



CARE
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Advanced Burn Life Support Course

**PROVIDER MANUAL
2018 UPDATE**

American Burn Association
311 South Wacker Drive, Suite 4150
Chicago, IL 60606
(312) 642-9260
www.ameriburn.org

2017–2018

ABLS Advisory Committee

Tam N. Pham, MD, FACS

Contributing Editor

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Seattle, WA

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Philadelphia, PA

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Washington, DC

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Contributing Editor

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Contributing Editor

UW Medicine Regional Burn Center at Harborview
Seattle, WA

Acknowledgements

The American Burn Association (ABA) gratefully acknowledges the leadership, time and dedication of the current and past members of the ABLIS Advisory Committee. Also, the continued assistance of the ABA Central Office Staff is deeply appreciated.

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CHAPTER 1

Introduction



Objectives

Upon completion of this chapter the participant will be able to:

- Understand the epidemiology of burn injuries in the United States
- Describe learning goals for this course

I. BURN BASICS

A burn is defined as damage to the skin and underlying tissues caused by heat, chemicals, or electricity. Each year in the United States about 450,000 people receive medical attention for burn injuries. An estimated 4,000 people die annually due to fire and burns, primarily from residential fires (3,500). Other causes include motor vehicle and aircraft crashes, contact with electricity, chemicals or hot liquids and substances, and other sources of burn injury. About 75% of these deaths occur at the scene of the incident or during initial transport. The leading cause of fire death in the United States is from fires due to smoking materials, especially cigarettes. The ABA has been a lead organization in the attempt to require all cigarettes sold in every state to be fire-safe cigarettes.

Approximately 45,000 people are hospitalized for burn injuries each year and will benefit most from the knowledge gained in the Advanced Burn Life Support (ABLS) Provider Course.

Below are a few interesting facts regarding burn injuries in the United States. These statistics are for patients admitted to burn centers and based on the ABA's National Burn Repository Report for Data from 1999-2008.

- Nearly 71% of patients with burns were men.
- Children under the age of 5 accounted for 17% of cases.
- Sixty-seven percent of the reported cases sustained burns of less than 10% TBSA.
- Sixty-five percent of the reported patients were burned in the home.
- During this 10-year period, the average length of burn center stay declined from roughly 11 days to 9 days.
- Four percent of patients died from their injuries.
- Ninety-six percent of patients treated in burn centers survived

II. COURSE OBJECTIVES

The quality of care during the first hours after a burn injury has a major impact on long-term outcome; however, most initial burn care is provided outside of the burn center environment. Understanding the dynamics of Advanced Burn Life Support (ABLS) is crucial to providing the best possible outcome for the patient. The ABLS Provide Course is an eight-hour course designed to provide physicians, nurses, nurse practitioners, physician assistants, firefighters, paramedics, and EMTs with the ability to assess and stabilize patients with serious burns during the first critical hours following injury and to identify those patients requiring transfer to a burn center.

The course is not designed to teach comprehensive burn care, but rather to focus on the first 24 post-injury hours.

Upon completion of the course, participants will be able to provide the initial primary treatment to those who have sustained burn injuries and manage common complications that occur within the first 24-hours post-burn. Specifically, participants will be able to demonstrate an ability to do the following:

- Evaluate a patient with a serious burn.
- Define the magnitude and severity of the injury.
- Identify and establish priorities of treatment.
- Manage the airway and support ventilation.
- Initiate, monitor and adjust fluid resuscitation.
- Apply correct methods of physiological monitoring.
- Determine which patients should be transferred to a burn center.
- Organize and conduct the inter-hospital transfer of a seriously injured patient with burns.
- Identify priority of care for patients with burns in a burn mass casualty incident.

III. CE AND CME CREDITS

The American Burn Association is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education hours for physicians. The American Burn Association designates this education activity for a maximum of 7.25 credits AMA PRA Category 1 Credits(s)[™]. Physicians should only claim credit commensurate with the extent of their participation in the activity.

This program has been approved by the American Association of Critical Care Nurses (AACN) for 7 contact hours, Synergy CERP Category A, File number 00019935 for 2017. Please consult the ABA website ABLS Course description for the accreditation information in future years.

IV. COURSE CONTENT

Burn Care is multidisciplinary. Therefore, the ABLS Course is designed in a multidisciplinary format applicable to all levels of care providers and is based on the guidelines for initial burn care developed by the American Burn Association. The ABLS Provider Course presents a series of didactic presentations on initial assessment and management, airway management, smoke inhalation injury, shock and fluid resuscitation, wound management, electrical injury, chemical injury, the pediatric patient, transfer and transport principles and burn disaster management. Participants then apply these concepts during small group case study discussions.

Participant are also given the opportunity to work with a simulated burn patient, to reinforce the assessment and stabilization principles and also as a means of applying the American Burn Association criteria for transfer of patients to burn centers. Final testing consists of a written exam and a practical assessment.

V. SUMMARY

The management of a seriously burned patient in the first few hours can significantly affect the long-term outcome. Therefore, it is important that the patient be managed properly in the early hours after injury. The complexity, intensity, multidisciplinary character and expense of the care required by an extensively burned patient have led to the development of specialty care burn centers. The regionalization of burn care at such centers has optimized the long-term outcomes of these extensively burned patients. Because of regionalization, it is extremely common for the initial care of the seriously burned patient to occur outside the burn center, while transport needs are determined and transportation is affected. The goal of the ABLS Course is to provide the information that will increase the knowledge, competence and confidence of healthcare providers who care for patients with burns in the first 24-hours post-burn injury.

VI. SELECT REFERENCES

- American College of Surgeons – Committee on Trauma. Resources for Optimal Care of the Injured Patient. Chicago, IL: American College of Surgeons, 2014 (*Describes Burns and Trauma Care Program Requirements.*)
- Sheridan RL, Hinson MI, Liang MH, et al. Long-term outcome of children surviving massive burns. JAMA 2000; 283-69-73. (*Demonstrates that quality of long term outcomes after burns is favorably influence by care in a multidisciplinary burn care environment.*)
- Centers for Disease Control and Prevention. Injury Prevention and Control: Data and Statistics (WISQARS). 2016. Retrieved from: <https://www.cdc.gov/injury/wisqars/fatal.html>

CHAPTER 2

Initial Assessment and Management



Objectives

Upon completion of this lecture the participant will be able to:

- Identify components of a primary and secondary survey
- Apply the “Rule of Nines” for burn size estimate
- Identify the ABLS recommendations for fluid resuscitation
- List ABA burn center referral criteria

I. INTRODUCTION

Proper initial care of patients with major burns is key to their clinical outcomes. The early identification and control of airway and breathing problems help prevent early deaths. Initiating proper fluid resuscitation avoids major complications. Recognizing and treating associated injuries are also essential. Finally, prompt consultation with burn center staff in patients who meet referral criteria is also an important link in the chain of survival for major burns.

II. BODY SUBSTANCE ISOLATION

Prior to initiating care, healthcare providers should take measures to reduce their own risk of exposure to infection and chemical contamination. Body Substance Isolation (BSI) is the most effective way, and includes use of gloves, eye wear, gowns and respiratory protection. The level of protection will depend on the patient presentation, the risk of exposure to body fluids and airborne pathogens, and/or chemical exposure.

Patients with burns are at high risk for infection. The use of BSI devices also helps to protect the patient from potential cross contamination from caregivers.

III. PRIMARY SURVEY

The initial assessment of the burn patient is identical to other trauma: recognize and treat life/limb-threatening injuries first. Many patients with burns also have associated trauma. First responders should not let the burn overwhelm them. Immediate priorities are outlined by the American College of Surgeons Committee on Trauma and promulgated in the Advanced Trauma Life Support Course.

The Primary survey consists of the following:

- Airway maintenance with cervical spine protection
- Breathing and ventilation
- Circulation and Cardiac Status with hemorrhage control
- Disability, Neurological Deficit and Gross Deformity assessment
- Exposure and Environmental Control (Completely undress the patient, Examine for associated injuries and maintain a warm Environment.)

A. Airway Maintenance with Cervical Spine Protection

Assess the airway immediately. Airway opening may improve using simple measures, including:

- Chin lift
- Jaw thrust
- Oropharyngeal airway placement (unconscious patient)

Otherwise, the patient needs endotracheal intubation. It is important to protect the cervical spine by in-line cervical immobilization in patients with associated trauma mechanism (i.e., fall, motor vehicle crash), and in patients with altered mental status.

B. Breathing and Ventilation

Ventilation, the movement of air, requires functioning of the lungs, chest wall, and diaphragm. Assess by:

- Chest auscultation and verify equal breath sounds in each lung
- Assess the rate and depth of breathing
- Start high flow 100% oxygen using a non-rebreather mask if inhalation injury is suspected
- Circumferential full-thickness burns of the trunk and neck may impair ventilation and must be closely monitored.

It is important to recognize that respiratory distress may be due to a non-burn condition such as a pre-existing medical condition or a pneumothorax from an associated injury.

C. Circulation and Cardiac Status

Assess circulation by blood pressure, pulse rate, and skin color (of unburned skin). A continuous cardiac monitor and pulse oximeter on an unburned extremity or ear will allow for continued monitoring. Increased circulating catecholamines after burns often elevate the adult heart rate to 100-120 bpm. Heart rates above this level may indicate hypovolemia from an associated trauma, inadequate oxygenation, unrelieved pain or anxiety. Abnormal cardiac rhythms may be due to electrical injuries, underlying cardiac abnormalities or electrolyte imbalances.

Insert a large bore intravenous catheter (through unburned skin, if possible). Burns greater than 20% should have 2 large bore, indwelling venous catheters, especially during transport. In the pre-hospital and early hospital settings, prior to calculating the Total Body Surface Area (TBSA) burned, the initial fluid rates for patients with visibly large burns are based on patient age:

- 5 years old and younger: 125 ml Lactated Ringers (LR) per hour
- 6-13 years old: 250 ml LR per hour
- 14 years and older: 500 ml LR per hour

Definitive calculation of hourly fluid rates (termed “adjusted fluid rates”) occurs during the secondary survey.

Circulation in a limb with a circumferential or nearly circumferential full-thickness burn may become impaired by edema formation. Typical indicators of compromised circulation, (pain, pallor, paresthesia) may not be reliable in a burned extremity. On the other hand, the absence of a radial pulse below (distal to) a full-thickness circumferential burn of the arm suggests impaired circulation. Doppler examination can also be used to confirm the circulation deficit.

Acute burns do not bleed. If there is bleeding, there is an associated injury—find and treat the cause. Associated trauma may also cause internal bleeding, resulting in tachycardia and hypotension. Maintain a high index of suspicion if the injury mechanism suggests possible non- burn trauma (i.e. fall, motor vehicle crash).

D. Disability, Neurologic Deficit, and Gross Deformity

Typically, the patient with burns is initially alert and oriented. If not, consider associated injury, carbon monoxide poisoning, substance abuse, hypoxia, or pre-existing medical conditions. Begin the assessment by determining the patient’s level of consciousness using the AVPU method:

A – Alert

V – Responds to verbal stimuli

P – Respond only to painful stimuli

U – Unresponsive

The Glasgow Coma Scale (GCS) is a more definitive tool used to assess the depth and duration of coma and should be used to follow the patient’s level of consciousness. See Appendix I.

E. Exposure and Environmental Control

Exposure and completely undress the patient, Examine for major associated injuries and maintain a warm Environment.

Stop the burning process. Remove all clothing, jewelry/body piercing, shoes, and diapers. If any material is adherent to the skin, stop the burning process by cooling the adherent material, cutting around it and removing as much as possible. Contact lenses, with or without facial burns, should be removed before facial and periorbital edema develops. Chemicals may also adhere to the lenses and present further problems.

For smaller size injuries (i.e., $\leq 5\%$ TBSA) cool the burn briefly (3-5 minutes) with water. Never use ice or cold water. Prolonged application of cold compresses pose the risk of wound and body hypothermia. Wound hypothermia reduces blood flow to the damaged area and may deepen the injury. Systemic hypothermia (core temperature less than 95° F / 35° C) may also increase the depth of the burn injury by vasoconstriction, decrease enzymatic activity, depress muscle reflexes, interfere with clotting mechanisms and respiration, and may cause cardiac arrhythmias and death. This is especially true in a pediatric patient who has limited ability to maintain core body temperature.

Maintaining the patient’s core body temperature is a priority. The EMS transport vehicles and treatment room should be warmed and, as soon as the primary survey is complete, the patient should be covered with dry sheets and blankets to prevent hypothermia.

Warmed intravenous fluid (37–40° C) may also be used for resuscitation. If the burn has already been cooled, remove all wet dressings and replace with a clean, dry covering. Apply blankets to re-warm the patient.

Tar and asphalt burns are an exception to brief cooling. These products must be thoroughly cooled with copious amounts of cool water (see Chapter 5, *Burn Wound Management*). For chemical burns, brush dry chemicals off the patient and then irrigate with copious running water. Immediate irrigation is essential in chemical injuries (see Chapter 7, *Chemical Burns*).

IV. SECONDARY SURVEY

The secondary survey does not begin until the primary survey is completed and after initial fluids are started. A secondary survey includes the following elements:

- History (injury circumstances and medical history)
- Accurate pre-injury patient weight
- Complete head-to-toe evaluation of the patient
- Determination of percent Total Body Surface Area burned
- Apply adjusted fluid rates after TBSA determination
- Obtain indicated labs and X-rays
- Monitor fluid resuscitation
- Pain and anxiety management
- Psychosocial support
- Wound care

The burn is often the most obvious injury, but other serious and even life-threatening injuries may be present. Thorough history and physical examination are necessary to ensure that all injuries and preexisting diseases are identified.

A. History

The circumstances surrounding the injury can be very important to the initial and ongoing care of the patient. Family members, co-workers and Emergency Medical Services personnel can all provide information regarding the scene of the incident and the circumstances surrounding the injury. Document as much detail as possible.

Every attempt should be made to obtain as much information from the patient as possible prior to endotracheal intubation. The following list includes important details to consider:

1. Circumstances: Flame injuries
 - How did the burn occur?
 - Did the fire occur inside or outside?
 - Was the patient found inside a smoke-filled room?
 - How did the patient escape?
 - If the patient jumped out of a window, from what floor did he/she jump?
 - Were others killed at the scene?
 - Did the clothes catch on fire?
 - How long did it take to extinguish the flames?
 - How were the flames extinguished?
 - Was gasoline or another fuel involved?
 - Was there an explosion?
 - Was there a blast injury?
 - Was the patient unconscious at the scene?
 - Was there a motor vehicle crash?
 - What was the mechanism of injury (T-bone, head-on, roll-over, other)

- How badly was the car damaged?
- Was there a car fire?
- Are there other injuries?
- Was the patient trapped in the burning vehicle?
- How long was he/she trapped?
- Is there any evidence of a fuel or chemical spill that could result in a chemical burn as well as thermal injury?
- Are the purported circumstances of the injury consistent with the burn characteristics (i.e., is abuse a possibility)?

2. Circumstances: Scalds

- How did the burn occur?
- What was the temperature of the liquid?
- What was the liquid?
- How much liquid was involved?
- What was the thermostat setting of the water heater?
- Was the patient wearing clothes?
- How quickly were the patient's clothes removed?
- Was the burned area cooled? With what? How long?
- Who was with the patient when the burn took place?
- How quickly was care sought?
- Where did the burn occur (e.g., bathtub, sink)?
- Are the purported circumstances of the injury consistent with the burn characteristics (i.e., is abuse a possibility)?

Pediatric scalds are sometimes due to child abuse. In addition to obtaining the patient history, it is helpful to ask EMS or other pre-hospital providers what they observed at the scene.

3. Circumstances: Chemical injuries

- What was the agent(s)?
- How did the exposure occur?
- What was the duration of contact?
- What decontamination occurred?
- Is there a Material Safety Data Sheet (MSDS) available?
- Is there any evidence of ocular involvement?
- Is there any evidence of illegal activity?

4. Circumstances: Electrical Injuries

- What kind of electricity was involved – high voltage/low voltage, AC/DC?
- What was the duration of contact?
- Was the patient thrown or did he or she fall?
- Was there loss of consciousness?
- Was CPR administered at the scene?

B. Medical History

The “AMPLET” mnemonic is useful for key history elements:

A – Allergies. Drug and/or environmental

M – Medications. Prescription, over-the-counter, herbal, illicit, alcohol.

P – Previous illness (diabetes, hypertension, cardiac or renal disease, seizure disorder, mental illness) or injury, past medical history, pregnancy

L – Last meal or drink

E – Events/environment related to the injury

T – Tetanus and childhood immunizations

Tetanus is current if given within five years for patients with burns. More information on recommendations for administration of tetanus is provided in Appendix II Tetanus Prophylaxis.

C. Pre-burn Weight

Adjusted fluid rates are based on the patient’s pre-burn weight. If the patient has received a large volume of fluid prior to calculating the hourly fluids, obtain an estimated of the patient’s pre-injury weight from the patient or family member if possible.

D. “Head to Toe” Examination

- Head/maxillo-facial
- Cervical spine and neck
- Chest
- Abdomen
- Perineum, genitalia
- Back and buttocks
- Musculoskeletal
- Vascular
- Neurological

E. Determining the Severity of a Burn

Burn severity depends primarily on the depth of injury and body surface area involved. However, other factors such as age, the presence of concurrent medical or surgical problems, and complications that accompany burns of functional and cosmetic areas such as the face, hands, feet, major joints, and genitalia must be considered. Pre-existing health and/or associated injuries also impact morbidity and mortality.

Even a small burn can have a major impact on the quality of life of a burn survivor. For example, a 1% TBSA hand burn can have a devastating effect on future hand function. Individual emotional and physiological responses to a burn vary and should be taken into consideration when determining the severity of injury in relation to the survivor’s perception of their own quality of life post-burn.

F. Depth of Burn

Burns are classified by degrees, or as partial vs. full-thickness injuries. The depth of tissue damage due to a burn is largely dependent on four factors:

- Temperature of the offending agent
- Duration of contact with the burning substance
- Thickness of the epidermis and dermis
- Blood supply to the area

Burn depth is classified into partial (some, but not all layers of the skin are injured) vs. full thickness (all layers of the skin are injured). Another complementary classification is by first-, second- and third-degree, as described below. Remember that it is sometimes difficult to determine the depth of injury during the first several days as the wound evolves. Certain areas of the body such as the palm of the hands, soles of feet, and back can tolerate a higher temperature for a longer period of time without sustaining a full thickness injury. Other areas such as the eyelids have very thin skin and burn deeply very quickly. People with circulatory problems may sustain deeper burns more easily.

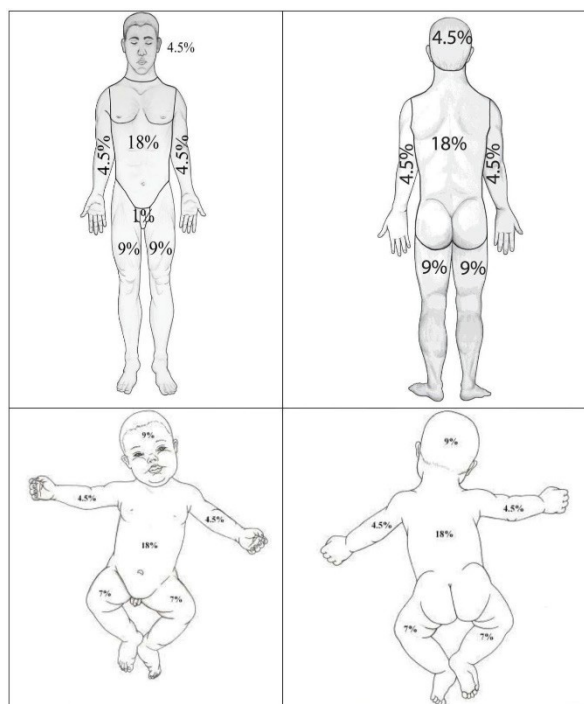
Young children and elderly patients have thinner skin. Their burns may be deeper and more severe than they initially appear. It is sometimes difficult to determine the depth of injury for 48 to 72 hours.

G. Extent of Burn

The most commonly used guide to estimate second and deeper degrees of burn is the “Rule of Nines.” In adults, distinct anatomic regions represent approximately 9% - or a multiple thereof – of the Total Body Surface Area (TBSA). In the infant or child, the “Rule” deviates because of the large surface area of the child’s head and the smaller surface area of the lower extremities. (Burn diagrams take these factors into account.) Note that first degree (superficial burn without blister formation) areas are not included in the TBSA burn calculation.

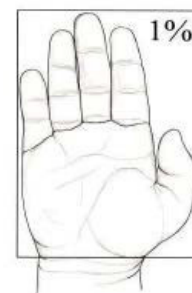
If only part of the anatomical area is burned, calculate the percent TBSA burned based on the percentage of that site injured and not the value of the whole (i.e., if the arm is circumferentially burned from the hand to the elbow, only half the arm is burned for a total of approximately 4.5%).

Burn centers typically use the Lund-Browder Chart for a more accurate determination of percent TBSA burn. A copy of this chart is included at the end of this chapter for your reference.



H. Estimating Size for Scattered Burns

The size of the patient’s hand—including the fingers—represents approximately one percent of his/her total body surface area. Therefore, using the patient’s hand-size as a guideline, the extent of irregularly scattered burns can be estimated.



I. Management Principles and Adjuncts

1. Fluid Resuscitation

The adjusted fluid rates are calculated according to the table below:

Category	Age and weight	Adjusted fluid rate
Flame or scald	Adults and older children (≥ 14 years old)	2 ml LR x kg x % TBSA
	Children (<14 years old)	3 ml LR x kg x % TBSA
	Infants and young children (≤ 30 kg)	3 ml LR x kg x % TBSA Plus D ₅ LR at maintenance rate
Electrical Injury	All ages	4 ml LR x kg x % TBSA Plus D ₅ LR at maintenance rate for infants and young children

Check the patient's urinary output and physiological response to decide further fluid titration. It is better to increase fluids based on response than to attempt to remove excess fluids once given.

Some patients, including those with a delayed start of fluid resuscitation, prior dehydration, chronic or acute alcohol use or abuse, methamphetamine lab injuries, high voltage electrical injuries, or inhalation injuries may require more than the estimated fluids. Again, the adjustments to fluid rates are based on patient response.

2. Vital Signs

Monitor vital signs at least hourly in burns $\geq 20\%$ TBSA.

3. Nasogastric Tube

Insert a nasogastric tube for intubated patients and monitor all other patients for signs of nausea and vomiting.

4. Urinary Catheter

A urinary catheter is important because urine output is the best monitor of adequate fluid resuscitation. In general, all patients with burns $\geq 20\%$ TBSA should have a urinary catheter.

5. Monitoring Extremity Perfusion

In constricting, circumferential extremity burns, edema developing in the tissue under the burn eschar may gradually impair venous return. If this progresses to the point where capillary and arterial flows are markedly reduced, ischemia and necrosis may result. Elevate the affected extremity to minimize swelling. An escharotomy is sometimes indicated to restore adequate circulation. An escharotomy is a releasing incision made in a longitudinal fashion through the burned skin (eschar) to allow the subcutaneous tissue expand (see Chapter 5, *Burn Wound Management*).

6. Monitoring Ventilation

Circumferential chest and/or abdominal burns may restrict ventilatory excursion and chest/abdominal escharotomy may be necessary in adults and children. A child has a more pliable rib cage (making it more difficult to work against constriction resulting from a circumferential chest burn) and may need an escharotomy earlier than an adult burn patient.

7. Pain and Anxiety Management

Burn pain may be severe. Assess whether pain is due to the burn injury or caused by associated trauma.

Morphine (or opioid equivalents) are indicated for control of pain associated with burns. Pain should be differentiated from anxiety. Benzodiazepines may also be indicated to relieve the anxiety associated with the burn injury. Titrate for effect by administering small frequent doses IV (never IM). It is not unusual for the opioid dose to exceed the standard weight based recommendations. Respiratory status should be constantly evaluated as large dosages may be required to alleviate pain and anxiety.

Changes in fluid volume and tissue blood flow make absorption of any drug given intramuscularly or subcutaneously unpredictable. The intra-muscular or subcutaneous routes should not be used, and opioids should only be given intravenously and in doses no larger than those needed to control pain. Tetanus immunization is the only medication given IM to a patient with burns.

8. Elevate the patient's head and affected extremities
Unless contraindicated by spine immobilization, elevate the patient's head to 45 degrees. This will help minimize facial and airway edema and prevent aspiration. Similarly, elevating the affected extremities reduces edema.
9. Psychosocial Assessment and Support
Patients with burns should initially be alert and oriented. As such, even patients with major burns can remember the first several hours post injury. Health care providers must be sensitive to the variable emotions experienced by burn patients and their families. Feelings of guilt, fear, anger, and depression must be recognized and addressed. In cases where intentional burning is suspected, either from self-immolation or abuse, efforts should be instituted to protect the patient from further harm.

In order for a burn survivor to reach optimal recovery and reintegration into family life, school, work, social and recreational activities, the psychosocial needs of the survivor and family must be met during and following hospitalization and rehabilitation.

V. INITIAL STUDIES

Skin burns can cause dysfunction of other organ systems. Thus, baseline screening tests are often performed and can be helpful in evaluating the patient's subsequent course:

- Complete Blood Count (CBC)
- Serum chemistries/electrolytes (e.g., Na⁺, K⁺, Cl⁻)
- Blood urea nitrogen
- Glucose levels, especially in children and diabetics
- Urinalysis for pregnancy, toxicology, and in diabetics
- Chest roentgenogram (X-Rays) in intubated patients

Under specific circumstances, additional specialized tests are appropriate:

- Arterial blood gases with Carboxyhemoglobin level (Carbon Monoxide) if inhalation injury is suspected
- ECG – With all electrical burns or pre-existing cardiac problems
- Type and screen (or cross) for associated trauma

VI. SPECIAL CONSIDERATIONS

A. Associated Trauma

Associated minor to life-threatening injuries may occur, depending on the mechanism of injury (i.e., motor vehicle crash, explosions, crush injuries due to building collapse, falls or assaults). Associated trauma may

delay or prevent escape from a fire situation resulting in larger TBSA burns or more severe inhalation injury.

