American Burn Association

ABLS™

Emergency care for burn injury

Advanced Burn Life Support Course Manual

2023 UPDATE

American Burn Association
311 South Wacker Drive, Suite 950
Chicago, IL 60606
(312) 642-9260
www.ameriburn.org

The editor and contributors have worked diligently to ensure that all information in this book is accurate as of the time of publication and consistent with standards of good practice in the burn community. As research and practice advance, however, standards may change. For this reason it is recommended that readers evaluate the applicability of any recommendations in light of particular situations and changing standards.

Acknowledgments

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

ABLS™ Advisory Committee

Callie Thompson, MD, FACS
Contributing Editor
ABLS™ Committee Chair 2022–2026
ABLS™ Committee Deputy Chair 2021–2022
University of Utah Health Burn Center
Salt Lake City, UT

Peter O. Kwan, MD, FRCSC, PhD
ABLS™ Advisory Committee Chair 2019–2022
University of Alberta
Edmonton, CND

Patricia Colston, MHA, WCC, MSN
USAISR Burn Center
San Antonio, TX

Christopher K. Craig, DMSc, PA-C
Atrium Health Wake Forest Baptist Burn Center
Winston-Salem, NC

Pat Delaney, RN
University of Vermont Medical Center
Cambridge, VT

Luis Derosa, RN, EMT-P
Jackson Miami Burn Center
Miami, FL

Guillermo Foncerrada, MD, MMS
Burn Evaluation and Management
Galveston, TX

Rebecca N. Garber, MSN, FNP-BC, FAANP
Burn and Reconstructive Center at
Swedish Medical Center
Englewood, CO

William Hickerson, MD, FACS
Board Liaison
Firefighters' Regional Burn Center
Memphis, TX

Kathleen Hollowed, RN, MSN
South Carolina Burn Center at MUSC
Charleston, NC

Michelle Hughes, RN, BSN
Jefferson Burn Center
Philadelphia, PA

Mark James Johnson, RN, BSN
Regions Hospital Burn Center
St. Paul, MN

Laura Nicole Johnson, OTR/L
Parkland Burn Center
Dallas, TX

Nicole Kopari, MD, FACS
Childrens Hospital New Orleans
New Orleans, LA

Jeanne Grace Lee, MD, FACS
UC San Diego Health Regional Burn Center
San Diego, CA

Christopher Derrek Miller, RN, MSN, CCRN
North Carolina Jaycee Burn Center
Durham, NC

Tamara L. Roberts, MSN
Clark Burn Center
Syracuse, NY

Alisa Savetamal, MD, FACS
Board Liaison
Connecticut Burn Center
Bridgeport, CT

Denise Mazzacano Searles
Oregon Burn Center
Portland, OR

Dylan Stewart, MD
Trauma Center at Westchester Medical Center
Valhalla, NY

Sherrina Stewart-Richards, RN, MSN-Ed
Warden Burn Center
Orlando, FL

Esther Teo, MD, FACS
Arkansas Children's Burn Program
Little Rock, AR

William A. Waswick, MD, FACS
Ascension Via Christi Regional Burn Center
Wichita, KS

Haig Yenikomshian, MD
LAC/USC, Regional Burn Center
Los Angeles, CA

Table of Contents

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, and Worldwide
- 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 more than 480,000 people receive medical attention for burn injuries, and worldwide this was nearly 11 million in 2004, according to the World Health Organization (WHO). Approximately 45,000 people are hospitalized for burn injuries each year. In the United States an estimated 3,200 people die annually due to fire and burns, primarily from residential fires (2,845), and 180,000 die worldwide primarily in low- and middle-income countries. Other causes include motor vehicle and aircraft crashes, contact with electricity, and chemicals or hot liquids and substances. About 75% of these deaths occur at the scene of the incident or during initial transport and the majority are attributed to smoke inhalation. The leading cause of fire death in the United States is from fires due to smoking materials, particularly cigarettes. The ABA has been a lead organization in the attempt to require all cigarettes sold in every state to be fire-safe cigarettes.

Every patient who sustains a burn injury will benefit from the knowledge learners will gain 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 2006–2015.

- Males make up 68% of the burn patient population
- Children under age 15 make up 30% of the total burn patient population
- Flame injuries are the etiology in 41% of cases with a known cause
- Ninety percent of the reported cases sustained burns of 20% TBSA or less.
- Seventy-three percent of the reported patients were burned in the home.

- Over this 10-year period, the length of stay decreased by a day.
- Over the 10-year period, mortality rate decreased from 4% to 3%.

On a global scale, the World Health Organization notes the following about worldwide burn injuries.

- In India over 1,000,000 are moderately or severely burned annually, and in Bangladesh almost 173,000 children are moderately or severely burned each year.
- In Bangladesh, Colombia, Egypt, and Pakistan 17% of burned children have a temporary disability, and another 18% have a permanent disability.
- The incidence of death in children under 5 years of age in low- and middle-income countries in the WHO African and Easter Mediterranean Regions is almost twice that of comparable populations worldwide and in the European Region.
- The vast majority of burns in low- and middle-income countries occur for women and children in the home, and men in the workplace, and most are entirely preventable.

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 Advanced Burn Life Support (ABLS™) principles is crucial to providing the best possible outcome for the patient. The ABLS™ Provider Course is 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 burn.
- Define the extent 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 referred and transferred to a burn center.
- Organize and conduct the inter-hospital transfer of a seriously injured burn patient.
- 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 7.0 credits AMA PRA Category 1 Credits(s)TM. Physicians should only claim credit commensurate with the extent of their participation in the activity.

The American Burn Association is accredited as a provider of Nursing Continuing Professional Development by the American Nurses Credentialing Center's Commission on Accreditation. This activity is accredited for 7.0 nursing contact hours.

IV. COURSE CONTENT

Burn Care is interdisciplinary. 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.

Participants are also given the opportunity to care for a simulated burn patient, to reinforce the assessment and stabilization principles, and to apply 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 initial management of a seriously burned patient can significantly impact the survivor's long-term outcomes. Therefore, it is important that the patient be managed properly in the early hours after injury.

The complexity, intensity, interdisciplinary character and expense of the care required by an severely 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 for survivors of severe burn injuries. Because of regionalization, it is extremely common for the initial care of the burned patient to occur outside the

burn center. 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

World Health Organization. Burns. 2018. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/burns

American Burn Association 2016 National Burn Repository Report of Data From 2006–2015. Version 12.0. Chicago, IL,

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 can prevent early deaths. Initiating proper fluid resuscitation avoids major complications such as organ failure and infection. Recognizing and treating associated injuries are also essential. Finally, prompt consultation with regional burn center staff 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 appropriate personal protective equipment (PPE) such as gloves, eye wear, gowns, and masks. 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 also helps to protect the patient from potential contamination from caregivers.

III. PRIMARY SURVEY

The initial assessment of the burn patient is identical to other trauma: recognize and treat life and limb-threatening injuries first. Many patients with burns also have associated trauma. First responders should not let the burn distract them from more immediately threatening injuries. 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:

- A – Airway maintenance with cervical spine protection
- B – Breathing and ventilation assessment
- C – Circulation and Cardiac Status, Vital signs, IV access , hemorrhage control, and starting resuscitation
- D – Disability, Neurological Deficit and Gross Deformity assessment
- E – Exposure and Environmental Control, stop the burning, remove any chemicals or ongoing heat source (Completely undress the patient, Examine for associated injuries and maintain a warm Environment.)

A. Airway Maintenance with Cervical Spine Protection

Assess the airway immediately. Depending on the mechanism of injury, patients may require the following maneuvers:

- Airway opening—may improve with chin life or jaw thrust
- Nasopharyngeal or oropharyngeal (in the unconscious patient only) airway placement
- Secure the airway with endotracheal intubation.
- Protect the cervical spine by in-line cervical immobilization in patients with associated trauma mechanism (i.e., fall, motor vehicle crash), high-voltage electrical injuries, and in patients with altered mental status.
- Facial burns can result in swelling and the need for a secure airway can rapidly arise, so the patient airway must be continuously reassessed.

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
- Supplemental Oxygen—Assess the rate and depth of breathing
- Start high flow 100% oxygen using a non-rebreather mask if inhalation injury is suspected (indoor, flame mechanism)
- 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/perfusion (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 120 bpm 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. Heartrates below 100 bpm are considered a relative bradycardia and may represent a significantly low cardiac output due to medications such as beta blockers or underlying cardiac dysfunction that may warrant further evaluation.

Insert a large bore intravenous catheter (through unburned skin, if possible). Burns greater than 20% should have 2 large bore IVs or 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 (>20%) are based on patient age:

- ≤5 years old: 125 ml Lactated Ringers (LR) per hour
- 6–12 years old: 250 ml LR per hour
- ≥13 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, and can be late findings. 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. Please note it is rare for compromised circulation to occur immediately after injury, rather, these "compression" syndromes typically arise after resuscitation starts and edema begins. Continuous monitoring of circulation in extremities with circumferential full-thickness burns is required throughout the resuscitation.

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). Bleeding should be treated with blood transfusion and hemorrhage control per ATLS protocols and this process should happen in tandem with the burn resuscitation.

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** – **A**lert
- **V** – Responds to **v**erbal stimuli
- **P** – Respond only to **p**ainful stimuli
- **U** – **U**nresponsive

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 1.

E. Exposure and Environmental Control

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

Stop the burning process. Remove all clothing, jewelry/body piercings, 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 contact lenses and continue burning until removed.

For smaller size injuries (i.e., ≤5% TBSA) cool the burn briefly (3–5 minutes) with cool water. Never use ice or cold water. Prolonged application of cold compresses poses 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 95o F / 35o 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 pediatric patients, as they have a limited ability to maintain core body temperature.

