

# Drowning Definitions

- Nonfatal drowning
  - Process of drowning interrupted
- Fatal drowning
  - Death from drowning
- Water rescue
  - Submersion or immersion without evidence of respiratory impairment
- All other terms should be avoided



# Epidemiology of Drowning

- One of top two leading causes of accidental death in children
- 2/3 of deaths are age < 30
- Young children
  - Inability to swim
  - Surveillance
  - Fencing and locks
  - Pools, bathtubs
  - Curiosity, play
- Teens and adults
  - Seizures
  - Alcohol
  - Associated trauma
  - Inability to swim
  - Exhaustion
  - Scuba

## Drowning Overview

- Mammalian diving reflex (sudden cold water immersion)
  - Bradycardia, apnea
  - Shunting of blood to CNS
  - Decreased metabolism
  - Children > adults
- Shock is rare in drowning
  - Rule out trauma
  - C-spine precautions: Diving, multiple trauma, or unknown circumstances
- Salt vs. fresh water: no effect on survival

# Drowning Survival Factors

- Primary factor is duration of immersion
- Also
  - Water temperature
  - Age
  - Diving reflex
  - Associated trauma
  - Associated dysbaric problems
  - Bystander CPR
  - Water contamination

Low core temperature  
correlates with bad outcome



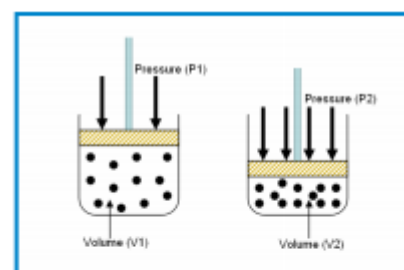
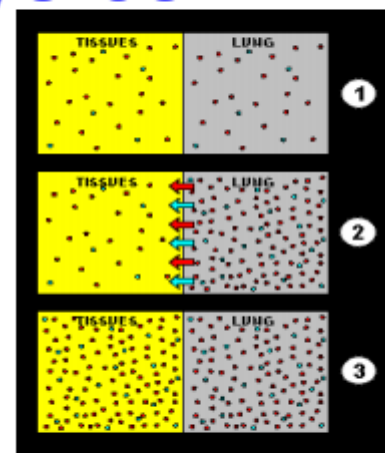
# SCUBA Diving Contraindications

- Asthma
- COPD
- Seizures
- Sinus and ear disease
- Syncope
- Panic disorder
- Vertigo
- Poor training



## Diving: Laws of Physics “Fizzyology”

- **Henry’s Law:** The amount of gas dissolved in a liquid is proportional to the partial pressure of the gas in contact with the liquid
- **Dalton’s Law:** Partial pressure of a gas increases with increasing pressure
  - **Both above - Decompression Sickness and Nitrogen Narcosis**
- **Boyle’s Law:** The volume of a gas varies inversely with the pressure
  - **Squeeze Syndromes and Barotrauma**



## Barotrauma from Diving

- Squeeze Syndromes
- **Disorders of descent** (Boyle's Law)
- Barotitis Media: "Ear squeeze"
  - Pain from pressure on the TM, due to inability to equalize pressure (blocked Eustachian tube)
- TM can rupture with severe vertigo, N&V
- Treatment: Nasal decongestants, maneuvers to open Eustachian tube (Valsalva, et al.)
- Other squeeze syndromes: Sinus squeeze, facemask squeeze, eye squeeze, suit squeeze, lung squeeze

## External / Inner Ear Barotrauma

- External ear barotrauma
  - Due to blockage of external auditory canal by cerumen or ear plugs
- Inner ear barotrauma
  - Hemorrhage or rupture of the inner ear round window with sensorineural hearing loss = labyrinthine window rupture
  - Severe vertigo, N/V, tinnitus, nystagmus, ataxia
  - Referral to ENT

## **Pulmonary Barotrauma**

### **Pulmonary Over Pressurization Syndrome**

- Rapid uncontrolled **ascent** (Boyle's Law)
  - Dropped weight belt
  - BC malfunction
  - Panic and charge to the surface
- Expansion of unvented lung gases on ascent results in a "burst lung"
  - Must exhale on ascent to "vent" the expanded gases
- Clinical presentation
  - PTX, pneumomediastinum, pneumopericardium
  - Hemothorax from injured lung
  - Arterial gas embolism can occur

## Pulmonary Barotrauma

- Arterial gas embolism or AGE (high morbidity and mortality)
  - Pulmonary overpressurization causes alveolar gas to enter systemic circulation
  - Air emboli in coronary, cerebral and retinal arteries
  - *Sudden* and dramatic symptoms often with focal neuro findings
  - Presents on surfacing or within 10 minutes (unlike decompression sickness, which occurs gradually)
  - ALOC is the rule and seizures are common
  - Dive chamber “stat” for treatment

# Nitrogen Narcosis

- A **disorder at depth** from breathing compressed air which may result in drowning
- High concentrations of nitrogen are neurotoxic
- Symptoms
  - Euphoria
  - Confusion
  - Disorientation
  - Poor judgment
  - Diminished motor control
- Treatment is controlled ascent to decrease the amount of dissolved nitrogen in the brain

## Dalton's Law

↑ depth = ↑ partial pressure

## Henry's Law

More gas dissolves with higher pressure



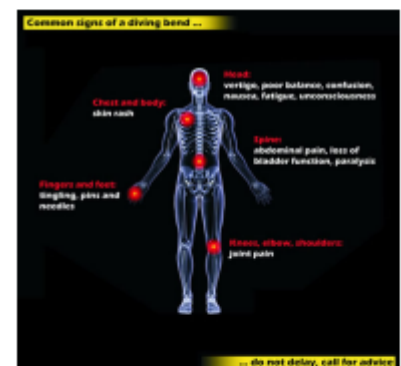
## Decompression Sickness

- A **disorder of ascent** (gas comes out of solution)
- At depth, increased amounts of nitrogen dissolve in blood and tissues
- Ascending too quickly causes nitrogen bubbles to form in blood and tissues
- A spectrum of illnesses depending on location and severity
- Length and depth of dive are the primary determinants of risk
- Obesity is a risk factor (nitrogen is lipid-soluble)
- Two categories: I and II (II more serious)
- Treatment: Recompression in a chamber



## Type I Decompression Sickness

- Affects musculoskeletal, skin, lymphatics
- “The Bends” or “Caisson’s Disease”
- Periarticular pain (especially elbows and shoulders) 70% of all cases
- Pruritus, erythema, skin marbling (“cutis marmorata”) from venous stasis
- Intravascular nitrogen bubbles cause a wide variety of presentations



## Type II Decompression Sickness

- Central nervous system decompression sickness
  - High CNS concentration of nitrogen
  - Prickly sensations in the limbs
  - Low back and abdominal pain
  - Spinal DCS: Limb paresthesias, weakness
  - Dermatome sensory distribution is common
  - Incontinence, priapism
  - Headache, diplopia, dysarthria, inappropriate behavior
  - LOC is rare (it is common in cerebral air embolism)
  - **Symptoms develop gradually hours after surfacing (unlike arterial gas embolism)**

## Type II Decompression Sickness

- DCS of the lungs = “The chokes”
- Decompression shock = Vasomotor DCS
- DCS involving cerebellum or inner ear = “The staggers”
  - Symptoms the same as inner ear barotrauma
  - Cause: Gas bubbles in inner ear or cerebellum

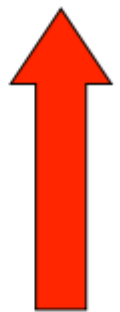
**All decompression syndromes develop slowly**

## Miscellaneous Ascent Disorders

- Alternobaric vertigo
  - Occurs on ascent
  - Caused by unequal middle ear pressures
  - Transient vertigo, nausea
- Barodontalgia (squeeze and reverse squeeze)
  - Air trapped in a dental cavity expands on ascent, causing tooth pain
- Gastrointestinal barotrauma
  - Serious problems are rare
  - Eructation, flatulence, bloating, abdominal cramps
  - Avoid carbonated beverages and gas-generating foods prior to diving

## Diving Injuries

- Disorders of *ascent*
  - Pulmonary over pressurization syndrome
  - Air embolism - sudden
  - Decompression illness - gradual
- Disorders of *descent*
  - Squeeze syndromes
  - Nitrogen narcosis (at depth)



# Hyperbaric Chamber





## Recompression Therapy

- Recompression is the definitive treatment for decompression sickness and arterial gas embolism
- Have **a low threshold for treatment of DCS**
  - Delayed onset of symptoms is common
  - More subtle symptoms may develop after treatment of major symptoms
  - Minor symptoms may progress
  - May recompress up to 14 days after symptom onset

# Recompression Therapy

- Risks associated with flying
  - Commercial planes pressurized to 5,000-8,000'
  - May exacerbate all symptoms of decompression sickness
  - May result in new symptoms of decompression sickness for divers without any symptoms initially
  - No flying for 3-7 days post-treatment of DCS-1
  - No flying for 1 month post-treatment of DCS-2



## Blast Injury Classification

- Type I: Pulse of pressure (barotrauma)
- Type II: Flying debris (penetrating trauma)
- Type III: Flying humans (deceleration impact)
- Type IV: Toxic gases, radiation, burns

Ear: TM rupture, ossicle disruption  
Lung: Pneumothorax, air emboli  
GI: Hollow viscus rupture  
CNS: Concussion, air emboli

Top 4 organs  
Type I injuries

## High-Altitude Illness (1)

- Pathophysiology of high altitude illness
  - Hypoxia-induced over perfusion and increased hydrostatic pressure with capillary leak
  - Increased sympathetic activity