Delay in diagnosing associated injuries leads to an increase in morbidity and mortality, increasing the length of stay and cost of care. Do not let the appearance of the burn delay complete trauma assessment and management of associated trauma.

B. The Pregnant Patient with Burns

Burn injuries during pregnancy are rare but can be problematic in this high-risk group of patients. Assess and treat the mother as the primary patient, with primary and survey. Good maternal and fetal survival outcomes are possible in specialized centers, in consultation with obstetrics service.

C. Blast Injuries and Burns

Blast injuries include the entire spectrum of injuries that can result from an explosion. Blast injuries are becoming a common mechanism of trauma in many parts of the world and high explosive events have the potential to produce mass casualties with multi-system injuries, including burns. The severity of the injuries depends upon the amount and composition of the explosive material, the environment in which the blast occurs, the distance between the explosion and the injured, and the delivery mechanisms. The use of radioactive materials and chemicals must also be considered in unintentional injuries as well as in acts of terrorism and war. Blast injuries are considered to be 1 of 4 types, or in combination:

1. Primary: due to the direct wave impacting the body surface. Injuries include tympanic membrane rupture, pulmonary damage, and hollow viscous injury.
2. Secondary: result when projectiles from the explosion such as flying debris hit the body, causing penetrating and blunt trauma.
3. Tertiary: result when the victim is thrown from the blast wind. Blunt and penetrating trauma, fractures and traumatic amputations.
4. Quaternary: include all other injury types (heat, light, and/or toxic gases). The fireball may cause flash burns to exposed body parts (hands, neck, head) or may ignite clothing. Other injuries include crush injuries, inhalation injury, asphyxiation and toxic exposures.

Blast injuries are due to over-pressurization and are common within the lungs, ears, abdomen and brain. The blast effect to the lungs is the most common fatal injury in those who survive the initial insult. These injuries are often associated with the triad of apnea, bradycardia, and hypotension, and suggested by dyspnea, cough, hemoptysis, and chest pain. The chest X-ray may have a butterfly pattern, an important indicators of blast lung. Prophylactic chest tubes prior to transport are highly recommended. Provide supportive ventilation until the lungs heal. Inhalation injury can result from the explosion's creation of particulate matter, smoke and superheated gases and toxic by-products. The patient may have clinical symptoms of blast lung injury immediately or clinical problems may not present for 24-48 hours post explosion.

Tympanic membranes may rupture from overpressure; treatment here is also supportive. Intra-abdominal organs can receive injury from the pressure wave, and should be treated as any blunt abdominal injury. Bowel ischemia and/or rupture should be considered. Lastly, brain injury is thought to be common in blast over-pressure (shock wave). Those with suspected injury should undergo brain imaging.

Burns are a common manifestation of significant blast injuries; these injuries are associated with the ball of flame with a potential for clothing ignition to extend the injury.

D. Radiation Injury

Serious radiation injuries are a rare cause of serious burns. *Appendix 3, Radiation Injury*, provides basic information on radiation burns and their management.

E. Cold Injuries

Cold injuries are frequently referred to a Burn Center for definitive care. Additional information is provided in *Appendix 4, Cold Injuries*.

VII. INITIAL CARE OF THE BURN WOUND

After the burning process has stopped, cover the patient with a clean dry sheet. Again, the primary goal is to avoid hypothermia. Also, covering all burn wounds prevents air currents from causing pain in sensitive partial thickness burns.

The ensuing chapters in this manual will provide additional information on wound care and special issues in the management of electrical and chemical injuries.

VIII. BURN CENTER REFERRAL CRITERIA

A. Definition of a Burn Center

A burn center is a service capability based in a hospital that has made the institutional commitment to care for burn patients. The burn unit is a specified unit within the institution dedicated to that care. A multidisciplinary team of professionals staffs the burn center with specialized expertise, which includes both acute care and rehabilitation.

The burn team also provides burn educational programs to external health care providers and is involved in research related to burn injury.

B. Referral Criteria

The American Burn Association has identified the following injuries that should be referred to a specialized burn facility after initial assessment and stabilization at a referring facility.

Burn injuries that should be referred to a Burn Center include the following:

1. Partial thickness burns greater than 10% total body surface area (TBSA.)
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints.
3. Third-degree (full-thickness) burns in any age group.
4. Electrical burns, including lightning injury.
5. Chemical burns.
6. Inhalation injury.
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.
8. Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the

greatest risk of morbidity or mortality. In such cases, if the trauma pose the greater immediate risk, the patient may be stabilized initially in a trauma center before being transferred to a Burn Center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.

9. Burned children in hospitals without qualified personnel or equipment for the care of children.
10. Burn injury in patients who will require special social, emotional or rehabilitative intervention.

For specific patient questions, consult with your local/regional burn center.

IX. SUMMARY

A burn of any magnitude can be a serious injury. Health care providers must be able to assess the injuries rapidly and develop a priority-based plan of care based on primary and secondary survey elements. The plan of care is determined by the type, extent, and depth of burn, as well as by available resources. Every health care provider must know how and when to contact the closest specialized burn care facility/Burn Center. For injury that meet ABA criteria for referral, the best treatment strategy can be coordinated in conjunction with your local burn center.

X. ADDITIONAL INFORMATION

The following three documents at the end of this chapter will assist ABLS participants after the course is complete. These pages may be useful in your workplace as quick references.

- ABLS Initial Assessment and Management Checklist
- Lund and Browder Chart
- ABA Burn Center Referral Criteria

XI. SELECTED REFERENCES

Cancio LC. Initial assessment and fluid resuscitation of burn patients. *SurgClinNorthAm*. 2014 94(4) 741-54

Faucher L, Furukawa K. Practice guidelines for the management of burn pain. *J Burn Care Res* 2006; 27 (5):657-668.

Blast Injuries. Atlanta, GA: Department of Defense and American College of Emergency Physicians. Centers for Disease Control and Prevention (CDC) 2009 www.emergency.cdc.gov/BlastInjuries. Accessed November 2011.

Orgill DP, Piccolo N. Escharotomy and decompressive therapies in burns. *J Burn Care Res* 2009; 30 (5): 759-768.

Guo SS, Greenspoon JS, Kahn A M. Management of burns in pregnancy. *Burns*. 2001;27, (4): 394-397.

Mann EA, Baun MM, Meininger JC, Wade CE. Comparison of mortality associated with sepsis in the burn, trauma and general intensive care unit patient: a systematic review of the literature. *Shock* 2012 (1):4-16.

Palmieri TL, Taylor S, Lawless M, et al. Burn center volume makes a difference for burned children. *Pediatr Crit Care Med* 2015 16(4): 319-24.

Al-Mousawi AM, Mecott-Rivera GA, Jeschke MG, Herndon DN. Burn teams and burn centers: the importance of a comprehensive team approach to burn care. *ClinPlastSurg* 2009 36(4):547-54.

ABLS INITIAL ASSESSMENT AND MANAGEMENT CHECKLIST

Body Substance Isolation

Primary Survey: A through E

Assess and manage life-and-limb threatening conditions

- Airway maintenance with cervical spine protection
 - In-line cervical immobilization
- Breathing and ventilation
 - Assess rate, depth and quality
 - 100% Oxygen per non-rebreather mask while waiting for intubation (if indicated)
 - » Assist with bag-valve-mask (if indicated)
 - If you are going to intubate-get history here
 - Intubate (if indicated)
 - If there are difficulties with ventilation, check for:
 - » Circumferential torso burns
 - » Correct endotracheal tube placement
 - » Need for suction
 - » Associated injury
- Circulation with hemorrhage control, Cardiac Status, Cardiac Monitor, C-spine if you didn't do it before
 - Burns do not bleed! If there is bleeding, identify and treat the cause
 - Assess peripheral perfusion
 - Identify circumferential burns (use Doppler if necessary)
 - Initiate monitoring of vital signs
 - » Common adult HR 110 – 120 BPM
 - » BP should be initially normal
 - » If abnormal HR or BP – find out why!
 - IV – insert large bore IV and initiate fluid resuscitation using Lactated Ringer's Solution (LR) – for burns > 20% TBSA, insert 2 large bore IVs
 - » Intravenous fluid rates during pre-hospital management and primary survey in the hospital
 - 5 years old and younger: 125 ml LR per hour
 - 6-13 years old: 250 ml LR per hour
 - 14 years and older: 500 ml LR per hour
 - Resuscitation rates will be fine-tuned during the secondary survey when the weight has been obtained and % TBSA burn has been determined
- Disability, Neurological Deficit, Gross Deformity
 - Assess level of consciousness using AVPU
 - Identify any gross deformity/serious associated injuries

- Exposure/Examine/Environment Control
 - Stop the burning process
 - Remove all clothing, jewelry, metal, contact lenses, diapers, shoes
 - Log roll patient to remove clothing from back, check for burns and associated injuries
 - Keep warm-apply clean dry sheet and blankets, maintain warm environment

LUND AND BROWDER CHART

Commonly used in burn centers

Estimate of % Total Body Surface Area (TBSA) Burn by sum of individual areas

Area	Birth-1	1-4 Years	5-9 Years	10-14 Years	15 Years	Adult	Total
Head	19	17	13	11	9	7	
Neck	2	2	2	2	2	2	
Anterior trunk	13	13	13	13	13	13	
Posterior trunk	13	13	13	13	13	13	
Right buttock	2.5	2.5	2.5	2.5	2.5	2.5	
Left buttock	2.5	2.5	2.5	2.5	2.5	2.5	
Genitalia	1	1	1	1	1	1	
Right upper arm	4	4	4	4	4	4	
Left upper arm	4	4	4	4	4	4	
Right lower arm	3	3	3	3	3	3	
Left lower arm	3	3	3	3	3	3	
Right hand	2.5	2.5	2.5	2.5	2.5	2.5	
Left hand	2.5	2.5	2.5	2.5	2.5	2.5	
Right thigh	5.5	6.5	8	8.5	9	9.5	
Left thigh	5.5	6.5	8	8.5	9	9.5	
Right lower leg	5	5	5.5	6	6.5	7	
Left lower leg	5	5	5.5	6	6.5	7	
Right foot	3.5	3.5	3.5	3.5	3.5	3.5	
Left foot	3.5	3.5	3.5	3.5	3.5	3.5	
Total							

Rows in **bold italics** indicate areas of difference between adult and pediatric patients. All other areas are the same for adults and children.

ABA BURN CENTER REFERRAL CRITERIA

(Also available at www.ameriburn.org)

Burn injuries that should be referred to a Burn Center are:

1. Partial thickness burns greater than 10% total body surface area (TBSA.)
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints.
3. Third-degree (full-thickness) burns in any age group.
4. Electrical burns, including lightening injury.
5. Chemical burns.
6. Inhalation injury.
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.
8. Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient may be stabilized initially in a trauma center before being transferred to a Burn Center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
9. Burned children in hospitals without qualified personnel or equipment for the care of children.
10. Burn injury in patients who will require special social, emotional or rehabilitative intervention.

CHAPTER 3

Airway Management and Smoke Inhalation Injury



Objectives

Upon completion of this lecture, the participant will be able to:

- Discuss the pathophysiology of inhalation injury.
- List the types of inhalation injury.
- Describe indications for early airway intervention.
- Discuss principles of airway management.
- List special considerations for children with inhalation injury.

I. INTRODUCTION

Inhalation injury is defined as the aspiration and/or inhalation of superheated gasses, steam, hot liquids or noxious products of incomplete combustion (found in smoke). The severity of the injury is related to the temperature, composition, and length of exposure to the inhaled agent(s). Inhalation injury is present in 2-14% of patients admitted to burn centers. Inhalation injury can occur with or without a skin burn. A significant number of fire-related deaths are not due to the skin burn, but to the toxic effects of the by-products of combustion (airborne particles).

Carbon monoxide (CO) and/or hydrogen cyanide poisoning, hypoxia, and upper airway edema often complicate the early clinical course of a patient with inhalation injury. In those with both a skin burn and inhalation injury, fluid resuscitation may increase upper airway edema and cause early respiratory distress and asphyxiation. Early intubation to maintain a patent airway in these individuals may be necessary.

The combination of a significant skin burn and inhalation injury places individuals of all ages (pediatric, adult, and seniors) at greater risk for death. When present, inhalation injury increases mortality above that predicted on the basis of age and burn size.

There are distinct types of inhalation injury:

- Injury caused by exposure to toxic gases including carbon monoxide and/or cyanide
- Supraglottic (above the vocal cords) injury, due to direct heat or chemicals, causing severe mucosal edema.
- Subglottic or tracheobronchial (below the vocal cords) airway inflammation and edema, which may cause atelectasis and pneumonia as late effects.

Note that patients may suffer from more than one type of inhalation injury. For instance, victims of house fires may exhibit symptoms of carbon monoxide poisoning, upper airway and lower airway injuries at the same time. It is also important to note that early respiratory distress in a patient with a skin burn may be due to a problem other than inhalation injury. Always consider the mechanism of injury and assess for the possibility of other traumatic or medical causes.

II. PATHOPHYSIOLOGY

A. Poisonous Gases

1. Carbon Monoxide

Most fatalities occurring at a fire scene are due to asphyxiation and/or carbon monoxide poisoning. Carbon monoxide is an odorless, tasteless, nonirritating gas that is produced by incomplete combustion.

Carboxyhemoglobin (COHb) is the term used to describe hemoglobin (the protein in red blood cells that normally carries oxygen from the lungs to the rest of the body) that has bonded with carbon monoxide instead of oxygen. Among survivors with severe inhalation injury, carbon monoxide poisoning can be the most immediate threat to life. Carbon monoxide binds to hemoglobin with an affinity 200 times greater than oxygen. If sufficient carbon monoxide is bound to hemoglobin, tissue hypoxia will occur. Oxygen delivery to the tissues is compromised because of the reduced oxygen carrying capacity of the hemoglobin in the blood.

The most immediate threat is to hypoxia-sensitive organs such as the brain. Carboxyhemoglobin levels of 5-10% are often found in smokers and in people exposed to heavy traffic. In this situation, carboxyhemoglobin levels are rarely symptomatic. At levels of 15-40%, the patient may present with various changes in central nervous system function or complaints of headache, flu-like symptoms, nausea and vomiting. At levels > 40%, the patient may have loss of consciousness, seizures, Cheyne-Stokes respirations and death. A more concise breakdown of symptoms can be found on the following table.

Effects of Elevated Carboxyhemoglobin (COHb) Saturation

Carboxyhemoglobin Saturation (%)	Symptoms
0 – 10	None
10 – 20	Tension in forehead and dilation of skin vessels
20 – 30	Headaches and pulsating temples
30 – 40	Severe headache, blurred vision, nausea, vomiting and collapse
40 – 50	As above; plus syncope, increased respiratory and heart rates
50 – 60	As above; plus coma, seizures and Cheyne-Stokes respirations
>60	Coma, seizures, weak respirations and pulse, possible death

A cherry red coloration of the skin is said to be associated with high carboxyhemoglobin levels but is rarely seen in patients with skin burns or inhalation injury associated with fire. In fact, patients with severe carbon monoxide poisoning may have no other significant findings on initial physical and laboratory exam. Cyanosis and tachypnea are not likely to be present because CO₂ removal and oxygenation are not affected. Although the O₂ content of blood is reduced, the amount of oxygen dissolved in the plasma (PaO₂) is unaffected by carbon monoxide poisoning. Blood gas analysis is normal except for an elevated COHb level. Oxygen

saturation (reflected by pulse oximetry measurement) is also usually normal. Pulse oximeter readings are normal because an oximeter *does not directly measure* carbon monoxide. Carbon monoxide turns hemoglobin bright red. Due to the variability of symptoms, it is essential to determine the COHb level in patients exposed to carbon monoxide.

Late effects of carbon monoxide poisoning include increased cerebral edema that may result in cerebral herniation and death.

2. Hydrogen Cyanide

Hydrogen cyanide is another product of incomplete combustion that may be inhaled in enclosed space fires. It occurs primarily from the combustion of synthetic products such as carpeting, plastics, upholstered furniture, vinyl and draperies. Hydrogen cyanide is a potent and rapid cellular poison. Cyanide ions enter cells and primarily inhibit mitochondrial cytochrome oxidase (oxidative phosphorylation). Cells are thus unable to produce ATP via the Krebs cycle and shift toward anaerobic metabolism. The incidence of cyanide toxicity in enclosed space fires is not well documented. Blood cyanide levels are difficult to obtain rapidly through routine laboratories. Treatment is therefore often initiated empirically without laboratory confirmation (See section IV B.2).

Cyanide toxicity symptoms can be vague and difficult to distinguish from other life-threatening issues. They include changes in respiratory rate, shortness of breath, headache, CNS excitement (giddiness, vertigo), confusion, irritation of the eyes and mucous membranes. Cardiovascular symptoms feature a hyperdynamic phase followed by cardiac failure (hypotension, bradycardia). In a patient with smoke inhalation, lactic acidosis that remains unexplained despite resuscitation suggests cyanide toxicity.

B. Inhalation Injury Above the Glottis

True thermal burns to the respiratory tract are limited to the airway above the glottis (supraglottic region) including the nasopharynx, oropharynx, and larynx. The rare exceptions include pressurized steam inhalation, or explosions with high concentrations of oxygen/flammable gases under pressure.

The respiratory tract's heat exchange capability is so efficient that most absorption and damage occurs above the true vocal cords (above the glottis). Heat damage of the pharynx is often severe enough to produce upper airway obstruction, and may cause obstruction at any time during the resuscitation period. In unresuscitated patients, supraglottic edema may be delayed at onset until fluid resuscitation is well underway. Early intubation is preferred because the ensuing edema may obliterate the landmarks needed for successful intubation. Supraglottic edema may occur without direct thermal injury to the airway but secondary to the fluid shifts associated with the burn injury and resuscitation.

C. Inhalation Injury Below the Glottis

In contrast to injuries above the glottis, subglottic injury is almost always chemical. Noxious chemicals (aldehydes, sulfur oxides, phosgenes) are present in smoke particles and cause a chemical injury, damaging the epithelium of the airways. Smaller airways and terminal bronchi are usually affected by prolonged exposure to smoke with smaller particles.

Pathophysiologic changes associated with injury below the glottis include:

- Sloughing of the epithelial lining of the airway (may obstruct airways)
- Mucus hypersecretion (may obstruct airways)
- Impaired ciliary activity (cilia are the fine, hair-like projections from cells in the respiratory tract that move in unison and help to sweep away fluids and particles)
- Inflammation

- Pulmonary surfactant inactivation (surfactant is produced by alveolar cells in the lungs; its function is to increase pulmonary compliance, prevent atelectasis, and facilitate recruitment of collapsed airways)
- Pulmonary edema
- Ventilation/perfusion mismatch (some areas of the lungs are not well aerated will still receive blood flow; less oxygen is exchanged leading to a lower oxygenation in the blood returning from the lung)
- Increased blood flow
- Spasm of bronchi and bronchioles
- Impaired immune defenses

Tracheobronchitis with severe spasm and wheezing may occur in the first minutes to hours post injury. Although there are exceptions, the higher the dose of smoke inhaled the more likely it is that the patient will have an elevated COHb level and respiratory distress in the early post-burn hours.

However, it must be noted that the severity of inhalation injury and the extent of damage are clinically unpredictable based on the history and initial examination. Also, chest x-rays are often normal on admission.

While inhalation injury below the glottis without significant associated skin burns has a relatively good prognosis, the presence of inhalation injury markedly worsens prognosis of skin burns, especially if the burn is large and the onset of respiratory distress occurs in the first few hours post injury. An asymptomatic patient with suspected lower airway inhalation injury should be observed given the variable onset of respiratory symptoms.

Mucosal epithelial sloughing may occur as late as 4-5 days following an inhalation injury.

Careful patient monitoring during resuscitation is necessary with inhalation injury. Excessive or insufficient resuscitation may lead to pulmonary and other complications. In patients with combined inhalation and skin burns, total fluids administered may exceed predicted resuscitation volumes based on the extent of the skin burns.

III. INITIAL ASSESSMENT

A. Oxygen Therapy and Initial Airway Management

The goals of airway management during the first 24 hours are to maintain airway patency and adequate oxygenation and ventilation while avoiding the use of agents that may complicate subsequent care (steroids) and development of ventilator-induced lung injury (high tidal volumes).

Any patient with suspected carbon monoxide or cyanide poisoning and/or inhalation injury should immediately receive humidified 100% oxygen through a non-rebreather mask until COHb approaches normal levels.

Inhalation injury frequently increases respiratory secretions and may generate a large amount of carbonaceous debris in the patient's respiratory tract.

Frequent and adequate suctioning is necessary to prevent occlusion of the airway and endotracheal tube.

B. Factors to Consider When Deciding Whether or Not to Intubate a Patient with Burns

The decision to intubate a burn patient is critical. Intubation is indicated if upper airway patency is threatened, gas exchange or lung mechanics inadequate, or airway protection compromised by mental status. Also, if there is concern for progressive edema during transport to a burn center, intubation prior to transport should be strongly considered. Stridor or raspy breath sounds may indicate impending upper airway obstruction and mandate emergency endotracheal intubation.

In contrast, overzealous intubation can lead to over-treatment, unnecessary transfers, ventilator-related complications, and death. For instance, many patients with superficial partial-thickness facial burns, singed facial and nasal hairs, and flash burns from home oxygen are frequently intubated when they can be simply observed.

Orotracheal intubation using a cuffed endotracheal tube is the preferred route of intubation. In adults, if possible, the endotracheal (ET) tube should be of sufficient size to permit adequate pulmonary toilet and a conduit for diagnostic and therapeutic bronchoscopy following transfer to the burn center. In children, cuffed endotracheal tubes are also preferred using an age-appropriate size.

In instances where non-burn trauma mandates cervical spine protection (falls, motor vehicle collisions), cervical spine stabilization is critical during intubation. In impending airway obstruction, X-ray clearance of the cervical spine should wait until after intubation.

Indications for early intubation:

- Signs of airway obstruction: hoarseness, stridor, accessory respiratory muscle use, sternal retraction
- Extent of the burn (TBSA burn > 40-50%)
- Extensive and deep facial burns
- Burns inside the mouth
- Significant edema or risk for edema
- Difficulty swallowing
- Signs of respiratory compromise: inability to clear secretions, respiratory fatigue, poor oxygenation or ventilation
- Decreased level of consciousness where airway protective reflexes are impaired
- Anticipated patient transfer of large burn with airway issue without qualified personnel to intubate en route

After ascertaining that the endotracheal tube is in the proper position by auscultation and X-Ray confirmation, the tube must be secured.

An endotracheal tube that becomes dislodged may be impossible to replace due to obstruction of the upper airway by edema. Adhesive tape adheres poorly to the burned face; therefore, secure the tube with ties passed around the head or use commercially available devices. Do not place ties across the ears in order to prevent additional tissue damage and potential loss of cartilage.

Because facial swelling and edema may distort the normal upper airway anatomy, intubation may be difficult and should be performed by the most experienced individual available. If time permits, a nasogastric tube should be inserted before intubation. Rarely is emergency cricothyroidotomy (incision made through the skin and cricothyroid membrane) required to establish a patent airway.

IV. MANAGEMENT

A. General Assessment Findings

The possible presence of inhalation injury is an important element in hospital transfer decisions. Normal oxygenation and a normal chest x-ray on admission to the hospital do not exclude the diagnosis of inhalation injury. The purpose of an initial chest x-ray is to verify that there are no other injuries such as a pneumothorax, and to verify the position of the endotracheal tube, if present. After adequate airway, ventilation, and oxygenation are assured, assessment may proceed with less urgency.

Mechanically ventilated patients can undergo diagnostic testing, such as bronchoscopy, after transfer to a

burn center to confirm the diagnosis of inhalation injury and stage its severity. Transfer to definitive care should not be delayed for purpose of diagnostic testing.

Historical facts most important in evaluation are:

- Did injury occur in an enclosed space?
- Is there a history of loss of consciousness?
- Were noxious (harmful, poisonous or very unpleasant) chemicals or gases involved?
- Is there a history of associated blunt or penetrating trauma such as an explosion, motor vehicle crash or fall?

Physical findings that suggest respiratory tract injury include the following:

- Soot in oropharynx
- Erythema or swelling of the oropharynx or nasopharynx
- Carbonaceous sputum (sputum containing gray or dark carbon particles)
- Hoarse voice, brassy cough, grunting, or guttural respiratory sounds
- Rales, brhronchi or distant breath sounds
- Inability to swallow
- Deep facial burns
- Agitation, anxiety, stupor, cyanosis, or other general signs of hypoxia; low Glasgow Coma Scale (GCS) score
- Rapid respiratory rate (consider age of the patient), flaring nostrils, use of accessory muscles for breathing, intercostal/sternal retractions

B. Treatment for Specific Types of Inhalation Injury

1. Carbon Monoxide Poisoning

The half-life of carbon monoxide in the blood is about 4 hours for patients breathing room air and is decreased to about 1 hour when breathing 100% oxygen. For this reason, patients with high or presumed high carboxyhemoglobin levels should receive 100% oxygen until COHb levels are normalized. This strategy often normalizes the COHb level for most patients upon admission to the burn center. Hyperbaric oxygen for carbon monoxide poisoning has not been shown to improve survival rates or to decrease late neurologic sequelae. Transfer to a burn center should not be delayed by efforts to institute hyperbaric oxygen therapy.

2. Hydrogen Cyanide Poisoning

Blood cyanide levels may be drawn but are usually sent out to regional labs, even in large centers, and not immediately available. Therefore, treatment must be initiated empirically in select patients. As long as it is not possible to determine blood cyanide levels immediately, in patients exposed to fire with smoke, a decreased GCS score, soot deposits (in the sputum), dyspnea and convulsions in the presence of persistent metabolic acidosis are to be regarded as risk markers for cyanide poisoning.

