# 10. Burns

| Key Concepts: | |
|---|---|
| | 1. Prevent hypothermia<br>2. Pain management<br>3. Burn surface area estimate<br>4. Cover wound<br>5. Fluid infusion: Parkland Formula<br>6. Enteric nutrition support<br>7. Debridement with anesthesia or sedation<br>8. Full-thickness skin burn resection plus graft<br>9. Initiate rehabilitation early |

When a burn injury to a child is associated with an explosion, the mortality risk increases. Clinical management of fluid volume resuscitation is a challenge because of interdependent factors:

- hypovolemic shock from the explosion injury,
- the need for fluid replacement following the burn injury, and
- the inflammatory response to the over-pressure wave.

In the absence of a sophisticated burn center, simple guidelines are essential to increase the potential for survival even with a burn of less than 30% total body surface area.

With an explosion injury, also suspect an *inhalation injury.* The presence of the following conditions and physiologic findings are associated with an inhalation injury:

- Explosion within a closed space,
- Cardiopulmonary resuscitation required at the scene of injury,
- Respiratory distress,
- Voice change,
- Singed nasal hair, and
- Elevated carbon monoxide blood level.

Confirm the diagnosis of inhalation injury after endotracheal intubation with fiber optic bronchoscopy. When inhalation injury is present, carbonaceous sputum and trachea-bronchitis is present. Inhalation injury to the pulmonary parenchyma complicates oxygenation, It also further complicates the management challenges related to the increased fluid requirements for burn management that may lead to pulmonary insufficiency (See the Thoracic Injury Section).

### Prevent Hypothermia

Prepare the resuscitation bay to deal with hypothermia before the child arrives, and be confident that hypothermia is manageable. Remove all of the clothing from the child to assess the injury. It is important to maintenance the core body temperature between 36.5° to 37.5° C to prevent hypothermia and acidosis. Simple maneuvers to warm the child to enhance survival include:

- Wrap the child in clean sheets or saran wrap,
- Cover the head,
- Apply a Bair Hugger device,
- Use only a warm solution to debride the injury,
- Expose the child to heat lamps, if available,
- Warm the inspired air from the ventilator, and
- Increase the ambient room temperature to 40° C, even when the outside temperature is 45° C.

**Assess the Burn**

See Figure 10-1 for anatomy of the skin.

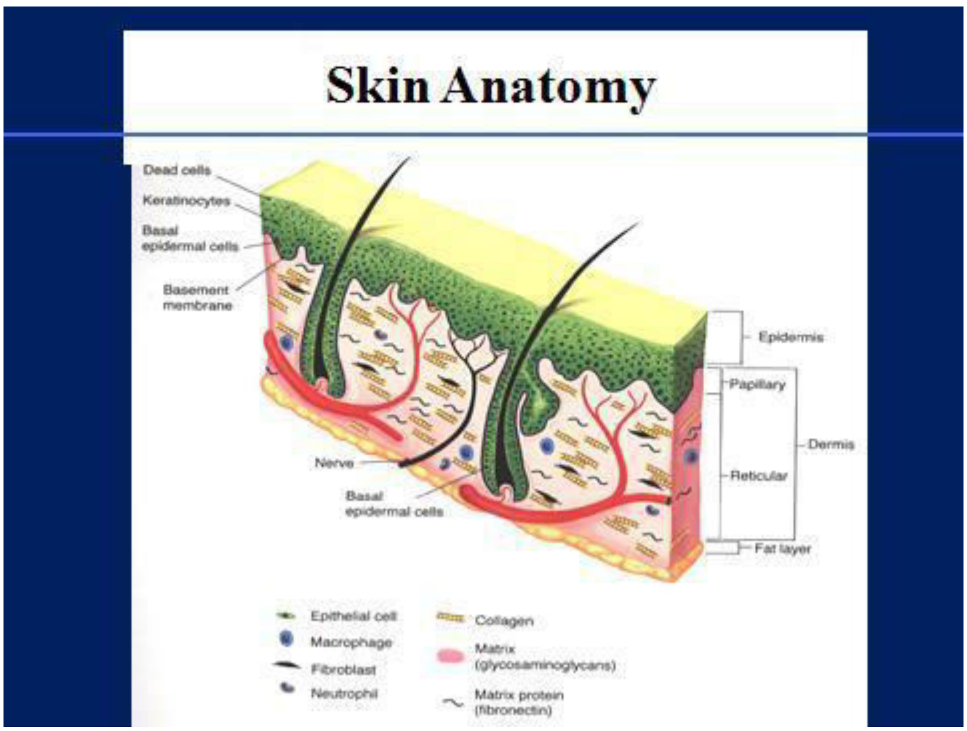
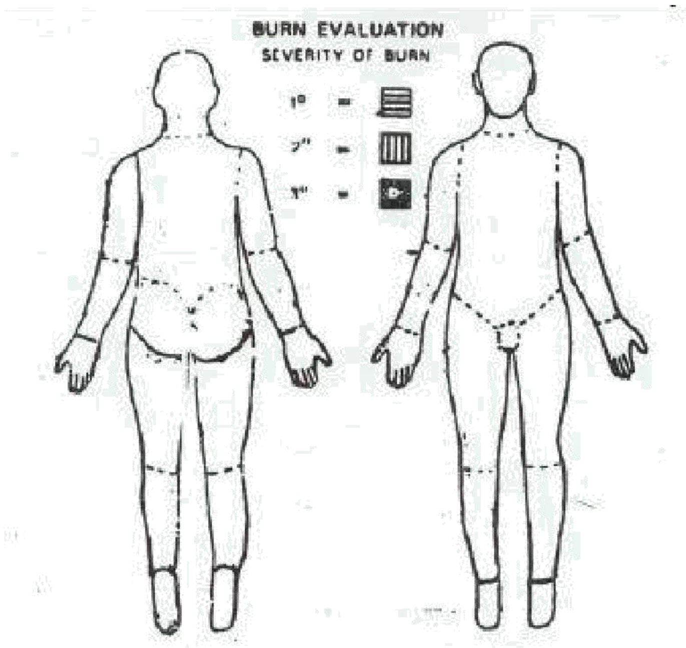



