Burns occur in children all too frequently. Approximately 80,000 individuals are hospitalized each year for burns in the United States, and one third to one half of them are younger than the age of 18. Because the treatment of burns demands many hours of wound care from nursing staff and possibly one or multiple surgical procedures, hospitalization costs associated with burn care are extremely high. Follow-up visits for therapy and for fitting of pressure garments (to control scarring) can last for months and even years, and simple or complex reconstructive surgical procedures may be required. The disfigurement and impaired function suffered by many burn victims may be lifelong, and returning to society with these handicaps can be extremely stressful, particularly for children.

Definitions
A cross-section depiction of the skin is shown in Fig. 1. Burns generally are divided into four categories, defined by the depth of injury. First-degree burns involve only the epidermal layer and do not extend into the dermis. These burns are painful but self-limiting. Second-degree or partial-thickness burns extend into the dermal tissue, but residual dermis remains viable (Figs. 2 and 3). Third-degree or full-thickness burns involve destruction of the entire dermis, leaving the subcutaneous tissue exposed (Fig. 4). Fourth-degree burns, which extend to muscle fascia or to bone, are relatively infrequent. Burns often are nonhomogeneous in their distribution of wound depth, and their appearance can change from day to day. For these reasons, evaluation and treatment decisions can be difficult, even for the experienced clinician. The burn wound is dynamic, and progressive dermal ischemia can result in deeper injuries than originally were apparent. Finally, the extent of total body surface area (TBSA) that is burned has a great impact on the morbidity and mortality associated with the burns.

Epidemiology
The National Burn Information Exchange is a voluntary burn patient registry that was established in 1964. The data collected showed that children from birth through 4 years of age have a disproportionately high number of burn accidents and accounted for nearly 52% of all pediatric burns. After 4 years of age, the incidence of burn injuries tapered off, but it rose again as adolescents entered the work force and sustained activity- and work-related injuries such as from motor vehicle crashes and repairs. In all age groups, accidental injuries most often are the result of carelessness and inattention to basic safety measures. The majority of burn injuries among children occur at home and are largely preventable.

In those younger than 4 years of age, the most frequent burns are scalds. The kitchen area and cooking...
activities present numerous hot liquid hazards. The curious toddler who reaches for a coffee cup or soup bowl may spill the hot liquid onto his or her face, neck, anterior torso, and dominant arm. A sudden swipe by an infant’s hand can tumble a hot cup of coffee into the face or lap. A less obvious home hazard is tap water. The temperature of water from the faucet often is hot enough to create significant burn injuries. Apartments, in particular, tend to have water heaters set too high; water at 70°C (158°F) can produce almost full-thickness burns in 1 second. Temperature settings of home water heaters should be no higher than 65.5°C (150°F). This may be difficult in apartment houses because of the heavy demand for hot water. Therefore, some states have laws prescribing temperature settings for water heaters.

Contact with hot objects is the second most commonly occurring burn mechanism in small children. The stove and hot oven doors, as well as clothing irons and heated hair curlers placed near infants and toddlers, create dangers if the child should bump into or grasp the object.

Preschool children have the motor function to strike a match or lighter, but they do not have the cognition to comprehend the danger involved in such an activity. The majority of burns among older children are related to fires, and boys are involved more frequently than girls.

The environment outside of the home also can be dangerous to children. In our community, which has extensive beaches, we treat many children who step or crawl into hot coals that are buried in sand. Some of these burns are extensive in area or very deep, and they can be truly mutilating because they usually involve hands, feet, or both. Many other children are burned after touching hot barbecue grills, hot mufflers and engines, and similar objects.

Pediatric burn accidents have an additional risk for injury severity because infants, toddlers, and small children may not be able to escape from the burning object. They often experience a long duration of contact with the hot substance, with a resultant deep burn injury.

Nonaccidental Burns

Unfortunately, nonaccidental burns are not uncommon among children (Fig. 5). These injuries appear to be most common among families in lower socioeconomic groups and may reflect familial stress and disruption as well as crowded living conditions. Tragically, one study reported that 9% of child abuse cases involved intentional burning.

If nonaccidental burns are suspected, the family should be questioned carefully and inconsistencies in their stories investigated thoroughly. Frequently, the mechanism of injury suggested by the family is implausible, given the distribution and depth of the burn and the developmental level of the child. If more than one family member is involved, each should be questioned separately about details of the accident and all stories compared for inconsistencies. Scalding burns of lower extremities in which the entire foot is burned, with a well-demarcated line of injury around the leg and absence of splash marks, suggest forced immersion into hot water. Accidental

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FIGURE 3. Extensive partial-thickness burns on a child who attempted to drink a pot of hot coffee. The wounds are pink, blanch with pressure, and are moist. Sensation is difficult to judge in a child.