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

Warmed intravenous fluid (37–40o 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
- Place a Nasogastric Tube (NGT) for intubated patients
- Place a foley catheter and monitor fluid resuscitation for patients with >20% TBSA burns
- 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 or 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? What was the degree of intrusion into passenger compartments?
     - 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?
   - What was the thermostat setting of the water heater?
   - Was the patient wearing clothes?
   - Was the burned area cooled? With what? How long?
   - Who was with the patient when the burn took place?
   - How quickly was care sought?
   - 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 Safety Data Sheet (SDS) 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—AC or DC?
   - What was the voltage? This information can sometimes be surmised by the location of the injury, or by calling local power company or speaking to the supervisor at construction sites.
   - Was the patient thrown or did they 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 – **A**llergies. Drug and/or environmental

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

P – **P**revious illness (diabetes, hypertension, cardic or renal disease, seizure disorder, mental illness) or injury, past medical history, pregnancy

L – **L**ast meal or drink

E – **E**vents/environment related to the injury

T – **T**etanus 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 2 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 estimate 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 impact on future hand function. Individual emotional and physiological responses to a burn vary and should be taken into consideration.

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:

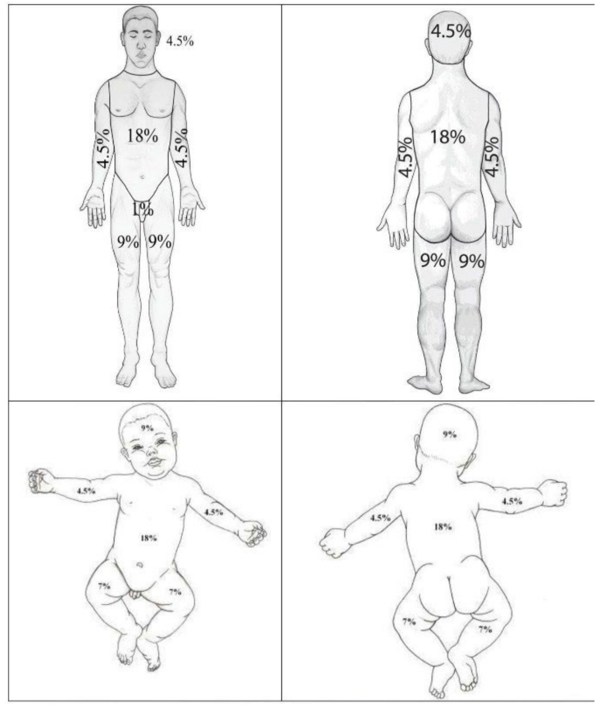
- Temperature of the offending agent
- Duration of contact with the burning substance
- Thickness of the epidermis and dermis
- Blood supply to the area

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 due to the thickness of the skin in those areas. 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

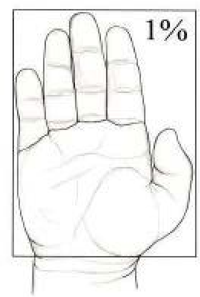


The most commonly used guide to estimate second and deeper degrees of burn is the “Rule of Nines.” In adults, distinct anatomic regions represent approximately 9%—or a multiple thereof—of the Total Body Surface Area (TBSA). In the infant or child, the “Rule” deviates because of the large surface area 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 and should not be used for calculations for fluid resuscitation.

If only part of the anatomical area is burned, calculate the percent TBSA burned based on the percentage of that site injured only (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—length of wrist crease to tip of longest finger and width of palm—represents approximately one percent of their total body surface area. Using this method is an easy way to determine the extent of irregularly scattered burns.

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 teenagers (≥ 13 years old)	**2** ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate
	Children (≤12 years old)	**3** ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate Plus D_5LR at maintenance rate
Electrical Injury	All ages	**4** ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate Plus D_5LR at maintenance rate for children ≤12 years old

This rate serves only as a **starting** fluid resuscitation rate and must be **titrated** based on patient response. The patient’s response and subsequent physiology determines the following hourly rates. 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, alcohol or other substance use, high voltage electrical injuries, or inhalation injuries may require more fluids than estimated. There is no calculation to adjust for these factors. Again, the adjustments to fluid rates are titrated based on patient response—urine output and blood pressure.

2. **Vital Signs**
   Monitor vital signs at least hourly in burns ≥20% TBSA.

3. **Nasogastric Tube**
   Insert a nasogastric tube for intubated patients and monitor all patients for signs of nausea and vomiting.

4. **Urinary Catheter**
   A urinary catheter is important because urine output is currently the best monitor of adequate organ perfusion and thus fluid resuscitation. All patients with burns ≥20% TBSA should have a urinary catheter. Additionally, a urinary catheter should be used in patients who cannot urinate, or in whom overall fluid status is unclear—even with a smaller burn.

5. **Monitoring Extremity Perfusion**
   In constricting, circumferential extremity burns, edema developing in the tissue under the burn eschar may gradually impair blood flow. 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 edematous subcutaneous tissue to expand (see Chapter 5, *Burn Wound Management*). Extremities initially evaluated as soft may become progressively tighter as resuscitation continues, therefore frequent reevaluation is necessary.

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**
   Burns hurt. Continuously assess pain and treat as needed. Assess whether pain is due to the burn injury or caused by associated trauma. Morphine (or opioid equivalents) are indicated for control of pain. Pain should be differentiated from anxiety. Benzodiazepines may also be indicated to relieve anxiety. Titrate for effect by administering small, frequent doses intravenously, as this has a more predictable absorption and effect than oral, subcutaneous, or intramuscular delivery. It is not unusual for the opioid dose to exceed the standard weight based recommendations. Respiratory status should be constantly evaluated as larger dosages may be required to alleviate pain and anxiety. Conversely, large doses may lead to vasodilation and increase fluid resuscitation requirements, so judicious administration is required. Tetanus immunization is the only recommended medication to be given intramuscularly 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 burned extremities reduces edema.

9. **Psychosocial Assessment and Support**
   Patients with major burns can often remember the events leading up to the burn and the first several post-injury hours. 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 X-Ray in intubated patients
- Toxicology screens including blood alcohol level

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 for patients with pre-existing cardiac disease
- Type and screen (or cross) for patients with 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 collision, explosion, electrical injury, 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 secondary survey. Optimal care of the mother will lead to optimal care of the fetus. Good maternal and fetal survival outcomes are possible in specialized centers, in consultation with obstetrics.

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 depend 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 (pressurized air that re-expands) impacting the body. Injuries include tympanic membrane rupture, pulmonary damage, and hollow viscous injury.
2. Secondary: result when projectiles from the explosion such as flying debris cause 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. The explosion may cause flash burns or may ignite clothing. Other injuries include crush injuries, inhalation injury, asphyxiation and toxic exposures.

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 are associated with 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. The patient may have clinical symptoms of blast lung injury immediately or 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 primary blast injuries. Those with suspected injury should undergo brain imaging.

D. Radiation Injury

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 GUIDELINES

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 for optimal outcomes.

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 developed the following guidelines to guide the consultation and transfer of patients with burn injuries following initial assessment and stabilization at a referring facility:

	Immediate Consultation with Consideration for Transfer	Consultation Recommended
Thermal Burns	• Full thickness burns • Partial thickness ≥10% TBSA* • Any deep partial or full thickness burns involving the face, hands, genitalia, feet, perineum, or over any joints • Patients with burns and other comorbidities • Patients with concomitant traumatic injuries • Circumferential injuries • Poorly controlled pain	• Partial thickness burns <10% TBSA* • All potentially deep burns of any size
Inhalation injury	All patients with suspected inhalation injury	Patients with signs of potential inhalation such as facial flash burns, singed facial hairs, or smoke exposure
Pediatrics (≤14 years, or <30 kg)	All pediatric burns may benefit from burn center referral due to pain, dressing change needs, rehabilitation, patient/caregiver needs, or non-accidental trauma	
Chemical injuries	All chemical injuries	
Electrical injuries	• All high voltage (≥1000V) electrical injuries • Lightning injury	• Low voltage electrical injuries (<1000 V) should receive consultation and consideration to follow-up in a burn center to screen for delayed symptom onset and vision problems

*For burn size determination please use Rule of Nines for adults and diagram shown for children or Palmar Method.

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 documents in Appendix 6 and 7 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

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.

Huang Z, Forst L, Friedman LS. Burn Center Referral Practice Evaluation and Treatment Outcomes Comparison among Verified, Nonverified Burn Centers and Nonburn Centers: A State-Wide Perspective. J Burn Care Res. 2020 Oct 6:iraa167. doi: 10.1093/jbcr/iraa167. Epub ahead of print. PMID: 33022054.

Bettencourt AP, Romanowski KS, Joe V, Jeng J, Carter JE, Cartotto R, Craig CK, Fabia R, Vercruysse GA, Hickerson WL, Liu Y, Ryan CM, Schulz JT. Updating the Burn Center Referral Criteria: Results From the 2018 eDelphi Consensus Study. J Burn Care Res. 2020 Sep 23;41(5):1052–1062. doi: 10.1093/jbcr/iraa038. PMID: 32123911; PMCID: PMC7510842.

Carter NH, Leonard C, Rae L. Assessment of Outreach by a Regional Burn Center: Could Referral Criteria Revision Help with Utilization of Resources? J Burn Care Res. 2018 Feb 20;39(2):245–251. doi: 10.1097/BCR.0000000000000581. PMID: 28570315.

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 duration 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 cutaneous burn. A significant number of fire-related deaths are not due to cutaneous burns, 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 cutaneous 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 cutaneous 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 alone.

There are distinct types of inhalation injury:

- Injury caused by exposure to and systemic toxicity from 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 have more than one type of inhalation injury. For example, patients in house fires may sustain 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 cutaneous 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 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 concise list of symptoms can be found in the following table.

Effects of Elevated Carboxyhemoglobin (COHb) Saturation

Carboxyhemoglobin Saturation (%)	Symptoms
0–10	None (smokers or large city dwellers often 5–10%)
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 associated with high carboxyhemoglobin levels but is rarely seen in patients with cutaneous 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 CO_2 removal and oxygenation are not affected. Although the O_2 content of blood is reduced, the amount of oxygen dissolved in the plasma (PaO_2) 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 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 using arterial blood gas analysis.

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 adenosine triphosphate 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 mucus membranes. Cardiovascular symptoms feature a hyperdynamic phase followed by cardiac failure (hypotension, bradycardia). In a patient with smoke inhalation, high lactic acidosis suggests cyanide toxicity. Pre-hospital burn patient cardiac arrest can also result from cyanide poisoning. In patients with suspected cyanide poisoning, hydroxocobalamin is the treatment, but will alter urine color and make monitoring urine for rhabdomyolysis difficult.

