# 8 Burn Trauma

# CASE STUDY

You are dispatched to a burn victim with the fire department. Details are sketchy as you respond to the side of a roadway in a part of town known for violence. As the fire department arrives they report a victim who was beaten and set on fire. Police are en route to the scene and arrive just before you. You notice a large crowd has grown around a man lying on the ground screaming in pain. The smell of burned flesh is in the air as you arrive at the patient's side.

Bystanders who have gathered around the victim begin to disclose the events leading up to this injury. They say a group of five men were beating and kicking the victim when one splashed the victim with fluid and then set him on fire. They state they ran over and chased the five men away and threw the victim to the ground and rolled him to put out the flames. The patient is anxious and crying out in pain. His clothes are still smoking and he is bleeding profusely from the head as you begin your assessment.

The initial/primary assessment shows a small amount of blood in the mouth but no soot or singed hair in the airway. Breathing is fast at 36 breaths/min and breath sounds are equal. The patient has a wound on the left side of his head that has a steady flow of blood coming from it. He has burns on his hands, upper chest, and back. His pulse is 130 beats/min and blood pressure is 90/60 mm Hg. You decide to move this patient to the hospital rapidly and to provide additional care en route.

1. What scene safety issues are present?
2. Approximately how much surface area is affected by the burn?
3. What is the first step in prehospital burn care?
4. Describe the priorities for assessment and initial care of your patient.
5. What is the cause of his shock?

## Introduction

Burns are a devastating injury that occur with some frequency. More than a million people in the United States are burned each year. Forty-five thousand patients require in-hospital care annually for burns. Of the 45,000, about half are admitted to specialized burn treatment centers and half to other hospitals; 3% to 5% are considered to have life-threatening injuries.

In the United Kingdom, 250,000 people are burned each year, of which 175,000 visit the accident and emergency department with burn injuries and around 13,000 are admitted to the hospital. Across the United Kingdom, about 30% of children and 40% of adults suffering burns requiring admission to the hospital are admitted to nonspecialist units. Approximately 1,000 patients per year are admitted with severe burns requiring fluid resuscitation, about half of whom are children younger than 16 years old.

Burns are also a major problem in the developing world. Over 2 million burn injuries are thought to occur each year in India (population 500 million), but this may be a substantial underestimate. Mortality in the developing world is much higher than in the developed world. For example, Nepal has about 1,700 burn deaths per year for a population of 20 million, giving it a death rate 17 times that of Britain.

The incidence of burn injuries and deaths has decreased since the advent of stricter building regulation codes, safer construction techniques, and the use of smoke detectors. Children younger than 5 years old and the elderly are at a particularly high risk to die in fires. Deaths and serious injuries also occur from electrical, chemical, and radiation burns.

Just as building regulation code enforcement and smoke detectors have decreased fire-related deaths, our ability to treat large burns effectively has steadily improved. Before the medical advances of the 20th century, death was almost inevitable when more than one third of the body was burned, no matter how superficially. Now, however, better understanding of burn shock, advances in the use of fluid therapy and antibiotics, improved ability to excise dead tissue, and the use of biologic dressings to aid early wound closure have vastly improved burn care.

Although you probably will not see moderate and severe burns on a daily basis, you will certainly encounter some serious thermal injuries during your career. You may even encounter serious electrical, chemical, and radiation events as well. The appropriate recognition of the severity of such injuries can dramatically enhance the care received by the burned patient. Although emergency medical services (EMS) providers are often most concerned with the immediate life threats caused by burn injuries, their early actions can also impact the long-term morbidity and even the psychological impact of this devastating traumatic pathology.

To comprehend the patient treatments indicated for thermal injuries, we must first review the structure of the skin, which is the primary organ affected by burn injuries.

## Anatomy and Function of the Skin

The skin, also known as the **integument**, is the body's largest organ. It plays a crucial role in maintaining **homeostasis**, or balance, within the body. The skin, which varies in thickness from 1 mm on the eyelid to 1 cm at the heel, is durable, flexible, and usually able to repair itself.

The primary functions of the skin are as a barricade against the outside world, a thermoregulatory organ, a fluid barrier, and a sensory organ. Significant damage to the skin may render the body vulnerable to bacterial invasion, temperature instability, and major disturbances of fluid balance, which is exactly what happens when burn trauma damages large portions of the integument.

### Layers of the Skin

The skin is composed of two principal layers: the **epidermis** and the **dermis** FIGURE 8-1. The epidermis, or outermost layer, is the body's first line of defense—the principal barrier against water, dust, microorganisms, and mechanical stress. Underlying the epidermis is a tough, highly elastic layer of connective tissue called the dermis. The dermis is a

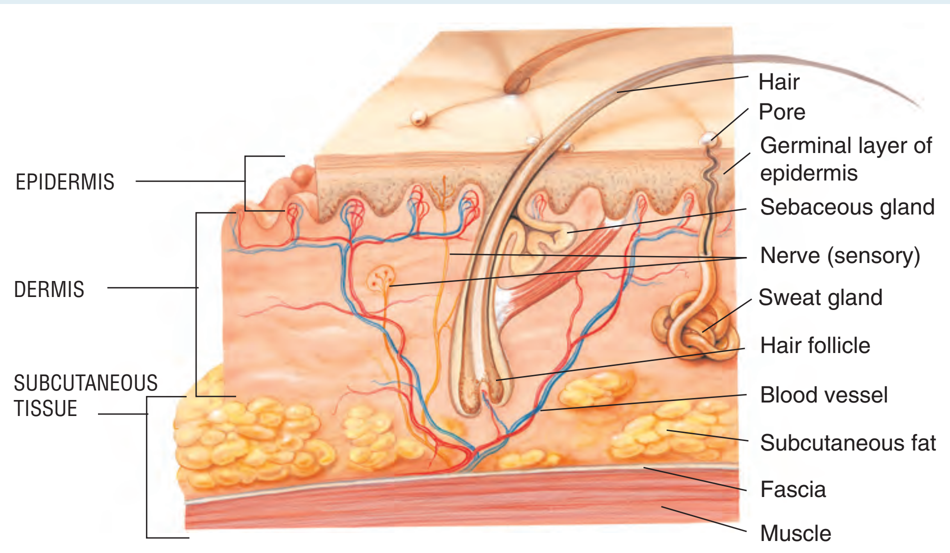


**FIGURE 8-1** The skin contains several important structures, including nerve endings, blood vessels, sweat glands, hair follicles, and sebaceous glands.

complex material composed chiefly of **collagen** fibers, **elastin**, and a **mucopolysaccharide gel**. Collagen is a fibrous protein with a very high tensile strength, so it gives the skin a high resistance to breakage under mechanical stress. Elastin, as the name implies, imparts elasticity to the skin, allowing the skin to return to its usual contours. The mucopolysaccharide gel gives the skin resistance to compression. These tissues are all susceptible to destruction by heat or chemicals.

Enclosed within the dermis are several specialized skin structures:

- *Nerve endings*, which mediate the senses of touch, temperature, pressure, and pain.
- *Blood vessels*, which—like blood vessels elsewhere in the body—carry oxygen and nutrients to the skin and remove the carbon dioxide and metabolic waste products. Cutaneous blood vessels also serve a crucial role in regulating body temperature by regulating the volume of blood that flows from the body's warm core to its cooler surface.
- *Sweat glands*, which produce sweat and discharge it through ducts passing to the surface of the skin. Evaporation of water from the skin's surface is one of the body's major mechanisms for shedding excess heat. People who survive large-area full-thickness burns have often lost many of their sweat glands and are highly susceptible to heat stress.
- **Hair follicles** are structures that produce hair and enclose the hair roots. Each follicle contains a single hair. Full-thickness scalds sometimes destroy the follicles, and hair will fall out or be painlessly and easily pulled out of the scalded skin.
- The **sebaceous gland** at the neck of each hair follicle produces an oily substance called sebum. The precise function of sebum is not well understood, although it has been suggested that sebum keeps the skin supple so it does not crack.

The layer of tissue beneath the dermis is, by definition, the subcutaneous layer, and it consists mainly of adipose tissue (fat). Subcutaneous fat serves as insulating material to protect underlying tissues from extremes of heat and cold. It also provides a substantial cushion for underlying structures, while serving as an energy reserve for the body.

Finally, beneath the subcutaneous layer are the muscles, tendons, bones, and vital organs. Muscles have thick, fibrous capsules that are prone to hypoxia and anaerobic metabolism in a burn state. Bones are living, changing tissue that can be severely affected by burn injury. Lastly, the proper function of these vital organs is sensitive and easily destroyed by thermal, chemical, and electrical injury.

### The Eye

The eye is particularly susceptible to thermal, ultraviolet, and chemical injury. Chemicals and heat denature the cellular proteins and cause secondary vascular ischemic damage. The cornea is most commonly injured because it is the part of the eye most susceptible to exposure. The tear ducts and eyelids combine to lubricate the surface of the eyes constantly FIGURE 8-2. Unfortunately, intense heat, light, or chemical reactions on the surface of the eye can quickly burn the thin membrane or skin covering the surface of the eye.

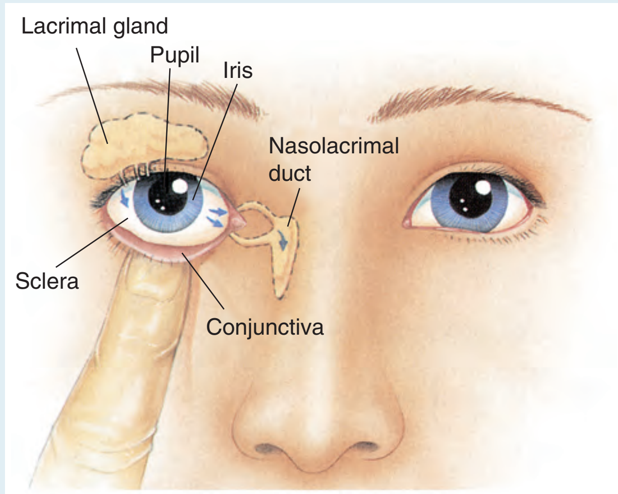


**FIGURE 8-2** Tears act as lubricants and keep the front of the eye protected.

Ocular damage is a common result of alkali (base) injury: The higher the pH of the substance, the more severe the damage to the eye. When a patient gets a substance like lime in the eyes, the damage is worsened by repeatedly rubbing the eyes. Initiate copious irrigation; the patient will also require follow-up treatment in the emergency department (ED).

Providers are typically quick to address chemical burns to the eyes, but may overlook thermal burns to the eyes in the complex scenario of a patient suffering burns from a house fire or motor vehicle crash. Ultraviolet eye burns present in skiers (snow blindness), people using tanning beds, or welders. Ocular burns represent as much as 20% of the eye trauma presenting to emergency departments in the United States. They are a common occupational injury. In the United States, 15% to 20% of patients with thermal burns of the face have sustained some degree of ocular burn.

## Pathophysiology

**Burns** are diffuse soft-tissue injuries created by destructive energy transfer via radiation, thermal energy, or electrical energy. Thermal burns can occur when skin is exposed to temperatures higher than 111°F (44°C). A typical home heating system can deliver hot water out of a tap at temperatures between 130° and 140°F (55° to 60°C). At these temperatures, children will suffer superficial burns in only 7 seconds and full-thickness burns in 90 seconds. In general, the severity of a thermal injury correlates directly with temperature, concentration, and the duration of exposure. For example, solids generally have higher heat content than gases, so exposure to a hot solid (such as the rack inside an oven) typically causes a more significant burn than exposure

**STATS**

In the United Kingdom, scalds caused by bathwater account for more than 20 deaths a year, and more than 450 children younger than 5 years old are admitted to the hospital with serious burn injuries caused by scaldings.

to hot gases (such as those coming out of an oven). Burns are a progressive process: The greater the heat energy, the deeper the wound.

Exposure time is another important factor. Thermal injury can occur to unresponsive or paralyzed patients from seemingly innocuous heat sources such as heating pads, transcutaneous oxygen sensors, and heat lamps left unattended for long periods.

## Thermal Burns

A thermal burn is caused by heat energy that can be transmitted in a variety of ways in addition to fire. Thermal burns are all caused by heat (as opposed to electricity, chemicals, or radiation), but different situations can cause thermal burns and pose a safety hazard to responding providers.

### Flame Burns

Most commonly, thermal burns are caused by open flame. Fires are chaotic and dangerous events, and patients involved in fires have often suffered other trauma in addition to their burns. Flame burns are very often deep burns, especially if a person's clothing catches fire FIGURE 8-3. They also are associated with inhalation injuries.

