Chapter 45
Environmental Conditions

Learning Objectives

• Describe the physiology of thermoregulation.
• Discuss the risk factors, pathophysiology, assessment findings, and management of specific hyperthermic conditions.
• Discuss the risk factors, pathophysiology, assessment findings, and management of specific hypothermic conditions and frostbite.
Learning Objectives

• Discuss the risk factors, pathophysiology, assessment findings, and management of submersion and drowning.
• Identify the mechanical effects of atmospheric pressure changes on the body based on a knowledge of the basic properties of gases.
• Discuss the risk factors, pathophysiology, assessment findings, and management of diving emergencies and high-altitude illness.

Thermoregulation

• Maintenance of body temperature, even under variety of external conditions
  – Body temperature is regulated in brain by thermoregulatory center
  • Located in posterior hypothalamus
  • Receives information from central thermoreceptors in or near anterior hypothalamus and from peripheral thermoreceptors in skin and some mucous membranes
  • Peripheral thermoreceptors are nerve endings usually categorized as cold receptors and warm receptors
  • Cold receptors are stimulated by lower skin-surface temperatures

Thermoregulation

• Maintenance of body temperature, even under variety of external conditions
  – Body temperature is regulated in brain by thermoregulatory center
  • Warm receptors are stimulated by higher skin-surface temperatures
  • Information from these receptors is transmitted by spinal cord to posterior hypothalamus
  • Posterior hypothalamus responds with appropriate signals to help body reduce heat loss and increase heat production (cold receptor stimulation) or increase heat loss and reduce heat production (warm receptor stimulation)
Why do you think the body has so many more cold receptors than heat receptors?

Thermoregulation

• Central thermoreceptors
  – Neurons sensitive to changes in temperature
  • React directly to changes in temperature of blood
  – Send messages to skeletal muscle through CNS
  – Affect vasomotor tone, sweating, and metabolic rate through sympathetic nerve output to skin arterioles, sweat glands, and adrenal medulla

Thermoregulation

• Thermoregulatory center has inherent set point
  – Maintains relatively constant core body temperature (CBT) of 98.6°F (37°C)
  – To maintain optimum environment for normal cell metabolism (homeostasis), body must keep CBT fairly constant, even when external and internal conditions tend to raise or lower it
  – Body temperature can be increased or decreased in two ways
    • Regulation of heat production (thermogenesis)
    • Regulation of heat loss (thermolysis)
Regulating Heat Production

• Body can generate heat in response to cold
  – Through mechanical, chemical, metabolic, and endocrine activities
  – Several physiological and biochemical factors affect direction and magnitude of these compensatory responses
    • Age
    • General health
    • Nutritional status

Regulating Heat Production

• Heat is controlled chemically by cellular metabolism (oxidation of energy sources)
  – Every tissue contributes to this type of heat production
  – Skeletal muscles produce largest amount of heat, particularly when shivering occurs
  – Vasoconstriction occurs to conserve as much heat as possible
  – Shivering is body’s best defense against cold
    • Can increase heat production by as much as 400 percent

What fuels does the body need for heat production to increase by shivering?
Regulating Heat Production

• Endocrine glands also regulate heat production
  – Through release of hormones from thyroid gland and adrenal medulla
  – Sympathetic discharge of epinephrine and norepinephrine increases metabolism
    • Results in increase in heat production

Regulating Heat Loss

• Heat is lost from body to external environment through skin, lungs, excretions
  – Skin is most important in regulating heat loss
  – Major mechanisms of heat loss
    • Radiation
    • Conduction
    • Convection
    • Evaporation
Regulating Heat Loss

• Radiation
  – Direct release of body heat to cooler surroundings
  – Surface of human body constantly emits heat in form of infrared rays
  – If surface of body is warmer than environment, heat is lost through radiation

Regulating Heat Loss

• Conduction
  – Direct movement of heat from warmer object to cooler one (simple transfer)
  – Heat moves from higher temperature to lower temperature
  – Body surface loses or gains heat by direct contact with cooler or warmer surfaces, including air
    • If ambient air temperature is lower than skin temperature, body heat is lost to surrounding air by conduction
  – Greater the temperature difference between two objects, the more quickly heat is transferred between them

Regulating Heat Loss

• Convection
  – Two objects in contact are also moving relative to one another
  – Heat transfer by mass motion of fluid such as air or water
  – Can be greatly aided by external forces such as wind or fans
  – Promotes conductive heat exchange by continuously maintaining supply of cool air
  – Factors that contribute to cooling effects of convection
    • Speed of air currents
    • Temperature of air
How does wearing the fully encapsulated hazardous materials suit affect your body’s ability to regulate temperature?

Regulating Heat Loss

• Evaporation
  – Process by which fluid changes from liquid to gas, and lowers temperature on surface where evaporation occurred
  – When fluid evaporates, it absorbs heat from surrounding objects and air
    • Temperature of surrounding air and relative humidity greatly affect amount of heat lost as result of evaporation of moisture from skin or respiratory tract (breathing)

Regulating Heat Loss

• Relative humidity is 100 percent when air is fully saturated with moisture
  – Sweating can markedly increase evaporative heat loss so long as humidity is low enough to allow sweat to evaporate
  – At humidity levels greater than 75 percent, evaporation decreases
  – At levels approaching 90 percent, evaporation essentially ceases
External Environmental Factors

• Some factors in environment can contribute to medical emergency
  – May affect rescue and transport
  – Elements include
    • Climate
    • Season
    • Weather
    • Atmospheric pressure
    • Terrain

External Environmental Factors

• When potential for an environmental emergency exists, consider factors
  – Localized prevailing weather norms and any deviations
  – Characteristics of seasonal variation in climate
  – Weather extremes (wind, rain, snow, humidity)
  – Barometric pressure (e.g., at altitude or under water)
  – Terrain that can complicate injury or rescue

External Environmental Factors

• Patient’s health is factor related to environmental stressors
  – Can also worsen other medical or traumatic conditions
  – Examples
    • Age
    • Predisposing medical conditions
    • Use of prescription and over-the-counter medications
    • Use of alcohol or recreational drugs
    • Previous rate of exertion
Hyperthermia

- Heat illness results from one or two basic causes
  - Temperature-regulating mechanisms overwhelmed by high temperatures in environment or by excessive exercise in moderate to extremely high temperatures
  - Temperature-regulating centers that fail, usually in older adults or in ill or incapacitated patients
  - Either cause can result in heat illness such as
    - Heat cramps
    - Heat exhaustion
    - Heat stroke

Heat Cramps

- Brief, intermittent, and often severe muscular cramps that occur in hot environments
  - Affect muscles fatigued by heavy work or exercise
  - Primary cause of heat cramps is sodium and water loss

Heat Cramps

- Sweat profusely and drink water without adequate salt
  - During times of high environmental temperatures, 1 to 3 L of water/hour can be lost through sweating
  - Each liter contains 30 to 50 mEq of sodium chloride
  - Water and sodium deficiency together cause muscle cramping
  - Normally occurs in most heavily exercised muscles, including calves and arms
Heat Cramps