B. Inhalation Injury Above the Glottis

Thermal burns to the respiratory tract are typically 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, which may occur at any time during the resuscitation period. In unresuscitated patients, supraglottic edema may be delayed until fluid resuscitation is well underway. Early intubation is preferred because the ensuing edema can distort the landmarks needed for successful intubation. Supraglottic edema may occur without direct thermal injury to the airway, secondary to fluid shifts associated with burn injury and resuscitation.

C. Inhalation Injury Below the Glottis

IIn contrast to injuries above the glottis, subglottic injury is almost always chemical. Noxious chemicals (aldehydes, sulfur oxides, phosgenes) are present in smoke 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 but 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, higher doses of inhaled smoke, are typically reflected by elevated COHb levels and respiratory distress in the early post-burn hours.

However, note that the severity of inhalation injury and extent of damage are clinically unpredictable based on the history and initial examination. Chest X-rays are often normal on admission.

While inhalation injury below the glottis without significant associated cutaneous burns has a relatively good prognosis, the presence of inhalation injury markedly worsens prognosis of patients with cutaneous 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.

Excessive or insufficient resuscitation may lead to pulmonary complications. In patients with combined inhalation and cutaneous burns, total fluids administered may exceed predicted resuscitation volumes based on TBSA alone.

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 100% oxygen through a non-rebreather mask until COHb approaches normal levels. Humidification should be added to administered oxygen when available.

Inhalation injury frequently increases respiratory secretions and may generate a large amount of carbonaceous debris in the patient’s respiratory tract. Thus 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 strongly be 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 (ETT) is preferred. In adults, if possible, the ETT should be of sufficient size to permit adequate pulmonary toilet, and 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, etc.), cervical spine stabilization is critical during intubation. In impending airway obstruction, clearance of the cervical spine should be postponed.

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

Once endotracheal intubation is confirmed by end-tidal CO_2 wave capnography, and adjuncts such as auscultation and chest X-ray to determine correct ETT placement, the tube must be secured.

An ETT 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. Be careful to avoid pressure from the device or ties used as facial edema progresses. 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 after intubation. Rarely, an emergency cricothyroidotomy (incision made through the skin and cricothyroid membrane) is required to secure 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.

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 for definitive care should not be delayed for diagnostic testing.

Important aspects of patient history 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, rhonchi, 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 a patient 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 normalize. This strategy often normalizes the COHb level for most patients by the time of admission to the burn center. Hyperbaric oxygen for carbon monoxide poisoning in the setting of burn injury has not been shown to improve survival rates or to decrease late neurologic sequelae, and is complex and interferes with other management priorities shown to improve outcomes. 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 are not immediately available. Therefore, treatment must be initiated empirically in select patients. Patients exposed to fire with smoke with a decreased GCS score, soot deposits (in the sputum), dyspnea, or convulsions in the presence of persistent metabolic acidosis should be treated for cyanide toxicity.

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 patients might benefit from hydroxycobalamin administration. This treatment also has risks. Hydroxycobalamin causes the urine to turn dark red or purple. If the patient also develops acute kidney injury during resuscitation, its detection may be delayed.

Hydroxycobalamin is best reserved for unresponsive patients, patients with persistent lactic acidosis in the setting of enclosed space fire, or those undergoing CPR in the pre-hospital setting. 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. Burn patients with pharyngeal burns or edema, 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 cutaneous burns, and the amount of fluid resuscitation received.

Of note, flash burns to the face resulting in facial burns, singed eyebrows or hair raise concern for potential upper airway injury but only patients demonstrating respiratory distress should be intubated. Many patients with facial burns can be managed safely with humidified oxygen, continuous pulse oximetry, frequent auscultation for stridor and elevation of the head of bed.

Elevating the head of the patient's bed will mitigate edema. 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 or resolve edema due to burns and are not indicated.

4. Inhalation Injury in Pediatric Patients
Because children have smaller 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 in adults; therefore, retraction of the sternum with respiratory effort can be used as an indication of severe respiratory distress and need 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.

5. 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. Potential care protocols include bronchodilators, pulmonary hygiene measures, and nebulized heparin and N-acetylcysteine, although none have been studied in large randomized controlled trials.

6. Special Consideration
Oxygen dependent COPD patients with inhalation injury after smoking often develop COPD exacerbations and should be managed accordingly.

V. SUMMARY

There are distinct types of inhalation injury:

- Systemic Poisoning (Carbon monoxide, Cyanide)
- 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.

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.

Dumestre D, Nickerson D. Use of cyanide antidotes in burn patients with suspected inhalation injuries in North America: A cross sectional survey. Journal of Burn Care & Research 2014;35:e112–117.

Kearns R, Conlon KM, Matherly A, Chung KK, Bebarta VS et al. Guidelines for Burn Care Under Austere Conditions: Introduction to Burn Disaster, Airway and Ventilator Management, and Fluid Resuscitation. Journal of Burn Care & Research 2016;37:e427–e439.

Mlcak RP. Inhalation Injury from Heat, Smoke, or Chemical Irritants. UpToDate 2020.

Moshrefi S, Sheckter CC, Shepard K, Pereira C, David DJ, et al. Preventing unnecessary intubations: A 5-year regional burn center experience using flexible fiberoptic laryngoscopy for airway evaluation in patients with suspected inhalation or airway injury. Journal of Burn Care & Research 2019;40:341–346.

Orozco-Pelaez Y. Airway Burn or Inhalation Injury: Should all patient be intubated? Columbian Journal of Anesthesiology 2018;46:26–31.

Sheridan R. Fire-related Inhalation Injury. The New England Journal of Medicine. 2016;375:464–9.

Foncerrada G, Culnan DM, Capek KD, González-Trejo S, Cambiaso-Daniel J, Woodson LC, Herndon DN, Finnerty CC, Lee JO. Inhalation Injury in the Burned Patient. Ann Plast Surg. 2018 Mar;80(3 Suppl 2):S98–S105. doi: 10.1097/SAP.0000000000001377. PMID: 29461292; PMCID: PMC5825291.

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
- Explain 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 minimal amount of fluid required.

Proper fluid management is critical to the survival of patients with extensive burns. The goal of resuscitation for all burn patients is 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 elicits a profound host response, resulting in multiple cellular and physiologic changes. While this response is similar to that observed in trauma patients, it is often 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 after burn injury, an intravascular hypovolemia ensues which is slow and progressive. It is characterized by massive fluid shifts from capillary leak and leads to tissue edema. 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 fluid 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 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 resuscitation-related morbidities. 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 the effective decrease in 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 fluid resuscitation should start as soon as possible.

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. All burn formulas account for the body weight and surface area of burn. 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 fluid resuscitation calculations.

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 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

IIn 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 in patients with burns clearly > 20% TBSA:

- ≤5 years old: 125 ml LR per hour
- 6–12 years old: 250 ml LR per hour
- ≥13 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 and Teenager Thermal and Chemical Burns:
2 ml LR × patient's body weight in kg × % second and third degree burns, with half of the 24-hour total (in mL) 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 × 70 (kg) × 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 for 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 (12 years and under):

3 ml LR × child's weight in kg × % TBSA second and third degree burns, with half of the 24-hour total (in mL) 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, pediatric patients should also receive LR with 5% Dextrose at a maintenance rate. In this course, we define pediatric as individuals 12 years old and under. 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 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 × patient's weigh t in kg × % T BSA second and third degree burns, with half of the 24 hour total (in mL) infused 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 and start with 4 ml LR × patient's weigh t in kg × % T BSA second and third degree burns, with half of the 24 hour total (in mL) infused over the first 8 hours plus maintenance fluids with D5LR.

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.

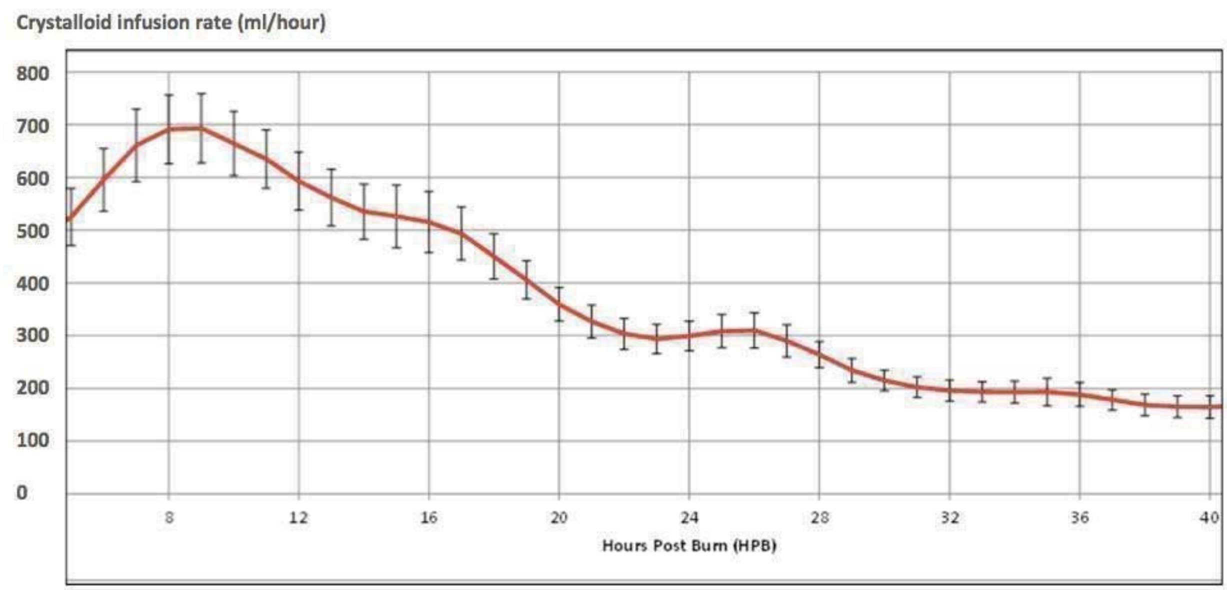
E. Titration of Fluids and Monitoring

Currently resuscitation is a very dynamic process that requires hourly re-evaluation of the patient's progress throughout 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. 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 ½ 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 can be 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 and Teenagers: 0.5 ml/kg/hour (or 30–50 ml/hour)
- Children (age ≤12 years): 1 ml/kg/hour (or 30 ml/hr once they reach 30 kg)
- 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 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 hypoperfusion from 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 oliguric 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 and should be avoided; 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 to 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 these. 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 is 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 increase or decrease fluid rates. The following groups are likely to be challenging and may require early 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 greater than expected fluid volumes, 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. Early consultation with the nearest burn center is advised when initiation of colloid is 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. Pro 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 inthe severely burn patient. JBurn 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
- Describe 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, and initiation of fluid resuscitation to prevent burn shock. 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 five functions crucial to survival:

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

- Regulation of body temperature
- Sensory contact with environment
- Vitamin D production

C. Burn Depth

Burn depth is classified into first-, second-, and third-degree (or superficial, partial thickness, and full thickness), 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. First-Degree / Superficial Burns

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

2. Second-Degree / Partial Thickness Burns

Second-degree, or partial thickness, burns involve the epidermis and part of the dermis. The skin may be red and blistered, wet, or weepy when they are thin partial thickness or dry and white or darker pink or red when they are thick partial. Second degree burns may heal spontaneously, though healing may require 2–3 weeks. Scarring is typically mild if healing occurs within 2–3 weeks though pigmentation changes can vary. 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 improves long-term functional and cosmetic outcome.

