Prehospital Burn Care

MODULE 2

York Region Base Hospital Program
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Acknowledgments

York Region Base Hospital Program proudly presents the Prehospital Burn Care Module. This Continuing Medical Education package was researched and compiled by Walter Tavares, Advanced Care Paramedic, York Region EMS.

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UNIT TERMINAL OUTCOME

At the completion of this module, the paramedic will be able to integrate pathophysiological principles and the assessment findings to formulate a field impression and implement a management plan for the patient with a burn injury.

CASE STUDY

You are asked by dispatch to provide standby coverage for a fire approximately 10 minutes from your station. As you make your way to the standby location, you are updated by the Fire Department that it is a working fire and that there are at least two patients. The Fire department have requested a rush. You arrive to find two patients on the front lawn being attended to by firefighters. Oxygen has been applied; one patient appears to be severely burned with approximately 50% of his body burned, the other appears to be covered in soot, with no obvious burns.

INTRODUCTION

The history of modern burn resuscitation can be traced back to observations made after large urban fires at the Rialto Theatre in New Haven, Connecticut in 1921 and the Coconut Grove nightclub in Boston Massachusetts in 1942. At that time, physicians noted that some patients with large burns survived the event but died from shock in the observation periods. Physicians identified the concept of thermal injury–induced intravascular fluid deficits and soon followed with fluid resuscitation formulas. It was initially thought that death following burns was always as a result of toxins. Over the next 50 years, advances in resuscitation further expanded these observations and lead to numerous modern strategies to treat burn injuries. (It was in 1962 that the first burn unit was built in Galveston Texas). It only made sense that burn care should begin on scene where some of the most important preliminary decisions are made. That is where you come in. The strategies have since become common practice but due to the relatively low incidence of burn injuries encountered by paramedics, frequent review is essential!

A burn is defined as any destruction of skin or body tissue resulting from heat, chemicals, radiation or electricity. The severity of a burn depends on several factors, a few of which include the amount of body surface area injured, the depth of destruction and the location of the burn. While the number of burn injuries is declining, according to the Canadian Institute for Health Information there were over 3000 hospital admissions in Ontario classified as burn injuries in 1999 alone. The majority of which were males, with the highest incidence between the ages of 1 and 4. Refer to Table # 1.

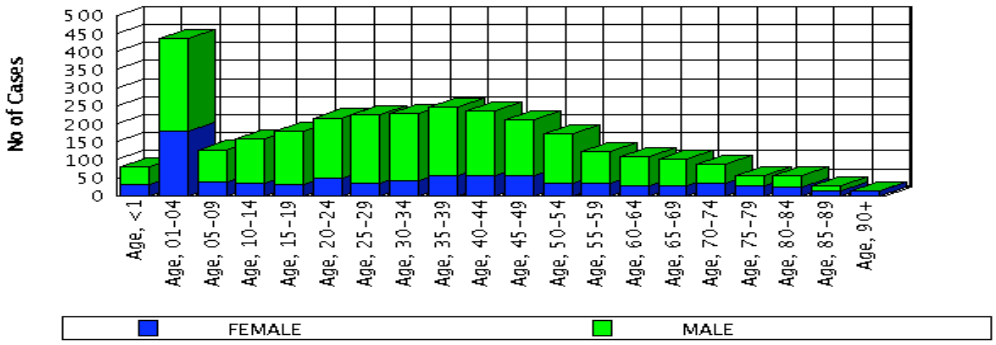


Table # 1- Identifies the number of cases resulting in death by age groups and gender.
Source: Canadian Institute for Health Information

Declines in burn fatalities can be attributed to safer buildings, smoke detectors and educational campaigns, improving prehospital care and advances in medicine relating to burn injuries. With modern medicine, technology and proper prehospital care, burn injuries as large as 80% of total body surface area (TBSA) can survive and children with up to 95% TBSA burned have a 50% survival rate. The three most common causes of burns in descending order are thermal (flame / fire), scalds and contact.

This module discusses the pathologic effects of burns on the tissues and the body in general as well as the effective assessment and management of burns. Early recognition, decisive action and appropriate management have a positive influence on a patient's outcome. Emphasis will be placed on thermal burns.

OBJECTIVES

After reading this chapter, you should be able to:

1. Describe the anatomy and physiology of the skin and remaining human anatomy as they pertain to thermal burn injuries.
2. Describe the epidemiology including: incidence, mortality, morbidity, and risk factors for thermal burn injuries as well as strategies to prevent such injuries.
3. Describe the local and systemic complications of a thermal burn injury.
4. Identify and describe the depth classifications of burn injuries including: superficial burns, partial-thickness burns, and full-thickness burns.
5. Describe and apply the "rule of nines," and the "rule of palms" methods for determining body surface area percentage of a burn injury.
6. Identify and describe the severity of a burn including: a minor burn, a moderate burn, and a critical burn.
7. Discuss complications of burn injuries caused by trauma, airway compromise and respiratory compromise.
8. Describe thermal burn management including: considerations for airway and ventilation, circulation, non-pharmacological measures, transport decisions, and psychological support/communication strategies.
9. Describe special considerations for a pediatric patient with a burn injury and describe the criteria for determining pediatric burn severity.
10. Describe the specific epidemiologies, mechanisms of injury, pathophysiologies, and severity assessments for inhalation, chemical, and electrical burn injuries.
11. Discuss special considerations that impact the assessment and management of patients with inhalation, chemical, and electrical burn injuries.

SKIN ANATOMY AND PHYSIOLOGY

In order to clearly understand the impact of the various sources of burns and/or to effectively assess and manage thermal injuries, a clear understanding of and appreciation for the anatomy of the skin is needed. We will begin this discussion by reviewing the layers of the skin and describing vital components of each layer. Review the following diagram then refer to it frequently while reading the next section.

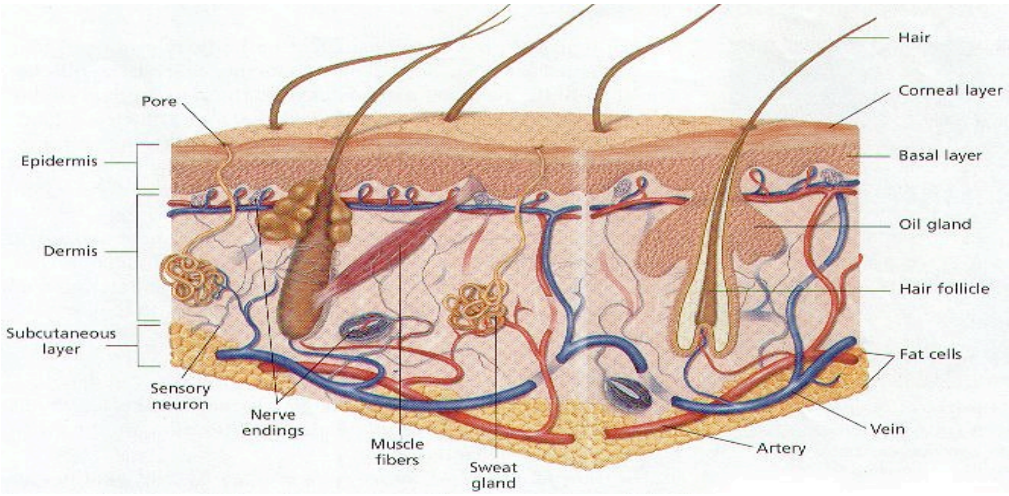


Figure # 1: Identifies the layers of the skin as well as the structures within each layer.
Source: http://www.sirinet.net/~jgjohnso/modskin.jpg

The skin is one of the largest and more versatile organs of the body, and it is vital in maintaining homeostasis. It is this protective covering that prevents many harmful substances, as well as microorganisms from entering the body. Skin also retards water loss by diffusion from deeper tissues and helps regulate body temperature. It houses sensory receptors, contains immune system cells, synthesizes various chemicals and excretes small quantities of waste.

The skin includes two distinct tissue layers; the epidermis and the dermis. The outer layer called the epidermis, is composed of stratified squamous epithelium[1] and lacks blood vessels. The deepest layer of the epidermis is called the basal layer and it sits adjacent to the dermis. This layer is nourished by dermal blood vessels. The epidermis is usually very thin averaging from 0.07 - 0.12 mm and is thickest on the palms of the hands and soles of the feet, where it can be as thick as 0.8 -1.4 mm. The inner layer or dermis, is thicker than the epidermis, and it is made up of connective tissue containing collagen, which gives skin its strength and holds everything together, and elastic fibers, epithelial tissue, smooth muscle tissue, nervous tissue, and blood. Beneath the dermis is the subcutaneous tissue (or hypodermis) which is made up of masses of loose connective and adipose tissues and serves to bind the skin to underlying organs.