## High-Altitude Illness (2)

- Manifestations
  - Acute Mountain Sickness (AMS)
  - High Altitude Cerebral Edema (HACE)
  - High Altitude Retinopathy (HAR)
  - High Altitude Pulmonary Edema (HAPE)
  - High Altitude Flatulent Expulsion (HAFE)
- Factors influencing development
  - Rate of ascent and final altitude
  - Physiology, acclimation, hydration
  - Sleeping at altitude (ventilation decreases)

## High-Altitude Illness (3)

- Risk factors
  - Prior history of altitude illness
  - Residence at an altitude below 900 meters
  - Pre-existing cardiopulmonary conditions
    - R to L cardiac shunts (listen for a heart murmur) and intrapulmonary shunts
    - Pre-existing pulmonary hypertension / mitral stenosis
  - Exertion (physical fitness is not protective)
  - Women and age >50 have a lower incidence

## Acute Mountain Sickness

- Common with rapid ascent to 8-10,000 feet
- Headache, nausea, fatigue, insomnia +/- GI sx
- Worse with drugs, alcohol, sedatives, and any respiratory depressant
- Prophylaxis: Acetazolamide (carbonic anhydrase inhibitor) – actual mechanism unclear
  - Renal bicarbonate diuresis and metabolic acidosis
  - Increased respiratory drive
  - Increased oxygenation since less sleep-related hypoventilation
  - Contraindicated in sulfa allergy
  - Causes paresthesias, and rarely, aplastic crisis
- Treatment: NSAIDs, steroids, oxygen, descent

# High-Altitude Pulmonary Edema (1)

- High-altitude pulmonary edema (HAPE)
  - Responsible for most altitude-related deaths
  - Most commonly on the second night at altitude
  - Resting tachypnea and tachycardia
  - Most patients also have mountain sickness
  - Fever / rales / pink sputum / normal heart size
  - Non-cardiogenic heart failure
  - Severe hypoxemia and respiratory alkalosis

## High-Altitude Pulmonary Edema (2)

- Treatment of HAPE
  - Improve oxygenation with supplemental oxygen
    - If rapid reversal does not occur (failure to increase oxygen saturation to above 90% within five minutes) descent is mandatory
    - Portable hyperbaric chamber is another option
    - Noninvasive ventilation may help
  - Nifedipine to treat pulmonary hypertension
  - Inhaled beta-adrenergics for wheezing
  - Dexamethasone is not helpful in HAPE (some recent debate exists here)



# High Altitude Cerebral Edema

- A severe form of acute mountain sickness
- Usually associated with high altitude pulmonary edema
- Increased ICP, cerebral edema
- Ataxia, vomiting, confusion, seizures, coma
- Treatment
  - Descent (definitive treatment)
  - Steroids, mannitol
  - Hyperbaric chamber (Gamow bag)





# Non-Cardiogenic Pulmonary Edema

- Environmental causes
  - HAPE
  - Thermal injury
  - Drowning
- Other causes
  - Toxins: ASA, phenobarbital, CO, opioids
  - Strangulation
  - Fat emboli, amniotic fluid emboli



# Hypothermia

## *Mechanisms of Heat Loss*

- Radiation: Majority of heat loss
- Conduction: Increases 25-fold when wet
- Convection: Wind chill, rewarming
- Evaporation: Important heat loss mechanism in hot environments
- Respiration: Small but obligate contribution

# Hypothermia Physiology (1)

- Hunter's response (CIVD)
  - Cold causes vasoconstriction to preserve heat
  - Then Cold Induced VasoDilatation
  - Paradoxical undressing
- Cold-induced diuresis
  - Distal collecting tubule dysfunction
- Paradoxical core afterdrop (PCA)
  - Warming vasodilates periphery
  - Cold, lactate-rich blood returns to core
  - Core pH and temperature drop

## Hypothermia Physiology (2)

- Volume resuscitate with NS
  - LR is poorly metabolized by cold liver
- Cold coagulopathy: All coag factors and reactions are temperature-dependent
- Glucose: High if diabetic or CVA, low if metabolized in attempt to keep warm
- Thermogenesis: Shivering thermogenesis is lost at 26°C, leading to rapid decompensation
- Oxyhemoglobin curve shifts to the left, increasing oxygen binding of hemoglobin

## Hypothermia Definitions

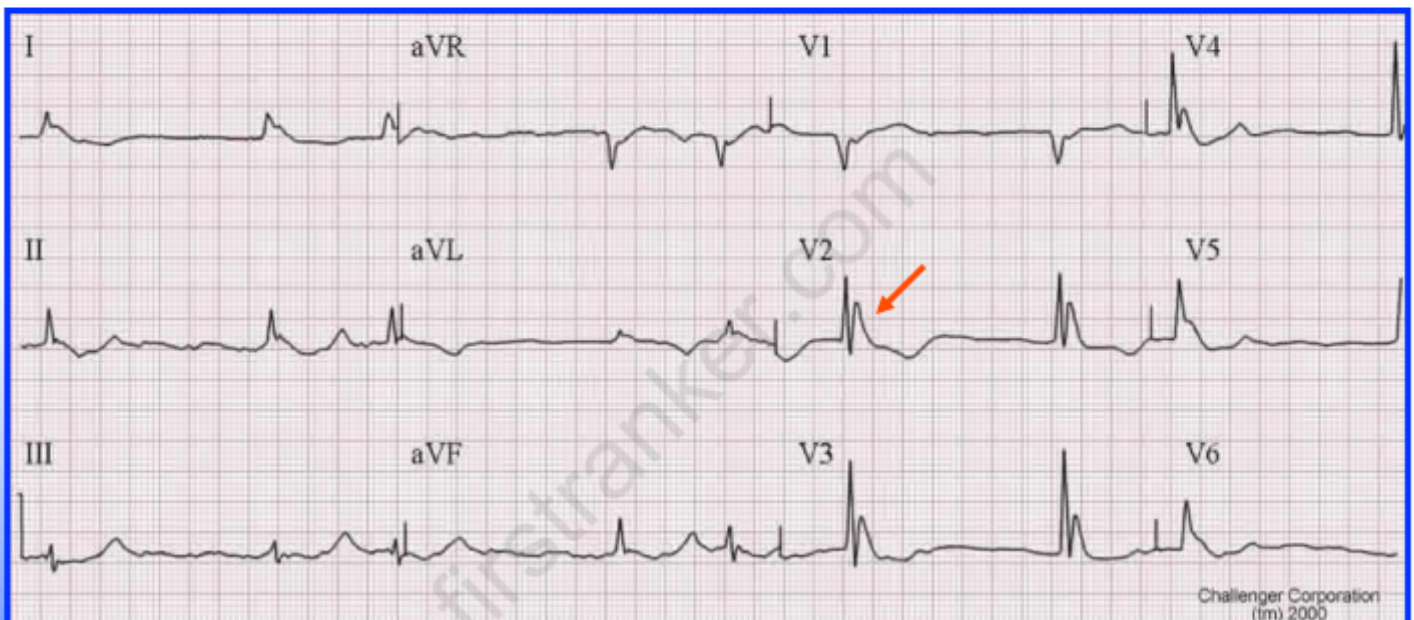
- Definition: core temp  $< 35^{\circ}\text{C}$ 
  - $32\text{--}35^{\circ}\text{C}$ : Adjustments to retain and generate heat (shivering thermogenesis)
  - $<32^{\circ}\text{C}$ : Slowdown of body functions and metabolism, decreased  $\text{O}_2$  utilization,  $\text{CO}_2$  production
- Risk factors: Extremes of age, altered sensorium for any reason, burns, trauma

# Hypothermia

## *Clinical effects*

- Pulmonary: Increased risk for aspiration
- CNS: Altered mental status, incoordination, confusion, lethargy, coma
- Renal: Cold diuresis and volume loss
- Vascular: Hyperviscosity, thrombosis, DIC
- Pancreatitis
- Bradycardia and slow A-fib with Osborn J waves
- Myocardial irritability (epinephrine, dopamine and atropine not indicated)

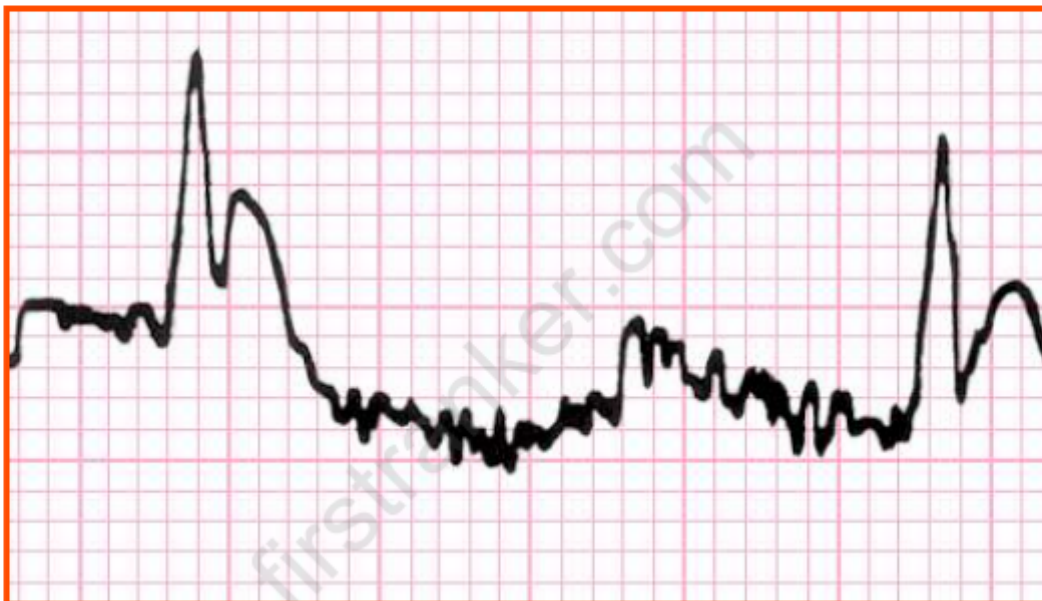
## EKG Consistent With Hypothermia



- Bradycardia with an idioventricular or junctional escape rhythm
- Prominent J waves in the anterior leads