HCN toxicity should be suspected in patients that do not respond to 100% oxygen and resuscitative efforts. Therapy can therefore be provided presumptively using the hydroxycobalamin cyanide antidote kit. In the pre-hospital phase, it is often difficult to identify which patient might benefit from hydroxycobalamin administration. This treatment is also not without risk. Hydroxycobalamin causes the urine to turn dark red. If the patient also develops acute kidney injury during resuscitation, its detection may be delayed. Hydroxycobalamin is probably best reserved for unresponsive patients and those undergoing CPR. Consult the nearest burn center to develop specific pre-hospital and emergency department protocols on its use.

3. Inhalation Injury Above the Glottis

Upper airway obstruction can progress very rapidly when it occurs. Patients with pharyngeal edema or burns,

hoarseness, or stridor have a high likelihood of developing upper airway obstruction and should be intubated prior to transfer to the burn center. Neither arterial blood gas monitoring nor pulse oximetry is useful in determining when endotracheal intubation is required. The upper airway has a remarkable ability to swell and form secretions in response to injury. Placing an endotracheal tube provides a life-saving stent until the airway edema subsides. Swelling may take several days to improve depending on the extent of injury, the severity of concomitant skin burns, and the amount of fluid resuscitation received.

Elevating the head of the patient's bed will mitigate edema. Checking for the presence of a cuff leak will help providers determine the appropriate time to safely extubate the patient.

4. Inhalation Injury Below the Glottis

Patients with inhalation injury often develop thick tenacious bronchial secretions and wheezing. Prior to transfer, endotracheal intubation is indicated to clear secretions, relieve dyspnea, and/or ensure adequate oxygenation and ventilation.

Inhalation injury often impairs respiratory gas exchange. However, impairment is usually delayed in onset, with the earliest manifestation being impaired arterial oxygenation (decreased PaO₂) rather than an abnormal chest x-ray. Careful monitoring is essential to identify the need for mechanical ventilation if the patient's condition deteriorates. Steroids do not decrease the secretions and are not indicated.

5. Inhalation Injury in Pediatric Patients

Because children have relatively small airways, upper airway obstruction may occur more rapidly. If intubation is required, a cuffed endotracheal tube of proper size should be well secured in the appropriate position.

A young child's rib cage is not ossified and is more pliable than an adult's; therefore, retraction of the sternum with respiratory effort can be used as an indication for intubation. In addition, children become rapidly exhausted due to the decrease in compliance associated with constrictive circumferential chest/abdominal full-thickness burns. In that scenario, an escharotomy (surgical release of the skin eschar) should be performed by the most experienced provider available and can be lifesaving. Consultation with a burn center should be initiated prior to performance of an escharotomy in children.

6. Supportive care for inhalation injury

Once inhalation injury is diagnosed, treatment should start immediately as outlined above. Providers should avoid large tidal volumes and excessive plateau pressures as they may exacerbate lung injury. A humidified circuit will facilitate pulmonary toilet. Positive end expiratory pressure of 5-8 mm Hg can be used to prevent small airway collapse. Patients should not receive prophylactic antibiotics or corticosteroids. Standard care protocols typically include bronchodilators and pulmonary hygiene measures.

V. SUMMARY

There are distinct types of inhalation injury:

- Carbon monoxide and cyanide poisoning
- Thermal inhalation injury above the glottis
- Chemical inhalation injury below the glottis

Patients with possible inhalation injury must be observed closely for complications. Any patient with the possibility of inhalation injury should immediately receive 100% humidified oxygen by mask until fully evaluated.

Burn patients with inhalation injuries will require burn center admission. The burn center should be contacted early to assist in coordinating the care prior to transfer.

VI. SELECT REFERENCES AND SUGGESTED READING

- Traber DL, Herndon DN, et al. The pathophysiology of inhalation injury. In: Herndon DN, ed. *Total Burn Care*. (Fourth Ed.) London: WB Saunders; 2012 pp. 219-228.
- Endorf FW, Gamelli RL. Inhalation injury, perturbations, and fluid resuscitation. *J. Burn Care Res* 2007; 28: 80-83.
- The Evidence Based Guidelines Group. Practice guidelines for burncare, Introduction. *J Burn Care Rehabil* 2001; 22(supp):v-xii.
- Micak RP, Suman OE, Herndon DN. Respiratory management of inhalation injury. *Burns* 2007; 33: 2-13.
- Wolf SE, Pruitt BA Jr. Burn Management. In Irwin RD, Rippe JM, eds. *Irwin and Rippe's Intensive Care Medicine* (6th Ed.) Philadelphia, PA: Lippincott Williams & Wilkins; 2008, pp. 1933-1934.
- Kawecki M, Wrobiewski P, Sakiel S, et al. Fiberoptic bronchoscopy in routine clinical practice in confirming the diagnosis and treatment of inhalation burns. *Burns* 2007; 33: 554-560.
- The Evidence Based Guidelines Group. Chapter 5, Inhalation Injury: Diagnosis. *J Burn Care Rehabil* 2001; 22 (supp): 19s-22s.
- Mosier MJ, Pham TN. American Burn Association Practice Guidelines. Prevention, diagnosis and treatment of ventilator-associated pneumonia in burn patients. *J Burn Care Res*. 2009; 30(6): 910-28.
- Hartzell GE, ed. *Advances in Combustion Toxicology*, Vol. 1, New York: Technomic Publishing, Inc, 1989, p. 23.
- Buckley NA, Jurrlink DN, et al. Hyperbaric oxygen for carbon monoxide poisoning (Review). *Cochran Database Syst Rev* 2011, 1-40.
- Hall AH, Rumack BH. Clinical toxicology of cyanide: *Ann Emerg Med* 1986; 15: 1067-1074.
- Navar PD, Saffle JR, Warden GD. Effect of inhalation injury on fluid resuscitation requirements after thermal injury. *AmJSurg* 1985, 150: 716-720.
- Lalonde C, Picard L, Youn YK, et al. Increased early post-burn requirements and oxygen demands are predictive of the degree of airway injury by smoke inhalation. *J Trauma* 1995; 38(2): 175-184.
- Kealy GP. Carbon monoxide toxicity. *J Burn Care Res* 2009; 30 (1): 146-147.
- Geldner G, Koch EM, Gottwald-Hostalek U et al. Report on a study of fires with smoke gas development: determination of blood cyanide levels, clinical signs and laboratory values in victims. *Anaesthesist* 2013; 62(80): 609-16.
- Jeschke MG, Herndon DN. Burns in children: standard and new treatments. *Lancet* 2014: 383; 1168-78.
- Dries DJ, Endorf FW. Inhalation injury: epidemiology, pathology, treatment strategies. *Scand J Trauma Resusc Emerg Med* 2013; 21: 31.
- Sheridan RL. Uncuffed endotracheal tubes should not be used in seriously burned children. *Pediatr Crit Care Med* 2006; 7: 258-259.
- Dorsey DP, Bowman SM, Klein MB et al. Perioperative use of cuffed endotracheal tubes is advantageous in young pediatric burn patients. *Burns* 2010; 36 (6): 856-60.

CHAPTER 4

Shock and Fluid Resuscitation



Objectives

Upon completion of this lecture, the participant will be able to:

- Discuss the host response to burn injury
- Identify the goals of burn resuscitation
- Calculate an adequate initial rate as a starting point
- Understand the importance of physiologic response- based resuscitation
- List common complications of burn resuscitation therapy
- Identify patients who require special fluid management

I. INTRODUCTION

Burns greater than 20% TBSA are associated with increased capillary permeability and intravascular volume deficits that are most severe in the first 24-hours post injury. Optimal fluid resuscitation aims to support organ perfusion with the least amount of fluid.

Proper fluid management is critical to the survival of patients with extensive burns. Fluid resuscitation for any burn patient must be aimed at maintaining tissue perfusion and organ function while avoiding the complications of inadequate or excessive fluid therapy. An understanding of the local and systemic effects of burn injury facilitates patient management in the early post-burn period. The damaging effects of burn shock may be mitigated or prevented by physiologically based early management of patients with major burn injury.

II. HOST RESPONSE TO BURN INJURY

Massive tissue injury from severe burns often elicits a profound host response, resulting in a number of cellular and physiologic changes. While this response is similar to that observed in trauma patients, it is clear that response to burn injury can be more dramatic. A marked decrease in cardiac output, accompanied by an increase in peripheral vascular resistance, is one of the earliest manifestations of the systemic effects of thermal injury. Soon thereafter, an intravascular hypovolemia ensues which is slow and progressive. It is characterized by massive fluid shifts from capillary leak and resultant tissue edema formation. The magnitude and duration of any systemic response are proportional to the extent of body surface injured.

The combined hypovolemic and distributive burn shock requires sustained replacement to avoid organ hypoperfusion and cell death. Replacement of intravascular volume in the form of fluid resuscitation must

continue until organ and tissue perfusion has been adequately restored. Infusion of adequate amounts of resuscitation fluid restores cardiac output and tissue blood flow thereby helping prevent organ failure.

III. RESUSCITATION

A. Vascular Access and Choice of Fluid

Reliable peripheral veins should be used to establish intravenous access. Use vessels underlying burned skin if necessary. If it is not possible to establish peripheral intravenous access, a central line will be necessary. The intraosseous route may be considered if intravenous access is not immediately available and cannot be established.

In the presence of increased capillary permeability, colloid content of the resuscitation fluid exerts little influence on intravascular retention during the initial hours post-burn. Consequently, crystalloid fluid is the cornerstone of resuscitation for burn patients. Lactated Ringer's (LR) is the fluid of choice for burn resuscitation because it is widely available and approximates intravascular solute content.

Hyperchloremic solutions such as normal saline should be avoided. (Refer to Chapter 10, *Burn Disaster Management* for possible exceptions to this caveat.)

B. Goal of Resuscitation

The goal of resuscitation is to maintain adequate tissue perfusion and organ function while avoiding the complications of over or under resuscitation. Burn fluid resuscitation must be guided by basic critical care principles and managed on a near-continuous basis to promote optimal outcomes.

1. Complications of Over-resuscitation

Edema that forms in dead and injured tissue reaches its maximum in the second 24 hours post-burn. Administration of excessive volumes of resuscitation fluid exaggerates edema formation, leading to various types of resuscitation-related morbidity. These include extremity, orbital, and abdominal compartment syndromes, as well as pulmonary edema, and cerebral edema.

2. Complications of Under-resuscitation

Shock and organ failure, most commonly acute kidney injury, may occur as a consequence of hypovolemia in a patient with an extensive burn who is untreated or receives inadequate fluid. The increase in capillary permeability caused by the burn is greatest in the immediate post-burn period and diminution in effective blood volume is most rapid at that time. Prompt administration of adequate amounts of resuscitation fluid is essential to prevent decompensated burn shock and organ failure. A delay in initiating resuscitation will often lead to higher subsequent fluid requirements, thus it is imperative that fluid resuscitation commence as close to the time of injury as feasible.

C. Traditional Fluid Resuscitation Formulas

With the inception of modern burn care, a number of burn fluid resuscitation formulas have been devised to estimate resuscitation fluid needs in the first 24-hours post-burn. Fluid resuscitation after burn injury is a cornerstone of burn care and fittingly, these formulas collectively are among the greatest advances in modern burn care. Appropriately, all burn formulas account for the surface area of burn and body weight. A patient's weight in kilograms is obtained or estimated and only second and third degree total burn surface are calculated, using the Rule of Nines or any of several commonly available burn diagrams. First-degree burns should not be included in the fluid resuscitation calculations as it is unnecessary and increases the likelihood of over-resuscitation.

By consensus, the American Burn Association published a statement in 2008 establishing the upper and lower limits from which the 24-hour post-burn fluid estimates could be calculated. These limits were derived from the two most commonly applied resuscitation formulas: the Parkland Formula (4 ml/kg/%TBSA/24 hours) and the Modified Brooke Formula (2 ml/kg/%TBSA/24 hours).

For any traditional formula, it was estimated that one-half of the calculated total 24-hour volume would be administered within the first 8 hours post-burn, calculated from the time of injury. The traditional formulas further estimated that the remaining half of the calculated total 24-hour resuscitation volume would be administered over the subsequent 16 hours of the first post-burn day.

It is important to emphasize that the volume of fluid actually infused in practice is adjusted according to the individual patient's urinary output and clinical response. Although being able to estimate and predict how the 24-hour burn resuscitation might unfold is highly valuable, the actual 24-hour total resuscitative volumes patients receive are highly variable due to patient variability in the response to injury.

D. The Initial Fluid Rate and Adjusted Fluid Rate

In the pre-hospital and early hospital settings, prior to calculating the percent Total Body Surface Area (TBSA) burned, the following guidelines based on the patient's age are recommended as the INITIAL FLUID RATE as a STARTING POINT:

- 5 years old and younger: 125 ml LR per hour
- 6 – 13 years old: 250 ml LR per hour
- 14 years and older: 500 ml LR per hour

Once the patient's weight in kg is obtained and the percent second and third degree burn is determined in the secondary survey, the ABLS Fluid Resuscitation Calculations are used to calculate the ADJUSTED FLUID RATE.

1. Adult Thermal and Chemical Burns:

2 ml LR x patient's body weight in kg x % second and third degree burns, with half of the 24-hour total (in mls) infused over the first 8 hours.

Research indicates that resuscitation based upon using 4 ml LR per kg per %TBSA burn commonly results in excessive edema formation and over-resuscitation.

EXAMPLE:

An adult patient with a 50% TBSA second and third degree burn who weighs 70 kg:

2 ml LR x 70 (kg) x 50 (% TBSA burn) = 7,000 ml LR in the first 24 hours. 3,500 ml (half) is infused over the first 8 hours from the time of injury. A minimum of 437 ml LR / hour should be infused over the first 8 hours.

If initial resuscitation is delayed, the first half of the volume is given over the number of hours remaining in the first 8 hours post-burn.

For example, if the resuscitation is delayed for two hours, the first half is given over 6 hours (3500 ml / 6 hours). A minimum of 583 ml LR per hour should be infused over the remaining 6 hours.

In the scenario where fluid resuscitation is delayed beyond six hours post-burn, the burn center should be consulted for the most appropriate 'catch-up' approach. Administration of crystalloids via bolus infusion should be avoided except when the patient is hemodynamically unstable.

2. Pediatric Patients (13 years and under):

3 ml LR x child's weight in kg x % TBSA second and third degree burns, with half of the 24-hour total (in mls) infused over the first 8 hours as per the adult calculation.

Children have a greater surface area per unit body mass than adults and require relatively greater amounts of resuscitation fluid. The surface area/body mass relationship of the child also defines a smaller intravascular volume per unit surface area burned, which makes the burned child more susceptible to fluid overload and hemodilution.

In addition to the resuscitation fluid noted above, infants and young children should also receive LR with 5% Dextrose at a maintenance rate. In this course, we define young children and infants as individuals weighing ≤ 30 kg. Hypoglycemia may occur as limited glycogen stores for a child can become rapidly exhausted. Therefore, it is important to monitor blood glucose levels and, if hypoglycemia develops, to continue resuscitation using glucose containing electrolyte solutions.

Consulting the burn center is advised when resuscitating infants and young children.

Additional information relating to pediatric fluid resuscitation will be addressed in Chapter 8, *Pediatric Burn Injuries*.

3. Adult Patients with High Voltage Electrical Injuries with evidence of myoglobinuria (dark red-tinged urine):

4 ml LR x patient's weight in kg x % TBSA second and third degree burns, with half of the 24 hour total (in mls) inf used over the first 8 hours.

The special fluid resuscitation requirements associated with high voltage electrical injuries are discussed in Chapter 6, *Electrical Injury*.

4. Pediatric Patients with High Voltage Injuries with evidence of myoglobinuria (dark red-tinged urine):

Consult a burn center immediately for guidance.

Once the ADJUSTED FLUID RATE based on the weight and burn size is infusing, the MOST CRITICAL consideration is the careful titration of the hourly fluid rate based on the patient's urinary output and physiological response. The next section provides guidance on how fluids should be titrated.

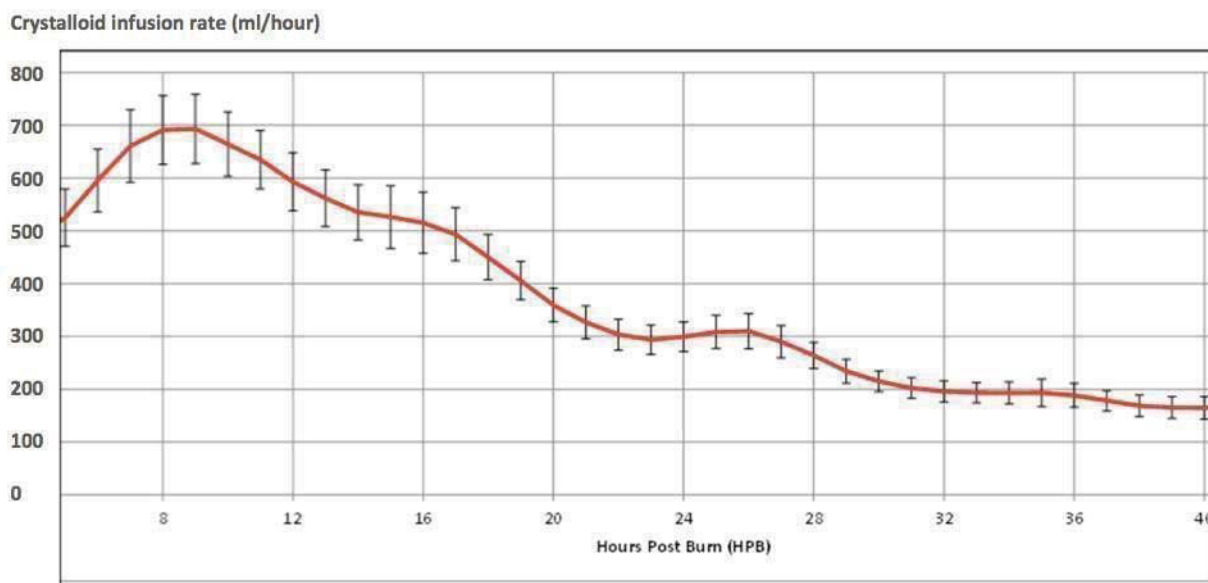
E. Titration of Fluids and Monitoring

Current resuscitation practice is a very dynamic process that requires hourly re-evaluation of the patient's progress through the first 24 hours. It is important to put the traditional formulas in the context of this current practice. Each patient reacts differently to burn injury and resuscitation. The actual volume of fluid infused will vary from the calculated volume as indicated by physiologic monitoring of the patient's response. It is easier during resuscitation to infuse additional fluid as needed than to remove excess fluid. A resuscitation regimen that minimizes both volume and salt loading, prevents acute kidney injury, and is associated with a low incidence of pulmonary and cerebral edema is optimal.

The overall goal is a gradual de-escalation of IV fluid rate over the first 24 hours. However, as the following graph summarizing average real life resuscitation volumes over the first 24 hours indicates, fluids often need to be titrated upward in major burns until the patient reaches target urine output in subsequent hours. Aggressive titration during this early phase is critical to minimize the chance of acute kidney injury. Once target urine output is reached, a gradual reduction in IV fluid rate is advisable to prevent over-resuscitation. It is not necessary to wait for 8 hours to start reducing fluids. It is also dangerous to suddenly reduce fluid rate by $\frac{1}{2}$ at 8 hours.

Conceptually, the IV fluid rate for the next 16 hours, as derived by traditional formulas, is simply a target IV fluid rate to achieve.

Figure. Representative graph of dynamic hourly fluid rate (y-axis) over the first 40 hours (x-axis) in severely burned patients. (Image obtained with permission from the United States Army Institute of Surgical Research)



With appropriate fluid resuscitation, cardiac output, which is initially depressed, returns to predicted normal levels between the 12th and 18th hours post-burn, during a time of modest progressive decrease in blood volume. Although uncommon in young and healthy individuals, cardiac dysfunction should be considered in many older adults with burns. Invasive monitoring may be required and treatment targets may need to be modified.

Reassess the patient frequently, including their mental status. Anxiety and restlessness are early signs of hypovolemia and hypoxemia. Fluid and ventilatory support should be adjusted as needed. In intubated patients, excessive doses of opioids and/or sedatives should be avoided. Their liberal use often exacerbates peripheral vasodilation and may cause hypotension, which then leads to administration of more fluids. Other medications that can cause hemodynamic compromise include propofol and dexmedetomidine and should be used with caution. Whether they are intubated or not, the goal is for every burn patient to remain alert and cooperative with acceptable pain control.

1. Urinary Output

The hourly urinary output obtained by use of an indwelling bladder catheter is the most readily available and generally reliable guide to resuscitation adequacy in patients with normal renal function.

- Adults: 0.5 ml/kg/hour (or 30-50 ml/hour)
- Young Children (weighing \leq 30kg): 1 ml/kg/hour
- Pediatric (Weighing $>$ 30 kg, up to age 17): 0.5 ml/kg/hour
- Adult patients with high voltage electrical injuries with evidence of myoglobinuria: 75 – 100 ml/hour until urine clears.

The fluid infusion rate should be increased or decreased based on urine output. The expected output should be based on ideal body weight, not actual pre-burn weight (i.e., the patient who weighs 200 kg does not need to have a urinary output of 100 ml per hour).

Once an adequate starting point has been determined, fluid infusion rate should be increased or decreased by up to one-third, if the urinary output falls below or exceeds the desired level by more than one-third every hour.

a. Management of Oliguria

Oliguria can be caused by mechanical obstruction, such as intermittent urinary catheter kinking or dislodgment from the bladder. This situation may present as intermittent adequate urine output with periods of anuria. Verifying that the catheter is functioning well is imperative in this situation.

Oliguria, in association with an elevation of systemic vascular resistance and reduction in cardiac output, is most frequently the result of insufficient fluid administration. In such a setting, diuretics are contraindicated, and the rate of resuscitation fluid infusion should be increased to achieve target urine output. Once a diuretic has been administered, urinary output is no longer an accurate tool to monitor fluid resuscitation.

Older patients with chronic hypertension may become oligouric if blood pressure falls significantly below their usual range. As such, a systolic blood pressure of 90-100 mm Hg may constitute relative hypotension in older patients.

b. Management of Myoglobinuria and Dark, Red-tinged Urine

Patients with high voltage electrical injury, patients with associated soft tissue injury due to mechanical trauma and very deep burns may have significant amounts of myoglobin and hemoglobin in their urine. The administration of fluids at a rate sufficient to maintain a urinary output of 1.0-1.5 ml per kg per hour in the adult (approximately 75-100 ml/hour) will often produce clearing of the heme pigments with sufficient rapidity to eliminate the need for a diuretic. When an adequate urinary output has been established and the pigment density decreases, the fluid rate can be titrated down.

Persistence of dark red-tinged urine may indicate compartment syndrome.

Administration of a diuretic or the osmotic effect of glycosuria precludes the subsequent use of hourly urinary output as a guide to fluid therapy; other indices of volume replacement adequacy must be relied upon.

2. Blood Pressure

In the first few hours post-burn, the patient should have a relatively normal blood pressure. Early hypovolemia and hypotension can be a manifestation of associated hemorrhage due to trauma. It is important recognize and treat hemorrhage in cases of combined burn/trauma injuries.

Blood pressure cuff measurement can be misleading in the burned limb where progressive edema is present. Even intra-arterial monitoring of blood pressure may be unreliable in patients with massive burns because of peripheral vasoconstriction and hemoconcentration. In such instances, it is important to place more emphasis on markers of organ perfusion such as urine output.

3. Heart Rate

Heart rate is also of limited usefulness in monitoring fluid therapy. A rate of 110 to 120 beats per minute is common in adult patients who, on the basis of other physiologic indices of blood volume, appear to be adequately resuscitated. On the other hand, a persistent severe tachycardia (>140 beats per minute) is often a sign of under treated pain, agitation, severe hypovolemia or a combination of all. The levels of tachycardia in pediatric patients should be assessed on the basis of the age-related normal heart rate.

4. Hematocrit and Hemoglobin

As fluid resuscitation is initiated, in the early post-burn period, it is very common to see some degree of hemoconcentration. In massive burns, hemoglobin and hematocrit levels may rise as high as 20 g/dL and 60% respectively during resuscitation. This typically corrects, as intravascular volume is restored over time. When these values do not correct, it suggests that the patient remains under-resuscitated.

Whole blood or packed red cells should not be used for resuscitation unless the patient is anemic due to pre-existing disease or blood loss from associated mechanical trauma at the time of injury. In that case, transfusion of blood products should be individualized.

5. Serum Chemistries

Baseline serum chemistries should be obtained in patients with serious burns. Subsequent measurements should be obtained as needed based on the clinical scenario. To ensure continuity of care and patient safety during transfer, the treatment of hyperkalemia and other electrolyte abnormalities should be coordinated with the burn center physicians.

F. The Difficult Resuscitation

Estimates of resuscitation fluid needs are precisely that — estimates. Individual patient response to resuscitation should be used as the guide to add or withhold fluid. The following groups are likely to be challenging and may require close burn center consultation:

- Patients with associated traumatic injuries
- Patients with electrical injury
- Patients with inhalation injury
- Patients in whom resuscitation is delayed
- Patients with prior dehydration
- Patients with alcohol and/or drug dependencies (chronic or acute)
- Patients with very deep burns
- Patients burned after methamphetamine fire or explosion
- Patients with severe comorbidities (such as heart failure, or end-stage renal disease)

In patients requiring excessive fluids, resuscitative adjuncts should be considered to prevent major complications such as pulmonary edema and compartment syndromes. Typical scenarios are: the provider is unable to achieve sufficient urine output at any point, or the patient develops oliguria when crystalloid infusion is reduced. Colloids in the form of albumin (and less commonly plasma) can be utilized as a rescue therapy. Synthetic colloids in the form of starches should be avoided due to their increased risk of harm. Close consultation with the nearest burn center is advised when initiation of colloid is being considered.

