Bibliography

Cold Injuries

1. Castellani JW, Young AJ, Ducharme MB, et al. American College of Sports Medicine position stand: prevention of cold injuries during exercise. [Review]. *Med Sci Sports Exer* 2006;38(11):2012-2029.

2. Hildebrand F, Giannoudis PV, van Griensven M, et al. Pathophysiologic changes and effects of hypothermia on outcome in elective surgery and trauma patients. *Am J Surg* 2004;187(3):363-371.

3. Konstantinidis A, Inaba K, Dubose J, et al. The impact of nontherapeutic hypothermia on outcomes after severe traumatic brain injury. *J Trauma* 2011;71(6):1627-1631.

4. Larach MG. Accidental hypothermia. *Lancet* 1995; 345(8948):493-498. 5. Mallett ML. Accidental hypothermia. *QJM* 2002;95(12): 775-785.

Heat Injuries

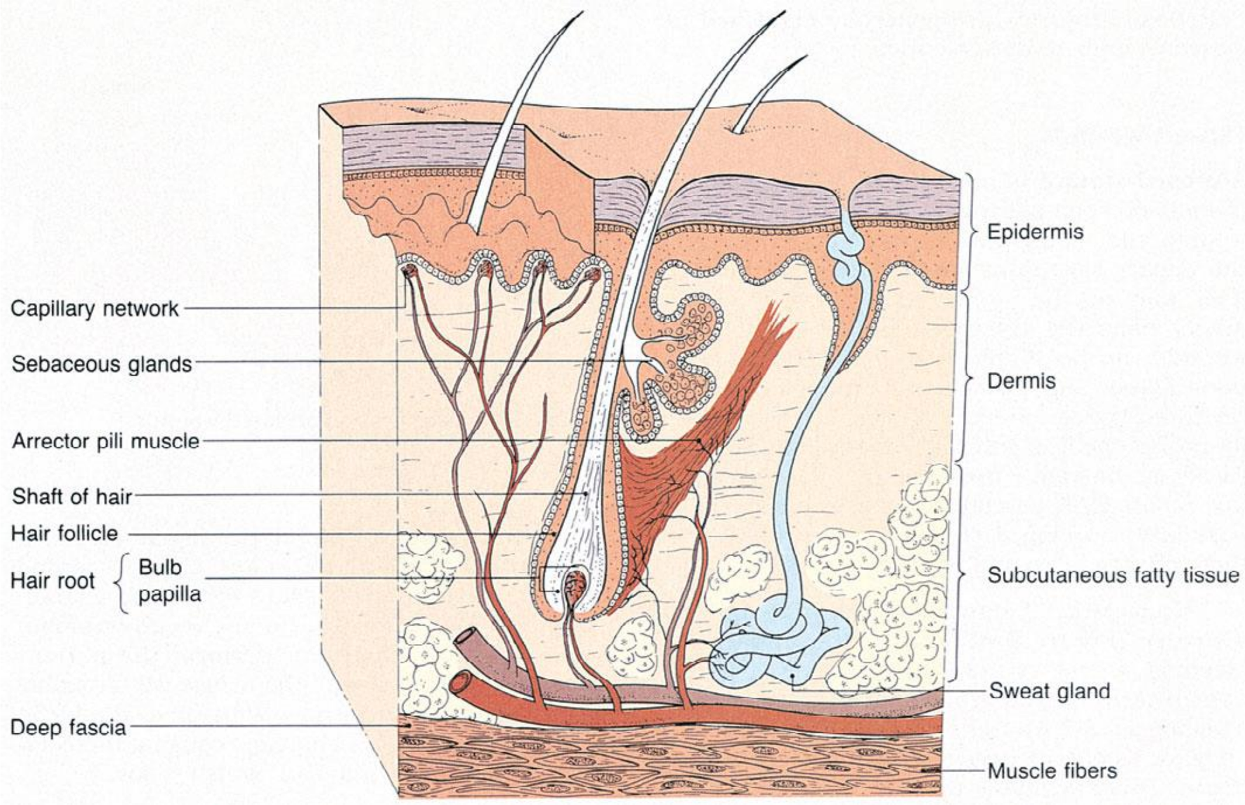
1. Glazer JL. Management of heatstroke and heat exhaustion. *Am Fam Physician* 2005;71(11):2133-2140.

2. Yeo TP. Heat stroke: a comprehensive review. *AACN Clin Issues* 2004;15(2):280-293.

Anatomy and Pathophysiology

The Skin

The largest organ of the body, the skin, is made up of two layers. The outer layer, which we can see on the surface, is called the *epidermis* . It serves as a barrier between the environment and our body. Underneath the thin epidermis is a thick layer of collagen connective tissue called the *dermis*. This layer contains the important sensory nerves and also the support structures such as the hair follicles, sweat glands, and oil glands (Figure -1).