## Osborn “J” Wave of Hypothermia



The name “J” wave is derived from the fact that the wave begins at the “J” point of the ST segment



# Hypothermic Cardiac Arrest

- Hypothermic arrest, core < 30 °C: Aggressive invasive rewarming measures (as indicated)
- PEA versus VFib
  - Vfib, Vtach
    - Bretylium (helpful if available)
    - Amiodarone preferred to lidocaine
    - Class III drugs which increase automaticity
- Single shock patterns better
- Only re-shock when core rises 1-2° C

# Hypothermia

## *External Rewarming Techniques*

- Passive external rewarming measures
  - Remove wet clothes
  - Cover with warm blanket
- Active external rewarming
  - Hot water bottles to groin and axillae
  - Radiant heaters
  - Bair hugger (blows hot air through perforated blankets – pictured)
- Potential problems with external rewarming: paradoxical core afterdrop and acidosis



# Hypothermia

## *Internal Rewarming Techniques*

- Active core rewarming: Core temp  $< 30^{\circ}\text{C}$  or cardiac instability evident
  - Warm humidified  $\text{O}_2$
  - Warmed IV fluids
  - Gastric, bladder, chest or peritoneal lavage with warm NS
  - Dialysis, extracorporeal bypass rewarming
- The patient is not dead until warm and dead (core temp  $> 30^{\circ}\text{C}$ ) is false... truly dead patients cannot be rewarmed

# Frostbite

- Frostbite: Local tissue freezing (irreversible)
- Frostnip: Transient freezing (reversible)
- 1<sup>st</sup> degree: Superficial, erythema, no blisters
- 2<sup>nd</sup> degree: Full thickness, edema, erythema, clear blisters
- 3<sup>rd</sup> degree: Hemorrhagic blisters, skin necrosis
- 4<sup>th</sup> degree: Extension to bone
- Early clear blebs = GOOD
- Early hemorrhagic blebs = BAD

## Frostbite

- Refreezing is VERY BAD
  - Causes more damage than waiting for evacuation and definitive treatment
- ED treatment
  - Rapid rewarming: Circulating water (40 °C)
  - Blister management
    - Clear blisters should be debrided
    - Hemorrhagic blisters should be left alone
- “Frostbite in January - amputate in July”
  - Conservative surgical debridement after demarcation



## Non-freezing Cold Injuries (1)

- Trench foot / immersion foot: prolonged wet feet (urine)
  - Mottled, anesthetic, pulseless foot
  - Severe pain upon rewarming/reperfusion
  - Hyperhidrosis and cold sensitivity are late findings



## Non-freezing Cold Injuries (2)

- Chilblains: Painful inflammatory skin lesions
  - Chronic intermittent exposure to damp non-freezing temperatures
  - Cutaneous symptoms 1-12 hours exposure
  - Hands, ears, legs, feet
  - Treatment: Rewarming, nifedipine, steroids





## Heat-Related Illnesses

- Heat stress: Perceived discomfort and physiologic strain associated with exposure to a hot environment, especially during physical work
- Heat exhaustion: Mild-to-moderate illness due to water or salt depletion that results from exposure to high environmental heat or strenuous physical exercise
  - Thirst / weakness / anxiety / dizziness / faintness / H/A
  - Core temperature may be subnormal, normal or SLIGHTLY elevated ( $<40^{\circ}\text{C}$ )
- Heat stroke: Hyperthermia associated with systemic inflammatory response syndrome (SIRS) and multi-organ dysfunction with **encephalopathy (altered mental status)**

# Heat Illness Spectrum

Severity	Name	Comments
Minor (normal core temp)	Heat cramps Heat edema Heat syncope Prickly heat	Na <sup>+</sup> losses (local) Elevation (not diuretics) Vasodilation Blocked sweat gland
Moderate (slight core temp elevation)	Heat exhaustion	N / V / D, water depletion, salt depletion
Severe (core > 40°C)	Heat stroke	CNS dysfunction, liver “melt down”, +/- anhidrosis

## Heat Illness Factors

- Heart disease, beta blockers (can't increase cardiac output)
- Anticholinergics, burns (can't sweat)
- Diuretics (can't sweat)
- Alcohol (can't sweat, impaired behavior)
- Hyperthyroidism (increased heat production)
- PCP, amphetamines, cocaine (increase heat production)
- Obesity (insulation, poor skin blood flow)

# Heat Stroke Types (1)

- Heat stroke mechanisms
  - “Classic,” nonexertional heat stroke
    - Results from exposure to high temperature and an inadequate physiologic response (e.g. the elderly in Chicago heat waves)
  - Exertional heat stroke
    - Results from strenuous exertion (long distance runners, military personnel, football players, manual laborers, adrenergic abuse)

## Heat Stroke Types (2)

- Classic
  - Epidemic (with heat wave)
  - Nonexertional
  - Elderly with chronic disease
  - **Anhidrosis**
  - Rarely ATN, rhabdomyolysis
- Exertional
  - Isolated
  - Exertional
  - Healthy, active
  - **Profuse sweating**
  - DIC, ATN
  - Rhabdo is common
  - Diarrhea

## Heat Stroke Features (1)

- Heat stroke manifestations
  - Core temperature  $>40^{\circ}\text{C}$
  - Tachycardia / hyperventilation / hypotension in about 25%
  - Respiratory alkalosis and lactic acidosis in exertional heat stroke
  - Manifestations of tissue destruction in those with exertional heat stroke – rhabdo, high K and  $\text{PO}_4$ , low calcium
  - Multi-organ failure in severe cases – shock, ARDS, renal failure, etc.
  - Altered mental status

## Heat Stroke Features (2)

- Thermoregulatory system can't overcome heat stress
- Body temperature  $>40^{\circ}\text{C}$
- Altered mental status
- Labs: Elevated LFTs (most sensitive), DIC, increased CPK and myoglobin

**Multi-organ failure + mental status changes**



# Heat Stroke Treatment (1)

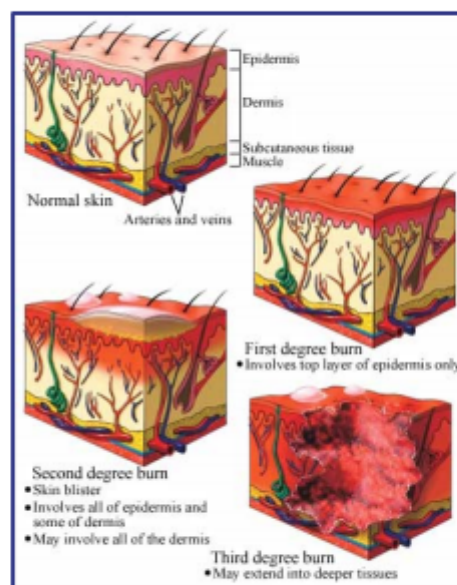
- Two main objectives: Immediate cooling and support of organ system function
  - Cooling methods
    - Conduction (increasing the temperature gradient between the skin and the environment)
      - Cold water immersion / ice slush / cooling blanket
    - Evaporation (increasing the gradient of water vapor pressure between the skin and the environment)
      - Spray atomized cold water on the skin
    - Convection via fanning (increasing the velocity of air next to the skin)
    - Radiation (do not cover the patient)

## Heat Stroke Treatment (2)

- Evaporative cooling: Fans and water spray
- Ice packs to axillae, groin and neck
  - Adjunct only (not mainstay therapy)
- Immersion generally is not recommended
- Peritoneal lavage, gastric lavage, C-P bypass
- Chlorpromazine to interrupt shivering which increases thermogenesis
- Correct electrolyte and acid-base disturbances

## Burn Definitions

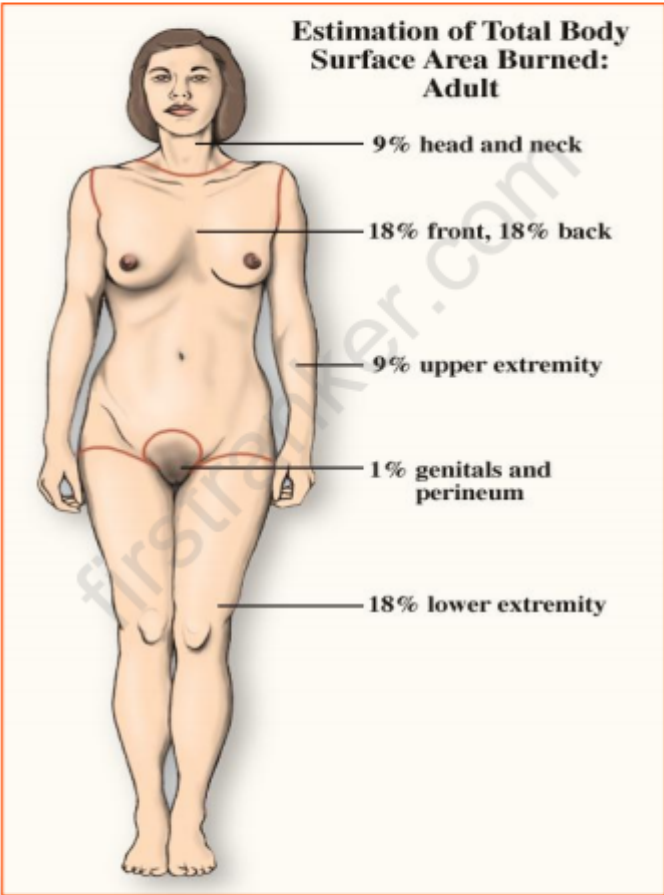
- 1st Degree
  - Epidermis only (sunburn), no blisters
- 2nd Degree
  - Dermis involved with blister formation
  - Sensation intact
- 3rd Degree
  - Full thickness
  - Anesthetic
  - White or charred, waxy
  - Eschar formation
- 4th Degree
  - Muscle, fascia, bone



