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

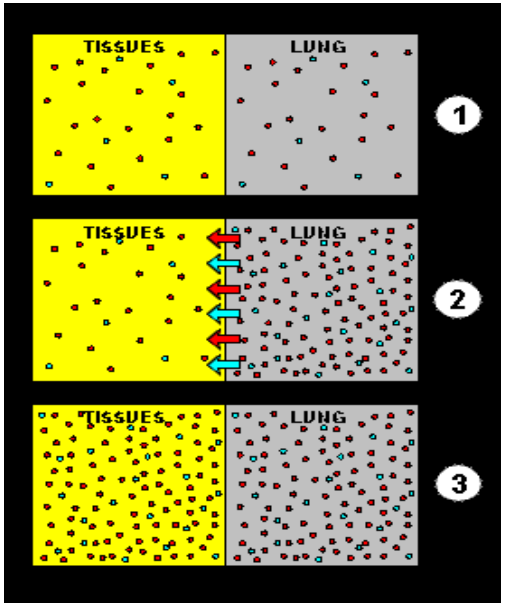
- Primary factor is duration of immersion
- Also
  - Water temperature
  - Age
  - Diving reflex
  - Associated trauma
  - Associated dysbaric problems
  - Bystander CPR
  - Water contamination

Low core temperature
correlates with bad outcome

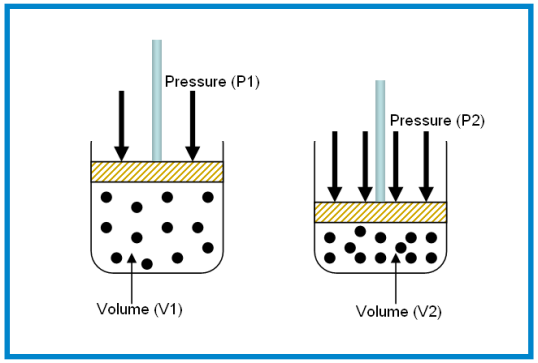
SCUBA Diving Contraindications

- 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

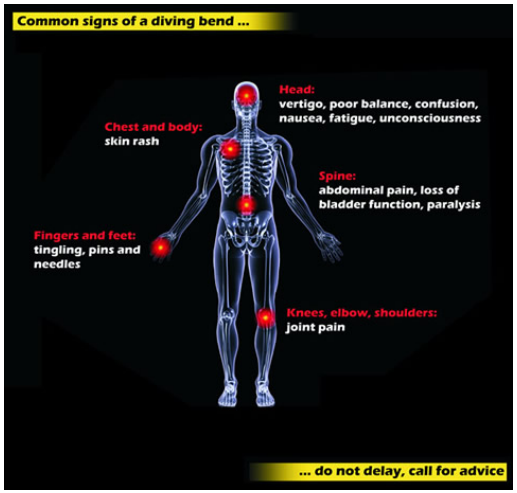
Dalton's Law
↑ depth = ↑ partial pressure
Henry's Law
More gas dissolves with higher pressure

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

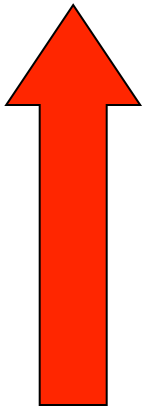
All decompression syndromes develop slowly

Miscellaneous Ascent Disorders

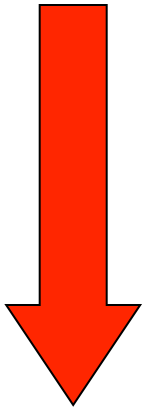
- Alternobaric vertigo
  - Occurs on ascent
  - Caused by unequal middle ear pressures
  - Transient vertigo, nausea
- Barodontalgia (squeeze and reverse squeeze)
  - Air trapped in a dental cavity expands on ascent, causing tooth pain
- Gastrointestinal barotrauma
  - Serious problems are rare
  - Eructation,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

