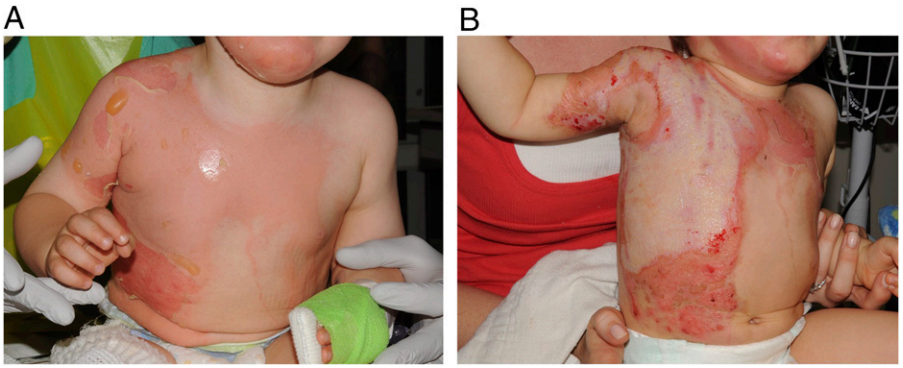


Figure 4. Burns commonly appear more superficial on initial presentation than they actually are. As shown here, there was significant change in wound appearance in this hot water scald between day 1 (A) and day 6 (B) This progression is not always easy to predict, but it is almost always to a deeper injury than initially apparent.

follow-up and wound care plans are established. The child's family should be able to support the child's wound care, monitoring, and transportation needs. If a child has circumferential wounds with risks of subeschar edema and distal ischemia, he or she should be monitored as inpatients until any risk of ischemia has passed. Small deep wounds that clearly need grafting should be surgically addressed promptly, sparing the child and family a prolonged outpatient prelude to surgery.

Outpatient Wound Care

Initially, wounds should be gently cleansed of debris and loose skin using clean (not sterile) technique with clean lukewarm tap water and bland soap. In most cases, blistered skin is gently removed. However, if blisters are intact and thick, and not tense or painful, and follow-up will be frequent, it is reasonable to simply monitor them. Some providers advocate blister drainage, allowing collapsed blistered skin to serve as a biologic dressing. Wounds should be kept clean, with periodic inspection and removal of fibrinous debris and any accumulated topical agent. Parents should be taught signs of infection (fever, malaise, or site erythema, swelling, and drainage) and told to return immediately if concerning signs are noted. Burn dressings prevent wound desiccation, decrease pain, reduce bacterial colonization, and minimize mechanical trauma. Topical antimicrobial ointments and gauze or one of the newer silver-releasing dressings can be effective. In most children, adequate pain control does not require narcotics. Elevation of the burn site above the heart reduces edema and helps with pain control. Creative collaboration with local medical and visiting nurse resources, community health programs, and family is useful in nearly every situation.

Burn Estimate: Age Versus Area

	Birth-1 yr	1-4 yr	5-9 yr	10-14 yr	15 yr	2°	3°	Total
Head	19	17	13	11	9			
Neck	2	2	2	2	2			
Anterior trunk	13	13	13	13	13			
Posterior trunk	13	13	13	13	13			
Right buttock	2½	2½	2½	2½	2½			
Left buttock	2½	2½	2½	2½	2½			
Genitalia	1	1	1	1	1			
Right upper arm	4	4	4	4	4			
Left upper arm	4	4	4	4	4			
Right lower arm	3	3	3	3	3			
Left lower arm	3	3	3	3	3			
Right hand	2½	2½	2½	2½	2½			
Left hand	2½	2½	2½	2½	2½			
Right thigh	5½	6½	8	8½	9			
Left thigh	5½	6½	8	8½	9			
Right leg	5	5	5½	6	6½			
Left leg	5	5	5½	6	6½			
Right foot	3½	3½	3½	3½	3½			
Left foot	3½	3½	3½	3½	3½			
					Total			