Figure 10-1. Anatomy of the skin.
Courtesy of Martin Eichelberger, MD, Children's National Medical Center, Washington, DC

Assess the total body surface area affected using the Lund-Browder chart (Figure 10-2). A calculator program and guidelines for use of the Lund-Browder chart are available at www.sagediagram.com




| Location | Age | | | | Percent burned | | |
|---|---|---|---|---|---|---|---|
| | 0-1 yrs | 1-4 yrs | 5-9 yrs | 10-15 yrs | PT (2°) | FT (3°) | Total |
| Head | 19 | 17 | 13 | 10 | | | |
| Neck | 2 | 2 | 2 | 2 | | | |
| Ant. trunk | 13 | 13 | 13 | 13 | | | |
| Post. trunk | 13 | 13 | 13 | 13 | | | |
| R buttock | 2.5 | 2.5 | 2.5 | 2.5 | | | |
| L buttock | 2.5 | 2.5 | 2.5 | 2.5 | | | |
| Genitalia | 1 | 1 | 1 | 1 | | | |
| R upper arm | 4 | 4 | 4 | 4 | | | |
| L upper arm | 4 | 4 | 4 | 4 | | | |
| R lower arm | 3 | 3 | 3 | 3 | | | |
| L lower arm | 3 | 3 | 3 | 3 | | | |
| R hand | 2.5 | 2.5 | 2.5 | 2.5 | | | |
| L hand | 2.5 | 2.5 | 2.5 | 2.5 | | | |
| R thigh | 5.5 | 6.5 | 8.5 | 9.5 | | | |
| L thigh | 5.5 | 6.5 | 8.5 | 9.5 | | | |
| R leg | 5 | 5 | 5.5 | 7 | | | |
| L leg | 5 | 5 | 5.5 | 7 | | | |
| R foot | 3.5 | 3.5 | 3.5 | 3.5 | | | |
| L foot | 3.5 | 3.5 | 3.5 | 3.5 | | | |
| | | | | TOTAL | | | |

Figure 10-2. Lund and Browder Chart to assess burn areas in each body region and then estimate the total body surface area burned (TBSA)

The total body surface area (TBSA) of the burn allows calculation that estimates the fluid requirements for burn resuscitation in the Parkland Formula for children. Additionally look for burn area that is circumferential. Re-calculate the burn depth and surface area after the child stabilizes.

Burn injury to the dermis of the skin provides helpful clinical signs to estimate the wound depth. The dermis contains three components that assist in the clinical determination of potential to healing without placement of a graft. See Table 10-1. For example, a wound that has visible follicles or hair, pink color, and pain will heal with local care. A wound with no follicles, black color, and no sensation is a full thickness burn that will require grafting. See Figures 10-3 through 10-5 provide images of burn depth. See Burn Wound Assessment for more information.