Diving Injuries

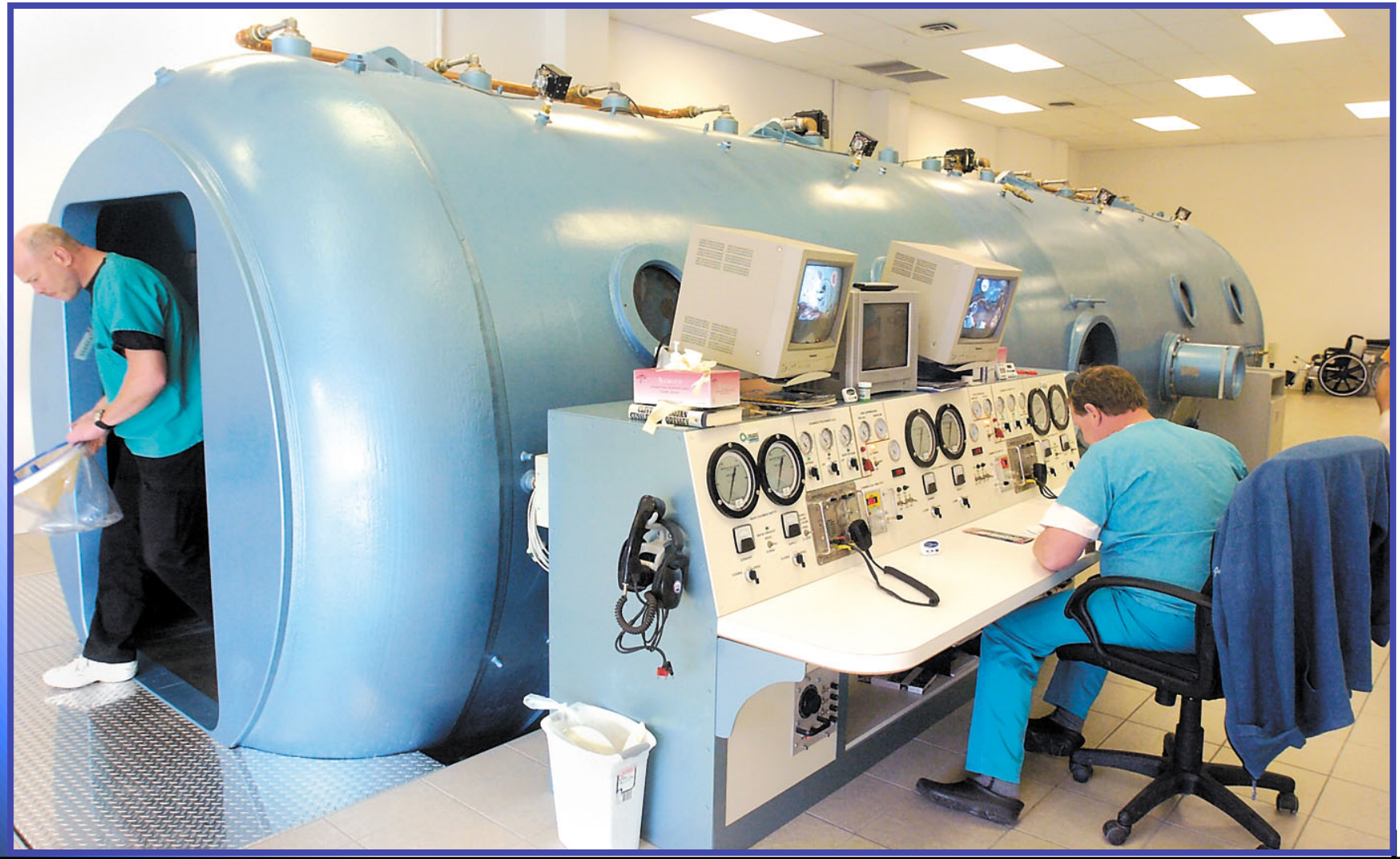
- Disorders of *ascent*
  - Pulmonary over pressurization syndrome
  - Air embolism - sudden
  - Decompression illness - gradual



- 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 **C**old **I**nduced **V**aso**D**ilatation
  - 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