3. Third-Degree / Full Thickness Burns

Third-degree or full thickness burns involve destruction of the entire thickness of the epidermis and dermis, including dermal appendages. These injuries produce a white, brown, or black charred appearance to the skin and coagulated vessels are sometimes visible. This burned skin tissue, with a dry and leathery appearance, is called an eschar.

4. 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. However, when calculating burn size for resuscitation, the only important distinction is between first-degree burns which are not included, and deeper (second-, third-, and fourth-degree) burns which are included.

III. PATHOPHYSIOLOGY OF THE LOCAL THERMAL INJURY

A. Cellular Damage

The degree of tissue destruction, and thus the depth of burn, corresponds with both the temperature of, and duration of exposure to, the heat source. The physiologic impact of a burn primarily depends on 1) total body surface area burned, 2) depth of injury, and 3) location of the burn.

The Zones of the Burn Wound were described by Jackson in 1947. 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 may survive under ideal circumstances, but typically progresses to necrosis in the ensuing 24 to 48 hours following injury. This is the zone of stasis. Further peripherally is the zone of hyperemia, which has sustained the least 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 excision and grafting. The term "burn wound conversion" refers to increased size of the zone of coagulation, whereby a partial-thickness area (which could heal) converts to a full-thickness injury (requiring surgery) within the first 3–5 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 and leak fluid, electrolytes, and proteins into the wound area. In patients with large burns, this capillary leak occurs throughout the body and edema formation occurs in unburned tissues as well. This fluid loss into both burned and unburned tissues causes hypovolemia and contributes to shock in burn patients. Circumferential full-thickness burns in the trunk may lead to inadequate chest wall excursion with accumulating edema. Circumferential full- thickness burns in the extremities may lead to decreased tissue perfusion, particularly with increasing edema. 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 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 controversial. This course recommends that cooling is appropriate by using cool tap water up to 30 minutes for burns ≤ 5% TBSA. In larger size injuries, the risk of hypothermia and delay in care outweighs the benefit of cooling. Removing the clothing and jewelry is the best method to stop the burning process.

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 clean, dry sheet or blanket and keep the patient warm. There is no need to cleanse wounds in patients who will undergo formal wound evaluation and care at the burn center. The priority 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. Pre-medicate the patient for pain and anxiety control and maintain a warm environment. Cleanse the wound (using soap or chlorhexidine) and removing dirt and debris, if present. Do not use chlorhexidine gluconate in close proximity to the eyes or ears. It is acceptable to use mild shampoo mixed with warm water to clean the head and neck area. Perform wound care one body section at a time, and then apply the dressing, to limit exposure and prevent hypothermia. Prepare warm water or warm saline ahead of time. Prepare all dressings ahead of time to apply immediately upon completion of wound cleansing for that specific area of the body.

2. Gently debride blisters >2cm in diameter using sterile gauze or scissors and apply a topical antimicrobial medication. Consult with the burn center for the preferred topical antimicrobial. If topical antimicrobial dressings are applied, the primary and secondary dressings method should be used. A primary dressing makes direct contact with the burn wound surface. This is a non-stick gauze with the ointment of choice applied to it. A secondary dressing provides a layer to absorb exudate and will provide mechanical protection. All secondary dressings are loosely secured with size appropriate rolled gauze or surgical netting. Be careful to not cause constriction when securing the dressings, and avoid compressive dressings.

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

If the patient has a minor injury and will be discharged directly from the local emergency department, we recommend consultation with a burn center to formulate a plan for wound care, therapy, and follow-up. In many cases, discharge with follow-up in a burn center clinic is appropriate. In this scenario, the initial healthcare facility provides the wound care and teaches the patient (or caretaker) subsequent wound care. Commonly, daily wound care will be recommended. The patient (or caretaker) should cleanse the wound and reapply the dressing daily until the patient is seen 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, so that the patient may continue to range the involved joints.

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 increase infection risk.

V. ESCHAROTOMY

An escharotomy is a longitudinal incision through the burn eschar and not into subcutaneous fat over the entire length of full-thickness circumferential burn. Escharotomy relieves the constriction that led to restriction of chest rise or loss of peripheral perfusion in an extremity. The technique of escharotomy and orientation of the incisions are beyond the scope of this course. The referring provider should consult their regional burn center for guidance before considering escharotomy. This is a surgical procedure using an electrocautery device. Local anesthesia is impractical as escharotomies often require extensive incisions along an extremity, and procedural sedation is often required. Escharotomy can cause significant morbidity, including severe damage to tendons and peripheral nerves, and significant bleeding, if not performed correctly. Escharotomies are generally not needed until several hours into the burn resuscitation when edema formation worsens. Therefore, most escharotomies should be delayed until the patient is transferred to a burn center. 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 develops, 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.

In a patient with full-thickness, circumferential torso burns the following are signs that the patient is in need of a chest escharotomy:

- Difficulty with bag-valve-mask ventilation
- Increased peak inspiratory pressures
- Refractory hypoxia and/or hypercarbia
- 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 may 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 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 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), or crush injury. Compartment syndrome is frequently diagnosed by measuring compartment pressures, and is treated by fasciotomy in the operating room. The majority of extremity circumferential burns with decreased perfusion and reduced Doppler signals resolve with 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 consult with a burn center for patients with burns of the face, feet, eyes, axilla, perineum, hands, or 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 can have a severe psychological impact.

B. Eye Burns

Complete a thorough examination of the eyes as soon as possible, because eyelid swelling will make delayed examination 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 a burn center. Avoid ophthalmic solutions containing steroids.

C. Ear Burns

Burns of the ears require examination of the external canal and tympanic membrane 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 by avoiding occlusive dressings on the ears and 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 hourly and avoid 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.

F. Burns of the Genitalia and Perineum

Partial-thickness burns of the genitals 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. Regardless of the depth of burn, if a patient is unable to urinate with a genital burn, a foley catheter should be placed. 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 for 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 does not become pliable until it reaches 180–200 °F (82–93 °C). The maximum storage temperature is 250 °F (121 °C) and it 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 of these burns 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 to promote healing and closure of the wound. Burn wound management never takes precedence over life threatening injuries or 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 outcomes depend on the initial management for these specialized areas.

X. SELECT REFERENCES

Handling Recommendations for Coal Tar Roofing Bitumens. Technical Bulletin. Asphalt Roofing Manufactures 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 “great masquerader” of burn injuries because although the surface injury may be small, the deep tissue or internal injuries may be devastating. 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 (≥ 1,000 V) or low (<1,000 V) 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 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 narrower the hose, the higher the resistance (measured in Ohms), and the less 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 ($J = I2 \times R \times Time$) highlights the importance of current, contact time, and tissue resistance.

Humans are more complex than simple electrical circuits, and damage reflects the interaction of current with tissues. Heat generation accounts for a significant portion of the damage observed. Thus, duration of contact, tissue resistance, and current flow are the primary determinants of heat injury. Contact duration is longer when the patient cannot "let go" of an electrical source. Above a threshold current (30 mA), tetanic contraction in the victim's hand flexor muscles become dominant over the extensor muscles, causing the hand to close and preventing the victim from opening the hand to let go. 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 while 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 are low resistance. 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. 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 or car batteries. Car batteries produce low voltage electricity and cause injuries if a metal object like a watchband or ring connects the battery terminals. Current flow heats the metal, causing a contact burn which may be circumferential.

In contrast, lightning involves very high voltage and 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 alternates direction while flowing. In North America, the 60 Hz- current used indicates that the current changes directions 60 times per second (50 Hz in many other parts of the world). It is the most efficient and common way to supply 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. With a contact time of even a fraction of a second, the current will change direction several times, possibly resulting in death from cardiac fibrillation or respiratory arrest. Since current travels in both directions, there are no entrance and exit sites, only contact points. Although DC current travels only in one direction, there may be multiple exit sites. Therefore, 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. Thus the term “electrical burn” is a misnomer when referring to a true conduction injury, and it is more appropriate use the term “electrical injury.”

C. Types of Injury, Based on Mechanism

1. Body Conduction

When electrical current flows through a person, their flexor muscles powerfully contract, causing their hand 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 electrophysiology of nerve and muscle required for function of the nervous system and 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 representative of electrical conduction injury.

High voltage current (>1000 volts) 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 and loss of life or limbs. High voltage injuries often occur in workers such as power line and construction workers. Thus, severe electrical injuries cause loss of work and may present a barrier to return to previous employment. Fortunately, with advances in prosthetics and rehabilitation, many survivors are able to return to pre-burn functional levels.

Findings that suggest electrical conduction injury include:

- Loss of consciousness
- Paralysis or mummified extremity
- Loss of peripheral pulse
- 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. 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, deep contact burns.

5. Associated Injuries

Many people sustain falls while working with electricity on power poles, off the ground in lift "buckets", and on roofs, or ladders. The electrical current itself also causes tetanic contraction of muscles that can result in dislocations of major joints and fractures of vertebral and/or long bones. Every patient sustaining an electric injury should be assessed and managed as a trauma patient until other associated injuries are ruled out.