FIGURE 4. Deep burns of the hand of a child after contact with a hair curler. The wounds are dry, leathery, and white without blanching.

FIGURE 5. Deep partial-thickness burns to the face resulting from contact with a hot spatula. These burns were nonaccidental.
scalding usually results in partial-thickness burns; deep full-thickness burns caused by scalding are suspicious and suggest sustained contact with hot water. Evidence of other trauma, such as bruising or numerous healed wounds, should be noted. Children who have a depressed affect may be chronically abused. A prior history of investigations into the family for nonaccidental trauma can be determined easily in most communities by contacting the social services department. It is imperative that nonaccidental burns be reported immediately to the appropriate child protection authorities.

**Initial Evaluation of Life-threatening Conditions**

In burns caused by flame or with a history of smoke exposure, the airway should be evaluated immediately for potential compromise. It is difficult for sufficient heated air to enter airways to cause a physical burn, but inhalation of smoke can result in severe inflammation of the airways and lungs. Although the classic signs that are reported to be associated with inhalation injury are burns to the face and nasal hairs and carbonaceous sputum, a careful history of the accident is very important. A person who is within a smoke-filled space for even a few moments can inhale toxic amounts of smoke without incurring any burns to the skin. These patients must be evaluated carefully, and if significant smoke inhalation is suspected, fiberoptic bronchoscopy can prove the presence of airway inflammation.

This condition must be treated aggressively because the airway can swell quickly, particularly in small children, resulting in obstruction. If the child is hoarse or stridorous, immediate intubation may be the safest procedure if a bronchoscopic team is delayed in evaluating the airway. The endotracheal tube must be small enough in diameter not to place excessive pressure on the mucosa. The child may be extubated when airway edema has resolved. We usually extubate our burn patients using direct vision of the airways, either by laryngoscopy or by fiberoptic bronchoscopy, to ensure that breathing will not be obstructed.

**Pathogenesis of the Burn**

Thermal injury can produce a complex injury response in the skin that typically follows a common pattern of tissue response. With deep burns, there may be a clear-cut area of full-thickness skin necrosis that is irreversible. Surrounding this area is usually an area of ischemia. Tissue in this zone may survive or die, depending on the preservation of blood flow. Infection, exposure, and dehydration may promote ischemia, resulting in progression of the area of ischemia into necrosis. Surrounding the ischemia zone is usually an area of hyperemia. Increased blood flow in this zone is promoted by numerous mediators that are liberated from the injured tissues.

**Clinical Aspects of Burns and Diagnosis of Burn Depth**

Burn wounds must be inspected closely and evaluated carefully. An accurate estimation of the depth of skin injury requires removal of devitalized tissue or debridement. This procedure usually is painful for the patient, and adequate analgesia/analgesics are required. In many cases, such as when peeling away a blister, anxiety is as prevalent a factor as the actual physical pain.

Following debridement, careful observation of the wound surface will enable the clinician to estimate the depth of the burn. General characteristics of burn wounds are shown in the Table, and examples of typical burn wounds are depicted in Figures 2 through 4.

During examination of the wounds, TBSA of skin covered by partial- and full-thickness burns must be estimated. Figure 6 can be used as a guide to estimate the sur-

### TABLE. General Characteristics of Burn Wounds

<table>
<thead>
<tr>
<th>TYPE OF BURN</th>
<th>PHYSICAL CHARACTERISTICS</th>
<th>SUBJECTIVE FINDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-degree</td>
<td>• Red</td>
<td>• Painful</td>
</tr>
<tr>
<td></td>
<td>• Dry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No epidermal sloughing or blisters</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Blanches with pressure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sensate</td>
<td></td>
</tr>
<tr>
<td>Second-degree (partial-thickness)</td>
<td>• Epidermal sloughing or blisters</td>
<td>• Painful</td>
</tr>
<tr>
<td></td>
<td>• Pink-pale pink</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sensate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Blanches with pressure</td>
<td></td>
</tr>
<tr>
<td>Third-degree (full-thickness)</td>
<td>• White/mottled/charred</td>
<td>• Relatively nonpainful</td>
</tr>
<tr>
<td></td>
<td>• Dry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• May be firm/leathery</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Insensate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No blanching</td>
<td></td>
</tr>
</tbody>
</table>
face area. The head is relatively larger and the legs relatively smaller in surface area for children compared with adults. A helpful rule is that the palm of the hand of the patient, including the area of the digits, is approximately 1% of the body surface area. Areas of first-degree burn are not included in the calculation of the TBSA of burn because although these injuries are painful, they are associated with negligible morbidity.