Classifying Burns by Depth

Burns are characterized, based on the depth of tissue damage and skin response, **as superficial (first degree),** partial thickness (second degree), or full thickness (third degree). Superficial burns result in minor tissue damage to the outer epidermal layer only, but do cause an intense and painful inflammatory response.

The most common injury of this type is “sunburn.” Although no medical treatment is usually required, various medications can be prescribed that significantly speed healing and reduce the painful inflammatory response.

Partial-thickness burns cause damage through the epidermis and into a variable depth of the dermis. These injuries will heal (usually without scarring) because the cells lining the deeper portions of the hair follicles, and sweat glands will multiply and grow new skin for healing. Antibiotic creams or various specialized types of dressings are routinely used to treat these burns, and therefore, appropriate medical evaluation and care should be provided for patients with these injuries. Emergency care of partial-thickness burns involves cooling the burn and covering it with a clean dry dressing.

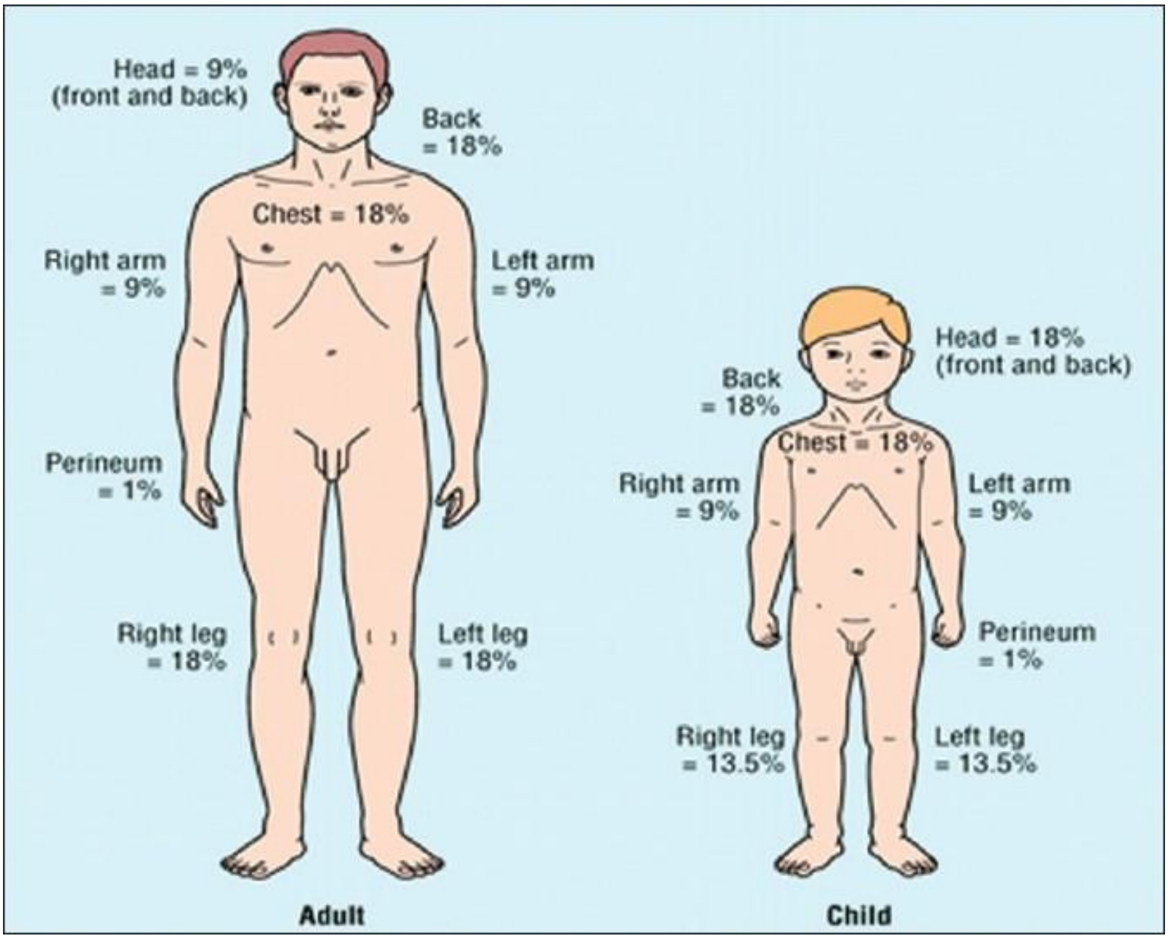
Deep Second Degree (partial thickness) Burns

Full-thickness burns cause damage to all layers of the epidermis and dermis. No more skin cell layers are left, so healing by regrowth of epidermal cells is impossible. All full-thickness burns leave scars that later may contract and limit motion of the extremity (or restrict movement of the chest wall). Deeper full-thickness burns usually result in skin protein becoming denatured and hard, forming a firm, leatherlike covering that is referred to as *eschar* .