It cannot be overemphasized that the appearances of electrical injury can be deceiving. Since many types of burns can occur simultaneously during electrical injuries, one should be thorough in their evaluation.

D. Lightning Strike

Lightning occurs more frequently in the summer months. The risk of being struck by lightning is about one per million per year in the United States. 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 current, and a typical strike may carry 100,000 Volts and up to 50,000 Amps. A direct cloud-to-ground lightning strike 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 may cause asystole. Respiratory arrest is common since electrical current can temporarily inactivate the respiratory center of the brain. Immediate CPR is necessary and can be 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. They 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 trauma or other associated injuries. In addition, cardiac monitoring should be initiated as soon as possible due to the high incidence of dysthymias.

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 due to the risk of associated trauma. A cervical-collar should be applied for this same reason.

2. Breathing and ventilation. Administer 100% oxygen per non-rebreather mask if not intubated.

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. 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 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 regardless of patient age. 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/hr 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 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.

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, resulting in compartment syndrome. In such cases, 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 scene. Do not become the next victim.

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

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

G. Hospital Admission and Cardiac Monitoring

Patients with a history of loss of consciousness, documented dysrhythmias either before or after admission to the emergency department, requiring cardiopulmonary resuscitation at some point, 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 unnecessary.

IV. SELECT REFERENCES

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

https://www.osha.gov/SLTC/etools/construction/electrical_incidents/m ainpage.html (accessed 07/19/2021).

Annual Burn Injury Summary Report 2020 Update. Chicago, IL: American Burn Association. 2020.

Bernal E, Arnoldo BD. Electrical injuries. In Herndon D, Ed. Total Burn Care, 5th ed. Edinburgh: Elsevier; 2018; 396–402.

Christophides T, Khan S, Ahmad M, Fayed H, Bogle R. Cardiac effects of lightning strikes. Arrhythmia & Electrophysiology Review 2017; 6(3):114–117.

Culnan DM, Farner K, Bitz GH, Capek KD, Tu Y, Jimenez C, Lineaweaver WC. Volume resuscitation in patients with high-voltage electrical injuries. Annals of Plastic Surgery 2018; 80(2):S113–S118.

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 3.4% of all burn center admissions (2006–2015). 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
- In combination with a burn (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 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 liquefactive necrosis and protein denaturation; essentially melting any tissue that it comes into contact with (alkalis react with lipids to form soaps). This process allows for a deeper spread of the chemical and more 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 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 personal protective equipment (PPE) including 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 patient yourself!

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. Powdered chemicals in contact with water irrigation may cause an exothermic reaction causing further damage. Then, begin continuous irrigation of the involved areas with copious amounts of water. No substance has proven to be superior to water for initial therapy. Irrigation should be continued from the pre-hospital scene through emergency evaluation in 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 which is normally acidic around 5.5 can be checked by using pH test strips and should be performed before and after irrigation. It may take 30 minutes or more of irrigation 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.

After initial therapy has begun, it is helpful to 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 an ophthalmologist and continuously irrigate the eye.

Many 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), combines with water to form calcium hydroxide with a pH >12. A 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 will develop at the site of exposure. The injury depth can be minimized by prompt decontamination.

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 contacts 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. 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 and magnesium in the blood. Cardiac dysrhythmias and death from hypocalcemia may occur. Higher concentrations cause immediate intense pain and tissue necrosis. 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 g 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 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, as 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. 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.

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 multiple categories, but is the vesicants (such as mustard agents, and Lewisite) that cause skin blistering and chemical burns.

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 to avoid secondary injury in providers. Agents used in chemical attacks frequently have both short and long-term morbidity and toxicity. In the US, contact the Poison Control Hotline at 1-800-222-1222 for specific treatment for these chemical agents.

Burns Associated with Illicit Drug Manufacturing, Methamphetamine Fires and/or Explosions: Burns associated with drug manufacturing such as methamphetamine explosions pose additional dangers to 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 inappropriate storage often result in explosions and fires, placing first responders at great 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 substance users who also manifest severe tachycardia, dehydration, agitation, and paranoia. If it is possible the patient was injured in a methamphetamine-related 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 are essential. Irrigation should be continued through transport until 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.

Palao R, Ruiz MM, Barrett JP. Chemical burns: pathophysiology and treatment. Burns 2010; 36(3): 295–304.

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. Though child mortality rates have been decreasing, fire and burns are a 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 grow up.

For the purpose of the ABLS™ course, children are defined as between birth and 13 years. Approximately 100,000 children 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 who are hospitalized in US Burn Centers (data from the ABA Burn Injury Summary Report). Scald burns are more common in young children and are also common causes of non-accidental burn trauma (child abuse, neglect). As children age, flame burns become more common and are a leading cause of burn injury in adolescents.

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 children have a smaller body surface area (BSA) than adults but have a relatively greater surface area per unit of body weight. Thus, when exposed to a similar offending agent (tap water, hot beverage, clothing iron), a child will sustain a proportionally larger TBSA burn than an adult. 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 as compared to an adult. Therefore, children can be expected to require more fluid per unit of body weight during resuscitation. 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. However, 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 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. Due to the 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 160 °F (71 °C) and create significant risk for full thickness 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 are identical to those 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 a life-threatening obstruction.

Airway Diameter: (Resistance is inversely proportional to the radius to the 4^{th} power) An infant's airway diameter is 4 mm (as opposed to 8 mm in an adult). Thus, 1 mm of edema will increase resistance 16 time essentially occluding one-fourth of the airway. Signs of significant airway edema include hoarseness, increased work of breathing, tachypnea, and ultimately use of accessory muscles with sternal retractions.

Endotracheal intubation is indicated in infants and children with significant respiratory distress/failure or compromise of the airway by edema involving the glottis and upper airway. Younger children, those with large burns, or significant inhalation injuries 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 pediatric airway management due to the anatomic differences between adults and children. An infant's larynx is located more anteriorly, and the glottis is more angulated and anterior than in adults. The narrowest portion of the airway in the young child is at the cricoid cartilage, not at the glottis. These anatomical differences make intubation 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+ 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 hazardous. Adjusting cuff volume/pressure is safer and allows for more adjustment as airway edema increases or decreases over the course of intubation.

After intubating the child, auscultate and check for CO_2 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 place through the cricothyroid membrane may be used as an expedient airway. After intubation, placement of a nasogastric tube is advisable. Infants 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 ≥ 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 acute renal failure and higher risk of mortality.

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

- ≤5 years old: 125 ml LR per hour
- 6–12 years old: 250 ml LR per hour
- ≥13 years: 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 has resulted from improperly place IO lines. IO lines should be removed as soon as IV cannulation is established. Central 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, confusion, or loss of consciousness 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 child. Due to the large surface area of an infant or child's head, it 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.

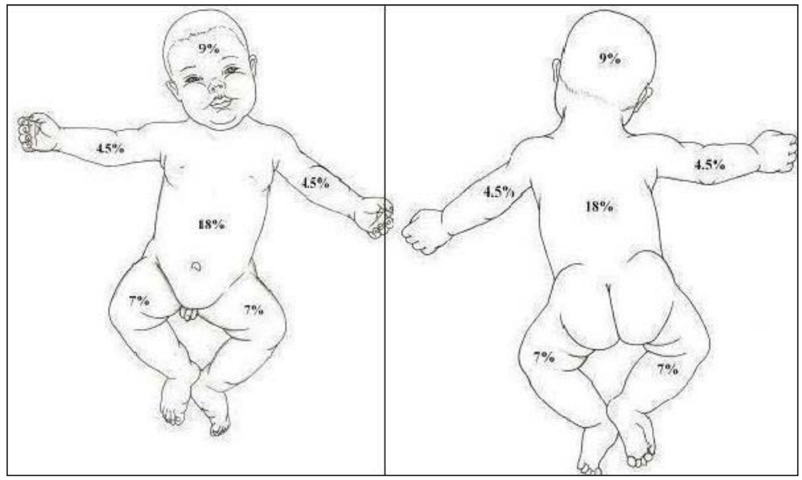
Important elements include:

- Circumstances of the injury and first aid administered
- Complete head-to-toe evaluation of the patient
- Determination of percent TBSA burned
- Fluid resuscitation using the adjusted fluid rates calculations
- Insertion of lines and tubes
- Lab and X-rays (including serial blood glucose)
- Monitoring of fluid resuscitation
- Pain and anxiety management
- Psychosocial support
- Wound care
- Pregnancy test: may be necessary depending on age and circumstances

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 burn 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. 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). Review the health history to determine the immunization status, paying particular attention to tetanus immunization.

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 average, subtract 1% from the head and add 0.5% to each leg. By the time the child reaches 14 years old, they have 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 resuscitation.

2. Estimating Scattered Burn Areas

The size of the patient’s hand—wrist crease to tip of longest finger—represents approximately one percent of the patient’s 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 ml × kg × % TBSA burn, except for electrical injury, where the rate is 4 ml × kg × % TBSA burn. The goal of resuscitation is to replace fluids lost as the result of the burn injury. Fluid rates should be adjusted hourly using hourly urine output goals until the resuscitation is decreased down to the estimated maintenance rate for the patient’s weight.

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

- Half of the total estimated is to be given in the first 8 hours from injury
- Therefore, first 8-hour fluid volume = (3 ml × weight (kg) × TBSA) divided by 2
- Divide the first 8-hour volume by 8 to obtain the starting fluid rate (ml/hour)

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-hours post-burn: 3 ml × 23 kg × 20 (TSBA) = 1380 ml (LR)
- Half of total in the first 8 hours: 1380 ml /2 = 690 ml
- Starting resuscitation fluid rate per hour (divide by 8): 690/8 = 86 ml/hr
- Titrate this fluid to maintain a urinary output of 0.5–1 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 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 adequate fluid resuscitation results in an average urinary output of 1 ml/kg/hr. In teenagers, adequate fluid resuscitation is assumed with a urinary output of 30ml/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. The fluid of choice is D5 LR. It is not titrated to urine output. Dextrose-based fluid is required as hypoglycemia may develop in infants and 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, it is simpler to think in terms of an hourly infusion rate to match physiologic losses. Use of the "4-2-1" rule for calculating hourly maintenance fluid infusion rates is a convenient method to ensure daily requirements are provided.

