Introduction

Burn injuries are the third most common injury causing death in children, following motor vehicle crash and drowning accidents. Burn injuries have the greatest length of stay (average of 7.8 days) for all hospital admissions due to injuries. Approximately 1.25 million people are burned in the United States every year. Fortunately, most burns do not require hospitalization; however, 60,000 to 80,000 patients sustain severe enough burns to demand hospital admission. Of those, 40% are children younger than 15 years. About 5500 burn patients die each year, and approximately 2500 of them are children.

House fires injure or kill over 10,000 people per year. House fires are among the leading causes of burn-related deaths in children at a rate of 12%; they are the leading cause of injury-related deaths for black children between the ages of 1 and 9 years. Children between 0 and 5 years of age are at a greater risk as a disproportionate number of fire deaths occur in homes. Deaths among preschool children are at a rate of more that twice the national average (29.6 deaths/million children) or an average of 20% of the total percentage of all home fire deaths.

Scalds are another common burn injury in children 2 years and under. Scald injuries may be due to household accidents or deliberate abuse. These may include spilling hot coffee or water, children reaching up to counter tops pulling pot handles or cords attached to cooking appliances and spilling the contents onto themselves, unknowingly putting body parts under a hot water faucet or climbing into a hot tub without realizing the water was too hot, and intentionally or unintentionally being placed into or brought in contact with a hot substance by another individual.

Great improvements have been made in the reduction of mortality related to thermal injuries over the past few decades. Advances in fluid resuscitation, early surgical excision and grafting of the burn wound, infection control, treatment of inhalation injury, nutritional support, and support of hypermetabolic response to injury have contributed to a 50% decline in burn-related deaths and hospital admissions in the United States. This overall improvement in mortality is most perceptible in the pediatric population. In 1949, Bull and Fisher reported the expected 50% mortality rate for 49% total body surface area (TBSA) burn size in children aged 0 to 14. This has improved to 50% expected mortality in 98% TBSA burn in the same population group.

The burn injury produces overwhelming physiological and psychological challenges to a child. The unique anatomical and physiological attributes of the child require the attention of physicians and nurses who are trained not only in burn care but also in the specifics of pediatric care. The most obvious differences between adults and children are in size and body proportion. Shorter lengths, tighter angles, and smaller diameters of various anatomical structures and spaces make certain manipulations more difficult. These differences also require the provision of special equipment and supplies, which reflect the configurations of pediatric anatomy. In addition to anatomical differences there are also many physiological differences between children and adults, which must be considered and will be discussed concerning the treatment of the pediatric burn patient.

Initial evaluation

A patient must be immediately removed from the source of burn and clothing and jewelry removed immediately as these burning items can prolong the burning process. Pouring cool water to minimize the depth of the burn can cause hypothermia in large burns and should be avoided. After the burning process is stopped, the patient should be kept warm by wrapping with a sterile sheet or blanket, if available, or clean sheet or blanket. If the burn involves chemical burns, the patient should be removed from the chemical immediately and the wound irrigated with copious amount of water at least for 30 minutes to dilute the chemicals.

Burn patients should be treated as a trauma patient and any other traumatic injuries diligently ruled out. Any potential life-threatening injuries should be identified and treated.
The airway should be assessed first: 100% oxygen should be administered and oxygen saturation monitored using pulse oximetry. Arterial blood gas and carboxyhemoglobin are obtained when appropriate. A full-thickness circumferential chest burn can interfere with ventilation. Chest expansion should be observed to ensure equal air movement. If the patient is on a ventilator, airway pressure and Pco₂ should be monitored. If ventilation is compromised, escharotomy of the chest should be performed to allow better chest movement and improve ventilation. Wheezing, tachypnea, stridor, and hoarseness indicate an impending airway problem due to inhalation injury or edema, and immediate attention is required.

A cuff blood pressure measurement may be difficult in patients with burned extremities. These patients may need an arterial line to monitor their blood pressure especially if they require a long transfer. A radial arterial line may not be reliable in patients with extremity burns and may be difficult to secure. A femoral line may be more reliable and easy to secure. These should be secured with sutures. Persistent tachycardia should alert a practitioner for a missed injury. Accurate and rapid determination of burn depth is vital to the proper management of burn injury.