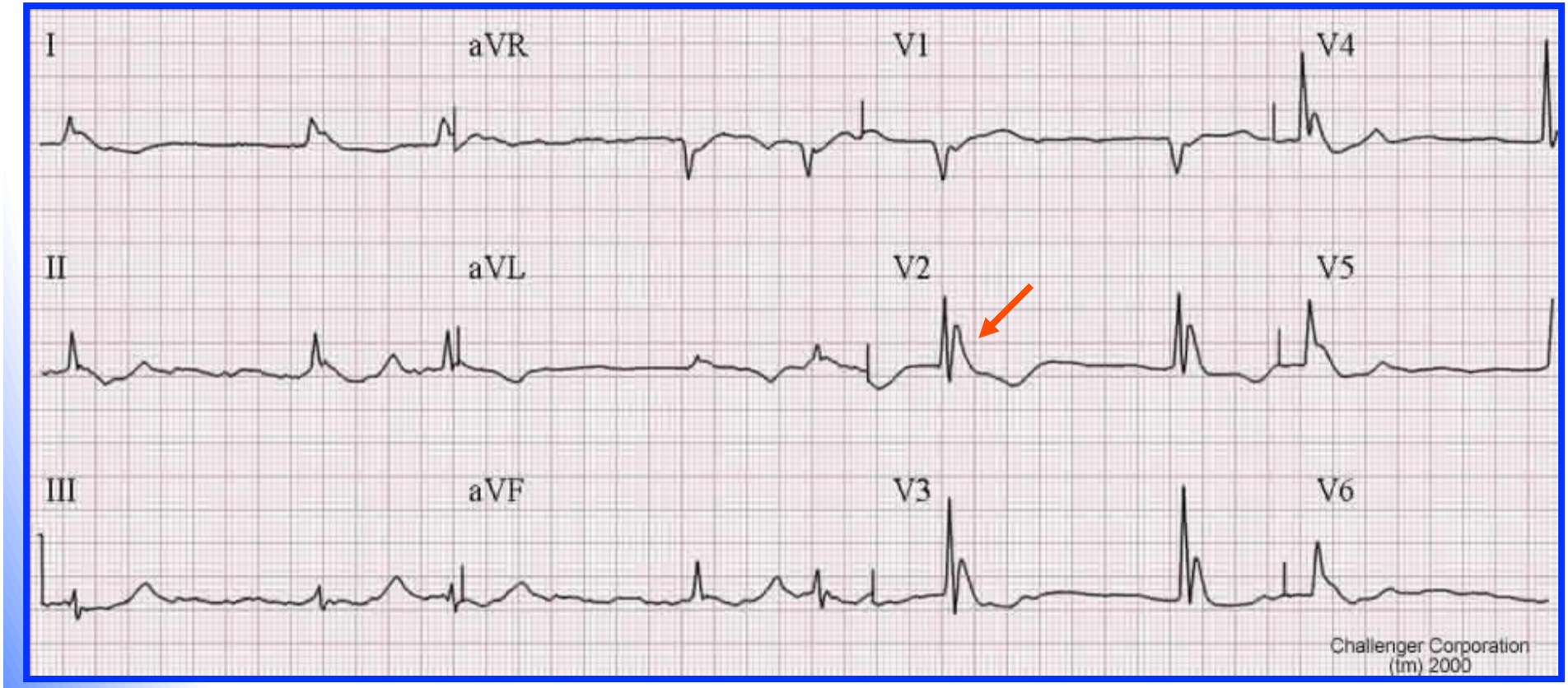
- Definition: core temp < 35 ^{o}C
  - 32-35 ^{o}C: Adjustments to retain and generate heat (shivering thermogenesis)
  - <32 ^{o}C: Slowdown of body functions and metabolism, decreased O_2 utilization, CO_2 production
- Risk factors: Extremes of age, altered sensorium for any reason, burns, trauma