### Scald Burns

Hot liquids produce scald injuries. Scalds are most commonly seen in children or disabled adults. They often cover large surface areas because spilled hot liquids will flow over any exposed body parts that are beneath them. Hot liquids can soak into clothing and will continue to burn until the clothing is removed. Some hot liquids, such as oil or grease, will adhere to the skin and are more resistant to flushing with cool water, causing particularly deep scald injuries. Scald injuries generally are not as deep as those caused by open flame (although boiling grease or boiling oil can produce deep burns). They are sometimes associated with child abuse FIGURE 8-4. Many scalds could be avoided if people would practice a few well-known methods of prevention. Consider the information presented in TABLE 8-1, keeping in mind that your role as a provider includes public education about these important injury prevention issues.

**FIGURE 8-3** Flame burns are often very deep burns.

### Contact Burns

Contact with hot objects, such as a cooking stove burner, produces contact burns. Ordinarily, reflexes protect a person from prolonged exposure to a very hot object, so contact burns are not usually deep unless the patient was somehow prevented from drawing away from the hot object (eg, unconscious, intoxicated/impaired, disabled). Burns in children, older people, or people with

**STATS**

In the United States, 100,000 scalds result from spilled food and beverages each year. Most frequently:

- Child pulls a pot or other container of hot liquid off the stove or kitchen countertop
- Child bumps into an adult carrying or holding a hot beverage or food
- Child pulls a tablecloth, spilling hot food or beverage from the table

Each year in the United States, 60,000 children are burned by coming in contact with hot objects such as:

- Clothing irons
- Hair curlers and curling irons
- Ranges/stoves
- Space heaters, floor furnaces, and fireplace glass
- Hot tap water; water heater temperatures should be lowered to 120°F (49°C)
- Fireworks

**FIGURE 8-4** Scald burns, like the doughnut burn pictured here, may indicate child abuse.

| TABLE 8-1 Scald Burn Exposure Times | |
|---|---|
| Water Temperature | Time Required for a Full-Thickness Burn to Occur |
| 155°F (68°C) | 1 second |
| 148°F (64°C) | 2 seconds |
| 140°F (60°C) | 5 seconds |
| 133°F (56°C) | 15 seconds |
| 127°F (52°C) | 1 minute |
| 124°F (51°C) | 3 minutes |
| 120°F (48°C) | 5 minutes |
| 100°F (37°C) | Safe temperature for bathing |

Adapted from Moritz AR, Henriques FC Jr. *Am J Pathol.* 1947; 23:695–720.

disabilities may be cause for a raised suspicion for abuse. Burns with formed shapes or unusual patterns, or burns in atypical places such as genitalia, buttocks, and thighs, are often consistent with a history of abuse FIGURE 8-5. Detecting nonaccidental injuries is important because up to 30% of children who are repeatedly abused die as a result of the abuse.

## Steam Burns

A steam burn can produce a topical (scald) burn. Steam (gaseous water) is also notorious for causing airway burns. Inhalation of other hot gases may cause **supraglottic** (upper airway) trauma but rarely leads to burns in the lower airway. Steam is unique because the minute particles of hot water *can* cause significant injury as they are carried into the lower airways.

**FIGURE 8-5** These types of burns may indicate abuse. **A.** Cigarette burn. **B.** Burn from an iron. **C.** Burn on the buttocks. **D.** Burn on the thigh. **E.** Burn on the genitalia.

### Flash Burns

A relatively rare source of thermal burns is the flash produced by some form of explosion, which may briefly expose a person to very intense heat FIGURE 8-6. Lightning strikes can also cause flash burns. For more information on lightning strikes, please see Chapter 9: *Environmental Trauma*.

## Burn Shock

**Burn shock** occurs because of fluid loss across the damaged skin and because of a series of volume shifts within the body itself. Capillaries become leaky, so intravascular volume oozes out of the circulation into the interstitial spaces. Meanwhile, cells of normal tissues take in increased amounts of salt and water from the fluid around them.

It is important to note that burn shock involves the entire body, not just the area burned. You may have experienced a sunburn over a reasonably large surface area (eg, your entire back is about 18% of your body surface area [BSA]). In addition to the discomfort from the burn, you may have experienced chills, nausea, and just feeling sick. This is secondary to the fluid shifts and electrolyte disturbances that are occurring in your body because of the burn. This is, in fact, a mild form of burn shock. Just as in other forms of shock, the changes that occur will limit the effective distribution of oxygen and glucose to the tissues, and limit the ability of the circulation to take away waste products from both healthy and damaged tissues. It is very important, therefore, that adequate fluid resuscitation of the burn patient occur at an early stage to prevent the devastating consequences of burn shock.

The burn shock process generally occurs 6 to 8 hours after the burn incident. You will not typically witness this in the field. Therefore, if an acutely burned patient is in shock in the prehospital phase, look for another injury as the source of shock. People caught in fires fall through floors, jump out of windows, and have things fall on them. There are ample opportunities for traumatic injuries on fire and explosion scenes, so you must be diligent in your assessment. At the same time, it is possible for you first to encounter a burn patient many hours after their injury, when the signs of burn shock are obvious.

## Airway Burns

Inhalation burns can cause rapid and serious airway compromise. Advanced airway equipment, such as an endotracheal tube to secure the airway, should be readily accessible when treating any burn patient. Heat acts as an irritant to both the lungs and the airway. Airway edema, cough, nasal hair singeing, laryngeal edema, laryngospasm, and bronchospasm may result from heat inhalation. Patients may experience pulmonary damage from direct thermal injury or later from toxic inhalation injury. Lower airway damage is more often associated with the inhalation of steam or hot particulate matter, whereas upper airway damage is more often associated with the inhalation of superheated gases.

### Smoke Inhalation

The process of combustion produces a variety of toxic gases. The less efficient the combustion, the more toxic gases (like carbon monoxide) may be involved. When furnaces, kerosene heaters, and other heating devices are in poor repair, or they are inadequately ventilated, they may emit unsafe levels of these toxic gases. Internal combustion engines may emit many of the same gases and should always have their exhaust vented to the outside. A common cause of carbon monoxide exposure is running a small engine in an enclosed space like a garage or basement.

When more complex materials (like plastic, PVC pipes, furniture foam fillings, and synthetic carpets) burn, more toxic and dangerous chemicals may be released. House fires and car fires may emit benzofurans, bicyclo compounds, carbon monoxide, cyanides, hydrochloric acid, and free radicals as their many synthetic components burn FIGURE 8-7. Regardless of the chemical composition of the smoke, it is best to stay low, thus limiting the chance of smoke inhalation FIGURE 8-8.

**FIGURE 8-6** Flash burns may be minor compared with the additional trauma inflicted by the explosion.

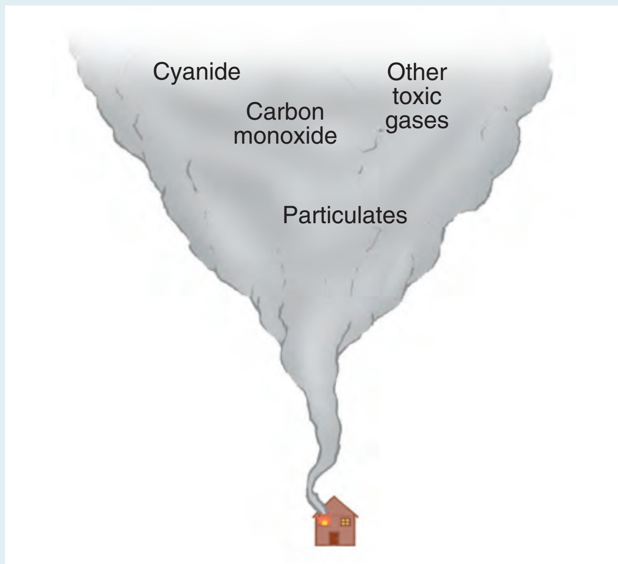


**FIGURE 8-7** Smoke from fires contains many toxins.


**FIGURE 8-8** Staying low limits the chance of injury from smoke inhalation.

## Carbon Monoxide Intoxication

Carbon monoxide (CO) is an odorless, colorless, and tasteless gas produced by incomplete combustion of fuels. These fuels range from oil, natural gas, petroleum/gasoline, and diesel to wood and charcoal. CO builds up where there is poor ventilation, particularly in an enclosed area. CO is a common gas found in and around structural fires. Providers must be alert for the signs and symptoms of CO poisoning when treating burn patients rescued from enclosed areas.

CO has a 200–250 times greater affinity for hemoglobin (Hb) than oxygen does, making even small concentrations of it dangerous. The primary negative effect of carbon monoxide is that it binds to hemoglobin, forming carboxyhemoglobin (COHb). Once attached to Hb, CO does not easily detach, taking a critical number of Hb molecules out of action for the transportation of oxygen to tissues.

From living in an urban/industrialized society, most of us have a 1%–2% carbon monoxide level all of the time. Smokers might have a 3%–4% level. Symptoms of carbon monoxide intoxication, such as nausea, discoordination, and sleepiness, may occur at saturation levels of around 20%. Death can occur at 50%. Keep in mind that the "normal" 97% pulse oximetry reading may actually be 95% oxygen and 2% carbon monoxide. Patients with toxic, or even fatal, levels of carbon monoxide poisoning will show normal or high pulse oximetry values because


**FIGURE 8-9** Pulse CO-oximeter devices can measure oxygen saturation as well as carbon monoxide levels.

a typical pulse oximeter cannot recognize the difference between an oxygen molecule ($O_2$) attached to Hb, and a carbon monoxide molecule (CO) attached to Hb. Specialized pulse CO-oximeters are now readily available that can measure the level of COHb in the blood **FIGURE 8-9**. Some fire departments and ambulances now carry these devices, and providers can make use of them at fire scenes.

Unfortunately, carbon monoxide is a common molecule. It is formed from incomplete combustion of hydrocarbons, so it is present in vehicle exhaust, house fires, inefficient space heaters, small engines, wood fireplaces, or malfunctioning heating systems in homes. Patients exposed to high levels of carbon monoxide are in immediate danger from hypoxia, but are also susceptible to long-term consequences such as cognitive defects, memory loss, and movement disorders.

**TIP**

### Effects of CO

As a point of interest, CO has other toxic effects on the body. CO interferes with the cytochrome oxidase mechanism in each cell (the same as cyanide does), making it difficult for cells to use any oxygen that is delivered. This is a less pronounced effect than Hb binding, but can contribute to mortality in the severely CO-intoxicated patient. This effect may lead to the cherry red color provider lore tells us patients exposed to carbon monoxide have. Although this is somewhat true, most experienced practitioners agree that an obvious red hue to the skin is not evident until the patient has a very high, perhaps fatal, dose. Never rule out carbon monoxide toxicity just because you don't see cherry red skin.

CONTROVERSIES

# Cyanide Treatment in Fire Victims

WHETHER TO TREAT FIRE VICTIMS for cyanide poisoning has been an issue of controversy for two decades. Justification for such treatment is straightforward. About 75% of fire-related fatalities result from smoke inhalation, not burns, and hydrogen cyanide is among the most toxic components commonly found in smoke. On the other hand, evidence of the clinical benefits of such treatment remains sparse and uncertain.

Smoke is a complex mixture of toxic compounds.[1,2] Its actual composition changes from fire to fire and over time, reflecting the materials being burned, the temperature of the fire, the adequacy of oxygen, and the completeness of combustion. Hydrogen cyanide is routinely found in smoke generated by burning of nitrogen-containing compounds. Examples include natural (wool, silk, cotton, and wood) and synthetic (acrylic, nylon, and plastic) materials. Case reports and autopsy studies have documented elevated cyanide levels in victims of closed-space fires, with levels often greater than those regarded as "toxic" (ie, > 39 μg/L) or "lethal" (ie, >100 μg/L).[3] Such findings argue that cyanide toxicity should be a routine concern in smoke inhalation victims.

Acting on such concerns, however, has not been easy. Until recently, the only cyanide antidote available in the United States was the "cyanide kit" comprised of amyl nitrite, sodium nitrite, and sodium thiosulfate. That combination poses hazards to smoke inhalation victims.[4] Nitrite oxidizes hemoglobin to methemoglobin, a dysfunctional molecule that does not transport oxygen. In smoke victims with an oxygen-carrying capacity compromised by formation of carboxyhemoglobin, nitrite-induced methemoglobin further reduces oxygen transport to tissues and worsens hypoxia.

Some experts suggest that sodium thiosulfate be given alone to treat smoke inhalation victims, thereby avoiding the risks of methemoglobin formation.[5] Thiosulfate acts as a sulfur donor, facilitating the enzymatic conversion of toxic cyanide to harmless thiocyanate which is readily excreted. A few anecdotal reports describe treatment of victims with sodium thiosulfate (8–15 g IV), but no controlled trials have been undertaken. Based on animal studies, some have argued that the onset of thiosulfate effects is too slow to be useful for the treatment of acute life-threatening poisonings.

More recently, hydroxocobalamin, a natural form of vitamin $B_{12}$, has been approved by the US FDA for treatment of known or suspected cyanide poisoning with a recommended dose of 5 to 10 mg IV.[6] Its effectiveness has been well established in animal studies and it has been widely adopted.[2,6,7] There are few serious side effects of this agent; most reports describe only transient elevations of blood pressure, skin discoloration, and possible allergic reactions. In principle, its use for suspected cyanide poisoning seems to pose probable benefits and few risks.