A nasogastric tube is placed in all patients with major burns, as the majority of children develop gastric distension or ileus. A bladder drainage catheter is placed to monitor urine output accurately as a measure of successful resuscitation.

**Resuscitation**

In the hours after a serious burn, there is a systemic capillary leak that increases with burn size. Capillary usually regains competence after 18–24 hours if resuscitation has been successful. Intravenous (IV) access should be established immediately for the administration of resuscitative fluid. Increased times to beginning resuscitation of burned patients results in poorer outcomes, and delays should be minimized. It is crucial that venous access be obtained early postburn, even though such access may be extremely difficult to obtain. Due to the small circulating volume, delays in resuscitation for periods as short as 30 minutes can result in profound shock. Peripheral IV access is preferred and may need to go through burned skin if necessary. When peripheral IV is not available due to extremity burns, a central venous line may be secured. Either subclavian or femoral line can be obtained but femoral venous access may be easier to obtain in edematous patients. Small-bore catheters limit the rates at which fluid can be administered; therefore, children with large burns require two large-bore IVs so that sufficient fluid can be given. The presence of two IVs also provides a safety margin if one infiltrates to allow continued resuscitation while the ‘safety’ line is re-established.

When vascular access is unobtainable in small children (less than 6 years old), the intraosseous route is a viable option and it is relatively easy to obtain. Children can be administered fluid volumes in excess of 100mL/h directly into the bone marrow. Intramedullary access can be utilized in the proximal tibia until IV access is accomplished. There is a very rare incidence of embolic complications with this procedure. A 16–18 gauge bone marrow aspiration needle can be used to cannulate the bone marrow compartment, although spinal needles and even butterfly needles can be pushed through the soft bone of a child. Although previously advocated only for children younger than 3 years of age, intraosseous fluid administration can be safely performed in children under 6 years of age, if the bone is sufficiently soft to allow needle penetration. The anterior tibial plateau, medial malleolus, anterior iliac crest, and the distal femur are preferred sites for intraosseous infusion. The needle should be introduced into the bone, taking care to avoid the epiphysis, either perpendicular to the bone or at a 60° angle with the bevel facing the greater length of bone (Figure 36.1). The needle has been properly inserted when bone marrow can be freely aspirated. Fluid should be allowed to infuse by gravity drip. The needle should be well secured to prevent inadvertent removal. The use of pumps should be discouraged in case the needle is dislodged from the marrow compartment.

Due to their small body weight to body surface area ratio, fluid losses are proportionally greater in children. Normal blood volume in children is approximately 80mL/kg body weight and neonates, 85–90mL/kg, compared to the adult whose normal blood volume is 70mL/kg. Evaporative water losses in a 20% TBSA burn in a 10kg child are 475mL or 60% of the circulating volume, while the same size burn in a 70kg adult causes the loss of 1100mL or only 25% of the blood volume. Although fluid losses after a burn injury are directly proportional to the burned surface area, the commonly used

![Fig. 36.1 Intraosseous line placement in the proximal tibia (a) and distal femur (b). (Redrawn with permission from Fleisher and Ludwig.)](image-url)
The 'rule of nines', useful in adults, adequate in adolescents, does not accurately reflect the surface area of children under 15 years of age (Figure 36.2). The standard relationships between surface area and weight in adults do not hold true in children, as infants possess a larger cranial surface area with less area in the extremities than adults. Most routinely used resuscitation formulas were developed using adult patients and are almost exclusively weight-based. Since the linear relationship between weight and surface area does not exist in children (surface area varies to weight as a 2/3 function), use of these formulas in children results in under- or over-resuscitation (Table 36.1).