National guidelines suggest that a burn covering 10% or more of the TBSA of a child is a critical burn. These patients should be managed in a burn unit where they can receive specialized expertise from both physicians and nurses. In addition, significant burns of the face, hands, genitalia, feet, or across the joints are categorized as serious, and patients who have these burns should be considered for transfer to or consultation with a burn center. Because many trivial burns of these body areas can be managed by non-burn physicians, clinical judgment is indicated.

**Management**

The primary steps in treatment of the minor burn are to: 1) debride devitalized tissue, 2) evaluate the wounds for surface area and depth of injury, and 3) make a wound care plan. Small isolated blisters may be left intact, although blister fluid has been shown to contain mediators such as thromboxanes, which can promote dermal ischemia that results in progression of the burn depth. Other mediators may promote inflammation, may suppress epithelial and fibroblast growth, and may inhibit function of immune cells. Finally, blister fluid is an excellent culture medium for bacteria. We generally debride any blister that is greater than several inches in diameter, but this is a personal or institutional choice.

**INITIAL TREATMENT**

Shallow or superficial partial-thickness burns that are limited in extent (in general, up to 3% of the TBSA) can be treated with a semi-occlusive dressing, such as Xeroform™ gauze. Such wounds should be pink and moist and exhibit good blanching, which indicates good capillary blood flow. The important principle is to place the gauze dressing on a clean, debrided wound bed that is free of loose, devitalized tissue. Outer layers of dry gauze dressing then are applied because the impregnated gauze offers little barrier to moisture evaporation, and the wound may dehydrate. The outer gauze layers also will draw secretions away from the wound bed (“wick” them away), yet keep the wound surface appropriately moist. Once the wounds are covered, pain largely will be controlled.

Wounds that are more extensive in surface area, that have poor blanching, or that are obviously full-thickness generally are treated with a topical antimicrobial agent, such as silver sulfadiazine, as will be discussed later.

**ELEVATION OF EXTREMITIES**

If an extremity is involved, directions to the patient and family should include immobility and elevation of the affected extremity as

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**FIGURE 6.** The “Rule of Nines” is used to determine total body surface area (TBSA) of injury. Only areas of partial- and full-thickness injury are included in the estimate. Compared with an adult, the head of a child is relatively larger in percent surface area and the lower extremities are relatively smaller.
much as possible. Failure to elevate the injured extremity will result in edema, which may compromise blood flow to already ischemic areas of the burn wound. This will result in progression of wound depth and may increase the chance for infection, which will decrease the chance of spontaneous healing. Because elevation of a young child’s extremity can be difficult to achieve at home and this is such an important modality of treatment, some children may be admitted to the hospital for 1 or 2 days simply to ensure the continuous elevation. Although this may appear not to be cost-effective, the alternative is a potentially infected wound that may require parenteral antibiotics and prolonged wound care as well as possible progression of the depth of the wound.

A partial-thickness wound that is completely capable of healing can progress to full-thickness in depth when the wound is compromised by dessication, edema, and infection. Patients who have circumferential burns of the extremities should be admitted to the hospital to be observed for the development of compartment syndrome, which can compromise circulation to the entire extremity. Incision of the burned skin (escharotomy) is the treatment for compartment syndrome.

**FLUIDS**

Patients who have burns covering 15% of the body or greater usually require parenteral fluids. This is particularly true for children because their insensible fluid losses are higher than those for adults proportionate to their body weight. Children also frequently fail to ingest sufficient fluids because of pain, anxiety, and the depressing effects of narcotics on the sensorium and gastrointestinal tract.

Patients who have 20% body surface burns or greater experience complex fluid shifts, including systemic-wide extravasation of fluids into unburned tissues. This effect, coupled with increased evaporation of water through the burn wound, will produce “burn shock.” The resultant intravascular hypovolemia can produce ischemia to body organs, lactic acidosis, and eventual cardiovascular collapse. Therefore, intravenous fluid resuscitation is essential.