Third Degree Burns

The burn size

is best estimated in the field using the **rule of nines** (Figure). The body is divided into areas that are either 9% or 18% of the total body surface, and by roughly drawing in the burned areas, the extent can be estimated. Only partial-thickness and full



thickness burns are used for this calculation.

For smaller or irregular burns, the size can be estimated using the palmar surface (including the fingers) of the patient'shand, which is about 1% of the total body surface area. Even small burns can be serious if they involve certain parts of the body that affect function or appearance

Point-of-Injury Care

The following are key steps in the first aid of burn patients:

Stop the burning process. Extinguish and remove burning clothing, and remove the patient from a burning vehicle or building. In an electrical injury, remove the patient from the power source, while avoiding rescuer injury. Wash chemical agents from the skin surface with copious water lavage.

Ensure airway patency, control hemorrhage, and splint fractures.

Remove all constricting articles, such as rings, bracelets, wristwatches, belts, and boots. However, do not undress the patient unless the injury has been caused by a chemical agent, in which case remove all contaminated clothing. _

Cover the patient with a clean sheet and a blanket, if appropriate, to maintain body temperature and to prevent gross contamination during transport to a treatment facility; special burn dressings are not required. Hypothermia is a complication of large surface area burns.

Establish intravenous access through unburned skin if possible, and through burned skin if necessary. Intraosseous access is also acceptable.

Primary Survey and Resuscitation of Patients with Burns

Adhere to the ABCDE's

- **A**irway management with C-spine control
- Restore **B**reathing
- Restore **C**irculation and **C**ontrol hemorrhage
- Assess **D**isability
- **E**xpose patient and control **E**nvironment

AIRWAY

Because burns can result in massive edema, the upper airway is at risk for obstruction.

How do I identify inhalation injury?

Although the larynx protects the subglottic airway from direct thermal injury, the airway is extremely susceptible to obstruction as a consequence of exposure to heat. Clinical indications of inhalation injury include:

■■ Face and/or neck burns

■■ Singeing of the eyebrows and nasal vibrissae

■■ Carbon deposits in the mouth and/or nose and carbonaceous sputum

■■ Acute inflammatory changes in the oropharynx, including erythema

■■ Hoarseness

■■ History of impaired mentation and/or confinement in a burning environment

■■ Explosion with burns to head and torso

■■ Carboxyhemoglobin level greater than 10% in a patient who was involved in a fire

Any of the above findings suggests an inhalation injury and the need for intubation.

♉ **Breathing.**

o Inhalation injury is more common in patients with extensive cutaneous burns, a history of injury in a closed space (eg, building or vehicle), facial burns, and at the extremes of age.

o Patients with major burns and/or inhalation injury require supplemental oxygen, pulse oximetry, chest radiograph and arterial blood gas measurement.

o Circumferential burns of the chest may prevent effective chest motion. If this occurs, **perform immediate thoracic escharotomy as a life-saving procedure to permit adequate chest excursion**.

o Definitive diagnosis of lower airway injury requires fiberoptic bronchoscopy.

CIRCULATION

The goal for assessing peripheral circulation in a patient with burns is to rule out *compartment syndrome*. Compartment syndrome results from an increase in the pressure inside a compartment that interferes with perfusion to the structures within that compartment.

Although a compartment pressure greater than systolic blood pressure is required to lose a pulse distal to the burn, a pressure of >30 mm Hg within the compartment may lead to muscle necrosis. Once the pulse is gone, it may be too late to save the muscle.

Signs of a compartment syndrome: increased pain with passive motion, tightness, numbness, and, eventually, decreased distal pulses. If there are concerns about a compartment syndrome, the compartment pressure is easily measured by inserting a needle connected to pressure tubing (arterial or central pressure monitor) into the compartment. If the pressure is >30 mm Hg, escharotomy is indicated.