- 4 ml/kg/hr for the 1st 10 kg (for each kg 1–10, multiple times 4ml; 40ml max), plus
- 2 ml/kg/hr for the 2nd 10 kg (for each kg 11–20, multiple times 2ml; 20ml max), plus
- 1 ml/kg/hr for each remaining kg (add 1ml for each kg greater than 20kg)

Example:30 kg child maintenance fluid (D5LR) rate:

- 4 ml/kg/hr for the 1st 10 kg = 4 ml × 10 (kgs 1–10) = 40 ml/hr, plus
- 2 ml/kg/hr for the 2nd 10 kg = 2 ml × 10 (kgs 11–20) = 20 ml/hr, plus
- 1 ml/kg/hr for each remaining kg = 1 ml × 10 (kgs 21–30) = 10 ml/hr
- Total maintenance fluid rate = 40 ml + 20 ml + 10 ml = 70 ml/hr

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 and difficult to discern in a child with burns. 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 there is no margin for error in children and there are significant risks of iatrogenic injury.

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 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 heat 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 a period of high risk for “dip” burns associated with child abuse. As some children mature, they increase their high-risk behavior and tend to sustain 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 younger 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 or stages of healing
- There is evidence of 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

Remember, a thorough assessment and patient history is essential when caring for a patient with suspected abuse or neglect. Small injuries suspicious for child abuse often predate a lethal abuse-related injury.

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
- Initiation of fluid resuscitation immediately
- Add D5LR as maintenance in children
- 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/safechild/child_injury_data.html, on 07/19/21.

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.

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

Lopez ON, Norbury WB, Herndon DN, Lee JO. Special considerations of age: the pediatric burned patient. In Herndon, D. Ed. Total Burn Care, 5th ed. Edinburgh: Elsevier; 2018; 372–380.

Tropez-Arceneaux LL, Sarpong KO. Intentional burn injuries. In Herndon D, Ed. Total Burn Care, 5th ed. Edinburgh: Elsevier; 2018; 660–672.

Annual Burn Injury Summary Report 2020 Update. Chicago, IL: American Burn Association. 2020.

Palmieri TL. Pediatric burn resuscitation. Crit Care Clin 2016; 32; 547–559.

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 one component of a 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, 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 by 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: 125 ml LR per hour
- 6–12 years old: 250 ml LR per hour
- ≥13 years: 500 ml LR per hour

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

Patients with hypotension should receive a bolus of fluid and an increase the fluids by 1/3 unless there is other associated trauma. If there is a concern for traumatic bleeding, blood transfusion and hemorrhage source control should occur simultaneously with burn resuscitation.

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 toxicity, substance use, hypoxia, hypoglycemia, 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 cover with a clean dry sheet and/or blanket. Reveal and examine one area at a time for major associated injuries while minimizing the risk of hypothermia.

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, remove contact lenses, brush dry chemicals off the patient, and then flush with copious amounts of water.

Maintaining the patient's core body temperature is a priority. The EMS transport vehicles and treatment rooms should be warmed. Continue to keep patient covered to minimize the risk of 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**
   Using the acronym AMPLET obtain the following history:

   A: Allergies to drugs and environment
   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

   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 their childhood immunizations.

2. **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 teenagers (≥ 13 years old)	**2** ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate
	Children (≤12 years old)	**3** ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate Plus D_5LR at maintenance rate
Electrical Injury	All ages	**4** ml LR × kg × % TBSA = ml/24hrs ÷ 16 = m/hr starting rate Plus D_5LR at maintenance rate for children ≤12 years old

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: 0.5–1 ml/kg/hour

3. **Vital Signs**
   Vital signs are monitored and documented at frequent intervals.

4. **Nasogastric Tube**
   Insert a nasogastric tube in intubated patients.

5. **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.

6. **Pain and Anxiety Management**
   Burn pain may be very severe and needs to be appropriately treated. Morphine (or other opioid equivalents) are indicated for pain control. Small, frequent doses should be administered through the IV route.

7. **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.

8. **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

	Immediate Consultation with Consideration for Transfer	Consultation Recommended
Thermal Burns	• Full thickness burns • Partial thickness ≥10% TBSA* • Any deep partial or full thickness burns involving the face, hands, genitalia, feet, perineum, or over any joints • Patients with burns and other comorbidities • Patients with concomitant traumatic injuries • Circumferential injuries • Poorly controlled pain	• Partial thickness burns <10% TBSA* • All potentially deep burns of any size
Inhalation injury	All patients with suspected inhalation injury	Patients with signs of potential inhalation such as facial flash burns, singed facial hairs, or smoke exposure
Pediatrics (≤14 years, or <30 kg)	All pediatric burns may benefit from burn center referral due to pain, dressing change needs, rehabilitation, patient/caregiver needs, or non-accidental trauma	
Chemical injuries	All chemical injuries	
Electrical injuries	• All high voltage (≥1000V) electrical injuries • Lightning injury	• Low voltage electrical injuries (<1000 V) should receive consultation and consideration to follow-up in a burn center to screen for delayed symptom onset and vision problems

*For burn size determination please use Rule of Nines for adults and diagram shown for children or Palmar Method.

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 prior to transfer. 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.

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.)

Schaefer TJ, Szymanski KD. Burn Evaluation And Management. [Updated 2020 Aug 10]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK430741/

CHAPTER 10

Burn Disaster Management

Objectives

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

- Define burn mass casualty and triage
- Explain 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 the 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 patients exceeds the capability (resources) of local or regional burn centers to provide optimal burn care. Severe burn injuries require vast amounts of resources (personnel, equipment, and time). Capability includes the availability of burn beds, burn surgeons, burn nurses, other support staff, operating rooms, equipment, supplies, and related resources. Capability is different at each burn center. It may be seasonal and vary from week to week or even day to day, based on the number of patients being treated prior to the disaster. Capability should not be confused with burn center surge capacity. Surge capacity is defined as 1.5 times the number of available burn beds in a burn center.

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, such as schools, churches, housing units, dormitories, workplaces, and entertainment venues. They can also occur due to natural disasters such as wild fires, earthquakes, etc. Each community has high-risk locations.

On September 11, 2001, terrorist attacks in New York and Washington, DC resulted in many patients with burn injuries in a short period. 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 cutaneous injuries, many patients also had inhalation injuries.

The number of injuries in structure fires and explosions frequently exceeds the care capabilities of local burn centers. The 2003 Rhode Island Station Nightclub Fire involved over 400 people. Of the 215 people injured, 47 were admitted with burns, and 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. In 2021, a fuel tanker exploded in Freetown, Sierra Leone, killing 99 people and leaving over 100 injured.

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

Burns average, by conservative estimates, one day of hospitalization per percent total body surface area (TBSA) burned. Burn injuries are unlike other traumatic injuries, often requiring a lengthy course of initial inpatient treatment. Thus, definitive care of burn patients with a significant burn injury should occur at a burn center.

In the United States, under normal 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, instead, at one located within the region. Non-burn centers such as trauma centers and general hospitals may be called upon to stabilize BMCI 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

This course demonstrates that burn patients have a unique pathophysiologic response to their injury and require injury-specific treatment. Early in a BMCI, 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 2,000 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 to provide 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 when planning, preparing, and practicing 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 treatment needs. In a disaster, triage takes on increased importance due to limited resources and burn treatment expertise. Patients are sorted into treatment categories based on the 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 largest number of individuals utilizing available resources. Triage decisions are based on medical necessity.

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, the criteria utilized to make decisions. Exposure to any triage system should occur before 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 coordinate a disaster, especially when multiple agencies are involved. Responders should implement ICS to make provisions for rapid triage and transport.

Primary triage occurs at the disaster scene or the emergency room of the first receiving hospital. Execute primary triage according to local and state mass casualty disaster plans. In a BMCI, the scene incident commander (IC) should coordinate with the regional command system, including 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 U.S. Department of Health and Human Services (DHHS) recommends that state disaster plans incorporate burn centers. Government and ABA 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).

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

These are the 3 basic stages of burn disaster response based on the American Burn Association's order of classification

Burn Mass Casualty Incident (BMCI) (Burn Disaster) Stages

Stage I Burn Disaster:

- Local burn center resources can handle a Stage I burn disaster. The strategy of management revolves around local/regional burn centers. In general, establish incident command, and they will carry out a needs assessment. Established local burn management protocols will be activated, with a coordinated response by local and regional healthcare 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 requires a national network of burn centers, coordinated with a federal response. This situation is catastrophic. The regional unified command must request national and federal assistance.

During the entire triage process, continue a basic level of care and initiate advanced life support as needed. The success of primary and secondary triage relies on the 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 possible. Secondary triage may occur from burn center to burn center (regional or national transfer). Transfer to a verified burn center is preferable.

As you may note, research literature contains a myriad of definitions and uses varying terminology when discussing the topics of disaster preparedness and response. This can often lead to confusion amongst providers and responders. It is, therefore, important to ensure that your planning and response documents use common terminology when defining burn mass casualty incidences. For instance, the American Burn Association's Stage I, Stage II, and Stage III Burn Disaster definitions above might easily be confused with the Type I, Type II, and Type III Burn Disaster scenarios defined in the literature by Kearns, et al. While the American Burn Association is defining their *staged response* to a disaster in an escalating fashion; the literature, in this specific case, is defining the *type of disaster* with descending terminology. This can easily lead to confusion, so care should be taken to explicitly define the terminology used in your institution's discussions and publications. There is no explicitly correct or incorrect way to define your stages of response or types of mass casualty incident as long as your message is clear and consistent throughout your documentation.

