Chapter 9: Injuries Due to Burns and Cold

Objectives:

Upon completion of this topic, the physician will be able to identify methods of assessment and outline measures to stabilize, manage, and transfer patients with burns and cold injuries. Specifically, the physician will be able to:

A. Estimate the burn size and determine the presence of associated injuries.

B. Outline measures of initial stabilization and treatment of patients with burns and patients with cold injury.

C. Identify special problems and methods of treatment of patients with burns and patients with cold injury.

D. Outline criteria for the transfer of burn patients.
I. Introduction

Burn and cold injuries constitute a major cause of morbidity and mortality. Attention to basic principles of initial trauma resuscitation and timely application of simple emergency measures should minimize the morbidity and mortality of these injuries.

These principles include a high index of suspicion for the presence of airway compromise in smoke inhalation, the maintenance of hemodynamic stability, and fluid and electrolyte balance. The physician also must have an awareness of measures to be instituted for prevention and treatment of the potential complications of thermal injuries, eg, rhabdomyolysis and cardiac dysrhythmias, as seen in electrical burns. Removal from the injury-provoking environment, cautious temperature control, and observation for definite demarcation of nonviable tissue before major debridement also constitute major principles of thermal injury management.

II. Immediate Life-saving Measures for Burn Injuries

A. Airway

Although the larynx protects the subglottic airway from direct thermal injury, 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, they may warn the examiner of potential airway obstruction. When a patient is admitted to the hospital after sustaining a burn injury, the physician should be alert to the possibility of airway involvement, identify signs of distress, and initiate supportive measures. Clinical indications of inhalation injury include:

1. Facial burns.
2. Singeing of the eyebrows and nasal vibrissae.
3. Carbon deposits and acute inflammatory changes in the oropharynx.
5. History of impaired mentation and/or confinement in a burning environment.

The presence of any of these findings suggest acute inhalation injury. Such injury requires immediate and definitive care, including airway support, which may involve endotracheal intubation and early transfer to a burn center.

B. Stop the Burning Process

All clothing should be removed to stop the burning process. 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 from the wound, with the individual caring for the patient avoiding direct contact with the chemical. The involved body surface areas are then rinsed with copious amounts of water.

C. Intravenous Lines

After establishing airway patency and identifying and treating immediately life-threatening injuries, intravenous access must be established. Any patients with burns over more than 20% of the body surface area needs circulatory volume support. Large-caliber (at least #16-gauge catheter) intravenous lines must be established immediately in a peripheral vein. If the extent of burn precludes placement of the catheter through unburned skin, overlying burned skin should not deter placement of the catheter in an accessible vein. The upper extremities are preferable to the lower extremities for venous access because of the high incidence of phlebitis and septic phlebitis in the saphenous veins. Begin infusion with Ringer's lactate solution. Guidelines for establishing the flow rate of Ringer's lactate solution are outlined later in this chapter.

III. Assessing the Burn Patient

A. History

A brief history of the nature of the injury may prove extremely valuable in the management of the burn patient. Associated injuries may be sustained while the victim attempts to escape the fire. Water heater explosions, propane gas explosions, and other explosions may throw the patient some distance and may result in internal injuries or fractures, ie, CNS, myocardial, pulmonary, and abdominal injuries. It is essential that the time of the burn injury be established.

The history, from the patient or relative, should include a brief survey of pre-existing illnesses: (1) diabetes, (2) hypertension, (3) cardiac, pulmonary and/or renal disease, and (4) drug therapy. Allergies and sensitivities also are important. The patient's tetanus immunization status also should be ascertained.