On the other hand, however, its actual efficacy for fire victims remains unclear. The uncertain benefits of hydroxocobalamin for smoke inhalation reflect the substantial challenges to performing controlled trials in emergency settings. It has also been difficult to differentiate the benefits of cyanide antidotes from those resulting from other resuscitation efforts. Finally, most smoke victims found in cardiac arrest do not survive despite antidotes; in two series from the Paris Fire Brigade (where hydroxocobalamin is used routinely), 49 of 53 (93.5%) of smoke-related cardiac arrest victims died within 8 days.[2,7] Thus, determining the benefits of antidotal treatment will require a large, multicenter random-control trial which itself may raise important ethical concerns.

In summary, there is strong toxicologic evidence that cyanide inhalation contributes to the morbidity and mortality of smoke inhalation, especially in residential and closed-space fires. A cyanide antidote that seemingly poses few risks of side effects is now available and it appears to be useful in these cases. Nevertheless, the clinical benefits of intervention remain unclear.

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## Chemical Burns

Chemical burns occur when the skin comes in contact with strong acids, alkalis/bases, or other corrosive materials TABLE 8-2. The burn will progress as long as the corrosive substance remains in contact with the skin. Thus, the cornerstone of therapy is safe and rapid removal of the chemical from contact with the patient's body.

### Injuries from Chemical Burns

Skin destruction is determined by the chemical's concentration and the duration of contact. Systemic toxicity is determined by the degree of absorption. Immediately removing the patient's clothing will often remove the majority of the chemical from skin contact. Most chemicals are most efficiently removed by washing with copious amounts of low-pressure cool water (such as in a shower, sink, or eye-wash station) FIGURE 8-10.

**TABLE 8-2 Acid/Alkaline Burns and Related Injuries**

| Chemical Type | Examples | Injury |
|---|---|---|
| Acids | Battery acid, hydrochloric acid | Coagulative necrosis |
| Alkalis | Sodium hydroxide (bleach), drain cleaner, oven cleaner, lye | Liquefactive necrosis |

FIGURE 8-10 Chemicals must be removed from the skin as soon as possible to limit the burning process.

**TIP**

**Acid Versus Alkaline Burns**

Acid burns produce a **coagulative necrosis**, where burned tissue forms a tough layer of scar tissue. Alkaline (base) burns produce a **liquefactive necrosis**, in which burned tissue liquefies and becomes "soapy," allowing the base to burn deeper. This is why, in general, alkaline burns can be worse than acid burns.

Some chemicals react violently with water, which obviously precludes irrigation. Such chemicals are usually powders, so it is reasonable to brush off as much dry powder as possible before irrigation of the chemical.

### Chemical Burns to the Eye

Improper handling can cause a variety of chemicals to splash into the eye, causing burns. Household bleach, chlorine for swimming pools, and splashed battery acid are common serious ocular burns. Chemical burns of the eye are also a common occupational injury, which could obviously be prevented by wearing safety glasses whenever pouring or working with any type of acidic or alkaline chemical FIGURE 8-11. Clouds of toxic chemicals, as may be released from pressurized containers of chlorine gas or ammonia, can also cause ocular burns. Providers should routinely wear eye protection when there is increased risk to their eyes at a scene.

## Electricity-Related Injuries

One out of every five construction deaths is caused by electrical contact. National Institute for Occupational Safety and Health (NIOSH) statistics indicate that electrocution is the fifth leading cause of death in the workplace, with more than 400 deaths per year in the United States. Domestic injuries, on the other hand, are most likely to involve children FIGURE 8-12.

FIGURE 8-11 Common causes of eye burns include industrial incidents.

**FIGURE 8-12** Children may sustain electrical burns from chewing on electrical cords.


**FIGURE 8-13** The three types of burns caused by electricity are (**A**) contact burns (type I), (**B**) flash burns (type II), and (**C**) flame burns (type III).

**STATS**

According to the Royal Society for the Prevention of Accidents (RoSPA), in 2005 there were 35 electricity-related deaths in the United Kingdom.

Electrical burns can produce devastating internal injury with little external evidence. The degree of tissue injury in an electrical burn is related to the resistance of various body tissues, the intensity of current that passes through the victim, and the duration of contact.

As electric current travels from the contact site into the body, it is converted to heat, which follows the current flow, causing extensive damage to the tissues in its path. When the voltage is low (ie, under 1,000 volts, as in household sources), current follows the path of least resistance, generally along blood vessels, nerves, and muscles, which results in minor contact burns and cardiorespiratory complication. When the voltage is high (greater than 1,000 volts, as that from high-tension lines and industrial sites), the electric current takes the shortest available path. In either case, the greater the current flow, the greater the heat generated. These injuries are associated with massive tissue loss, with a high incidence of limb amputation.

Alternating current is considerably more dangerous than direct current because the alternations cause repetitive (tetanic) muscle contractions, which may "freeze" the victim to the conductor until the current source is turned off. Furthermore, alternating current is more likely than direct current to induce ventricular fibrillation. The direction of current flow is also significant. Current moving from one hand to the other is particularly dangerous because current may then flow across or near the heart; a current of only 0.1 ampere to the heart can provoke ventricular fibrillation.

## Electricity-Related Burns

Electricity can cause three types of burns **FIGURE 8-13**. The most common is the type I burn, or contact burn, a true electric injury in which the current is most intense at the entrance and exit sites. At those points, you may see a characteristic bull's-eye lesion, with a central, charred zone of full-thickness burns; a middle zone of cold, gray, dry tissue; and an outer, red zone of coagulation necrosis **FIGURE 8-14**. The contact burn, although usually not in itself very serious, is an important marker because it can signal devastating injury inside the body.

The type II burn, or flash burn, is really an electrothermal injury and is caused by the arcing of electric current. If a person passes close enough to a source of high voltage current, they will reach a point where the resistance of the air between the current source and themselves is sufficiently low that current arcs through the air from the current source to the passerby. An arc of that sort has a temperature


**FIGURE 8-14** Electrical burns have entrance (**A**) and exit (**B**) wounds, characterized by bull's-eye lesions.

anywhere from 5,400°F to 36,000°F (3,000° to 20,000°C)—high enough to produce significant charring. Victims standing near an object that was struck by lightning may get "splashed" and have areas of burns that resemble a fine red rash.

The type III electric burn, or flame burn, is another thermal injury; it occurs when electricity ignites a person's clothing or surroundings.

### Nonburn Injuries from Electricity

Burns can be only one of the problems of a patient who has come in contact with an electric source—and not necessarily the most serious one. The two most common causes of death from electric injury are asphyxia and cardiac arrest. Asphyxia can occur when prolonged contact with alternating current induces tetanic contractions of the respiratory muscles; asphyxia can also be the result of current passing through the respiratory center in the brain and knocking out the impulse to breathe.

Cardiac arrest can occur either secondarily, from hypoxia, or as a direct result of the electric shock. As noted earlier, currents as small as 0.1 ampere can trigger ventricular fibrillation if they pass directly through the heart, which is particularly likely when current travels across the body from hand to hand or from upper to lower limb. In cases where cardiac arrest does not occur, cardiac damage can nonetheless be manifested in various rhythm changes seen on the electrocardiogram (ECG).

A whole host of neurologic complications have been reported in connection with electric injury, including seizures, delirium, confusion, coma, and temporary quadriplegia. Destruction of muscle tissue (rhabdomyolysis) occurs with deeper burns. Damage to muscle releases the contents of the muscle cells into the plasma. These cell contents include enzymes (creatinine kinase), myoglobin, and electrolytes such as potassium and phosphates. Damage to the kidneys is common after electric injury and resembles the syndrome seen after a crush injury, which is due to the breakdown products of damaged muscle (myoglobin) being liberated into the circulation.

Severe tetanic muscle spasms can lead to fractures and dislocations, which are often overlooked because of preoccupation with the electric injury itself. Posterior dislocation of the shoulder and fracture of the scapula—both otherwise rather rare injuries—have been reported in a number of cases of electrocution. And don't forget the cervical spine, especially in an electrical worker (lineman) who has fallen from a utility pole.

All of these potential injuries conspire to make the victim of an electrical contact a very complex assessment challenge. Never let obvious injuries distract you from a complete assessment including the neurologic, respiratory, cardiac, and musculoskeletal systems.

**TIP**

**Electrical Cautions**

- Seemingly "dead" wires can jump back to life because of automatically resetting breakers.
- The ground can become electrified by downed high-voltage wires.
- Take small steps—the electrical gradient can increase as you get closer to the source.
- Be wary if the hairs on your arm stand up on their own.
- Assume railroad tracks convey electrical current until proven otherwise.
- Look for dead animals on the ground.

As soon as the electric hazard has been neutralized and made safe, proceed to the ABCs. Open the airway using the jaw-thrust maneuver, bearing in mind the possibility of cervical spine injury. Start cardiopulmonary resuscitation (CPR) as indicated. If the patient is not in cardiac arrest, but has received a significant electrical burn, cardiac monitoring is indicated for 24 to 36 hours after the injury.

## Radiation Burns

Acute radiation exposure has become more than a theoretical issue as use of radioactive materials increases in industry and medicine. You must understand radiation exposure to function effectively in the prehospital arena. Since 1946, there have been more than 400 radiation accidents involving significant radiation exposure to more than 3,000 people worldwide. Potential threats include incidents related to the

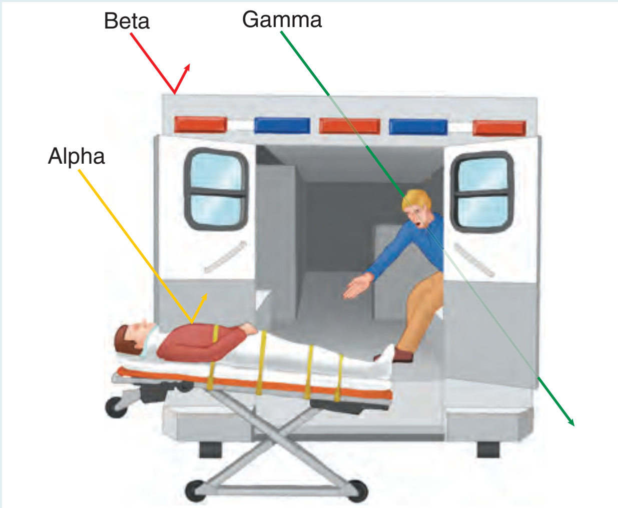



**FIGURE 8-15** Alpha, beta, and gamma radiation.

use and transportation of radioactive isotopes or intentionally released radioactivity in terrorist attacks. To be effective, you must first suspect radiation and attempt to determine whether ongoing exposure exists. Increasingly, individual providers in some services and some special response units are equipped with pager-sized radiation detectors. Such detection also can be provided by other public safety services.

There are three types of ionizing radiation: alpha, beta, and gamma FIGURE 8-15. Alpha particles have little penetrating energy and are easily stopped by the skin. Beta particles have greater penetrating power and can travel much farther in air than alpha particles. They can penetrate the skin but can be blocked by simple protective clothing designed for this purpose. The threat from gamma radiation is directly proportional to its wavelength. This type of radiation is very penetrating and easily passes through the body and solid materials.

Radiation dosage is measured in joules per kilogram (J/kg); 1 J/kg is also known as 1 gray (Gy). Small amounts of everyday background radiation are measured in rad; the amount of radiation released in a major incident can be measured in gray (100 rad = 1 Gy). Mild radiation sickness can be expected with exposures of 1 to 2 Gy (100–200 rad), moderate sickness at 2 to 4 Gy, and severe sickness at 4 to 6 Gy. Exposure to more than 8 Gy is immediately fatal.

The vast majority of ionizing radiation accidents involve gamma radiation or x-rays. People who have suffered a radiation exposure generally pose no risk to the people around them. However, in some types of incidents—particularly those involving explosions—patients can be contaminated with radioactive particulate matter. It is speculated that after a nuclear explosion, most patients will have sustained some type of trauma in addition to the radiation exposure.

It is important to limit any particulate contamination if the patient has been involved in an incident other than simple irradiation (explosions, aerosolization of material, etc). At the scene, clothes should be removed and patients should be decontaminated using soap and water. Open wounds should be irrigated. Washing should be gentle to avoid abrading the skin. The head and scalp should be irrigated the same way. Be sure to decontaminate the bottoms of the feet, because this is a commonly missed area. The receiving emergency department should be notified as soon as practical so they can prepare a special reception.

## Acute Radiation Syndrome

Acute radiation syndrome causes hematologic, central nervous system, and gastrointestinal changes. Many of these changes occur over time and so will not be apparent during contact with providers. Patients who are rendered unconscious by radiation or who manifest vomiting within 10 minutes of exposure have a 100% chance of mortality. Those who manifest vomiting in less than an hour have severe exposure and a 20% to 70% mortality rate. Many people with moderate exposure will vomit within 1 to 2 hours and have a 0% to 50% mortality rate TABLE 8-3.