Hypothermia

Clinical effects

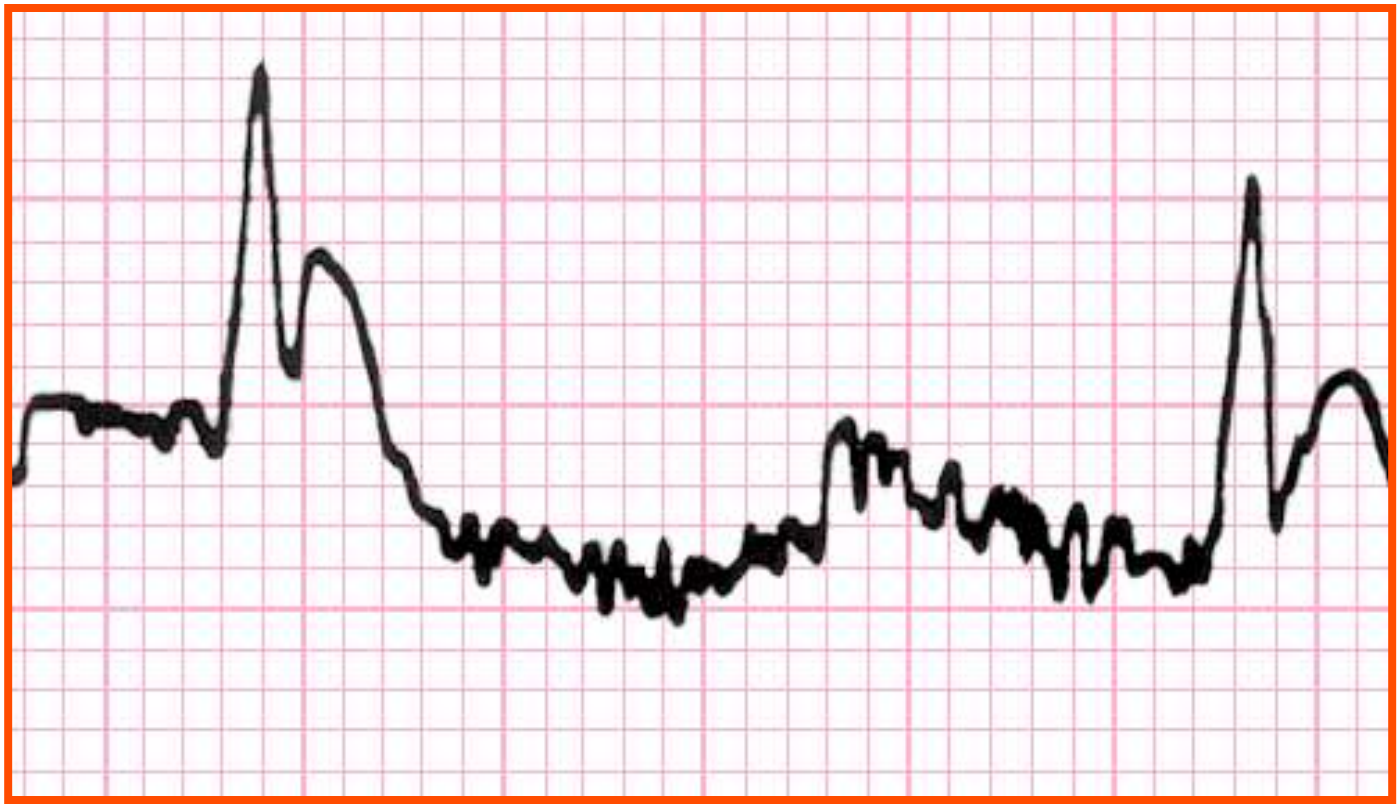
- Pulmonary: Increased risk for aspiration
- CNS: Altered mental status, incoordination, confusion, lethargy, coma
- Renal: Cold diuresis and volume loss
- Vascular: Hyperviscosity, thrombosis, DIC
- Pancreatitis
- Bradycardia and slow A-fib **with Osborn J waves**
- Myocardial irritability (epinephrine, 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 ˚C or cardiac instability evident
  - Warm humidified 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 ˚C) is false… truly dead patients cannot be rewarmed

Frostbite

- Frostbite: Local tissue freezing (irreversible)
- Frostnip: Transient freezing (reversible)
- 1st degree: Superficial, erythema, no blisters
- 2nd degree: Full thickness, edema, erythema, clear blisters
- 3rd degree: Hemorrhagic blisters, skin necrosis
- 4th 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 ºC)
  - 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˚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^+ 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˚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 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 °C
- Altered mental status
- Labs: Elevated LFTs (most sensitive), DIC, increased CPK and myoglobin

Multi-organ failure + mental status changes

Heat Stroke Treatment (1)

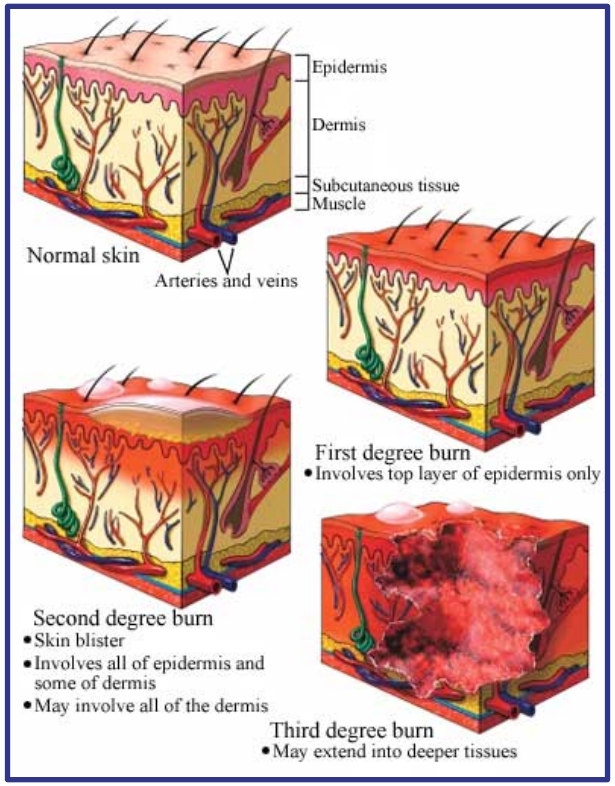
- Two main objectives: Immediate cooling and support of organ system function
  - Cooling methods
    - Conduction (increasing the temperature gradient between the skin and the environment)
      - Cold water immersion / ice slush / cooling blanket
    - Evaporation (increasing the gradient of water 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