Therefore pediatric burned patients should be resuscitated using formulas based on body surface area, which can be calculated from height and weight using a standard nomogram (Figure 36.3) or formulas (Table 36.2). The most commonly

![Fig. 36.2 The 'rule of nines' altered for the anthropomorphic differences of infancy and childhood.](image)

### Table 36.1 Resuscitation by the Parkland Formula Only Compared to Maintenance Fluid Requirements Alone

<table>
<thead>
<tr>
<th>Example</th>
<th>% Burn</th>
<th>Calculated needs</th>
<th>Replacement burn loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Resuscitation*</td>
<td>Maintenance†</td>
</tr>
<tr>
<td>1 year old</td>
<td>15</td>
<td>600</td>
<td>800</td>
</tr>
<tr>
<td>10 kg</td>
<td>30</td>
<td>1200</td>
<td>800</td>
</tr>
<tr>
<td>0.48 m² BSA</td>
<td>60</td>
<td>2400</td>
<td>800</td>
</tr>
<tr>
<td>90</td>
<td>3600</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>4 years old</td>
<td>15</td>
<td>990</td>
<td>1200</td>
</tr>
<tr>
<td>16.5 kg</td>
<td>30</td>
<td>1980</td>
<td>1200</td>
</tr>
<tr>
<td>0.68 m² BSA</td>
<td>60</td>
<td>3900</td>
<td>1200</td>
</tr>
<tr>
<td>90</td>
<td>5940</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>12 years old</td>
<td>15</td>
<td>2400</td>
<td>2250</td>
</tr>
<tr>
<td>40 kg</td>
<td>30</td>
<td>4800</td>
<td>2550</td>
</tr>
<tr>
<td>1.13 m² BSA</td>
<td>60</td>
<td>9600</td>
<td>2250</td>
</tr>
<tr>
<td>90</td>
<td>14400</td>
<td>2250</td>
<td></td>
</tr>
</tbody>
</table>

*4 mL/kg/% burn. †2000 mL/m² BSA.
used resuscitation formula in pediatric patients calls for the administration of 5000 mL/m² total body surface area (TBBSA) burned plus 2000 mL/m² TBSA for maintenance fluid given over the first 24 hours after burn, with half the volume administered during the first 8 hours and the second half given over the following 16 hours. The subsequent 24 hours, and for the rest of the time their burn is open, call for 3750 mL/m² TBSA burned or remaining open area (for evaporation from wound) plus 1500 mL/m² TBSA (for maintenance requirements). This need decreases as a patient achieves more wound coverage and healing. As in the adult patient, resuscitation formulas offer a guide to the initial starting point for the amount of fluid necessary for replacing lost volume in children and the amount of fluid should be titrated according to effects.

Loss of renal medullary concentrating capacity is usual secondary to washout of the medulla during resuscitation and immature kidneys’ inherent inability to concentrate. Hyponatremia is a frequently observed complication in pediatric patients after the first 48 hours post-injury. Frequent monitoring of serum sodium is necessary to guide appropriate salt or water supplementation. Children of less than 1 year of age may require more sodium supplementation due to higher urinary sodium losses. Further, potassium losses should usually be replaced with oral potassium phosphate rather than potassium chloride as hypophosphatemia is frequently observed in this population. Calcium and magnesium losses must also be supplemented.
An indwelling urinary catheter is essential for burns greater than 20%. During the early phase of resuscitation urine output should be assessed as frequently as every 15 minutes and titrated appropriately. Fluid administration should be titrated to achieve a urine output of 1 mL/kg/h in children and 2 mL/kg/h for infants. If the patient is making more than that, IV fluid should be titrated down. Other endpoints should also be followed, such as mental status, heart rate, blood pressure, and capillary refill. One can also follow the trend of either lactic acid or base deficit and see the resolution. Initial fluid boluses should be administered in amounts appropriate for the size of the child and should represent no more than 25% of the total circulating volume (10 mL/kg). If urine output is less than minimal, it may be more appropriate to increase the rate of IV fluid rather than giving bolus.

Intravenous resuscitation fluid should be isotonic and replace lost electrolytes. Lactated Ringer’s (LR) is the most commonly used solution for the first 24 hours postburn. Electrolyte loss in the wound correlates better with LR. Children less than 1 year of age should also receive maintenance fluid containing dextrose solution to prevent hypoglycemia as their glycogen stores are limited.