- Sweat profusely and drink water without adequate salt
  - Patient usually
    - Is alert
    - Has hot, sweaty skin
    - Tachycardia
    - Has normal BP
    - CBT is normal

- Managed by removing patient from the hot environment
  - Sodium and water should be replaced
  - In more serious cases, medical direction may recommend IV infusion of balanced sodium chloride solution
  - Oral salt additives (e.g., salt tablets) can cause GI irritation, ulceration, vomiting
    - Worsens electrolyte imbalance
  - Follow local protocol with providing salt-containing beverage to help rehydrate patients

Heat Exhaustion

- More severe form of heat illness
  - Characterized by
    - Dizziness
    - Nausea
    - Headache
    - Mild to moderate elevation of CBT (up to 103°F [39°C])
    - In severe cases, dizziness caused by significant intravascular volume loss
    - Fainting
Heat Exhaustion

- More often associated with a hot environment and results in profuse sweating
  - Contributors to inadequate peripheral and cerebral perfusion
    - Loss of water and salt
    - Electrolyte imbalance, and difficulty maintaining BP
  - Person usually recovers rapidly when removed from hot environment and given replacement fluids
    - Patients with significant fluid loss or orthostatic hypotension may require IV administration of balanced sodium chloride solution
    - Heat exhaustion can progress to heat stroke if left untreated

Heat Stroke

- Occurs when body's temperature-regulating mechanisms break down entirely
  - As result of this failure, body temperature rises to 105.8°F (41°C) or higher
  - Damages tissue in all body systems and results in total body collapse
  - True medical emergency
  - Syndrome commonly classified into two types: classic heat stroke and exertional heat stroke

Heat Stroke

- Classic heat stroke
  - Occurs during periods of sustained high ambient temperatures and humidity
  - Commonly affects
    - Very young
    - Older adults
    - Those who live in poorly ventilated homes without air conditioning
Heat Stroke

- Classic heat stroke
  - Victims of classic heat stroke also often suffer from chronic diseases
    - Diabetes
    - Heart disease
    - Alcoholism
    - Psychiatric disorders

Heat Stroke

- Diseases predispose individual to syndrome
  - Many patients susceptible to classic heat stroke take prescribed medications for other conditions
    - Diuretics
    - Antihypertensives
    - Psychotropics (antipsychotics, antihistamines, phenothiazines)
    - Anticholinergics
  - Further impair person's ability to tolerate heat stress
  - In these patients illness develops from poor dissipation of environmental heat

Heat Stroke

- Patients with exertional heat stroke are usually young and healthy
  - Athletes
  - Military recruits
  - Firefighters who work or exercise in heat and humidity
  - Heat builds up more rapidly in body than it can be dispersed into environment
Heat Stroke

• Preventive measures to reduce risk of exertional heat illness for all age groups
  – Avoid or limit exercise in hot environments, especially on consecutive days
  – Maintain adequate fluid intake
  – Achieve acclimatization
    • Results in more perspiration with lower salt concentration
    • Increases fluid volume in body

Clinical Manifestations

• In response to hypothalamic stimulation, physiological events occur
  – Respiratory rate quickens to increase heat loss through exhaled air
  – Cardiac output increases to provide more blood flow through skin and muscle to enhance heat radiation
  – Sweat gland activity increases to enhance evaporative heat loss

Clinical Manifestations

• Compensatory mechanisms require normally functioning CNS to properly respond to temperature extreme
  – Require working cardiovascular system to move excess heat from core to surface of body
  – Problems in either or both of these systems lead to rapidly increasing CBT
CNS Manifestations

- CNS manifestations of heat stroke vary
  - Frank coma
  - Confusion and irrational behavior before collapse
  - Convulsions
    - Can occur early or late in course of illness
  - Because the brain stores little energy, it depends on constant supply of O₂ and glucose
  - Decreased cerebral perfusion pressure results in cerebral ischemia and acidosis
  - Increased temperatures markedly increase metabolic demands of brain

CNS Manifestations

- Extent of brain damage depends on severity and duration of hyperthermic episode
  - Fever from illness and increased CBT from heat stroke produce similar symptoms, especially in CNS
  - Obtain thorough history (if available) so as to distinguish between two syndromes
  - If unsure of cause, treat patient for heat stroke

What other conditions can present with these types of mental status changes?
Cardiovascular Manifestations

- Rise in skin temperature reduces thermal gradient between core and skin
  - Causes increase in skin blood flow (peripheral vasodilation)
    - Gives skin flushed appearance
  - About 50 percent of victims of exertional heat stroke have persistent sweating
    - Results from increased release of catecholamines

Cardiovascular Manifestations

- In classic heat stroke, sweating usually is absent due to
  - Dehydration
  - Drug use that impairs sweating
  - Direct thermal injury to sweat glands
  - Sweat gland fatigue

Cardiovascular Manifestations

- Presence of sweating does not rule out diagnosis
  - Cessation of sweating is not cause of heat stroke
  - Peripheral vasodilation results in decreased vascular resistance and shunting as illness progresses
  - High-output cardiac failure is common
    - Manifested by extreme tachycardia and hypotension
  - Cardiac output initially can be four to five times normal
    - As temperatures continue to rise, myocardial contractility begins to decrease
Cardiovascular Manifestations

- Central venous pressure rises
  - In any age group, presence of hypotension and decreased cardiac output points to poor prognosis

Cardiovascular Manifestations

- Other systemic manifestations associated with heat stroke
  - Pulmonary edema (accompanied by systemic acidosis, tachypnea, hypoxemia, and hypercapnia)
  - Myocardial dysfunction
  - Gastrointestinal bleeding
  - Reduction in renal function (secondary to hypovolemia and hypoperfusion)
  - Hepatic injury
  - Clotting disorders
  - Electrolyte abnormalities

Heat Stroke Management

- Heat stroke almost invariably leads to death if left untreated
  - Factors most important to successful outcome
    - Initiation of basic life support (BLS)
    - Advanced life support (ALS) measures
    - Rapid recognition of heat illness
    - Rapid cooling of patient
Heat Stroke Management

• After ensuring adequate airway and ventilatory and circulatory support, manage patient with heat stroke as follows
  – Move patient to shady environment and remove restrictive clothing
    • If available, use hyperthermic thermometers (e.g., rectal probes) to monitor CBT
  • Take and record temperature at least every 5 minutes during cooling process
    – Ensures adequate rates of cooling
    – Helps to prevent inadvertent (rebound) hypothermia
  • Rebound hypothermia can best be avoided by stopping cooling measures when patient’s CBT reaches about 102°F (39°C)