[1] A layer of cells covering the outside of the body consisting of several layers of cells in which the surface cells are flattened and scale-like.

Regulation of Body Temperature

The body is constantly in a state of thermoregulation attempting to maintain a temperature of 37°C. The regulation of body temperature is vitally important because even slight shifts can disrupt the rates of metabolic reactions and skin plays a key role in the homeostatic mechanism that regulates body temperature. As the body temperature rises, the blood vessels of the dermal layer dilate to allow heat to escape into the environment. Radiation, conduction, convection and evaporation all play a role in regulating body temperature through the skin. When the body (hypothalamus) senses a lower temperature than the normal set point of 37°C, dermal blood vessels contract, reducing blood flow to the skin limiting the effects of heat loss through the methods mentioned above. In addition to regulation of body temperature the skin also provides the following functions:

- Combats infection (forms a barrier to invading microorganisms)
- Protects against ultraviolet radiation (UVR)
- Protects against mechanical and chemical assaults
- Contains sensory organs which assist with its regulatory function
- Prevents excessive fluid and electrolyte loss
- Is an important part of the body's immune system

As you can expect, injuries resulting in damage to the skin can have significant impact and result in life threatening conditions such as hypothermia and sepsis.

PATHOPHYSIOLOGY OF BURNS

In this section we will discuss how burns actually cause the damage or injury they do and the effect or complications they have on the body. As mentioned in the introduction, we will focus on thermal burns, but we will also briefly discuss electrical and chemical burns. Due to the extremely rare occurrence of radiation burns, will we limit the discussion to the mechanisms listed above, although it should be mentioned that burns may result from radiation as well. We will complete this section by discussing specifically burns resulting in inhalation injury which may come from one or more of the sources mentioned above.

Thermal Burns

A thermal burn causes damage by increasing the rate at which the molecules within an object move and collide with each other. We measure the energy of this molecular motion as temperature. At a temperature greater than zero, the molecules of any object move about. As the object's temperature increases, so does the speed of the molecules and the incidences of their collisions with other molecules. As molecular speed increases, the cell components begin to break down. The result of exposure to extreme heat is progressive injury and *cell death*.

The extent of a burn injury relates to the amount of heat energy transferred to the patient's skin. The amount of that *heat energy* in turn depends upon three components of the burning agent. To apply this to real world problems we'll use water, which produces scald burns as an example:

1. **Temperature** (eg. water > 60ºC (140ºF) will create a deep burn)
2. **The concentration of heat energy it possesses** (eg. water has a high concentration of heat energy)
3. **The length of its contact time with the patient's skin**. (eg. Water at the temperature mentioned above will cause a deep burn in 4 seconds. Whereas soups and sauces tend to stay on the skin longer and therefore cause deeper burns)

Obviously, the greater the temperature of an agent, the greater the potential for damage exists. However, it is also important to consider the amount of heat energy possessed by the object or substance. The concentration is directly related to the amount of molecules in a specified area and the heat energy of a substance is determined by how active its molecules are. While in the field, this may not be a primary concern or factor to consider, careful incident history gathering and reporting will provide vital information to emergency departments and burn unit staff (remember hospital staff do not have the benefit of viewing the scene and/or source of injury). And finally as described above, the duration of exposure to the heat source is also obviously important in determining the severity of a burn. Refer to Table # 2.

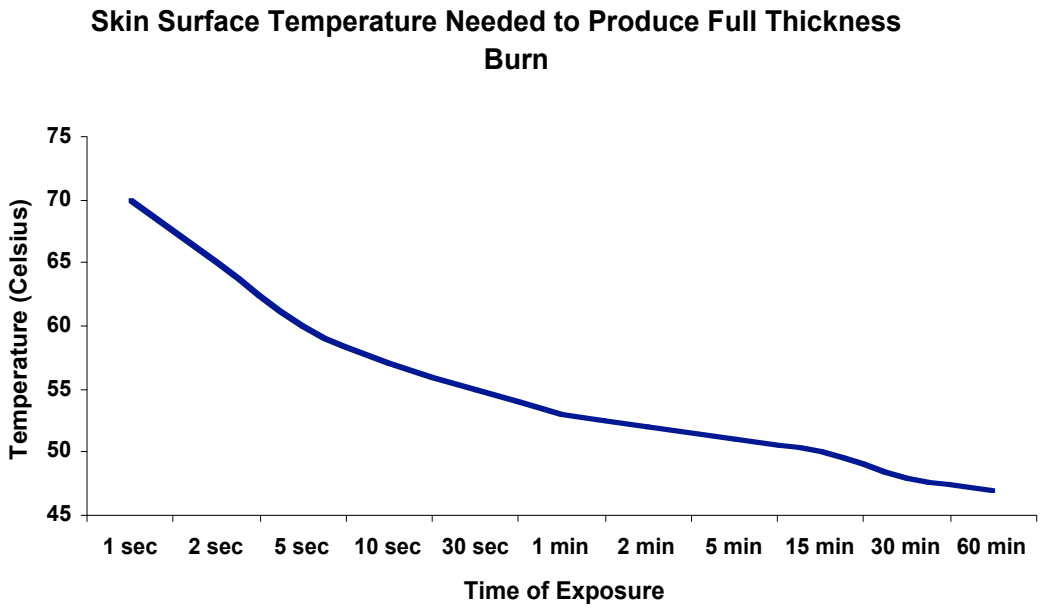


Table # 2: This table illustrates the relationship between temperature and time associated with burns injury. The results are based on actual fact but are represented here as estimations.
Source: David Herndon. 2004. **Total Burn Care (2nd Edition)**

A burn is a progressive process, and the greater the heat energy (recall the 3 components above) transmitted to the body, the deeper the wound. Initially, the burn damages the epidermis by the increase in temperature. As contact with the substance continues, heat energy penetrates further and deeper into the body tissue. Thus, a burn may involve the epidermis, dermis and subcutaneous tissue as well as muscles, bones, and other internal tissue. Table #2 illustrates the relationship of temperature and time associated with burns. The higher the temperature the less time required to produce a full thickness burn. For example, contact with a hot object of 60°C for approximately 10 seconds would result in a 3rd degree (full thickness) burn. We will revisit this principle later in the module during management of thermal burns.

Burning Agent	Average Temperatures
Water	> 60ºC produces 3rd degree burns in 4 seconds
Freshly Brewed Coffee	Generally 68ºC, produces burns in 1 second
Public Hot Water Heaters	Maximum temperature 54ºC
Cooking oil or Grease (hot enough to cook with)	Between 176ºC – 204ºC
Tar (that used for road repair)	Between 204ºC -260ºC

Table # 3: This table provides "real world" examples of burn injury sources and their average temperature ranges.
Source: David Herndon. 2004. **Total Burn Care (2nd Edition)**

At the level of local tissues, thermal burns cause a number of effects collectively termed *"Jackson's Theory of Thermal Wounds";* an explanation of the physical effects of thermal burns. This theory helps us understand the physical effects of high heat and helps explain a number of clinical effects. With a burn, the skin nearest the heat source suffers the most profound changes. Cell membranes rupture and are destroyed, blood coagulates, and structural proteins begin to denature (break down). This most damaged area is the zone of coagulation. Adjacent to this area is a less damaged, yet still inflamed region where blood flow decreases that is called the zone of stasis. More distant from the burn source is a broader area where inflammation and changes in blood flow are limited. This is the zone of hyperemia; this zone accounts for the erythema associated with some burns.

