Introduction

Burns affect approximately one million Americans each year (LaBorde 2004), half of whom receive medical treatment (American Burn Association 2007). Unfortunately, about 4,000 of these patients die as the result of their injuries (American Burn Association 2007). Many of the hospitalized patients who survive are severely disfigured or disabled. By providing proper care, prehospital personnel can reduce the morbidity and mortality associated with burn injuries.

Anatomy and physiology review

The organ most often affected by thermal injury is the skin. Human skin consists of two broad divisions, the outermost epidermis and the innermost dermis. The epidermis includes the outer five layers of the skin and does not include a capillary bed (Marieb 1989). Because of this lack of capillaries, cells in the epidermis must receive nutrients through diffusion from the underlying dermal blood supply. The outermost layer of the epidermis is made up of dead cells that flake away as the result of daily activity. The deeper layers of the epidermis then replace those cells.

The dermal layer contains nerve endings, blood vessels, lymph vessels and various glands for sweat and oil (Marieb 1989). The dermis provides the blood supply to the overlaying epidermis. The dermal layer is analogous to the layer of animal skin used to make leather.

The skin primarily serves as an organ of protection by preventing harmful bacteria from invading internal structures and by restricting fluid loss (Marieb 1989). In addition, the skin has many other functions, including maintaining temperature, synthesizing and storing certain nutrients, and providing a support matrix for hair follicles, sweat glands, oil glands and the sensory nerve endings that allow the brain to receive information about the world around us.

Pathophysiology of burns

Burns damage the skin by one of three general mechanisms: thermal (or heat) exposure, chemical exposure or electrical exposure.

Thermal burns

According to data from the National Burn Repository, about three-fourths of all burns are thermal in nature and are often caused by exposure to heat from fires, superheated gases or hot water (Latenser et al. 2007). Exposure to a temperature of 55°C (131°F) for as little as 30 seconds will produce a burn injury similar to a mild scald (Bull and Jackson 1952). Exposure to a 60°C (140°F) temperature for the same amount of time usually results in a deeper injury that produces blistering. Finally, exposure to temperatures of at least 65°C (149°F) for 30 seconds results in complete...
destruction of the epidermal layers.

The body responds to cellular injury by activating a protective mechanism called inflammation. The chemicals, or mediators, released during the inflammatory process attempt to minimize and then repair tissue damage. One important feature of this process is that the mediator release is graduated, meaning that minor damage results in the release of a small amount of mediator while more severe injury results in the release of a larger amount.

Once the burn reaches about 30 percent of body surface area, the mediators produce systemic effects (Hettiaratchy and Dziewulski 2004). Some produce an increase in capillary permeability, resulting in leakage of plasma and circulating proteins out of the vasculature (Hettiaratchy and Dziewulski 2004). The leaking fluid then collects in the interstitial spaces of the body and organs.

The original burn source also damages the ion pumps found on cellular membranes. Sodium moves into the injured cells from the interstitial space (the space between the cells), which pulls even more fluid from the leaking capillaries. If the burn is small, the fluid shift from the blood vessels to the tissues produces few systemic effects. However, if the burn area is large, the loss of intravascular fluid reduces myocardial contractility (strength of contraction). All of these changes plus the evaporative fluid loss from the burn itself result in hypotension and organ hypoperfusion. Clinicians refer to this hypoperfusion as burn shock.

Burns covering an area larger than 15 percent of the body surface area of an adult or more than 10 percent of the body surface area of a child will produce burn shock unless the patient receives adequate fluid replacement (Bull and Jackson 1952). However, burn shock does not develop as quickly as hemorrhagic shock. Intravascular and interstitial fluid shifts continue for 24 to 36 hours depending upon the extent of the burns. The greatest fluid shift occurs within the first eight to 12 hours after the burn. If the prehospital assessment reveals the presence of hypovolemia in a burn patient, EMS personnel should evaluate the patient for other injuries that may be contributing to the fluid loss.

Children have a proportionately larger body surface area than adults. This anatomical difference allows children to loose fluids faster than adults, which places them at a greater risk for developing burn shock more quickly.

Blood pressure readings are not an effective method of determining the presence of hypovolemia and the risk of burn shock. Adults may lose approximately 25 percent of their circulating volume before the blood pressure falls (Jackson 1959).

Chemical burns

Another mechanism that produces burn injuries is dermal contact with certain chemicals. Although most often associated with industrial environments, chemical burns may also occur in the home. In many cases, chemical burns are more serious than thermal burns because the offending chemical clings to the skin surface and will continue to cause damage until rescuers decontaminate the area completely. In general, alkaline substances tend to penetrate deeper into the tissues and therefore produce burns that are more serious (Hettiaratchy and Dziewulski 2004).