Heat Stroke Management

• Begin cooling by fanning patient while keeping skin wet
  – Continue lowering body temperature by this method en route to hospital
  – If transport is delayed, complete immersion or spraying tepid water (60°F [16°C]) over body surface is recommended
  – Shivering should be controlled with IV diazepam

Heat Stroke Management

• If hypovolemia is present, administer IV fluids per medical direction
  – 1 to 2 L of fluid should be administered during first hour after collapse and additional fluids administered according to level of hydration
  – In most patients, BP rises to normal range during cooling process
  – Occurs as large volumes of blood from skin move back to central circulation
Heat Stroke Management

• If hypovolemia is present, administer IV fluids per medical direction
  – Rapid cooling directly improves cardiac output
  – Be very cautious with fluid replacement
  – Closely monitor patient for signs of fluid overload
  – Administration of too much fluid can cause pulmonary edema, especially in older adults

Heat Stroke Management

• After ensuring adequate airway and ventilatory and circulatory support, manage patient with heat stroke as follows
  – Administer medications as prescribed by medical direction
    • Depending on patient’s status and response to cooling methods, these drugs may include
      – Diazepam or lorazepam for sedation and seizure control
      – Mannitol to promote renal blood flow and diuresis
      – Glucose to manage hypoglycemia

Hypothermia

• Hypothermia (CBT less than 95°F [35°C]) can result from
  – Decrease in heat production
  – Increase in heat loss
  – Combination of these two processes
Hypothermia

• Causes
  – Metabolic
  – Neurological
  – Traumatic
  – Toxic
  – Infectious

• Most often seen in cold climates and in exposure to extremely cold conditions in environment
  – Failure to recognize and properly treat can increase rate of morbidity and mortality

Hypothermia Pathophysiology

• Exposure to cold produces chain of events in body aimed at conserving core heat
  – Initially, immediate vasoconstriction in peripheral vessels occurs
  – At same time, rate of metabolism by CNS increases
  – BP and heart and respiratory rates also increase dramatically
  – As cold exposure continues, muscle tone increases

Hypothermia Pathophysiology

• Body generates heat in form of shivering
  – Shivering continues until
    • CBT reaches about 86°F (30°C)
    • Glucose or glycogen is depleted
    • Insulin is no longer available for glucose transfer
  – When shivering stops, cooling is rapid
    • General decline then begins in function of all body systems
Hypothermia Pathophysiology

• With continued cooling
  – Respirations decline slowly
  – Pulse rate and BP decrease
  – Blood pH drops
  – Significant electrolyte imbalances emerge
• Hypovolemia
  – Can develop from shift of fluid out of vascular space, with increased loss of fluid through urination (cold diuresis)

Hypothermia Pathophysiology

• After early tachycardia, progressive bradycardia develops
  – Often does not respond to atropine
  – Significant ECG changes occur
    • Prolonged PR, QRS, and QT intervals
    • Obscure or absent P waves
    • J point (Osborn wave) may be present at junction of QRS complex and ST segment
    • Events generally followed by cardiac and respiratory arrest as CBT approaches 68°F (20°C)
Hypothermia Pathophysiology

- Progression of clinical signs and symptoms of hypothermia is divided into 3 classes based on CBT
  - Mild
    - CBT between 93.2°F and 96.8°F (34°C and 36°C)
  - Moderate
    - CBT between 86°F and 93°F (30°C and 34°C)
  - Severe
    - CBT below 86°F (30°C)

Hypothermia Pathophysiology

- Those at increased risk for developing unintentional hypothermia
  - Outdoor enthusiasts
  - Older adults
  - Very young
  - Individuals with concurrent medical or psychiatric illness

Hypothermia Pathophysiology

- Thermoregulatory mechanisms also can be impaired by
  - Brain damage caused by trauma
  - Hemorrhage
  - Hypoxia
  - CNS depression from drug overdose or intoxicant
Hypothermia Pathophysiology

- Drugs known to impair thermoregulation
  - Alcohol
  - Antidepressants
  - Antipyretics
  - Phenothiazines
  - Sedatives
  - Various pain medicines
    - Aspirin
    - Acetaminophen
    - Nonsteroidal anti-inflammatory drugs (NSAIDs)

What group of people is especially vulnerable to hypothermia as a result of their environmental, medical, and social situation?

Hypothermia Management

- First step in managing hypothermia
  - Maintain high degree of suspicion for its presence
  - When exposure is obvious, diagnosis is simple
  - Some situations, signs and symptoms may be subtle
Hypothermia Management

• When hypothermia is suspected, paramedic’s immediate action is to
  – Extricate and evacuate patient to site of warm shelter
  – Remove cold, wet clothing
  – Prevent further drop in victim’s CBT
  – Survey for traumatic injuries
  – Cover patient with warm blankets and increase temperature in ambulance
  – Rapidly and gently transport patient for definitive care

Hypothermia Management

• Rewarming techniques for managing patients with hypothermia are classified as
  – Passive
    • Moving patient to warm environment
    • Removing wet clothing
    • Applying warm blankets
  – Active external
  – Active internal
    • Heating methods or devices such as radiant heat, forced hot air, warm water packs

Hypothermia Management

• Active internal rewarming is invasive
  – Some of these procedures can be performed in field, such as administering warmed IV fluids and providing warm, humidified O₂
  – Other procedures are reserved for in-hospital care
    • Peritoneal and/or pleural lavage with warm fluids
    • Use of esophageal rewarming tubes
    • Cardiopulmonary bypass (active core rewarming)
    • Extracorporeal circulation (blood warming with partial bypass)
Mild Hypothermia

- In mild cases of hypothermia, removal of victim from cold environment and passive rewarming may be all that is necessary to manage cold exposure
  - Can accomplish this by removing wet clothing
  - Wrapping victim in dry blanket to prevent further chilling and help retain patient's body heat
  - If victim is conscious, warm drinks and sugar sources can support gradual rise in CBT and help correct any dehydration present

Mild Hypothermia

- Patients should not be permitted to
  - Smoke, which causes vasoconstriction
  - Drink alcoholic beverages, which produce peripheral vasodilation and increase heat loss from skin
  - Drink caffeine-containing beverages, which cause vasoconstriction and diuresis
- May be lethargic and somewhat dulled mentally but generally are oriented with no marked mental derangements
Moderate Hypothermia

- At CBTs below 93°F (34°C), mental derangements are invariably present and include
  - Disorientation
  - Confusion
  - Lethargy proceeding to stupor and coma

Moderate Hypothermia

- Patients with moderate hypothermia usually
  - Have lost their ability to shiver
  - Their uncoordinated physical activity renders them unable to perform meaningful tasks
- Management
  - Ensuring adequate airway, ventilatory, and circulatory support
  - Maintaining body temperature

Moderate Hypothermia

- First employ passive rewarming techniques and should not permit these patients to move about independently or physically exert themselves
  - Even minor physical activity can bring about dysrhythmias, including ventricular fibrillation
  - External rewarming
  - Rapid and gentle transportation
  - Careful monitoring of patient’s mental status, ECG, and vital functions is crucial
Severe Hypothermia