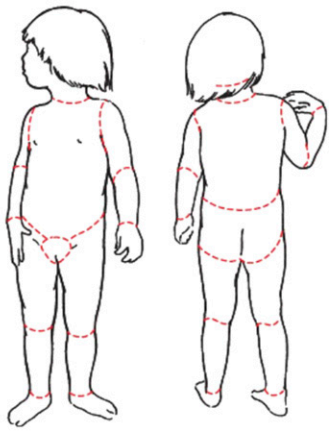


Figure 5. Because body proportions change with age, evaluation of burn size should include use of anthropometric diagrams, such as the Lund-Browder diagram. (Reprinted with permission from McInerny TK, Adam HM, Campbell DE, DeWitt TG, Meschan Foy J, Kamat DM *American Academy of Pediatrics Textbook of Pediatric Care*. 2nd ed. Elk Grove Village; American Academy of Pediatrics; 2017: 2428.)

TABLE 3. **Suggestions for Outpatient Burn Management**

Patient Selection Suggestions
• Airway is clear
• Burn small enough that fluid resuscitation not needed
• Child can eat and drink
• Family support adequate to meet monitoring, wound care, and transportation needs
• Family clearly understands care plan and follow-up recommendations
• No concern for abuse or neglect
Wound Care Suggestions
• Debride loose tissue and debris
• Gently debride leaking, loose, or thin blisters
• Apply antibiotic ointment or silver-releasing membrane based on local experience and protocols
• Schedule periodic inspections of the wound at 24 to 72 h; consider a pain control plan that minimizes opioid use
• Describe specific reasons for early return to family
• Schedule and track clinic visits
• Consult liberally with supporting inpatient burn facility
• Use local visiting nurse and outpatient medical support resources

Burns appropriate for outpatient care can generally be expected to heal within 3 weeks. Infection, most commonly cellulitis, is infrequent but should prompt immediate evaluation and antibiotic therapy. Infection most commonly occurs during the first week after injury. Prophylactic antibiotics are not routinely advised. (29) A 24-hour ability to contact the burn program is important should problems arise in the outpatient setting.

The most common clinic scenario involves a small scald burn that appears second degree on initial inspection. There are innumerable successful methods of managing such injuries. This author's usual practice is as follows. Using clean technique, initial wound examination and debridement are performed with distraction. Wounds are gently cleansed with saline and thin blisters removed. Normal distal perfusion and capillary refill are noted if relevant. Wounds are dressed with an antibiotic ointment (such as bacitracin, assuming no allergies) and gauze or a silver-releasing membrane. Assuming there are no indications for admission, a follow-up examination is planned for 24 to 72 hours later. At that time, real burn depth is usually apparent (burns very often appear more superficial on early examination than they actually are). Gentle cleaning is performed. If the wound still appears second degree, a similar antibiotic ointment dressing or a silver-releasing membrane is applied, and repeated examination is scheduled for 48 to 72 hours later. Families are taught how to replace the dressing. Visiting nurse or local pediatric resources may be engaged. Families are told that if fever, malaise, malodor, drainage, swelling, or increased pain occur, they should not wait for their scheduled follow-up but return immediately. Most children do not require narcotics in this setting because the ointment or membrane dressings provide significant comfort.

MANAGEMENT OF LARGE BURNS

Referring children with large burns (>20% of the total body surface area [TBSA]) to pediatric burn centers enhances survival. (5) Burn centers strive to deliver in 1 location a comprehensive package of care that meets all the needs of the burned child, from wound closure through emotional and social recovery.

Patient-Centered Care of Large Burns

An organized approach to the care of children with large deep burns will optimize outcome. The overarching focus is to achieve prompt closure of large deep wounds to avoid lethal sepsis and chronic painful and debilitating granulating wounds. General aspects of such an approach are outlined in Table 4. For greater detail of the medical and surgical approach to such children, the reader is referred to other resources. (30)

Fluid Resuscitation

In children with burns covering less than approximately 15% of the TBSA, metabolic changes tend to be limited, clinically significant capillary leak does not develop, and fluid resuscitation is generally unnecessary. Such children can usually be managed with fluid administered at 150% maintenance requirements by the oral and/or intravenous route while hydration status is monitored by physical examination and weighing diapers or measurement of urine output. Children with burns covering more than 15% of TBSA usually develop a diffuse capillary leak requiring resuscitation. Fluid resuscitation needs increase with burn size, burn depth, vapor transmission characteristics of the wound, inhalation injury, concomitant trauma, resuscitation delay, and other factors.