**Mortality**

In a review of 103 children with >80% TBSA burns over a 15-year period, it was found that 69 survived with an overall mortality of 33%. Mortality was greatest in children under 2 years of age and in burn >95% TBSA (Figures 36.4 and 36.5). Another major predictor in mortality was the length of time to intravenous access (Figure 36.6). Burns that received resuscitation fluids within the first hour had a significantly higher chance of survival. The mortality rate also increases significantly with smoke inhalation injury. In no pediatric patient, no matter how large the burn, how young or with what type of inhalation injury could it be accurately predicted whether they would live or die at the time of admission.

**Assessment of resuscitation**

Evaluation of the efficacy of resuscitation is difficult in children. The routine clinical signs of hypovolemia for the adult burn patients – low blood pressure and decreased urine output – are late manifestations of shock in the pediatric patient and tachycardia is omnipresent. Children have remarkable cardiopulmonary reserve, often not exhibiting clinical signs of hypovolemia until more than 25% of the circulating volume has been lost and complete cardiovascular decompensation is imminent. Mental status, pulse pressures, arterial blood gases, distal extremity color, capillary refill, and body temperature reflect volume status. Capillary refill is a good indicator of volume status in burned children. Decreased capillary refill should warn a practitioner of imminent danger. A child with normal blood pressure and acceptable heart rate, but with cool clammy extremities, obtundation, and a delayed

![Fig. 36.5 Mortality for increasing burn size.](image)

![Fig. 36.6 Time to intravenous access in survivors and non-survivors. Mortality increases with delays in starting an intravenous line and instituting volume resuscitation.](image)
capillary refill, is a child in dire danger. Measurement of arterial blood pH with attention to base deficit or lactic acid is of particular importance in this age group, reflecting decreased tissue perfusion.

Children frequently develop a reflex tachycardia after even the most trivial injury due to an overexuberant catecholamine response to the trauma or anxiety. Systolic blood pressures of less than 100 mmHg are common in children younger than 5 years of age (Table 36.3). Young children with immature kidneys have less tubular concentrating ability than adults, and urine production may continue in spite of hypovolemia. Arterial pH, lactic acid, or base deficit can be followed to assist resuscitation.

Volume overload must be avoided. Volume overload can lead to pulmonary edema, right heart failure, abdominal deep muscle compartment syndromes, and cerebral edema in burn patients. Although children possess a large cardiopulmonary reserve, the young heart is less compliant, and stroke volumes plateau at relatively low filling pressures, shifting the Starling curve to the left. Cardiac output is almost completely dependent upon heart rate, and the immature heart is more sensitive to volume and pressure overload. Cardiac output can be measured using a PICCO monitor, which is less invasive than a Swan–Ganz catheter and only requires an arterial line and a central venous line. Transesophageal echocardiograms should be utilized early to assess the cardiac function in patients who are failing or not responding to the conventional therapy. Children are particularly prone to the development of edema from both vasogenic and hydrostatic sources. Vasogenic edema occurs within the early postburn period when vascular integrity is impaired. Of particular concern is the development of cerebral edema. Care should be taken in order to maintain head of bed elevation, particularly during the initial 24–48 hours postburn and avoid hypercarbia. The maintenance of intravascular osmotic pressures decreases the likelihood of edema development. Salt-poor albumin can be expected to remain in the intravascular space if administered after 8 hours postburn in amounts necessary to maintain serum albumin levels at more than 2.5 g/dL. Albumin deficit can be calculated using the formula:

\[ (2.5 \text{ g/dL} - \text{current serum albumin (g/dL)}) \times [\text{wt (kg)} \times 3] \]

The deficit can be administered as 25% albumin and given in three divided doses gradually.

### Evaluation and management of airways

The smaller aperture of the pediatric trachea predisposes it to obstruction. Equal amounts of airway edema in pediatric and adult airway results in significantly disproportionate increases in amounts of resistance and decreases in cross-sectional area. A 1 mm increase in tissue thickness of a 4 mm diameter pediatric trachea results in a 16-fold increase in resistance with a 75% decrease in cross-sectional area. The same edema in an adult airway would increase the airway resistance threefold and reduce airway area by 44%. Therefore early intubation is advocated. As edema develops promptly following injury, airway evaluation and management must be given priority in pediatric patients. During emergent conditions when edema is present, inability to secure the airway with an endotracheal tube is a clear indication of the need for surgical airway control.