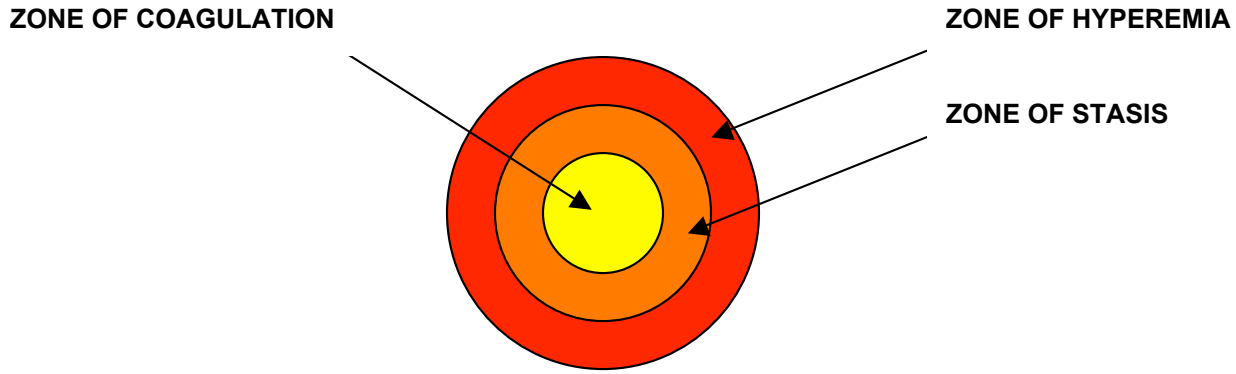


Figure # 2: Identifies the three areas associated with the Jackson's Theory of Thermal Wounds. Source: Byran E, Bledsoe, Robert S. Porter, Richard A. Cherry. 2003. **Essentials of Paramedic Care.**

The body's response to burns occurs over time and can usefully be classified into four phases:

1. Emergency phase
2. Fluid Shift phase
3. Hypermetabolic phase
4. Resolution phase

The first stage immediately following the burn is called the "Emergency Phase". This is the body's initial reaction to the burn. This phase includes a pain response as well as the outpouring of catecholamines in response to the pain (think about and predict some vital signs you might expect to find), physical and emotional stress.

The Fluid Shift Phase follows the Emergency Phase and can last for up to 18-24 hours. The fluid shift phase begins shortly after the burn and reaches its peak in 6-8 hours. You are therefore not likely to see this in the prehospital setting. In this phase, damaged cells release agents that initiate an inflammatory response in the body. This increases blood flow to the capillaries surrounding the burn and increases the permeability of the capillaries to fluid. The response results in a large shift of fluid away from the intravascular space into the extravascular space resulting in massive edema. It is important to note that the capillaries leak water, electrolytes and some dissolved protein, not blood. The shift in proteins alters osmolarity further increasing the amount of fluid loss.

The Hypermetabolic Phase follows the fluid shift phase which may last for many days or weeks depending on the severity of the burns. This phase is characterized by a large increase in the body's demand for nutrients as it begins the long process of repairing damaged tissue. This phase leads to the Resolution Phase, in which scar tissue is generated.

The local and systemic complications associated with burns are extensive. As already mentioned, immediately after a burn injury, the body's inflammatory response is triggered both at the injury site itself, and in areas of the body distant from the injury. The systemic response is not likely to be seen in the prehospital environment but a simple understanding will improve overall management.

Cardiovascular Response

Immediately after the burn injury the changes that occur in the cardiovascular system are important and require immediate consideration. The cardiovascular changes include, decreased blood flow to tissues and organs and is thought to be caused by hypovolemia following injury. Hypovolemia may develop following the release of vasoactive mediators from injured areas (involved in the inflammatory response) which increases the capillary permeability and promotes fluid and protein loss into the extravascular space. This shift in osmolarity further contributes to the fluid loss, and widespread edema may be noted. Within minutes of the burn injury, cardiac output falls (in proportion to the burn size) as a result of the significant decrease in blood volume, with an increase in peripheral vascular resistance. Increased production and release of catecholamines also occurs which may lead to cardiac ischemia and cardiac arrhythmias. The patient's heart may become unstable while in your care and careful monitoring is required.

Pulmonary Response

Respiratory failure is one of the major causes of death after a burn injury. The damage to the lung tissue may be as a direct result of thermal injury and/or smoke inhalation. Respiratory complications from smoke inhalation vary based on amount of smoke, chemical involved, duration, available oxygen, health status etc. Mortality as a result of burns is attributed to a combination of hypoxemia and thermal or chemical effects. With regards to the lung tissue itself, bronchial obstruction, increased airway resistance, reduced pulmonary compliance, and atelectasis can be expected. The most common vascular complication within the lungs is altered capillary permeability. Chemical mediators are released which lead to ventilation and perfusion abnormalities which of course leads to hypoxia (severe gas exchange problems). This will be discussed in greater detail in the inhalation injury section.

Renal Response

Blood flow to the kidneys is reduced (decreased glomerular filtration rate) which is a result of the decreased cardiac output, systemic vasoconstriction and decreased blood volume (as a result of fluid shift) discussed earlier. Elevated hormones that you would expect to see in “fight or flight” responses such as epinephrine, norepinephrine, angiotensin and vasopressin all contribute to renal complications. Renal complications are seen with extensive deep burns with large surface areas affected.

Immune Response

The immune response in burn victims is reduced. The natural protective function of the skin is removed. The epidermis of the skin becomes damaged allowing invasion of bacteria and the coagulated skin and exudate that results from the burn are excellent environments for bacteria to grow. This may ultimately lead to septicemia and septic shock. Cellular and hormonal aspects of the immune response are also depressed, how much so is directly related to burn size and depth.

Electrical Burns

Another type of burn is the Electrical Burn which includes lightning strikes. Electrical injuries occur when an electric current travels from the contact site into the body, arcing from one body point to the other. As the current goes into the body, it is converted to heat. The heat, which causes extensive damage, most commonly follows the current flow, which is usually along blood vessels and nerves (the path of least resistance), and less commonly, may damage other structures, such as muscle and bone. Electrical current can cause the following three types of burns:

- Contact Burn Injuries: this is a true electrical injury in which the current is most intense at the sites of entrance and exit and along the tissue it damages. At the entrance and exit sites, a “bull’s-eye lesion” may be present with a charred zone in the center; a middle zone of gray dry tissue; and an outer red zone. The entrance and exit sites may not appear serious, but these wounds indicate there may be considerable damage along the path of the current. Electrical currents may cause damage to other organs such as the heart and lens of the eye.
- Flash Burn (Electrical), this type of burn is an electrothermal injury and is caused by the arcing of the current.

- Flame Burn which is the same as a thermal injury, except this type of burn occurs when electricity ignites a person's clothing or surrounding material.

Physics of Electrical injuries

There are essentially two forms of current in which electrical injuries may result from. They are alternating and direct current. Alternating current (AC) is current that switches polarity on a regular basis. It is defined by the number of cycles per second as it switches from positive to negative. 60-cycle AC will have 60 negative half cycles and 60 positive half cycles per second. Common frequencies for AC include 60 cycles (household current), 50 cycles (European household current), and 400 cycles per second, used in some aircraft and military applications. A transformer only works with AC, so most commercial high tension power lines are AC to allow for more efficient change of voltage. Some long distance, very high tension lines may be DC to increase the efficiency of transmission over long distance, but this is infrequent. Virtually all electrical injuries due to commercial current at any voltage are due to AC supplies.

The other form of current is direct current. Direct current (DC) is a constant current in a single direction. Sources of direct current include electronic power supplies, battery chargers, arc welders, and third rails for some transportation devices such as subways and trams. DC current injuries are not common, as few DC sources deliver much more than 30 volts. The exception to this is the subway third rail.

Electricity's power is the result of an electron flow from a point of high concentration to one of low concentration. The difference between the two concentrations is called the voltage. It is helpful to envision voltage as the pressure of the electric flow. Voltage is the pressure that forces the electrons through the line. The rate or the amount of flow in a given time is termed the current and is measured in amperes. Another factor that affects the flow of electricity is resistance. Resistance is measured in ohms. Copper electrical wire has very little resistance and allows a free flow of electrons. Tungsten (the filament is a light bulb) is moderately resistant and heats, glows, and emits light as more and more current is applied to it. The relationship between current, resistance and voltage is well known as Ohm's Law:

> Common voltages encountered in Canadian households are 120 and 240 volts. Business users may encounter 440 volt lines, while the transformer on the street corner will be supplied by a 1200- or 2400-volt line.