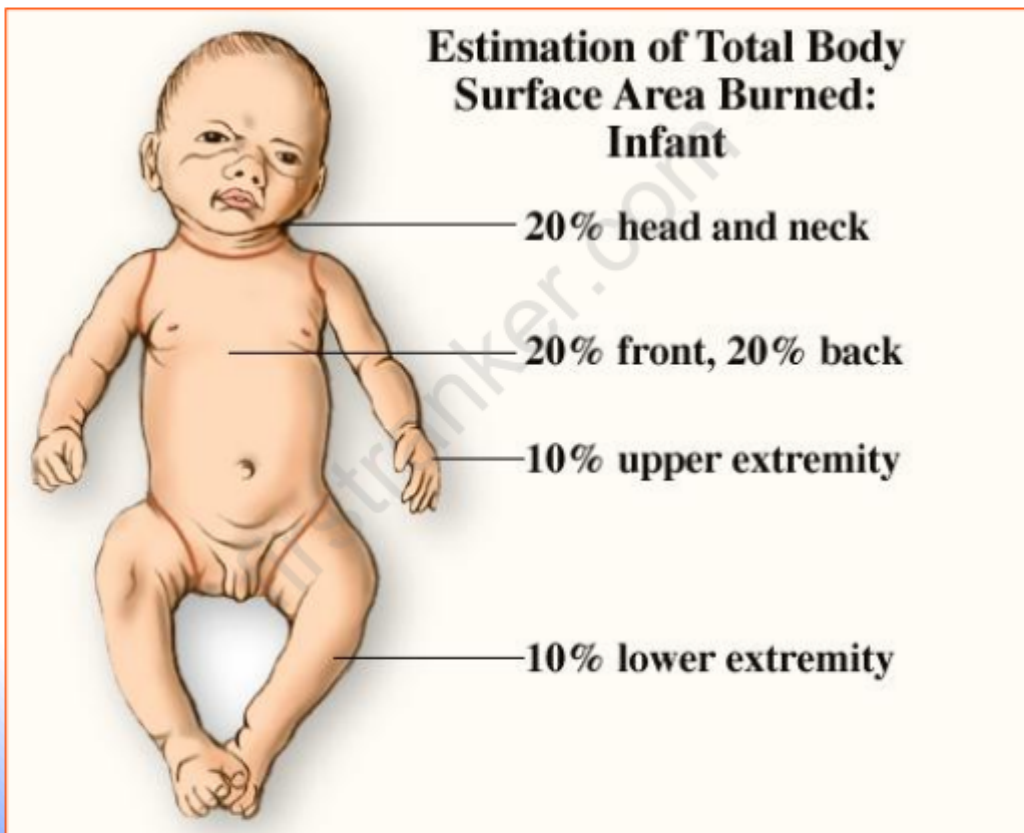
## BSA & Resuscitation Formulas

- Rule of palms
  - 1 Palm = 1% BSA
- Rule of nines for adults
- Lund-Browder chart for pediatrics
- Parkland (4), Consensus (3), or Brooke (2) resuscitation formula .....
- 4 mL x kg x % BSA per day of LR
- 1/2 of volume over 1<sup>st</sup> 8 hours
- More if pulmonary or electrical components
- Galveston formula (using NS) for peds burns
- Follow urine output (>1 mL/kg/hr)

# Rule of Nines / Adult



## Lund-Browder chart / Infant



## ABA Admission Criteria

- Depend on practice setting, social parameters
- All 2° burns >10% BSA
- All 3° burns (unless extremely small)
- All inhalation injuries
  - Seared nasal hairs
  - Sooty mouth
  - Enclosed space
- All burns to face, ears, eyes, hands, feet, genitalia, perineum, major joints
- Electrical burns
- Circumferential burns
- Co-morbid diseases likely to worsen progression
- Children <12 months of age

**VERY  
CONSERVATIVE**



# Second and Third Degree Burns



# Third Degree Burn



# Tar Burn to Hand



# Tar Burn to Hand



## Burn Complications

- Infection
  - Pseudomonas (common)
  - Other Gram negatives
- ARDS
  - From shock state
  - From direct pulmonary injury
- DIC from diffuse tissue injury
- Toxicity of smoke (CO, CN)
- Stress ulcers, GI bleeding
- Barotrauma (explosions)



# Escharotomy

- Full thickness circumferential limb burns
  - Vascular insufficiency, poor pulses and capillary refill
- Full thickness chest wall burns
  - Inadequate ventilatory motion
- Cut along long axis sides (avoid vasculature)
- Chest wall box
- Painless “pop” as sub-Q tissues expand
- Minimal bleeding





## Electrical Injuries (1)

- Tissue damage caused by electric current
- Traumatic injuries common (falls)
- Electrocution: Death caused by electricity
- 3 high risk groups
  - Toddlers: Household sockets, cords
  - Adolescents: Risky behaviors, power lines
  - Utility workers
- Many of the clinical effects related to amount, duration, type (AC/DC) and path of current



## Electrical Injuries (2)

- Voltage = Current x Resistance  $V=IR$

**Current more important than voltage**

- Increased resistance produces increased heat
- Tissue resistance: nerve < blood < muscle < skin < tendon < fat < bone
- Arc burns across flexor creases (kissing burns)

**AC worse than DC**

- AC: exit = entrance (held)
- DC: exit > entrance (thrown)

**Oral commissure burns → delayed labial artery bleed**

## Electrical Injuries (3)

- Injury depends on current and tissue resistance
- Increased injury severity with increased resistance
  - Bone, fat, and tendons heat up and coagulate
- Skin and neurovascular exam may underestimate injury extent in deep tissue electrical burns
- Skin injury variable (wet, dry, salty)
- Falls: Rule out other trauma
- Household electrical current: 60 Hz AC
- Maximum “let go” current: 30 mAmp

## Electrical Injuries (4)

Low voltage injury: <1000 V

- More common, greater access, ½ of all injuries and deaths
- Burns tend to be minor (110 V)
- ½ of low voltage deaths have no burns
- Low voltage AC causes cardiac arrest: Vfib
- Other arrhythmias rare with 110 V

## Electrical Injuries (5)

- High voltage:  $>1000$  V
  - Significant injury and death  $>600$  V
  - US power lines 7620 V, lines entering house 220 V, household sockets 110 V, 3<sup>rd</sup> rail subway 600 V
- High voltage injury
  - Skin burns severe
  - Violent skeletal muscle contraction, throw victim
  - Fractures, dislocations (posterior shoulder)
  - Clinical picture resembles crush injury
  - High voltage AC/DC causes asystole cardiac arrest
  - Dysrhythmias are common (PACs, PVCs, SVT, Afib)

# Electrical Injury



# Electrical Injury



**Oral commissure burn : 10% severe labial artery bleed, usually after 5 days**

- Recommend admission
- Out patient: reliable parents, can control bleeding



## Lightning Injuries

- 2/3 present with lower extremity paralysis
- 2/3 have permanent sequelae
- Deep burns, extensive tissue damage, renal failure rare (unlike electrical injury)
- Strike types: Direct (most serious), side flash, contact strike (e.g. holding flag pole), ground current
- Massive DC electrical shock, brief duration, passes over body, deep injury rare
- Ruptured TM (Type I blast injury)
- Motor paralysis
  - Pupils unreliable (paralysis of the iris)
  - Diaphragm paralysis
  - Hypoxia



## Lightning Effects

- Cardiac arrest
  - Initial asystole → sinus tach (automaticity)
  - Diaphragm paralyzed longer than heart
  - Respiratory arrest outlasts cardiac arrest
  - Hypoxia → Vfib
- Immediate cause of death: Apnea
- Early: CPR rather than cardioversion (AED)
- TM perforation and cataracts are common
- 50% of pregnancies have fetal demise
- Permanent cognitive and motor sequelae common

# Lightning Injury



# Lightning Injury




## Radiation Exposure (1)

- Types of exposure
  - External (e.g. radiation therapy)
  - Internal (inhalation, ingestion)
  - Contact with skin and clothes requires decontamination
- Median lethal dose: 4.5 Gy
- Doses over 1 Gy produce GI symptoms (N/V/D)
- Survival probable <2 Gy
  - N/V for 24-48 hours, then home
- Survival unlikely >8 Gy
  - Fulminant N/V/D, desquamation
- Earlier symptoms indicate a higher dose and worse prognosis