Potential hemorrhage and edema formation make emergency intubation difficult. Early intubation should be considered when a long transfer is anticipated or a patient has a large burn which likely will develop airway edema with a large amount of fluid resuscitation. Concurrent placement of an endotracheal tube over the bronchoscope should be considered at the time of bronchoscopy. A readily available estimate of airway diameter is the width of the patient’s little finger, an age-based formula (age + 16)/4 or the use of Broselow tape.

Following placement of the ET tube, it must be adequately secured. With a child, oozing wounds and moist dressings, this can be a difficult task. One successful approach is to attach the ET tube with tape around the back of the head both above and below the ears. An additional piece of tape over the top of the head, secured to the tape behind the head, will prevent accidental extubation in most children.

### Inhalation injury

Inhalation injury, and its sequelae of infection and pulmonary failure, are major determinants of mortality after burn injury.
The mortality rate of children with isolated thermal burns is 1–2%, but it increases to approximately 40% in the presence of in-halation injury.\textsuperscript{15,16} Carbon monoxide poisoning coupled with hypoxia is the most frequent cause of death due to 'smoke inhalation'. Any flame-related injury, particularly if it is confined in closed space, should be evaluated for an inhalation component. If inhalation injury is suspected, arterial blood gas and carboxyhemoglobin level should be obtained and the patient placed on 100% oxygen. Children may be spared some of the overt signs of inhalation injury due to their short stature and proximity to the floor-level cool air. As with adults, the only definitive method to diagnose an inhalation injury is through direct visualization of the airway and early examination of arterial carboxyhemoglobin level. Signs of potential inhalation injury include facial burns, singed nasal hairs, carbonaceous sputum, abnormal mental status (agitation or stupor), respiratory distress (dyspnea, wheezing, stridor, hoarseness), or elevated carboxyhemoglobin level >10%.\textsuperscript{17} Carboxyhemoglobin levels must be calculated from the time drawn, back to the time of the accident or for \( O_2 \) given as described in the chapter on this subject. A carboxyhemoglobin level >60% has more than 50% chance of mortality (Table 36.4).

Common treatment modalities for inhalation injury include airway maintenance, clearance, and pharmacological management (Table 36.5). A recent study has shown that a group of children treated with a regimen of nebulized heparin and acetylcysteine had a significant decrease in reintubation rates, atelectasis, and mortality when compared to a control group.\textsuperscript{18}

### Hypermetabolism

Children with burn injury demonstrate a remarkable increase in metabolic rate. No other disease state produces as dramatic an effect on the metabolic rate as burn injury.\textsuperscript{19,20} This hypermetabolism is thought to slow wound healing and prolong generalized weakness. This prolonged metabolic dysfunction can lead to loss of lean body mass and increase morbidity. Marked wasting of lean body mass occurs within a few weeks of injury.

#### Table 36.4: Carbon Monoxide Poisoning

<table>
<thead>
<tr>
<th>Carboxyhemoglobin (%)</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–10</td>
<td>Normal</td>
</tr>
<tr>
<td>10–20</td>
<td>Headache, confusion</td>
</tr>
<tr>
<td>20–40</td>
<td>Disorientation, fatigue, nausea, visual changes</td>
</tr>
<tr>
<td>40–60</td>
<td>Hallucination, combativeness, convulsion, coma, shock state</td>
</tr>
<tr>
<td>60–70</td>
<td>Coma, convulsions, weak respiration and pulse</td>
</tr>
<tr>
<td>70–80</td>
<td>Decreasing respiration and stopping</td>
</tr>
<tr>
<td>80–90</td>
<td>Death in less than 1 hour</td>
</tr>
<tr>
<td>90–100</td>
<td>Death within a few minutes</td>
</tr>
</tbody>
</table>