Each child presenting with a severe burn wound has unique resuscitation needs; formulas derived for quick calculation of fluid requirements provide only a rough approximation of actual requirements. Meeting these needs accurately requires that each child be approached as an individual, with careful tracking of response and adjustment of infusions as indicated. Careful bedside monitoring with titration of infusions usually results in a resuscitation that meets the child's individual physiologic needs accurately. (31)

TABLE 4. **Organizational Scheme for the Care of Large Burns**

PHASE	MAJOR OBJECTIVES
1: Initial evaluation and resuscitation	• Identification of all injuries • Completion of individualized fluid resuscitation • Liberal decompression of tight compartments to optimize perfusion and ventilation
2: Initial excision and biologic cover	• Clear identification and excision of deep burns • Biologic closure of resulting wounds
3: Definitive wound closure	• Replacement of temporary membranes with permanent grafts • Closure of complex deep wounds of face, hands, feet, genitalia
4: Rehabilitation, reconstruction, reintegration	• Initiation of program of passive joint movement, splinting, and antideformity positioning • Progression to an active joint movement and strengthening program • Initiation of scar management program • Fostering emotional health and community reintegration

Crystalloid-based burn fluids for burn resuscitation are effective in reversing burn shock but are associated with significant anasarca, which contributes to compartment syndromes, abdominal hypertension, airway compromise, and pulmonary dysfunction. (32) Traditional crystalloid-based resuscitation practice is perhaps best represented by the Parkland formula, which recommends administration of 4 mL of fluid per kilogram of body weight per percent surface area burn over the first 24 hours after injury, (2) with the first half of this volume given in the first 8 postinjury hours. Although meeting hemodynamic needs, this amount of fluid can be associated with anasarca in some children with larger burns. (33) In recent years, many providers are more often using early colloid in burn resuscitations. (34) Although this remains an area of controversy, it is the author's routine practice to administer 5% albumin at a maintenance rate in children with burns over 30% of the body surface, while subtracting this amount from calculated crystalloid needs. If children have burns covering more than 50% of TBSA, the author recommends administering twice the maintenance requirements of fluid as 5% albumin (Table 5).

During the first 24 hours of resuscitation of a child with a large burn covering more than 30% of TBSA, serum electrolytes tend to become similar to lactated Ringer solution because infusion rates are so high. Serum concentrations of potassium, ionized calcium, and magnesium may need to be corrected during resuscitation of children with such large injuries.

Inhalation injury, very deep burns, and delay in resuscitation will predictably increase resuscitation volume requirements. Although very small children with immature renal-concentrating abilities need more fluid per unit body weight than older children, they are often fluid overloaded if urine output targets are set too high. A urine output of 2 mL/kg per hour is not needed by most children. Even in mature infants, 0.5 to 1 mL/kg per hour generally suffices as a resuscitation end point.

Enteral fluid resuscitation of children with midsize burns is an option in austere or disaster situations. (35) An enteral fluid resuscitation plan can be calculated similar to an intravenous resuscitation plan, with fluid administered by gastric tube infusion or by frequent coached drinking.

Pediatric Burn Critical Care

An embedded pediatric critical care capability is necessary for pediatric burn programs. This can be accomplished either by a surgeon-run burn-specific ICU or through close

TABLE 5. **Author's Fluid Resuscitation Practice: Initial Infusions**

BURN SIZE, %	LR	5% ALBUMIN
1–20	1.5M	None
>20–50	P < 1M	1M
>50	P < 2M	2M

LR=lactated Ringer, 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 the first 8 hours).