• If patient’s CBT is less than 86.4°F (30°C), he or she usually is unconscious
  – Gently move to warm environment if vital signs are present
  – Institute passive and external rewarming
  – Administer oxygen
  – Transport

Severe Hypothermia

• If patient with moderate-to-severe hypothermia is in cardiac arrest (VF or pulseless VT), begin CPR and attempt defibrillation once
  – If patient does not respond to one shock, further defibrillation attempts should be deferred
  – Care should be focused on
    • Effective CPR
    • Rewarming patient
    • Rapid transport
• In-hospital active internal rewarming will be required for these patients

Severe Hypothermia

• Prolonged resuscitation can be beneficial in these patients
  – CPR is indicated even if signs of death are present
  – Resuscitation may be withheld if
    • Victim has obvious lethal injuries
    • Body is frozen so that nose and mouth are blocked by ice and chest compression is impossible
    • Some physicians will not presume hypothermic patient to be dead until near-normal CBT has been achieved and resuscitation efforts are still unsuccessful
Special Care Considerations for Patients with Hypothermia

- Prehospital care should focus on airway, breathing, and circulation with some modifications
  - Pulse and respirations may be difficult to detect
  - Vital signs (including ECG readings) should be assessed for 30 to 45 seconds to confirm need for CPR
  - If there is any doubt as to presence of pulse, begin CPR immediately

Special Care Considerations for Patients with Hypothermia

- Prehospital care should focus on airway, breathing, and circulation with some modifications
  - For unresponsive patients and those in arrest, endotracheal intubation is indicated
  - Intubation will serve two purposes
    - Will enable provision of effective ventilation with warm, humidified oxygen (if available)
    - Will isolate airway to reduce likelihood of aspiration

Special Care Considerations for Patients with Hypothermia

- Prehospital care should focus on airway, breathing, and circulation with some modifications
  - Hypothermic heart may be unresponsive to cardiovascular drugs
    - Drug metabolism is reduced, allowing for toxic accumulation of drug in peripheral tissues
    - For these reasons, IV drugs often are withheld when CBT is less than 30°C
    - If CBT is greater than 30°C, IV drugs may be given, but with increased intervals between doses
    - IV drug therapy should be guided by medical direction
Special Care Considerations for Patients with Hypothermia

- Prehospital care should focus on airway, breathing, and circulation with some modifications
  - Sinus bradycardia may be protective in severe hypothermia
  - Rhythm may maintain sufficient oxygen delivery when hypothermia is present
  - Cardiac pacing usually is not indicated or successful

Frostbite

- Localized injury
  - Results from environmentally induced freezing of body tissues
  - Often occurs in lower extremities, particularly toes and feet
  - Less often occurs in upper extremities (fingers and hands)
  - Occurs on ears, nose, other body areas not protected from environmental extremes

Frostbite Pathophysiology

- Occurs as ice crystals form in tissue
  - Produces macrovascular and microvascular damage and direct cellular injury
  - Freezing depth depends on intensity and duration of cold exposure
  - Severe freezing can also occur in tissue exposed to volatile hydrocarbons (e.g., from industrial injuries) at low temperatures
Frostbite Pathophysiology

• Under most conditions of frostbite, ice crystals form in extracellular tissue
  – Draws water out of cells and into extravascular spaces
  – As result, electrolyte concentration in cell can reach toxic levels
  – Ice crystals can also expand and cause direct mechanical destruction of tissue

Frostbite Pathophysiology

• Under most conditions of frostbite, ice crystals form in extracellular tissue
  – Leads to
    • Damage to blood vessels (particularly endothelial cells)
    • Partial shrinkage and collapse of cell membrane
    • Loss of vascular integrity
    • Local edema
    • Disruption of nutritive blood flow
  – Ischemia often produces most damaging effects of frostbite

Frostbite Pathophysiology

• When frozen tissue thaws, blood flow through capillaries is initially restored
  – Blood flow declines within minutes after thawing
  – Occurs as arterioles and venules constrict and release emboli, which travel through small vessels
  – Progressive tissue loss results from thrombosis and hypoxia
  – Endothelium is damaged and results in deterioration of microvasculature and dermal necrosis
  – Process of thawing and refreezing is more harmful to tissue than allowing frostbitten part to remain frozen until it can be warmed with minimal risk of refreezing
Frostbite Pathophysiology

- In addition to extreme temperature, wind, and humidity, predisposing factors include:
  - Lack of protective clothing
  - Poor nutrition
  - Preexisting injury or medical or psychiatric illness
  - Fatigue
  - Decrease in local tissue perfusion
  - Tobacco use
  - Atherosclerosis

Frostbite Pathophysiology

- In addition to extreme temperature, wind, and humidity, predisposing factors include:
  - Tight, constrictive clothing (especially socks and boots)
  - Increased vasodilation
  - Alcohol or other drug consumption in hypothermic patients
  - Use of medications
  - History of previous cold injury

Classifications and Symptoms

- Cold injury can be subdivided into number of classifications:
  - Frostnip and frostbite
  - Initial evaluation of severity of frostbite is difficult
    - Injury does not always reflect underlying vascular changes
    - Regardless of depth of injury, area may appear to be frozen
  - Palpation may help paramedic to distinguish between superficial and deep injury
    - With superficial injury, underlying tissue springs back on compression
    - With deep injury, underlying tissue is hard and cannot be compressed
Frostnip

• Manifested by transient numbness and tingling that resolves after rewarming
  – Cold injury does not represent true frostbite, because no tissue destruction occurs
  – Initial symptoms are coldness and numbness in affected area

Frostbite

• Frostbite can be graded as first-, second-, and third-degree injuries, based on severity of exposure
  – Affected areas may include
    • Dermal and shallow subcutaneous layers
    • Subdermal layers and deep tissues
  – All grades involve at least some tissue loss
  – Disrupted nutritional capillary flow is never restored to damaged tissue
  – With severe injuries, affected area remains cold, mottled, and blue or gray after rewarming
  – After rewarming, edema usually appears within 3 hours

Frostbite

• Followed by formation of vesicles within 3 to 24 hours
  – Blisters begin to resolve within 1 week
  – Skin blackens into hard eschar
  – Eventually blackened tissue peels away (demarcation)
    • Reveals shiny, red skin beneath
    • Sensitive to heat and cold and often remains susceptible to repeated frostbite injury
Frostbite Management

- Limited to
  - Supporting patient’s vital functions
  - Elevation and protection of affected extremity
  - Pain management
  - Rapid transport to medical facility
  - Vigorous rubbing or massage is ineffective and harmful
  - Partial, slow rewarming with blankets or other warm objects can worsen injury
  - If frostbite involves patient’s lower extremities, person should not be allowed to walk
Frostbite Management