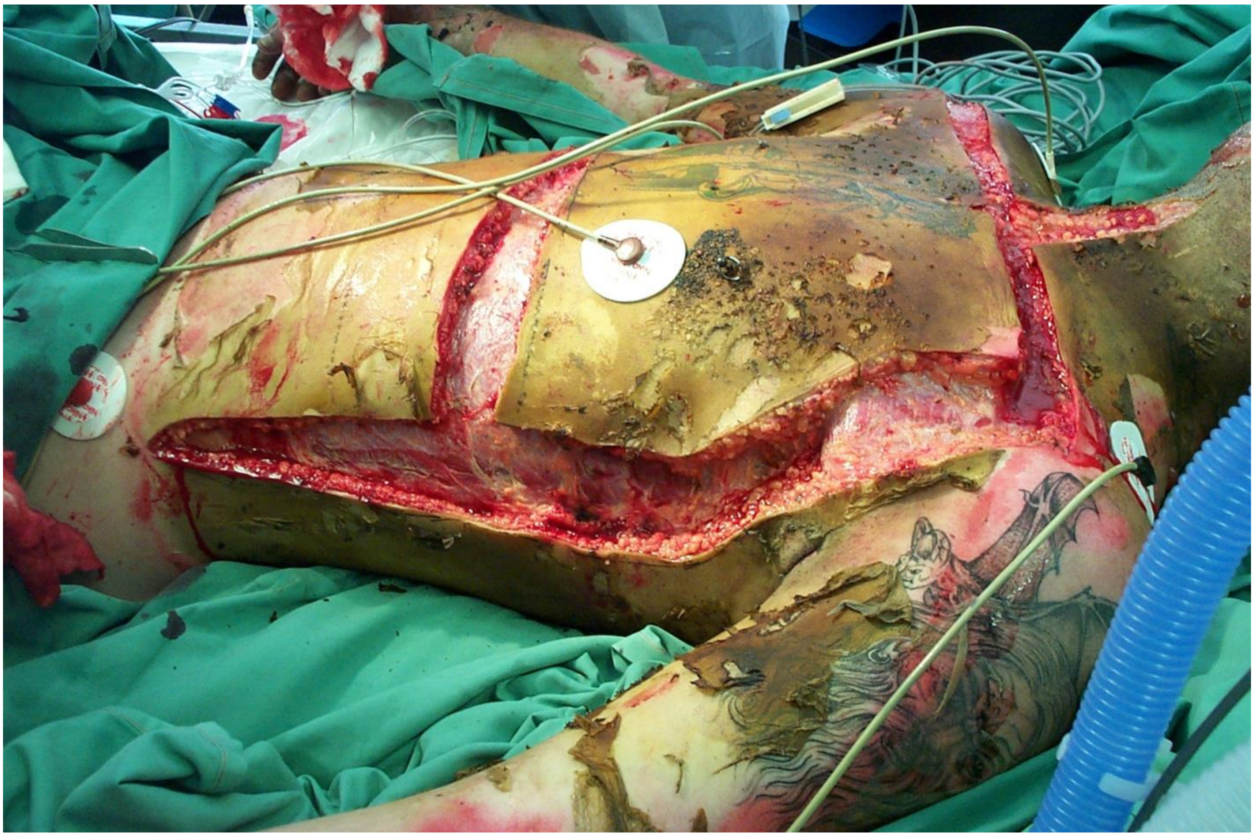
In order to maintain peripheral circulation in patients with circumferential extremity burns, the clinician should:

■■ Remove all jewelry on the patient's extremities.

■■ Assess the status of distal circulation, checking for cyanosis, impaired capillary refill, and progressive neurologic signs, such as paresthesia and deep-tissue pain. Assessment of peripheral pulses in patients with burns is best performed with a Doppler ultrasonic flow meter.

■■ Relieve circulatory compromise in a circumferentially burned limb by escharotomy, always with surgical consultation. Escharotomies usually are not needed within the first 6 hours after a burn injury.

■■ Although fasciotomy is seldom required, it may be necessary to restore circulation for patients with associated skeletal trauma, crush injury, high-voltage electrical injury, and burns involving tissue beneath the investing fascia.