Additional Points

1. During the first 24 hours, the infusion rate is titrated hourly to physiologic end points. For the first 24 hours, LR solution is titrated. At 24 hours, LR solution and albumin are titrated in tandem. Typically, patients are requiring approximately 1.5M at 24 hours.

2. If the patient is a child weighing less than 20 kg, 1M of initial LR solution is provided as 5% dextrose in LR, and the reminder as LR solution.

3. If needed, boluses are given as 10 mL/kg of 5% albumin.

4. The goal is to be "just on the dry side of euvolemia."

5. Tube feedings can be started at a trophic rate during the first 24 hours in stable patients with monitored advancement. The tube feeding rate is subtracted from the LR solution rate.

6. Resuscitation end points include a comfortable but easily arousable mental status, warm distal extremities, systolic blood pressure greater than 60 mm Hg in infants and 70 to 90 mm Hg plus 2 times age in years for older children, pulse of 80 to 180 beats/min, urine output of 0.5 to 1 mL/kg per hour, and base deficit less than 2.

collaboration with a general PICU. Continuous coordination and communication among all members of the burn team, including nurses, pediatricians, psychologists, anesthesiologists, intensivists, child life therapists, surgeons, and rehabilitation therapists, is essential for success. Severely burned children present a few unique issues to the critical care team.

Secure placement of the endotracheal tube can be more difficult to maintain in children with facial burns. Edema can make reintubation after unplanned extubation incredibly difficult. Both issues highlight the importance of vigilant attention to endotracheal tube security, which can be maintained using a tie-harness system. Early tracheostomy for children requiring intubation has been advocated, (36) but fairly long-term oral intubation can be associated with good outcomes while avoiding short- and long-term complications associated with tracheostomy. (37)

Children with serious burns experience a level of pain and anxiety unmatched in most any other disease processes. Tachyphylaxis to usual doses of opiates and benzodiazepine is routine. Significant dose escalation and use of additional agents such as dexmedetomidine are often required. (38) Proper control of this extraordinary pain and anxiety can benefit the child from a physiologic as well as an emotional perspective. Reduced catecholamine secretion can reduce systemic hypermetabolism. Control of pain and anxiety can have positive long-term emotional implications. (39)

Children with severe burns rapidly develop a catabolic hypermetabolic physiology that requires support. Tube feedings should be started concomitantly with fluid resuscitation unless children are hemodynamically unstable. In children who are not tolerating enteral feedings because of sepsis or for whom enteral feeds are contraindicated, short-term parenteral nutrition is well tolerated and can be particularly useful in young burn victims who are in a hypermetabolic state and, therefore, cannot tolerate prolonged fasts. (40) General consensus recommendations include nutritional goals of 2 to 2.5 g/kg per day of protein with a caloric target of 1.5 to 1.7 times a calculated basal metabolic rate or 1.3 to 1.5 times a measured resting energy expenditure. (41) The role of anabolic agents in children with burns is a long-standing area of controversy in the field and remains a program-specific practice. In most children, accurate enteral support will suffice to maintain lean body mass through the challenge of catabolic burns. (16)

Young children with burns have a propensity to develop high fever, even in the absence of systemic infection, while at the same time sepsis remains a major source of morbidity and mortality. (42) This concern results in a frequent treatment conundrum as clinicians struggle to determine whether a febrile burned child is infected and requires antibiotic treatment. General physical examination and wound evaluation should guide initial therapy. If hypotension or lethargy or other obvious signs of infection are present, bacterial cultures should be taken and broad spectrum antibiotic therapy started. Culture results with antibiotic sensitivities will allow for narrowing of bacterial spectrum coverage. In the absence of concerning findings, vigilant monitoring without antibiotic initiation is appropriate.