Box 1

These are the 3 basic types of burn mass casualty incidents relying on the National Incident Management System order of classification; these classifications were first published in 2014

Burn Mass Casualty Incident (BMCI) (Burn Disaster) Scenarios

Type I BMCI:

- Description and example: catastrophic event, to include multiple casualties with various and combined burn injuries over a wide geographic area, such as earthquakes to include the 1994 Northridge earthquake,[68,69] the 9/11 attacks,[70–72] the Great East Japan earthquake (2011),[51,73] or an improvised nuclear device.[57,60,74,75]
- Impact: critical infrastructure
- Logic: impact to the infrastructure could be devastating. When the infrastructure is damaged, from highways to utilities, the magnitude of the disaster is amplified by the compromised facilities. When the facilities in which care is provided are damaged or essential utilities are disrupted, in addition to the surge of both burn and general traumatic injuries, most likely the management of the disaster will be suboptimal. Radiation-related incidents would include activation of the Radiation Injury Treatment Network, a cooperative effort of the National Marrow Donor Program and the American Society for Blood and Marrow Transplantation.[76]

Type II BMCI:

- Description and example: multiple-aspect burn disaster, such as an explosion, with significant numbers of traumatic as well as burn-injured patients producing multiple casualties with various blunt force and combined thermal injuries. This type of disaster would include the Madrid train bombings (2004)[65,66] and London subway attack (2005).[67]
- Impact: health care system
- Logic: impact to the health care system may be significant; due to the nature of the disaster, there may or may not be ample critical care and trauma care beds that can be adapted to care for those burn-injured patients who need less intensive attention by burn care professionals. Given the competing interests of traumatic injury with burn injury, filling the need without crossing into a crisis surge capacity may be problematic in the immediate geographic area near the site of the disaster.

Type III BMCI:

- Description and example: an isolated burn disaster with mostly thermal injuries, such the Rhode Island Station Night Club fire (2003)[61–63] or the Kiss Nightclub fire in Santa Maria, Brazil (2013).[64]
- Impact: burn care system
- Logic: impact to the burn care system may be significant; but due to the nature of the disaster, critical care and trauma care beds can be adapted to provide care for burn-injured patients who need less intensive attention by burn care professionals.

Figure 1: Modified from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7112249/pdf/main.pdf

B. Scene Safety

Disaster scenes are often hectic and seemingly out of control. The arrival of first responders is a first step in bringing order to chaos. The priority of scene responders must be their own well-being. Decisions about the 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 themselves in danger when there is little chance for improving the status of the situation. The incident management team must conduct a risk assessment for the circumstances at hand. All individuals operating within the confines of the emergency must understand that reckless acts may impact 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 or should not receive immediate care. Each state or jurisdiction may have its version; however, the basic principles are the same. Hospital personnel should be familiar with the triage tags used in your locale to understand the pre-hospital assessment and care provided before 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 while caring for more critical patients.

Minimal/Green: Outpatient treatment and returned to duty/home. These are ambulatory, alert, and oriented patients who 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). You may need to deny treatment to patients with severe injuries who would theoretically be considered salvageable under more favorable circumstances. 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

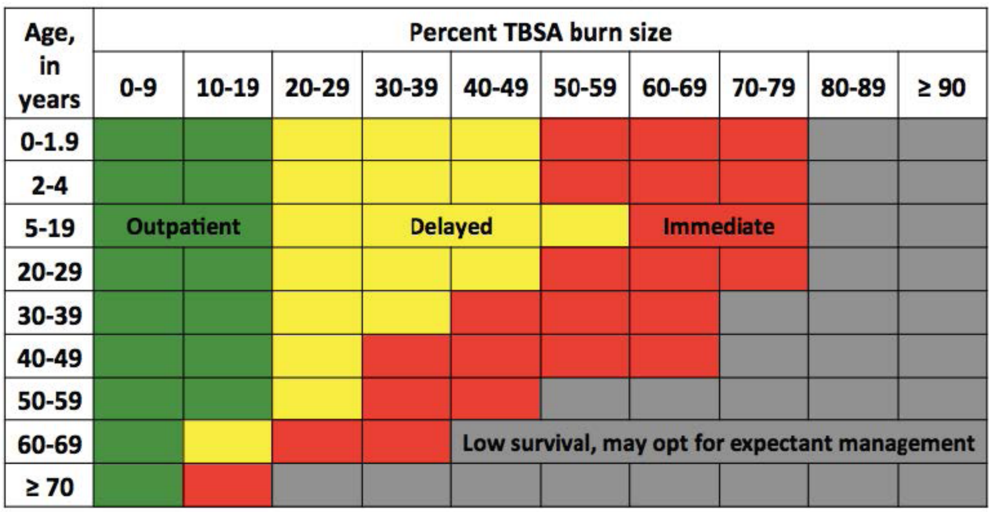
Burn size is the most readily identified factor in determining the potential survivability of patients with burns. Accurate assessment of % TBSA burn is critical for appropriate triage, especially in a disaster. Health care providers who are inexperienced with calculating this may wish to consider implementing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

1. Two independent providers calculate % TBSA burn. If the difference is more 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 their injury unless there are associated injuries or comorbid medical conditions in addition to the burn.
- Patients between age two and 60 years old will fare better.
- Patients with inhalation injury will fare worse than those without inhalation injury.
- Treat some patients as "expectant." Definitive treatment must be delayed or withheld for expectant patients to adequately treat those with a better chance of survival.

Other factors, including the presence of associated injuries and pre-existing health status, impact 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, situational awareness and good communication are essential during initial triage. The scene incident commander will relay reliable information to the regional command center and work with the local burn center in this response phase. In the setting of overwhelmed resources or austere conditions, the following grid provides an example of potential triage decisions. 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.



III. BURN MCI PRIMARY AND SECONDARY SURVEY

"A. and B." Airway, Breathing, and Ventilation

Inhalation injury alone jeopardizes survival. After starting fluids, airway edema significantly increases. Therefore, resources must be available to assess and manage the airway before starting large fluid resuscitation volumes. It is crucial 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. Having more intubated patients than ventilators requires additional personnel to provide manual ventilation. Intubate patients based on assessment, need, and resources. Do not intubate patients placed in the "Expectant" category. Administer oxygen only to provide comfort and prevent air hunger.

"C." Circulation and Cardiac Status

ABLS™ teaches to ideally insert two large-bore I.V.s in patients with burns and resuscitate with Lactated Ringers. Give IV fluid priority to patients with burns > 20% TBSA or associated trauma with blood loss. When supplies of Lactated Ringers are depleted, fluid resuscitation may continue using other crystalloids or colloids.

Do not give packed red blood cells unless blood loss has occurred, or the patient has a hemoglobin < 7 g/dL

Consider oral resuscitation for awake and alert pediatric patients with burns < 10% TBSA and adult patients with burns < 20% TBSA. Offer flavored sports drinks 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, intravenous access may be started for medication administration to manage pain and anxiety, only if resources allow. Do not administer large volumes of fluid. 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 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. Perform patient identification and history during this timeframe and before 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. If needed, wrap patients in plastic wrap or aluminum foil for insulation and warmth. Consider covering a patient's head, especially a child, to maintain body temperature.

In an MCI, wound care supplies may also be limited. Burns do not require sterile dressings. For patients who will not be transferred or will 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 a 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 all plans are compatible.

"F." Pain Management

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

IV. SUMMARY

Burn patients 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 play a vital role in a significant burn MCI. When needed, achieve initial resuscitation and stabilization in the field and at non-specialized centers. Definitive care of burn injuries requires vast resources only available at burn centers. 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 the best patient outcomes.

V. SELECT REFERENCES

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

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

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.

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

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

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.

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.

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.

Emergency Management Assistance Compact. 2021. https://www.emacweb.org. Accessed November 18, 2021.

Fofana U. Ninety-nine killed in fuel tanker blast in Sierra Leone capital. Reuters. 2001. https://www.reuters.com/world/africa/fuel-tanker-blast-sierra-leone-capital-kills-least-91-says-morgue-2021-11-06/. Accessed November 18, 2021.

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

Kearns RD, Conlon KM, Valenta AL, et al. Disaster planning: the basics of creating a burn mass casualty disaster plan for a burn center. J Burn Care Res. 2014:35(1):e1–e13.

Kearns RD, Marcozzi DE, Barry N, Rubinson L, Hultman CS, Rich PB. Disaster Preparedness and Response for the Burn Mass Casualty Incident in the Twenty-first Century. Clin Plast Surg. 2017;44(3):441–449. Doi:10.1016/j.cps.2017.02.004

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

Staudenmayer K, Schecter 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.

US Department of Health and Human Services. National Disaster Medical System. 2021 https://www.phe.gov/Preparedness/responders/ndms/Pages/default.aspx. Accessed November 18, 2021.

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.

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.

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.

APPENDIX 1

Glasgow Coma Scale

The Glasgow Coma Scale (GCS) is the standard measure to assess a patient's mental status. The scale relies upon evaluating three systems: eye movement, response to verbal stimuli, and motor response. A lower GCS may be due to hypoxia, hypotension, or intoxication. In intubated patients, the inability to speak automatically reduces 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 a tool to help establish the severity of a traumatic brain injury (TBI) and 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, therefore, the Centers for Disease Control and Prevention (CDC) guidelines on tetanus prophylaxis 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 three doses of fluid toxoid have been received, the 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

We are all continuously exposed to low levels of radiation in the environment, called background radiation. Exposure is increased near sources of radiation, for example, X-ray machines and CT 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 machines, which transiently generate radiation. The radiation is produced only when the device 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. Radioactive compounds used in nuclear medicine, nuclear power plants, nuclear weapons processing facilities, and research laboratories are released into the environment. In this case, contact with the body will cause a cumulative radiation injury. A “dirty bomb” refers to a conventional explosive packaged with radioactive material that is scattered over a wide area when detonated, thus, it 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, to minimize environmental contamination of the EMT’s equipment and the receiving hospital facilities. Normal resuscitation management must be followed.

II. Definition

Radiation injuries result from exposure to electromagnetic or particulate ionizing radiation. Radiation contamination is a unique form of chemical injury (radionuclides are unstable chemical elements that damage tissue by emitting alpha, beta, or ionizing gamma radiation). The electromagnetic radiation (EMR) spectrum includes non-ionizing wavelengths like visible light, infrared, and radio waves, which lack the energy to remove electrons from atoms. Higher energy EMR (e.g. ultraviolet light, X-rays, and gamma rays) efficiently ionize molecules and react with local tissue, which results in damage to the cellular DNA. Ionizing particles released from the natural decay of unstable atomic nuclei can include alpha particles (two protons and two neutrons bound together) or beta particles (high-speed electrons). Manufactured devices, like synchrotrons or thermonuclear bombs, produce high-speed protons, neutrons, and other energetic particles.