## Radiation Exposure (2)

- Procedures and decontamination
  - Evacuation (prevent new victims)
  - Determine exposure type
  - Early hospital notification
  - Number of victims
  - Decontaminate on scene if possible
  - Separate hospital entrance
  - Closed system drainage and ventilation
  - Wash with soap and water (including hair)
  - Trim nails, cut hair

## Radiation Exposure (3)

- Rad = radiation absorbed dose
  - Energy imparted to matter
- 100 rads = 1 Gray (Gy)
- Nonionizing visible light  
microwave  
radar } 
- Ionizing
  - $\alpha$  - least penetrating
  - $\beta$  - 8 mm penetration (burns)
  - $\gamma$  - deep penetration, acute radiation sickness
- Neutrons: fallout
- Radon gas: decay of uranium 238 ( $\alpha$ )



## Radiation Exposure (4)

- Tissues with high cell division are most affected
- GI & heme systems are the most vulnerable
- Suspect radiation illness
  - Unexplained burns, GI sx & pancytopenia
- Skin dosimetry and lab dosimetry (more accurate)
  - Epilation ~ 3 Gy
  - Erythema ~ 6 Gy
  - Dry desquamation ~ 10 Gy

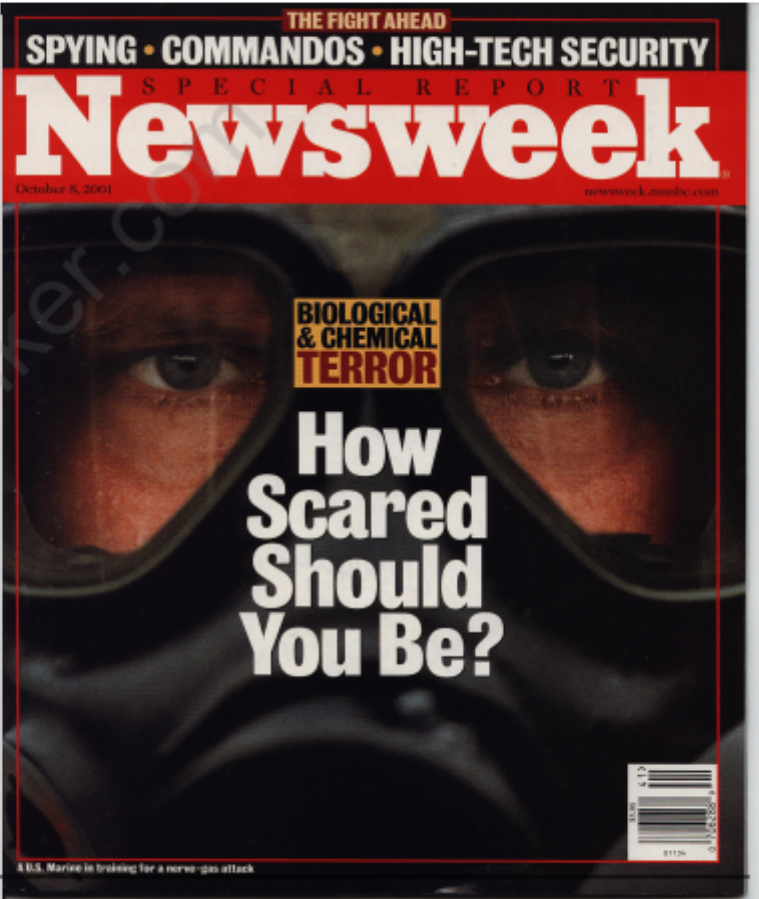
48 hour absolute lymphocyte count  
(cells most affected)  
> 1200 (very good)  
300-1200 (possibly lethal)  
< 300 (lethal)



## Radiation Exposure (5)

- Internal decontamination
  - GI decontamination
    - Activated charcoal and whole bowel irrigation
    - Potassium iodide for I-131 ingestion
    - Chelating agents for radioactive heavy metals
    - Supportive care

# Biologic / Chemical Weapons



## Biologic / Chemical Weapons

- Biological or chemical agents used with the intent to kill, incapacitate, or cause fear
- Cheaper and easier to produce than nukes
- Mortality potential equal to that of nuclear weapons
- Easily dispersed and difficult to detect
  - Aerosolization (stationary or mobile sprayers)
  - Contamination of food and water
  - Person-to-person

## Biologic / Chemical Weapons

- Characteristics that make bio-agents good weapons
  - Infectivity, virulence, toxicity, incubation period, transmission, lethality, stability
- Agents
  - Bacterial: Anthrax, cholera, plague, tularemia, Q fever
  - Viral: Smallpox, Venezuelan equine encephalitis, viral hemorrhagic fevers, hantavirus (cultivation is difficult and expensive)
  - Biological toxins: Botulinum toxin, ricin

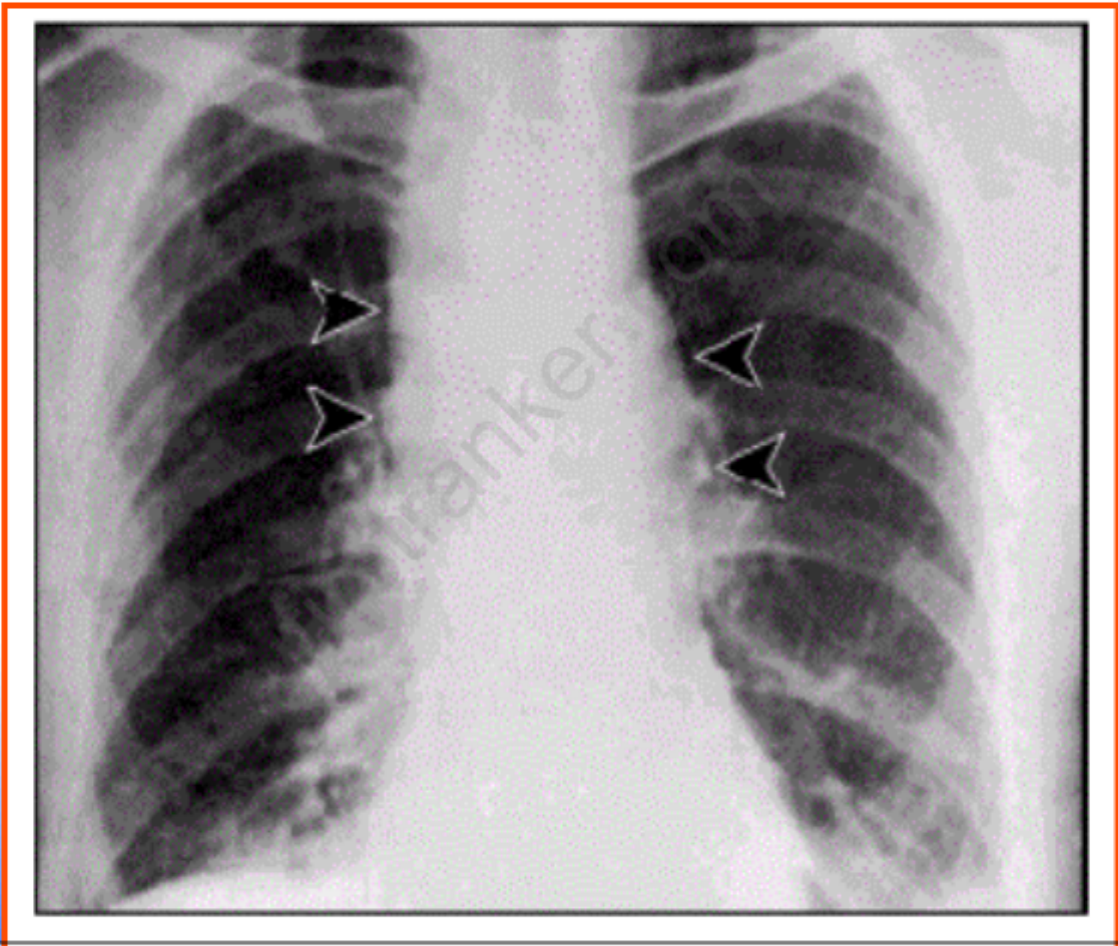
## Anthrax (1)

- “Woolsorter’s disease” = Cutaneous form
- Three forms: Cutaneous, inhalational, GI
- Inhalation of spores, incubation 1-6 days
- Fever, chills, drenching sweats, profound fatigue, minimally productive cough, nausea, vomiting, chest discomfort → sepsis and death (24 hours)
- Chest X-ray: Mediastinal widening, paratracheal & hilar fullness, pleural effusions, infiltrates
- Ciprofloxacin or doxycycline, vaccine