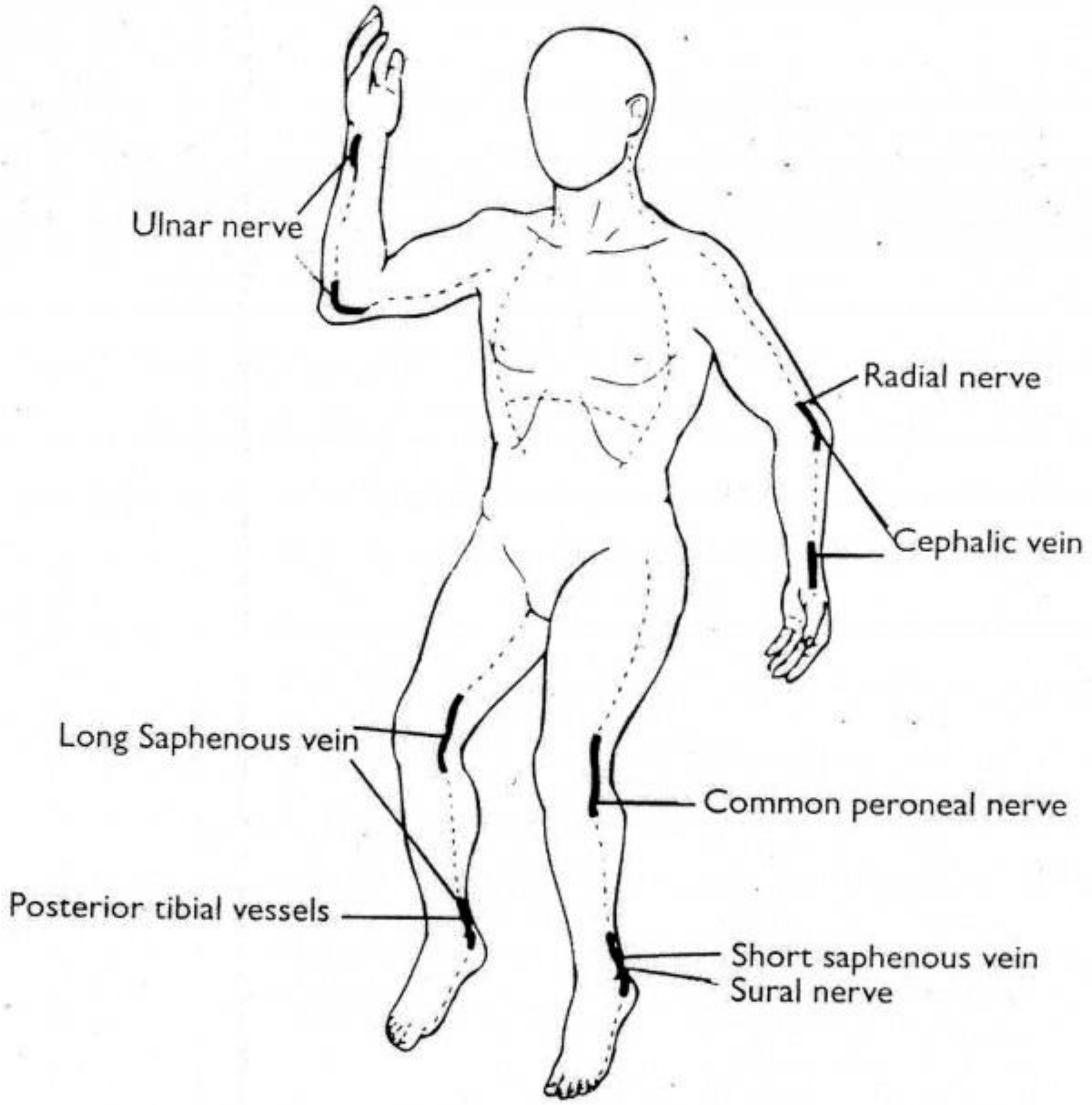


Fig. 28-1. The dashed lines indicate the preferred sites for escharotomy incisions. The bold lines in the figure indicate the importance of extending the incision over involved major joints. Incisions are made through the burned skin into the underlying subcutaneous fat using a scalpel or electrocautery. For a thoracic escharotomy, begin incision in the midclavicular lines. Continue the incision along

the anterior axillary lines down to the level of the costal margin. Extend the incision across the epigastrium as needed. For an extremity escharotomy, make the incision through the eschar along the midmedial or mid-lateral joint line.

- **DISABILITY**

Severely burned patients may be restless and anxious from hypoxemia or hypovolemia rather than pain. Altered mental stauts can be caused by poisoning of inhaled smoke.

Carbon Monoxide Poisoning .

Carbon monoxide poisoning and asphyxiation are by far the most common causes of early death associated with burn injury. When any material burns, oxygen in the air is consumed, and the fire environment should be considered to be an oxygen-deprived environment. Carbon monoxide is a by-product of combustion and is one of the numerous chemicals in common smoke. It is present in high concentrations in auto exhaust fumes and fumes from some types of home space heaters. Because it is colorless, odorless, and tasteless, its presence is virtually impossible to detect without special instruments. Carbon monoxide binds to hemoglobin (257 times stronger than oxygen), resulting in the hemoglobin being unable to transport oxygen. Patients quickly become hypoxic even in the presence of low concentrations of carbon monoxide. An alteration in level of consciousness is the predominant sign of this hypoxia. A cherry-red skin color or cyanosis is rarely present as a result of carbon monoxide poisoning and, therefore, cannot be used in the assessment of patients for carbon monoxide poisoning. Pulse oximetry will remain normal to high in the presence of carbon monoxide and cannot be used to assess patients for carbon monoxide poisoning. Some newer model pulse oximeters can specifically measure carboxyhemoglobin levels and, if available, should be used on all those who have the possibility of exposure to carbon monoxide. Death usually occurs because of either cerebral or myocardial ischemia or myocardial infarction due to progressive cardiac hypoxia. Treat patients suspected of having carbon monoxide poisoning with highflow oxygen by mask. If such a patient loses consciousness, begin advanced life support with intubation and ventilation using 100% oxygen. If a patient is simply removed from the source of the carbon monoxide and allowed to breathe fresh air, it takes up to 7 hours to reduce the carbon monoxide/hemoglobin complex to a safe level. Having the patient breathe 100% oxygen decreases this time to about 90 to 120 minutes, and use of hyperbaric oxygen (100% oxygen at 2.5 atmospheres) will decrease this time to about 30 minutes (Figure 16-8). All suspected cases of carbon monoxide poisoning or toxic inhalation should be transported to an appropriate hospital. The decision to transport the patient to a hyperbaric chamber should be made by medical direction.