Electrical burns

Electricity can also produce burn injuries in a variety of ways (Hettiaratchy and Dziewulski 2004). An electrical current can produce damage at the entry point, the exit point and all of the tissues and organs in between. Injury occurs as the potential energy within the current transforms into thermal energy as the current encounters the body’s natural resistance to an electrical pathway. Voltage is the greatest determinant of the degree of tissue damage. Therefore, it is reasonable to categorize electrical burn injuries into those caused by low voltage exposure and those caused by high voltage exposure.

An example of a low voltage source is the common household electrical outlet. Burns from a low voltage source are often small but deep and are concentrated at the entry and exit points (Hettiaratchy and Dziewulski 2004). The alternating nature of an outlet’s current may also interfere with normal electrical conduction through the heart and produce arrhythmias, including ventricular fibrillation.

Clinicians may subdivide high voltage injuries into high-tension injuries or flash burns. High-tension injuries occur when the electrical current travels through the patient’s tissues in a manner similar to that in low voltage injuries (Hettiaratchy and Dziewulski 2004). However, the voltage is usually about 1000 volts or greater, which therefore produces a greater degree of damage. The extensive bone and muscle necrosis produced with this type of injury often results in loss of limbs.

If the electrical pathway is close to but not through the patient’s body, the heat from the conducted electricity may produce a flash burn (Hettiaratchy and Dziewulski 2004). These burns most often appear on exposed skin that is facing the electrical pathway. If the heat is high enough,
Burn injury is more common in African-American children than those of any other race (LaBorde 2004). Children also are at risk of intentional burns from caregivers. These most often involve liquid splash burns, hot water immersion, or burns with solid metal objects.

Burn experts have identified three factors that increase the odds of death from burns: increasing age, increasing body surface area of injury and the presence of inhalation injury (Hettiaratchy and Dziewulski 2004). For example, 90 percent of patients over the age of 60 years with 40 percent of body surface area burn and an inhalation injury will die (Hettiaratchy and Dziewulski 2004).

Burn categories

Health care providers often categorize burns by the depth of damage created. First-degree burns are usually the least dangerous. First-degree burns damage only the outer epidermal layer of skin. This produces an intense and painful inflammatory response with swelling and redness. There are usually no blisters associated with the first-degree burn. These patients do not require complicated medical care, as their injuries will heal on their own in a few days. Pain management is a major prehospital concern, especially if the area of burn is large. Sunburn is an example of a first-degree burn.

Second-degree burns extend through the epidermal layer and into the dermis. Burns at this depth can still heal on their own because some of the regenerating skin cells survive exposure to the thermal source. The skin appears mottled (blotchy) and red. Blisters appear in the area of a second-degree burn. Some of the blisters may remain intact while others rupture. These burns are usually painful and the patients will require analgesia as early as possible. Infection is a major concern and therefore these patients require evaluation at an appropriate medical facility. These burns should heal within two to four weeks, depending upon the area involved. Exposure to direct flame or hot liquids will produce this type of burn.

Third-degree burns extend through the epidermal and dermal layers. These burns occur more rapidly in children and in the elderly because their skin is thinner. The burn damages all of the regeneration cells, thereby impairing healing except in cases where the area of the burn is small and scar tissue can fill in from the sides. The skin in third-degree burns appears pearly white or charred and is often dry. Deep third-degree burns can alter tissue proteins to produce a hard leather-like covering known as eschar. Burns of this magnitude extend through all the skin layers and destroy nerve endings. Therefore, despite their severity, third-degree burns often are not painful, although the surrounding area of less severe burn will likely produce a pain sensation requiring analgesia. This type of burn will not heal without skin grafting.

Jackson’s Thermal Wound Theory

Jackson’s Thermal Wound Theory describes three distinct zones in fresh burns: the coagulation zone, the zone of stasis and the zone of hyperemia (Jackson 1959). In general, the most severe cellular damage occurs at the center of the burn as the result of longer or more intense contact with the burn source. The cells in this area die and coagulate. Within this coagulation zone, the tissue is non-viable. EMS personnel can only manage the consequences of this zone; they cannot bring these cells back to life.

The zone of stasis surrounds this core of dead cells. In this zone, the initial exposure does not result in immediate cellular death. However, within a matter of minutes to a period of several hours, the injury causes localized circulation to slow and finally stop. The cells become increasingly hypoxic and are extremely vulnerable to the effects of decreased perfusion. Cells within this zone will die within 24 to 48 hours if they are not cared for properly.