**TABLE 8-3 Effects of Acute Radiation Exposure and Expected Mortality**

| Assessment | Lethal Exposure (> 8 Gy) | Severe Exposure (4–6 Gy) | Moderate Exposure (2–4 Gy) | Mild Exposure (1–2 Gy) |
|---|---|---|---|---|
| **Vomiting** | Most will vomit in < 10 min | Most will vomit in < 1 h | Many will vomit in 1–2 h | Half will vomit after 2 h |
| **Diarrhea** | Most will have severe diarrhea in < 1 h | 10% will have some diarrhea in 3–8 h | None | None |
| **Unconsciousness** | Some will be unconscious for seconds to minutes; in massive exposure (> 50 Gy), all will lose consciousness. | None | None | None |
| **Fatigue** | Yes | Yes | Yes | Yes |
| **Headache** | Severe | Moderate | Mild | Slight |
| **Fever** | High fever in < 1 h | Moderate fever in 4–24 h | Mild fever | No fever |
| **Expected mortality** | 100% will die in 1–2 wk | 20%–70% will die in 4–8 wk | 0%–50% may die in 6–8 wk | Typically, all will survive |

Adapted from IAEA and WHO. *Safety Reports Series No. 2: Diagnosis and Treatment of Radiation Injuries.* International Atomic Energy Agency, 1998.

Clearly, the onset of vomiting soon after exposure is a predictor of poor outcomes. Consider this fact when triaging patients or considering the risks of entering a high-radiation environment to attempt rescue.

### Radiation Contact Burns

A person who briefly handles a radioactive source can sustain a local soft-tissue injury without a lot of total body irradiation. This scenario might arise, for example, in a collision involving a vehicle transporting radioactive material or after the detonation of a "dirty bomb." The injury could resemble anything from superficial sunburn to a chemical burn. Although chemical burns usually become apparent almost immediately after exposure, radiation burns could appear hours or even days after exposure.

## General Assessment of Burns

Burned patients can fool you. We expect our critically injured patients to act sick. Most severely injured and dying cardiac and trauma patients are hypotensive and unresponsive, or in such distress that we can tell they are critical before we ever get close to them. On the other hand, patients suffering from isolated severe burn injury sometimes walk up to you on a scene. Their chief complaint may be "I'm terribly cold," and the severity of their injuries may not become apparent to you until you have completed your assessment and realized that they fit the criteria for transfer to a burn center.

Burn injuries sometimes happen in remote locations, and patients may be found hours after their traumatic burn event, where they may present with an entirely different spectrum of problems than we are typically used to dealing with. Burned patients often have additional traumatic injuries from falling debris, explosions, or injuries sustained while they were trying to get away from the source of the burn FIGURE 8-16. Serious burn patients may need to be transferred from tertiary facilities to larger burn centers, and you may be required to deal with advanced issues like **escharotomies** and advanced fluid management during the secondary transport.

### Scene Size-up

As always, begin with scene safety and body substance isolation (BSI) FIGURE 8-17. Do not proceed to the patient's side if the scene is not safe. Be wary of entering closed spaces if there is evidence of a recent fire—the heat may be intense and there may be a large residue of fumes. Never enter a burning building unless you are trained and wearing the appropriate protective gear. Make sure there is no continuing danger to you or the patient(s). Keep a high index of suspicion for the presence of toxic gases: CO, cyanide, and hydrogen sulfide. Cyanide can kill within 15 seconds of exposure. Look for placards indicating hazardous materials. Never enter an area that potentially has hazardous materials. Always follow direct instructions from the senior fire officer at the scene in relation to aspects of health and safety.

There are two aspects to maintaining scene safety. The first is staging yourself and others in a place that is safe to render patient care and that is outside of the hot zone. This allows you to stay far enough removed from the situation to keep a wider focus.

The second concern is to extinguish the flame. Always extinguish the fire before providing medical care. Extinguish overt flames using copious irrigation or covering with a heavy wool or cotton blanket that can smother the flames.

**FIGURE 8-16** Burned patients often sustain additional traumatic injuries while trying to get away from the source of the burn.


**FIGURE 8-17** Checking for scene safety requires due diligence at every scene.

PRO/CON

### Wet Versus Dry Dressings

Burns that cover greater than approximately 10% body surface area should be covered with dry clean dressings. Water-soaked dressings will encourage evaporation and cooling of the skin under the dressing. This can provide some pain relief; however, the damaged skin has become unable to limit the amount of temperature lost by the body. If larger burns are allowed to cool too much, the patient may become hypothermic. An exception to this rule is the gel burn bandages that insulate the skin from excessive heat loss by cooling down only to normal body temperature. These products have thermal properties that do not let the patient cool too quickly. It is advisable on all dressings to rewrap the patient with protective blankets to avoid wind chill.

That may seem obvious, but it is remarkable how many patients still arrive by ambulance at hospital emergency departments with clothes smoldering.

## Initial/Primary Assessment

As mentioned earlier, patients who have been burned may have sustained other trauma. Consider and examine other mechanisms associated with the burn: Did the patient jump from a high window to escape flames? Do they have musculoskeletal trauma from tetanic spasms after an electrical burn? Were they trapped in an enclosed space? Did the patient lose consciousness? All of these questions affect the initial response to the patient and their ultimate care. Evaluate the need for additional resources and request them early on if necessary.

As you approach the burn trauma patient, simple clues can help identify how serious the injuries are and how quickly you need to assess and treat. If your patient greets you with a hoarse voice or is reported to have been in an enclosed space, you should be concerned about their airway. Similarly, if the patient has singed facial hair, eyebrows, nasal hair, or moustache, your general impression might be that the patient has a potential airway and/or breathing problem.

### Evaluate Mental Status

Patients who have suffered from a burn injury can have a varied mental status response. All patients who present as combative must be deemed hypoxic until proven otherwise. Because burns are extremely painful injuries, the patient may present awake but not responsive, or be hysterical and inconsolable. Even patients with excessive burns will most likely be awake and attempting to communicate. Isolated burns do not cause unconsciousness (although toxic inhalations can). Unresponsive burn patients must be carefully assessed to search for sources of other lethal injuries.

**TABLE 8-4 Clues to Airway Compromise in the Burned Patient**

| |
|---|
| Standing and/or screaming while on fire |
| Burns in an enclosed space |
| Soot in the sputum |
| Hoarse voice |
| Singed eyebrows or nasal hairs |
| Burns of the face or in the mouth or nose |

### Ensure an Open Airway

As in any other seriously ill or injured patient, the airway comes first. In the burned patient, the airway may be in particular jeopardy; the same heat and flames that caused the external burn may have produced potentially life-threatening damage to the airway TABLE 8-4. Laryngeal edema can develop with alarming speed in burn patients, especially in infants and children where a small amount of edema can occlude their small airways. Early endotracheal intubation—before the airway has closed off—will be life-saving in such cases and should be performed by the most experienced provider on your team. To intervene early, however, you need to spot the problem early.

### Assess for Adequate Breathing

The vast majority of deaths from fires are not from burns, but from pulmonary injury due to the inhalation of toxic gases. Direct pulmonary injury may occur from the inhalation of very hot steam, which can conduct heat all the way down into the smaller airways and produce damage at the bronchiolar and alveolar level. At the same time, carbon monoxide and other toxic products of combustion can displace oxygen from both the alveolar air and the blood hemoglobin. Carbon monoxide binds to receptor sites on hemoglobin about 200 times more easily than oxygen, so the patient's hemoglobin is well saturated with the wrong chemical. For this reason, pulse oximetry readings may be inaccurate. Listen to lung sounds, paying special attention to stridor, which may predict upper airway compromise.

### Ensure Adequate Circulation

During the first 24 to 48 hours of a patient's burn care, a great deal of emphasis is placed on fluid resuscitation by the ED and the burn center to prevent burn shock. Burn shock is caused by fluid shifts that typically occur 6 to 8 hours after the burn. This fluid shift may not be complete until 24–48 hours after the burn. Severely burned patients will ultimately require large volumes of fluid, but they don't need it during the first minutes of prehospital care unless their burn injury occurred some time ago. While prehospital IV access is an important route for analgesia and fluid, most patients will ultimately require central venous access, and most prehospital intravenous (IV) lines will be removed owing to tissue swelling and infection risk. If the patient is *not* grossly hypotensive (ie, detectable peripheral pulse), do not delay transport by making multiple attempts at vascular access.

Patients with other trauma may require immediate vascular access just like any other trauma patient. It is preferable, however, to avoid starting IV lines through burned tissue to decrease the chance of infection during the patient's recovery. Burned patients may challenge your vascular access skills. Options for intraosseous access may provide you with more choices than intravenous options. Access locations can include the tibia, femur, iliac crest, humerus, or sternum.

## Burn Severity

The burn wound is identified by degree of injury. The injury may be described by three pathologic progressions or zones. Skin nearest to the heat source suffers the most profound cellular changes. The central area of the skin, which suffers the most damage, is called the **zone of coagulation**. The peripheral area surrounding the zone of coagulation has decreased blood flow and inflammation. This area can undergo necrosis within 24 to 48 hours after the injury, particularly if perfusion is compromised due to burn shock. This is known as the **zone of stasis**. Lastly, the area that is least affected by the thermal injury is the **zone of hyperemia**, in which cells will recover in 7 to 10 days. These three zones are important for providers because treatments rendered in the prehospital environment involve understanding these basic principles FIGURE 8-18.

### Burn Location

One factor used to determine whether a burn is critical enough to require a burn specialty center is the location of the burn on the body. Most burns are determined to be critical by the depth and size of the burn. However, burns on particular parts of the body are critical regardless of the overall size of the burn. Burns must still be partial thickness or worse to be considered critical. Superficial burns are not counted when occurring alone.

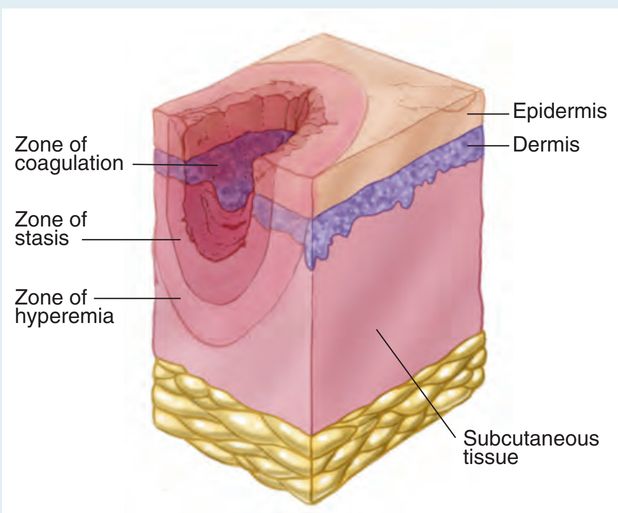



**FIGURE 8-18** A burn injury can be described by three different zones. **A.** Zone of coagulation. **B.** Zone of stasis. **C.** Zone of hyperemia.

Burns to the face, eyes, ears, hands, feet, perineum, genitals, or major joints that may result in cosmetic or functional disability should be transferred to a burn specialty center when available. These burns often leave the victim physically, psychologically, and socially scarred if they do not receive careful debridement and cleansing of the wounds, definitive reconstructive surgery, proper follow-up wound care, and complete rehabilitation to assist the victim in returning to pre-injury function.

### Burn Depth

Keep in mind that you are performing a rapid initial assessment with the goal of determining what level of care the patient requires (burn center, trauma center, local hospital), and also getting an idea of size and severity to pass on to the receiving facility. The nature of the patient's burns will evolve over the next 24 hours, and estimations of their size and severity will change, so there is little to be gained from a comprehensive and time-consuming evaluation of every inch of the patient's body in the field. That being said, you would obviously like to have a reasonably accurate estimation of the scope of the patient's injuries.

The first step in burn management is to assess the burns quickly. Consider the presence or absence of pain, swelling, skin color, capillary refill, moisture, and blisters; the appearance of wound edges; presence of foreign bodies, debris, contaminants, and bleeding; and circulatory adequacy. Assess for concomitant soft-tissue injury. Determination of burn depth is a subjective assessment dependent on provider judgment.

The traditional labels given to burns were first, second, and third degree. Most centers expanded that concept, and discussed fourth-, fifth-, and sixth-degree burns, as tissue destruction went into the deeper tissues, muscle, and bone. It is probably more appropriate for prehospital providers to limit their assessment to superficial, partial-, and/or full-thickness burns FIGURE 8-19 to simplify the process and avoid confusion and miscommunication.

Sometimes called a first-degree burn, a **superficial burn** involves the epidermis only. The skin is red and when touched the color will blanch and refill. Blisters are not usually present. Patients will experience pain as the nerve endings are exposed to the air. This burn will heal spontaneously in 3 to 7 days. One common example of a superficial burn is a sunburn.