IV. SUMMARY

In burns greater than 20% TBSA, fluid resuscitation should be initiated using estimates based on body size and surface area burned. The goal of resuscitation is to maintain tissue perfusion and organ function while avoiding the complications of inadequate or excessive therapy. Excessive volumes of resuscitation fluid can exaggerate edema formation, thereby compromising the local blood supply. Inadequate fluid resuscitation may lead to shock and organ failure.

Promptly initiated, adequate resuscitation permits a modest decrease in blood and plasma volume during the first 24 hours post-burn and restores plasma volume to predicted normal levels by the end of the second post-

burn day. In the event that the patient transfer must be delayed beyond the first 24-hours, close consultation with nearest burn center is recommended regarding ongoing fluid requirements.

V. SELECT REFERENCES

Freiburg C, Igneri P, Sartorelli K, et al. Effects of differences in percent total body surface area estimation on fluid resuscitation of transferred burn patients. *J Burn Care Res* 2007; 28:42-48.

Seok J, Warren HS, Cuenca AG, et al. Genomic responses in mouse models poorly mimic human inflammatory diseases. *Proc Natl Acad Sci U S A* 2013; 110:3507-3512.

Saffle JR. The phenomenon of “fluid creep” in acute burn resuscitation. *J Burn Care Res* 2007; 28:382-395.

Wolfe SE, Pruitt BA Jr. Burn Management. In: Irwin RS & Rippe JM, eds. *Irwin and Rippe’s Intensive Care Medicine* (6th ed.) Philadelphia, PA: Lippincott Williams & Wilkins; 2008, pp. 1931-1933.

Pruitt BA Jr., Gamelli RL. Burns. In: Britt LD, Trunkey DD, and Feliciano DV, eds. *Acute Care Surgery: Principles and Practice*. New York: Springer; 2007, pp. 182-134.

Pruitt BA Jr. Protection from excessive resuscitation: “Pushing the pendulum back”. *J Trauma* 2000; 49:567-568.

Hershberger RC, Hunt JL, Arnoldo BD, Purdue GF. Abdominal compartment syndrome in the severely burn patient. *J Burn Care Res* 2007; 28:708-714.

Alvarado R, Chung KK, Cancio LC, and Wolf SE. Burn resuscitation. *Burns* 2009;35:4-14.

Engrav LH, Colescott PL, Kemalyan N, et al. A biopsy of the use of the Baxter formula to resuscitate burns or do we do it like Charlie did it? *J Burn Care Rehabil* 2000; 21(2): 91-95. (Review of the Baxter formula.)

Graves TA, Cioffi WG, McManus WF, et al. Fluid resuscitation of infants and children with massive thermal injury. *J Trauma* 1988; 28: 1656-1659. (Provides guidance on the resuscitation of children.)

Navar PD, Saffle JR, Warden GD. Effect of inhalation injury on fluid resuscitation requirements after thermal injury. *Am J Surg* 1985; 150:716-720. (Review of resuscitation of those with simultaneous cutaneous burn and inhalation injury.)

Chung KK, Wolf SE, Cancio LC, et al. Resuscitation of severely burned military casualties: fluid begets more fluid. *J Trauma* 2009;67:231-237.

Pham TN, Cancio LC, Gibran NS. American Burn Association practice guidelines burn shock resuscitation. *J Burn Care Res* 2008; 28(1): 257-266.

Greenhalgh DG. Burn resuscitation: the results of the ISBI/ABA survey. *Burns* 2010; 36:176-182.

CHAPTER 5

Burn Wound Management



Objectives

At the conclusion of this lecture the participant will be able to:

- Differentiate between partial thickness and full thickness burns
- Understand indications for trunk and extremity escharotomies
- Discuss management of patients with burns of specialized areas

I. INTRODUCTION

Attention is directed to the burn wound after initial assessment and stabilization of life-threatening problems, such as airway, and initiation of fluid resuscitation to prevent burn shock. Nevertheless, the long-term outcome of the burn patient depends on the effective treatment and ultimate healing of the burn wound. Furthermore, the severity of the patient's multi-system response to injury, the likelihood of complications, and the ultimate outcome are all intimately linked to the extent of the burn wound and to its successful management.

II. ANATOMY AND PHYSIOLOGY OF THE SKIN

A. Structure

The skin is composed of two layers, the epidermis and dermis. The epidermis is the outer, thinner layer; the dermis is the deeper, thicker layer. The dermis contains hair follicles, sweat glands, sebaceous glands, and sensory fibers for pain, touch, pressure and temperature. The subcutaneous tissue lies beneath the dermis and is a layer of connective tissue and fat.

B. Functions

The skin provides at least four functions crucial to survival:

- Protection from infection and injury
- Prevention of loss of body fluid

- Regulation of body temperature
- Sensory contact with environment

C. Burn Depth

Burn depth is classified into partial (some, but not all layers of the skin are injured) vs. full thickness (all layers of the skin are injured). Another complementary classification is by first-, second- and third-degree, as described below. Remember that it is sometimes difficult to determine the depth of injury during the first several days as the wound evolves.

1. Superficial, Partial-Thickness Burns/First- and Second- Degree

A first-degree burn is a superficial injury limited to the epidermis and is characterized by redness, hypersensitivity, pain and no skin sloughing. Within a few days, the outer layer of injured cells peels away from the totally healed adjacent skin with no residual scarring. First-degree burns are seldom medically significant and are not included when calculating the percent TBSA burn.

Second-degree burns involve the epidermis and part of the dermis. The skin may be red and blistered, wet, weepy or whiter, yet edematous. Survival of injured dermis and associated epidermal appendages is in jeopardy unless optimal conditions for preservation of these elements can be maintained. Such wounds may heal spontaneously, though healing may require two to three weeks or even longer. Scarring is typically mild if healing occurs within 2-3 weeks. If the wound is open for a longer period of time, grafting is indicated to minimize scarring. In this situation, skin grafting reduces time to healing and long-term functional and cosmetic outcome.

2. Full-Thickness Burns/Third-Degree

Full-thickness burns (third-degree burns) involve destruction of the entire thickness of the epidermis and dermis, including dermal appendages. These injuries produce a whitish or charred appearance to the skin and coagulated vessels are sometimes visible. The burned skin tissue with a dry, leathery appearance is called an “eschar”. Although the area of a full-thickness burn does not appear edematous, sub-eschar fluid may develop.

3. Fourth Degree Burns

Wounds that penetrate below the skin into the subdermal fat are classified as fourth degree burns. These burns also have an eschar on the surface, but the presence of subdermal coagulated vessels, and sometimes indented wound shape compared to adjacent skin indicate involvement below the dermal layer. Deeper injuries involving underlying fascia, muscle and/or bone are described as “with deep tissue loss”. The physiological impact of a burn is proportional to the extent of the body surface area involved with second-, third-, and fourth-degree burns.

Superficial partial-thickness burns typically do not result in scar formation. Deep partial thickness burns that heal by scar formation and full thickness burns are more likely to develop burn scar contractures, even with skin grafting. Burn depth determines the wound care required, the need for grafting, and the functional and cosmetic outcomes.

III. PATHOPHYSIOLOGY OF THE LOCAL THERMAL INJURY

A. Cellular Damage

The degree of tissue destruction, and thus the depth of burn, correlates with both the temperature and the duration of exposure to the heat source. The physiologic impact of a burn primarily depends on 1) the extent of the burn (total body surface area injured with second- and deeper degree burns) and 2) depth of injury.

The central area of the burn wound, having had the longest contact with the heat source, is characterized by coagulation necrosis of the cells. Therefore, it is termed the zone of coagulation. Extending peripherally from this central zone of coagulation is an area of injured cells with decreased blood flow, which under ideal circumstances may survive, but more often than not will progress to necrosis in the ensuing 24 to 48 hours following injury. This is the zone of stasis. Lying farther peripherally is the zone of hyperemia, which has sustained less severe injury, and will often recover over a period of seven to ten days. The implications of these zones are that improper wound care and inappropriate resuscitation may lead to more extensive injury. For large burns, the likelihood of survival depends on optimizing resuscitation. Improper fluid management may extend the zone of stasis and cause conversion into the zone of coagulation. Localized or systemic hypothermia causing vasoconstriction may also extend the zone of coagulation increasing the size of the burn that requires surgical intervention and grafting. The term “burn wound conversion” refers to increased size of the zone of necrosis, whereby a partial-thickness area on admission converts to a full-thickness injury within a few days after injury.

B. Fluid Accumulation (Edema Formation)

In addition to cellular damage, thermal injury generates an intense inflammatory reaction with early and rapid accumulation of fluid (edema) in the burn wound. Capillaries in the burn wound become highly permeable, leak fluid, electrolytes and proteins into the area of the wound. In patients with large burns, edema formation occurs in unburned tissues as well. This fluid loss into both burned and unburned tissues causes hypovolemia and is the primary cause of shock in burn patients. At the same time, edema formation can also cause decreased blood flow to the extremities and/or impaired chest movement during breathing. Circumferential full-thickness burns in the trunk may lead to inadequate chest wall excursion with accumulating edema. Circumferential full-thickness burns in the extremities lead to decreased tissue perfusion. Escharotomies are occasionally needed to relieve the tight eschar and should only be performed after consultation with a burn center.

IV. WOUND CARE

A. Pre-Hospital Wound Care: Cooling

Cooling of the burn using tap water is sensible as long as it does not delay in care and transfer to a hospital facility. Cooling relieves pain and may reduce the depth of injury in evolving partial-thickness burns. However, the exact method and length of cooling is still controversial. This course recommends that cooling is appropriate by using tap water up to 30 minutes for burns $\leq 5\%$ TBSA. In larger size injuries, the risk of hypothermia and delay in care potentially outweighs the benefit of cooling.

B. Patients Who Meet Criteria for Referral to a Burn Center

Evaluation and treatment of life-threatening problems always takes precedence over the management of the burn wound. The priorities for initial wound management differ from definitive wound management in several ways. During initial stabilization, once the primary and secondary survey have been completed and interventions planned, the provider should document the areas of second- and third-degree prior to transfer. To avoid hypothermia, cover the patient with a dry clean dressing and keep the patient warm. There is no need to cleanse extensive wounds in patients who are to undergo formal wound evaluation and cleansing once at the burn center. The priority here is stabilization and rapid transfer. Elevate any extremity with a burn injury above the level of the heart to minimize burn wound edema. Use pillows to ensure the extremity remains elevated during transport.

C. Patients Who Do Not Meet ABA Referral Criteria, or Patients With Anticipated Delay in Transfer to a Burn Center

If the patient's injuries do not meet criteria for referral, or if transfer to a burn center will exceed 24 hours

because of mass casualty or other logistical reasons, this course recommends the following 2 steps:

1. Cleansing the wound with a cleansing agent (i.e., soap or chlorhexidine) and removing dirt and debris from the wound area, if present. Perform wound care one body section at a time to limit the exposed areas to a minimum. Prepare warm water or warm saline ahead of time. Prepare all dressings ahead of time to apply immediately upon completion of wound care for that specific area of the body. Warm water with dilute chlorhexidine gluconate to cleanse the burn wounds is optimal due to broad-spectrum antimicrobial coverage. Do not use chlorhexidine gluconate in close proximity to the eyes. It is acceptable to use baby shampoo mixed with warm water to clean the head and neck area along with the rest of the body if chlorhexidine gluconate is not available. Pre-medicate the patient for pain and anxiety control and maintain a warm environment.
2. Gently debride blisters >2cm in size using sterile gauze or scissors; apply a topical antimicrobial medication. Consult with the burn center for the preferred topical antimicrobial medication. Common topical ointments are silver sulfadiazine for full-thickness burns and bacitracin for partial- thickness burns. If topical antimicrobial dressings are to be applied, the primary and secondary dressings method should be used. A primary dressing makes direct contact with the burn wound surface. For instance, 1% SSD (silver sulfadiazine) is commonly used. This cream can be applied directly to the burn wound or impregnated into gauze and then applied to the wound. Other topical ointments can be used, either alone or in combination, depending on the depth of the wound. Examples are bacitracin, double- or triple-antibiotic ointment, and petrolatum. A secondary dressing provides a layer to absorb drainage and will provide mechanical protection. All secondary dressings are loosely secured with size appropriate rolled gauze or surgical netting if available. Do not secure dressings in a constrictive manner that may interfere with perfusion.

D. Patients Discharging From the Emergency Department With Burn Center Follow Up

If the patient has a minor injury and may be discharged directly from the local emergency department, we recommend consultation to formulate a plan together with the nearest burn center. In many cases, discharge with follow-up in a burn center clinic may be appropriate. In this scenario, the initial healthcare facility provides the wound care and teaches to patient (or caretaker) subsequent wound care needs. The most common recommendation is to cleanse the wound with soap and water, remove debris from the wound bed, and apply a topical antimicrobial medication such as bacitracin or silver sulfadiazine. If daily reapplication of topical antimicrobial medication is chosen, the patient (or caretaker) should cleanse the wound and reapply the dressing daily until the patient follows up in the burn clinic. Upon discharge, ensure that the dressing is secure and does not impair full range of motion in the area of the burn wound.

Another wound care option for partial-thickness burn wounds is the application of multi-day dressings. Several commercial dressings are available. They can be applied to a cleansed and debrided wound bed and left in place for several days. Without the need for daily changes, these dressings improve comfort and ease for the patient. These dressings should be applied with caution and in consultation with the burn center, as inappropriate use can delay healing and cause patient harm. Additionally, some of these dressings can impair range of motion or increase edema in the burn wound area. While multi-day dressings offer distinct advantages for patients and caregivers, they should not be used as a substitution for the expert burn wound care delivered in a burn center. If these types of dressings are not applied correctly or to the most appropriate wound bed, serious complications can occur.

V. ESCHAROTOMY

An escharotomy is a longitudinal incision through the burn eschar down to subcutaneous fat over the entire length of full-thickness circumferential (or nearly circumferential) burns. Escharotomy relieves the constriction that led to restriction of chest rise or loss of peripheral perfusion in an extremity. This situation is analogous to the patient with a tight-fitting orthopedic cast. Just as relief is obtained by splitting the cast, an escharotomy

splits the eschar. The technique of escharotomy and orientation of the incisions are beyond the scope of this chapter. The referring provider should consult their regional burn center for guidance when considering escharotomy. This is typically a bedside procedure using an electrocautery device. Local anesthesia is often impractical since escharotomies are often extensive incisions along an extremity. Small doses of intravenous opioids or ketamine are helpful for analgesia. Escharotomies are rarely indicated prior to transfer of a burn patient as it takes time for accumulated fluid to increase the pressure in the affected body location. Escharotomy can cause significant morbidity, and generally is not needed until several hours into the burn resuscitation. Therefore, most escharotomies should be delayed until the patient is transferred to a burn center familiar with performing these procedures. Before considering need for escharotomy, other causes of circulatory or ventilatory compromise (i.e., associated trauma, severe hypotension/shock, etc.) must be ruled out. There are two common escharotomy locations:

1. Circumferential Trunk Burn

Monitor for adequate gas exchange throughout the resuscitation period. If respiratory distress develops, it may be due to a deep circumferential burn wound of the chest, which makes it difficult for the chest to expand adequately. When this problem is recognized, relief by escharotomy is indicated and may be life-saving. Other causes of respiratory distress such as airway obstruction, pneumothorax, right mainstem intubation, and/or inhalation injury must be considered first and ruled out.

Signs that the patient is in need of a chest escharotomy include:

- Difficulty with bag-valve-mask ventilation
- Increased peak inspiratory pressures
- Restlessness or agitation
- Decreased air exchange and decreased breath sounds

2. Circumferential (or Near Circumferential) Extremity Burn

During the primary survey of all burn patients, remove all rings, watches, and other jewelry from injured limbs to avoid distal ischemia.

Elevation and active motion of the injured extremity may alleviate minimal degrees of circulatory distress. Assess skin color, sensation, capillary refill and peripheral pulses and document hourly in any extremity with a circumferential burn. In an extremity with tight circumferential eschar, fluid accumulation increases pressure in the underlying tissues and may produce vascular compromise in that limb. On physical exam, the patient will report increasing tightness, pain, tingling and numbness in the affected extremity. With increasing pressure, distal pulses will become weaker. In patients who cannot report symptoms (for example because of sedation), loss or progressively weaker Doppler signals in a tense extremity is an indication for escharotomy. Verify that lack of pulses is not due to profound hypotension, arterial or other associated injuries, and is compatible with the burn injury.

In the hand, full-thickness burns may also lead to increasing pain, tingling and numbness. The swollen hand will appear more contracted, with cool fingers indicating poor perfusion. Escharotomies on the dorsum of the hand relieve the increased pressure. Finger escharotomy is seldom required and should never be attempted by inexperienced personnel.

VI. EXTREMITY COMPARTMENT SYNDROME

In contrast to the decreased flow seen in circumferential burns requiring escharotomies, compartment syndrome features edema within (beneath) the deep investing fascia of the muscles. Compartment syndrome can occur in burned or unburned limbs, and may result from massive fluid resuscitation, high voltage electrical

injury, delay in escharotomy (ischemia- reperfusion injury), crush injury, etc. This syndrome is frequently diagnosed by the measurement of compartment pressures and is treated by fasciotomy in the operating room. The great majority of extremity circumferential burns with decreased Doppler signals respond well to escharotomy and do not require fasciotomy.

VII. BURNS IN SPECIALIZED AREAS

Burns of specialized anatomical areas require unique evaluation and management. This course strongly recommends non-burn providers to consult with a burn center for patients with burns of the face, feet, eyes, axilla, perineum, hands, or across major joints.

A. Face Burns

Face burns are a serious injury and often require hospital care. Consider the possibility of respiratory tract damage. Due to the rich blood supply and loose areolar tissue of the face, facial burns are associated with extensive edema formation. Rapid, dramatic swelling may occur. It is not uncommon for the patient's eyes to swell closed for several days post burn. To minimize facial swelling (in a patient without cervical spine immobilization), elevate the patient's head 30 to 45 degrees. To avoid chemical conjunctivitis, use only water or saline to clean facial burns and protect the eyes while cleansing the face. Deep face burns are associated with scar formation, and are associated with severe psychological impact.

B. Eye Burns

Complete a careful examination of the eye as soon as possible because eyelid swelling makes ocular examination extremely difficult. Check for and remove contact lenses before swelling occurs. Fluorescein helps identify corneal injury. Rinse chemical burns to the eye with copious amounts of saline as indicated (see Chapter 7, *Chemical Burns*). Ophthalmic antibiotic ointments or drops may be used to treat corneal injury, but only after consultation with the burn center. Avoid ophthalmic solutions containing steroids.

C. Ear Burns

Burns of the ears require examination of the external canal and drum before swelling occurs. Patients injured in an explosion (blast injury) may also have a tympanic membrane perforation. Avoid additional trauma or pressure to the ear. Thus, avoid occlusive dressings on the ears and avoid pillows under the head.

D. Hand Burns

Some burns of the hands may result in only temporary disability and inconvenience; however, deep and extensive thermal injury can cause permanent loss of function. The most important aspect of the physical assessment is to determine motor and nerve function in the hand, and check for good perfusion. Elevate the burned extremity above the level of the heart—for example on pillows—to minimize edema formation. In patients who can cooperate, active motion of the hand each hour will further minimize swelling. Monitor pulses every hour and be careful to not apply constrictive dressings that will impair blood flow.

E. Feet Burns

As with burns of the upper extremity, it is important to assess the circulation and neurologic function of the feet on an hourly basis. Minimize edema by elevating the extremity and avoid constrictive dressings—just as with hand burns. Foot burns are associated with a higher risk of infection and delayed healing, especially in patients with peripheral neuropathy (diabetes) or poor circulation (peripheral arterial disease).

F. Burns of the Genitalia and Perineum

Partial-thickness of the burns genitalia do not require urinary catheter placement unless indicated for other reasons (such as monitoring of resuscitation). Full-thickness burns of the penis may require insertion of a urinary catheter in case of severe swelling to maintain the patency of the urethra. Scrotal swelling, though often significant, does not require specific treatment other than reassurance. Burns of the perineum are difficult to manage, and therefore an indication to transfer to a burn center.

VIII. TAR AND ASPHALT BURNS

Hot tar and asphalt burns are sometimes grouped with the chemical burns category, although they are essentially, contact thermal burns. The bitumen compound of tar/asphalt itself is not absorbed and is not toxic. Roofing asphalt doesn't even become pliable until it reaches 180-200° F (82-93° C). The maximum storage temperature is 250° F (121° C) and is much hotter when being applied. These extreme temperatures combined with the thick viscosity result in very deep burns if not cooled immediately and adequately.

Emergency treatment consists of cooling the molten material with cold water until the product is completely cooled. Physical removal of the tar is not an emergency. After cooling, adherent tar should be covered with a petrolatum- based ointment (such as white petrolatum jelly) and dressed to promote emulsification of the tar. Removal of the tar or asphalt may be delayed until patient arrives at the accepting burn center.

IX. SUMMARY

The successful treatment of the patient with thermal burns requires attention to wound management in order to promote healing and closure of the wound. Burn wound management never takes precedence over life threatening injuries or the management of fluid resuscitation, but it is an important aspect of care during the acute burn phase. Burns in specialized areas present specific evaluation and management challenges. Good functional and aesthetic results depend on the initial management for these specialized areas.

X. SELECT REFERENCES

Handling Recommendations for Coal Tar Roofing Bitumens. Technical Bulletin. Asphalt Roofing Manufacturers Association. March 1993.

Singer AJ, Brebbia J, Soroff HH. Management of Local Burn Wounds in the ED. *Am J Emerg Med* 2007 25(6): 666–671.

Sargent RL. Management of blisters in the partial-thickness burn: an integrative research review. *J Burn Care Res* 2006 27(1): 66–81.

Pham TN, Gibran NS. Thermal and electrical injuries. *Surg Clin North Am.* 2007 87(1): 185-206.

Branski LK, Dibildox M, Shahrokhi S, Jeschke MG. Treatment of Burns- Established and Novel Technology. In *Handbook of Burns, Vol 1. Acute Burn Care.* Eds Jeschke, Kamolz, Sjoberg, & Wolf. Springer, 2012.

Atiyeh BS, Gunn SW, Hayek SN. State of Art in Burn Treatment. *World J Surg* 2005; 29(2):131-48.

Orgill DP, Piccolo N. Escharotomies and Decompressive Therapies in Burns: Practice Guidelines. *J Burn Care Res* 2009; 30(5): 759-767.

Greenhalgh DG. Chapter 8: Wound Healing. In *Burn Care for General Surgeons and General Practitioners.* Ed Greenhalgh. Springer 2016.

CHAPTER 6

Electrical Injuries



Objectives

At the conclusion of this lecture the participant will be able to:

- Describe the pathophysiology of electrical injuries
- Discuss special assessments required for electrical injury
- Outline the principles of management for electrical injury

I. INTRODUCTION

Electrical injury has been called the “grand masquerader” of burn injuries because small surface wounds may be associated with devastating internal injuries. Electrical injuries account for approximately 4% of all burn center admissions and cause around 1,000 deaths per year in the United States. Frequently these are work-related injuries and have a significant public health and economic impact. Electrical injuries are caused by direct or alternating current (DC or AC), and are arbitrarily divided into high ($\geq 1,000V$) or low ($<1,000V$) voltage.

A century ago, virtually all electrical injuries were caused by lightning, but today they are outnumbered tenfold by incidents associated with commercially generated electricity. Electricity may also be used during suicide attempts.

Electricity can cause injury by current flow, arc flash, ignition of clothing or concomitant physical trauma such as fractures or dislocations. Understanding these mechanisms may help to predict the severity of the injury and the potential sequelae.

II. PATHOPHYSIOLOGY

A. Terms to Describe Electricity and Electrical Damage

In physics, the flow of electricity in an electrical circuit is analogous to water in a garden hose. The smaller the wire, the higher the resistance (measured in Ohms) and the less the current flows for any given pressure (measured in Volts). Ohm’s Law defines this relationship, where current (I) is directly proportional to the voltage (V) and inversely proportional to the resistance (R): $I = V/R$. Heat creation by the Joule Effect ($J = \text{Current}^2 \times \text{Resistance} \times \text{Time}$) highlights the importance of current, contact time and tissue resistance.

Humans are of course more complex than simple electrical circuits and damage is a reflection of the interaction of the electricity with tissues. Heat generation accounts for a significant portion of the damage observed. Thus, duration of contact, resistance and current flow are the primary determinants of heat injury. Contact duration is longer when the victim's hand cannot "let go" of an electrical source. Above a threshold current, tetanic contraction in the victim's flexor muscles are dominant over the extensor muscle. This can lead to extraordinarily long contact times and resulting extensive tissue damage similar to a high voltage injury even with relatively low voltage. Similar injuries can be found if the patient becomes unconscious in contact with the source of electricity.

Different tissues possess different resistance properties. Generally speaking, skin and bone are high resistance while nerves, muscle and blood vessels have the least resistance. The position of the limb (flexed or extended) compared to the direction of current flow can also change the dynamics of tissue damage. Therefore, conceptualizing the body as a conduit with a resistance proportional to the cross-sectional area is an oversimplification. Dry skin has a resistance as high as 100,000 Ohms. Once this resistance is overcome, current flows through the underlying tissue, especially muscles, following a highly unpredictable path. On the other hand, wet skin has a much lower resistance. At the cellular level, multiple processes damage cell membranes including electroporation (electrical injury alters and damages cells at a microscopic level), which explains the damage that is not immediately apparent on physical exam and may lead to progressive cellular damage and tissue death.

Consequently, deep tissues may be severely injured even when superficial tissues appear normal or uninjured. Given this unpredictability, providers must suspect deep injury when examining the patient exposed to electrical current. Contact points may be in unexpected locations and the external findings may be innocuous and not reflective of a severe underlying injury that threatens limb or life.