B. Body Surface Area

The "Rule of Nines" is a useful and practical guide to determine the extent of the burn. The adult body configuration is divided into anatomic regions that represent 9%, or multiple of 9%, of the total body surface. Body surface area differs considerably for children. The infant's or young child's head represents a larger proportion of the surface are, and the lower extremities a lesser proportion, than an adult's. The percentage of total body surface of the infant's head is twice that of the normal adult. (See Figure 1, "Rule of Nines"). Remember, the palm (not including the fingers) of the patient's hand represents approximately 1% of the patient's body surface. This guideline helps estimate the extent of burns of irregular outline or distribution.
C. Depth of Burn

The depth of burn is important in evaluating the severity of the burn, planning for wound care, and predicting functional and cosmetic results. **First-degree burns** (eg, sunburn) are characterized by erythema, pain, and the absence of blisters. They are not life threatening, and generally do not require intravenous fluid replacement. This type of burn will not be discussed further in this chapter.

**Second-degree burns or partial-thickness burns** are characterized by a red or mottled appearance with associated swelling and blister formation. The surface may have a weeping, wet appearance and is painfully hypersensitive, even to air current.

**Full-thickness or third-degree burns** appear dark and leathery. The skin also may appear translucent, mottled, or waxy white. The surface is painless and generally dry. (See Figure 2, Depth of Burn.)

IV. Stabilizing the Burn Patient

A. Airway

Objective signs of airway injury or history of confinement in a burning environment dictates evaluation of the airway and definitive management. Pharyngeal thermal injuries may produce marked upper airway edema, and early maintenance of the airway is important. The clinical manifestations of inhalation injury may be subtle and frequently do not appear in the first 24 hours. If the physician waits for roentgenographic evidence of pulmonary injury or change in blood gas determinations, airway edema may preclude intubation, and a surgical airway may be required.

B. Breathing

The initial treatment of injuries is a graded response based on the patient's signs and symptoms. Major concerns regarding the respiratory status in the patient exposed to smoke and heat are:

1. Direct thermal injury, producing upper airway edema and/or obstruction.

2. Inhalation of products of incomplete combustion (carbon particles) and toxic fumes, leading to chemical tracheobronchitis, edema, and pneumonia.

Always assume carbon monoxide (CO) exposure in patients burned in enclosed areas. Diagnosis of carbon monoxide poisoning is made primarily from a history of exposure. Cherry-red skin color is rare. Headache, nausea, vomiting, and mental disturbances occur at higher carbon monoxide levels. Because of the increased affinity of carbon monoxide for hemoglobin (240 times that of oxygen), it displaces oxygen from the hemoglobin molecule and shifts the oxyhemoglobin dissociation curve to the left. Carbon monoxide dissociates very slowly, and its half-life is 250 minutes while the patient is breathing room air, compared with 40 minutes while breathing 100% oxygen. Therefore, patients suspected of exposure to carbon monoxide should receive initially, high-flow oxygen via a nonrebreathing mask.
Early management of inhalation injury may require endotracheal intubation and mechanical ventilation. Arterial blood gas determinations should be obtained immediately as a baseline for the evaluation of the pulmonary status. However, measurements of arterial PO$_2$ do not reliably predict carbon monoxide poisoning, because a carbon monoxide partial pressure of only 1 mm Hg results in carboxyhemoglobin level of 40% or greater. Therefore, baseline carboxyhemoglobin levels should be obtained, and 100% oxygen should be administered.

**Figure 1. "Rule of Nines"
**

The "Rule of Nines" is used in the hospital management of severe burns to determine fluid replacement. It also is useful as a practical guide for the evaluation of severe burns. The adult body is generally divided into surface areas of 9% each and/or fractions or multiplies of 9%.

- **Adult:** Face and neck - 9%; Front - 18%; Back - 18%; Arm - 9%; Leg - 18%; Genital area - 1%.
- **Child:** Face and neck - 18%; Front - 18%; Back - 18%; Arm - 9%; Leg - 14%.

**Figure 2. Depth of Burn
**

**Second-degree or Partial-thickness Burn Injury. Depth of Burn:** Second-degree burns are deeper than first-degree burns. They commonly result from contact with hot liquids or flash burns from gasoline flames. **Signs and Symptoms:** Red or mottled appearance, blistered and broken epidermis. Considerable swelling. Weeping, wet surfaces. Painful. Sensitive to air.