A **partial-thickness burn**, which is sometimes called second degree, involves the epidermis and varying degrees of the dermis. This category can be subdivided into superficial partial-thickness and deep partial-thickness burns.

A superficial partial-thickness burn is one in which the skin color is red and when touched the color will blanch and refill. Usually there are blisters or moisture present. Patients will experience extreme pain. Hair follicles remain intact. The burn will heal spontaneously, but may scar or have changed appearance.

A deep partial-thickness burn extends into the dermis, damaging hair follicles and sweat and sebaceous glands. Hot liquids, steam, or grease are usually to blame for these

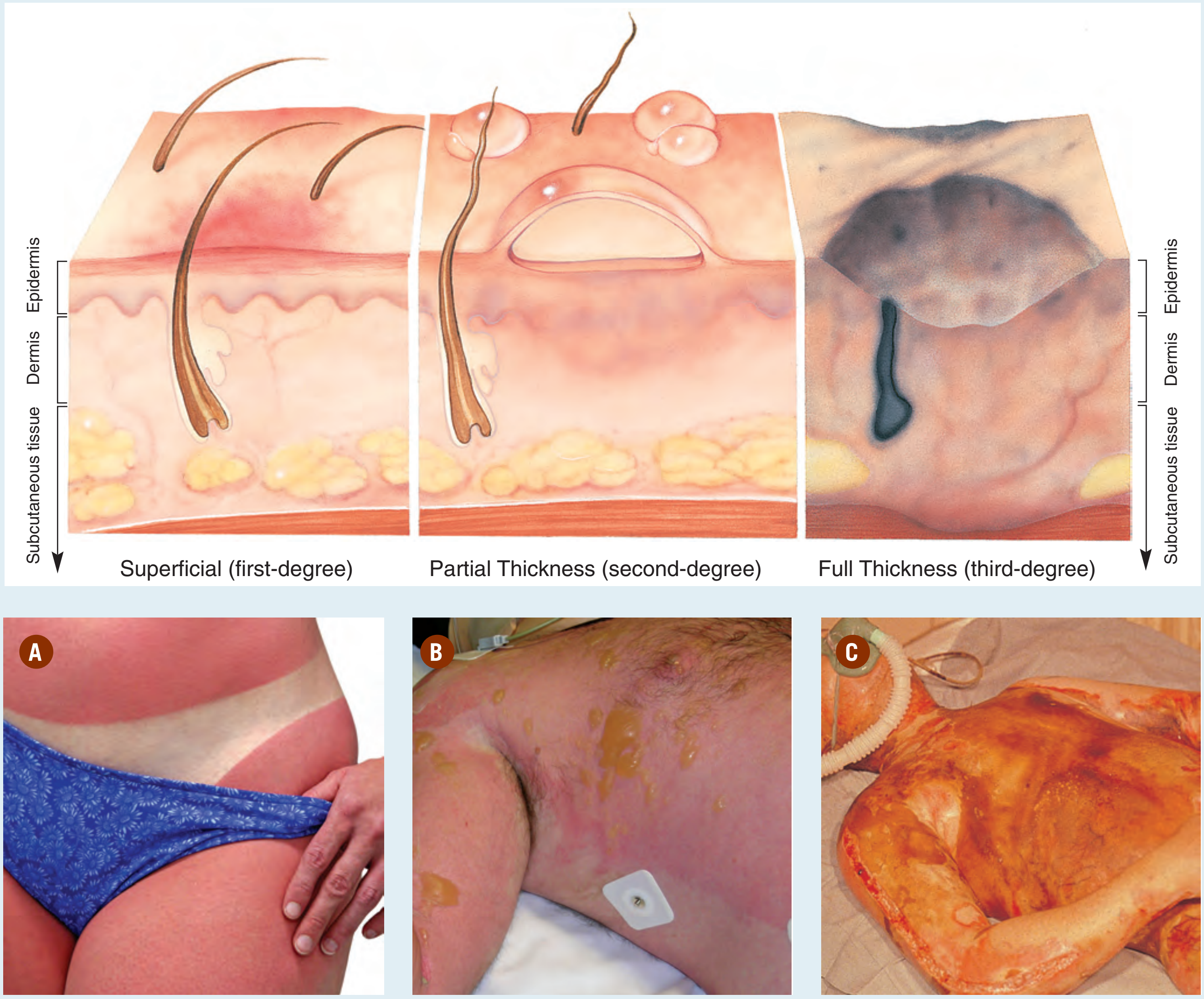



**FIGURE 8-19** Classification of burns. **A.** Superficial (first-degree) burns involve only the epidermis. **B.** Partial-thickness (second-degree) burns involve some of the dermis but do not destroy the entire thickness of the skin. The skin is mottled, white to red, and often blistered. **C.** Full-thickness burns extend through all layers of the skin and may involve subcutaneous tissue and muscle. The skin is dry, leathery, and often white or charred.

injuries. In the prehospital setting, the difference between deep partial thickness and full thickness may be difficult to determine at this early stage.

**Full-thickness burns**, sometimes called third-degree burns, involve destruction of both layers of the skin, including the basement membrane of dermis, which produces new skin cells. The skin color is white and pale, or brown, or charred in appearance. The skin is dry and sometimes described as "leathery." There is no capillary refill because the capillaries are destroyed. Sensory nerves are destroyed so there is typically no pain in the full-thickness section. Patients usually have mixed depths of burns so they often will still experience significant pain in the areas surrounding the full-thickness burns. Treatment of this burn will require skin grafting because the dermis has been destroyed.

## Burn Surface Area

Once the thickness of the burn has been determined, the provider must approximate the total body surface area (TBSA) burned. TBSA is based on all burned surfaces from reddened to partial- and full-thickness burns. The typical approach to calculating TBSA is using the Rule of Nines FIGURE 8-20, which is based on fractionalizing the body into 9% segments. The provider adds the portions of the body for a total of the percentage of the body affected by the burn injury. Because our proportions change as we grow, there is a different Rule of Nines for infants, children, and adults.

Another mechanism of assessing the TBSA is the Rule of Palms. This assessment utilizes the size of the patient's palm to represent about 1% of the patient's body surface area. This calculation is helpful when the extent of the burn is less than 10% TBSA or it is an irregularly shaped burn.

The Lund and Browder chart FIGURE 8-21 is an even more specific and more accurate method used to estimate burn area, and its modifications take into account the proportional differences in adults and children. It recognizes that the proportion of body surface covering specific body parts changes with age (for example, the head and neck of an infant constitute 20% TBSA compared with 9% in an adult).

The provider must balance the need for accuracy against the time required to complete the assessment. The prehospital estimation of burn area is used to get the patient to the correct place for treatment. The emergency department estimation of burned area may be used to initiate fluid therapy. The burn center's estimation of injured area will undoubtedly need to be more accurate and specific. In any case, reassessment is vital after an hour to assess changes from the prehospital assessment.

## Rapid Trauma/Secondary Assessment

Once you have evaluated the ABCs and treated any conditions noted, then proceed through the steps of physical assessment in the usual sequence, starting with the patient's general appearance, then complete a set of vital signs. Obtaining vital signs may be challenging if the patient has extensive burns over the arms. It is still important to try to document accurate vital signs because the management of shock, airway compromise, and pain control will all depend to some extent upon them.

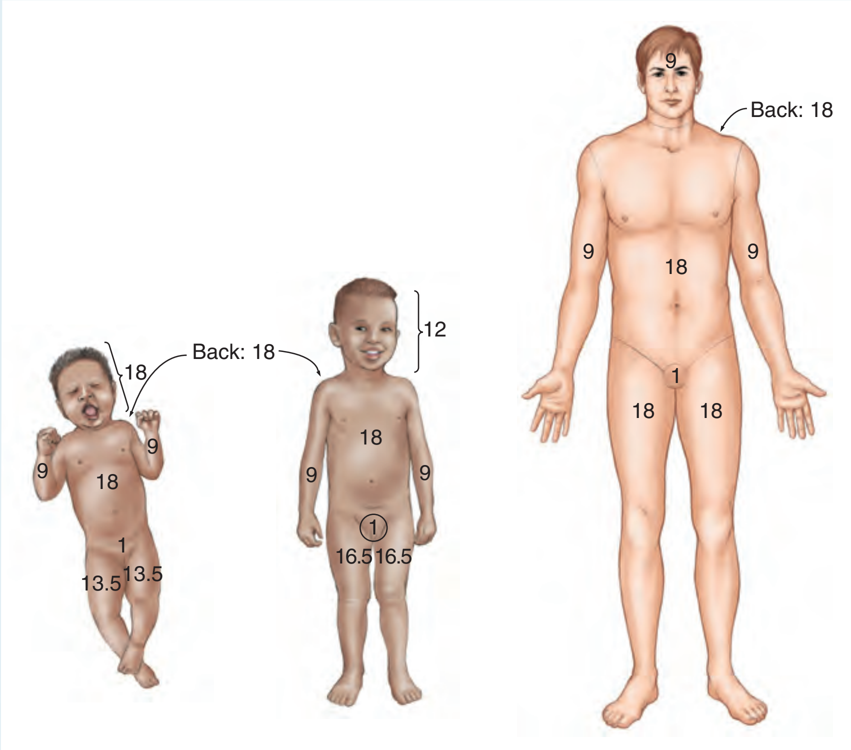
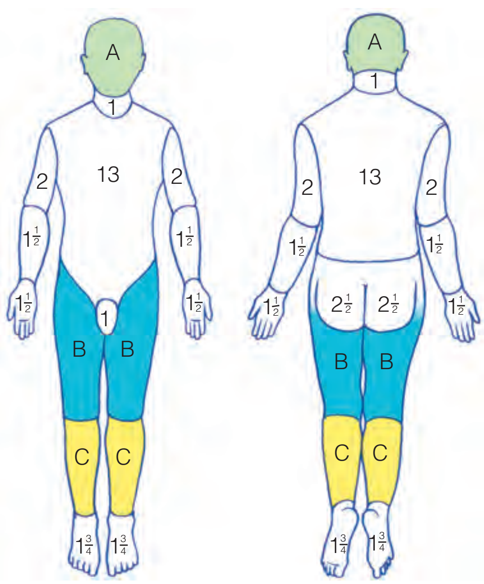



FIGURE 8-20 The Rule of Nines is a quick way to estimate the amount of surface area that has been burned. It divides the adult body into sections, each representing approximately 9% of the total body surface area. The proportions differ for children and infants.

| Region | % |
|---|---|
| Head | |
| Neck | |
| Ant. Trunk | |
| Post. Trunk | |
| Right arm | |
| Left arm | |
| Buttocks | |
| Genitalia | |
| Right leg | |
| Left leg | |
| Total burn | |




**Relative percentages of body surface area affected by growth**

| Age (years) | A ($\frac{1}{2}$ of head) | B ($\frac{1}{2}$ of one thigh) | C ($\frac{1}{2}$ of one leg) |
|---|---|---|---|
| 0 | $9\frac{1}{2}$ | $2\frac{3}{4}$ | $2\frac{1}{2}$ |
| 1 | $8\frac{1}{2}$ | $3\frac{1}{4}$ | $2\frac{1}{2}$ |
| 5 | $6\frac{1}{2}$ | 4 | $2\frac{3}{4}$ |
| 10 | $5\frac{1}{2}$ | $4\frac{1}{4}$ | 3 |
| 15 | $4\frac{1}{2}$ | $4\frac{1}{2}$ | $3\frac{1}{4}$ |
| Adult | $3\frac{1}{2}$ | $4\frac{3}{4}$ | 3 |

FIGURE 8-21 The Lund and Browder chart.
*Source*: Adapted from Lund CC, Browder NC. *Surg Gyn Obst*. 1944; 79:352–358.

When you have finished your brief inspection of the patient's skin, you have only just begun the head-to-toe exam. The purpose of doing the head-to-toe exam is to make sure there are no other injuries that have higher priority for treatment. Often the burn itself may obscure such injuries, so you need to pay attention to the circumstances of the burn and the possible mechanisms of injury. Look for injuries to the eyes, and cover injured eyes with moist, sterile pads or a water-gel face dressing. Check the neck, chest, and extremities for circumferential burns. Progressive edema beneath a circumferential burn—especially when the burned skin has become leathery and unyielding (as in a full-thickness burn)—may act as a tourniquet. In the neck, a circumferential burn may obstruct the airway; in the chest, it may restrict the respiratory excursion; and in an extremity, it may cut off the circulation and put the extremity in jeopardy. Patients with circumferential burns must therefore reach a medical facility quickly because it may be necessary to make an incision (called an escharotomy) into the burned area to allow blood flow in the limb, chest, or neck. An escharotomy is a surgical procedure that cuts the thickened and damaged external skin to allow the pressure in the tissue below to decompress and blood flow to continue through the constricted area. Measure and document the distal pulses in burned extremities.