• During transport, all restrictive and wet clothing should be removed from patient
  – Replaced with warm, dry clothing and blankets
  – Patient prohibited from alcohol or tobacco
  – Rapid rewarming of frozen part by immersion in hot water (maximum of 104°F [40°C]) is most effective therapeutic measure for preserving viable tissue
    • Because of risk of refreezing, this method of rewarming should not be used in prehospital setting if transport will be delayed (e.g., backwoods rescue, natural disasters)

Submersion

• Drowning was fifth leading cause of unintentional death in U.S. in 2006
  – Second leading cause of unintentional injury death among children and youth
  – About 80,000 submersion incidents are reported each year
    • Of these, 85 percent of victims are male, 2/3 of victims are nonswimmers

Classifications

• Defined as “process resulting in primary respiratory impairment from submersion/immersion in liquid”
  – Submersion usually refers to head being below water
  – Immersion refers to head being above water
    • Terms often used interchangeably
    • Definition further requires that liquid/air interface be present at entrance of victim’s airway, preventing victim from breathing air
  – According to this definition, victim may live or die after this process; regardless, he or she has been involved in drowning event
### Submersion

- Victims of submersion incidents usually fall into one of two categories
  - Conscious patients
    - Nonswimmers
    - Exhausted swimmers
    - River canoeists who become trapped by roots or strong currents
    - Individuals who fall overboard or off dock
    - Motor vehicle crash victims trapped in submerged vehicles
    - Those who fall into extremely cold water and do not resurface (sudden submersion syndrome)

### Submersion

- Victims of submersion incidents usually fall into one of two categories
  - Unconscious patients
    - Suffer stroke or cardiac arrest while swimming
    - Fall into water and die as result of hypothermia

### Submersion Pathophysiology

- Drowning begins with intentional or unintentional submersion
  - After submersion, victim realizes he or she is in distress
  - Begins with conscious victim taking in several deep breaths
    - Attempt to store oxygen before breath-holding
    - Victim holds breath until breathing reflexes override breath-holding effort
Submersion Pathophysiology

- As water is aspirated, laryngospasm occurs
  - Produces severe hypoxia
  - Results in serious hypoxemia and acidosis
- Lead to cardiac dysrhythmias and CNS anoxia
- Physiological events that follow are partly determined by type and amount of water aspirated
- Regardless of type of water aspirated, pathophysiology of drowning can result in cardiac arrest and is characterized by
  - Hypoxia
  - Hypercapnia
  - Acidosis

Do other swimmers or onlookers often “hear” a person who is drowning?

Submersion Pathophysiology

- Drowning can occur in almost any type of water
  - In theory, different fluids have different effects
  - These differences are not clinically significant in prehospital care
    - Should not be considered in initial management of submersion patients
  - Single most important factors that determine outcome are duration of submersion and duration and severity of hypoxia
Pulmonary Pathophysiology Secondary to Drowning

- Submersion complications
  - Respiratory failure
  - Hypoxia
  - Acidosis

- Hypoxia can result from
  - Fluid in alveoli and interstitial spaces
  - Loss of surfactant
  - Contaminant particles in alveoli and tracheobronchial tree
  - Damage to alveolar–capillary membrane and vascular endothelium

- Poor perfusion and hypoxemia lead to metabolic acidosis in most patients
  - In those who survive incident, acute respiratory failure may occur
  - Includes development of adult respiratory distress syndrome (ARDS)
  - ARDS reduces lung compliance and increases ventilation–perfusion mismatches and intrapulmonary shunting
  - Onset of symptoms can be delayed for as long as 24 hours after submersion (secondary drowning)
**Pulmonary Pathophysiology Secondary to Drowning**

- In addition to pulmonary effects, submersion can affect other body systems
  - Cardiovascular derangements can occur as a result of hypoxia and acidosis
    - Lead to dysrhythmias and decreased cardiac output
  - CNS dysfunction and nerve damage result from cerebral edema and anoxia

**Pulmonary Pathophysiology Secondary to Drowning**

- Be suspicious of spinal injury in drowning victims
  - Renal dysfunction is not common complication
    - Can progress to acute renal failure
    - Usually result of hypoxic injury or hemoglobinuria, leading to acute tubular necrosis

**Factors that Affect the Clinical Outcome**

- Duration of submersion
  - Longer the time submersed, less likely patient is to survive
    - When rescue takes more than 30 minutes, victims rescued from warm water in summer months or in warm southern waters usually do not survive
    - Submersion in cold water for up to 66 minutes in children has been associated with survival, including intact brain function
Factors that Affect the Clinical Outcome

• Duration of submersion
  – Resuscitation is indicated for all patients unless physical evidence of death is present (e.g., putrefaction, dependent lividity, and rigor mortis)
  • Submersion victims who have spontaneous circulation and breathing when they reach hospital usually recover, with good outcomes

Factors that Affect the Clinical Outcome

• Cleanliness of water
  – Contaminants in water have irritant effect on pulmonary system
  – May lead to bronchospasm and poor gas exchange
  – Can cause secondary pulmonary infection with delayed severe respiratory compromise

Factors that Affect the Clinical Outcome

• Temperature of water
  – Submersion in cold water can have beneficial and negative effects
  – Rapid onset of hypothermia can serve protective function
    • Especially with brain viability in patients who have undergone prolonged submersion
  – Incident in which child was submerged for 66 minutes in creek with water temperature of 37°F (5°C) is longest documented submersion with good neurological outcome
  – Phenomenon is not fully understood
Factors that Affect the Clinical Outcome

- Temperature of water
  - Contributing factor may be mammalian diving reflex in infant and child submersions
    - Reflex stimulated by cold water
    - Shunts blood to brain and heart from skin, GI tract, and extremities
    - Reflex occurs in seals and lower mammals
    - Occurs in humans to some extent

Factors that Affect the Clinical Outcome

- Temperature of water
  - Hypothermia may slow brain-cell death and organ demise that can lead to permanent neurological damage
    - Hypothermia can also contribute to neurological recovery after prolonged submersion by reducing metabolic needs of brain
    - May develop secondary to submersion and later heat loss through evaporation during attempts at resuscitation
    - In these cases, hypothermia is not protective
    - Relative contributions of diving reflex and hypothermia are not clear
    - Adverse effects of submersion in cold water include severe ventricular dysrhythmias

Factors that Affect the Clinical Outcome

- Age of victim
  - Younger patient or victim has better chance for survival
Submersion Management

- At site of submersion incident, safety of EMS crew is paramount
  - Only personnel trained in water rescue should try to intervene
  - Depending on type and duration of submersion, patient’s symptoms may vary from an asymptomatic presentation to cardiac arrest
  - After gaining access to victim, take spinal precautions while victim is still in water only if spinal injury is suspected

Submersion Management

- Rescue breathing (if needed) should be initiated as soon as possible
  - Use of subdiaphragmatic thrusts to remove water from airways is ineffective and dangerous
    - May cause vomiting and aspiration
  - Subdiaphragmatic thrusts are indicated if foreign body airway obstruction is suspected