Voltage = Current x Resistance ***or*** **Current = voltage / resistance**

Like tungsten, the internal parts of the human body are moderately resistant to the flow of electricity. The skin, on the other hand, is highly resistant to electrical flow. Moisture or sweat on the skin lowers resistance. If the human body is subjected to voltage, the body initially resists the flow. If the voltage is strong enough, the current begins to pass into and through the body. As it does, heat energy is created. The heat produced is proportional to the square of the current flow and is related to power as expressed in Joule's Law:

$$\textbf{Power} = \textbf{Current}^2\ \textbf{Resistance}$$

The highest heat occurs at the points of greatest resistance, often at the skin. This accounts for the severe "entry" and "exit" wounds sometimes seen in electrical injuries. Dry, calloused skin can have enormous resistance values. Wet skin, particularly the thin skin on the palm side of the arm or on the inner thigh can have very low resistance values. Mucous membranes have

even lower resistance values and allow even small currents to pass. This accounts for the relative ease with which household current can cause lip and oral burns in children who accidentally bite electrical cords. See figure # 3.

With small currents, the heat energy produced is of little consequence. But if the voltage or current is high, profound body damage may occur. The longer the duration of contact, the greater the potential for injury. Electrical burns can be particularly damaging because the burn heats the victim from the inside out, causing great damage to internal organs and structures while possibly leaving little visible damage on the surface, except for the entry and exit wounds.

Figure # 3: Illustrates an electrical injury associated with a child who has accidentally chewed on an electrical cord.
Source: http://bms.brown.edu/pedisurg/Brown/Image%20bank%20pages/Trauma.html

Thermal injury due to electrical current occurs as energy travels from the point of contact to the point of exit. At both of these points, the concentration of electricity is great, as is the degree of damage you might expect. Between the entrance and exit points, the energy spreads out over a larger cross-sectional area and generally causes less injury.

Electrical contact also interferes with control of muscle tissue. The passage of current, especially alternating current, severely disrupts the complicated electrochemical reactions that control muscles. If contact with a current as small as 20 – 50 mA is maintained for a period of time, the muscles of respiration may be immobilized. The result can be prolonged respiratory arrest, anoxia, hypoxemia and eventually death. Electrical currents greater than 50 mA, may also disrupt the hearts electrical system causing ventricular fibrillation. Alternating electrical current such as that found in household current can also cause uncontrolled contractions of muscles. If the victim is holding a wire at such a time, the victim may be unable to let go, thereby prolonging the exposure and increasing the severity of the injury (you often see this type of behavior in movies). This can occur with as little as 9 mA of current.

At times, electrical energy may cause flash burns secondary to the heat of the current passing through adjacent air. Air is very resistant to the passage of electrical current. If the current is strong enough and the space through which it passes is small, the electricity arcs, producing tremendous heat. If the patient's skin is close by, the heat may severely burn or vaporize tissue. In addition, the heat may ignite articles of clothing or other combustibles and produce thermal burns.

Chemical Burns

Chemicals break down the biochemical makeup of cell membranes and destroy cells. Such injuries are not transmitted through the tissue as are thermal injuries. Instead, a chemical burn must destroy the tissue before it can chemically burn any deeper. This fact generally limits the "burn" process unless very strong chemicals are involved. Agents that cause chemical burns are either strong acids or bases (alkalis).

Both acids and alkalis burn by disrupting cell membranes and damaging tissue on contact. As they cause damage, acids usually form a thick, insoluble mass at the point of contact. This process is called coagulation necrosis and helps limit the depth of acid burns. Alkalis, however, do not form a protective mass. Instead the alkali continues to destroy cell membranes releasing the intercellular and interstitial fluid, destroying tissue in a process called liquefaction necrosis. This process allows the alkali to rapidly penetrate the underlying tissue, causing progressively deeper burns. For this reason, alkali burns can be quite serious.

Specific Agents you might Encounter	General Information
Strong Alkalis	This chemical is found in many household or industrial cleaning agents. Exposure to the eyes is extremely devastating and can cause significant permanent damage quickly.
Dry Lime	This substance reacts with water and generates heat. Brush the dry lime away, then irrigate. The remaining chemical will react with water, it will also cool the burn and wash away any remaining substance, which is better than reacting with the water in the skin.
Cement	When mixed with sweat can cause a heat producing reaction.
Hydrochloric Acid	This chemical will burn the skin. Fumes can also cause inhalation injury with a sudden onset of pulmonary edema. (Nitro is not the treatment for this type of pulmonary edema)
Phenol	Powerful industrial cleaner that is usually removed with alcohol (which is usually available in areas using this substance). Once removed, should be irrigated.
Hydrofluoric Acid	This chemical is used as a cleaning agent, will cause tremendous electrolyte abnormalities if it enters the body.

Table # 4: Examples of substances that may result in chemical burns encountered in the field, as well as general information about each substance.
Source: Byran E, Bledsoe, Robert S. Porter, Richard A. Cherry. 2003. **Essentials of Paramedic Care.**

Inhalation Injury

The burn environment frequently produces inhalation injury. This is especially true if the patient is in an enclosed space or unconscious. A patient who is unconscious or trapped in a smoke filled area eventually inhales gases, heated air, flames or steam. The inhalation results in airway and respiratory injury.

Toxic Inhalation

Approximately 80% of fire related deaths occur, not from burn injury to the airway but from inhalation of toxic products of combustion. Modern residential and commercial construction uses synthetic resins and plastics that release toxic gases as they burn. Combustion of these materials can form compounds of toxic agents such as cyanide and hydrogen sulfide. If a patient inhales these gases, the gases react with lung tissue, causing internal chemical burns, or they diffuse across alveolar-capillary membrane and enter the blood stream causing systemic poisoning. The signs and symptoms of these injuries may present immediately following

exposure or their onset may be delayed for an hour or two after inhalation. Toxic inhalation injury occurs more frequently than thermal inhalation burns.

Carbon Monoxide Poisoning

An additional concern associated with the burn environment is carbon monoxide (CO) poisoning which should be suspected in every fire victim and any patient who has been within an enclosed space during combustion. Carbon monoxide is created during incomplete combustion, like that which may occur with a faulty heating unit or when someone tries to heat a room with an un-vented device like a barbecue grill.

Poisoning occurs because carbon monoxide has an affinity for hemoglobin more than 200 times greater than oxygen. If your patient inhales carbon monoxide even in the smallest quantities (as low as 0.1% CO), the carbon dioxide displaces oxygen on the hemoglobin and remains there for hours. The result is hypoxemia (or anoxia) and associated manifestations can be expected. Hypoxemia, which is difficult to detect, subtly compromises the delivery of oxygen to the patient's vital organs. You may notice impaired decision making or poor psychomotor skills as subtle signs.

If carbon monoxide inhalation is associated with airway burns, the respiratory compromise will be further compounded.

Remember, if possible, to have fire departments measure the CO levels and report that to the hospital. With oxygen administration en route and removal from the environment, doctors may not be able to evaluate the true exposure sustained by the patient.

The following chart identifies a list of signs and symptoms associated with toxic CO poisoning. The column on the right provides the signs and symptoms while the column on the left provides a concentration of CO levels in the blood, specifically percentage of hemoglobin saturated with CO. It is not necessarily important to know about the percentages in the field but understanding the progression of severity can be quite helpful.

CO-Hb%	Signs and Symptoms
0-10%	None
10-20%	Slight headache, may complain of a tightness of the forehead, may appear slightly flushed
20-30%	May complain of throbbing headache, usually in the temples
30-40%	Severe headache, weakness, dizziness, trouble with vision, nausea, may have vomited, possibly collapsed
40-50%	As above: with a greater possibility of collapse or syncope, you may notice an elevated heart rate and respiratory rate
50-60%	Syncope, increased heart and respiratory rate, coma, possibly seizures, cheyne-stokes breathing
60-70%	Coma, seizures, depressed cardiac and respiratory function, pre-arrest
70-80%	Weak pulse, slow respirations, pre-arrest
80-90%	Pre-arrest or VSA
90-100%	VSA

Table # 5: Demonstrates a relationship between amount of Carbon Monoxide in the blood and common signs and symptoms. Source: David Herndon. 2004. **Total Burn Care (2nd Edition)**

Airway Thermal Burns

Another, although less frequent injury, is the airway thermal burn. Very moist mucosa lines the airway and helps insulate it against heat damage. Because of this mucosa, supraglottic, or upper airway structures may absorb the heat and prevent lower airway burns. High levels of thermal energy are required to evaporate the fluid and injure the cells. Inspiration of hot air or flame rarely produces enough heat to cause significant thermal burns to the lower airway (that is not to say that a high index of suspicion should not be maintained).

20-35% of patients admitted to burn centers and some 60-70-% of burn patients who die have an associated inhalation injury.