**Exposed / infected patients  
DO NOT require isolation**



# Inhalation Anthrax

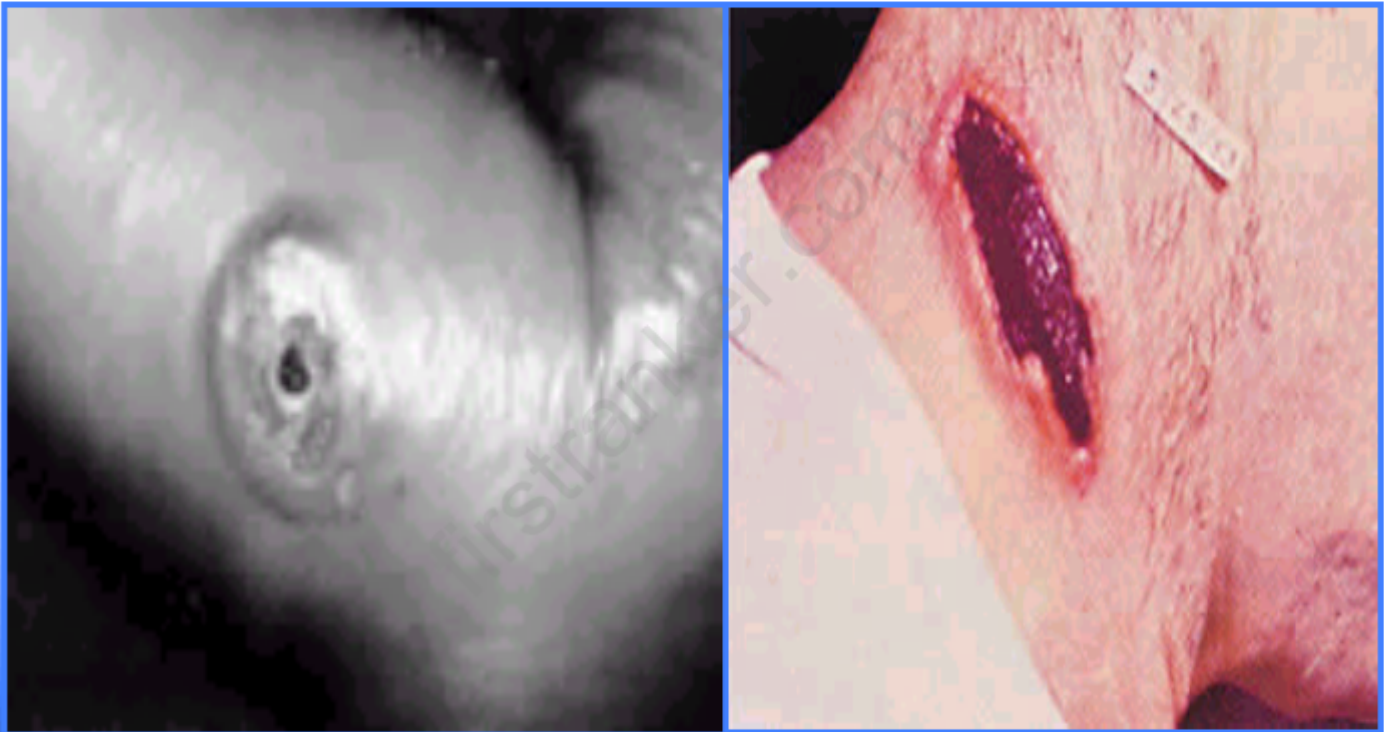


## Anthrax (2)

- Cutaneous Anthrax
  - Painless, no rash
  - Pruritic papule resembling an insect bite → vesicle (sometimes hemorrhagic) → rupture and ulceration → eschar
  - Patients with cutaneous anthrax may have fever, extensive edema and other systemic signs
  - Antibiotics may not alter course
- Prophylaxis: Ciprofloxacin or doxycycline
  - 8 weeks if exposure is confirmed



# Cutaneous Anthrax



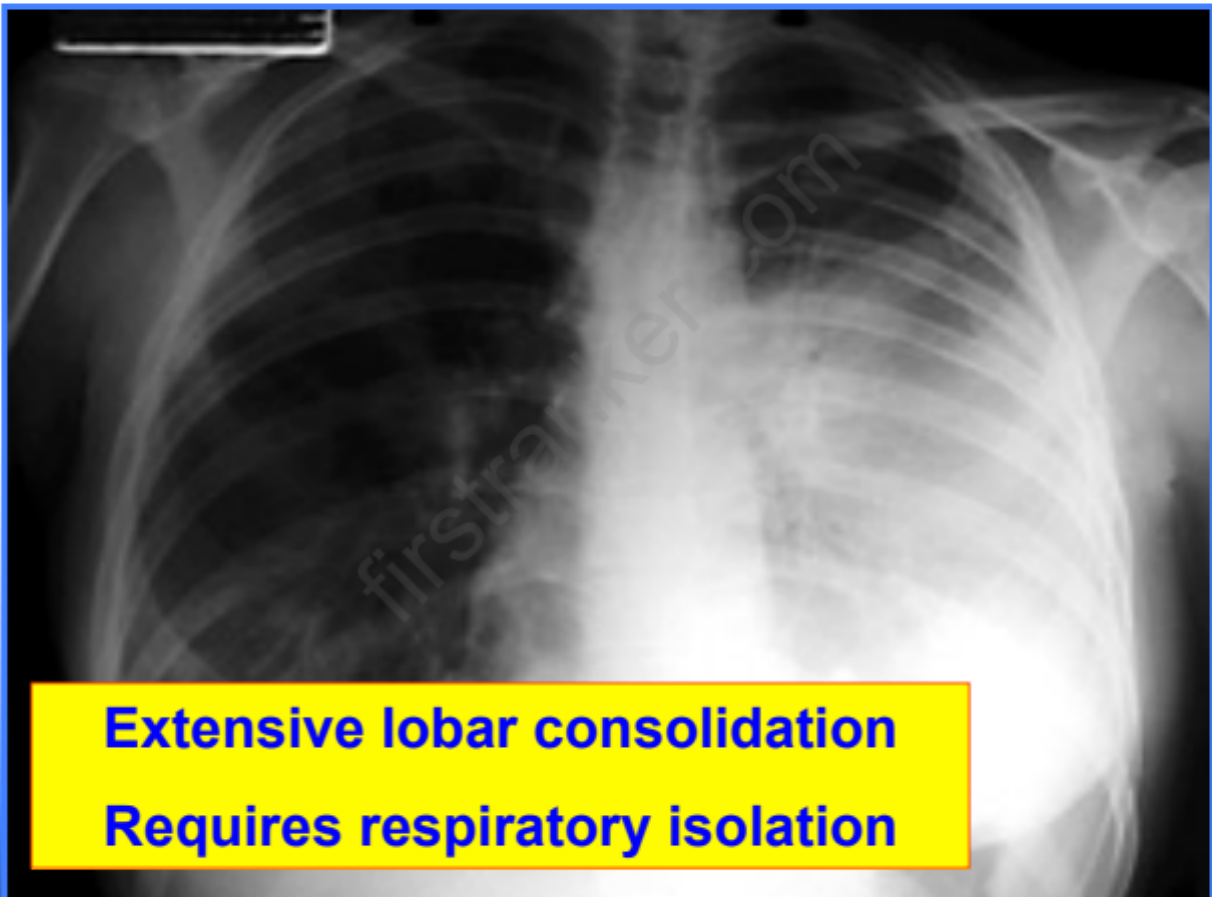
# Plague

- *Yersinia pestis* via a rodent zoonosis (transmitted by flea bites, contact and inhalation)
  - Pneumonic plague: Incubation 2-3 days, inhalation of aerosolized bacteria (resp. isolation required)
    - Fever, cough, bloody sputum, shock, DIC, ↑LFTs; Gram's stain, culture, serology; streptomycin, doxycycline, chloramphenicol, vaccine
  - Bubonic plague: The most common form of plague  
Infected flea bites a person, or materials contaminated with *Y. pestis* enter through a break in the skin
    - Swollen, tender lymph nodes (buboes), fever, headache, chills. No spread from person to person
  - Septicemic plague: Complication of above

# Bubonic plague



# Pneumonic plague



**Extensive lobar consolidation**  
**Requires respiratory isolation**

## Smallpox

- Smallpox (variola virus)
  - Airborne transmission, highly infectious
  - Even one case is a public health emergency
  - Incubation 7-17 days, not contagious until rash
  - All lesions progress at same time
- Vaccine: live virus (vaccinia). 1° protection fades after 5 years, revaccination lasts 30+ years
  - Post-exposure vaccine is effective up to 3 days
  - Adverse reactions: Accidental implantation, 2° infection, eczema vaccinatum, EM, generalized vaccinia, progressive vaccinia, keratitis



# Smallpox



# Smallpox (vaccinia) Vaccine

## *Adverse Reaction*



Progressive vaccinia (vaccinia necrosum)



# Smallpox (vaccinia) Vaccine

## *Adverse Reaction*



# Isolation Recommendations

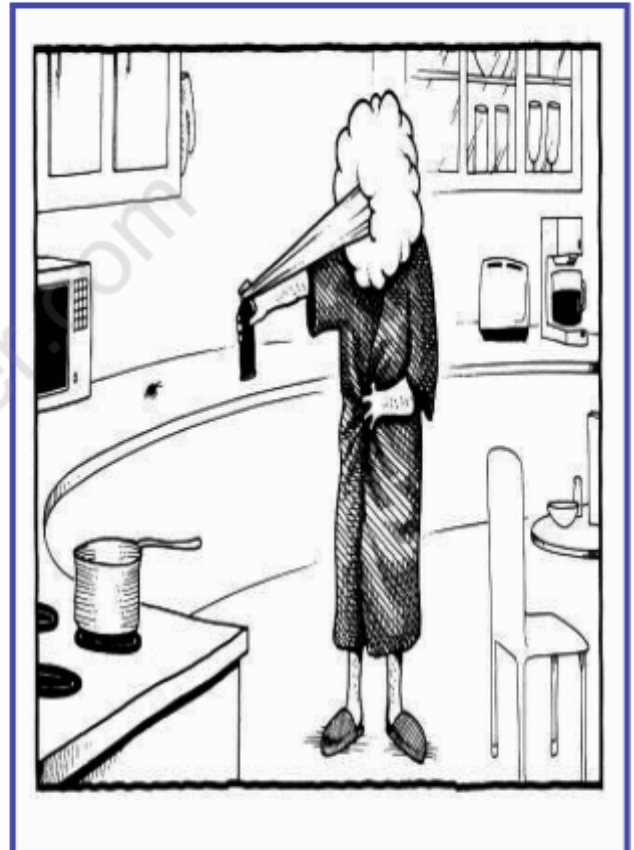
- Isolation is not required for anthrax
- Plague
  - Respiratory isolation (48 hours), sputum and tissue testing, CXR
  - Bubonic plague can disseminate if untreated, and secondary pneumonic plague (contagious) can develop
- Smallpox
  - Strictly quarantined
  - Exposure contacts require respiratory isolation for 17 days