Submersion Management

- After removing patient from water, evaluate patient to ensure an adequate airway
  - Ventilatory and circulatory
  - High-concentration oxygen
  - Pulse oximetry
  - ECG monitoring
  - Establishment of IV line
  - Patients who are in cardiac arrest should be managed with standard BLS and ALS protocols
Submersion Management

- Victims of submersion incidents often are at risk for hypothermia
  - Heat loss in water can be up to 32 times greater than in air
- Hypothermia can make resuscitation more difficult
  - Calls for special consideration with regard to
    - Gentle handling
    - Administration of drugs
    - Defibrillation

Submersion Management

- As with all other victims of hypothermia, remove patient’s wet clothing
  - Patient then should be dried and wrapped in blankets to conserve body heat
  - External warming and administration of heated, humidified oxygen at scene and during transport should be considered

Submersion Management

- According to AHA, “all victims of drowning who require any form of resuscitation (including rescue breathing alone) should be transported to the hospital”
  - Asymptomatic patients require transport for physician evaluation
  - Give oxygen
  - Carefully monitor to guard against aspiration pneumonia and undetected hypoxia that can result from submersion
  - Oxygen is most important treatment needed by submersion victims
What are the risks to rescuers on a call involving submersion victims?

Diving Emergencies

- U.S. has over 4 million recreational scuba divers; more than 400,000 new sport divers are certified each year
  - Emergencies unique to pressure-related diving include
    - Those caused by mechanical effects of pressure (barotrauma)
    - Air embolism
    - Breathing of compressed air (decompression sickness and nitrogen narcosis)

Basic Properties of Gases

- Weight of atmosphere exerts a pressure of 14.7 pounds psi of force at sea level
  - 1-inch column of air as tall as atmosphere would weigh 14.7 pounds
  - Weight is commonly referred to as 1 atmosphere of pressure (1 atm)
  - Water weighs considerably more than air and can exert much more pressure
Laws Pertaining to Gases

• Three laws of properties of gases underpin all pressure diving-related emergencies (some high-altitude illnesses)
  – Boyle’s law
  – Dalton’s law
  – Henry’s law

Laws Pertaining to Gases

• Properties of gases can aid comprehension of these laws
  – Increased pressure dissolves gases into blood
  – Oxygen metabolizes
  – Nitrogen dissolves

Boyle’s Law

• If temperature remains constant, volume of given mass of gas is inversely proportional to absolute pressure
  – When pressure is doubled, volume of gas is halved (compressed into smaller space), vice versa
  – Expressed by equation \( PV = K \)
    • \( P \) is pressure
    • \( V \) is volume
    • \( K \) is constant
  – Law explains “popping” or “squeezing” sensation in ears that person may feel when traveling by air

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Boyle’s Law

- Basic mechanism for all types of barotrauma
  trapped gases expand as pressure decreases
  - Example
    - When diver uses scuba tank of pressurized air, lung volumes remain constant at various depths
    - If diver ascends but does not exhale, water pressure decreases and gas in lungs expands
    - Greatly increases pressure in lungs

Dalton’s Law

- Pressure exerted by each gas in mixture of gases is same pressure that gas would exert if it alone occupied same volume
  - On other hand, total pressure of a mixture of gases equals sum of partial pressures that make up mixture
  - Expressed by equation $P_t = P_{O_2} + P_{N_2} + P_x$
    - $P_t$ is total pressure
    - $P_{O_2}$ is partial pressure of oxygen
    - $P_{N_2}$ is partial pressure of nitrogen
    - $P_x$ is partial pressure of remaining gases in mixture

Dalton’s Law

- To simplify, air we breathe is about 80 percent nitrogen and 20 percent oxygen
  - About 80 percent of pressure of air (i.e., gas mixture) is exerted by nitrogen in mixture
  - About 20 percent of pressure is exerted by oxygen in mixture
  - Means that at sea level, pressure exerted on us by nitrogen in air is 80 percent of 14.7, or 11.76 psi
  - Pressure from oxygen is 20 percent of 14.7, or 2.94 psi
  - Together, account for 14.7 psi of pressure at surface
Dalton’s Law

• Even though gas mixtures remain with normal percentages of nitrogen and oxygen, partial pressures of these gases change at different altitudes above sea level or at depths below sea level
  – Principles of this law explain problems that can arise from breathing of compressed air
    • Gas expansion causes partial pressure of oxygen to drop as gas molecules move farther apart, reducing available oxygen

Henry’s Law

• At constant temperature, solubility of gas in liquid solution is proportionate to partial pressure of gas
  – Means that more gas can be dissolved into liquid at higher pressure
  – Less gas can be dissolved into liquid when that pressure is released
  – Example
    • When container of carbonated beverage (pressurized with dissolved carbon dioxide gas) is opened, “pop” is heard, and bubbles form on liquid
    • Occurs because pressure in container is no longer great enough to hold dissolved gas inside

Henry’s Law

• Expressed by equation %X = Px/Pt X 100
  – %X is amount of gas dissolved in liquid
  – Px is partial pressure of gas
  – Pt is total atmospheric pressure
  – Law explains why more nitrogen, which makes up almost 80 percent of air, dissolves in diver’s body as ambient pressure increases with descent
    • Dissolved nitrogen is released from tissues on ascent as pressure decreases
Barotrauma

- Tissue injury caused by change in pressure, which compresses or expands gas contained in various body structures
  - Type depends on whether diver is in descent or ascent
  - Most common injury of scuba divers

Barotrauma of Descent

- Barotrauma of descent (also known as squeeze)
  - Results from compression of gas in enclosed spaces as ambient pressure increases with descent under water
  - Air trapped in noncollapsible chambers is compressed
  - Leads to vacuum-type effect that results in
    - Severe, sharp pain caused by distortion
    - Vascular engorgement
    - Edema
    - Hemorrhage of exposed tissue

Barotrauma of Descent

- As a rule, squeeze usually results from blocked Eustachian tube or from failure of diver to clear (open) Eustachian tube with exhalation during descent
  - Ears and paranasal sinuses most likely to be affected
  - Occurs in
    - Ears
    - Sinuses
    - Lungs and airways
    - GI tract
    - Thorax
    - Teeth (pulp decay, recent extraction sockets or fillings)
    - Added air spaces (face mask or diving suit)
Barotrauma of Descent

- Management of barotrauma of descent
  - Slowly returning diver to shallower depths
- Prehospital care is mainly supportive

Barotrauma of Descent

- Definitive care
  - Bed rest with head elevated
  - Avoidance of strain and strenuous activity
  - Use of decongestants
  - Antihistamines and antibiotics
  - Surgical repair

What preexisting illness can make a diver more susceptible to squeeze?
Barotrauma of Ascent

• Occurs through reverse process of descent ("reverse squeeze")
  – Assuming that air-filled cavities of body have equalized pressure during diver’s descent, volume of air trapped in this pressurized space expands as ambient pressure decreases with ascent (Boyle’s law)