Superheated steam has greater heat content than hot, dry air and can cause subglottic, or lower airway burns. Superheated steam is created under great pressure and can have a temperature well above 221ºC. Superheated steam is created when a stream of water strikes a hot spot and vaporizes explosively. The steam contains enough heat energy to severely burn the upper airway. It also may damage the lower respiratory tract, although this happens less frequently.

The progressive decline in oxygenation seen with smoke inhalation injury results partially from the loss of pulmonary vascular regulation called hypoxic pulmonary vasoconstriction. In other words, what normally happens when an area of the lung is poorly ventilated, blood vessels carrying blood to that area constrict which moves blood to areas of the lung better ventilated making the ventilation and perfusion more efficient. With smoke inhalation this mechanism may be lost which keeps blood going to areas where ventilation is poor or ineffective. This problem affects the lungs ability to effectively oxygenate hemoglobin and therefore, hypoxia results.

DEPTH CLASSIFICATION OF BURNS

We will now discuss the classification of burns prior to moving on to the management of burns section. Here we used two types of classifications[2]. The classification discussed in terms of "degrees" is used as well as the classification system which identifies layers of skin (eg. superficial). Both systems are used to facilitate and relate additional reading, previously learned material and improve retention. The following classifications are discussed:

- First degree / superficial
- Second degree / partial thickness
- Third degree / full thickness

Please note: Some sources may mention an additional classification; Fourth degree. This level of injury refers to situations where the burn injury has extended to deep structures such as muscle, tendon, bone etc.

[2] There are a variety of methods used and varies from source to source. This CME module uses the classification identified in the text "Total Burn Care 2nd Edition" (see references)

First Degree Burns / Superficial

First degree burns also known as superficial burns involve only the outer layers of the epidermis. The skin is usually red or pink (due to increased blood flow to the area), dry and painful with no blister formation. Mild sunburn is an example. The skin maintains its ability to function as a vapor and bacterial barrier and usually heals in 3-10 days. First degree burns usually require only palliative treatment such as pain relief measures and adequate fluid intake. Rarely is EMS contacted for these types of burns. Extensive first degree burns to infants or elderly patients may require additional care. See Figure # 4.

Figure # 4 - FIRST DEGREE BURN

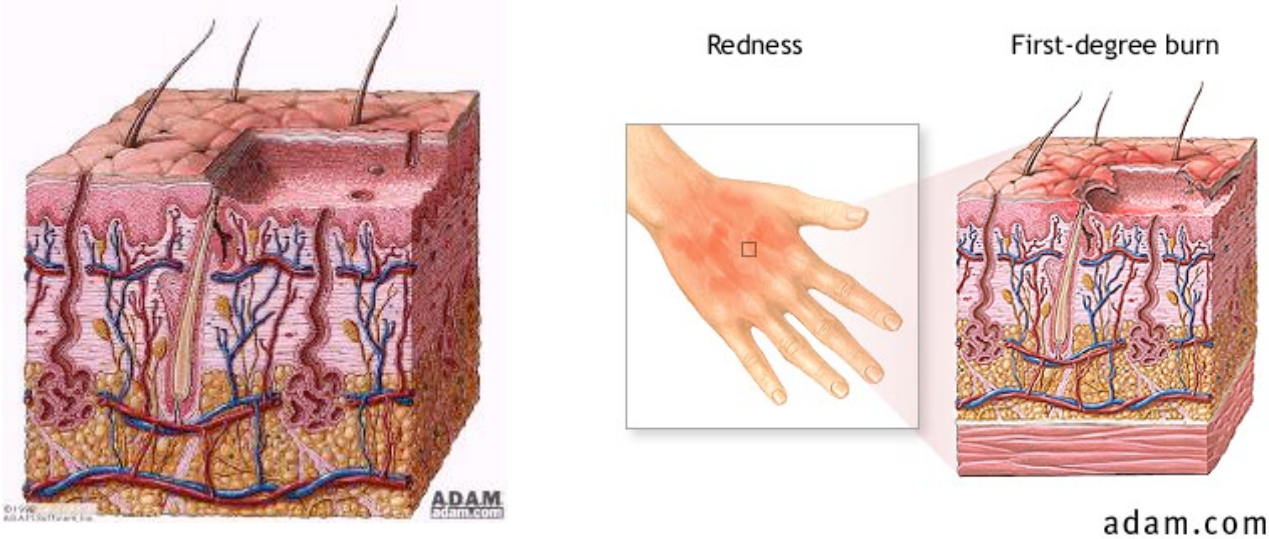
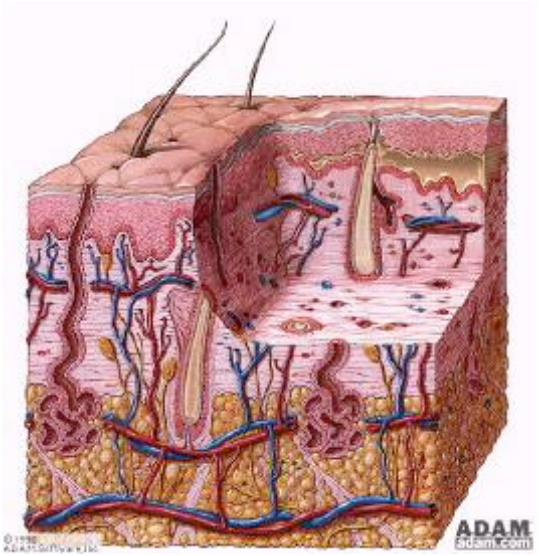


Figure # 4 – Demonstrates the layers of the skin with a section damages (removed) due to first degree thermal injury and exposes underlying structures.
Source: http://www.nlm.nih.gov/medlineplus/ency/imagepages/8600.htm

Second Degree Burns / Partial Thickness Burns

Second degree are partial thickness burns by definition but can be further classified into superficial and deep. In superficial injuries all of the epidermis is destroyed as well as varying superficial portions of the dermis. The injury presents as moist, red, blistered and painful due to surviving nerve endings. The skin is sensitive to temperature changes, air exposure, and touch. The blisters prevent the loss of body water and superficial dermal cells. Blisters serve as good "bandages" and promote healing. These burns usually heal within 1-2 weeks. ***Second degree*** *full thickness deep burns* on the other hand, involve the entire epidermis and dermis. Structures that originate in the subcutaneous layer, such as hair follicles and sweat glands remain intact. These burns can be very painful because the pain sensors remain intact. Tactile sensors may be absent or greatly diminished in the areas of deepest destruction. These burns appear as mottled pink, red or waxy white areas with blisters and edema. The blisters resemble flat dry tissue paper rather than the bulbous blisters seen with superficial second degree burns. See figure # 5.

Figure # 5 – SECOND DEGREE BURN



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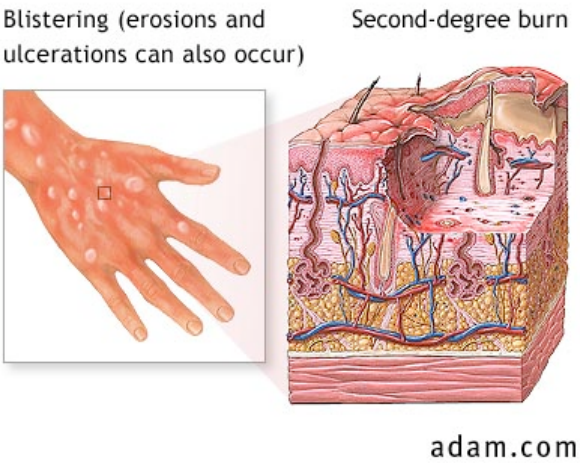


Figure # 5 – Demonstrates the layers of the skin with a section damaged (removed) due to second degree thermal injury and exposes underlying structures.
Source: http://www.nlm.nih.gov/medlineplus/ency/imagepages/8601.htm

Third Degree Burns / Full Thickness

Third degree full thickness burns extend into the subcutaneous tissue and may involve muscle and bone. Thrombosed vessels can be seen under the burned skin, indicating that the underlying vasculature is involved. Third degree burns vary in color from waxy white or yellow to tan, brown, deep red, or black. These burns are hard, dry and leathery. Edema is extensive in the burn area and surrounding tissues. There is no pain because the nerve sensors have been destroyed. However, there is no such thing as a “pure” third degree burn. Third degree burns are almost always surrounded by second degree burns. The injury sometimes almost has a target appearance because of the various degrees of burn. Full thickness burns wider than 1.5 inches usually require skin grafts because all the regenerative elements have been destroyed. See figure # 6.