Finally, the outermost damage zone is the zone of hyperemia. Blood flow is actually increased within this area as the result of the normal inflammatory response. Unless overwhelmed by infection or shock, this zone should recover in seven to 10 days.

Morbidity and mortality

Some people are at greater risk for burn injury. Cognitive or physical impairment such as drug and alcohol dependence, psychiatric illness, neurologic illness and physical disability increase the risk of serious burns (LaBorde 2004). Patients at the extremes of age are also at an increased risk of burn injury.

A variety of factors increase the risk of serious injury in the elderly (Anous and Heimbach 1986; Hunt and Purdue 1992). Skin layers become thinner with increasing age, thereby allowing the thermal source to penetrate deeper into the tissues. Mobility impairment and slower reaction time may prolong contact time with the thermal source. Elderly patients living alone may not have assistance when burns occur, and a delay in treatment is possible. Mortality rates are three times higher than the national average for burn patients over the age of 70 years.

Individuals at the opposite end of the age spectrum are also at an increased risk for serious burns. Fires are responsible for more deaths in the pediatric age group than motor-vehicle collisions or drowning (Parker et al. 2003; Rodriguez 1990). Burn injury is more common in African-American
Chemicals, electricity and prolonged exposure to thermal sources will produce third-degree burns. Sometimes burns are categorized as either partial or full thickness. Partial thickness would include the first- and second-degree burns while a full thickness injury refers to a third degree burn.

**Burn area**

Medics should triage burn victims to an appropriate treatment facility by determining the percentage of the body surface area that is burned. The *Rule of Nines* is a tool to determine the extent of the damage. Usually, EMS providers include only second- and third-degree burns when calculating the percent of body surface area involved.

Experts divide the body into sections representing multiples of nine percent of the body surface area. For example, the complete adult head, the entire right arm, the entire left arm, the front of the chest and the front of the abdomen each represent nine percent of the total body surface area. The entire right leg, the entire left leg and the entire back represent 18 percent each. The genital region represents the remaining one percent of the body.

Because of the anatomical differences between children and adults, EMS providers must modify the rule of nines for that age group. The head is proportionally larger in infants and toddlers and actually represents 18 percent of their total body surface area. Each of the child’s legs represents 13.5 percent and all other body areas remain the same as for an adult.

Burns generally considered serious are:
- Those that cover more than 15 percent of the body surface area regardless of the degree.
- Burns of the hands, feet or genitalia (with the potential loss of function and inability to care for self).
- Electrical, chemical or inhalation burns.
- Burns with other associated injuries (such as fractures).
- Burns in patients with pre-existing medical conditions (such as elderly, diabetic, cardiac, etc).

**Initial assessment and management**

The mechanism and history of the injury may provide important clues about the possibility of complicating factors (Hettiaratchy and Papini 2004). The likelihood of respiratory involvement increases if the thermal burn occurred while the patient was in an enclosed space. Multi-system trauma is more likely if an explosion occurred.

Assessment and management of burned patients begin with the same security considerations required of every field situation. Rescuers must protect their personal safety as well as ensure a safe environment for their teammates. After ensuring the safety of the team, provide for the safety of the patient.

If the patient’s clothing is still burning or saturated with chemicals, separate the patient from the source of the injury. While maintaining personal safety, remove the clothing or extinguish the burning process. If the mechanism of injury involves chemicals, flush the patient’s skin with copious amounts of water. After halting the burning process, proceed to an initial assessment and correct any life-threatening conditions as soon as possible.

Evaluate the patient’s airway status. Pay special attention to any respiratory noise such as stridor, which indicates a narrowing of the patient’s upper airway. Additionally, the patient may have a harsh cough. Look for evidence of respiratory involvement, such as burns around the mouth or nose, burns around the neck, soot inside the mouth or nostril, singed facial hair or swelling in the lips and tongue. If there is any evidence of respiratory involvement, monitor the airway very closely and rapidly transport the patient to a burn center. Because the pediatric patient has a smaller trachea, airway obstruction from edema is a constant concern in a child or infant with respiratory burns.

Be prepared to perform early nasotracheal intubation, even if the patient is conscious.

Swelling caused by upper airway burns results in progressive hypoxia and a deteriorating mental status. Waiting for enough of a reduction in the level of consciousness to permit acceptance of an orotracheal tube may result in a degree of airway swelling that will not permit passage of an endotracheal tube.

Evaluate the quality of the respiratory effort. A pulse oximeter used during the respiratory assessment may give misleading information in a burned patient. Often, combustion produces carbon monoxide. Hemoglobin in the red blood cells binds easier to carbon monoxide than to oxygen, thus creating both intracellular and extracellular hypoxia (Hettiaratchy and Papini 2004). The pulse oximeter cannot differentiate between hemoglobin bound to carbon monoxide and hemoglobin bound to oxygen. Therefore, the pulse oximeter will give a falsely high reading if the patient inhaled any carbon monoxide.