**Table 10-1. Signs for Assessment of Burn Injury Depth**

| Dermis Component | Characteristics Associated with Skin Regeneration | Characteristics Associated with Need for Grafting |
|---|---|---|
| Follicle: Contains epithelium, marks depth of the dermis involved | Superficial injury<br>Mid follicle injury | Deep follicle injury, high potential for scarring |
| Vascular integrity | Pink or Ivory color | Brown, or black |
| Nerve | Sensation present | Sensation absent |


Figure 10-3. Superficial dermal burn. Note the large bullae, the loss of superficial follicle integrity, pink under bullae. Pain is present.
Courtesy of Martin Eichelberger, MD, Children's National Medical Center, Washington, DC


Figure 10-4. Partial thickness burn. Note the bullae, pink skin, and visible follicles. Pain is present.
Courtesy of Martin Eichelberger, MD, Children's National Medical Center, Washington, DC


Figure 10-5. Full thickness burn. Note the brown, and black color. Pain is absent.
Courtesy of Martin Eichelberger, MD, Children's National Medical Center, Washington, DC

The estimated timeline for burn wound healing depends upon depth of injury to the dermis. See Table 10-2. The more superficial the injury, the faster the wound heals.

**Table 2. Estimated Healing Time by Burn Depth**

| Burn Depth | Healing Time | Potential for Scarring |
|---|---|---|
| Superficial | 0 to 7 days | Low |
| Mid partial thickness | 2 to 3 weeks | Medium |
| Deep partial thickness | 3 to 6 weeks | High |
| Full thickness | Graft needed | High |

**Fluid Resuscitation and Maintenance Fluids**

| **Treatment Priority:** | **Fluid Resuscitation Management** |
|---|---|
| Diagnosis: | Lund and Browder chart to estimate total surface burn area |
| Treatment: | Parkland Formula for fluid resuscitation<br>Weight (kg) x %Burn x **4mL/kg** = 24 hr Lactated Ringers (LR) volume<br>< 30 kg: LR + maintenance fluid (D5LR solution)<br>Give ½ total over first 8 hours post burn injury<br>Give ½ over next 16 hours<br>Urine Output: < 30 kg: 1ml/kg/hr<br>≥ 30 kg: 0.5ml/kg/h<br>After 24 hour: Maintenance Fluid (D5LR) to maintain urine output<br>Albumin 5%: 0.3 mL x weight in kg x TBSA% per 24 hr in a continuous infusion |
| Balance: | Fluid requirement needs of the brain, lung, kidney, and burn |
| Urine output: | Greater than goal: decrease LR by 1/3 per hour until goal is met<br>Less than goal: increase LR by 1/3 per hour until goal is met |

***Burn Fluid Resuscitation***

Use the Parkland Formula for fluid resuscitation of burns greater than 20% TBSA. The total volume of Lactated Ringer's solution for the first 24 hours = weight (kg) x % TBSA burn x 2−4 mL. Give one half of the total over first 8 hours; give the remaining one half over next 16 hours. Adjust rate hourly. See the Parkland formula algorithm.

Select ***4 mL/kg*** initially to calculate the formula for the child with an explosion injury. The child frequently manifests associated injuries that add challenges to the overall fluid infusion management. Excessive fluid infusion, which is unfortunately common, will worsen the edema that results as a consequence of the over-pressure wave, especially cerebral edema from brain injury. The objective is to balance the fluid infusion to accommodate the impact upon the brain, lung, and kidney, as well as burn fluid loss—a challenging requirement of clinical judgment. Begin with an estimate of 4mL/kg and evaluate the hourly urine output. Adjust the rate of fluid infusion to meet the guidelines. The balance of fluid input and urine output impacts upon the outcome of the child.

Monitor the urine output hourly. Careful maintenance of the urine output at the appropriate level is essential to prevent fluid overload, pulmonary edema, anatomic compartment syndrome, cerebral edema and for survival. The urine output target varies by weight of the child.

- For the child weighing < than 30 kg urine output should be 1.0 mL/kg/hr
- For the child weighing 30 kg or more, urine output should be 0.5 mL/kg/hr

It is prudent to only modify the Parkland formula fluid infusion and, not the maintenance fluid volume when adjustment is necessary to achieve the urine output target. If urine output is greater than the goal, reduce the infusion by a third. See example calculation. See the Parkland Formula Worksheet.