Electrocution means either death, or at least temporary loss of pulses, by electrical shock. Thus, the term electrocution is rarely appropriate for most patients who are alive and transported to a health care facility.

B. Direct Current (DC) Versus Alternating Current (AC) Conduction Injuries

Direct current (DC) indicates that the current flows in one direction. Examples include injuries caused by lightning and occasionally by car batteries (including hybrid cars). Car batteries produce low voltage electricity and cause injuries if a metal object like a watchband or ring comes into contact with the source of electricity. The current flow heats the metal, causing a circumferential contact burn.

In contrast, lightning involves very high voltage and amperage current. Lightning can strike a person directly, causing massive injuries, or travel through a nearby object to the victim, dissipating much of the energy.

Alternating Current (AC) indicates that the current changes direction while traveling. It is the most efficient and common way of high voltage power transmission over long distances. Commercially generated AC is used to power most appliances and household items. Even low voltage AC can be dangerous to the human body, and might cause death from cardiac fibrillation or respiratory arrest.

In North America, the 60 cycle current used indicates that the current changes direction 60 times per second. With a contact time of even a fraction of a second, the current may have changed direction several times. Unlike the terminology for gunshot wounds, there are no entrance and exit sites. DC current travels in one direction and entrance and exit sites may be possible. However, even with DC current, more than two sites may be evident. It is generally more appropriate to use the term "contact point" when describing the wounds seen with electrical injury. The pathway of electric current and hence damage may not be accurately defined by the contacts points.

Regardless of whether the electrical injury comes from AC or DC, it is not truly identical to other thermal injuries. In many cases, the appearance of the electrical contact point is different than other thermal injuries.

Electrical contact points often are blackened, dark and dry but with a hole in the skin leading to the erroneous term “entrance wound”. The cellular damage and ultimate prognosis is also quite different compared to other thermal injuries. Suffice it to say that the term “electrical burn” is a misnomer when referring to a true conduction injury. It is more appropriate to say “electrical injury” than to say “electrical burn”.

C. Types of Injury, Based on Mechanism

1. Body Conduction

When electrical current flows through a person, their flexor muscles contract powerfully, causing the victim’s hands to clench and maintain contact with the electrical source. Low voltage electricity may cause few physical findings, but delayed onset of migratory pains, neurologic findings and psychological effects can be very debilitating. Referral for burn center evaluation is recommended even for minor electrical injuries. This is due to the electrical nature of nerve and muscle that allows function of the central nervous system and the heart. Low voltage current rarely causes significant muscle damage, but wet skin has a lowered electrical resistance and *even low voltage current can cause fatal cardiac arrhythmias*. Cutaneous contact points have concentrated current flow, causing the cratered skin wounds that are diagnostic of electrical conduction injury.

High voltage current heats tissue immediately, causing deep tissue necrosis, which may not be externally visible except for the charred contact points. High voltage injuries can result in extreme injuries resulting in prolonged healing, loss of limb(s), or life. High voltage injuries often occur in workers such as linemen, construction workers. Thus, severe electrical injuries cause loss of work and may present a barrier to return to work. Fortunately, with advances in prosthetics and rehabilitation, many survivors are able to return to their pre-burn functional level.

Findings that suggest electrical conduction injury include the following:

- Loss of consciousness
- Paralysis or mummified extremity
- Loss of peripheral pulse
- Flexor surface contact injury (antecubital, axillary, inguinal or popliteal burns)
- Myoglobinuria (red or black urine)

2. Arc Flash and Arc Blast Injuries

When electrical current travels through the air between two conductors, the resulting arc has a temperature of up to 4000°C. The heat released can cause flash burns to exposed skin and even ignition of clothing or surrounding objects. The explosive force of the superheated air may cause associated blunt trauma from a fall. The blast wave may create enough pressure to rupture eardrums and/or collapse lungs. Hence, it is important to examine tympanic membranes as part of the secondary survey.

3. Secondary Ignition

An arc flash releases sufficient energy as radiant heat to ignite clothing or surrounding flammable materials. A severe flame burn can result even in the absence of electrical conduction injury.

4. Thermal Contact Burns

As the electrical current passes through the body, heat is generated. Any metal, such as jewelry, body piercings, zippers, metal in shoes, etc., may be superheated by conducting electricity, resulting in small, but deep contact burns.

5. Associated Injuries

Many people working with electricity are working off the ground on power poles, in truck “buckets”, on roofs or ladders and suffer falls. The electrical current itself causes tetanic contraction of muscles that can result in dislocations of major joints and fractures of vertebral and/or long bones. Every victim of electric shock should be assessed and managed as a trauma patient until associated injuries are ruled out.

It cannot be overemphasized that the appearances of electrical injury can be deceiving. Even if the exam looks as if the patient has a simple thermal injury, it may really be a conduction injury. Electrical injury can confuse even the most experienced burn surgeon.

D. Lightning Strike

Lightning occurs chiefly in the summer months. The risk of being struck by lightning is about one per million per year in the U.S. Lightning kills 80 to 100 people in the U.S. annually and injures another 300 per year. Up to 70% of survivors suffer serious complications.

Lightning is direct electrical current and a typical strike may carry 100,000 Volts and up to 50,000 Amps. A direct cloud-to-ground lightning strike, which hits you or something you are holding, is usually fatal. Most injuries occur indirectly from a side flash, when lightning current discharges from a nearby object (e.g., a tree or building) and travels through the air to the victim. The current may also strike the ground close to the victim (considered the strike point) and travel through the ground to the person, (the strike point potential). One may also be injured by a surge voltage, which occurs when lightning strikes the source of power or network the individual is using (electrical appliance or telephone) and the person receives a shock.

The presentation of a lightning injury varies widely, even within groups of people struck at the same time. The lightning current causes immediate depolarization of the entire myocardium, much like a defibrillator machine, which can produce asystole. Respiratory arrest is more common, since electrical current can temporarily inactivate the respiratory center of the brain. Immediate CPR is lifesaving. Survivors often have reddened areas of the body where the current flowed over the moist skin. A characteristic temporary ferning pattern on the skin called Lichtenberg figures is pathognomonic for electrical injury. These usually occur within an hour of the injury and may persist for up to 36 hours and are not associated with any pathological changes in the epidermis or dermis.

III. MANAGEMENT

STOP! Confirm that the scene is safe from electrical current. Do not become the next victim.

Subsequent evaluation of the patient with electrical injury is similar to other burn injuries. Extra effort must be taken to find all contact points and to detect evidence of blunt trauma or other associated trauma. In addition, cardiac monitoring should be initiated as soon as possible due to the high possibility of dysrhythmias.

A. Primary Survey

The primary survey is the same as discussed in Chapter 2, *Initial Assessment and Management*.

1. Airway maintenance with cervical spine protection is indicated if a fall or blunt force trauma is suspected. Due to the high potential for associated injury or vertebral injury as the result of muscle contraction, a c-collar should be applied.
2. Breathing and ventilation. Administer 100% oxygen per non-rebreather mask.
3. Circulation and cardiac status. Apply cardiac monitor and monitor for cardiac dysrhythmias. Insert two

large bore IVs and initiate fluid resuscitation. Assess peripheral perfusion and examine for circumferential burns. Obtain initial vital signs.

4. Disability, Neurological Deficit, Gross Disability. Assess level of consciousness. Assess neurological status and any gross deformity. Suspect spine injuries in high voltage injuries.
5. Exposure and Environmental Control. Stop the burning process, remove all clothing and metal and protect the patient from hypothermia.

B. Secondary Survey

- Obtain patient history using AMPLET
- Perform a head-to-toe physical examination.
- Identify all contact points. Carefully check hands, feet, and scalp (hair may obscure wounds).
- Determine burn severity. Calculate % TBSA burn. Assess depth of injury.
- Perform a detailed motor and sensory neurological examination and document changes with time. This is even more important in electrical injury due to the greater possibility of nerve damage and compartment syndrome with even minimal cutaneous injury.
- Continually monitor for fractures/dislocations, occult internal injury, and evidence of compartment syndrome.
- Administer medications for pain and anxiety.

C. Resuscitation

Prompt initiation of fluid resuscitation to maintain a high urine volume is important when red pigment is evident in the urine. Initiate fluid resuscitation using Lactated Ringer's at 4ml/kg/percent surface burn area. This volume of fluid may be inadequate if muscle injury or other associated injuries are present.

- Insert a urinary catheter.
- Titrate Lactated Ringer's at a rate sufficient to maintain a urine output of 30-50 ml per hour in an adult or 1 ml/kg/hour in a child.
- If there is evidence of red pigment such as myoglobin, the urine output should be maintained between 75-100 ml per hour until the urine grossly clears.

D. Cardiac Monitoring

Electrical injuries can result in potentially fatal cardiac dysrhythmias. An electrocardiogram (EKG) should be performed on all patients who sustain high or low voltage electrical injuries. A 12-lead EKG will help detect any cardiac rhythm changes that require ongoing monitoring. Maintain continuous cardiac monitoring if dysrhythmias or ectopy is evident.

Prolonged monitoring is not required if there is a normal EKG, and no history of unconsciousness, cardiac arrest, or abnormal rate or rhythm.

E. Maintenance of Peripheral Circulation

All rings, watches and other jewelry must be removed from injured limbs; otherwise a "tourniquet-like" effect may cause distal vascular ischemia.

Skin color, sensation, capillary refill and peripheral pulses must be assessed hourly in any extremity with a circumferential cutaneous burn, an electrical contact site, or abnormal neurologic exam.

Decreased blood flow suggests the development of a compartment syndrome. Compartment syndrome can occur with circumferential third degree burns requiring surgical escharotomy at the burn center. High voltage electrical burns frequently injure deep muscles that swell within the muscle fascia and interrupt blood flow to the extremity. Surgical fasciotomy by an experienced surgeon is required.

F. Special Situations: Cardiac and/or Respiratory Arrest

STOP. Assess the risk that current may be flowing at the accident scene. Do not become the second victim.

Ventricular fibrillation, asystole, and other life-threatening dysrhythmias are treated as outlined by the Advanced Cardiac Life Support course.

Endotracheal intubation may be necessary if the patient has had a respiratory arrest, a head injury from a fall or if there are burns involving the head, face, or neck.

Patients with a history of loss of consciousness or documented dysrhythmias either before or after admission to the emergency department, or those with documented EKG abnormalities should be admitted for continuous cardiac monitoring. Patients with low voltage injuries and normal EKGs may be discharged unless wound issues otherwise dictate. Serial measurements of cardiac enzymes are generally unnecessary.

IV. SELECT REFERENCES

Rouse RG, Dimick AR. The treatment of electrical injuries compared to burn injury: a review of pathophysiology and comparison of patient management protocols. *J Trauma* 1978; 18(1):43-47.

Spies C, Trohman RC. Narrative review: electrocution and life-threatening electrical injuries. *Ann Int Med* 2006; 145(7):531-537.

National Burn Repository Report of Data from 1999-2008. Chicago, IL: American Burn Association. 2009 (Version 5.0).

Arnoldo B, Klein M, Gibran NS. Practice guidelines for the management of electrical injuries. *J Burn Care Res* 2006; 27 (4):439-447.

Purdue FG, Arnoldo BD, Hunt JL. Electrical injuries. In Herndon DM (ed) *Total Burn Care*, Third Ed. Philadelphia, PA: WB Saunders; 2007, pp 513- 520.

Ritenour AE, Morton MJ, McManus JG, et al. Lightning injury: a review. *Burns* 2008,34(5):585-94.

https://www.osha.gov/SLTC/etools/construction/electrical_incidents/mainpage.html (accessed 05/13/2016).

CHAPTER 7

Chemical Burns



Objectives

Upon completion of this lecture the participant will be able to:

- List distinct chemicals injury mechanisms
- List the factors that contribute to injury severity
- Describe initial management principles
- Identify and describe the treatment for special chemical burns, including hydrofluoric acid, phenol, and petroleum exposure

I. INTRODUCTION

There are currently over 500,000 different chemicals in use in the United States, including more than 30,000 chemicals that have been designated as hazardous by one or more regulatory agencies. Approximately 60,000 people seek professional medical care annually as the result of chemical burns.

Chemical burn injuries account for 3% of all burn center admissions (1999-2008). Most chemical burns are unintentional injuries, but chemicals can also be used as a form of assault, abuse or self-harm. There is also an increased risk of chemical exposure to first responders due to illicit drug manufacturing.

Toxic chemicals react with the skin, may not be easily removed, and thereby continue to cause injury for an extended time. The severity of a chemical burn is reduced by prompt recognition and reducing the duration of contact.

Chemicals cause injury in four ways:

- Absorption through the skin and mucous membranes
- Oral Ingestion
- Inhalation
- A combination of any of the three (i.e., a scald burn with chemicals in the water)

Chemical burns are progressive injuries and it is often very difficult to determine the severity early in the course of treatment. The initial appearance of a chemical burn can be deceptively superficial and any patient with a serious chemical burn injury should be referred to a burn center for evaluation and definitive management.

II. FACTORS THAT DETERMINE INJURY SEVERITY

The severity of a chemical injury is related to:

- Chemical composition of the agent and the mechanism of action
- Concentration of the agent
- Temperature of the agent
- Volume or quantity of the agent
- Duration of contact

The chemical composition of the agent (alkali, acid or organic compound) determines its interaction with the skin, and the potential depth of tissue penetration. Temperature affects the rate at which a chemical reacts with the tissue. Concentration and duration of contact influence the depth of injury, and the volume of the chemicals affects the extent of body surface area involved. Immediate removal of affected clothing and on-site irrigation can result in decreased morbidity.

III. CLASSIFICATION

The most common chemicals that causes cutaneous burns fall into one of three categories: alkalis (bases), acids, and various organic compounds. Alkalis and acids are used in cleaning agents, at home and at work. Organic compounds, including petroleum products, can be topically irritating and systemically toxic.

A. Alkalis (pH>7)

Alkalis damage tissue by liquefaction necrosis and protein denaturation; essentially melting any tissue in its path (alkalis react with lipids to form soaps). This process allows for a deeper spread of the chemical and progression of the burn than with acids. Alkalis, including lye and other caustic sodas, may contain the hydroxides, or carbonates of sodium, potassium, ammonium, lithium, barium and calcium. They are commonly found in oven, drain and toilet bowl cleaners, and heavy industrial cleansers like wax stripping agents. Hydrated calcium hydroxide forms the structural bond in cement and concrete. Wet cement, with a pH of approximately 12, can cause a severe alkali chemical burn. Another common alkali is anhydrous ammonia, discussed in Section V, *Specific Chemical Burns*.

B. Acids (pH<7)

Acids damage human tissue by coagulation necrosis and protein precipitation (leather is manufactured when dermis comes in contact with a weak acid). Thus acids cause a leathery eschar of variable depth, which, unlike alkalis, may limit the spread of the injury.

Like alkalis, acids are also prevalent in both the home and in industry. They may be found in many household products. Bathroom cleansers and calcium or rust removers may contain hydrochloric acid, oxalic acid, phosphoric acid or hydrochloric acid. Concentrated hydrochloric (muriatic) acid is the major acidifier for home swimming pools and is used to clean masonry and brick. Concentrated sulfuric acid is utilized in industrial drain cleaners and lead-acid car batteries. Two examples of acidic substances injuries are discussed in the next section.

C. Organic Compounds

Organic compounds cause cutaneous damage due to their solvent action on the fat in cell membranes. Here again, they essentially melt the fatty tissue in their path. Once absorbed, they can produce harmful effects, especially on the kidneys and liver. Many organic compounds, including phenols, creosote, and petroleum products, produce contact chemical burns and systemic toxicity. Phenols are prevalent in a variety of chemical

disinfectants. Petroleum, including creosote, kerosene, and gasoline, is commonly used in the home, in industry, and in recreation, and is discussed below.

IV. TREATMENT PRINCIPLES

A. Personal Protection Equipment and Decontamination

Body Substance Isolation (BSI) must be observed in the treatment of all patients with a suspected chemical injury. All pre-hospital and in-hospital personnel should wear gloves, gown, and eye protection prior to contact with the patient. Remember that patient's clothing often contains remnants of the toxic agent and "off-gassing" may occur. Contaminated clothing can release toxic fumes, exposing first responders to inhalation injury. Failure to take simple precautions can lead to significant provider injury. Don't become a victim!

All chemical burns should be immediately decontaminated while using BSI protection. Decontamination is the process of removing or neutralizing a hazard from the victim to prevent further harm and enhance the potential for full clinical recovery. For all chemical burns, immediate removal of the contaminated clothing (including underwear, gloves, shoes, jewelry and belongings) is critical. All contaminated clothing and belongings should be handled or disposed of according to organizational/institutional protocols to prevent secondary contamination to others.

B. Water Irrigation

Brush any powdered chemical from the skin prior to beginning irrigation. Then, begin continuous irrigation of the involved areas with copious amounts of water. No substance has been proven to be superior to water for initial therapy. Irrigation should be continued from the pre-hospital scene through emergency evaluation in the hospital. Efforts to neutralize the chemical are contraindicated due to the potential generation of heat (an exothermic reaction), which could contribute to further tissue destruction. Irrigation in the hospital should be continued until the patient experiences a decrease in pain or burning in the wound or until the patient has been evaluated in a burn center. Skin pH can be checked by using pH test strips and should be performed before and after irrigation. It may take 30 minutes of irrigation or more, depending on initial skin pH, to achieve a normal skin pH level.

If the chemical exposure is to a large body surface area, caution must be taken to avoid hypothermia. Use warm water for irrigation and maintain a warm environment whenever possible.

C. Primary Survey

Support the "ABCs" (airway, breathing, circulation); volatile chemical agents like ammonia can have profound respiratory effects. It is important to continually evaluate the patient's airway status and to address promptly any evidence of airway compromise. Intravenous access should be obtained for all significant chemical injuries.

Patients who are wearing contact lenses, with or without facial burns, should have the lenses removed prior to development of facial and periorbital edema. Chemicals may also adhere to the lenses, prolonging exposure to the chemical and presenting further problems.

Only after initial therapy has begun, it is helpful to try and identify the causative agent and any associated medical risks, including potential systemic toxicity. However, initial therapy should NOT be delayed while attempts are made to identify the agent involved. A Poison Control Center may be helpful in identifying the active agent in many commercial products (1-800-222-1222 or your local Poison Control Center).

D. Chemical Injuries to the Eye

Alkalis cause chemical eye injuries twice as frequently as acids, and occur primarily in young adults at home, in industrial accidents, and in assaults. Alkalis bond to tissue proteins and require prolonged irrigation to dilute the chemical and stop progression of the injury. Chemical eye injuries cause severe lacrimation, conjunctivitis and progressive injury to the cornea that can lead to blindness. A patient who develops an opaque cornea on exam may have limited prognosis for recovery. Water or saline irrigation is the emergency treatment of choice. Irrigation from the scene to the emergency room is mandatory to minimize tissue damage. In the case of a chemical burn to the eye, consult all an ophthalmologist and continuously irrigate the eye.

The majority of patients presenting with an alkali eye burn will have swelling and/or spasm of the eyelids. To adequately irrigate for extended periods of time, the eyelids must be forced apart to allow flushing of the eye. In the emergency department, irrigation should be performed by placing catheters in the medial sulcus for irrigation with normal saline or a balanced salt solution. This allows for prolonged irrigation without runoff of the solution into the opposite eye. Alternatively, an irrigating catheter (Morgan lens) may be fitted over the globe. Extreme caution should be used when employing this irrigating modality to prevent additional injury to the eye. Patients who wear contact lenses, with or without facial burns, should have the lenses removed prior to development of facial and periorbital edema. Chemicals may adhere to the lenses, prolonging exposure to the chemical and causing further injury. Continue irrigation until the patient has been fully evaluated by a qualified professional. An ophthalmologist in consultation with the burn center should see all chemical injuries to the eye.

E. Pediatric Chemical Burns

Children have thin skin which is easily injured by toxic chemicals. In addition to skin injuries, remember that children are more likely to ingest chemicals than adults. Lye ingestion is especially dangerous and may lead to esophageal perforation. Children are less able to process and eliminate chemicals and the developing brain and organs may be more susceptible to damage associated with chemical injuries. Evaluation and treatment of chemical ingestions are beyond the scope of this course.

V. SPECIFIC CHEMICAL BURNS

Cement Burns: The active ingredient calcium oxide (quicklime) can combine with water to form calcium hydroxide with a pH >12. For instance, cement powder exposure at a construction site can lead to severe alkali burns. Often, the unsuspecting worker is exposed to cement powder in their socks, or around the knees while kneeling at work. Sweat will activate the powder and lead to chemical injury that will evolve over 6–12 hours. The injury site will first be erythematous and may not be recognized as a chemical injury by the patient or a health care provider unless the exposure is obtained during history- taking. Hours later, a full-thickness eschar often develops at the site of exposure.

Anhydrous Ammonia: is commonly used as a fertilizer, industrial refrigerant and in the illicit manufacture of methamphetamine. It is a strong base (pH 12), with the penetrating odor of smelling salts. Anhydrous ammonia is activated when it comes in contact with body moisture. Moist or sweaty areas of the body such as the axilla or groin are frequent sites of serious injury; see examples discussed below.

- Skin Exposure: Exposure causes blistering of the skin. Contact with vaporizing liquid anhydrous ammonia may cause frostbite due to rapid evaporative cooling.
- Eye Irritant: Anhydrous ammonia is an eye irritant that may cause severe eye irritation with corneal injury and permanent vision impairment. Eye injuries require prolonged irrigation of the eye and need to be evaluated by an ophthalmologist.

- Respiratory Effects: Inhalation of anhydrous ammonia may result in serious injury to the entire respiratory tract. Delayed effects may include potentially life-threatening edema of the upper and lower airway. Chemical pneumonitis and pulmonary edema may develop up to several hours after exposure. At high concentrations, laryngeal spasm may occur, resulting in rapid asphyxiation. At lower concentrations, effects are more pronounced in children, elderly, and persons with impaired lung function. Inhalation injuries with hypoxemia and copious secretions may require ventilatory support.

Immediately after exposure, all clothing (including undergarments), shoes, and jewelry should be removed and disposed of according to organizational protocols. The eyes and affected areas should be copiously irrigated with water for at least 30 minutes.

Hydrofluoric Acid (HF): is a corrosive agent used in industry in a variety of ways such as glass etching, the manufacture of Teflon, and to cleanse metals and silicon semiconductors, and for a variety of other uses. It is used in home and industrial cleaners as a rust remover, and is often combined with other agents in these products. HF may cause damage to the skin and eyes, and when inhaled, leads to severe respiratory problems.

While the local effects of HF are limited because it is a weak acid, the fluoride ion is very toxic. Fluoride rapidly binds with free calcium in the blood. Cardiac dysrhythmias and death from hypocalcemia may occur. Higher concentrations cause immediate intense pain and tissue necrosis. Death can occur from hypocalcemia as the fluoride rapidly binds free calcium in the blood. Cardiac dysrhythmias may occur. Exposure to at low concentrations (less than 10 percent) causes severe pain, which does not appear for 6- 8 hours.

After hydrofluoric acid exposure, all clothing including undergarments should be removed and disposed of appropriately. The affected areas should be copiously irrigated with water beginning at the scene for at least 30 minutes.

Once in an appropriate facility, topical calcium gel may be used to neutralize the fluoride (one ampule of calcium gluconate and 100 gm of water soluble lubricating jelly). *This is one of the rare exceptions of a direct neutralizing agent being used to acutely treat a chemical exposure.* The gel is applied with a gloved hand to avoid spread of the fluoride to other body parts or to medical personnel.

This calcium mixture can be placed inside a surgical glove worn by the patient to treat injuries of the hand. Patients who have persistent pain may require intra-arterial infusion of calcium at a regional burn center and require careful monitoring.

Severe pain indicates exposure to a high concentration, which may also cause life-threatening hypocalcemia. In addition to topical calcium, begin cardiac monitoring and place an intravenous catheter in anticipation of calcium gluconate infusion to treat hypocalcemia. Burn center consultation is required, since aggressive calcium infusion and early excision of the wound may be lifesaving.

Phenol Burns: Phenol is an acidic alcohol with poor solubility in water, and is frequently used in disinfectants, chemical solvents, and wood and plastic processing. It damages tissue by causing coagulation necrosis of dermal proteins. Initial treatment consists of copious water irrigation followed by cleansing with 50% polyethylene-glycol (PEG) or ethyl alcohol, which increases the solubility of the phenol in water and allows for more rapid removal of the compound. Of note, diluted solutions of phenol penetrate the skin more rapidly than concentrated solutions, which form a thick eschar via coagulation necrosis.

Petroleum Injuries (Not Due to Flame Burns): Gasoline and diesel fuel are petroleum products that may cause severe tissue damage. Prolonged contact with gasoline or diesel fuel may produce (by the process of de-lipidation) a chemical injury to the skin that is actually full thickness but initially appears to be only partial thickness or second degree. Sufficient absorption of the hydrocarbons can lead to organ failure and even death. It is important to look for petroleum exposure in the lower extremities, the back, and the buttocks after a motor vehicle crash, especially if patient extraction is delayed. Clothing and belongings exposed to the fuel are

potentially flammable, and must be kept away from any ignition source until appropriate disposal.

Systemic toxicity may be evident within 6 to 24 hours, with evidence of pulmonary insufficiency, hepatic and renal failure. Within 24 hours, hepatic enzymes are elevated and urinary output is diminished.

Patients with these injuries require immediate transfer to a burn center.

Toxic Inhalation: Today, many items such as electronics, children's products and upholstered furniture are treated with chemical compounds known as fire retardants. The effectiveness of these compounds to slow the spread of fire is questionable.

Studies are currently being conducted to quantify firefighters' level of exposure to flame retardants and their byproducts through inhalation, absorption and ingestion pathways. These exposures have been linked to a variety of health issues, including an increased risk of certain occupational cancers. Firefighters are likely to have high exposures due to the high concentrations found in smoke, repeated exposures, and the bioaccumulation of these toxins throughout their career. Providers should conduct a thorough respiratory assessment with follow-up treatment as outlined in Chapter 2, *Airway Management and Smoke Inhalation Injury*.