Patients with carboxyhemoglobin levels of 20 to 30 percent or higher will likely need assisted ventilation. Hyperbaric therapy is usually not immediately available and there is little evidence to supports its use (Hettiaratchy and Papini 2004).

Mortality increases dramatically if the burn injury also involves respiratory structures. Respiratory burns are present in 60 to 70 percent of burn patients who die. These complicating injuries most often occur as the result of smoke...
inhalation or the inhalation of superheated gases in confined spaces. Smoke inhalation is defined as the inhalation of the products of combustion below the level of the glottis (Dries 2009). Medics should provide high-flow oxygen to all patients with major burns, carbon monoxide exposures and burns involving the respiratory tract.

Evaluate the circulatory status. Fluid loss significant enough to produce burn shock occurs eight to 12 hours after the burn occurs. Therefore, medics who discover a hypotensive burn patient should search for other explanations for the fluid loss.

Perform a neurological examination using the AVPU scale. Do not automatically assume that the burn is responsible for any altered mental status discovered during the assessment. An associated head injury or medical condition may be complicating the burn. Take all necessary precautions to protect the spine if indicated.

Physical examination
Move quickly to the physical examination. Obtain a complete set of vital signs. Medics can obtain a blood pressure even if both arms are circumferentially burned, although they should protect the tissues by placing sterile gauze between the cuff and the patient’s arm. Advanced providers who performed tracheal intubation should monitor tube placement using waveform capnography while en route to the hospital. Monitoring also includes the patient’s electrocardiogram (ECG). In the case of thoracic burns, medics may need to modify the placement of the ECG leads.

After identifying and correcting all life-threatening problems, focus attention on the burn itself. Remove any jewelry, belts, shoes, or other constricting objects from the burned areas. Remove burned or singed clothing that is not stuck to the skin. Assess the depth of the burn (first, second or third degree) as well as the total area of the burn using the Rule of Nines.

Cooling the burn helps reduce the seriousness of the injury, but medics should not cool the burn for longer than one minute. Cooling for longer periods may induce hypothermia, which can complicate the care of the patient. The use of ice to cool a burn is contraindicated since ice causes vasoconstriction, which reduces blood flow to the damaged area.

After cooling the burn, cover the injury with a clean, dry dressing. Sterile sheets are not necessary, unless they are immediately available. Do not soak the sheets with water or saline unless it is a small area of minor burns. If the burn area is large, the patient may have difficulty regulating body temperature and is at risk for hypothermia.

Medics should attempt IV insertion, preferably through unburned tissue. Fluid resuscitation is rarely indicated for isolated burn injuries, since burn shock takes hours to develop. The presence of hypotension suggests other injuries. There is no universal consensus on the type of fluid or rate of administration for burn patients (Dries 2009). In general, administer just enough fluid to maintain a systolic blood pressure of 90 mm Hg in the adult or 70 mm Hg in the pediatric patient. Attempts at IV access should be made en route to the hospital.

First- and second-degree burns can be extremely painful. Medics should administer a narcotic analgesic, such as morphine or fentanyl as soon as possible. A common prehospital intravenous dose of fentanyl for both adult and pediatric patients is 1 to 2 micrograms per kilogram (mcg). Medics may also administer fentanyl through the nasal passages with a mucosal atomizer. The standard prehospital dose of intravenous morphine is 2 to 4 milligrams for the adult patients and 0.1 mg/kg for the pediatric patient, with a warning not to exceed the adult dose.

Some patients will require higher doses of analgesics. Medics must weight the benefits of increased analgesia against the risk of complications, including respiratory depression.

Summary
Burn injuries represent a danger to EMS providers and to the patient. For this reason, medics must protect themselves from injury before being of any value to the patient. Inhalation burns are present in over half of all burn deaths. Airway assessment and management is the highest priority and requires frequent reassessment to detect problems before they become too big to handle in the field.

Burn shock generally takes hours to develop. If medics discover hypotension in the field, additional injuries are likely present. It is appropriate to cool burns, although medics should not cool for longer than one minute. Cover burns with a clean, dry dressing. However, if the burn resulted from a chemical exposure, medics should irrigate the burn with copious amounts of water for at least 15 minutes.

Pain control is another high priority treatment in the prehospital environment. Begin with small doses of an intravenous or intranasal narcotic and re-administer as needed to achieve adequate analgesia.

References