Barotrauma of Ascent

• If air is not allowed to escape because of obstruction (e.g., breath-holding, bronchospasm, or mucus plug), expanding gases distend tissues surrounding them
• Most common cause breath-holding during ascent

Barotrauma of Ascent

• Problems from reverse squeeze are rare
  – Pulmonary overpressurization syndrome (POPS) can occur as result of expansion of trapped air in lungs
    • Can lead to alveolar rupture
    • Can lead to leakage of air into areas outside alveoli
Barotrauma of Ascent

• Problems from reverse squeeze are rare
  – Clinical syndromes
    • Pneumomediastinum
    • Subcutaneous emphysema
    • Pneumopericardium
    • Pneumothorax
    • Pneumoperitoneum
    • Systemic arterial air embolism

Barotrauma of Ascent

• POPS usually requires only administration of oxygen, observation, and transport for evaluation by a physician
  – Except for tension pneumothorax
    • Rare complication that may require needle or tube decompression
  – Air embolism
    • May require hyperbaric recompression therapy

Air Embolism

• Most serious complication of pulmonary barotrauma
  – Major cause of death and disability among sport divers
  – Divers risk this condition when they ascend too rapidly or hold their breath during ascent
  – Classic description of dive causing air embolism is rapidly ascending to surface because of panic
Air Embolism

• Results as expanding air disrupts tissues and air is forced into circulatory system
  – Air bubbles pass through left side of heart and become lodged in small arterioles
  – Occludes distal circulation
  – Syndrome usually manifests as diver surfaces and exhales
    • Exhaling releases high intrapulmonic pressure that resulted from lung overexpansion

Air Embolism

• With decrease in intrathoracic pressure
  – Bubbles advance into left side of heart
    • Enter systemic arterial supply
  – Results in dramatic presentation
    • Clinical manifestations depend on site of systemic arterial occlusion

Air Embolism

• With decrease in intrathoracic pressure
  – Most common presentation is similar to that of stroke and includes
    • Vertigo
    • Confusion
    • Loss of consciousness
    • Visual disturbances
    • Focal neurological deficits
Air Embolism

• Should be suspected if diver suddenly loses consciousness immediately after surfacing
  – Begin BLS and ALS measures
  – Rapidly transport for recompression treatment
  – Thoroughly evaluate for signs of POPS, such as a pneumothorax

Air Embolism

• Patient suspected of having air embolism should be transported in horizontal, neutral position
  – Helps to avoid aggravating cerebral edema that may develop

Air Embolism

• If air transport is used, should be transported by aircraft that is pressurized to sea level
  – Can be transported by rotary wing aircraft that flies at low altitude
  – Prevents existing intra-arterial air bubbles from expanding further
  – Flight altitude must be as low as possible if internal cabin pressure cannot be maintained at sea level
  – Should never be over 1000 feet above sea level
Recompression

- Use of elevated pressure (including hyperbaric oxygen therapy) to treat conditions within body caused by a rapid decrease in pressure (e.g., air embolism)
  - Takes place in hyperbaric oxygen chamber
    - Allow for delivery of oxygen at higher than normal atmospheric pressure
    - Process is used to overcome natural limit of oxygen solubility in blood

Recompression

- Reduces intravascular bubble volume and restores tissue perfusion
  - Slow decompression helps to prevent bubbles from reforming
  - Paramedics should know location of nearest hyperbaric treatment facility
  - Follow protocol established by medical direction
  - Ground transportation to hyperbaric facility is preferred over air transportation
    - Increase in altitude lowers the ambient pressure and allows microbubbles to expand

Recompression

- Not required for diving injuries such as
  - Ear or facial barotrauma
  - Nitrogen narcosis
  - Pneumothorax
  - Pneumomediastinum
  - Subcutaneous emphysema
Where is the nearest hyperbaric chamber in your area?

Decompression Sickness

- Also known as
  - The bends
  - Dysbarism
  - Caisson disease
  - Diver’s paralysis
Decompression Sickness

- Multisystem disorder
  - Results when nitrogen in compressed air
  - Dissolved into tissues and blood from increase in partial pressure of gas at depth
  - Converts back from solution to gas
  - Results in formation of bubbles in tissues and blood

Decompression Sickness

- Occurs when ambient pressure decreases (Henry’s law)
  - Cause is ascent that is too rapid
    - Balance between dissolved nitrogen in tissue and blood and partial pressure of nitrogen in inspired gas cannot be reached
  - Because nitrogen bubbles can form in any tissue, can cause
    - Lymphedema (accumulation of lymph in soft tissues)
    - Cellular distention
    - Cellular rupture also can occur

Decompression Sickness

- Net effect of all these processes is poor tissue perfusion and ischemia
  - Joints and spinal cord are most often affected
  - Signs and symptoms
    - Rashes
    - Itching
    - Complaint of "bubbles under the skin"
    - Chest pain
    - Cough
    - Shortness of breath
Decompression Sickness

• Failure to make recommended decompression "stops" during ascent usually causes decompression sickness
  – Stops are based on diving tables and charts that consider depth, duration of dive, and previous dives completed
  – Making stops during ascent allows more time for safe off-gassing

Decompression Sickness

• Many hyperbaric professionals advise 3- to 5-minute safety stop at 15 to 20 feet for any dive
  – For dives below 60 feet, another safety stop at 30 feet may be of value
  – Ask diver about safety stops made during ascent

Decompression Sickness

• Suspect decompression sickness in any patient who has symptoms within 12 to 36 hours after scuba dive
  – Will be symptoms that cannot be explained by other conditions
Decompression Sickness

• Prehospital care
  – Support of vital functions
  – High-concentration oxygen
  – Fluid resuscitation
  – Rapid transportation for recompression
  – Patient transport and air evacuation guidelines
described for air embolism should also be used

Nitrogen Narcosis

• “Rapture of the deep” is condition in which
  nitrogen becomes dissolved in blood
  – Caused by higher than normal partial pressure of
    nitrogen
  – Dissolved nitrogen crosses blood–brain barrier
    • Produces depressant effects similar to those of alcohol
    • Can seriously impair diver’s thinking and lead to lethal
      errors in judgment
    • Symptoms of nitrogen narcosis usually become evident
      at depths of 75 to 100 feet

• At depths < 300 feet, with standard air
  (oxygen-nitrogen mixture), diver loses
  consciousness
  – Affects all divers, is better tolerated by
    experienced divers
  – More likely to occur if diver is cold, fatigued,
    frightened
Nitrogen Narcosis

- Helium-oxygen mixtures are used to improve nitrogen complication (improving mental clarity) for deep dives
  - Narcotic effects of nitrogen are reversed with ascent

Nitrogen Narcosis

- Common factor in diving accidents
  - May be responsible for memory loss
- Prehospital care is mainly supportive
  - Assess patient for injuries that may have occurred during dive, and patient should be transported for evaluation by physician