Chemical Warfare Agents: The use of chemicals in warfare has been practiced for hundreds of years. Chemical agents played a major role in the morbidity and mortality associated with World War I and have also been used in terrorist attacks. Chemical warfare agents can be divided into categories like vesicants, such as mustard agents, Lewisite and chlorine gas, and nerve agents, such as Sarin.

These chemicals can produce both cutaneous and systemic toxicity, including pulmonary, hepatic, and neurologic damage.

Treatment of victims of chemical attacks must follow the same principles used for other chemical agent exposures: use of Body Substance Isolation gear, removal of all patient clothing, shoes and jewelry, and copious irrigation with water. Patients with respiratory compromise should be intubated if necessary. Facilities should establish a single area for isolation of contaminated clothing and equipment when treating multiple casualties in order to avoid secondary injury in providers. Agents used in chemical attacks frequently have both short and long-term morbidity and toxicity. Contact the Poison Control Hotline at 800-222-1222 for specific treatment for these chemical agents.

Burns Associated with Illicit Drug Manufacturing, Methamphetamine Fires and/or Explosions: Burns associated with illicit drug manufacturing such as methamphetamine {meth lab} explosions pose additional dangers to all healthcare providers. There are many hazardous chemicals involved. Pseudoephedrine, iodine, red phosphorus, ether, hydrochloric acid, sodium hydroxide and methanol can be used to produce methamphetamine. Unsafe manufacturing procedures, dangerous combinations and storage often result in explosions and fires, placing first responders at even greater risk.

Patients involved in these incidents are sometimes vague about the circumstances of injury, reporting that he/she was involved in a "fire" of some type. Upon evaluation, the pattern of burn injury is inconsistent with the history being reported. The patient may present with serious burns that appear to be thermal/flame burns in appearance but actually are a combination of flame and chemical injuries. Methamphetamine producers may also be chronic users who also manifest severe tachycardia, dehydration, agitation and paranoia. If it is possible the patient was injured in an illegal drug or meth lab explosion, treatment must include appropriate protective clothing by healthcare providers, decontamination of the skin and eyes, proper disposal of contaminated clothing and belongings, and treatment of the thermal injuries.

VI. SUMMARY

Chemical burns constitute a special group of injuries and require referral to a burn center for evaluation and definitive management. Individuals caring for patients exposed to chemical agents must always wear protective clothing to avoid personal contact with the chemical. To limit tissue damage, immediate removal of the agent and contaminated clothing, followed by copious irrigation with water is essential. Irrigation should be continued through transport until patient pain is relieved or the patient is transferred to a burn center. Ammonia, phenol, petroleum, and hydrofluoric acid burns, as well as any chemical injury to the eye, require special consideration. Adherence to basic therapeutic treatment principles can significantly decrease patient morbidity after a chemical injury.

VII. SELECT REFERENCES

Kirkpatrick JJ, Enion DS, and Burd DA. Hydrofluoric acid burns: a review. *Burns* 1995; 21:483-493. (A review of hydrofluoric acid burn physiology and management.)

Wagoner MD. Chemical injuries of the eye: current concepts in pathophysiology and therapy. *Surv Ophthalmol* 1997; 41:275-313. (A review of ocular chemical burn management.)

Smith KJ. The prevention and treatment of cutaneous injury secondary to chemical warfare agents. *Dermatol Clin* 1999;17:41-60. (A review of chemical burn management secondary to warf are related agents.)

Anhydrous Ammonia Material Safety Data Sheet. <http://www.tannerind.com/anhydrous-msds.html>. Accessed November 2011

Hydroflouric Acid Material Safety Data Sheet. <http://www.honeywell.com/sites/docs/D5A9G5Q9KLOG7PPCOK2TL3RYO4HKUBEZU0803114619616.pdf>. Accessed November 2011.

Sykes RA1, Mani MM, Hiebert JM. Chemical burns: retrospective review. *J Burn Care Rehabil.* 1986 Jul-Aug; 7(4):343-7.

Bloom GR1, Suhail F, Hopkins-Price P, Sood A. Acute anhydrous ammonia injury from accidents during illicit methamphetamine production. *Burns.* 2008 Aug;34(5):713-8.

Wang X1, Zhang Y2, Ni L2, You C1, Ye C2, Jiang R2, Liu L2, Liu J2, Han C3. A review of treatment strategies for hydrofluoric acid burns: current status and future prospects. *Burns.* 2014 Dec;40(8):1447-57.

CHAPTER 8

Pediatric Burns



Objectives

Upon completion of this lecture the participant will be able to:

- Describe the injury epidemiology of burns
- Describe pathophysiologic changes that impact burn care
- Discuss pediatric airway management
- Describe pediatric fluid resuscitation requirements
- List signs of non-accidental burn trauma (abuse, neglect)

I. INTRODUCTION

A. Epidemiology

Each year, up to 600 children die from fire and burn injuries in the United States. Fires and burns are the leading cause of unintentional death in the home for children. Children under 5 years of age are at the greatest risk for home fire death and injury. This risk progressively decreases as children age.

For the purpose of the ABLS course, children are defined as between birth and 14 years. About 104,000 children under the age of 14 are burned seriously enough each year to require medical attention in the United States. Scald burns, typically from tap water or food/beverages, are the most common injury mechanism in children up to age 5 who are hospitalized in US Burn Centers (data from the ABA National Burn Repository). Scald burns are also common causes of non-accidental burn trauma (child abuse, neglect). In contrast, flame burns are more common in older children.

B. Burn Injury Prevention in Children

Almost every pediatric burn can be prevented! Although the ABLS course does not teach fire safety and burn prevention, the ABA believes that all healthcare providers play a role in mitigating fire and burn injuries and deaths. Prevention topics include:

- Scald Prevention (tap water, food and beverage)
- Children's Sleepwear Flammability
- Youth/Juvenile Fire-Setting
- Smoke Alarms and Fire Escape Planning for the Family

Fire safety and burn prevention materials are available for all members of the family and can be found at <http://www.ameriburn.org/prevention>. These prevention programs were developed for community education and outreach initiatives, with the support of a grant from the US Fire Administration, Federal Emergency Management Agency, Department of Homeland Security, with funds appropriated by the US Congress under the Assistance to Firefighters Act (Fire Prevention and Safety Grants). There are six comprehensive campaigns (including PowerPoint presentations) available for download on topics including:

- Scald Injury Prevention
- Electrical Safety
- Fire/Burn Safety for Older Adults
- Leaving Home Safely
- Gasoline Safety
- Summer Burn Safety

II. PATHOPHYSIOLOGY

A. Body Surface Area

Infants and young children have a smaller body surface area (BSA) than adults, but are often exposed to the same offending agent (tap water, a hot drink, clothing iron), and thus will sustain a proportionally larger TBSA burn than an adult. Yet, it is important for providers to remember that children have a relatively greater surface area per unit of body weight. For example:

A seven-kilogram child, is only one-tenth the weight of a 70-kilogram adult, but has one-third the body surface area of the adult. This relatively large body surface area results in both a greater surface exposure to the environment and evaporative water loss per unit of weight than adults. Therefore, children can be expected to require more fluid per unit of body weight during resuscitation than adults. By age 14, relative BSA-to-weight ratios are similar to adults.

B. Temperature Regulation

Maintaining normal body temperature in infants and children is also affected by the child's relatively greater BSA-to-weight ratio. Intrinsic heat is generated by shivering. This mechanism is hampered in children less than six months due to limited muscle mass. Temperature regulation for this age group depends more on intrinsic metabolic processes and the environmental temperature control.

C. Skin Thickness and Depth of Burn

Children under age 2 years have thinner skin and are more prone to full-thickness burns at lower temperatures or shorter duration of contact than adults. Skin exposed to temperatures at or below 111 °F (43.5° C) can be tolerated for extended periods of time by infants and adults. In the adult, exposure for 30 seconds at 130°F (54°C) is required to produce burn injury. Because of a thinner dermal layer in children, exposure at 130°F (54°C) for 10 seconds produces a full thickness injury. At 140°F (60°C), a common setting for home water heaters, tissue destruction occurs in five seconds in adults and 3 seconds in children. At 160°F (71°C), a full-thickness burn occurs almost instantaneously in any age group.

Therefore, the Consumer Product Safety Commission (CPSC) recommends setting residential hot water heaters at 120°F (49°C). In contrast, many hot liquids that a child may encounter in the home are much hotter than 106°F (71°C) and cause a great risk for full-thickness (a.k.a. 3rd degree) skin burn.

Approximate temperatures for frequently encountered hot liquids:

102–104°F	38.9–40°C	Spa/Jacuzzi
120°F	48.9°C	Recommended water heater setting
175–185°F	79.4–85°C	Holding temperatures for fast food and coffee
212°F	100°C	Boiling water
300–500°F	148.9–260°C	Grease - frying

III. INITIAL ASSESSMENT AND MANAGEMENT

A. Primary/Secondary Survey and Management

Primary and secondary surveys for children follow the same format as for an adult (described in Chapter 2, *Initial Assessment and Management*), however pediatric patients do have special considerations that will be covered in this chapter.

1. Airway

Fundamental considerations of airway injuries are discussed in Chapter 3, *Airway Management and Smoke Inhalation Injury*. Edema leading to airway obstruction is a major concern in children.

Anatomically, a child's airway is smaller than an adult's, so less edema is needed to develop.

Airway Diameter: (Resistance is proportional to the radius ⁴)

An infant's airway diameter is 4 mm (as opposed to 8 mm in an adult). Thus, with 1 mm edema = resistance will increase 16x. Signs of significant airway edema include hoarseness, increased work of breathing, tachypnea, and ultimately use of accessory muscles, sternal retractions.

Endotracheal intubation is indicated in infants and children with significant respiratory distress or compromise of the airway by edema involving the glottis and upper airway. Younger children or those with large burns are more likely to require intubation due to the smaller diameter of the child's airway and the need for significant fluid volumes during resuscitation. Extensive facial burns also increase the risk of airway edema.

Intubation should be by someone experienced in managing the child's airway due to the anatomic differences between adults and children. The infant's larynx is located more anteriorly and the glottis is more angulated and located more anteriorly than in the adult. The narrowest portion of the airway in the young child is at the cricoid cartilage, not at the glottis. These anatomical differences make intubation by the inexperienced more difficult. The diameter of the child's nares or small finger may be used to gauge the size for an endotracheal tube. An alternative method of estimating the proper endotracheal tube size is to use the equation $(16 + \text{age in years} / 4)$. Choose a cuffed endotracheal tube whenever possible, as airway-tube size mismatch often leads to large cuff leaks after intubation with a cuffless tube. At that point, switching to a cuffed tube (i.e., reintubating the child who has progressive edema) would be very hazardous. Adjusting cuff volume/pressure is much safer overall.

After intubating the child, auscultate and check for CO₂ return to ensure the endotracheal tube is in the correct location and both lung fields are being sufficiently ventilated. Open (or surgical) cricothyroidotomy is rarely indicated in the infant or small child. A large bore needle placed through the cricothyroid membrane may be used as an expedient airway. After intubation, placement of a nasogastric tube is advisable. Infant and children often swallow air when crying, resulting in gastric distension, which can impair ventilation. Nasogastric tube decompression is helpful in eliminating swallowed air.

2. Breathing and Ventilation

Children may have few physical or radiographic signs of pulmonary injury in the first 24-hours post burn. All pediatric patients with suspected inhalation injury should be prepared for immediate transfer to a burn center. In addition, children have more compliant chests and tend to use the abdominal muscles for breathing when compared to adults. It is essential that the practitioner listen for bilateral breath sounds (and preferably obtain a chest x-ray) to confirm proper positioning of the endotracheal (ET) tube prior to transfer. It is critical that the ET tube and NG tube are secured well. A child should have the head of bed elevated at least 30 degrees unless contraindicated by an associated injury or medical condition. Elevation helps open the airway and decreases head and neck edema.

3. Circulation and Cardiac Status

Infants and children with burn injuries $\geq 10\%$ TBSA partial-thickness or any full-thickness component should be referred to a burn center for definitive care. After the airway has been secured, the next immediate measures include establishment of intravenous access and administration of intravenous fluids. Delay in initiation of fluid resuscitation may result in both acute renal failure and higher mortality.

As with adult patients with burns, Lactated Ringer's (LR) is the initial resuscitation fluid of choice. Insert an intravenous cannulae and start resuscitation immediately if the burn clearly appears $> 20\%$ TBSA. During pre-hospital care and the primary survey in the hospital, fluid resuscitation are as follows:

- 5 years old and younger: 125 ml LR per hour
- 6-13 years old: 250 ml LR per hour
- 14 years and older: 500 ml LR per hour (considered as adults)

This fluid should be administered before the patient's weight is obtained and the exact percent TBSA burn is calculated. The earlier the intravenous cannula is attempted, the easier it is to place. If available, ultrasound can be helpful in guiding IV placement. Once shock occurs, finding a vein may be quite difficult. In patients with extensive burn injury, intravenous cannulae can be inserted through burned skin. Large bore peripheral access is preferred. Intraosseous (IO) infusion may be lifesaving in the severely burned child, but is indicated only when intravenous line placement has been unsuccessful. Compartment syndrome in the extremities have resulted from improperly place IO lines. IO lines should be removed as soon as IV cannulation is established. Femoral venous catheterization is the next option for children with massive burns.

Intravenous access by cut-down is occasionally necessary if there is no available access for resuscitation. However, since the cut-down technique eliminates future IV access, it should be the last choice for access.

4. Disability, Neurological Deficit, and Gross Deformity

All children need to be assessed for changes in level of consciousness and neurological status as described in Chapter 2, *Initial Assessment and Management*. Hypoglycemia and hypoxia often present as agitation and confusion in children. It is important to identify and treat the cause of any mental status changes. Altered mental status may have multiple causes and should not be assumed to be related solely to the burn injury.

5. Exposure, Examine and Environment Control

Initial triage of the burn wound should include stopping the burning process, removing all clothing, diapers, jewelry, shoes and socks to examine the entire body and determine the extent of the burn injury. The child should also be examined to assess for any associated or pre-existing injuries.

Then, cover the patient with clean, dry linens. Topical antimicrobial dressings are not indicated prior to transfer. During treatment and transfer, measures to conserve body heat, including thermal blankets, are essential for the infant and young child. Due to the large surface area of an infant or young child's head, the head should be covered to conserve body temperature during treatment and transport of children with large TBSA burns.

B. Secondary Survey

The secondary survey does not begin until the primary survey is completed and after resuscitative efforts are established. A secondary survey primarily entails a complete history and physical examination, which includes an exact determination of percent TBSA burned.

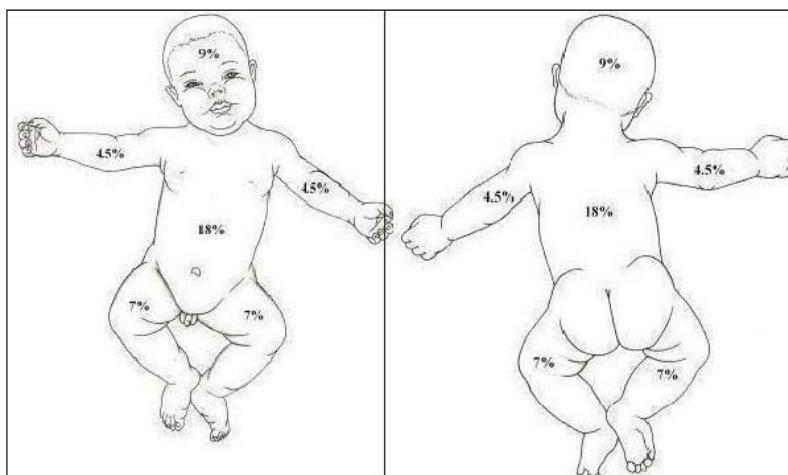
Important elements include:

- Circumstances of the injury and first aid administered
- Complete head-to-toe evaluation of the patient
- Determination of percent TBSA burned
- Fluid calculations using the adjusted fluid rates calculations
- Insertion of lines and tubes
- Lab and X-rays
- Monitoring of fluid resuscitation
- Pain and anxiety management
- Psychosocial support
- Wound care
- Pregnancy test: may be necessary depending on age and circumstances
- Exposure to communicable diseases needs to be determined. Communicable diseases such as chickenpox may complicate recovery and pose a hazard to other patients and healthcare providers

Use the same mnemonic, AMPLET, discussed in Chapter 2, *Initial Assessment and Management* to obtain a history about the child. Special considerations need to be given to the following: the events leading to the thermal injury and any past medical history. These are extremely important in the initial evaluation of an infant and child. One must rely on the caregiver to provide a history, since the child may not be able to provide one. It is important to take into consideration that the story should be consistent with the injury pattern. In some instances, the person providing the information may have contributed in some manner to the child's injury. Follow local protocols when considering the potential for non-accidental trauma (child abuse or neglect). In addition to checking the child's tetanus status, review the health history to determine the immunization status and potential exposure to communicable diseases such as chickenpox.

1. Calculate the Percent TBSA Burned

The "Rule of Nines" is of less value in estimating the size of burn in the young child since the head is relatively larger and the legs smaller. The head and neck represent 18% TBSA, twice that of an adult. Each lower extremity represents 14% TBSA in the infant. As the child ages, each year and a half on the average, subtract 1% from the head and add half to each leg. By the time the child reaches 14 years old, he or she has the same surface and weight ratios as an adult. A Lund and Browder Chart is helpful in detailing the extent of burn and in calculating the percentage

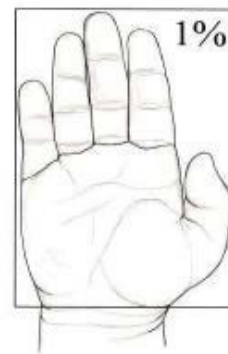


of body at different stages. A copy of the Lund and Browder Chart can be found at the end of Chapter 2, *Initial Assessment and Management*. Only second and third degree burns are used in the calculations for fluid requirement.

2. Estimating Scattered Burn Areas

The size of the patient's hand—including the fingers—represents approximately one percent of his/her total body surface area.

Therefore, the patient's hand-size can be used as a guide to estimate the extent of scattered burns.



3. Adjusted Fluid Resuscitation Rates

Estimated fluid requirements with the adjusted fluid resuscitation rates for burned children recommends $3 \text{ ml} \times \text{kg} \times \% \text{ TBSA burn}$, except for electrical injury, where the rate is $4 \text{ ml} \times \text{kg} \times \% \text{ TBSA burn}$. The goal of resuscitation is to replace fluids lost as the result of the burn injury. Fluid rates should be adjusted hourly for the initial 24 hours, along with close monitoring of urine output.

Initial intravenous resuscitation fluid rate in the infant and child is calculated using the following formula: Total volume (ml) is $3 \text{ ml LR} \times \text{weight (kg)} \times \text{total body surface area (TBSA) second and third degree burns over the first 24-hours post-burn}$:

- Half of the total estimated for the first 8 hours
- Therefore, first 8-hour total fluid volume = $(3 \text{ ml} \times \text{weight (kg)} \times \text{TBSA})$ divided by 2
- Starting fluid rate/hour for the first 8 hours (divide by 8)

Example: resuscitation fluid requirements in a 23 kg child with a 20% TBSA full thickness burn:

- Resuscitation Fluid: LR
- Total resuscitation volume to be given over first 24-hour post-burn: $3 \text{ ml} \times 23 \text{ kg} \times 20 \text{ (TBSA)} = 1380 \text{ ml (LR)}$
- Half of total in the first 8 hours: $1380 \text{ ml} / 2 = 690 \text{ ml}$
- Starting resuscitative fluid rate per hour (divide by 8): $690 / 8 = 86 \text{ ml/hr}$
- Titrate this fluid to maintain a urinary output of 1 ml/kg/hour

It is important to remember that the resuscitation formulas are only estimates. The patient's response to fluid therapy determines the rate and volume of fluid administration. Whereas burn resuscitation was traditionally taught as "administer the first half of estimated needs in the first 8 hours, and the second half in the next 16 hours", this unfortunately has led to insufficient adjustments when resuscitation is performed by non-experienced providers. Instead, this course now emphasizes that hourly titration is far more important than the 8 versus 16-hour concept.

A urinary catheter is needed to monitor the effectiveness of fluid resuscitation. In children weighing up to 30 kg, adequate fluid resuscitation results in an average urinary output of 1 ml/kg/hr. In children larger than 30 kg, adequate fluid resuscitation is assumed with a urinary output of 0.5 ml/kg/hr, the same as in adults. Urine volumes less than or greater than these thresholds require adjustment in fluid resuscitation rates.

Adjuncts to monitoring urine, output include monitoring the sensorium, the blood pH, and the peripheral circulation. Delays in initiating resuscitation, underestimation of fluid requirements, and overestimation of fluid requirements may result in increased mortality. After starting fluids, consult the burn center regarding ongoing fluid requirements.

a. Maintenance Fluid Rates

Maintenance therapy replaces on-going daily losses of water and electrolytes occurring via physiologic processes (urine, sweat, respiration, and stool). It is important to recognize that young children need this replacement during burn resuscitation to preserve homeostasis. Maintenance fluid is required for children weighing up to 30 kg. The fluid of choice is D5 LR. It is calculated and infused over the first 24-hours post-burn. It is not titrated to urine output. Hypoglycemia may develop in infants and young children due to limited glycogen reserves; therefore, blood glucose levels should be closely monitored.

Even though it is useful to think about fluid requirements on a 24-hour basis, if infusing fluids using standard hospital delivery pumps, it is simpler to think in terms of an hourly infusion rate. The 24-hour number is often divided into approximate hourly rates for convenience, leading to the “4-2-1” formula.

- 100 ml/kg/24-hours = 4 ml/kg/hr for the 1st 10 kg
- 50 ml/kg/24-hours = 2 ml/kg/hr for the 2nd 10 kg
- 20 ml/kg/24-hours = 1 ml/kg/hr for the remainder

So, for a 30 kg child, maintenance fluid rate would be:
40 ml/hr + 20 ml/hr + 10 ml/hr = 70 ml/hr of D₅LR

IV. ESCHAROTOMY

Escharotomy in a child with burns may be necessary to relieve elevated pressures in the extremities, chest or abdomen. Vascular impairment occurs with circumferential burns of the limbs. Deep tissue pain, paresthesia, pallor, and pulselessness are classic manifestations, but are frequently late in appearance. The chest wall is more compliant in children than in adults. Consequently, edema and restrictive effects of a circumferential chest wall burn may progressively exhaust the child’s breathings. In that scenario, chest wall escharotomy will be required to restore adequate breathing. Incisions along the anterior axillary lines must extend well on to the abdominal wall and be accompanied by a transverse costal margin bridging incision. Abdominal compartment syndrome may also occur in the child. This syndrome is recognized by decreasing urine output despite aggressive resuscitation, and occurs in the face of hemodynamic instability and increased peak inspiratory pressures. Judicious fluid titration helps avoid this problem. However, escharotomy is almost never required prior to burn center transfer, (Chapter 5, *Burn Wound Management*) unless there is a delay in transport greater than 12 hours after injury. Consult the nearest burn center when escharotomy is being considered as the margin for error is extremely small in children.

V. NON-ACCIDENTAL BURN TRAUMA (ABUSE, NEGLECT)

The potential for non-accidental burn trauma (child abuse, neglect) must always be considered, particularly in young children, and in all vulnerable children (for instance those with chronic disability or developmental delay). The key strategy is to match the skin burn pattern with the description of the circumstances of injury.

Another important aspect of the history of injury in a child is to match the burn with the developmental age of the child. Infants are unable to escape a hot source and thus develop deep injuries. Toddlers tend to explore their environment with their hands and mouths. The reflex to pull away after contacting a hot surface has not yet been developed, so they tend to sustain burns to the palm and fingers as they grab or touch items. Toddlers may also sustain burns to the oral commissure when they chew on electric cords. The period of toilet training is the period of high risk for “dip” burns associated with child abuse. As some children mature they increase their high-risk behavior and tend to suffer flame burns as they play with matches, lighters and/or accelerants. Some teenagers are at risk for burns from peer pressure, social media or other outside influences and in some instances, suicide attempts.

Key aspects of the circumstances of the injury and health history are important if child abuse or neglect is suspected. If possible, question pre-hospital care providers about scene observations. Query the child's pediatrician in addition to the caregiver to determine an accurate health history if possible. Reporting of suspected child abuse is mandatory in every state in the United States. Even if the child is being transferred to a burn center, the initial hospital should initiate the reporting process. Documentation, including photographs, is essential.

In order to detect such an event, the examining physician and staff must have a high level of suspicion, which should be triggered when:

- The pattern of injury is not compatible with the history given
- The history changes between individuals or over time
- The history is inconsistent with the child's developmental level
- A young sibling is blamed for the burn
- The caregiver was absent at the time of injury
- The lines of demarcation between uninjured and burned skin are straight or smooth or when there is a "glove" or "stocking" distribution to the burn pattern
- There is a delay between burn injury and the seeking of treatment
- The caregivers are more concerned about themselves than the child
- The child appears unusually passive when subjected to painful procedures
- There are burns of different ages
- There are other forms of injury
- The siblings have similar injuries
- The child has signs of neglect such as lack of cleanliness, malnutrition, poor dentition
- There is a history of previous Child Protective Services (CPS) reports

VI. CRITERIA FOR REFERRAL TO A BURN CENTER

Infants and children with full-thickness burns, burns of the face, hands, feet, genitalia or perineum, as well as those with inhalation, electrical or chemical injuries should be transferred to a burn center. All pediatric patients with partial thickness burns of ten percent or more total body surface area, or with any full-thickness component should be referred to a burn center for definitive care. Also, burned children in hospitals without qualified personnel or equipment for the care of children should be transferred (For a complete listing of the criteria for referral to a burn center, see Chapter 9, *Stabilization, Transfer and Transport.*)

VII. SUMMARY

Emergency management of the pediatric burn patient requires an individual care plan. Consideration must be given to the age-specific relationship between body surface area and body weight when calculating fluid replacement. Knowledge of unique physiology and pathophysiologic changes with burns are important in planning therapy. Main factors that influence the care of the child with major burns are:

- Major airway differences compared to adults
- Impaired ability to maintain temperature control
- Thinner skin, which predisposes the child to deeper injury than in adult, given a similar duration of contact

- Importance to initiate fluid resuscitation immediately
- Add D₅LR as maintenance in children up to 30 kg in weight for the first 24-hours post-burn
- Be aware of possible non-accidental trauma (child abuse, neglect)

VIII. SELECT REFERENCES

CDC Childhood Injury Report, 2000-2006. Accessed via: http://www.cdc.gov/safecild/child_injury_data.html, on 10/10/16.