If possible, attempt to get a brief history from the patient. Patients with preexisting pathologies, such as chronic obstructive pulmonary disease (COPD) or heart disease, may be triaged as critical burns even if their burn injury or area is small. As in any other trauma, allergies, medications, and other pertinent past medical history may affect the patient's care plan.

## Detailed Physical Exam and Reassessment

If the patient is considered to have a significant mechanism of injury (MOI), then the provider should perform a detailed physical exam relative to the time criticality of the assessment, as well as the continued reassessment, while en route to the ED or burn center. The specific steps to these are not significantly different than for any other trauma patient. Reassessment of vital signs to establish trends is done every 5 minutes for time-critical patients and every 15 minutes for the lower priority (stable) patient.

**TIP**

A quick tool to assist the provider in assessing burns is the mnemonic OLDEST.

- **O** Other injuries (c-spine, etc.)
- **L** Location of burn injury
- **D** Depth of burn
- **E** Exposure time
- **S** Surface area estimation
- **T** Temperature (eg, was coffee freshly brewed or standing for a minute or two)

## Assessment Considerations for Specific Burn Types

### Assessment of Airway Burns

Initial/primary assessment of the burn patient must include a careful examination of the external and internal airway. Look at the mouth, lips, and nares for swelling or blistering. Review the interior of the mouth and nasal passages for soot, reddening, swelling, or obstruction. Examine the tongue and oral pharynx for signs of burns, thick secretions, or soot. Suction any secretions and remove any obstructions that can be cleared.

Listen for stridor, the noisy breathing heard from air passing through swollen air passages in the upper airway. If the patient is conscious, ask them a question and listen to how they speak. A harsh or raspy voice can indicate burns or swelling of the vocal cords. Finally listen to lung sounds for wheezing or rhonchi indicating swelling or obstructions from smoke inhalation or deeper burns. When signs of airway burns are noted, continuous care and reassessment are indicated. Airway burns can become life threatening in minutes. Immediate transport is indicated to a hospital with a suitably set up ED. Securing an advanced airway should be attempted by the most skilled provider available because additional swelling from the attempt may worsen the condition.

### Assessment of Chemical Burns

The scene of a chemical burn is by definition a hazardous materials scene. Personal safety must be assessed before the provider or additional personnel enter the scene without personal protective equipment (PPE). When possible, have the patient moved to a well-ventilated area for further assessment. Most chemical exposures require flooding the skin with copious amounts of water. Do not position yourself in the runoff from the patient. Strip the patient while irrigating the patient, looking for burns in the folds of skin and along areas where the chemical can collect, such as the shirt collar, along the beltline, and in socks, shoes, and gloves.

After the patient has been decontaminated, assess the patient's breath for odd smells indicating the patient inhaled additional chemicals. Assess the airway as noted above. Although personal modesty is to be considered, all areas of the body exposed or potentially exposed must be examined for burns, including along the folds of the skin under the breasts, under the scrotum, and around the buttocks.

### Assessment of Electrical Burns

The first priority at the scene of an electric injury is to protect yourself and bystanders from becoming the next victims. Do not rush in and attempt to dislodge the patient from the current source, even if you intend to use a rope, wooden pole, or any other object. High voltage will still have the capacity to jump the relatively short distance. Clearly, relatively low domestic voltage from lamps and the like are not such an area of caution. Do not go anywhere near a high-tension line. There is only one safe way to deal with a live high-tension wire, and that is to call the electric

**TIP**

Do not use a rope, wooden pole, or any other object to try to dislodge a patient from a high-voltage current source.

**TIP**

Not all EDs are equipped to handle patients exposed to radiation, so learn the capabilities of your hospitals before an incident occurs.

company. Wait until a qualified person has shut off the power before you approach the patient, who in reality will mostly likely be close to death if not already dead.

Make careful note of the patient's state of consciousness and record his or her vital signs. Try to determine the path the current has taken through the body by looking for an entrance wound and an exit wound and by carefully palpating the skin and soft tissues. When deep tissues have been seriously damaged by heat, the surrounding muscle swells and becomes rock hard. Thus, if you find a rigid abdomen or rigid extremity, there is a high probability of serious internal injury. Be alert for fractures or dislocations, and check the distal pulses on all four extremities.

### Assessment of Radiation Burns

First and foremost, the assessment of a patient who may have been exposed to radiation involves a scene size-up to determine that the scene is safe for rescuers. In some cases, it may be appropriate to contact the hazardous materials response team so they may determine the appropriate precautions, including exposure-limiting suits, and the most appropriate ED for the patient's treatment. Not all EDs are set up to handle a patient who has been exposed to radiation, so learn the capabilities of your hospitals before an incident occurs. If in any doubt, contact your local ED via dispatch and establish their up-to-date capability. In general, EDs do not like surprise visits of radiation burns. EMS agencies that operate in an area where there is a nuclear power plant or other research facility typically have additional training offered by the facility and regularly practice responding to radiation-related emergencies.

Once the scene is deemed safe, you may proceed with your initial assessment of the patient. Unfortunately, patients who have sustained a significant radiation exposure and a major burn are unlikely to survive, even with major resources expended to keep them alive. You should also consult with the ED via dispatch in these complicated cases. In the field, it is difficult to determine the extent of the patient's internal injuries because radiation can "cook from the inside out."

## Management of Burns

Burn care can be divided into five phases. Although prehospital providers will be most involved in the first phase, it is important to appreciate the magnitude of care that a severe, or even moderate, burn patient must receive. Early actions of the prehospital provider may dramatically affect the long-term outcome for the patient. Providers may also find themselves transporting patients to specialty or rehab facilities at later stages of their care. The five phases of burn care are outlined in TABLE 8-5.

Note that, unlike many emergencies you will encounter, burn patient care is measured in weeks, not hours. Burns are devastating multisystem traumatic injuries that will dramatically alter your patient's life. It is valuable for providers to comprehend not only the massive physical trauma caused by burns, but also the emotional, psychological, and financial burdens caused by these horrific traumatic events. Once appreciated, it is easy to understand the importance of teaching injury prevention strategies to those we serve.

### General Management

Management of the burned patient begins with the steps taken during the scene size-up and initial/primary assessment to extinguish the fire and ensure adequate ABCs. Only when the active burning is extinguished and the ABCs are under control should you turn your attention to the burn itself. It is important to have all resuscitative equipment ready for use when treating the burn patient. This includes advanced airway equipment and heart monitors.

**TABLE 8-5 Five Phases of Burn Care**

| Phase | Time Frame | Treatment Objectives |
|---|---|---|
| At emergency scene | First 30 minutes | Stop the burning, airway, pain relief, wound dressing, and rapid transport |
| Initial evaluation and resuscitation | First 72 hours | To achieve accurate fluid resuscitation and perform a thorough evaluation |
| Initial wound excision and biologic closure | Days 1 through 7 | To identify and remove all full-thickness wounds and obtain biologic closure |
| Definitive wound closure | Day 7 through week 6 | To replace temporary covers with definitive ones and close small complex wounds |
| Rehabilitation, reconstruction, and reintegration | Entire hospitalization | To maintain range of motion and reduce edema, and to strengthen and prepare for return to the community |

Keep the following equipment and materials handy for burn management:

- Foil blanket
- Woven blanket
- Large sterile burn sheet
- Face mask dressing
- Hand and finger dressings
- Sterile gauze bandages of various sizes
- Conforming gauze roll bandages
- Tape rolls
- 1,000-mL sterile water bottles
- Eye wash
- Scissors (shears)
- Ring cutter
- Some kits may include gel dressings, which have TBSA in percentage on the back of the wrappings

It is important to determine accurately the extent of the burn injury to facilitate proper treatment and transportation of the burn patient. All the patient's clothes must be removed to assess accurately the extent of the burn injury and to make sure all hot materials have been removed. Do not try to remove clothing that is adhered to the patient's skin. It is important to maintain warmth during this process because there is an alteration in the normal thermal regulation process. Anticipate shivering and loss of body temperature in all burns exceeding 20% of the total body surface area. Evaporative heat losses can be enormous. For this reason it is imperative to monitor the patient's temperature. Avoiding wind chill is ideal and can be helped by providing a blanket.

The following three areas should be assessed:

- Depth of the burns
- Total body surface area burned (calculate partial and full thickness only)
- Need to transfer to a burn specialty center with consideration to running time

## Immediate Management

**Stop the Burning** When a person burns their hand on a hot oven rack at 375°F (190°C), they will usually stick their hand under cool running water for a few seconds. Is that long enough to cool the tissues and stop the burning? It often takes a few minutes under cool running water to completely cool the burned area and achieve some pain relief. That being the case with a minor burn in the home, providers should be aware that a quick spray from a fire hose will not completely stop the burning in a patient whose clothing was on fire a few moments before. The burned areas need to be cooled to 98.6°F (37°C).

Watchbands, zippers, and rings not only can retain enough heat to continue burning the patient, they can melt your gloves and burn you as well! Take extra care to be certain that metal on the patient's person has been cooled appropriately.

If the hands are burned, they will swell considerably and rings will become tourniquets if not removed early. If bits of smoldering cloth adhere to the skin, do not pull them off the skin; cut them away. Pulling fabrics from the skin may cause additional tissue trauma and bleeding, which will worsen the situation. Let the burn center or hospital deal with items that are melted to the flesh.

In addition to extinguishing flames, the skin should be cooled. Never use ice on a burn. Cool partial-thickness burns of less than 10% body surface area or full-thickness

> **TIP**
>
> The following steps list the approach to the burn patient:
>
> 1. Ensure scene safety and body substance isolation.
> 2. Put out the fire.
> 3. Safeguard the airway: Be alert for clues to an airway in jeopardy. Consider the need for spinal immobilization if the burn is associated with trauma. Intubate early if clinically necessary; defer to the hospital if reasonable to do so.
> 4. Help the patient breathe: Give high-flow, high-percentage oxygen to reduce CO concentrations via nonrebreathing mask. Consider a nebulized beta-agonist if respiratory distress is present.
> 5. Ensure the circulation: Start intravenous or intraosseous fluids, but don't extend your on-scene time to do so.
> 6. Give narcotics (or other agents as directed by your protocols) IV for pain management.
> 7. Perform the rapid trauma/secondary assessment:
>    a. Find out the circumstances of the burn.
>    b. Check vital signs often.
> 8. Be alert for the following:
>    a. Injuries sustained in falls (fractures, spine injury)
>    b. Circumferential burns
>    c. Absence of distal pulses
> 9. Treat the burns.
>    a. Do not use remedies such as creams or lotions on the burn.
>    b. In the prehospital setting, and in the first stages of the ED, burns of less than 10% should have cool, wet dressings applied until the burning process stops. Otherwise, cover with clean, dry dressings.
>    c. Elevate burned extremities; remove constricting jewelry.
> 10. Transfer the patient to an appropriate treatment facility.
> 11. Maintain the patient's temperature; do not allow them to cool too rapidly.

**FIGURE 8-22** Maintain the burn patient's warmth.

burns of less than 2% body surface area with irrigating solution (normal saline) in the first 10 to 15 minutes after the burn. Cooling larger surface areas will contribute to hypothermia, especially with wind chill factors.

**Maintain the Patient's Warmth** This seems like a contradiction to the above because it is. The trick is to cool the burn without making the patient hypothermic. Remember, people with large area burns have lost their primary mechanism for thermoregulation. Keep the burn patient covered and move them into the ambulance as soon as possible to minimize hypothermic stress FIGURE 8-22.

**Do Not Forget Other Injuries** If the patient is at risk for spinal trauma from a fall or explosion, that trauma needs to be addressed the same way as it would in any other trauma patient. The same is true for gross bleeding or other traumatic injuries. Burns can also exacerbate a patient's underlying medical conditions. COPD, asthma, and cardiac conditions may all need attention. Follow the same priorities for these emergencies as you would for any other time-critical patient.

## Airway Management

Bear in mind that intubation of an awake, scared patient in the field is particularly challenging, and considerable damage can be inflicted on the airway if the patient is struggling. If intubation does become necessary under such circumstances, consider the consequences of failure before using paralytics or muscle relaxants to intubate (Chapter 3). Have all the equipment set up at your side so that intubation, once begun, can proceed rapidly and smoothly. Select and use the largest tube in relation to the lumen of the available airway. Burn patients' secretions are sometimes thick and sooty, so be sure to have a suction unit with large catheters available. Progressive airway swelling will make it difficult to reintubate or change the endotracheal (ET) tube at the hospital. Even if there is no evidence of airway involvement, early intubation should also be considered in any fire victim who is stuporous or comatose, but it is preferable that it be performed in the more controlled environment of the hospital, where additional drugs and devices are available if the airway is difficult to achieve.