Cyanide and Smoke Inhalation.

In the modern world, many items in homes and businesses are made of plastics. When combusted, many of them give off t oxic gases, which can cause significant pulmonary injury. Among the toxic components in smoke is hydrogen cyanide. It is highly toxic and causes cellular hypoxia by preventing the cell from using oxygen to generate energy to function. Studies of smoke inhalation victims have shown elevated levels of cyanide in some cases.

Chemical Burns

Thousands of different types of chemicals can cause burn injuries. Chemicals may not only injure the skin, but they also can be absorbed into the body and cause internal organ failure (especially liver and kidney damage). Volatile forms of chemicals may be inhaled and cause lung tissue damage with subsequent severe life-threatening respiratory failure. The effects of the chemical agents on the other organ systems, such as the lung or liver, may not be immediately apparent after exposure. A chemical injury frequently is deceiving in that initial skin changes may be minimal even when the injury is severe. This could lead to secondary contamination of rescuers. Minimal burns on the patient may not be obvious. As a result, you can get the chemicals on your own skin unless appropriate precautions are taken. Factors that lead to tissue damage include chemical concentration, amount, manner, and duration of skin contact, and the mechanism of action of the chemical agent. The pathological process causing the tissue damage continues until the chemical is either consumed in the damage process, detoxified by the body, or physically removed. Attempts at inactivation with specific neutralizing chemicals are dangerous because the process of neutralization may generate other chemical reactions (heat) that may worsen the injury.

Electrical Burns

Electrical burns result when a source of electrical power makes contact with a patient's body. The body can serve as a volume conductor of electrical energy, and the heat generated results in thermal injury to tissue. Different rates of heat loss from superficial and deep tissues allow for relatively normal overlying skin to coexist with deepmuscle necrosis. As such, electrical burns frequently are more serious than they appear on the body surface, and extremities, especially digits, are particularly prone to injury. In addition, the current travels inside blood vessels and nerves and thus may cause local thrombosis and nerve injury. Patients with electrical injuries frequently need fasciotomies and should be transferred to burn centers early in their course of treatment. Immediate treatment of a patient with a significant electrical burn includes attention to the airway and breathing, establishment of an intravenous line in an uninvolved extremity, ECG monitoring, and placement of an indwelling bladder catheter. Electricity may cause cardiac arrhythmias that may require chest compressions. If there are no arrhythmias within the first few hours of injury, prolonged monitoring is not necessary. Since electricity causes forced contraction of muscles, clinicians need to examine the patient for associated skeletal and muscular damage, including the possibility of spinal injuries. Rhabdomyolysis results in myoglobin release, which can cause acute renal failure. Do not wait for laboratory confirmation before instituting therapy for myoglobinuria. If the patient's urine is dark, assume that hemochromogens are in the urine. Fluid administration should be increased to ensure a urinary output of 100 mL/hr in adults or 2 mL/ kg/hr in children <30 kg.

TYPES OF COLD INJURY

Three types of cold injury are seen in trauma patients:

frostnip, frostbite, and nonfreezing injury.

Frostnip

Frostnip is the mildest form of cold injury. It is characterized by initial pain, pallor, and numbness of the affected body part. It is reversible with rewarming and does not result in tissue loss, unless the injury is repeated over many years, which causes fat pad loss or atrophy.

Frostbite

Frostbite is due to freezing of tissue with intracellular ice crystal formation, microvascular occlusion, and subsequent tissue anoxia. Some of the tissue damage also can result from reperfusion inju ry that occurs on rewarming. Frostbite is classified into first-degree, second-degree, third-degree, and fourthdegree according to depth of involvement.