**Third-degree or Full-thickness Burn Injury. Depth of Burn:** Third-degree burns cause damage to all skin layers, nerve endings and even subcutaneous tissues. They can be caused by fire, prolonged exposure to hot liquids, contact with hot objects, or electricity. Initially, they may resemble second-degree burn injuries. **Signs and Symptoms:** Pale, white, charred, or leathery appearance. Broken skin with fat exposed. Dry surface. Painless. Edema.

**C. Circulating Blood Volume
**

Evaluation of the circulating blood volume is often difficult in the severely burned patient. Blood pressure may be difficult to obtain and may be unreliable. Monitoring hourly urinary outputs reliably assesses circulating blood volume in the absence of osmotic diuresis (eg, glycosuria). Therefore, an indwelling urethral catheter should be inserted. A good rule of thumb is to infuse fluids at a rate sufficient to produce 1.0 mL of urine per kilogram body weight per hour for children who weigh 30 kilograms or less, and 30 to 50 mL of urine per hour in the adult.

The burn patient requires 2 to 4 mL of Ringer's lactate solution per kilogram body weight per percent body surface burn in the first 24 hours to maintain an adequate circulating blood volume and provide adequate renal output. The estimated fluid volume is then proportioned in the following manner: one half of the total estimated fluid is provided in the
first eight hours postburn, and the remaining one half is administered in the next 16 hours. To maintain an average urinary output of 1 mL per kilogram per hour in small children who weigh 30 kilograms or less, it may be necessary to calculate and add glucose-containing maintenance fluids to the burn formula.

Any resuscitation formula provides only an estimate of fluid need. Fluid requirement calculations for infusion rates are based on the time from injury, not from the time fluid resuscitation is initiated. The amount of fluid given should be adjusted according to the individual patient's response, ie, urinary output, vital signs, and general condition.

D. Physical Examination

The following must be done in order to plan and direct patient management:

1. Estimate extent and depth of burn.
2. Assess for associated injuries.
3. Weigh the patient.

E. Flow Sheet

A flow sheet, outlining the patient's management, should be initiated when the patient is admitted to the emergency department. This flow sheet should accompany the patient when he is transferred to the burn unit.

F. Baseline Determinations for the Major Burn Patient

1. Blood

Obtain samples for CBC, type and crossmatch, carboxyhemoglobin, serum glucose, electrolytes, and pregnancy test in all females of child-bearing age. Arterial blood samples also should be obtained for blood gas determinations.

2. Roentgenograms

A chest film should be obtained. An additional film may be required if endotracheal intubation and/or subclavian or internal jugular vein catheterization are accomplished. Other roentgenograms may be indicated for appraisal of associated injuries.

G. Circumferential Extremity Burns - Maintenance of Peripheral Circulation

1. Remove all jewelry.

2. Assess the status of distal circulation, checking for cyanosis, impaired capillary refilling, or progressive neurologic signs (ie, paresthesia and deep tissue pain). Assessment of peripheral pulses in burn patients is best performed with a Doppler Ultrasonic Flow Meter.
3. Circulatory embarrassment in a circumferentially burned limb is best relieved by escharotomy, preferably with surgical consultation. Incision of the eschar to relieve edema pressure can be performed as an emergency procedure without anesthesia, because the incision is limited to insensate full-thickness burn. The incision must extend across the entire length of the eschar in the lateral and/or medial line of the limb including the joints. The incision is limited to nonviable tissue, and to limit blood loss, viable subeschar tissue should not be incised. Escharotomy of the fingers is rarely indicated and should be done only in consultation with an experienced burn surgeon.

4. Circumferential burns of the thorax may impair respiratory excursion. Bilateral, escharotomy incisions in the anterior axillary lines should be considered if respiratory excursions are limited.