Many burn patients will ultimately require intubation, even though they were talking to you and in no distress in the field. Although it is obviously preferable to have such patients intubated in a controlled environment with a full complement of anesthesia agents, there will be a few patients who absolutely require an emergency airway in the field. Burn patients fall into four general categories for airway management:

1. *The patient with the acutely decompensating airway that requires field intubation.* This will include those burn patients who are in cardiac or respiratory arrest and conscious patients whose airways are swelling up before your eyes. These are chaotic and difficult situations where you need to have planned for the possibility that you cannot intubate. Supraglottic swelling or complete obstruction can occur in some burn scenarios, and surgical airways or rescue devices may be necessary if intubation is not possible and bag-mask ventilation fails or is inadequate.
2. *The patient with the deteriorating airway from burns and toxic inhalations.* This is also a very difficult scenario. It is obviously better for the patient to defer this airway to hospital teams with anesthesia, surgery, specialized equipment, and a fully stocked pharmacy. The patient will often be conscious and may become combative with attempts to place them supine, let alone to intubate them. "Awake" techniques, such as nasal intubation, are dramatically more complicated in victims of upper airway burns, and should be avoided. Attempt to intubate this patient only if left with no other choice. If their airway continues to swell and will become impossible to intubate if you wait for arrival at the hospital, you will have little choice but to attempt intubation. Where applicable, try to consult medical direction for advice in this situation.
3. *The patient whose airway is currently patent, but who has a history consistent with risk factors for eventual airway compromise.* Cool, humidified saline or a beta-agonist from a nebulizer is appropriate for this patient. If this equipment is not available, consider using an aerosol nebulizer with saline FIGURE 8-23. This patient will probably not require acute interventions in the field, but make sure you pass on their history to the hospital. Many of these patients may ultimately undergo elective intubation.
4. *The patient with no signs of, or risk factors for, airway compromise, and who is in no distress.* It is reasonable to provide supplemental oxygen to burned patients, even if they are not in distress. Remember

that carbon monoxide can make oxygen saturation readings inaccurate. It is safe to oxygenate until you are very comfortable with the situation surrounding the burn and have completed a full assessment.

## Fluid Resuscitation

The two reasons to establish an intravenous (IV) or an intraosseous (IO) line are to administer fluids and to administer pain medications. An IV/IO should be established as early as possible in any patient who has been severely burned. Do not delay transport to do so, but try to get a large-bore IV catheter into an antecubital vein, or an IO into the tibia and hang lactated Ringer's or Hartmann's solution. Normal saline can be substituted if local protocols prohibit lactated Ringer's. You can use a superficially burned extremity if you cannot find another site—an IV in a burned upper extremity is still preferable to an IV in a lower extremity.

**FIGURE 8-23** For a patient with a history consistent with risk factors for eventual airway compromise, provide oxygen using a nebulizer.

Approximate the amount of fluid the burned patient will need by using the Parkland formula **TABLE 8-6**, which states that during the first 24 hours, the burned patient will need:

$$4 \text{ mL} \times \text{kg body weight} \times \text{\% of body surface burned} = \text{total mL of fluid needed}$$

Half of that amount needs to be given during the first 8 hours. For example, if a 70-kg man has sustained burns to 30% of his body, his fluid needs over the first 8 hours will be:

$$4 \text{ mL} \times 70 \text{ kg} \times 30\% \div 2 = 2{,}100 \text{ mL to be infused in 8 hours}$$

Half of the 4,200 mL (2,100 mL) needs to be administered in the first 8 hours.

As aggressive as the Parkland formula may seem, current trends actually lean toward delivering *more* fluid than the Parkland formula indicates. In instances of high-tension electrical injuries, substantially more fluid is required. At the same time, keep in mind that you do not need to attempt to deliver the entire initial amount in the field. It is *not* helpful to administer *too much* fluid in the field. Most serious burn patients will ultimately need central venous access, and prehospital IV lines will most often be lost as the patient begins to swell peripherally. Do not focus all of your prehospital, on-scene attention on vascular access and fluid delivery.

## Pain Management

Beyond oxygenation, cooling the burn to stop damage, and maintenance of core temperature for the patient, it is important to provide aggressive pain management. Even minor burns are painful and need analgesia. The provider should assess the patient's pain before administering medication. Burn patients may require high doses of pain medications to achieve relief. Their metabolism rates are accelerated, requiring higher than normal doses of pain medicines.

**TABLE 8-6 Parkland Formula Chart**

| % Burn | 10 kg | 20 kg | 30 kg | 40 kg | 50 kg | 60 kg | 70 kg | 80 kg | 90 kg | 100 kg |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 25 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 |
| 20 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
| 30 | 75 | 150 | 225 | 300 | 375 | 450 | 525 | 600 | 675 | 750 |
| 40 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1,000 |
| 50 | 125 | 250 | 375 | 500 | 625 | 750 | 875 | 1,000 | 1,125 | 1,250 |
| 60 | 150 | 300 | 450 | 600 | 750 | 900 | 1,050 | 1,200 | 1,350 | 1,500 |
| 70 | 175 | 350 | 525 | 700 | 875 | 1,050 | 1,225 | 1,400 | 1,575 | 1,750 |
| 80 | 200 | 400 | 600 | 800 | 1,000 | 1,200 | 1,400 | 1,600 | 1,800 | 2,000 |
| 90 | 225 | 450 | 675 | 900 | 1,125 | 1,350 | 1,575 | 1,800 | 2,025 | 2,250 |
| 20 mL/kg | 200 | 400 | 600 | 800 | 1,000 | 1,200 | 1,400 | 1,600 | 1,800 | 2,000 |

This table represents the fluid recommended in the *first hour* (1/8 of the initial 8-hour dose) by the Parkland formula. The final row represents the amount of a 20-mL/kg bolus.

Narcotic pain relief medications are often the first line of relief for these patients beyond cooling the burn. These medications often produce a decrease in blood pressure and a decrease in respiratory effort. Titration to adequate pain relief with careful monitoring of vital signs is necessary. Narcotics should be given only by IV or IO and in doses no larger than is needed for pain relief. Doses will need to be adjusted when coexisting trauma or preexisting medical conditions are present.

Pain relief may be enhanced by appropriate relief of anxiety. Agents such as diazepam or midazolam must be used with caution when combined with narcotic analgesics unless a provider with advanced airway skill is available to deal with the respiratory depression or hypotension that can result from synergism.

Nitrous oxide mixtures are useful and provide immediate oxygen. Nitrous oxide must not be continued together with narcotics and sedatives because the effect of these three types of drugs together is essentially a general anesthetic. Reassessment of pain should be completed using the same scale (for example, 0 to 10) every 5 minutes. Seek advice from the ED or medical command via dispatch regarding increasing pain medication and dosages that are beyond normally accepted dosage. Non-narcotic analgesics can be valuable in certain scenarios.

## Management of Superficial Burns

Although superficial burns can be very painful, they rarely pose a threat to life unless they involve nearly the whole surface of the body. If you reach the patient with superficial burns within the first hour of the injury, immerse the burned area in cool water or apply cold compresses to the burn FIGURE 8-24. Burned hands or feet may be soaked directly in cool water, while towels soaked in cool water may be applied to burns of the face or trunk.

The object of the exercise is twofold: to stop the burning process and to provide relief of pain. Commercial products are available to do both those things and also to provide a good burn dressing. However, in cooling the burn, take care not to overcool the whole patient; that is, do not let the patient become chilled. A dry sheet or blanket applied over the wet dressings will help prevent systemic heat loss, especially in inclement weather conditions PROCEDURE 28.

Whatever you put on the burn, do not use salves, ointments, creams, sprays, or any similar materials on any type of burn. They will just have to be scrubbed off in the emergency department, causing the patient further pain. No additional treatment should be necessary in the field for the uncomplicated (no other injury) superficial burn. Simply transport the patient in a comfortable position to the hospital.

**FIGURE 8-24** Moisten dressings of superficial burns to stop burning and reduce pain.

## Management of Partial-Thickness Burns

Treatment of partial-thickness burns in the field is very similar to that of superficial burns. Again, cool the burned area in cool water or apply a wet or water-based gel dressing within the first hour. Doing so will diminish edema and provide significant pain relief. Burned extremities should also be elevated, again to minimize edema formation.

Do not attempt to rupture blisters over the burn; they are the best burn dressing in the short term. Establish IV fluids with lactated Ringer's or Hartmann's solution or normal saline, as dictated by local protocol. Pain in partial-thickness burns may be very severe. Complete a pain assessment and administer pain medication as allowed by your protocols.

## Management of Full-Thickness Burns

Although full-thickness burns do not cause the same level of pain for the patient, most patients will have varying degrees of burns within the affected region of injury. For this reason, a pain assessment should be completed and pain medication should be administered as described above. There is little else you can do for a full-thickness burn in the field, but be sure to cover with a sterile dressing and monitor any areas of circumferential burns as noted above.

## Management of Chemical Burns

As with any burn, rapidly stopping the burning process is central to early management. Flush the exposed area of the patient's body immediately with copious quantities of water to remove the offending chemicals. A few chemicals react violently with water, which obviously precludes irrigation. Such chemicals are usually powders, so it is reasonable to brush off as much dry powder as possible before irrigating any chemical exposure FIGURE 8-25. Skin destruction is determined by the concentration and duration of contact. Systemic toxicity is determined by the degree of absorption.

Immediately remove the patient's clothing, especially shoes and socks that may have become contaminated with the chemical agent, taking care not to get any of the hazardous chemicals on your own clothing or skin. This will often remove the majority of the chemical from skin contact. Most chemicals are most efficiently removed by washing with

**FIGURE 8-25** Dry chemicals may burn the patient further if you add water. Before flushing a dry chemical burn with water, brush off as much of the chemical as you can.

**FIGURE 8-26** Have the patient wash areas that are along joints and between fingers and toes.

copious amounts of low-pressure water, as may be available in a shower, sink, or eye wash station. If the patient is in or near the home, the shower or a garden hose is ideal. Have the patient bend over when washing hair and head, to avoid having residual chemicals run over the rest of the patient's body. Chemicals collect in skin folds, where they remain in contact with the tissue, causing more severe damage. Care must be taken to wash the skin folds at joints, and between fingers and toes meticulously **FIGURE 8-26**.

In an industrial setting, use the decontamination shower or a hose. After a thorough initial flushing (usually at least 5 minutes), some chemicals may adhere to the skin and a mild detergent (dishwashing liquid) will aid in the washing. Remember to rinse and wash gently to avoid abrading the skin and causing increased injury or absorption of the chemical.

Do not waste time looking for specific antidotes; copious flushing with water is more effective and more immediately available. Furthermore, so-called neutralizing agents often work by combining with the chemical that caused the burn in an **exothermic reaction** (ie, a reaction that produces heat). Thus, the very process of neutralizing the offending chemical may cause further burns to the patient.

Flushing should be continued for a minimum of 30 minutes; for chemical burns caused by strong alkalis (eg, oven and drain cleaners), 1 to 2 hours of flushing is recommended. It is obviously preferable that you begin transport as soon as is practical and continue the flushing en route. Specialist burn centers have specialized equipment to complete the flushing and cleaning process. When flushing is complete, cover the burned area with a sterile dressing or cover the whole patient with a sterile sheet.

## Special Cases of Chemical Burns

In alkali burns caused by dry lime, mixing with water may produce a highly corrosive substance. For that reason, when a patient has been in contact with dry lime, first remove his or her clothing and brush as much lime as you can from his or her skin (wearing gloves). Then start flushing copiously with a garden hose or shower, and continue flushing for at least 30 minutes. The potential for overcooling is great; take care.

Sodium metals produce considerable heat when mixed with water and may explode. Although rarely practical, consider covering the burn with oil, which will stop the reaction by preventing the sodium from coming in contact with the atmosphere.

Hydrofluoric acid (HF) is used in drain cleaners in the home; industrially it is used for etching glass and plastic. The patient burned with HF will complain bitterly of pain, and the pain will not get any better even with continuous flushing—a sign that the process of tissue destruction is ongoing. Treatment of HF burns requires the injection of calcium chloride (CaCl) into the burn wound, a procedure that should be undertaken in the ED, not in the field. The patient with HF burns, therefore, should be moved to the hospital after an initial 5 to 10 minutes of flushing to remove surface chemical. A slurry of 10% CaCl and a water-soluble lubricant can be applied to small HF burns and may provide some pain relief.

Hot tar burns are, strictly speaking, thermal burns, not chemical burns, although they tend to be classified with chemical burns. The most important treatment in the prehospital phase is to immerse the affected area in cold water to dissipate the heat from the tar and speed up the hardening process. Once the tar has cooled, it will not do any further damage, and there is no need to try to remove it in the field.

If you do not know the identity of the chemical that caused the burn, assume it is not a special case. Flush the burn wound with water for at least 30 minutes as previously described.

## Chemical Burns of the Eye

If chemicals have splashed into the patient's eyes, the eyes too must be flushed with copious amounts of water. The most efficient way to do so is simply to support the patient's head under a faucet, directing a steady stream of lukewarm

**FIGURE 8-27** Flood the affected eye with a gentle stream of water. Hold the eyelids open, a challenging task because the patient's natural reflex is to close the eye or even keep the eye shut. Take care to prevent any of the chemical from getting into the other eye during the flushing.