#### Table 36.5: Airway Maintenance, Clearance, and Pharmacological Management

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn side to side</td>
<td>q 2h</td>
</tr>
<tr>
<td>Sitting or rocking in chair</td>
<td>As soon as physiologically stable</td>
</tr>
<tr>
<td>Ambulation</td>
<td>Early</td>
</tr>
<tr>
<td>Chest physiotherapy</td>
<td>q 2h</td>
</tr>
<tr>
<td>Suctioning and lavage (nasal/oral tracheal)</td>
<td>q 2h</td>
</tr>
<tr>
<td>Bronchodilators</td>
<td>q 2h</td>
</tr>
<tr>
<td>Aerosolized heparin/acetylcysteine</td>
<td>q 2h alternating</td>
</tr>
<tr>
<td>Heparin 5000–10 000 units with 3 mL NS q 4h</td>
<td>Alternated with acetylcysteine 20% 3 mL q 4h</td>
</tr>
</tbody>
</table>

### Thermoregulation

Core body temperature is consistently elevated after a major burn. A hypothalamic reset induced by various inflammatory cytokines and pain causes this elevation even in the absence of infection. The temperature reset is thought to be an adaptive mechanism to bolster host defense against potential pathogens. Burned patients strive for temperatures of about 38°C. Depressed or ‘normal’ temperatures are more indicative of overwhelming sepsis or exhausted physiological capabilities to maintain temperature and should be viewed as an ominous sign. After major thermal injuries, routine methods of heat conservation are inadequate due to the extensive heat loss through convection and evaporation. Infants and toddlers, with their increased surface area/volume ratios, less insulating fat, and lower muscle mass for shivering, are particularly susceptible to hypothermia.

Hypothermia produces numerous consequences. The heart is particularly sensitive to temperature, and ventricular arrhythmias are not uncommon. Hypothermia also increases the susceptibility of the myocardium to changes in electrolyte concentrations. The oxyhemoglobin dissociation curve is shifted to the left by lowered body temperature, impairing peripheral oxygenation. In extreme cases, hypothermia
produces central nervous system and respiratory depression, coagulopathies, and loss of peripheral vasomotor tone.

Every effort should be made to reduce the heat loss experienced by pediatric patients. Ambient temperatures and humidity should be maintained at 30–33°C and 80%, respectively, in order to decrease energy demands and evaporative water losses. Wet dressings should be avoided or at least wrapped, and wet bedding promptly changed so as to decrease evaporative or conductive cooling. The patient should be positioned so that drafts are avoided, including the inlets and outlets for air-conditioning and heating ducts. Bathing or showering should be expeditiously completed, avoiding undue environmental exposure.

**Nutritional support**

Nutritional support of the hypermetabolic response in severely burned patients is best accomplished by early enteral nutrition. Early institution of enteral feeding can abate the hypermetabolic response to burn. Patients with smaller burns are immediately placed on a high-protein, high-caloric diet to support their metabolic response. Those with larger burns (>30%) are placed on enteral feedings.

Almost immediate enteral nutrition can be initiated via a transpyloric feeding tube. Most children will tolerate enteral feedings as early as 1–2 hours postburn, if not immediately. Several studies have demonstrated the efficacy of early alimentation and the additional salutary effects. Enteral feedings can be given through a flexible Silastic duodenal feeding tube, bypassing the stomach, which may be experiencing decreased peristaltic action.

Early enteral feeding preserves gut mucosal integrity and improves intestinal blood flow and motility.

Milk has been demonstrated to be one of the least expensive and best tolerated of all enteral formulas. Additionally, it is palatable and easily recognized by children when they are able to take oral feedings. Because of the low sodium content of milk, sodium supplementation may be necessary. Hyperosmolar feedings, commercially available, should be diluted because of the high incidence of subsequent diarrhea if used full strength. It is diluted to 1/2 or 3/4 strength. Diarrhea is particularly troublesome in children because of their increased sensitivity to volume deficits.

Several formulas are available to estimate caloric requirement in burn patients. Since caloric demands are related to burn size, caloric support should be given in amounts calculated based on body surface area. A series of different formulas based on body surface area have been developed at Shriners Hospitals for Children, Galveston to meet the differing requirements of the various age groups. The Curreri formula has likewise been amended to reflect the differing demands of the pediatric group (Table 36.6).