High-Altitude Illness

- Principally occurs at altitudes 8200 feet or more above sea level
  - Attributed directly to exposure to reduced atmospheric pressure
    - Results in hypobaric hypoxia
  - Associated activities
    - Mountain climbing
    - Aircraft or glider flight
    - Riding in hot air balloons
    - Use of low-pressure or vacuum chambers

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High-Altitude Illness

- Emergency care for all forms of high-altitude illness includes
  - Airway, ventilatory, and circulatory support
  - Descent to lower altitude
  - Physician should evaluate all patients with high-altitude illness

High-Altitude Illness

- Strategies for preventing high-altitude illness
  - Gradual ascent (days)
  - Limited exertion
  - Decreased sleeping at altitude
  - Adequate fluid intake to prevent dehydration
  - High-carbohydrate diet
  - Medications (all are controversial)
    - Acetazolamide (to speed acclimatization and reduce incidence of AMS)
    - Nifedipine (used solely by those with history of HAPE to prevent recurrence upon ascent)
    - Steroids

High-Altitude Illness

- Exposure to high altitude can worsen chronic medical conditions
  - This is case even without apparent altitude sickness
    - Can worsen as result of low partial pressure of oxygen
    - Low partial pressure of oxygen means that less oxygen is inhaled with each normal respiratory volume
Acute Mountain Sickness

• Common high-altitude illness
  – Results when unacclimatized person ascends rapidly to high altitudes
  – Usually develops within 4 to 6 hours of reaching high altitude and reaches maximum severity within 24 to 48 hours
  – Abates on third or fourth day after exposure with gradual acclimatization

Acute Mountain Sickness

• Physical findings with AMS vary
  – Tachycardia
  – Bradycardia
  – Postural hypotension
  – Ataxia (impaired ability to coordinate movement)
    • Key sign of progression of illness
  – As AMS becomes severe, victim may experience alterations in consciousness, disorientation, and impaired judgment

Acute Mountain Sickness

• Emergency care
  – Administration of oxygen
  – Descent to as low an altitude as needed to achieve relief
• Definitive treatment
  – Use of diuretics to treat fluid retention associated with AMS
  – Steroids to reduce associated cerebral edema
  – Hyperbaric therapy
High-Altitude Pulmonary Edema

• Caused at least partly by increased pulmonary artery pressure that develops in response to hypoxia
  – Increased pressure results in release of leukotrienes
    • Increase permeability of pulmonary arterioles

• Increased pressure also results in leakage of fluid into extravascular space
  – Initial symptoms of HAPE usually begin 24 to 72 hours after exposure to high altitudes
    • Often are preceded by vigorous exercise

• Physical findings
  – Hyperpnea
  – Crackles
  – Rhonchi
  – Tachycardia
  – Cyanosis
High-Altitude Pulmonary Edema

- Emergency care
  - Oxygen administration to increase arterial oxygenation and reduce pulmonary artery pressure
  - Descent to lower altitude
  - May be hospitalized for observation

High-Altitude Pulmonary Edema

- Portable hyperbaric chambers are commercially available
  - May temporarily reverse effects of high-altitude pulmonary and cerebral edema
  - Used by some EMS agencies in high-risk areas when immediate decent is not possible

High-Altitude Cerebral Edema

- Most severe form of acute high-altitude illness
  - Characterized by progression of global cerebral signs in presence of AMS
  - Probably related to increase in intracranial pressure caused by cerebral edema and swelling
High-Altitude Cerebral Edema

• Distinctions between AMS and HACE are inherently blurred
  – Progression from mild AMS to unconsciousness associated with HACE can occur quickly (i.e., within 12 hours)
    • Usually requires 1 to 3 days of exposure to high altitudes

High-Altitude Cerebral Edema

• Must be managed promptly
  – Without treatment, rapidly progresses to stupor, coma, death
• Emergency care
  – Airway, ventilatory, and circulatory support
  – Descent to lower altitude

Summary

• Body temperature is regulated by a thermoregulatory center in posterior hypothalamus
  – Body temperature can be increased or decreased in two ways
    • Through regulation of heat production
      – Known as thermogenesis
    • Through regulation of heat loss
      – Known as thermolysis
Summary

• Heat illness results from one of two basic causes
  – Normal temperature-regulating functions can be overwhelmed by conditions in environment
    • Conditions can include heat stress
    • More often involve excessive exercise in moderate to extreme environmental conditions
  – Failure of body’s thermoregulatory mechanism
    • May occur in older adults or ill or debilitated individuals
    • Heat cramps are brief, intermittent, and often severe, and are muscular cramps that occur in muscles fatigued by heavy work or exercise

Summary

• Heat exhaustion is characterized by minor aberrations in mental status, dizziness, nausea, headache, and a mild to moderate rise in the core body temperature (CBT) (up to < 103°F [39°C])
• Heat stroke occurs when the temperature-regulating functions break down entirely
  – Results in body temperature rises to 105.8°F (41°C) or higher
    • Damage all tissues and lead to collapse

Summary

• Hypothermia (CBT lower than 95°F [35°C]) can result from decrease in heat production, an increase in heat loss, or a combination of these factors
  – Progression of clinical signs and symptoms of hypothermia is divided into three classes based on the CBT: mild (CBT between 93.2°F and 96.8°F [34°C and 36°C]), moderate (CBT between 86°F and 93°F [30°C and 34°C]), and severe (CBT below 86°F [30°C])
  – Severely hypothermic patients have no vital signs, including respiratory effort, pulse, and blood pressure
Summary
• Frostbite is a localized injury
  – Results from environmentally induced freezing of body tissues
    • Leads to damage to blood vessels
  – Ischemia often produces the most damaging effects of frostbite
    • In deep frostbite, this can include mummification and sloughing of nonviable skin and deep structures

Summary
• Drowning is a process that results in primary respiratory impairment from submersion/immersion in a liquid medium that presents the person from breathing air
  – Regardless of the type of water aspirated, pathophysiology of drowning is characterized by hypoxia, hypercapnia, and acidosis, which result in cardiac arrest

Summary
• Three laws pertaining to the basic properties of gases that are involved in all pressure-related diving emergencies are Boyle’s law, Dalton’s law, and Henry’s law
  – Increased pressure dissolves gases into blood; oxygen metabolizes, and nitrogen dissolves
Summary

• Barotrauma is tissue damage
  – Results from compression or expansion of gas spaces when gas pressure in body differs from ambient pressure
    • Type of barotrauma depends on whether diver is in descent or ascent
    • Air embolism is most serious complication of pulmonary barotrauma
    • Major cause of death and disability among sport divers

Summary

• High-altitude illness results from exposure to reduced atmospheric pressure, which results in hypoxia
  – Forms of high-altitude illness include acute mountain sickness, high-altitude pulmonary edema, and high-altitude cerebral edema

Questions?