The standard “burn formula” generally used for children is derived from the “Parkland Formula” that was developed for adults in the 1960s. This formula provides an estimation of fluid requirements during the first 24 hours following burn injury and is as follows:

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Estimated Fluid Volume = 3 × body weight (kg) × % TBSA burn + standard pediatric maintenance fluids
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For example, a child weighing 10 kg who sustained partial- and full-thickness burns over 30% of the body surface area would be estimated to require 1,900 mL of fluid for the initial 24 hours (3 × 10 × 30 + 1,000). This fluid generally is provided as normal saline or Ringers lactate solution. Provision of 5% dextrose in the fluids should be considered for infants, although this can produce hyperglycemia if the patient is provided with enteral nutrition. Colloids should be avoided in the acute resuscitation period unless serum albumin falls below 1.7 g/dL. This is because the fluid leaking from capillaries contains proteins, and administering protein to the patient may exacerbate tissue edema as protein extravasating into extravascular tissues draws more fluid from the intravascular compartment.

The patient is resuscitated carefully to maintain a urinary output of 1 mL/kg per hour. This urinary output is lower than generally desired in pediatric patients, but it is acceptable in the case of burn injury. Providing fluid amounts that result in a greater urinary output than this guide will increase wound and whole body edema because increased hydrostatic pressure in the presence of lower osmotic pressure (from protein losses) exacerbates fluid shifts. Patients who have moderate and major burns can suffer respiratory compromise as fluids shift into the lung tissues during the acute period when capillary leakage is high. Every effort should be made to monitor the child as closely as possible to avoid over- and underhydration during and after resuscitation. Central venous pressure monitoring frequently is useful in guiding fluid therapy, but pulmonary artery catheters do not generate useful additional information in most patients. Because blood flow may be decreased to tissues, subcutaneous or intramuscular medications should be avoided.

**NUTRITIONAL SUPPORT**

Nutritional support is very important for patients who have major burns. The catabolic response after a burn injury may be severe, and the basal metabolic rate may increase to more than twice the baseline. There is no easy way to predict metabolic demands following burns. In general, the child’s baseline caloric needs should be determined by using standard charts. As a rough rule, the metabolic expenditure will increase in proportion to the burn injury, and a child who has burns over 50% TBSA will require at least a 50% increase in the basal level of calories. Increased protein administration is important to help control loss of muscle mass. Approximately 20% of administered calories should be in the form of protein. There is recent evidence that high fat intake may be deleterious because fatty acids, particularly in the oxidized form, are inflammatory to cells and tissues. Systemic oxidants are elevated in burn patients, and endogenous antioxidants are low, resulting in peroxidation of lipids on cell membranes and in plasma. Some burn centers are studying the administration of high concentrations of exogenous antioxidants such as ascorbic acid.

**ANTIMICROBIAL AGENTS**

Extensive burn wounds are treated initially with topical antimicrobial agents to control bacterial proliferation. This is accompanied by once- or twice-daily dressing changes, wound debridements, and repeated application of the topical agent. The standard topical agent used in the United States is silver sulfadiazine, a soothing cream. It is spread on the wound and covered with dry gauze dressings. Side effects of silver sulfadiazine are minimal, but it should not be used if the patient has a
known sulfa drug allergy. It has been taught that the drug induces leukopenia, but this effect never has been documented in a controlled trial, and it is more likely an effect of the burn on leukocyte margination and sequestration in tissue beds. Silver sulfadiazine is most effective against Gram-positive organisms and is relatively ineffective against Pseudomonas sp. If the wounds develop greenish drainage or a sweet smell, P aeruginosa colonization or infection should be suspected, although other Gram-negative pathogens now are common in burn wounds. Mafenide acetate cream will provide better coverage against pseudomonal and other Gram-negative species, but it is painful on application because it is hyperosmolar, and if patients have extensive wounds covered with mafenide acetate, metabolic acidosis may develop.

Enzymatic debridering preparations have proven useful in the treatment of burns. These agents accelerate the removal of necrotic tissue, which permits the epithelialization process to proceed more rapidly. Debriding procedures typically are less painful with the use of enzymatic treatment because wound debris is liquified gradually and separates more easily from the wound surface. Enzymatic agents currently available include collagenase and a papain-urea preparation. These agents are not inexpensive, which may be a consideration.