Figure # 6 - THIRD DEGREE BURN

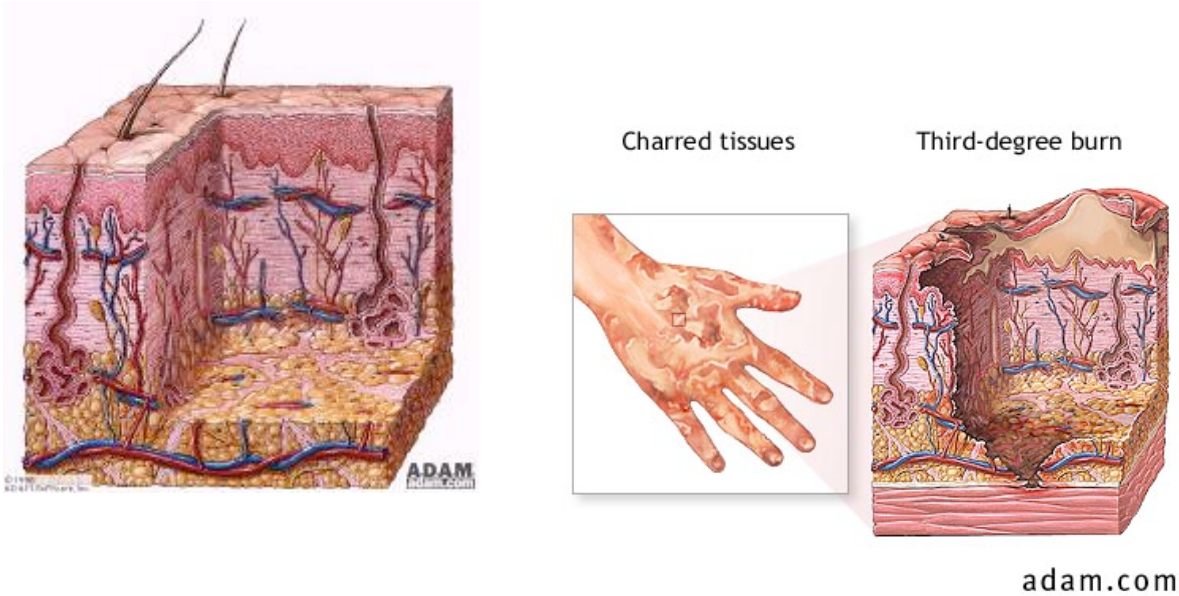


Figure # 6 – Demonstrates the layers of the skin with a section damaged (removed) due to third degree thermal injury and exposes underlying structures.
Source: http://www.nlm.nih.gov/medlineplus/ency/imagepages/8602.htm

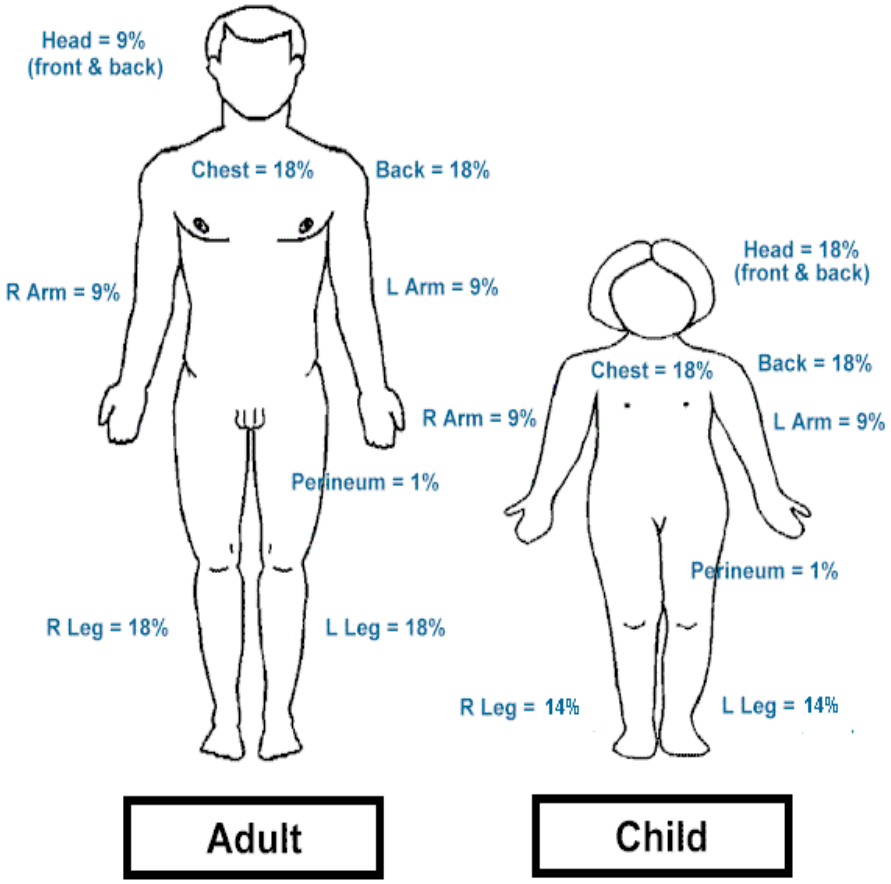
METHODS FOR DETERMINING BODY SURFACE AREA BURNED

"Rule of Nines"

The "rule of nines" identifies topographical body regions, each of which approximates a percentage of the patients' body surface area (BSA). These regions include the entire head and neck; the anterior chest; the anterior abdomen; the posterior chest; the lower back (the posterior abdomen); the anterior surface of each upper and lower extremity. The genitalia make up the remaining 1% of body surface area.

Because infant and child anatomy differs significantly from that of adults, you modify the rule of nines to maintain an accurate approximation of BSA. Divide the head and neck area into the anterior and posterior surface and assign 9% to each. Reduce the surface area of each lower extremity by 4.5% to ensure the total body surface area remains at 100%. The rule of nines is at best an approximation of the area burned. It is, however, an expedient and useful tool to help measure the burn's extent. See figure # 7.

Figure # 7 - Rule of Nines



"Rule of Palms"

The "rule of palms", an alternative system for approximately the extent of a burn, uses the palmar surface as a point of comparison in gauging the size of the affected body area. The patient's palm (the hand less the fingers) represents about 1% of the BSA, whether the palm is adult, a child, or an infant. If you can visualize the palmar surface area and apply it to the burn area mentally, you can then obtain an estimate of the total body surface area affected.

ASSESSMENT OF THERMAL BURNS

The assessment and management of a burned patient is often complicated and associated with emotional and psychological factors. It's important to recognize that most burn victims do not die immediately during or following the burn. If death does occur it is related to associated trauma or conditions associated with inhalation injury; airway complications. Therefore, with a

few exceptions, your approach to a burn patient should be very similar to that of a trauma patient.

Skin evaluation tells more about the body's condition than any other aspect of patient assessment. Not only is the skin the first body organ to experience the effects of burns, it is often the first and often only organ to display them. Therefore, assessment of the skin and the associated burns must be deliberate, careful and complete.

While the burn process varies, assessment is simple and well structured. Assess burn patients carefully and completely to assure that you establish the nature and extent of each injury. This helps you to assign burns the appropriate priority for care.

Scene Size Up

The safety of your patients, partner, allied services and of course yourself depends on a complete and thorough scene size up. Look around carefully as you arrive at the scene to ensure there is no continuing danger to you or your patient. Be wary of entering closed spaces, such as a bedroom or garage if there is evidence of a recent fire. Even small fires can cause intense heat and leave lingering toxic gases such as carbon monoxide, cyanide[3] and hydrogen sulfide. Cyanide can cause lethal complications with as little as 15 seconds of exposure.[4] In addition to safety consider additional potential mechanisms of injury during your scene size up. It is often easy to become distracted by gruesome looking burn injuries. Associated trauma can greatly reduce the patient's chances of survival and can sometimes be overlooked. Apply principles of BTLS when handling any burn victim.

Initial Assessment

Start your initial assessment by forming a general impression of the patient. Perform ABC assessment, rule out any danger of associated trauma or the possibility of head and spine injury. Evaluate the patient's level of consciousness and consider toxic inhalation as a cause. Protect the patient from further cervical injury if indicated by the suspected mechanism of injury or by the patients' symptoms.