Inhalation injury also remains an important source of morbidity and mortality in burned children. Management strategies include airway protection from upper airway edema, vigilant pulmonary hygiene for removal of sloughed endobronchial debris, and accurate specific treatment of pulmonary infection. (43)

Historically, young age was an independent predictor of mortality from burns. However, with the evolution and application of pediatric critical care techniques to burned children, mortality has been sharply reduced, and young age is no longer a predictor of mortality. (44)

TABLE 6. **Important Considerations in Nonburn Conditions Commonly Referred to Burn Units for Definitive Care**

NONBURN CONDITION	CLINICAL IMPLICATIONS	COMMON TRAPS
Toxic epidermal necrolysis	Diffuse progressive cutaneous and visceral epidermal slough	Underappreciation of the trajectory of disease and involvement of visceral epithelium.
Staphylococcal scalded skin syndrome	Diffuse midepidermal cutaneous slough	Delayed realization of severity of illness and search for focus of colonization and antibiotic treatment.
Purpura fulminans	Diffuse small vessel thrombosis secondary to transient protein C deficiency associated with sepsis	Underappreciation of rapidity of disease progression and extent of soft tissue necrosis and debridement required.
Tar injury	Very hot and viscous agent adheres to skin	Delayed cooling of persistently hot viscous materials.
Chemical injury	Diffuse group of cutaneous and pulmonary injury	Underappreciation of effects of fumes on lungs and of systemic effects of absorbed chemical (notably hydrofluoric acid)
Electrical injury	Range of soft tissue injury with increasing voltage and contact duration and quality.	Underappreciation of occult cardiac and muscle injury, rhabdomyolsis, and secondary compartment syndrome.
Crush injury	Graded soft tissue, bone, and visceral injury with secondary consequences of edema and of reperfusion.	Underappreciation of injury severity with missed muscle ischemia due to primary ischemia and to reperfusion edema.
Blast injury	Graded injury severity (primary to quaternary injury patterns), occult visceral injury. Frequently associated with fragmentation injury.	Underappreciation of secondary, tertiary, and quaternary components of injury. Missed associated visceral injury.
Frostbite	Graded soft tissue ischemia secondary to small vessel thrombosis	Missed opportunities for thrombolytic therapy. Refreezing during transport.
Soft tissue infections	Rapidly spreading deep infection with systemic inflammation and sepsis	Underappreciation of rapidity of progression and extent of debridement required.

NONBURN PROBLEMS IN THE BURN UNIT

The burn unit has a unique set of resources that includes critical care, complex operative and nonoperative wound management, and rehabilitation. (45) This resource set is useful for a variety of medical and traumatic nonburn conditions that are commonly referred to burn units for management. (46) Conditions, clinical implications, and common traps are highlighted in Table 6.

RECONSTRUCTION, REHABILITATION, REINTEGRATION

With larger numbers of children surviving serious burns, an increasing focus has been directed toward long-term burn outcomes. Early data seem to indicate that with participation in comprehensive burn aftercare programs, even children with severe burns can enjoy a very satisfying quality of life. (47) Components of these programs include scar management, burn-specific physical and occupational therapy, ready access to burn reconstruction, emotional counseling, and family and peer support. (19) Facilitating access to effective burn aftercare and recovery tools represents a wonderful opportunity to improve the lives of children with burns after the acute treatment phase has passed. (48)

Summary

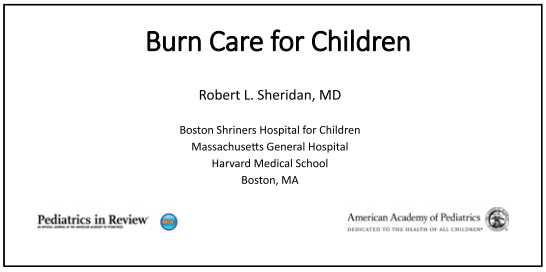
- Based on epidemiologic studies, burns are common injuries seen in most emergency and general pediatric practices. (1)(2)
- Observational studies demonstrate that serious burns are most successfully and cost-effectively managed in dedicated programs. (4)(5)
- Observational data demonstrate that burn injury causes a graded stereotypical set of physiologic changes. (12)(13) Initially a hypodynamic state is seen, requiring resuscitation for larger injuries. Subsequently, a hypermetabolic and catabolic state ensues. Observational studies suggest a benefit to nutritional support during this evolving physiologic process. (14)
- Observational studies and expert opinion suggest that patient selection, gentle wound care, and close follow-up are key principles of successful outpatient management (27) and that membrane dressings have a useful role. (28)
- Based primarily on consensus due to lack of relevant clinical studies, in recent years fluid resuscitation priorities have

included a more restrictive approach to volume administration and the more liberal use of colloid. (30)