5. Fasciotomy is seldom required. However, it may be necessary to restore circulation for patients with associated skeletal trauma, crush injury, high-voltage electrical injury, or burns involving tissue beneath the investing fascia.

H. Nasogastric Tube Insertion

Insert a nasogastric tube and attach it to suction if the patient experiences nausea, vomiting, abdominal distention, or if burns involve more than 20% of the total body surface area. Prior to transfer it is essential that a nasogastric tube be inserted and functioning in such patients.

I. Narcotics, Analgetics, and Sedatives

The severely burned patient may be restless and anxious from hypotension or hypovolemia rather than pain. Consequently, the patient responds better to oxygen or increased fluid administration, rather than to narcotic analgesics or sedatives that may mask the signs of hypoxemia or hypovolemia. Narcotics, analgesics, and sedatives should be used sparingly. If narcotics are necessary, they should be administered in small, frequent doses by the intravenous route only.

J. Wound Care

Partial-thickness (second-degree) burns are painful when air currents pass over the burned surface. Gently covering the burn with clean linen relieves the pain and deflects air currents. Do not break blisters or apply any antiseptic agent. Any applied medication must be removed before appropriate antibacterial topical agents can be applied. Application of cold compresses may cause hypothermia. Do not apply cold water to a patient with extensive burns.

K. Antibiotics

Prophylactic antibiotics are not indicated in the early postburn period. Antibiotics should be reserved for the treatment of infection.
V. Special Burn Requirements

A. Chemical Burns

Chemical injury can result from exposure to acids, alkalies, or petroleum products. Alkali burns are generally more serious than acid burns, because the alkalies penetrate more deeply. Removal of the chemical and immediate attention to wound care are essential.

Chemical burns are influenced by the duration of contact, concentration of the chemical, and amount of the agent. Immediately flush away the chemical with large amounts of water, using a shower or hose if available, for at least 20 to 30 minutes. Alkali burns require longer irrigation. If dry powder is still present on the skin, brush it away before irrigation with water. Neutralizing agents have no advantage over water lavage, because reaction with the neutralizing agent may itself produce heat and cause further tissue damage. Alkali burns to the eye require continuous irrigation during the first eight hours after the burn. A small-caliber cannula can be fixed in the palpebral sulcus for such irrigation.

B. Electrical Burns

Electrical burns result from a source of electrical power making contact with the patient's body. Electrical burns frequently are more serious than they appear on the surface. The body may serve as a volume conductor of electrical energy and the heat generated results in thermal injury of tissue. Different rates of heat loss from superficial and deep tissues account for relatively normal overlying skin coexisting with deep muscle necrosis. Rhabdomyolysis results in myoglobin release, which can cause acute renal failure.

The immediate management of a patient with a significant electrical burn includes attention to the airway and breathing, establishment of an intravenous line, electrocardiographic monitoring, and placement of an indwelling urinary catheter. If the urine is dark, assume that hemochromogens are in the urine. Do not wait for laboratory confirmation before instituting therapy for myoglobinuria. Fluid administration should be increased to ensure a urinary output of at least 100 mL per hour in the adult. If the pigment does not clear with increased fluid administration, 25 grams of mannitol should be administered immediately and 12.5 grams of mannitol should be added to subsequent liters of fluid in order to maintain the diuresis.

Metabolic acidosis should be corrected by maintaining adequate perfusion and adding sodium bicarbonate to alkalinize the urine and increase the solubility of myoglobin in the urine.
VI. Criteria for Transfer

A. Types of Burn Injuries

The American Burn Association has identified the following types of burn injuries that usually require referral to a burn center:

1. Partial-thickness and full-thickness burns greater than 10% of the total body surface area (BSA) in patients under 10 years or over 50 years of age.

2. Partial-thickness and full-thickness burns greater than 20% BSA in other age groups.

3. Partial-thickness and full-thickness burns involving the face, eyes, ears, hands, feet, genitalia, or perineum or those that involve skin overlying major joints.