Burn victims require special attention of their airway. Look for signs of thermal or inhalation injury by carefully searching for clues / clinical indications of inhalation injury such as:

- Singed facial and nasal hairs
- Facial burns
- Carbonaceous sputum
- History of altered LOC and/or confinement in a burning environment
- Any airway sounds, such as stridor, hoarseness, or coughing, that indicate irritation or inflammation of the mucosa

[3] Cyanide may be given off when nitrogen-containing plastics burn

[4] Cyanide compounds are highly toxic, causing harm by interfering with the body's use of oxygen. Cyanide poisoning essentially causes suffocation in the patient. This is because cyanide stops the use of oxygen in metabolic pathways

The presence of any of these findings suggests acute inhalation injury. Such injury requires rapid transport followed by immediate and definitive care (call for ALS back-up if available to provide airway support through endotracheal intubation, but do not delay transport to wait for ALS).

Although the larynx protects the subglottic airway from direct thermal injury (as discussed earlier), the supraglottic airway is extremely susceptible to obstruction as a result of exposure to heat. Signs of airway obstruction may not be obvious immediately, although if present may warn you of potential airway obstruction. It is crucial to identity signs of distress early, initiate support measures and provide rapid transport to hospital.

Stop the Burning Process – The First Step in Burn Care

All clothing should be removed to stop the burning process, keeping in mind that this step is often difficult and poses a risk to the Paramedic removing the articles. Careful consideration of personal safety must be taken. This is the first step in managing a burns patient. Synthetic fabrics ignite, burn rapidly at high temperatures, and melt into hot residue that continues to burn the patient. Any clothing with chemical involvement should be removed carefully. Chemical powders (dry) should be brushed off while being careful to avoid direct contact with the chemical. Once the chemical has been removed then the body surface areas are then rinsed with copious amounts of water. This is a recommendation that should be taken with caution to avoid excessive cooling.

Focused and Rapid Trauma Assessment

The focused history and physical exam for the burn patient are much the same as for any other trauma patient, beginning with a rapid trauma survey followed by a focused physical exam, baseline vital signs and patient history. With a burn patient, however, you must also accurately approximate the area of the burn and its depth. This approximation guides your care and helps emergency departments prepare effectively.

Except in cases of localized burns, examine the patient's entire body surface, both anterior and posterior. Remove any clothing that was or could have been involved in the burn. If any of the clothing adheres to the burn or resists removal, cut around if necessary.

In trying to interpret the severity of a burn apply the "rule of nines" to establish the total body surface area burned. If only a portion of a "9% region" is affected estimate how much of the region is affected. (eg. 1/3 = 3%, _ = 4.5%) Also, attempt to identify depth of burn and areas where there is extreme pain and/or sensory function is absent / diminished. Next take into careful consideration the areas of the body affected. Burns to the face, hands, feet, joints, genitalia and circumferential burns pose a higher concern. These areas have additional impact on patient recovery. We'll now discuss briefly these injuries and their implications.

Body Area	Reason for Concern
Face	Reassess the face and note any potential for airway compromise keeping in mind that swelling of the airways when exposed to high heat may result quickly. Burns to the face also pose esthetic concerns during recovery. Give high priority to these injuries even if you rule out respiratory involvement.
Feet and Hands	These areas are critical for much of the patient's daily activities. Serious burns and the associated scar tissue make thermal hand or foot injuries very debilitating.
Joints	These injuries can be extremely debilitating due to the scar tissue that develops after the burn leading to loss of joint flexibility and mobility.
Circumferential	These types of burns are especially concerning when they involve the thorax, abdomen or neck. Constriction may occur and may hinder respiration, restrict blood flow or cause hypoxia for underlying tissues.

Table # 6: Summary of burn injuries posing additional concerns, and or requiring additional attention. Source: Byran E, Bledsoe, Robert S. Porter, Richard A. Cherry. 2003. **Essentials of Paramedic Care.**

Once you have determined the depth, extent and other factors that contribute to burn severity, categorize the patient as having either minor, moderate or critical burns.

Burn Severity: **Minor**

- Superficial: BSA < 50%
- Partial Thickness: < 15%
- Full Thickness: < 2%

Burn severity: **Moderate**

- Superficial: BSA > 50%
- Partial Thickness: BSA < 30%
- Full Thickness: BSA < 10%

Burn Severity: **Critical**

- Partial Thickness: BSA > 30%
- Partial Thickness: BSA > 10%
- Any partial or full thickness burns involving the feet, hands, joints, face or genitalia

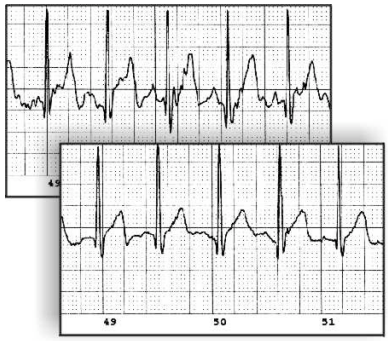
The burn severity should be increased one level with pediatric and geriatric patients and patients suffering from other trauma or acute medical problems. Also consider burns as critical with a patient who shows any signs or symptoms of respiratory involvement.

Conclude the focused history and physical exam by prioritizing the patient for transport. Rapidly transport any patient with full thickness burns over a large portion of the BSA. Patients with associated injuries to the face, joints, hands, feet, or genitalia are also candidates for immediate transport. Other cases needing rapid transport to the hospital include patients who have experienced smoke, steam, or flame inhalation, or any geriatric or pediatric patient, otherwise ill, or trauma patients.

A special note regarding incident history gathering, which tends to be a problem (often forgotten) in calls involving burned victims due to the sense of urgency is remembering to find out the details of the incident. For example, was there entrapment, an explosion, mechanisms

for other injuries, length of time exposed to burn agent, under what circumstances (eg. while sleeping, smoke exposure, etc). Other factors to find out would be what chemical caused the burn, what voltage and type of current, length of contact, etc. Remember this information is not readily available to hospital staff and your report of what happened is crucial.

Ongoing Assessment



Conduct ongoing assessment for all burn patients every 15 minutes for minor burns and every 5 minutes for moderate or critical burns. Although the burn injury mechanism has been halted, the nature of the burn will continue to affect the patient. In addition to monitoring vital signs, watch for early signs of hypovolemia and airway problems. Also, monitor distal circulation and sensation with any circumferential burn. Finally, monitor the ECG to identify any abnormalities, which may be caused by electrolyte imbalances secondary to fluid movement and tissue destruction. Avoid placing electrodes over burned areas. Chest placement provides the best view of lead II interpretation but placing lead on the limbs (as you would for a 12 lead) is also acceptable. There is no need to obtain a 12 lead ECG on these patients.

MANAGEMENT OF THERMAL BURNS

Once you complete your burn patient assessment and correct or address any immediate life threats, you can begin certain burn management steps, either in the field or en route to the hospital keeping in mind airway compromise and/or potential for airway compromise when making that decision. Thermal burn management can be divided into two categories: for local or minor burns and for moderate to severe burns. First let's review what is available to us (this applies directly to York Region EMS at time of printing):

York Region EMS Burn Kit

- 1 Large sterile burn sheet
- 2 medium sterile burn sheets
- 2 small sterile burn sheets
- 1 liter of Normal Saline

The sterile sheets essentially serve 3 principal functions. The first is protection. When the skin is burned beyond the layer of the epidermis the physical barrier is destroyed. The larger the burn area, the harder it gets to use the sheets as a form of protection. The second is for thermoregulatory purposes.

Recall the functions of the skin? Properly applied dressings minimize heat loss. Large burn areas should have dry dressings while small areas can use moist dressings, and ice is never indicated. The last function is comfort - superficial burns are extremely sensitive to air current, and properly applied sheets can reduce this pain. If additional dressings are required, make every attempt to use sterile sheets in areas making direct contact with the skin and additional dressings over those. It should be mentioned that while sterile sheets are optimal they are not essential. Therefore, in the absence of a proper burn kit, injuries should not be left exposed in fear of causing contamination. Every effort should be made to ensure that whatever dressing is used is as clean as can be. The supplied saline is used to stop burns through irrigation, provide cooling, alleviate pain, and moisten dressings.

Local and Minor Burns

Use local cooling to treat minor soft tissue burns involving only a small proportion of the body surface area at a partial thickness. Provide this care only for partial thickness burns that involve < 15% of the BSA or very small full thickness burns (< 2% BSA). Cooling of larger surface areas may subject the patient to risk of hypothermia (mild hypothermia is a core temperature > 32ºC and severe hypothermia is a core temperature < 32ºC). Cold or cool water immersion has some effect in reducing pain and may limit the depth of the burning process if applied immediately (within 1-2 minutes) after the burn.