**Growth**

Hypermetabolism and muscle protein catabolism persist long after the wound is closed. Protein breakdown continues 6–9 months after severe burn. There is almost a complete lack of bone growth for 2 years after injury. This results in long-term osteopenia, which may adversely affect peak bone mass accumulation in children. Severely burned children with a burn size of >80% have a linear growth delay for years after injury.

<table>
<thead>
<tr>
<th>Table 36.6 Nutritional Requirements for Children</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infant</strong></td>
</tr>
<tr>
<td><strong>Toddler</strong></td>
</tr>
<tr>
<td><strong>Child</strong></td>
</tr>
</tbody>
</table>

In severely burned patients, nail and hair growth are attenuated during the acute postburn period, and bone growth is slowed. Damaged height and weight gain velocities have been documented in children during the first 3 years postburn, thereby rendering these burned children shorter and shorter than their age-matched peers.

Nutritional support of acute burn patients becomes an essential part of treatment during their hospitalization.

**Wound closure**

One of the more important advances in the last 20 years has been the development of early excision and early wound closure. Improvements in the treatment of burn wounds and utilization of antimicrobial dressings have dramatically decreased the incidence of fatal sepsis in burned patients. Two decades ago third-degree burns were treated by removing small amounts of eschar at a time, approximately 10–15%, followed by grafting. Commonly, eschar was allowed to separate with lysis by bacterial enzymes. This led to a high incidence of invasive infection and wound sepsis and prolonged length of hospital stay with increased mortality. Today massive excision can be easily managed in children, providing results of decreased mortality and decreased length of hospital stay. Early excision even in the first 24 hours is safe and effective. Performing early excision within the first 48 hours can significantly reduce blood loss.

By using skin substitutes such as allograft skin, xenograft, and Integra (Figure 36.7), the burn wound can be covered and protected for many weeks until enough donor site is available for grafting (repeat autografting is performed when the donor site is healed for reharvesting). Cultured epithelial autografts (CEA) is available for massive burn injuries (Figure 36.8). Although it is an effective way to cover large burns with limited donor sites, it may not be the most cost-effective approach. A group of patients treated with CEA had greater hospital costs, a longer length of stay, and more reconstructive admissions than conventional treatment with meshed autograft skin. Cultured skin substitute (CSS) is currently undergoing investigative study and holds promise. CSS, consisting of autologous cultured keratinocytes and fibroblasts attached to collagen-based sponges, may reduce the requirement for donor skin and number of autograftings in massive burns.

Scald burns in young children are best managed with delayed treatment. Unless the wound is clearly third degree, the scald injury should be conservatively managed for approximately 2 weeks to allow the wound to heal or demarcate (Figures
Fig. 36.7 Dermal and skin substitutes can be used as temporary cover for severe burns. Integra, a bilaminar skin substitute, can replace homografts as temporary cover. The Silastic superficial layer can be removed after 3 weeks and a super-then autograft then placed on top. The entire wound can be covered with Integra, which is subsequently autografted when donor sites are available. (Reprinted with permission from Barret J, Herndon DN, eds. Color atlas of burn care. London: WB Saunders; 2001: 107, Plate 6.95.)

Fig. 36.8 The cultured epidermal autografts are ready to use 18–21 days later. Extreme care with handling is needed because of the fragility of the cultured cells. (Reprinted with permission from Barret J, Herndon DN, eds. Color atlas of burn care. London: WB Saunders; 2001: 106, Plate 6.89.)

Fig. 36.9 Superficial and small areas of deep second-degree scald burns before topical treatment: 25% total body surface area. (Reprinted with permission from Barret J, Herndon DN, eds. Color atlas of burn care. London: WB Saunders; 2001: 79, Plate 5.39.)

Fig. 36.10 Deep second-degree burns treated for 10 days with silver sulfadiazine. Note that the edges are regenerating. Pseudoeccrad challenges the evaluation of the wounds. Foul smell, discoloration, surrounding cellulitis, and eschar separation are signs of infection. (Reprinted with permission from Barret J, Herndon DN, eds. Color atlas of burn care. London: WB Saunders; 2001: 77, Plate 5.31.)