4. Full-thickness burns greater than 5% BSA in any age group.

5. Electrical burns, including lightning injury; (significant volumes of tissue beneath the surface may be injured and result in acute renal failure and other complications).

6. Significant chemical burns.

7. Inhalation injury.

8. Burn injury in patients with pre-existing illness that could complicate management, prolong recovery, or affect mortality.

9. Any burn patient in whom concomitant trauma poses an increased risk of morbidity or mortality may be treated initially in a trauma center until stable before transfer to a burn center.

10. Children with burns seen in hospitals with qualified personnel or equipment for their care should be transferred to a burn center with these capabilities.

11. Burn injury in patients who will require special social and emotional or long-term rehabilitative support, including cases involving suspected child abuse and neglect.

B. Transfer procedure

1. Transfer of any patient must be coordinated with the burn-center physician.

2. All pertinent information regarding tests, temperature, pulse, fluids administered, and urinary output should be recorded on the burn/trauma flow sheet and sent with the patient. Any other information deemed important by the referring or receiving physician also is sent with the patient.
VII. Cold Injury

Severity of cold injury depends on temperature, duration of exposure, and environmental conditions. Lower temperatures, immobilization, prolonged exposure, moisture, the presence of peripheral vascular disease, and open wounds all increase the severity of the injury.

A. Types

Three types of cold injury are seen in trauma patient:

1. **Frostbite** is due to freezing of tissue from intracellular ice crystal formations and microvascular occlusion. Similar to thermal burns, frostbite is classified into first, second, third, and fourth degree according to depth of involvement.

   a. First degree - Hyperemia, edema without skin necrosis.

   b. Second degree - Vesicle formation accompanies the hyperemia and edema with partial thickness necrosis of skin.

   c. Third degree - Full-thickness skin necrosis occurs, with necrosis of some underlying subcutaneous tissue.

   d. Fourth degree - Full-thickness skin necrosis, including muscle and bone with gangrene.

2. **Nonfreezing** injury is due to microvascular endothelial damage, stasis, and vascular occlusion. With ambient temperature above freezing, prolonged exposure leads to "trench foot" over several days while "immersion foot" develops more slowly at higher temperatures. Although the entire foot may appear black, deep tissue destruction may not be present. **Chilblain or pernio**, common among mountain climbers, results from exposure to dry temperatures just above freezing leading to superficial ulceration of the skin of the extremities.

3. **Hypothermia** is a state in which the patient's generalized core temperature drops below 35 degrees centigrade.

   Estimation of depth of injury and extent of tissue damage is not usually accurate until demarcation is evident. This often requires several weeks of observation.

B. Management of Frostbite and Nonfreezing Cold Injuries

Treatment should be immediate to decrease duration of tissue freezing. Constricting, damp clothing should be replaced by warm blankets and the patient should be given hot fluids by mouth, if able to drink.

Place the injured part in circulating water at 40 degrees centigrade until the pink color and perfusion return (usually within 20 to 30 minutes). Avoid dry heat.
C. Local Wound Care of Frostbite

The goal of wound care for frostbite is to preserve damaged tissue by preventing infection, avoiding opening noninfected vesicles, and elevating the injured area, which is left open to air. Narcotic analgesics are required.

Tetanus prophylaxis depends on the patient's tetanus immunization status. Antibiotics are administered if infection is obviously present. Only rarely is fluid loss massive enough to require resuscitation with intravenous fluids.

VIII. Hypothermia

Total body hypothermia is defined as a core temperature below 35 degrees centigrade. Clinically, hypothermia may be classified as mild (32 to 35 degrees centigrade), moderate (30 to 32 degrees centigrade), or severe (below 30 degrees centigrade). This drop in core temperature may be rapid, as in immersion in near-freezing water, or slow, as in exposure to more temperate environments. The elderly are particularly susceptible to this condition, because of their impaired ability to increase heat production and decrease heat loss by vasoconstriction. Children also are more susceptible because of relative increased BSA and limited energy sources. Trauma patients also are susceptible to hypothermia. Such hypothermia is preventable with the administration of warmed intravenous fluids and maintenance of a warm environment. Since determination of the core temperature, preferably esophageal, is essential for the diagnosis, special thermometers capable of registering low temperatures are required.