**Example: Parkland Formula Calculation using Lactated Ringers (LR) solution.**

**Child weighs 20 Kg + 20% TBSA burn**

Formula: Weight (Kg) x % burn x **4mL** = Total volume LR for 24 hrs 20 Kg x 20% x 4mL = 1600 mL LR

Give 1/2 total volume over the first 8 hrs (from time of the burn): ½ (1600) = 800 mL over 8 hrs → 100 mL/hr of LR

Give remaining 1/2 over next 16 hrs:
½ (1600) = 800 mL over 16 hrs → 50 mL/hr of LR

**Plus**

**Maintenance Fluid for 24 hours: D5 LR solution**

For a weight of 10-20 kg the child needs 40 mL + 2mL for each additional kg over 10 kg
20 kg = 40mL + (2 mL x 10) = 60 mL/hr

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**Total Fluid Infusion**:

| | | |
|---|---|---|
| Parkland Formula | = 100 mL/hr | LR |
| Maintenance Fluid | = 60 mL/hr | D5LR |

Total Fluid = 160 mL/hr

**Urine output goal** for the child weighing <30 kg is 1.0 mL/kg/hr. For the child weighing 20 kg, the urine output goal is 20 mL/hr.

If urine output is ***greater*** than goal, ***reduce*** the LR by 1/3 until goal is met.
1/3 LR x 100 mL/hr = 33 mL/hr LR
100 mL/hr – 33mL/hr = 67 mL/hr LR (adjusted rate)

Total infusion = 67 mL/hr (LR) + 60 mL/hr (D5LR) = 127mL/hr

If urine output is ***less*** than goal, ***increase*** the LR by 1/3 until goal met.
1/3 LR x 100 mL/hr = 33 mL/hr LR
100 mL/hr + 33mL/hr = 133 mL/hr

Total infusion = 133mL/hr (LR) + 60 mL/hr (D5LR) = 193mL/hr Do not adjust the maintenance fluid rate.

*Maintenance Fluids*

After 24 hours continue the D5LR especially for the child weighing less than 30 kg since dextrose is essential to prevent hypoglycemia and ketosis. The formula for hourly maintenance fluid is specific for the child's weight. See Table 10-3. Calculate the maintenance fluid using the formula to identify the hourly maintenance fluid to infuse.

**Table 10-3. Maintenance Fluid Volume Formula**

| Child Weight | Volume per Kg | Example Calculation |
|---|---|---|
| 1-10 kg | 4 mL/kg/hr | 10 kg child: 4mL(10kg) = 40cc/hr |
| 10-20 kg | 4 mL/kg/hr + 2 mL for each kg between 10 and 20 kg | 14 kg child: 40mL + (2mL x 4kg) = 48cc/hr |
| 20-30 kg | 4 mL/kg/hr + 2 mL/kg for each kg between 10 and 20 kg + 1 mL/kg for each kg > 20 kg | 28 kg child: 40 mL + (2 mL x 10 kg) + (8 mL x 8 kg) = 68 mL/hr |

Continue to monitor the child's urine output every hour. Maintaining the urine output at the appropriate level is essential to prevent fluid overload, pulmonary edema, anatomic compartment syndrome and for survival.

In the second 24 hour period of care adjust the fluid intake by infusion of D5 Lactated Ringer's solution at an IV rate to maintain appropriate urine output. Also, add colloid as Albumin 5%: 0.3 mL x weight in kg x TBSA%/24 hours as a continuous infusion. Monitor urine output. This will reduce the edema and reduce the need for crystalloid infusion.

**Damage Control Surgery**

Wound management follows damage control resuscitation. Debride the burn during general anesthesia. Warm water (essential to prevent hypothermia), a chlorhexidine solution to clean the wound, scrub brush, gauze, and a laparotomy pad are useful to debride the bullous or sloughing skin. If a burn to head occurs, shave the scalp because the burn is commonly larger than it appears. It is prudent to re-calculate the TBSA after each debridement.

The child needs aggressive pain management. Monitor the pain level and provide analgesia around the clock. Morphine or methadone is used to manage severe pain. Less severe pain is treated with a non-opioid drug. Benzodiazepines may be prescribed for anxiety. Debridement and dressing changes with sedation and analgesia help prevent the child from anticipating painful procedures. See Anesthesia and Pain Management in Section 3 and Burn Pain Guidelines.