## Biologic Toxins

- **Aerosolized botulism:** Toxin can be absorbed through inhalation. It is relatively easy to produce, stable for aerosolization, and highly lethal
  - Binds to the preganglionic membrane of cholinergic synapses and inhibits acetylcholine release
  - Earliest complication involves the eyes (double vision). Progresses to descending paralysis and respiratory failure
  - Unlike nerve agents, doesn't cause miosis or copious respiratory secretions
- **Ricin:** Cytotoxin, castor bean mash, inhalation; airway necrosis, fever, cough, sweating, hemorrhagic pulmonary edema; ELISA; treatment is supportive

## Chemical Weapons

- Vesicants
- Nerve agents
- Cyanide
- Lung-damaging agents
- Riot control agents
  - CN and CS (Tear gas)
  - OC spray



## Vessicants

- Cause blisters on dermis
- **Mustard:** Dangerous as a liquid or gas
  - After entering the body through dermis or via respiration, it reacts with water. The resulting chemical causes large necrotic blisters on the dermis and mucus membranes
- **Phosgene:** Pulmonary edema, not a true vessicant
  - Skin blanch and wheal usually without blisters
- **Lewisite:** Dangerous as a liquid or gas
  - Unlike mustard, causes immediate pain
  - Results in increased capillary permeability which leads to severe shock and end-organ damage

# Chemical Weapons

## *Nerve Agents*

- Developed in WW II
- Tabun (GA), Sarin (GB), Soman (GD), GF, VX
- VX is the most potent, sarin the most volatile
- Powerful inhibitors of acetylcholinesterase (SLUDGE, killer “B”s, paralysis, death)
- High risk of secondary contamination
- Self-protection, decontamination
- Treatment: Oxygen, **atropine, 2-PAM**
- Military Mark 1 auto injector kit (2 mg atropine and 600 mg 2-PAM)



## Mammalian Bites

- Dog bite
  - Lowest infection risk
  - *Pasteurella multocida*
  - Rx: Amoxicillin / clavulanate
- Cat bite (and scratch)
  - Moderate infection risk
  - *Pasteurella multocida*
  - Rx: Amoxicillin / clavulanate
- Human bite
  - Clenched fist
  - Consider in genital wounds
  - **Highest infection risk**
  - *Eikenella corrodens*
  - Rx: Amoxicillin / clavulanate





# Clenched Fist - Human Bite



## Axillary Adenopathy of Cat Scratch Fever



- Begins as small vesicle / macule at the site of the bite or scratch
- Regional lymphadenopathy draining the site of the injury
- Can be caused by dogs, cats, monkeys
- Etiology believed to be *Bartonella henselae*
- Antibiotics usually not indicated / usually a self-limiting disease
- Avoid I & D or other trauma to nodes (fistulas tracks may result)

## Rabies

- RNA virus infects CNS, 0-5 cases/year in the US
- Dogs are main vector worldwide
- Bats are main vector in US
- Negri bodies in sacrificed brain
- Prodrome
  - Excitement
  - Opisthotonus
  - Hydrophobia
  - Salivation, lacrimation, unsteady gait
- Virtually always 100% fatal once symptomatic
- Post-exposure prophylaxis
  - Active HDCV: 0 - 3 - 7 - 14 days (add a 28 day dose if immunocompromised)
  - Passive HRIG: 20 IU/kg

Rabies  
Bat, raccoon, fox,  
skunk

No rabies  
Squirrel, rodent,  
rabbit

# Snakes



## Coral Snake

Red on Black, Venom  
Lack

Red on Yellow, Kill a  
Fellow



## Rattlesnake Bite

- Envenomation grades
  - Local (minimal), moderate, severe
- Up to 1/4 are dry bites
- Venom effects on humans
  - Cell injury: Swelling, ecchymosis, tissue necrosis, pain
  - Coagulation system: Increased prothrombin time, INR, decreased platelets, decreased fibrinogen level: DIC
  - Systemic injury: Capillary leak and myocardial depression (may lead to shock)

# Rattlesnake Bite

## Management

- No tourniquets
  - Constriction bands may decrease lymphatic spread of venom
- Incision and suction not recommended
  - Human oral flora contamination
  - Risk of neurovascular injury
- Ooze at fang mark is a reliable sign of envenomation
- Antivenom





# Rattlesnake Bite

## *Antivenom*

- Indications
  - Progression of local injury
    - Pain, swelling, ecchymosis
  - Evidence of coagulopathy
    - Prolongation of PT or INR, low platelet count, low fibrinogen level
  - Systemic effects
    - Hypotension, confusion, repeated nausea and vomiting, fasciculations, paresthesias or other venom effects remote from the bite site

## **Rattlesnake Bite**

### *Antivenom*

- 2 types
  - Polyvalent crotalidae immune Fab (sheep), trade name CroFab
  - Antivenin (crotalidae) polyvalent whole antibody (horse), commonly called “Wyeth antivenin”
- Dose varies with bite and antivenin used
- Side effects
  - Anaphylactic and anaphylactoid reactions
  - Delayed allergic reactions (serum sickness)
  - Febrile response to immune complexes

# Rattlesnake bite



Med-Chall

# Rattlesnake bite



## Coral Snake Bite

- Family Epapidae
- Bites uncommon (less than 1% of venomous snake bites in U.S.)
- Venom is neurotoxic
- Onset of symptoms may be delayed 10-12 hours
- Minimal local complaints
- Paresthesias, altered mental status, cranial nerve dysfunction, respiratory failure
- Supportive care
- Antivenom if severe; often not available

# Spiders

**Black Widow (Lactrodectus)**



**Brown Recluse (Loxosceles)**





## Spiders

- **Black Widow (Lactrodectus)**
  - Red “hourglass”
  - Outhouses, dumps, woodpiles
  - Immediate pain
  - Aggressive
  - N/V, cramps
  - Rigid abdomen (mimics appy)
  - Ice, opioids
  - Ca gluconate +/-
  - Antivenom available
- **Brown Recluse (Loxosceles)**
  - Dark “violin” top
  - Woodpiles, cellars
  - Delayed pain
  - Reclusive
  - “Volcano” lesion
  - Ischemic necrosis, hemolysis
  - NO ice
  - Dapsone, HBO, surgery
  - No antivenom

# Brown Recluse Spider Bite



# Brown Recluse Spider Bite



# Brown Recluse Spider Bite





## Bees, Wasps, Ants

- Acute Severe Systemic Reactions (Anaphylaxis)
  - IgE-mediated
  - Cause of most bee sting deaths
  - Usually only 1-2 stings
  - Occur 10-30 minutes after the sting
- Cardiovascular
  - Hypotension and shock
  - Ischemia
  - Arrhythmias
- Respiratory
  - Laryngeal edema
  - Bronchospasm
  - Stridor



## Bees, Wasps, Ants

- Systemic Toxicity
  - Multi-organ complications
    - DIC, renal failure, neurologic
  - Response to large doses to venom
  - Onset can be delayed 8-24 hours
  - Mechanism not completely understood
  - More likely if >50 stings (Africanized honey bees or fire ants)
- Median lethal dose of honeybee venom
  - 19 stings per kilogram
  - 500-1,400 stings per human



# Africanized Honey Bee Sting



**Venom load causes systemic toxicity**

## Ticks

- RMSF
  - Tick-transmitted Rickettsial infection
  - Rumpel-Leede test (tourniquet produces petechiae)
- Q Fever: Influenza-like illness
- Tularemia: Rabbits
- Tick paralysis: Check hair
- Babesiosis: Hemolytic anemia
- Lyme disease: Ixodes tick transmits spirochete
- Borreliosis: Relapsing fever
- Ehrlichiosis: Monocytic, granulocytic

# Tick





# Lyme Disease



# Lyme Disease



## Mosquitos

- Local hypersensitivity, severe local reactions, secondary bacterial infection
- Diseases transmitted by mosquito vectors
  - Japanese B encephalitis
  - Yellow fever
  - Malaria
  - West Nile virus
    - A seasonal North American epidemic, from summer to fall with manifestations ranging from asymptomatic (80%) to viral encephalitis (1/150).
  - Dengue hemorrhagic fever
    - Viral infection in tropics and subtropics (Aedes mosquito); acute, self-limited fever, myalgias, headache, rash, lymphadenopathy, leukopenia
  - Equine encephalitis



## Marine Envenomations

- Jellyfish, box jellyfish, anemones, fire coral, and Portuguese man-o-war
- Nematocyst: Spring-loaded stinging apparatus injects venom; toxicity mechanism unclear
- Local reaction (erythema, pain, urticaria)
- Death is rare, **box jellyfish deadliest (respiratory arrest)**
- Envenomation treatment
  - **No scrubbing**; pick off tentacles
  - Vinegar may help; hot water may help
  - No fresh water
  - Topical lidocaine may help



# Marine Envenomations

- Coral cuts
  - Prone to infection
  - Some may contain stinging nematocysts (fire coral)
  - Treatment: Soap and water; fresh water flush. Vinegar if stinging. Antibiotics if appears infected. Topical steroids, antihistamines if itching.