A. Signs of Hypothermia

In addition to a decrease in core temperature, a depressed level of consciousness is the most common feature of hypothermia. The patient is cold to touch and appears gray and cyanotic. Vital signs, including pulse rate, respiratory rate, and blood pressure are all variable, and the absence of respiratory or cardiac activity is not uncommon in patients who eventually recover. Because of severe depression of the respiratory rate and heart rate, signs of respiratory and cardiac activity are easily missed unless careful assessment is conducted.

B. Management of Hypothermia

Immediate attention is devoted to the ABCs, including the initiation of cardiopulmonary resuscitation and the establishment of intravenous access if the patient is in cardiopulmonary arrest.

Prevent heat loss by removing the patient from the cold environment and replacing wet, cold clothing with warm blankets. Administer oxygen via a bag-reservoir device. The patient should be managed in a critical care setting whenever possible. A careful search for associated disorders, such as diabetes, sepsis, and drug or alcohol ingestion, should be conducted. These disorders should be treated promptly. Blood should be drawn for CBC, electrolytes, blood glucose, creatinine, amylase, and blood cultures. Abnormalities should be treated accordingly. For example, hypoglycemia would require intravenous glucose administration.
Determination of death can be very difficult in the hypothermic patient. Patients who appear to have suffered a cardiac arrest or death as a result of hypothermia should not be pronounced dead until they are rewarmed.

The rewarming technique depends on the patient's temperature and his response to simpler measures. For example, treat mild and moderate hypothermia by **passive external rewarming** in a warm room using warm blankets, clothing, and warmed intravenous fluids. Severe hypothermia may require **active core rewarming methods** that may include invasive surgical rewarming techniques, eg, peritoneal lavage, thoracic/pleural lavage, hemodialysis, or cardiopulmonary bypass, all of which are better done in a critical care setting.

The risk of cardiac irritability increases with body temperatures below 30 degrees centigrade, and asystole may occur with body temperatures below 28 degrees centigrade. Cardiac drugs and defibrillation are not usually effective in the presence of acidosis, hypoxia, and hypothermia. Sodium bicarbonate and 100% oxygen should be administered while the patient is warmed to 32 degrees centigrade, and cardiopulmonary resuscitation is continued. Cardiac drugs and defibrillation may then be instituted when the patient is rewarmed, as indicated. Attempts to actively rewarm the patient should not delay transfer to a critical care setting. (See Chapter 3, Shock.)
IX. Summary

A. Burns - Thermal, Chemical, Electrical

Immediate life-saving measures for the burn patient include the recognition of inhalation injury and subsequent endotracheal intubation, and the rapid institution of intravenous fluid therapy. All clothing should be removed rapidly.

Early stabilization and management of the burn patient include:

1. Identifying the extent and depth of the burn.
2. Establishing fluid guidelines according to the patient's weight.
4. Obtaining baseline laboratory and roentgenographic studies.
5. Maintaining peripheral circulation in circumferential burns by performing an escharotomy if necessary.
6. Identifying which burn patients require transfer to a burn unit or center.

B. Cold Injuries

Diagnose the type of cold injury by obtaining an adequate history and noting the physical findings as well as measuring the core temperature using a low-range thermometer (esophageal temperature probe preferred). The patient should be removed from the cold environment immediately, and vital signs should be monitored and supported continuously. Rewarming techniques should be applied as soon as possible. The patient with hypothermia should not be considered dead until rewarming has occurred.

Early management of cold-injury patients includes:

1. Identifying the type and extent of cold injury.
4. Initiating rapidrewarming techniques.
5. Determining the patient's life or death status after rewarming.