Liberal use of burn escharotomy prevents impairment of circulation, ventilation and compartment syndrome of the abdomen or extremity (Figures 10-6 and 10-7). Significant blood loss is associated with the tangential excision of the skin burn. Limit the intra-operative exsanguination by use of a tourniquet for the extremity, carefully monitoring the blood loss for replacement, or applying direct pressure with warm lap pads soaked in epinephrine. Work effectively with the anesthesiologist to judge when the child's physiology indicates a need to stop the procedure. Limit blood loss to one-half of the blood volume, stop the surgical procedure to allow resuscitation and plan to return another day when the child is more physiologically stable. Remember that hypothermia associated with extensive blood loss during surgery can result in acidosis, coagulopathy and refractory hypotension − the *lethal triad*.

Figure 10-6. Excharotomy of the lower extremities.
Courtesy of Kevin K. Chung,M.D, Uniform Services of the Health Sciences

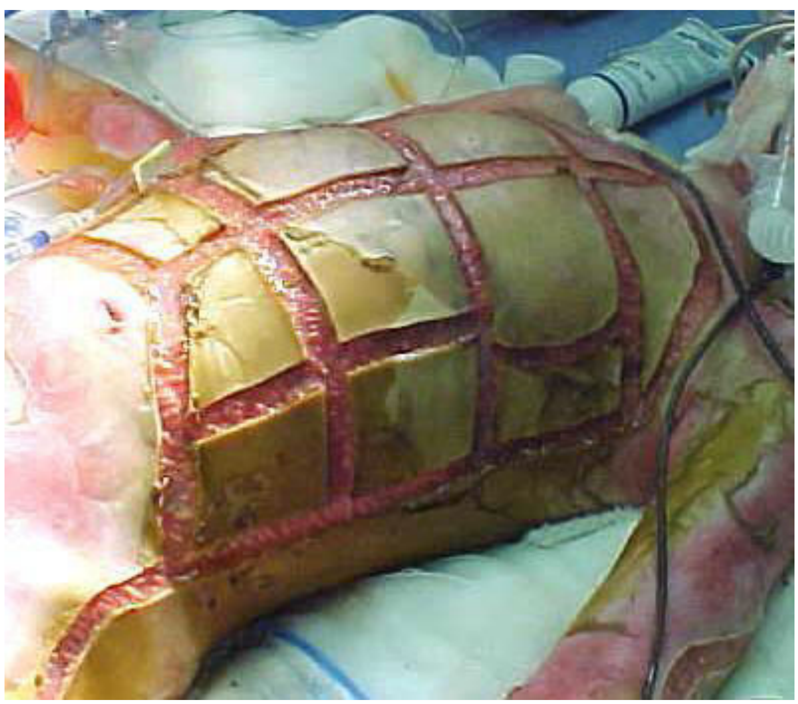

Figure 10-7. Escharotomy of the thorax
Courtesy of Rob Sheridan, M.D., Shriners Hospital, Harvard University, Boston, MA

## Wound Management

Application of gauze with silver sulfadiazine is simple (Figures 10-8). When possible, a daily change should occur in the operating room to remove the silvadene, to further debride the skin, to fully evaluate the status of the burn wound and to prevent pain.


Figure 10-8. Application of silver sulfadiazine to a partial thickness burn.
Courtesy of Martin Eichelberger, MD, Children's National Medical Center, Washington, DC

Mafenide acetate (11%) cream (Sulfamylon), a good agent to penetrate cartilage, is useful to apply to a deep ear burn twice a day. It is not well tolerated for general application to the skin since it can result in pain, and it is a carbonic anhydrase inhibitor, which causes metabolic acidosis due to alkaline diuresis. See Burn Care Treatment Options.

Use Aveno cream to moisturize the burn skin of the face. Avoid Bacitracin because it accumulates on the skin surface, is difficult to remove, and complicates the nursing care. Infection of a facial wound is rare since the face has such a generous blood supply.

For an eye burn, assess corneal injury with a Wood's lamp examination, and apply erythromycin ophthalmic ointment into the eye four times each day if injury to the cornea is present.