Barrow RE, Jeschke MG, Herndon DN. Early fluid resuscitation improves outcomes in severely burned children. *Resuscitatio* 2000;45:91-96.

D'Souza AL, Nelson AG, McKenzie LB. Pediatric burn injuries treated in US emergency departments between 1990-2006. *Pediatrics* 2009;124:1424-1430.

Palmieri TL, Taylor S, Lawless M, et al. Burn center volume makes a difference for burned children. *Pediatr Crit Care Med* 2015; 16:319-324.

Benjamin D, Herndon DN. Special considerations of age: the pediatric burned patient. In Herndon D, Ed. *Total Burn Care*, 4th Ed. New York: WB Saunders; 2002; 427-38.

Sheridan RL. The seriously burned child: resuscitation through reintegration— part 1 *Cur Prob Ped*. 1998; 28:105-27 (part 2) 1998; 28:139-67. (A comprehensive review of burn injury management in children.) National Fire Protection Association www.nfpa.org

Mortiz AR, Herriques FC Jr. Studies of thermal injuries: II The relative importance of time and surface temperature in the causation of cutaneous burns. *AM J Pathol* 1947; 23:659-720.

Delgado J, Ramirez-Cardich ME, Gilman RH, et al. Risk factors for burns in children: crowding, poverty and poor maternal education. *Inj Prev* 2002; 8:38-41. <http://www.safekids.org/our-work/research/fact-sheets/fire-safety-fact-sheet.html>

American Burn Association. Prevention Information developed under a grant from the US Fire Administration, Federal Emergency Management Agency, <http://www.ameriburn.org/prevention>.

CHAPTER 9

Stabilization, Transfer and Transport



Objectives

Upon completion of this lecture the participant will be able to:

- Review important steps in pre-transfer stabilization
- Identify American Burn Association (ABA) referral criteria
- Describe the transfer procedures

I. INTRODUCTION

The patient with a compromised airway, electrical, chemical or major thermal injury requires immediate assessment and stabilization. Hospital personnel must complete a primary and secondary survey and evaluate the patient for potential transfer to a burn center. Burn injuries may be a manifestation of multiple trauma and the patient must be evaluated for associated injuries. All procedures employed must be documented to provide the receiving burn center with a transfer record that includes a flowsheet. Transfer agreements should exist to ensure expeditious transfers.

II. STABILIZATION IN PREPARATION FOR TRANSFER TO A BURN CENTER

It is essential that the patient be properly stabilized prior to transfer. The principles of stabilization are implemented during the primary and secondary survey, and are briefly summarized again here.

A. Body Substance Isolation

Healthcare providers should take necessary measures to reduce their own risk of exposure to potentially infectious substances and/or chemical contamination. The level of protection will be determined by patient presentation, risk of exposure to body fluids and airborne pathogens and/or chemical exposure.

B. Primary Survey

During the primary survey, all life and limb-threatening injuries should be identified and management initiated.

1. Airway Maintenance with Cervical Spine Protection

The airway must be assessed and management initiated immediately. One hundred percent oxygen per non-rebreather mask should be applied to all patients with serious burns and/or suspected inhalation injury. Intubation should be performed when indicated. Protect the cervical spine with in-line immobilization if cervical spine injury is suspected based on injury mechanism (i.e., fall, motor vehicle crash) or in patients with altered mental status.

2. Breathing and Ventilation

Ventilation requires adequate functioning of the lungs, chest wall, and diaphragm. Circumferential full thickness burns of the trunk and neck, and the abdomen in children may impair ventilation and must be closely monitored. It is important to recognize that respiratory distress may be due to a non-burn condition, such as a preexisting medical condition, or a pneumothorax from associated trauma.

3. Circulation and Cardiac Status

Major thermal injury results in a predictable shift of fluid from the intravascular space. Assessment of circulation includes evaluation of blood pressure, pulse rate, and skin color (of unburned skin). Baseline vital signs are obtained during the primary survey and are monitored throughout care and transport. Prior to calculation of TBSA burn, the fluid infusion rate should be based on patient age:

- 5 years old and younger: 125 ml LR per hour
- 6-13 years old: 250 ml LR per hour
- 14 years and older: 500 ml LR per hour (considered as adults)

Frequent assessment of the peripheral circulation, especially in areas of circumferential extremity burns, should be performed.

4. Disability, Neurological Deficit, and Gross Deformity

Typically, the patient with burns is initially alert and oriented. If not, consider associated injury, carbon monoxide/cyanide poisoning, substance abuse, hypoxia, or pre-existing medical conditions. Assess for any gross deformity that may be due to an associated trauma.

5. Exposure and Environment Control

Expose, completely undress the patient and examine the patient for major associated injuries and maintain a warm environment.

The burning process must be stopped during the primary assessment. Remove all clothing, jewelry/body piercings, contact lenses, shoes, and diapers to complete the primary survey. If any material is adherent to the skin, stop the burning process by cooling the adherent material, cutting around it and removing as much as possible. For chemical burns, remove all clothing and foot coverings, brush dry chemicals off the patient and then flush with copious amounts of running water.

Maintaining the patient's core body temperature is a priority. The EMS transport vehicles and treatment rooms should be warmed. As soon as the primary survey is completed, the patient should be covered with dry sheets and blankets to prevent hypothermia.

C. Secondary Survey

The secondary survey does not begin until the primary survey is completed and after resuscitative efforts are established. A secondary survey primarily entails:

- History

- Complete head-to-toe evaluation of the patient
- Determination of percent TBSA burned
- Adjusted fluid calculations
- Insertion of lines and tubes
- Lab and X-rays
- Monitoring of fluid resuscitation
- Pain and anxiety management
- Psychosocial support
- Wound care

1. History

2. Using the acronym AMPLET obtain the following history:

A: Allergies. Drugs and Environmental

M: Medications: Prescription, over-the-counter, herbal and home remedies

P: Past Medical History: Previous illnesses or injuries, potential for pregnancy

L: Last meal or drink

E: Events/environment relating to incident. Suspicion of abuse or neglect? Intentional or unintentional injury?

T: Tetanus and childhood immunizations

3. Tetanus is considered current if given within the past five years. It is also important to document if a child is up-to-date with his/her childhood immunizations.

4. Complete Physical Exam

This includes an assessment of burn extent (TBSA) and subsequent adjustment of the IV fluid rate. During the secondary survey the Total Body Surface Area (TBSA) burn is determined using the Rule of Nines. Use the following formulas to derive the adjusted fluid rate:

Category	Age and weight	Adjusted fluid rate
Flame or scald	Adults and older children (≥ 14 years old)	2 ml LR x kg x % TBSA
	Children (<14 years old)	3 ml LR x kg x % TBSA
	Infants and young children (≤ 30 kg)	3 ml LR x kg x % TBSA Plus D_5LR at maintenance rate
Electrical Injury	All ages	4 ml LR x kg x % TBSA Plus D_5LR at maintenance rate for infants and young children

The adjusted IV fluid rate is then titrated as needed to maintain adequate urine output. The hourly urine output goals are:

- Adult thermal and chemical burns: 30–50 ml/hour
- Adults with pigment in urine: 75-100 ml/hour until urine clears
- Children: 1 ml/kg/hour

5. Vital Signs

Vital signs are monitored and documented at frequent intervals.

6. Nasogastric Tube

Insert a nasogastric tube in intubated patients, otherwise monitor spontaneously breathing patients with burns greater than 20% TBSA for signs/symptoms of nausea and vomiting.

7. Assessment of Extremity Perfusion

Frequently re-assess perfusion of the extremities, and elevate affected extremities to decrease swelling. Doppler assessment may be necessary if pulses are difficult to palpate.

8. Pain and Anxiety Management

Burn pain may be very severe and needs to be mitigated. Morphine (or other opioid equivalents) are indicated for pain control. Small, frequent doses should be administered through the IV route.

9. Burn Wound Care

All burn wounds should be covered with a clean dry sheet. A blanket may be needed to maintain body temperature. It is imperative that the patient remains warm during stabilization and transfer. Do not delay transfer for debridement of the wound or application of an antimicrobial ointment or cea.

10. Documentation

Transfer records need to include information about the circumstances of injury as well as physical findings and the extent of the burn. A flow sheet to document all resuscitation measures must be completed prior to transfer. All records must include a history and document all treatments and medications given prior to transfer. Send copies of any lab, X-ray results and Advance Directives/Durable Power of Attorney for Health Care if applicable.

III. ABA BURN CENTER REFERRAL CRITERIA

The American Burn Association (ABA) has identified the following injuries as those requiring referral to a burn center. A burn center may treat adults, children, or both. Burn injuries that should be referred to a burn center include:

- Partial thickness burns of greater than 10% total body surface area.
- Burns that involve the face, hands, feet, genitalia, perineum or major joints.
- Third-degree burns in any age group.
- Electrical burns, including lightning injury.
- Chemical burns.
- Inhalation injury.
- Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality.
- Any patient with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient's condition may be stabilized initially in a trauma center before transfer to a burn center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.

- Burned children in hospitals without qualified personnel or equipment for the care of children.
- Burn injury in patients who will require special social, emotional or rehabilitative intervention.

Remember that young children and older adults are less tolerant of burn injuries. The burn team approach, combining the expertise of physicians, nurses, psychologists, dieticians, social workers, and therapists improves the outcomes of individuals with major burn injuries.

IV. TRANSFER PROCESS

Provider to provider hand-off is essential to ensure that the patient's needs are met throughout every aspect of the transfer. The referring provider should provide both demographic and historical data, as well as the results of his/her primary and secondary assessments.

The burn center and the referring provider, working in collaboration, should make the decision as to the means of transportation and the required stabilization measures. Personnel trained in burn resuscitation should conduct the actual transport. In most cases and subject to state law, the referring physician maintains responsibility for the patient until the transfer is completed.

A transfer agreement between the referring hospital and the burn center is desirable and should include a commitment by the burn center to provide the transferring hospital with appropriate follow-up. Quality indicators will provide continuing education on initial stabilization and treatment of burn patients.

V. SUMMARY

Patients with compromised airways, electrical, chemical or thermal injuries that meet the ABA Criteria for Burn Center Referral should be assessed, stabilized, and promptly transferred to a burn center. Burn Center personnel must be available for consultation and may assist in stabilization and preparation for transfer.

VI. SELECT REFERENCES

Brown RL, Greenhalgh DG, Kagan RJ, Warden GD. The adequacy of limb escharotomies-fasciotomies after referral to a major burn center. *J Trauma* 1994;37(6):916-20 (This article underscores the importance of early transfer in cases of severe extremity burns, as compartment problems and inadequate decompression often lead to major sequelae.)

Sheridan R, Weber J, Prelack K, et al. Early burn center transfer shortens the length of hospitalization and reduces complications in children with serious burn injuries. *J Burn Care Rehabil* 1999; 20:347-50. (Demonstrates that delay in transfer of seriously burned patients compromises outcome, increases length of hospitalization and increases costs.)

Vestrup JA. Interinstitutional transfers to a trauma center. *Am J Surg* 1990; 159:462-5. (Reviews protocols for transfer of seriously injured patients.)

Klein MB, Nathens AB, Heimbach DM, Gibran NS. An outcomes analysis of patients transferred to a regional burn center: transfer status does not impact survival. *Burns* 2006; 32(8):940-5 (Indicates that major burns initially stabilized and transferred have equally good outcomes to those admitted directly from the field.)

Romanowski, KS, Palmieri TL, Sen S, Greenhalgh DG. More than one third of intubations in patients transferred to burn centers are unnecessary: proposed guidelines for appropriate intubation of the burn patient. *JBCR* 2016; 37(5):e409-14 (This paper highlights the current tendency for referring providers to intubate more burn patients than is clinically necessary.)

CHAPTER 10

Burn Disaster Management



Objectives

Upon completion of this lecture, the participant will be able to:

- Define burn mass casualty and triage
- Understand the role of burn centers in triage and definitive care
- Identify treatment and transfer priorities

I. BURN MASS CASUALTY INCIDENT/DISASTER

A. Definitions

A mass casualty incident (MCI) is any situation in which the needs of victims exceed the abilities of available medical resources to manage each patient. A disaster occurs when imminent threat of widespread injury or loss of life results from man-made or natural events exceeding the capacity of a local agency. A burn mass casualty incident (BMCI) is a disaster that includes patients with burn injuries. For the remainder of this chapter, the terms “BMCI” and “burn disaster” will be used interchangeably.

A BMCI can further be defined as any catastrophic event in which the number of burn victims exceeds the capability (resources) of local or regional burn centers to provide optimal burn care. Extensive burns require vast amounts of resources (personnel, equipment and time). Capability includes availability of burn beds, burn surgeons, burn nurses, other support staff, operating rooms, equipment, supplies, and related resources. Capability should not be confused with burn center surge capacity, which is defined as 1.5 times the number of available burn beds in a burn center. Surge capability is different at each burn center, may be seasonal, and will vary from week to week or possibly even day to day, based on the number of patients being treated prior to disaster.

B. Burn Disasters Often Exceed Local and Regional Capability

Events that result in multiple burn injuries can occur in any community. They occur anywhere people congregate: schools, churches, housing units, dormitories, workplaces and entertainment establishments. They can also occur as a result of natural disasters such as wild land fires, earthquakes, etc. Each community has its own high-risk locations.

On September 11, 2001 terrorist attacks in New York and Washington, DC resulted in a large numbers of patients with burn injuries in a short period of time. Almost immediately each local burn center experienced a surge of patients, and in the weeks that followed were challenged with the demands of ongoing care for those burn survivors. In addition to surface injuries, many patients also had inhalation injuries.

The number of injuries in structure fires and explosions also frequently exceeds the care capabilities of local burn centers. The 2003 Rhode Island Station Nightclub Fire involved over 400 people inside. Of the 215 people injured, 47 were admitted with burns whereas 28 had inhalation injuries. The 2015 Taiwan Formosa Fun Coast explosion resulted in nearly 500 injured individuals who received care in over 50 hospitals across Taiwan.

C. Definitive Care of Burn Injuries Requires Highly Specialized and Extensive Care

Burn injuries are unlike other trauma injuries, often requiring a lengthy course of treatment. Burns average one day of hospitalization per percent total body surface area (TBSA) burned. For example, the average length of stay for a burn patient with 50% TBSA can equal 50 days. Thus, definitive care of burn patients with a major burn injury should take place at a burn center.

In the United States, under usual conditions, severe burns are immediately referred to the nearest burn center for care. Since a relatively small number of patients would quickly overwhelm any burn center, this referral paradigm may be detrimental for disaster response. Thus it is imperative that local/regional disaster planning consider the resources of the burn center(s). Patients injured in a burn mass casualty incident may not receive their burn care at the nearest burn center but rather at one located within the region. Non-burn centers such as trauma centers and general hospitals may be called upon to stabilize burn MCI patients for up to 72 hours while awaiting sufficient resources to transport patients to more definitive care.

D. Burn Centers Will Play a Unique Role in Burn Disasters

Burn patients, as demonstrated in this course, have a unique pathophysiologic response to their injury and require injury-specific treatment. Early in a burn MCI, burn centers will assist with patient triage, and transport decisions. Following initial stabilization, the role of burn centers is to provide definitive care given their expertise in burn physiology, operative management and rehabilitation.

Burn centers constitute a valuable and limited resource, with fewer than 2000 dedicated burn beds in the United States. Approximately 60% of U.S. burn beds are located within verified burn centers. Verification is a rigorous joint review program of the American Burn Association (ABA) and the American College of Surgeons (ACS) designed to ensure burn centers have the resources for the provision of optimal burn care from the time of injury through rehabilitation. To find the closest verified burn center in your area visit <http://ameriburn.org/public-resources/find-a-burn-center/>

All healthcare providers should be aware of the potential for multiple burn injuries in order to plan, prepare, and practice community wide drills. When developing a facility or regional disaster plan, it is imperative to consider individual burn center mass casualty response policies.

II. TRIAGE PLAN

A. Definition

Triage is the process of sorting a group of patients to determine their immediate needs for treatment. Patients are sorted into treatment categories based on type of injury or illness, injury severity, availability of medical facilities, and the likelihood of survival. The goal of triage is to maximize survival for the greatest number of individuals utilizing available resources. Triage must be based on medical necessity. In a disaster, triage takes on increased importance due to limited resources and burn treatment expertise.

Survivability of the injured depends on an organized on-scene triage. Many local and state agencies already have established systems for on-scene triage. It is imperative that everyone involved in disaster response be familiar with this methodology, including how and when it is activated and, most of all, what criteria will be utilized to make decisions. Exposure to any triage system should occur before, and not during a disaster. Hospital personnel must have a working knowledge of the pre-hospital triage system. It is also helpful for personnel to be familiar with the incident command system (ICS). Incident command is a standardized system used to establish command, control and coordination of a disaster situation, especially when multiple agencies are involved. It is implemented to make provisions for rapid triage and transport.

Primary triage occurs at the disaster scene or at the emergency room of the first receiving hospital. Primary triage should be handled according to local and state mass casualty disaster plans. In a BMCI, the scene incident commander (IC) should be coordinating with a regional command system that includes one (or more) regional burn centers to assist with patient triage, referral and transport priorities. Under federal bioterrorism legislation, the Office for the Assistant Secretary for Preparedness and Response (ASPR) of the US Department of Health and Human Services (DHHS) recommends that state disaster plans incorporate burn centers. Government and American Burn Association resources will be critical in coordinating the evaluation and transfer of burn patients from the local area to regional burn resource locations for definitive care (secondary triage).

B. Scene Safety

The scene at any disaster is often hectic and seemingly out of control. Arrival of first responders is a first step in bringing order to chaos. The first priority of scene responders must be for their own well-being. Decisions pertaining to use of personal protective equipment and the ability to deliver immediate care will be determined by the hazardous elements causing the problem. No one should ever place himself or herself in danger when there is little chance for improving the status of the situation. The incident management team must conduct a risk management assessment for circumstances at hand. All individuals operating within the confines of the emergency must understand that foolhardy acts may have an impact on themselves and others, and can affect the overall outcome of an incident. Preparation, practice and patience lead to a more successful outcome.

C. Triage System and Tags

Color-coded tags are used during a mass casualty incident to triage who should/should not receive immediate care. Each state or jurisdiction may have their own version however; the basic principles are the same. Hospital personnel should be familiar with the triage tags used in your locale to facilitate understanding of the pre-hospital assessment and care provided prior to hospital arrival. In order of priority, there are four triage categories:

Immediate/Red: immediate treatment needed to save life, limb, or sight (highest priority). These patients have a higher probability of survival with immediate treatment.

Delayed/Yellow: less urgent than immediate, but still potential for life or limb threatening issues. These patients are not in danger of going into immediate cardiac or respiratory arrest. Treatment may be temporarily delayed in order to care for more critical patients.

Minimal/Green: outpatient treatment and returned to duty/home. These are patients who are ambulatory, alert and oriented and have no life- or limb- threatening injuries. (Note: These “walking wounded” may initially refuse care at the scene, then present at the local hospital for treatment compromising capability assessments).

Expectant/Black: poor prognosis even with treatment (lowest priority). Treatment may need to be denied to patients with severe injuries who, under more favorable circumstances, are theoretically salvageable. In this way, the greatest number of patients benefit from the limited care and resources available.

D. Burn Survivability

There are three critical factors in determining patient survivability:

- TBSA burn size
- Age
- Presence of inhalation injury

Burn size is the most readily identified factor in determining the potential survivability of patients with burns. Accurate assessment of % TBSA burn is critical for appropriate application of triage criteria, especially in a disaster. Health care providers who are inexperienced with calculating this may wish to consider implementing one or more of the following strategies, if staffing allows:

1. Two independent providers calculate % TBSA burn. If the difference is greater than 5%, recalculate.
2. Have one provider calculate % TBSA burn. A second person calculates unburned (or superficial, first degree burn) areas. If the sum is different than 95-100%, recalculate.
3. Use digital photographs and coordinate consultation with the nearest regional burn center via the scene incident commander when possible.

In general:

- Patients with burns do not develop decompensated shock immediately after injury, unless there are associated injuries or medical conditions in addition to the burn.
- Patients older than two years old and younger than 60 years old will fare better.
- Patients with inhalation injury will fare worse than those without inhalation injury.
- Some patients will have to be treated as “expectant”. Definitive treatment must be delayed or withheld for expectant patients in order to adequately treat those with a better chance of survival.

Other factors including presence of associated injuries and/or pre-existing health status have an impact on resources (i.e., personnel, supplies, equipment and time) required for prioritizing patient care. Survivability thresholds will depend on the magnitude of the event and the resources available locally, regionally and nationally. Thus, situation awareness and good communication are essential during initial triage. The scene incident commander will relay reliable information to the regional command center, and work in conjunction with the local burn center in this response phase. The following grid provides an example of triage decisions that may become necessary in the setting of overwhelmed resources, or in austere conditions, where altered standards of care need to be instituted. This survivability grid utilizes the same 4-color code scheme used for EMS personnel. Survivability will differ if the patient has also sustained an inhalation injury.

Age, in years	Percent TBSA burn size									
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	≥ 90
0-1.9	Green	Green	Yellow	Yellow	Yellow	Red	Red	Red	Grey	Grey
2-4	Green	Green	Yellow	Yellow	Yellow	Red	Red	Red	Grey	Grey
5-19	Outpatient			Delayed		Yellow	Immediate		Grey	Grey
20-29	Green	Green	Yellow	Yellow	Yellow	Red	Red	Red	Grey	Grey
30-39	Green	Green	Yellow	Yellow	Red	Red	Red	Grey	Grey	Grey
40-49	Green	Green	Yellow	Red	Red	Red	Red	Grey	Grey	Grey
50-59	Green	Green	Yellow	Red	Red	Grey	Grey	Grey	Grey	Grey
60-69	Green	Yellow	Red	Red	Low survival, may opt for expectant management					
≥ 70	Green	Red	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey

Depending upon the size and scope of an incident, local resources and number of burn centers, response to the burn disaster situation may be a tiered, staged response:

Stage I Burn Disaster

Local burn center resources handle a Stage I burn disaster. The strategy of management revolves around local/regional burn center. In general, incident command will be established and a needs assessment will be carried out. Previously established local burn management protocols will be activated, with a coordinated response by local and regional health care facilities with the burn center.

Stage II Burn Disaster

A Stage II burn disaster overwhelms local but not regional burn resources. Planning will involve a regional network of burn centers. Response to a Stage II burn disaster will require a unified command across several medical operations on a regional basis. The local burn center serves as the burn triage facility and assists with regional burn resource management.

Stage III Burn Disaster

A Stage III burn disaster overwhelms the regional resources and will require response from a national network of burn centers, coordinated with a federal response. This situation is truly a catastrophe. Regional unified command must request national and federal assistance.

During the entire triage process, basic level care is continued and advanced life support is initiated as needed. The success of primary and secondary triage relies on immediate availability of patient transportation to definitive care facilities. As such, regional medical transport resources should also be part of regional MCI response plans. The ABA/ABLS recommendations are to triage major burns to a burn center within the first 72 hours if at all possible. Secondary triage may occur from burn center to burn center (regional or national transfer). Transfer to a verified burn center is preferable.

III. BURN MCI PRIMARY AND SECONDARY SURVEY

“A. and B.” Airway, Breathing and Ventilation

Inhalation injury alone jeopardizes survival. Airway edema increases significantly after fluids are started. Therefore, it is critical that resources are available to assess and manage the airway prior to starting large volumes of fluid resuscitation. It is important for pre-hospital providers and transport teams to know what resources may be available at receiving hospital(s). In many rural areas the number of available ventilators is severely limited. If more patients are intubated than there are ventilators, additional personnel will be required to provide manual ventilation. Intubate patients based on assessment, need and resources. Patients placed in the Expectant category should not be intubated. Oxygen may be administered to only provide comfort and prevent air hunger.

“C.” Circulation and Cardiac Status

ABLS teaches that ideally, two large bore IVs be inserted in patients with burns, and resuscitated with LR. IV priority should be given to patients with burns > 20% TBSA and/or with associated trauma with blood loss. When supplies of LR are depleted, fluid resuscitation may continue using other crystalloids or colloids. Unless blood loss has occurred, or the patient is extremely anemic, packed red blood cells should not be given.

Oral resuscitation should be considered for awake and alert pediatric patients with burns < 10% TBSA, and adult patients with burns < 20% TBSA. Offer flavored sport drinks and/or an oral electrolyte maintenance solution. Have the patient or family monitor the quality and quantity of urinary output and watch for signs of dehydration. For patients placed into the Expectant category, IVs may be started for administration of medication to manage pain and anxiety, only if resources allow. Large volumes of fluid should not be administered. Excessive fluids result in decreased circulation and increased pain due to edema and constriction from circumferential burns, increased respiratory effort due to airway edema and/or constriction of circumferential burns of the torso or neck.