III. Mechanism of Injury

Ionizing radiation transmits energy to living tissue and causes tissue damage. At low doses, the primary effect is the 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 and tolerates small doses of radiation over a prolonged period much better than the same dose received acutely. Rapidly dividing cells in the hematopoietic system and the gastrointestinal tract are most easily damaged, although maximum doses of radiation will disrupt the metabolic activity of all somatic cells.

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 results in rapid systemic absorption of radioactive elements, indicating early decontamination.

3. External contamination results from the presence of radionuclide material on exposed body surfaces or clothing. This scenario presents a continuous hazard to the patient and to all those who come in contact with them. Immediate decontamination procedures will minimize the radiation exposure to all involved.

V. Radiation Detection

The most helpful instrument following a radiation incident is a radiation survey meter commonly called a Geiger-Muller counter. This device 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 industry to quantify the accumulated radiation dose for those who frequently work near radiation sources such as X-ray machines, medical radionuclides, and other radioactive materials. 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 patient. Use Personal Protective Equipment to prevent possible skin contamination with ANY radioisotope.

- Remove the patient 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 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 of the skin should be presumed to be contaminated. Copious but gentle irrigation of the exposed tissue with water or saline will remove most of the contaminants. The goal of decontamination is to dilute and neutralize particles without spreading them to unexposed areas. Therefore, victim must not be submersed in a tub.

Continue irrigation until a radiation detector survey indicates minimal residual radiation or at least a steady-state condition. Then transport the victim to the designated health care facility.

Intact skin should also be irrigated, ideally under a stream of warm tap water, a soft brush or a surgical sponge may aid with the decontamination process. If this is insufficient, patient might be scrubbed with neutral soap or detergent (pH of 7) for at least 4 minutes. This is followed by application of povidone-iodine solution or hexacholorophene soap, which is then rinsed again for at least 3 minutes and dried. Note that all these interventions should be performed ideally at the scene to decrease exposure of healthcare personnel and facilities. All exposures greater than 100 rem (1 Sv/Gy) require transport to the hospital for a complete assessment, if the exposure is greater than 200 rem (1Sv/Gy) or the patient develops symptoms of acute radiation syndrome (pancytopenia, bleeding, severe nausea, vomiting, bowel cramps, watery diarrhea, respiratory distress, cardiovascular collapse) urgent transfer to specialized centers is mandated to treat bone marrow failure and concomitant complications.

JCAHO requires hospitals to have a protocol for decontamination of radioactive or chemically contaminated patients. This requirement 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

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. For localized radiation injury, it is often difficult to assess the level of severity quickly and with accuracy because of the delay between exposure and appearance of lesions and because of hidden lesions in underlying tissues.

Massive irradiation of a single body part is harmful but seldom 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 gastrointestinal tract. Initially, there is gastrointestinal bleeding, which may be lethal. These changes are followed by sepsis as bacteria enter the bloodstream. There is a prolonged depression of the bone marrow, and death results from bleeding or sepsis.

VIII. Prognosis

Treatment of radiation injury, whether or not it is combined with other injuries, requires specialized knowledge and resources. The combination of radiation injury with associated injuries appears to have a synergistic effect on outcome. The total body radiation dose, the presence of any trauma or co-morbid medical conditions, and the availability of appropriate medical treatment facilities determine the prognosis. Radiation syndrome is often fatal unless managed with all the resources of a major medical research facility. Aplastic anemia, immunosuppresion, hemorrhage, and sepsis will be major complications for survivors. Currently bone marrow transplantation is the treatment of choice.

IX. References

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

APPENDIX 4

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. Still, systemic hypothermia can be rapidly fatal, so local cold injuries are treated only after reversing any associated hypothermia.

The physiologic changes associated with cold injuries are distinct from heat injury and require a unique therapeutic approach.

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

II. Hypothermia

A. Incidence

Primary hypothermia due to cold environmental exposure or cold-water immersion is most common during the winter months in geographical locations with extreme cold and/or elevation, 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.

First, the patient experiences a generalized cold sensation with uncontrollable shivering, followed by confusion, lethargy, impaired coordination of body movements and respiration, and decreased heart rate. With further reductions in core temperature, shivering stops, and the patient becomes somnolent with depressed respiration 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 and should be regularly monitored and corrected as needed.

C. Signs and Symptoms of Hypothermia

Table 1. Findings in Hypothermia

Hypothermia Class	CoreTemperature	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, cardiac arrest due to asystole

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

Some clinical thermometers will not register below 93°F (34 °C), so a digital thermometer or thermocouple should be used. A urinary catheter tipped with an integral thermocouple is more accurate than standard rectal temperature measurements to monitor the 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. Transport the patient in a warm environment and remove all wet clothes. 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 burn injury. 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 further temperature drops, wrap cold extremities (even with frostbite) in dry towels and do not rewarm them until the core temperature reaches 35° C. Rewarm one cold extremity at a time by immersion in the bath as the core temperature rises. Immersion contraindications 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. Accomplish active core heating 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 or Extra Corporeal Membrane Oxygenation (ECMO) allows for rapid rewarming and simultaneously can support circulation.

Weigh the potential complications of such invasive procedures against the advantages, especially in patients with traumatic injuries.

Hypothermic patients require frequent pH and electrolyte monitoring, especially if systemic acidosis is present. 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.

Perform a secondary assessment following rewarming to identify predisposing or contributing diseases, including sepsis, diabetes mellitus, cerebral ischemia, hypothyroidism, or alcoholism.

III. Local Cold Injury (Frostbite)

A. Pathophysiology

If tissue is cooled very rapidly, ice crystals will form inside and rupture cells resulting in cellular death. 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 and may produce a reperfusion injury with microvascular thrombosis and progressive tissue ischemia and necrosis.

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 0° C, ice crystals slowly form within the extracellular fluid. This process concentrates the extracellular solutes, and this hyperosmolar fluid dehydrates and shrinks the cells. There is sludging in the capillary beds, and eventually, blood flow stops in the exposed digits. Reduction of the metabolic rate allows frozen tissue to survive for a limited time. Rapid rewarming, while potentially damaging due to reperfusion, overall 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 months to determine the full extent of the injury.

B. Signs and Symptoms

Initially, the patient develops a cold, clumsy, and ultimately insensate extremity that 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 damage are found in Table 2. Hemorrhagic blisters indicate a deep dermal injury, and severely frostbitten skin eventually forms a black, dry eschar. This process 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

Like other thermal injuries, there are classification systems for frostbite injuries. Clinical classification should be done after rewarming. The most commonly used classification uses a 1st through 4th degree injury scale.

- First-degree frostbite: Superficial damage to the skin from tissue freezing with redness (erythema), some edema, hypersensitivity, and stinging pain. First -degree frostbite will generally heal without significant tissue loss.
- Second-degree frostbite: Deeper damage to the skin with a hyperemic or pale appearance, significant edema with clear or serosanguinous fluid-filled blisters, and severe pain. Second-degree frostbite will generally heal without significant tissue loss.
- Third-degree frostbite: Deep damage to the skin and subcutaneous tissue. On presentation, the tissue may be very pale and insensate without much tissue edema. Shortly after rewarming edema rapidly forms along with the presentation of hemorrhagic blisters. Blistering may take up to 24 hours and will often continue for up to seven days.
- Fourth-degree frostbite: All the elements of a third-degree injury with evidence of damage extending to the affected area's muscle, tendon, and bone. The depth of the damage may not be truly realized without radiologic imaging or eventually with operative intervention.

C. Treatment

The initial therapy for frostbite is rapid transport to a safe, consistently warm environment before rewarming. Constrictive or damp clothing is removed and replaced with dry, loose garments. The extremity should be padded and elevated, and should not be rubbed or massaged, which may exacerbate the injury. Isolated frostbite rarely requires fluid resuscitation. Avoid partial rewarming, and re-freezing which increases ischemic-reperfusion injury and could be catastrophic. Be sure to diagnose and treat concomitant injuries, especially systemic hypothermia.

Rewarm the affected areas by immersing them in gently circulating water at 38–40 °C for 30–40 minutes. Provide pain medication. Current wound care recommendations vary by center, consult with your regional burn center before de-roofing any blisters. Administer tetanus prophylaxis. Oral ibuprofen is used to treat pain and may limit injury by blocking prostaglandin production. Existing literature suggest that thrombolytics (local or systemic) administered within 12–24 hours of thawing a frostbitten extremity can limit the amount of tissue loss and decrease the need for or level of amputation in selected patients. However, this topic is outside of the purview of this course. Due to the high-risk nature of this treatment, consultation with your local or regional burn center is recommended prior to starting any thrombolytic therapy. Early amputation before definitive demarcation (which can take weeks to months to occur) is generally contraindicated as watchful waiting can often result in increased functional limb length.

IV. Summary

Cold injuries can range from mild, local tissue damage to 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 of these injuries.

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.

APPENDIX 5

Blast Injuries

Blast injuries are a common mechanism of trauma in many parts of the world, and high explosive events can produce mass casualties with multi-system injuries, including burns. The severity of the 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. Consider the presence of radioactive materials and chemicals in non-intentional injuries and acts of terrorism and war. Blast injuries can include:

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

Blast injuries are due to over-pressurization and often occur within the lungs, ear, abdomen, and brain. The blast effect to the lungs is the most common injury and can cause delayed fatality to those who survive the initial insult. The classic chest X-ray finding is a butterfly pattern, and symptoms of dyspnea, cough, hemoptysis, and chest pain are indicators of barotrauma. These injuries are often associated with the triad of apnea, bradycardia, and hypotension. Prophylactic chest tubes are recommended before 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 is also supportive. The pressure wave can cause blunt abdominal injury, and bowel ischemia/rupture should be considered. Lastly, brain injury is expected in blast injuries and imaging and monitoring should keep this potential injury high in the differential. Treat those without anatomic injury for mild to moderate traumatic brain injury, primarily supportive care with cognitive function testing during recovery.

Burns should be treated as thermal injuries without significant caveats other than some crush component that may compound the depth and extent of injury. Burns are common with significant blast injuries. The ball of flame emanating from most explosive devices can ignite clothing and extend the damage.

APPENDIX 6

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

APPENDIX 7

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.