36.9 and 36.10). This conservative treatment results in less wound excised, less blood loss, and less apparent scarring. Treatment methods for the conservative care of scald burns were analyzed. Scald injuries greater the 20% TBSA (mean 31%) were randomized to treatment with allograft skin versus topical antimicrobial therapy. Treatment with allograft led to decreased time to healing and decreased pain. In another study, patients greater than 40% TBSA burn (mean 65%) were randomized to allograft skin or topical antimicrobial. Patients who received treatment with allograft skin had a significantly decreased length of stay. The current recommended treatment for second-degree burns, primarily scalds less than 30% TBSA, is immediate application of Biobrane. Biobrane can be safely used in children, even in infants less than 2 years of age. When applied within 48 hours of injury there is no difference in infection between Biobrane and topical antimicrobials. Further, application of Biobrane versus topical antimicrobials leads to decreased pain, decreased length of hospitalization, and decreased healing time.

Pain management

Children do not always express their pain in the same way as adults. Children may exhibit behaviors of fear, anxiety, agitation, anger, aggression, tantrums, depression, withdrawal, and regression. How the child's experience of pain from the burn injury and anxiety from the hospitalization are clinically managed will have lasting psychological effects for many months and years to follow. A severe burn injury brings many weeks of surgeries, dressing changes, and
exercises that can cause intense pain. Pain can also exist as a constant state throughout the hospitalization. Morphine sulfate is the most commonly used analgesia. It should be given intravenously, and not intramuscularly. Fentanyl can be also used. Fentanyl Oralet can be used successfully for dressing changes (10 μg per kg). Most outpatients are treated with hydrocodone/acetaminophen.

Rehabilitation

Rehabilitation is a key component to success of burn treatment and starts at the time of the admission. During the acute phase of burn care, splints are used to minimize joint deformities and contractures. Splints are used continuously except during a therapy session. They are fabricated to each patient's needs and used from day 1 of hospitalization. Bedside therapy, including passive and active range of motion, is started early. Early mobilization should be practiced. Early ambulation after the grafts has taken and early physical and occupational therapies are important to success of rehabilitation of burned children. Patients with leg grafting are kept bedrest after the operation, but on postoperative day 4, they are gotten out of bed and started on ambulation. Early therapy and ambulation are keys to success of long-term rehabilitation of burned children. When patients are discharged from their acute care hospitalization, they undergo rigorous therapies, including stretching, and range of motion and strengthening exercises.

In general, deep partial-thickness burn wounds requiring 3 or more weeks to heal will likely produce hypertrophic scars. The longer it takes to heal, the more likely are scars. Using dressings that exert constant pressure on the healing wound and pressure garments exerting constant pressure on the healed wound are the most effective ways of decreasing the incidence of hypertrophic scar formation. Pressure garments may be worn up to 2 years or until scars mature.

Prevention

Prevention remains the single best way to manage pediatric burn injuries. National prevention and education efforts have positively impacted the number of pediatric burns each year. Lowering the temperature set point on hot water heaters and teaching families to check the bath water temperature before placing a child in the bath has decreased hot water scald injuries. Prevention groups have worked with gas hot water heater companies and the Consumer Product Safety Commission (CPSC) to provide education to raise gas water heaters 12 inches off the ground, which significantly reduces the risk of accidental explosions and fires.

Much work still needs to be done in the area of 'child fire play'. Three-fourths of 'child fire play' involves matches or lighters. All matches and other ignition sources must be placed out of reach of children. A positive step toward prevention occurred in 1994 when CPSC placed into effect a child-resistant lighter to protect children under 5 years of age. The importance of placing smoke detectors in multiple areas in a house has received much public education over the last several years. Current prevention education focuses on children, and especially infants that are not able to remove themselves from a fire. Since the CPSC has reduced flammability standards on children's sleepwear in 1997, there has been an increased incidence of sleepwear-related burn injuries in children. One way to protect infants and children is to dress them in fire-resistant sleepwear and clothing to protect them from a burn injury if a fire does occur.

Children have no idea of the dangerous situations they place themselves in. Educating children as early as possible that fire is dangerous is imperative. Providing safe environments for our children and providing appropriate education to them is the responsibility of healthcare providers, the adults that care for them, and the community at large.

References


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