Most deep partial-thickness burns eventually heal by epithelialization, which begins in the hair follicles that remain in the dermis (Fig. 7). These emerging epithelial “buds” eventually grow together to close the wound unless infection supervenes. Full-thickness wounds are characterized by destruction of hair follicles, and these wounds must be closed by skin grafting.

The initial use of systemic antibiotics to treat burns no longer is indicated. Several trials have shown that such practice does not protect against wound infections and may contribute to the development of resistant organisms in the wound and organs.

Fever is frequent in burned children and adults. The burned skin is a potent source of mediators that produce fever, primarily interleukin-1. Every fever spike in a burned patient does not demand an extensive evaluation with blood cultures and other diagnostic modalities; careful studies in both children and adults have shown that fevers are unrelated to infections after burn injury. The wounds should be followed closely because they most frequently are the source of an infection. Evidence of cellulitis, increased drainage, or discoloration of wounds suggests the need for systemic antibiotics. Bacteremias are uncommon in small burns.

Electrical Burns
Children rarely are exposed to high-voltage electric shock (usually defined as 1,000 volts or greater); most electrical burns in children are from household current. The most severe burns occur when the skin is exposed directly to electric wires, such as frayed electrical cords. The passage of current through tissues can generate intense heat and produce deep injuries. Fortunately, the injuries produced by house current usually are limited in depth and extent.

Frequently, a child will insert a metal object into an electrical outlet and produce a short. The resultant arc and electric flash usually produce superficial burns, typically to the hands and fingers. If the heat is intense, small areas of full-thickness skin loss can occur. Deeper injuries to nerves and tendons are rare via this mechanism.

One of the worst injuries that a child can incur from electric current is the burn to the lips from inserting a live electric cord into the mouth. These burns can extend entirely through the lip and the oral mucosa and can require plastic reconstructive surgery. The acute danger is for the necrotic zone to extend into the labial artery, which supplies the lips. When this artery erodes during the sloughing of necrotic tissue, bleeding can be severe and sudden. We have provided care for one child who bled twice from the lip following this type of injury. The spurting of arterial blood can be frightening, and the parents should be instructed on how to occlude the vessel by pinching the tissues with the fingers. If the parents appear to be unreliable, admission may be indicated simply to watch for hemorrhage, which can occur as late as 1 week following the burn.

The word “electrocution” refers to death resulting from the flow of electric current. Such cases are fortunately rare among children. However, the cardiac electrical system is particularly sensitive to the 60-cycle frequency of household alternating current, and ventricular fibrillation may occur even with these low voltages. Frank myocardial “injury” produced by electric current appears to be rare, and the custom of admitting patients for cardiac observation who have been shocked from household current does not seem to be necessary in the experience of most clinicians who treat burns.

Long-term Effects of Burn Injury
Many patients will develop scarring and contractures as the result of

FIGURE 7. These deep partial-thickness wounds are healing by growth of new epithelium from the deep skin appendages, primarily the hair follicles. These epidermal “buds” result from proliferation of basal cells, which line the appendages. The small islands eventually will grow together to form an epithelialized wound.
burn injuries. Hypertrophic scarring refers to the development of thickened, raised skin (Fig. 8). Scarring may be characterized by contractures of joints. In general, children scar worse than adults, and patients who have darker skin color tend to develop worse scarring. Wounds that heal spontaneously without the need for grafting still may leave scars. In general, wounds that require 3 weeks for healing are at high risk for scar formation.

Continuous wearing of pressure garments for up to 1 year after healing has been shown to help limit the progression of hypertrophic scarring. These garments must be worn nearly 24 hours a day to be effective. Various commercial suppliers can provide these garments, which generally are prescribed by a burn clinician. The family or parents may require steady encouragement by the pediatrician to maintain use of the garments.

Adequate support for burn victims is important. The rehabilitation process is dynamic and incorporates both physical and emotional adaptations. Physical and occupational therapy may be required for many months as scar tissue matures and contractures develop. Psychological support may be of benefit for years as the child matures and experiences new social situations. Many burn centers offer support programs in which burn patients and their families have the opportunity to discuss their concerns and share their experiences and feelings. Therapeutic recreational programs such as camps and day trips offer opportunities to associate with others who share these traumatic experiences. Professional counseling during these sessions is also helpful.

**SUGGESTED READING**


**FIGURE 8.** Severe hypertrophic scarring resulted from deep partial-thickness burns to the face in this child. In general, wounds that require 3 weeks or longer to heal tend to result in significant hypertrophic scar. Scarring also is worse in children and in dark-skinned individuals for reasons that are unknown.