- Based on expert consensus, the American Burn Association has promulgated a set of burn center transfer criteria that have been largely implemented in the United States. (6) Observational data demonstrate that referral of children with complex needs to regional burn programs for acute and collaborative aftercare is beneficial (4) (5) and that participation in burn aftercare programs is associated with enhanced physical and emotional outcomes. (19)(48)

References for this article are at http://pedsinreview.aappublications.org/content/39/6/273.

To view teaching slides that accompany this article, visit http://pedsinreview.aappublications.org/content/39/6/273.supplemental.



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1. A 2-year-old boy sustains a 40% burn while participating in match play with older siblings. The child is airlifted to a regional burn center and undergoes resuscitation and initial debridement over the next 5 days. Enteral tube feedings were started 18 hours after admission. Today is day 9 after the injury. The child is not clinically septic. Which of the following physiologic responses is expected to be seen at this point in this patient?
    A. Bradycardia.
    B. High cardiac output.
    C. High peripheral vascular resistance.
    D. Hypothermia.
    E. Relative hypothyroidism.
2. A 5-year-old girl takes a tumble into a recently extinguished campfire while camping with her family. She experiences contact burns from the scattered hot coals to both arms, both legs, portions of her anterior torso, and her right cheek. Which of the following is the most practical method to estimate her scattered nonconfluent burn size?
    A. Estimate assuming the patient's palm is 1% of the body surface.
    B. Measurement of each wound's dimensions using a measuring tape.
    C. The Lund-Browder diagram with detailed drawings of each wound.
    D. The pediatric "rule of nines."
    E. Wound photography with use of a planimetry application.
3. A 12-month-old boy is badly burned when a cribside candle ignites his bedding. Burn size is estimated to be 65%, and all looks to be third degree. The face is involved. The child is transported to a local emergency department, arriving 20 minutes after injury. He is intubated, and central venous access is secured. A bladder catheter is placed. The child weighs approximately 10 kg. Which of the following is the most appropriate starting total initial (8 hours) hourly rate of resuscitation fluid in this patient?
    A. 80 mL/h of 5% dextrose lactated Ringer (D5LR) solution.
    B. 80 mL/h as D5 normal saline.
    C. 110 mL/h of normal saline solution and 5% albumin.
    D. 160 mL/h of D5LR solution, LR solution, and 5% albumin.
    E. 160 mL/h of D5 normal saline.
4. The child in question 3 survives his injury. His acute burn care was provided at a regional pediatric burn unit 200 miles from his home. The burn team collaborates with his local pediatric practice to craft a comprehensive long-term aftercare program. Which of the following is not an essential component of a typical aftercare program?
    A. Burn reconstruction.
    B. Daycare placement requirements.
    C. Emotional counseling and family and peer support.
    D. Physical and occupational therapy.
    E. Scar management.
5. A 3-year-old girl pulls a hot cup of coffee off the kitchen table onto her upturned lower face and anterior torso. She experiences approximately a 9% scald burn that is blanching and painful. Her lips are swollen and tender, but she has no intraoral blistering, and her airway seems clear. She will not drink. A peripheral intravenous line is started. Which of the following intravenous fluid regimens is the most appropriate to administer in this patient?

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A. 5% albumin solution at a maintenance rate.
B. D5LR solution at a maintenance rate with an additional half maintenance rate of LR solution without dextrose.
C. D5 in one-quarter normal saline at a maintenance rate.
D. LR solution at twice the maintenance rate.
E. Normal saline at a rate calculated by the Parkland formula.