Debridement of dead skin and coverage of the area of burn with temporary material is useful to reduce the physiological response to the burn. Xeroform gauze and a clean dressing is practical to seal the wound and reduce fluid loss from the skin until development of a definitive plan . After sharp debridement, gauze impregnated with silver sulfadiazine is best until the wound lacks ischemic tissue. Subsequently, application of porcine collagen, acellular dermal matrix, or cadaver skin replaces the injured skin until a clean, pink, granulation tissue is evident (Figure 10-9). Skin graft then is indicated for final would closure of deep partial thickness and full thickness burns. A vacuum-assisted closure device is useful for temporary wound closure or to maintain placement of the new skin graft (Figure 10-10). See Burn Graft Guidelines.

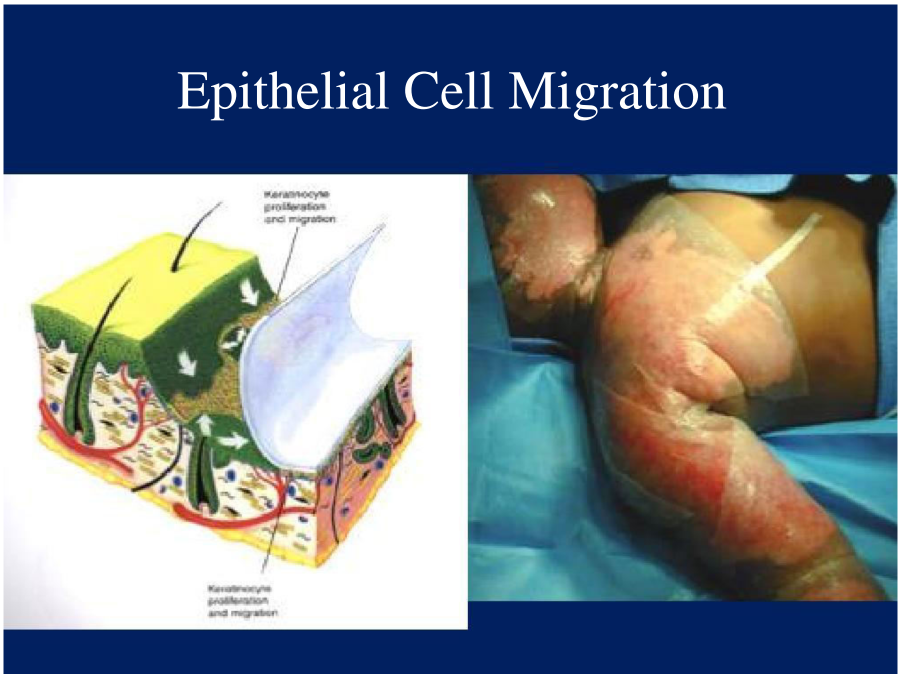


Figure 10-9. A temporary cover over the burn area can stimulate epithelialization of the wound.
Martin Eichelberger, MD, Children's National Medical Center, Washington, DC

Figure 10-10. Vacuum-assisted closure over the burn dressing.
Courtesy of Martin R. Eichelberger, MD, Children's National Medical Center, Washington, D.C.

## Electrical and Chemical Burn Mechanisms

Electrical and chemical burns may sometimes be experienced, even with explosion injuries. See Electrical Burn Guidelines and Chemical Burn Guidelines.

## Nutrition Considerations

The child commonly manifests a hypermetabolic, physiological response to a burn as a consequence of increased catabolic hormones (catecholamines and cortisol) and decreased anabolic hormones (growth hormone and testosterone). Hypermetabolism is characterized by increase in basal energy expenditure, muscle protein catabolism, dynamic circulation, and release of substrates from protein and fat stores. The result is muscle wasting and weight loss that can last for months after severe burn injury. Aggressive nutritional support, *B*-blockade of the cardiovascular affect, and oxandrolone can mitigate the muscle abnormality (Wolf, Edelman, & Kemalyan, 2006; Herndon, Hart, & Wolf, 2001). See Nutrition Section and Burn Nutrition Guidelines.

## Rehabilitation Considerations

Rehabilitation begins upon admission to the care facility, and it is an essential component of the overall success of burn treatment. Physical and occupational therapy mitigate burn wound contraction and prevent severe physical restrictions. After wound coverage is complete, resumption of mobility is the priority of clinical management. Application of a splint, elevation of the injured extremity, early mobilization of the child, and passive range of motion establish the foundation for good rehabilitation. Long-term clinical management includes continued range of motion and pliability of the scar. Contemporary scar treatment includes use of a compression garment, massage, gentle stretch of the extremity, injection of kenalog, and application of a skin moisturizer, such as Aveno cream.