1. First-degree frostbite: Hyperemia and edema without skin necrosis

2. Second-degree frostbite: Large, clear vesicle formation accompanies the hyperemia and edema with partial-thickness skin necrosis

3. Third-degree frostbite: Full-thickness and subcutaneous tissue necrosis occurs, commonly with hemorrhage vesicle formation

4. Fourth-degree frostbite: Full-thickness skin necrosis, including muscle and bone with gangrene Although the affected body part is typically initially hard, cold, white, and numb, the appearance of the lesion changes frequently during the course of treatment. In addition, the initial treatment regimen is applicable for all degrees of insult, and the initial classification is often not prognostically accurate. Hence, some authorities simply classify frostbite as superficial or deep.

Nonfreezing Injury

Nonfreezing injury is due to microvascular endothelial damage, stasis, and vascular occlusion. Trench foot or cold immersion foot (or hand) describes a nonfreezing injury of the hands or feet, typically in soldiers, sailors, and fishermen, resulting from long-term exposure to wet conditions and temperatures just above freezing (1.6°C to 10°C, or 35°F to 50°F). Although the entire foot can appear black, deep-tissue destruction may not be present. Alternating arterial vasospasm and vasodilation occur, with the affected tissue first cold and numb, then progressing to hyperemia in 24 to 48 hours. With hyperemia comes intense, painful burning and dysesthesia, as well as tissue damage characterized by edema, blistering, redness, ecchymosis, and ulcerations. Complications of local infection, cellulitis, lymphangitis, and gangrene can occur. Proper attention to foot hygiene can prevent the occurrence of most such injuries.

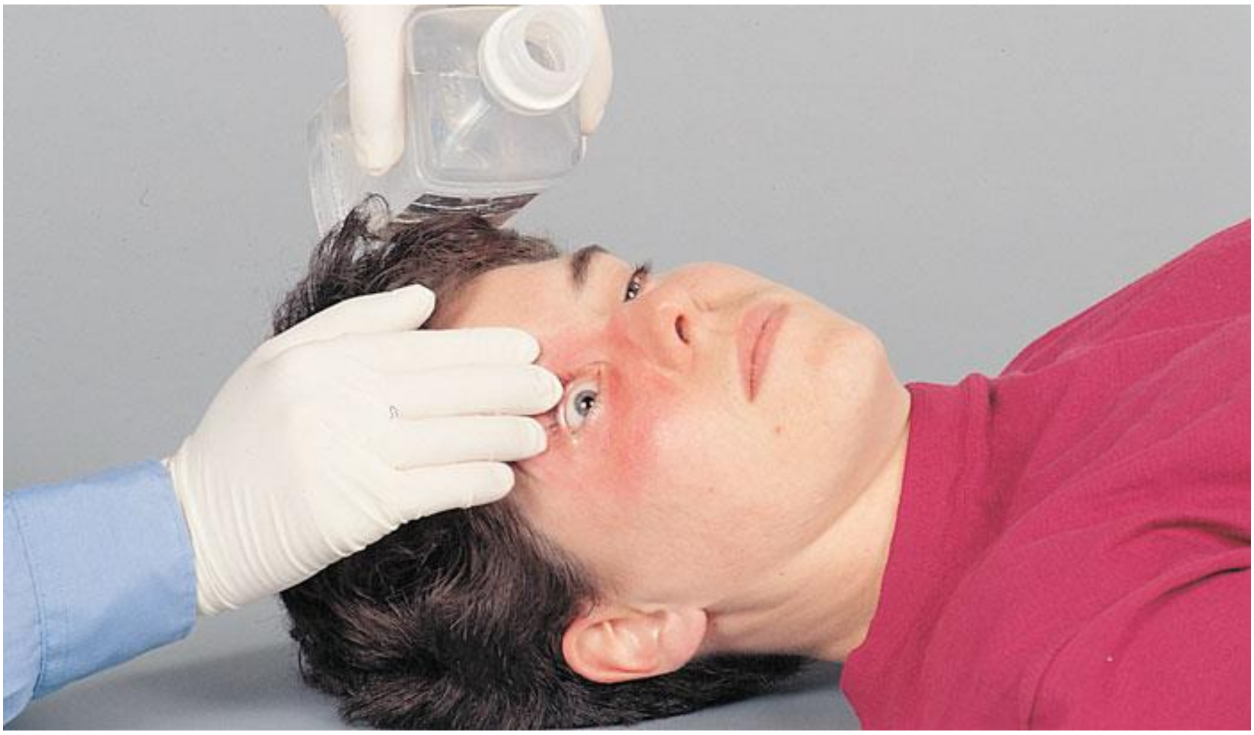
Frostbite. Frostbite is due to freezing of tissue with intracellular ice crystal formation,microvascular occlusion, and subsequent tissue anoxia. Some of the tissue damage also can result from reperfusion injury that occurs on rewarming.