“D.” Disability, Neurological Deficit, and Gross Deformity

Patients with burns are often alert and oriented at the scene, and at the first receiving hospital. Patient identification and history should be performed during this timeframe, and definitely prior to intubation. Remember that all burn patients are trauma patients first. Depending on the mechanism of injury, initial assessment should include other potential injuries such as brain and spinal cord injuries, non-burn wounds, or fractures.

“E.” Exposure and Environmental Control

Maintaining a warm environment and core temperature in a mass casualty incident can be a challenge. When blanket supplies are depleted, be creative. Patients may be wrapped in plastic wrap or aluminum foil for insulation and warmth. Consider covering a patient’s head, especially a child, to further maintain body temperature.

In a MCI, wound care supplies may also be limited. Burns do not need to be dressed with sterile dressings. For patients who will not be transferred, or have a delayed transfer (longer than 24 hours) to a burn center, burn, wounds may alternatively be dressed with clean, cotton diapers cut into appropriate size wraps. Clean cotton tee shirts make excellent dressing substitutions for torso, shoulder, upper arm or axilla burns. White cotton gloves may serve as dressings for hand burns; socks work well to dress foot burns. In some instances burn centers or medical coordination centers may have supply caches available for supplemental wound care. When developing plans for a burn MCI in your locale, contact the burn center in your area for more information, and to ensure both plans are compatible.

“F.” Pain Management

Burn pain is excruciating and patients will require in aggregate large doses, opioids and some sedatives. Patients with burns less than 20% TBSA can be managed with oral or intramuscular (IM) narcotics and anxiolytics, if IVs are in short supply. For additional more detailed information on management of burn patients in a disaster, the American Burn Association has developed Guidelines For Burn Care Under Austere Conditions. Guidelines are located on the ABA web site; <http://ameriburn.org/quality-care/mass-casualty/>

IV. SUMMARY

Burn casualties need immediate triage and prompt initiation of resuscitation of patients with the highest expectation of survival. Field triage officers, pre-hospital personnel, trauma centers, general hospitals and burn centers will all play a key role in a major burn MCI. Whereas initial resuscitation and stabilization can be achieved in the field and at non-specialized centers, definitive care of burn injuries require vast resources only available at burn centers. To be effective, disaster planning should fully integrate burn centers into the process. Appropriate primary and secondary triage, stabilization and resuscitation and ultimate transfer to proper burn facilities using available regional and national support will help achieve best patient outcomes.

V. SELECT REFERENCES

American College of Surgeons. Bulletin. Civilian Hospital Response to Mass Casualty Events. 2007;92(7):6-20.

Staudenmayer K, Schechter W, Saffle J, et al. Defining the ratio of outcomes to resources for triage of burn patients in mass casualties. J Burn Care Rehab 2005; 26(6):478-482.

ABA Board of Trustees and the Committee on Organization and Delivery of Burn Care. Disaster Management and the ABA Plan. J Burn Care Rehab 2005;26(2):102-106.

Barillo DJ, Wolf S. Planning for burn disasters: lessons learned from one hundred years of history. J Burn Care Res 2006;27(5):622-634.

Barillo DJ. Burn disasters and mass casualty incidents. J Burn Care Res 2005;26(2):107- 108.

2001: a burn center's experience. J Burn Care Rehab 2005; 26(2):109-116.

Yurt RW, Bessy PQ, Bauer GJ, et al. A regional burn center's response to a disaster; September 11, 2001 and the days beyond. J Burn Care Rehab 2005; 26(2):117-131.

National Disaster Medical System (NDMS). <http://www.hhs.gov/aspr/oepo/ndms/index.html>

Emergency Management Assistance Compact. <http://www.emac.org>

Barillo DJ. Planning for burn mass casualty incidents. J Trauma 2007; 62(6 Suppl); S68.

Barillo DJ, Dimick AR, Cairns BA, et al. The Southern Region burn disaster plan. J Burn Care Res 2006; 27(5):589-595.

Cairns BA, Stiffler A, Price F, et al. Managing a combined burn trauma disaster in the post-9/11 world: lessons learned from the 2003 West Pharmaceutical plant explosion. J Burn Care Rehabil 2005;26(2):144-150.

Klein MB, Kramer CB, Nelson J, et al. Geographic access to burn center hospitals. JAMA 2009; 302(16):1774-1781.

Wetta-Hall R, Berg-Copas GM, Cusick Jost J, et al. Preparing for burn disasters: predictors of improved perceptions of competency after mass burn care training. *Prehosp Disaster Med* 2007;22(5):448-453.

Yurt RW, Lazar EJ, Leahy NE, et al. Burn disaster response planning: an urban region's approach. *J Burn Care Res* 2008; 29(1):158-165.

American Burn Association. Prevention Information developed under a grant from the US Fire Administration, Federal Emergency Management Agency, <http://www.ameriburn.org/prevention.php>

Jeng, J, Gibran N, Peck M. Burn care in disaster and other austere Settings. *Surg Clin North Am*. 2014 94(4): 893-907.

APPENDIX 1

Glasgow Coma Scale

The Glasgow Coma Scale (GCS) is the standard measure to assess patients for an altered mental status. The scale relies upon the evaluation of 3 systems: Eye movement, response to verbal stimuli, and motor response. Falsely lowered initial GCS may be due to hypoxia, hypotension, and intoxication and in patients that are intubated, the inability to speak automatically lowers the verbal response to a score of 1. In addition, facial burns often have periorbital edema and the assessment of spontaneous eye movement may be difficult.

RESPONSE	SCORE	SIGNIFICANCE
Eye Opening		
Spontaneously	4	Reticular activating system is intact; patient may not be aware
To verbal command	3	Opens eyes when told to do so
To pain	2	Opens eyes in response to pain
None	1	Does not open eyes to any stimuli
Verbal Stimuli		
Oriented, converses	5	Relatively intact CNS, aware of self and environment
Disoriented, converses	4	Well articulated, organized, but disoriented
Inappropriate words	3	Random, exclamatory words
Incomprehensible	2	Moaning, no recognizable words
No response	1	No response or intubated
Motor Response		
Obeys verbal commands	6	Readily moves limbs when told to
Localizes to painful	5	Moves limb in an effort to remove painful stimuli
Flexion withdrawal	4	Pulls away from pain in flexion
Abnormal flexion	3	Decorticate rigidity
Extension	2	Decerebrate rigidity
No response	1	Hypotonia, flaccid: suggests loss of medullary function or concomitant spinal cord injury

Marx J, Hockberger R, Walls, R, eds. Rosen's Emergency Medicine: Concepts and Clinical Practice, 7th ed. 2009.

The GCS is not only a tool to help establish the severity of a traumatic brain injury (TBI) but also to help determine if the condition is stable, improving or worsening. The scores for each response are totaled to give the proposed severity of the TBI. A score of 13-15, 9-12, and 3-8 represent mild, moderate, and severe injuries, respectively.

APPENDIX 2

Tetanus Prophylaxis

Burn injuries are considered tetanus prone and the Centers for Disease Control and Prevention (CDC) guidelines should be followed.

History of Adsorbed Tetanus Toxoid (Doses)	Clean, Minor Wound		All Other Wounds*	
	TDAP, TD or DTAP [†]	TIG	TDAP, TD or DTAP [†]	TIG [§]
Unknown or <3	Yes	No	Yes	Yes
≥3 [¶]	No ^{**}	No	No ^{††}	No

- Such as, but not limited to, wounds contaminated with dirt, feces, soil, and saliva; puncture wounds; avulsions; and wounds resulting from missiles, crushing, burns and frostbite.
- † Tdap is preferred to Td for adolescents and adults aged 11-64 years who have never received Tdap. Td is preferred to TT for adults who received Tdap previously, or when Tdap is not available. DTaP is indicated for children <7 years old.
- § Equine tetanus antitoxin should be used when TIG is not available. If only 3 doses of fluid toxoid have been received, a fourth dose of toxoid, preferably an adsorbed toxoid, should be given.
- ** Yes, if >10 years since the last tetanus toxoid-containing vaccine dose.
- †† Yes, if >5 years since the last tetanus toxoid-containing vaccine dose.
- Source: <http://www.cdc.gov/travel/yellowbook/ch4/tetanus.aspx>

APPENDIX 3

Radiation Injury

I. Introduction

Every person is continuously exposed within the environment to low levels of radiation, called background radiation. Exposure is increased near sources of radiation, especially X-ray machines and CAT scanners used in diagnostic radiology. Those who use such equipment are required to wear monitoring devices called dosimeters.

Radiation injuries can result from exposure to any of these machine which transiently generates radiation. The radiation is produced only when the machine is powered up and, therefore, can cause internal or external contamination of a person during this time.

Many other radiotherapy devices used to treat cancer contain highly radioactive elements. If radioactive compounds used in nuclear medicine, nuclear power plants, nuclear weapons processing facilities, and research laboratories are released in the environment, contact with the body will cause a cumulative radiation injury. A “dirty” bomb containing radioactive material can produce combined radiation and traumatic injuries.

The primary duty of a first responder is to evaluate and treat traumatic injuries and assess the possibility of external contamination with radionuclides. It is best to begin the decontamination process as early and completely as possible, ideally before transport to the local health care facility. This will minimize environmental contamination of the EMT equipment and the receiving hospital facilities.

II. Definition

Radiation injuries result from exposure to electromagnetic or particulate ionizing gradiation. The electromagnetic radiation (EMR) spectrum includes non-ionizing wave lengths like visible light, infrared waves and radio waves, which lack the energy to remove electrons from atoms. Higher energy EMR, like ultraviolet light, x-rays and gamma rays, easily ionize molecules, which then react with local tissue and damage the cellular DNA. Ionizing particles released from natural decay of unstable atomic nuclei can include alpha particles (2 protons and 2 neutrons), or beta particles (high speed electrons). High speed protons, neutrons, and other energetic particles are produced by man-made devices like synchrotrons or thermonuclear bombs.

III. Mechanism of Injury

Ionizing radiation causes tissue damage as energy is transmitted to living tissue. At low doses the primary effect is production of ionized free radicals that readily damage DNA. Sunburn is a radiation injury caused by ultraviolet light.

The body has efficient self-repair mechanisms, so that small doses of radiation over a prolonged period are much better tolerated than the same dose received acutely. Rapidly dividing cells in the hemapoietic system and the GI tract are most easily damaged, although maximum doses of radiation will disrupt the metabolic activity of all somaticcells.

IV. Mechanisms of Exposure

There are three mechanisms of exposure to ionizing radiation that may occur alone or in combination.

1. External irradiation occurs if there is transient exposure to radiation but no physical contact with

radionuclides. Tissue injury occurs only while in proximity to the radiation source, and no decontamination is needed. These patients represent no risk to others and only require transport to an appropriate medical facility.

2. Internal contamination can result from inhalation, ingestion or transdermal absorption of radioactive material. In many cases, low dose internal contamination is initially difficult to detect. Contamination of open wounds can result in rapid systemic absorption of radioactive elements, so early decontamination is indicated.
3. External contamination results from presence of radionuclide material on external body surfaces or clothing. This presents a continuous hazard to the patient and to all those who come in contact with him. Immediate decontamination procedures will minimize the radiation exposure to all involved.

V. Radiation Detection

The most useful instrument following a radiation incident is a radiation survey meter commonly called a Geiger-Muller counter. This will readily detect sources of ionizing radiation including alpha, beta, or gamma energy released from radioactive elements. The Geiger counter can immediately detect contaminated sites and demonstrate the efficiency of decontamination. However, it cannot determine the total dose of radiation received by an individual.

Personal dosimeters are used in medicine and in industry to quantify the accumulated radiation dose for those who frequently work near sources of radiation such as x-ray machines, medical radionuclides, and other radioactive materials used in research and industry. Electronic dosimeters provide a real time determination of radiation exposure, whereas film based dosimeters require processing after removal from the patient.

VI. Initial Evaluation and Treatment

STOP: Do not become the next victim. Radiation contamination is a unique form of chemical injury (radionuclides are unstable chemical elements which damage tissue by emitting alpha, beta or gamma ionizing radiation). Use Personal Protective Equipment to prevent possible skin contamination with ANY radioisotope.

- Remove the victim from the vicinity of any possible radionuclide spill.
 - If external contamination is suspected, begin IMMEDIATE field decontamination before transport to reduce the total radiation dose, and minimize contamination of you, your rig, your medical equipment and the medical facility that will receive the patient.
 - Treat all patients as potentially contaminated until they are scanned with a Geiger-Mueller counter (available at most hospital Radiology suites). Patients with a NEGATIVE scintillation counter scan do not represent a danger to others and do not require external decontamination.
- a. **History:** A careful history of potential radiation exposure is critical. For example, a release in a nuclear power plant or a spill while a medical worker is handling radioactive iodine suggests external contamination.
 - b. **Safety priorities:** When encountering a patient with suspected radiation injury, the priorities include rapid removal from any presumed source of ongoing radiation exposure, decontamination including removal of possibly contaminated clothing and thorough irrigation of the contaminated skin with water. Any wound to the skin should be presumed to be contaminated. Copious irrigation of the exposed tissue with water or saline will remove most of the contaminants.

Irrigation is continued until a survey with a radiation detector indicates minimal residual radiation, or at least a steady state condition. Then transport the victim to the designated health care facility.

JCAHO requires hospitals to have a protocol for decontamination of radioactive or chemically contaminated patients. This includes radiation detectors, personal protective equipment to minimize direct contact with the

radionuclide, plastic covered equipment to minimize environmental contamination, and a system for collection of the contaminated irrigation fluid. Consult your regional health care facility disaster plan for details of these protocols.

VII. Severity of Exposure

STOP If a person is wearing a personal dosimeter, **KEEP** the device with the patient during and after decontamination. At Chernobyl, when the patients were undressed, all the dosimeters remained attached to the contaminated clothing, received additional radiation exposure, and were useless in determining the radiation exposure of individual victims.

Massive irradiation of a single body part is harmful but almost never fatal. Total body irradiation can produce acute radiation syndrome. Initially there is a sharp drop in the circulating leukocytes and platelets, followed by a drop in erythrocyte production. Over several days there is loss of the mucosa of the entire GI tract. Initially there is GI bleeding which may be lethal. This is followed by sepsis as bacteria enter the bloodstream. There is a prolonged depression of the bone marrow and death results from bleeding or septicemia.

VIII. Prognosis

The prognosis is determined by the total body radiation dose, the presence of any trauma or co-morbid medical conditions, and the availability of sophisticated medical treatment facilities. Radiation syndrome is often fatal unless managed with all the resources of a major medical research facility. Bone marrow transplant is required in the most severe cases.

IX. References

Melnick AL. Biological, Chemical and Radiological Terrorism. New York: Springer; 2008, pp. 159-196.

Cold Injuries

I. Introduction

Cold injury most commonly occurs after exposure to a cold environment without appropriate protection. Localized cold injuries (frostbite) can cause severe disabilities or require amputation, but systemic hypothermia can be rapidly fatal, so local cold injuries are treated only after reversal of any associated hypothermia. The physiological changes associated with cold injuries are distinct from heat injury and require a unique therapeutic approach.

Military personnel, winter sports enthusiasts, older adults, and homeless persons are most at risk for these injuries.

II. Hypothermia

A. Incidence

Primary hypothermia due to frigid environmental exposure or cold water immersion is most common during the winter months, accounting for approximately 500 deaths per year in the United States. Secondary hypothermia occurs when a medical illness, injury or drug ingestion lowers the set point for body temperature. For example, older adults with severe hypothyroidism, sepsis or uncontrolled diabetes may develop hypothermia, even indoors.

B. Pathophysiology

Heat flows down any temperature gradient. The mechanisms for heat transfer include conduction, convection, radiation and evaporation. As heat leaves the body, the body temperature drops and metabolism slows.

Respirations and heart rate decrease. The patient experiences first a generalized cold sensation with uncontrollable shivering, followed by confusion, lethargy and impaired coordination of body movements. With a further decrease in core temperature, shivering stops and the patient becomes somnolent with depressed respirations and profound bradycardia. Death results from hypoventilation and asystolic cardiac arrest.

Even mild hypothermia induces diuresis and cold patients become rapidly hypovolemic. A brisk urine flow is not an indicator of adequate resuscitation. Metabolic acidosis and electrolyte imbalances are common. Secondary accidental hypothermia is a highly lethal illness where the core temperature is reduced to 32°C and is almost always fatal.

C. Signs and Symptoms of Hypothermia

Table 1. Findings in Hypothermia

Hypothermia Class	Core Temperature	Characteristics
Mild	32°C–35°C (90°F–95°F)	Vasoconstriction, shivering, cold sensations, coagulopathy
Moderate	28°C–32°C (82.4°F–90°F)	Bradycardia, confusion or agitation, metabolic acidosis, cold-induced diuresis
Severe	20°C–28°C (68°F–82.3°F)	Coma, respiratory depression, profound hypovolemia
Profound	Below 20°C (Below 68°F)	Apnea, asystolic arrest

Signs and symptoms of hypothermia are non-specific (see Table 1). An altered level of consciousness is present in 90% of patients with core temperatures less than 32°C and range from mood changes, poor judgment, and confusion to severe agitation and coma. Hypothermic patients in a confused state may undress outdoors and die quickly of exposure.

Hypothermia can mimic other disease states, such as alcohol or drug intoxication, cerebral vascular ischemia, hypothyroidism, or diabetic coma.

D. Diagnosis

Older clinical thermometers will not register below 93°F, so a digital thermometer or thermocouple must be used. A urinary catheter tipped with an integral thermocouple is more accurate than standard rectal temperature measurements to monitor core temperature in the hypothermic patient.

E. Treatment

The effects of primary hypothermia are reversible with aggressive rewarming, fluid resuscitation and correction of metabolic imbalances. Measures to prevent further heat loss followed by prompt rewarming efforts are lifesaving. All wet clothes are removed when the patient is transported in a warm environment. An alert patient with mild to moderate hypothermia will respond to hot liquids orally and external warming methods including warm air via convective heating blankets. Shivering will generate body heat, albeit at a metabolic cost. Overhead radiant heat devices are inefficient, and only warm exposed skin which is then at risk for burns. Hypothermia induces diuresis so a brisk urine flow is not an indicator of adequate resuscitation. Cold patients are hypovolemic and should receive warm intravenous fluids until body temperature is normal.

Severe hypothermia can be rapidly fatal and active rewarming measures are necessary. Active rewarming by immersion in a circulating water bath at 40°C is the most rapid conductive rewarming technique. To prevent even further temperature drop, cold extremities (even with frostbite) are wrapped in dry towels and not rewarmed until the core temperature reaches 35°C. As the core temperature rises, one cold extremity at a time is rewarmed by immersion in the bath. Contraindications to immersion include CPR or electrical defibrillation, active bleeding, open traumatic wounds, or unstable fractures.

If the patient is unconscious, endotracheal intubation may be necessary to protect the airway. Active core heating can be accomplished in unstable patients with pleural or peritoneal lavage. Usually two catheters

are placed in the peritoneal cavity or the left pleural space to permit simultaneous infusion and drainage of warmed isotonic fluid (40-42° C). Cardiopulmonary bypass permits more rapid rewarming, and simultaneously supports the circulation.

The potential complications of such invasive procedures must be weighed against the advantages, especially in patients with traumatic injuries. Newer methods of extracorporeal circulation or continuous arteriovenous hemodialysis may prove equally effective.

Hypothermic patients require frequent pH and electrolyte determinations, especially if systemic acidosis is present, and continuous electrocardiographic monitoring is necessary during rewarming.

Hypotensive patients with a slow but detectable pulse require aggressive volume expansion with warmed fluids, but chest compressions, which may trigger intractable ventricular fibrillation, should be avoided. If documented asystole or ventricular fibrillation occurs, CPR is initiated and continued during aggressive rewarming efforts. Defibrillation is ineffective if the heart is cold; few patients will survive unless rapidly rewarmed and cardioverted.

Following rewarming, secondary assessment is performed to identify predisposing or contributing diseases, which may include septicemia, diabetes mellitus, cerebral ischemia, hypothyroidism, oral-coholism.

III. Local Cold Injury (Frostbite)

A. Pathophysiology

If tissue is cooled very rapidly, ice crystals will form inside cells and rupture. These flash freeze or cold contact injuries resemble thermal burns except the tissue proteins are not denatured. Rewarming efforts will not restore the non-viable cells produced by these conditions.

But under ideal circumstances human skin can be frozen and remain viable, in a process called cryopreservation. Frostbite injuries can mimic this process. Following exposure to cold temperatures, exposed skin exhibits profound vasoconstriction as the body attempts to maintain a stable core temperature. As the tissue reaches -4° C, ice crystals slowly form within the extracellular fluid. This concentrates the extracellular solutes, and this hyper-osmolar fluid dehydrates and shrinks the cells, which are less easily punctured by the enlarging ice crystals. There is sludging of the capillary beds and eventually blood flow stops in the exposed digits. The metabolic rate is so reduced that slowly frozen tissue can survive for a limited time. Rapid rewarming minimizes further cellular damage.

After thawing, blood flow returns but endothelial cells soon detach and embolize into the capillary bed, leaving a thrombogenic basement membrane. Progressive thrombosis of the digital vessels causes ischemic necrosis of the affected areas. It may take several weeks to determine the full extent of injury.

B. Signs and Symptoms

Initially the patient develops a cold, clumsy and ultimately insensate extremity which appears pale or mottled blue. Rapid rewarming produces intense burning pain and redness of the affected extremity. Edema and blisters may develop over the next 12-24 hours. It is difficult to determine the depth of injury on early examination; signs and symptoms of deep injury are found in Table 2. Hemorrhagic blisters indicate deep dermal injury and severely frostbitten skin eventually forms a black, dry eschar. This progresses to mummification with a clear line of demarcation by 3 to 6 weeks. Time and patience often result in remarkable preservation of tissue.

Table 2 Signs and Symptoms Following Rewarming

Mild Injury	Deep Injury
Brief cold exposure, early rewarming	Prolonged exposure, delayed warming
Bright red or normal skin color	Mottled or purple skin
Warm digits	Cool digits
Sensation present	No sensation
Clear blisters	Hemorrhagic blisters
Blisters to digit tips	Proximal blisters only

C. Treatment

The initial therapy for frostbite is rapid transport to a safe environment before attempts at rewarming. Constrictive or damp clothing is removed and replaced with dry, loose garments. The extremity should be padded, splinted and elevated, and should not be rubbed or massaged, which may exacerbate the injury. Fluid resuscitation is rarely required for isolated frostbite. Partial rewarming should be avoided and any re-freezing of the extremity is catastrophic. Care must be taken to diagnose and treat concomitant injuries, especially systemic hypothermia.

The affected areas are rewarmed by immersion in gently circulating water at 40–42° C for 15 to 30 minutes. Pain medication should be provided. Blisters are deflated and left in place. Tetanus prophylaxis should be administered. Oral ibuprofen is used to treat pain and may limit injury by blocking prostaglandin production. Preliminary published studies suggest that systemic thrombolytics administered within 12 hours of thawing a frostbitten extremity can limit the amount of tissue loss in highly selected patients. There are many contraindications; therefore, this therapy should be administered by an experienced burn team. Early amputation prior to definitive demarcation (which can take weeks or months to occur) is generally discouraged, as delay can often result in increased functional limb length.

IV. Summary

Cold injuries can range from very mild, local injury to possibly lethal systemic hypothermia. The severity of the exposure to cold and the associated injuries are easily underestimated. Consultation with a burn center is encouraged to optimize the management for these individuals.

V. Select References

Britt LD, Dascombe WH, Rodriguez A. New horizons in the management of hypothermia and frostbite injury. *Surg Clin North Am.* 1991; 71:345-70. (Review of the management of cold injury.)

Murphy JV, Banwell PE, Roberts AH, McGruntner DA. Frostbite: Pathogenesis and treatment. *J Trauma.* 2000; 48(1): 171-8. (A review of the presentation and management of frostbite.)

Edelstein JA, Li J, Silverberg MA, Decker W: Hypothermia: Treatment and medication. Available online at: <http://emedicine.medscape.com/article/770542-treatment>

Zachary L, Kucan JO, Robson MC, Frank DH. Accidental hypothermia treated with rapid rewarming by immersion. *Ann Plast Surg.* Sep 1982; 9(3):238-41.

Blast Injuries

Blast injuries are a common mechanism of trauma in many parts of the world and such high explosive events have the potential to produce mass casualties with multi-system injuries, including burns. The severity of injury depends upon the amount and composition of the explosive material, the environment in which the blast occurs, the distance between the explosion and the injured, and the delivery mechanism. The presence of radioactive materials and chemicals must be considered in non-intentional injuries as well as in acts of terrorism and war. Blast injuries are considered to be one of four types or combinations:

- 1- direct organ damage from blast overpressure (shockwave);
- 2- blunt and penetrating injury from flying objects;
- 3- blunt injury due to the patient flying through the air; and
- 4- associated injuries such as burns and crush injuries.

Blast injuries are due to over-pressurization and occur most often within the lungs, ear, abdomen, and brain. The blast effect to the lungs is the most common injury causing delayed fatality to those who survive the initial insult. The chest x-ray has a butterfly pattern and dyspnea, cough, hemoptysis, and chest pain are indicators of this barotrauma. These injuries are often associated with the triad of apnea, bradycardia, and hypotension. Prophylactic chest tubes are recommended prior to operative intervention or air transport. Supportive ventilation is indicated until the lung heals.

Another commonly injured organ is the tympanic membrane which ruptures with significant overpressure; treatment here is also supportive. The pressure wave can cause blunt abdominal injury, and bowel ischemia/rupture should be considered. Lastly, brain injury is thought to be common in blast overpressure situations, but this has not been completely defined as yet.

Those with suspected injury should undergo computed tomography or magnetic resonance imaging and treated appropriately. Those without anatomic injury should be treated for mild to moderate traumatic brain injury, which is mostly supportive with cognitive function testing during recovery.

Burns should be treated as thermal injuries without significant caveats other than some crush component which may compound the injury. Burns are common with significant blast injuries. The ball of flame emanating from most explosive devices has a potential to ignite clothing and extend the injury.