**FIGURE 8-28** The Morgan Lens makes eye irrigation more comfortable, efficient, and effective.

tap water into the affected eye FIGURE 8-27. If the patient wears contact lenses and the stream of water does not flush them out, pause after a minute or two of irrigation to allow the patient to remove their own contact lenses. If the lenses remain in place, they will prevent water from reaching the cornea underneath. Be sure to irrigate well underneath the eyelids PROCEDURE 30.

Never use any chemical antidotes (eg, vinegar or baking soda) in the eyes. Irrigate with water only. After irrigating for a minimum of 30 minutes, patch the patient's eyes with lightly applied dressings and transport the patient to the hospital for evaluation.

Eye irrigation is extremely important in any situation where a chemical has gotten into the eye. It is uncomfortable and inefficient to attempt to irrigate an eye by prying it open and rinsing with a standard normal saline IV set. The Morgan Lens makes eye irrigation more comfortable, efficient, and effective FIGURE 8-28. Ocular anesthetic drops are preferable (if allowed by your local protocols), but care must be taken when the eye is numb to keep the patient from scratching or rubbing it PROCEDURE 29.

## Management of Electrical Burns

The first priority at the scene of an electrical injury is to protect yourself and bystanders from becoming the next victims. Do *not* use a rope, wooden pole, or any other object to try to dislodge the patient from the current source. Do *not* try to cut the wire. Do *not* go anywhere near a high-voltage line.

Many parts of the electrical grid are protected by automatically resetting breakers. Should the wind blow a branch into wires, bridging the gap between two wires, it is desirable to have the breaker reset after a few moments to avoid power outages. As a consequence, a downed wire that "looks dead" can jump back to life, perhaps several times. There is only one safe way to deal with a downed high-tension wire: Call the electric company. Wait until a qualified person has shut off the power before you approach the patient. This can be a traumatic event for providers, who will feel helpless waiting for the power to be shut down while a possibly critical patient lies on the ground nearby. But remember—*providers can die in these situations.* You can help the greatest number of people by being cautious and safe in this circumstance.

Once the electric hazard has been neutralized, proceed to the ABCs. Open the airway using the jaw-thrust maneuver, keeping in mind the possibility of cervical spine injury. If the patient is in cardiac arrest, beginning CPR and applying an ECG monitor or the automated external defibrillator (AED) will, of course, have priority. There is usually a very good chance of successfully resuscitating the patient with an electric injury, but doing so might require prolonged CPR.

If the patient is not in cardiac arrest, arrhythmias remain a risk and cardiac monitoring is indicated for 24 hours after significant burns. Take the following steps when treating patients with electrical burns:

1. Administer high-flow oxygen.
2. Monitor the patient's cardiac rhythm.
3. Start at least one IV or IO and run in a lactated Ringer's, Hartmann's, or normal saline solution bolus to keep the kidneys flushed.
4. Contact the ED or base physician via dispatch for advice, which may include:
   a. If the patient has fallen, immobilize the cervical spine.
   b. Cover any surface burns with dry, sterile dressings.
   c. Splint any fractures.

## Management of Radiation Burns

Patients with radiation burns might be contaminated with radioactive material, so they should be decontaminated before transport. The majority of contaminants can be removed simply by disrobing the patient.

Irrigate open wounds. Washing should be gentle to avoid further damage to the skin, which could result in additional internal radiation absorption. The head and scalp should be irrigated the same way. The ED should be notified as soon as practical if you are transporting a potentially contaminated patient. In contrast with other types of contamination, radioactive particulate matter probably poses a relatively small risk to the rescuer. Consider providing basic care to the patient before decontamination if you are wearing protective clothing.

Radiation injury follows the **inverse square law**: Exposure drops exponentially as distance is increased. Increasing your (and your patient's) distance from the source by even a few feet may dramatically decrease your exposure, so it is important to identify the radioactive source and the length of the patient's exposure to it. You must try to limit your duration of exposure, increase your distance from the source, and attempt to place shielding between yourself and sources of gamma radiation.

With contact radiation burns, decontaminate the wound as if it were a chemical burn to remove any radioactive particulate matter. You may then treat it as a burn.

Many radioactive isotopes are used in medicine and industry. Some of these isotopes can be absorbed or have their toxic effects blunted by another substance. Like their radioactive effects, the toxic effects of these isotopes vary. Antidotes may help bind an isotope, enhance its elimination from the body, or reduce the toxic effects on other organs TABLE 8-7. Such expert antidotal therapy should be considered only under the guidance of a knowledgeable doctor or specialist radiographer.

Potassium iodide is distributed to people who live near a nuclear power plant and may help protect the thyroid gland if taken within 6 hours of exposure. Contrary to popular belief, however, it is effective only for radionuclides released from fission products from nuclear power plants and would be of little value for exposure to medical radiation.

## Management of Burns in Pediatric Patients

Escaping from a fire can be difficult for children. More than half of child fire fatalities and injuries are preschoolers. Recent research suggests that young children are not as effectively awakened by smoke detectors and are often disoriented immediately after waking. Young children are also more likely to suffer severe scald injuries. Children's thin skin and delicate respiratory structures are more easily damaged by thermal insults than in older children and adults.

In children, fluid resuscitation may be more challenging because they have an increased body surface-to-weight ratio. They may have a greater fluid requirement than adults. It is acceptable to start with the Parkland formula in children; however, local protocols may provide for standard pediatric dosing of fluids. In addition, because of poor glycogen stores, children might require dextrose-containing solutions earlier than adults. Certainly routine blood glucose monitoring should be done.

In children, it is vitally important to differentiate accidental burns from child abuse. Pay careful attention to the mechanism of injury, which should be relayed to the hospital staff at the ED.

**TABLE 8-7 Antidotes to Selected Isotopes***

| Isotope | Antidote |
|---|---|
| Cesium 137 | Prussian blue adsorbs cesium in the GI tract and may enhance elimination. |
| Iodine 131 | Potassium iodide blocks thyroid uptake. |
| Plutonium 239 | DTPA or EDTA can be used as a chelator and for wounds. Aluminum hydroxide antacids may bind plutonium in the GI tract. |
| Radium 226 | Provide immediate lavage with 10% magnesium sulfate followed by saline solution and magnesium purgatives. Ammonium chloride may increase fecal elimination. |
| Strontium 90 | Aluminum hydroxide antacids may bind strontium in the GI tract. Aluminum phosphate can decrease its absorption by 85%. Ammonium chloride can acidify urine and enhance its secretion. Barium sulfate may reduce strontium absorption. |
| Tritium | Oral fluids will reduce biologic half-life from 12 to approximately 6 days. |
| Uranium | Sodium bicarbonate reduces nephrotoxicity. |

*GI indicates gastrointestinal; DTPA, diethylenetriamine pentaacetic acid; and EDTA, ethylenediaminetetraacetic acid.

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## Management of Burns in Elderly Patients

In the United States, 1,200 older adults die from fire each year, making fires the sixth leading cause of death in this population group. Thirteen percent of older adults smoke, and smoking is the leading cause of fires that lead to death in the elderly. Elderly patients are particularly sensitive to respiratory insults. The leading sentinel event in home health care is fires caused by smoking while wearing supplemental oxygen. Cooking fires represent another distinct hazard to the elderly.

Older patients may also have poor glycogen stores, and their blood glucose levels should be checked to determine possible hypoglycemia. In addition, careful cardiac monitoring should occur. Although fluid resuscitation is important, elderly patients are more likely to develop pulmonary edema. The provider must routinely assess lung sounds for developing rales.

## Transfer to a Specialty Burn Center

The American Burn Association has identified the following referral criteria. Patients suffering from any of the following burn injuries should be transferred to a specialty burn center:

- Partial-thickness burns of greater than 10% body surface area
- Burns that involve the face, hands, feet, genitalia, perineum, or major joints
- Full-thickness burns in any age group
- Electrical burns, including those from lightning
- Chemical burns
- Inhalation burns
- Burn injury with preexisting medical conditions that could complicate management, prolong recovery, or affect mortality
- Burns and concomitant trauma in which the burn injury poses the greatest risk of morbidity or mortality
- Burn injury that requires special social, emotional, long-term rehabilitation intervention

There are some differences between European and American guidelines that relate to both burn care and the capabilities of different burn centers. The European Practice Guidelines for Burn Care mirror the American Burn Association but also include:

- Any type of burn if any type of doubt about the treatment exists
- Diseases associated to burns such as toxic epidermal necrolysis, necrotizing fasciitis, staphylococcal scalded child syndrome, etc
- Burns over 10% TBSA for children
- Burns over 15% TBSA for the elderly

The American Burn Association also has published burn severity classifications TABLE 8-8. All critical burns should be transported to a specialty burn center.

**TABLE 8-8 Burn Severity Classifications**

| | | |
|---|---|---|
| **Minor burns** | Superficial | Body surface area less than 50% (sunburns, etc) |
| | Partial thickness | Body surface area less than 15% |
| | Full thickness | Body surface area less than 2% |
| **Moderate burns** | Superficial | Body surface area greater than 50% |
| | Partial thickness | Body surface area less than 30% |
| | Full thickness | Body surface area less than 10% |
| **Critical burns** | Partial thickness | Body surface area greater than 30% |
| | Full thickness | Body surface area greater than 10% |
| | Inhalation injury | |
| | Partial- or full-thickness burn involving hands, feet, joints, face, or genitalia | |

## Consequences of Burns

Burns are horrifying injuries. They leave scars on both the victims and rescuers, and they tax the system's resources. Sophisticated burn centers are available to treat these complex injuries, but the total number of burn center beds has decreased in recent years. These limited beds are often occupied by patients who require care for weeks or months. The surge capacity of burn units is limited, and an incident that generates multiple burn patients can tax this limited resource.

### The Patient

As previously mentioned, burns are devastating injuries that may require months of recuperation. Burn patients must survive not only their traumatic burn injuries, but also end-organ dysfunction and the specter of infection. The psychological trauma inflicted by burns may be as bad as the physical trauma. After the acute phase, months or years of rehabilitation might be necessary to maximize the use of limbs and joints damaged by the burn and extensive immobility. Patients with major injuries average about 1 day of inpatient treatment for each percentage of TBSA burned. After initial treatment, extensive rehabilitation may be necessary to regain function. Serious burn survivors are left with a host of long-term consequences including problems with thermoregulation, fluid imbalance, and neurosensory deficits. Tremendous improvements in the care of critical burn patients have made long-term survival possible for many who would have died from their injuries a decade ago, but large surface area burns remain a critical care challenge on par with other forms of severe multisystem trauma.

### The Provider

Caring for patients with severe burn emergencies can be one of the most horrifying tasks undertaken by a provider. Fire scenes are chaotic and dangerous places. Patients are often in severe pain. The smell of burned hair and flesh permeates your clothes and equipment. Sheets of skin may peel off the patient when you perform simple tasks like attempting to take vital signs or moving the patient. These calls are among the most traumatic events most providers will be called upon to cope with. Providers should consider psychological first aid after any major burn event.

# CHAPTER RESOURCES

## CASE STUDY ANSWERS

**1** What scene safety issues are present?

Scenes of violence require constant vigilance to maintain scene safety. The fire that was present and the fluid that was used to start the fire are concerning as well. The developing crowd can also become an issue of safety if the crowd becomes difficult to control.

**2** Approximately how much surface area is affected by the burn?

Using the Rule of Nines, the upper chest is 9% + the upper back 9% + hands 6% = 24%. This burn estimate may be high or low and should be adjusted based on the patient's actual presentation. Other methods could also be used to help estimate the burns.

**3** What is the first step in prehospital burn care?

Stopping the burning process must be addressed immediately following scene safety. It is appropriate to wet the patient to stop the burning. Thermal transfer is a concern that can be managed after the burning process has stopped. Warming the patient with dry blankets and dressing wounds can be completed in the treatment phase of burn management.

**4** Describe the priorities for assessment and initial care of your patient.

Immediate threats to life from thermal trauma revolve almost exclusively around the airway and breathing. The initial/primary assessment is completed with these in mind, however bleeding and early presentation of shock is more often a significant sign of traumatic injuries, not burns. Your patient has only minor trauma to the airway and while he is breathing fast, he is not having difficulty moving air in and out. Shock does appear to be present based on his appearance and vital signs. Treatment should be geared at stopping the burning and treating for shock.

**5** What is the cause of his shock?

Your patient is most likely in shock due to the injury sustained from the assault prior to being set on fire. Look for additional signs of bleeding such as internal blunt trauma or unseen penetrating trauma. The fluid loss from burns has a delayed presentation as it takes time for the fluid to shift out of the damaged cells into the tissue.

### Trauma in Action

1. What are the local burn specialty hospitals in your area?
2. How will you transport to those facilities if they are far away?
3. What are the capabilities of your local hospitals for chemical exposures? Radiation exposures?
4. Does your agency have protocols for response to a chemical or radiation exposure? Have you reviewed them recently?

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