MANAGEMENT OF FROSTBITE AND NONFREEZING COLD INJURIES

Treatment should be immediate to decrease the duration of tissue freezing, although rewarming should not be undertaken if there is the risk of refreezing. Constricting, damp clothing should be replaced by warm blankets, and the patient should be given hot fluids by mouth, if he or she is able to drink. Place the injured part in circulating water at a constant 40°C (104°F) until pink color and perfusion return (usually within 20 to 30 minutes). This is best accomplished in an inpatient setting in a large tank, such as a whirlpool tank. Avoid dry heat, and do not rub or massage the area. Rewarming can be extremely painful, and adequate analgesics (intravenous narcotics) are essential. Cardiac monitoring during rewarming is advised.

EYES INJURY

Irrigation of caustic chemicals in the eye is exceptionally important because irreversible damage will occur in a very short period of time (less than the transport time to get to the hospital). Irrigation of injured eyes may be difficult because of the pain associated with eye opening. However, you must begin irrigation to prevent severe and permanent damage to the corneas (Figure 16-14). Check for contact lenses or foreign bodies and, if present, remove them early during irrigation. A nasal cannula hooked to an IV bag of normal saline and placed over the bridge of the nose makes an excellent bilateral eyewash system during transport.



Estimation of Fluid Resuscitation

Needs Initiate resuscitation with LR based on the patient's weight and the burn size. Then, use the urine output as the primary index of adequacy of resuscitation (see below). It is equally important to avoid both over-resuscitation and underresuscitation.

Determine the burn size

based on the Rule of Nines

. A patient's hand (palm and fingers) is approximately 1% of the total body surface area (TBSA). Only 2nd and 3rd degree burns are included in burn size calculations.

o Overestimation is common and may lead to overresuscitation

and over-evacuation.

Estimate crystalloid needs for the first 24 hours, using the following formula:

Total Volume = (2 mL) • (% burn) • (kg weight).

_ **Half of this total volume is programmed for the first 8 hours postburn,** and half for the second 16 hours postburn:

o Hourly rate, first 8 hours postburn = (Total Volume /2) /(8h – elapsed time in hours since burn).

Assume: 40% burn, 70-kg person, time of injury 1 h ago, (no fluids received yet).

Fluid Requirements for First 24 h = 2 x 40 x 70 = 5600 ml

One half of this to be given over first 8 h = 5600/2 = 2800 ml

But one hour has elapsed, therefore hourly rate =2800 ml/7 h = 400 ml/h

These calculations are only an initial estimate.

Patients with inhalation injury, predominantly full-thickness burns, and delay in resuscitation will have higher fluid requirements.

The rate of infusion of LR must be adjusted every 1–2 hours, based on physiologic response (see below). Despite the formula, no abrupt change is made at the 8-hour mark. _

If LR is not available, use other crystalloids such as normal saline. If crystalloid supplies are severely limited, consider starting colloid at the 12-hour mark, at the rate recommended for the second 24 hours (see below). _

Children (< 30 kg) have a greater surface-to-weight ratio, and their fluid requirements are greater.

The formula for children is based on 3 cc/kg/% burn.

Resuscitation Management, First 24 Hours

On an hourly basis, reassess the patient's urine output, which is the single most important indicator of the adequacy of resuscitation.

Seek a urine output **of 30–50 mL/h in adults or 1 mL/kg/h** in children. If the urine output is less than the target for 1–2 consecutive hours, increase the LR infusion rate by about 25%. If it is greater than the target, decrease it by about 25%.

Avoid over-resuscitation, which may lead to edema-related complications (eg, compartment syndromes and pulmonary edema).

Other indices of adequate resuscitation include a decreasing base deficit, a moderate tachycardia (typically a pulse of 100 to 130 is normal in adult burn patients), and an acceptable mental status.

Diuretics are never indicated in the treatment of burn shock, except when gross pigmenturia is present (see below).

Glycosuria is common following severe thermal injury and may cause hypovolemia secondary to osmotic diuresis. Check the urine for glucose and treat hyperglycemia with IV insulin as needed.

Burn victims must be adequately immunized against tetanus and (if arrival at the burn center will take longer than 24 hours) should be treated with a 5-day course of penicillin or similar antibiotic (intravenously for large burns, orally for small ones).

ANTIBIOTICS

There is NO indication for prophylactic antibiotics in the early post-burn period.

Antibiotics should be reserved for the treatment of infection.

Analgesia

- Significant pain is present from partial thickness burns
- Unpredictable absorption from eneteral and intramuscular routes
- Intravenous Morphine sulfate (0.1 mg/kg every 1 -2 hrs)