If you have not already done so, remove any article of clothing or jewelry that might possibly act to constrain edema. If swelling encounters any constriction, it increases pressure of surrounding tissue and may in effect serve as a tourniquet. This pressure may result in compromised distal circulation and sensation, therefore, frequent reassessment is required.

Also it is often the last thing on your mind, but try not to forget to provide comfort and support, both physically and emotionally. Even rather minor burns can be extremely painful and psychologically devastating.

Moderate to Severe Burns

Use dry sterile dressings to cover partial thickness burns that involve more than 15% BSA or full thickness burns involving more than 5% of the BSA. Dressings keep air movement past the sensitive partial thickness burns to a minimum, and thereby reduce pain. Bulky sterile dressings also provide padding against minor bumping and other trauma. In full thickness burns, they provide a barrier to possible contamination.

Keep the patient warm. When burns involve large surface areas, the patient loses the ability to effectively control body temperature. If the burn begins to seep fluid, as in a full thickness burns, evaporative heat loss can be extreme. Cover such an area with dry sterile dressings, cover the patient with a blanket, and maintain a warm environment.

When treating a full thickness burn of the fingers, toes or other locations where burned surfaces may contact each other, place soft, non-adherent bandages between the burned skin areas. Without this precaution, the disrupted and wet wounds would stick together and cause further damage when pulled apart for care at the emergency department or burn unit.

Infection is a classic and deadly problem associated with extensive soft tissue burns. The life-threatening condition does not develop until well after prehospital care is concluded. However,

proper field care can significantly reduce mortality and morbidity. Providing a clean environment and sterile dressings can lessen the bacterial load for the patient.

Inhalation Injury

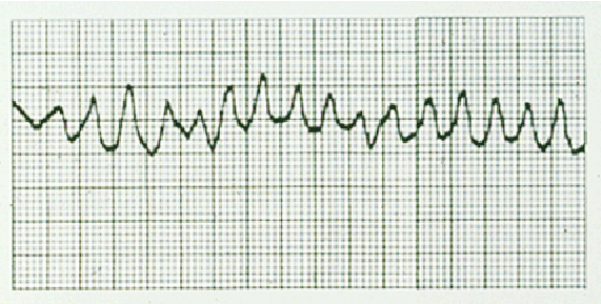
If you suspect thermal (or chemical) airway burns and airway compromise is imminent, intubation is required. As primary care paramedics this option is not available and therefore early recognition, initiation of transport and/or early request for back-up based on high index of suspicion is key. Until intubation is achieved, provide high-flow oxygen by NRB mask at 15 lpm. Oxygen not only counters hypoxia but is also therapeutic in carbon monoxide and cyanide poisoning. Review the areas discussed earlier regarding inhalation injury.

ASSESSMENT AND MANAGEMENT OF ELECTRICAL BURNS

The most important factor in the prehospital management of electrical injuries is the safety of the Paramedic. Be certain that the power has been shut off before you approach the scene of a suspected electrical injury. Until it is, do not allow anyone to approach the patient or the proximity of the electrical source. Remember that an energized power line need not spark or whip around to be deadly; a power line simply lying on the group can still present a significant danger. Note also that some utility lines have breakers that will try to re-establish power periodically. Establish a safe perimeter if there is any question about the status of the lines that are down. Keep vehicles and personnel at a distance from the downed lines or the source pole that is greater than the distance between the power poles. Also, be aware that downed power lines may energize metal structures such as buildings, vehicles or fences.

Source: www.inorum.com/specials/flood5yrslater/images

Once the scene is secure and the source has been removed from the patient, ABC's assume priority along with spine motion restriction. Assess the patient and prepare him/ her for transport. Search for both an entrance and an exit wound. Look specifically for possible contact points with both the ground and the electrical source. In some circumstances, multiple entrance and exit wounds are present. Remember that electrical current passes through the body and therefore may result in significant internal burns, especially to blood vessels and nerves, while the assessment reveals only minimal superficial findings. Rapidly progressive cardiovascular collapse can follow contact with an electrical source. These patients should be carefully monitored. Pulses and capillary refill should be checked in all extremities, documented and repeated at frequent intervals. Cardiac monitoring is essential in all patients with electrical injuries. Electrical current may induce arrhythmias including bradycardias, tachycardias, ventricular fibrillation and asystole. Perform frequent neurological assessments, and examine the patient for any fractures resulting from forceful muscle contractions caused by the



current's passage. Remove rings, watches, and any other constrictive items from the fingers, limbs and the neck.

At the very least try to determine:

1. The type of current (alternating versus direct) and the voltage if possible
2. Path of the current through the body (difficult to determine in the field but entrance and exit wounds should be noted)
3. Duration of contact with the current source

Lightning strikes to humans have a mortality rate as high as 30%. Strikes to people riding tractors, on open water, on golf courses and under trees are the most common, and are the victims of 75% of all strikes. A lightning strike is a high voltage (up to 100,000 volts – your car has 12 volts), high current (10,000 amperes – your LifePak twelve can generate up to 200 *milli*-amperes during transcutaneous pacing) and high temperature (50,000ºF) even if it only lasts for a fraction of a second. A direct strike will impart this energy to the patient. However, the lightning will often strike a nearby object with some voltage traveling through sideways (side flash) or the voltage may radiate outward in alternate pathways from the strike point, thus diminishing the voltage (step voltage).

By the time anyone reaches the patient of a lightning strike, the electricity has long since dissipated. (there will be, however, a continued risk of further strikes as long as the storm remains nearby). There is no danger of electrical shock from touching the victim of a lightning strike. The victim's clothing however, may continue to smolder, so remove it if necessary. Among other serious effects, lightning can produce a sudden cessation of breathing**.**

Treat cardiac or respiratory arrest in electrical burn patients with aggressive airway, ventilatory, and circulatory management. Patients in cardiac arrest due to contact with an electrical current have a high survival rate if prehospital intervention is prompt. Check immediately for ventricular fibrillation and defibrillate if necessary. These patients should also have spine motion restriction principles applied.

ASSESSMENT AND MANAGEMENT OF CHEMICAL BURNS

The most important aspects of prehospital care for chemical burn victims involve removal of the burning agent from contact with the patient. This requires removal of all potentially contaminated clothing and copious irrigation using the supplied saline in your burn kit. It is not recommended that you "wash" away powders, instead they should be brushed off. The chemical reaction of water and "unknown" powders may result in additional heat and burns. Before irrigating or removing any substances keep in mind personal protection and be sure to don personal protective equipment prior to doing so.

Any recommendation to place the patient in a tub of some sort should never be taken! The irrigation should be large volumes (you might need additional saline) and should be toward the floor. Irrigation is meant to dilute the agent and prevent additional contact with the skin. When you think you have irrigated enough, irrigate some more. While there is no standard on time, some hospital burns units irrigate for 30 minutes to 2 hours. Irrigate as best you can keeping in mind that transport is still required. Minimal delay is acceptable for proper irrigation (assuming no other injuries exist).

Try to get the Material Safety Data Sheet (MSDS) if you can. Emergency procedures are described on these forms as well as very important information about the chemical which may be required by the hospital staff.

In the field use of neutralizing agents or “home remedies” should be avoided due to the wide variety of chemicals patients can come into contact with. The certainty of neutralizing agents is controversial in the burns units, let alone the field!

CONCLUSION

Burn care has made many advances over recent years and continues to improve. With advances in prehospital care, paramedics are expected to manage the first few minutes of a burn victim effectively to promote improved prognosis, reduce complications and facilitate recovery. If we think back to the case study presented at the start of the module, we can all appreciate the likeness of a call similar to this, as well as the fairly rare frequency in which we are encountered with this type of patient. It is for this reason that frequent review in principles of burn care is essential. By completing this module, you have reviewed anatomy and physiology, discussed the pathophysiology of burns, physics associated with electrical injuries, predictable responses of the body, assessment and management options and more. When caring for a burn victim, prioritization skills, recognition of the severity, and a thorough understanding for the potential for complications all work together to ensure the best outcome for the patient. Something that cannot be taught in a module of this kind is critical thinking. However, with the knowledge base reviewed within this CME, you are better equipped to make the right decisions when presented with victims of burn injuries.

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