## Marine Envenomations

- Sting Ray stings
  - Barbed stinger apparatus
  - Laceration, then envenomation
  - Symptoms include local injury, nausea, flushing, diarrhea, diaphoresis, cramps
  - Treatment
    - Clean wound with water flush
    - Debride
    - Soak in water as hot as can be tolerated (treats pain by deactivating toxin)
    - Antibiotics
    - X-Ray for retained foreign body



## Marine Infections

- Many pathogenic bacteria: Aeromonas, Bacteroides, E. coli, Salmonella, Staph, Vibrio, Clostridium
  - Vibrio (Gram negative rod, rapid infection)
    - Pain, swelling, hemorrhagic bullae, vasculitis, necrotizing fasciitis, sepsis
    - Particularly problematic in alcoholics or patients with liver disease
    - Antibiotics: Ciprofloxacin, bactrim, tetracycline
    - Look for retained foreign bodies

## Marine Infections

- Erysipelothrix (fish handler's disease)
  - Painful, marginating plaques on hands
- Mycobacterium marinum (acid-fast bacillus)
  - Chronic cutaneous granulomas
- Aeromonas hydrophila: fresh water
  - Cellulitis and gastroenteritis

## Ciguatera Toxicity

- Most common nonbacterial fish-borne poisoning in U.S.
- From eating reef fish that consume dinoflagellates on coral reefs (amberjack, groupers, etc)
- Ciguatoxin causes GI, cardiac and nervous system symptoms (paradoxical temperature reversal) and is heat-stable
- Treatment
  - Antiemetics
  - Cool showers, diphenhydramine for itching
  - Atropine for bradyarrhythmias



## Scombroid Toxicity

- Mahi-mahi, amberjack, tuna
- Histamine-like reaction
- Toxin is not activated with cooking
- Toxin causes “allergic reaction” – flushing, palpitations, abdominal pain, diarrhea; may see wheezing, tachycardia
- Treatment
  - Supportive
  - Antihistamines



# ENVIRONMENTAL QUESTIONS

**A SCUBA diver sees a blow fish and panics, ascending quickly with his mouth closed, expelling no air. What is the most likely consequence of his breath holding?**

- A. “The bends”
- B. Nitrogen narcosis
- C. Pulmonary over pressurization syndrome
- D. Decompression sickness type I
- E. Arterial gas embolism

**A 40 y/o commercial diver is evaluated for decompression sickness. Which of the following is true regarding this diagnosis?**

- A. Recompression is the treatment of choice
- B. Delayed symptoms are uncommon
- C. Minor symptoms do not progress
- D. Cannot recompress more than 2 days after the onset of symptoms
- E. Recompression is frequently unnecessary



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**A 22 y/o triathlete flew from New Orleans to the Rocky mountains to train. She began experiencing headache and fatigue. Regarding the medication she should be treated with, which is true?**

- A. It causes a metabolic alkalosis resulting in improved ventilation and oxygenation
- B. It causes fluid retention thus improving blood volume and perfusion
- C. It is an effective analgesic
- D. Although effective, its mechanism of action has not been proven
- E. It increases production of CSF

**A patient presents with a reddened, marbled look to the skin and pains in his shoulders and elbows. He just landed from a vacation in Cozumel. What activity has caused his symptoms?**

- A. Eating fish
- B. Deep sea fishing
- C. SCUBA diving
- D. Getting too much sun
- E. Playing rugby



**A patient presents following a simple, itchy laceration from coral while diving. Which regimen below is the most appropriate treatment for this injury?**

- A. Decontamination, antihistamines and topical steroids
- B. Hot water and tetanus immunization
- C. Prophylactic treatment for vibrio species infection
- D. Rinse with ½ water ½ isopropyl alcohol to remove coral dust
- E. Excision of wound edges

**A 19 y/o swimmer is stung by a box jellyfish. What is the usual cause of death resulting from this injury?**

- A. Anaphylaxis
- B. Respiratory arrest
- C. Sepsis
- D. DIC
- E. Hyperkalemia



**A 25 y/o patient received multiple venomous hymenoptera stings. He is short of breath and lightheaded. Which of the following is true, regarding such stings?**

- A. Stings from “Africanized” honey bees are more toxic than those from ordinary honey bees
- B. Most deaths are secondary to anaphylaxis from one or two stings
- C. Anaphylaxis from hymenoptera stings is IgM mediated
- D. The median lethal dose of honey bee venom is 10-20 stings
- E. Systemic toxicity is less likely with Africanized honey bees

**A 35 y/o hunter was bit by a snake near a lake in Georgia. He described the snake as having red, yellow and black rings. Which of the following is true regarding this snake?**

- A. It is a diamond back rattlesnake
- B. It is a coral snake
- C. Its nostrils sense heat of the victim to adjust the size of the envenomation
- D. It is a water moccasin
- E. It is a member of the Crotalidae (pit viper) family

**A rattlesnake bites a 10 y/o boy on the hand. Fifteen minutes later swelling, pain and ecchymosis have developed. Which statement is true, regarding this envenomation?**

- A. Tourniquets are very helpful
- B. Incision and suction are critical to the victim's survival
- C. Early antivenin therapy is indicated
- D. Coagulopathy is a rare complication
- E. Death is common from significant envenomations

**A 34 y/o firefighter presents after working an active fire for 8 hours. He is diaphoretic and has a rectal temp of 40.9. He is confused. Which statement is most accurate, regarding his heat illness?**

- A. This patient's presentation is consistent with heat exhaustion
- B. Active cooling should be minimized to decrease shivering
- C. This patient's LFTs will likely be elevated
- D. Syncope is common with heat cramps
- E. Rhabdomyolysis is not associated with this heat illness



**A 40 y/o climber experiences headache, nausea and fatigue at 11,000 feet. Which of the following is true regarding this illness?**

- A. Drugs and alcohol will not exacerbate these symptoms
- B. Commonly seen with rapid descent
- C. Acetazolamide (Diamox) may be helpful
- D. The patient should immediately descend to sea level
- E. Rest and time for acclimatization are not effective

**48 hours after radiation exposure, a patient has severe nausea and vomiting. His total lymphocyte count equals 200. Which statement is the most accurate, regarding his prognosis?**

- A. The patient has had a lethal exposure
- B. GI symptoms will persist for a maximum of 72 hours
- C. The patient will recover with expectant development of leukemia within 5 years
- D. The patient will have persistent immunological problems
- E. The patient will recover without complications following chelation therapy



**A 29 y/o patient was involved in a house fire. He has extensive 3rd degree burns including his chest and abdomen. His lungs are clear. His blood gas confirms a respiratory acidosis. Which is the most appropriate next step?**

- A. Continuous albuterol aerosols
- B. Intravenous solumedrol
- C. Reduce his oxygen delivery as he is a CO<sub>2</sub> retainer
- D. Box chest escharotomy
- E. Sit the patient upright

**A 30 y/o golfer is struck by lightning and brought in for an evaluation. Which of the following is associated with this injury?**

- A. Examination of pupils may be unreliable
- B. 50% mortality rate
- C. Myoglobinuria is rare
- D. Massive AC electrical shock
- E. Cognitive deficits are transient

**A firefighter was not using his SCBA while putting out a house fire. He collapsed and experienced respiratory arrest . Which toxic gas is the most likely cause?**

- A. CO
- B. CN
- C. HS
- D. CO<sub>2</sub>
- E. H<sub>2</sub>O<sub>2</sub>

**A child bites an electrical cord sustaining an oral commissure burn. Which is the most serious complication?**

- A. Cataract formation
- B. Delayed dysrhythmias
- C. 7th cranial nerve palsy
- D. Delayed bleeding 2° to labial artery
- E. Facial cellulitis



**An adult patient weighing 70 kgs has burns over both lower extremities. Which is the best estimate of how much fluid the patient should receive in the first eight hours?**

- A. 630cc/hr = 5.0L
- B. 275cc/hr = 2.2L
- C. 950cc/hr = 7.6L
- D. 500cc/hr = 4.0L
- E. 1550cc/hr = 10L



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**A climber develops respiratory distress and confusion after climbing to an elevation of 15,000 ft. Examination reveals rales in both lungs and ataxia. The most appropriate treatment for this patient is?**

- A. Immediate descent
- B. Mannitol
- C. Steroids
- D. Nitroglycerin
- E. Loop diuretics

**A 36 y/o male is evaluated for severe frostbite. Which of the following actions should be taken?**

- A. Avoid early debridement of clear blisters
- B. Refreeze the extremity if definitive care is delayed
- C. Rapid re-warming via 40°C immersion
- D. Hemorrhagic blisters should be debrided
- E. Avoid analgesics as they alter the assessment

## Why does passive external re-warming of a hypothermic patient potentially result in a worsened condition?

- A. Vasodilation returns cold lactate rich blood to the core circulation
- B. The rate of re-warming is too fast
- C. Rhabdomyolysis results from shivering
- D. Vasodilatation results in rebound hyperthermia
- E. Ventricular fibrillation occurs most often with passive external re-warming

## Environmental Answer Key

- |       |       |
|-------|-------|
| 1. C  | 11. C |
| 2. A  | 12. A |
| 3. D  | 13. D |
| 4. C  | 14. A |
| 5. A  | 15. B |
| 6. B  | 16. D |
| 7. B  | 17. A |
| 8. B  | 18. A |
| 9. C  | 19. C |
| 10. C | 20. A |