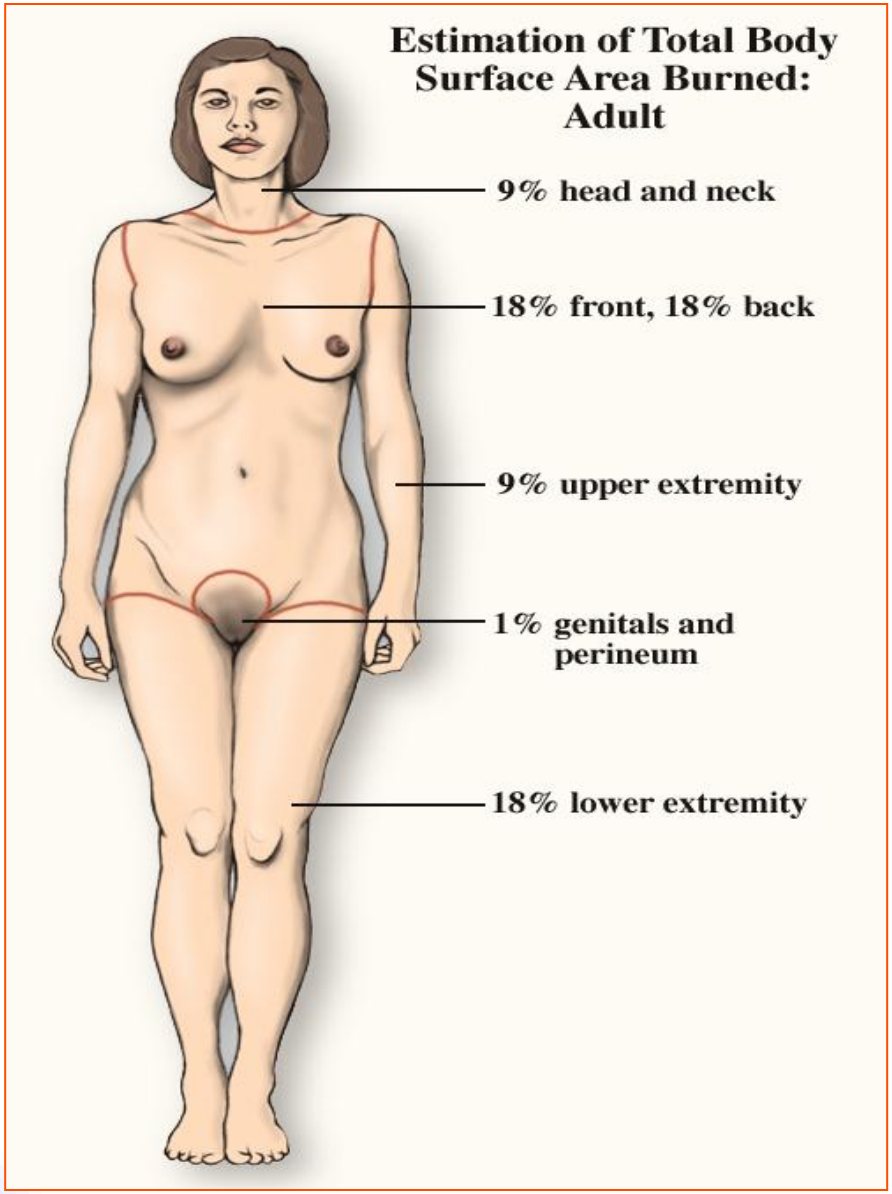
- 1st Degree
  - Epidermis only (sunburn), no blisters
- 2nd Degree
  - Dermis involved with blister formation
  - Sensation intact
- 3rd Degree
  - Full thickness
  - Anesthetic
  - White or charred, waxy
  - Eschar formation
- 4th Degree
  - Muscle, fascia, bone



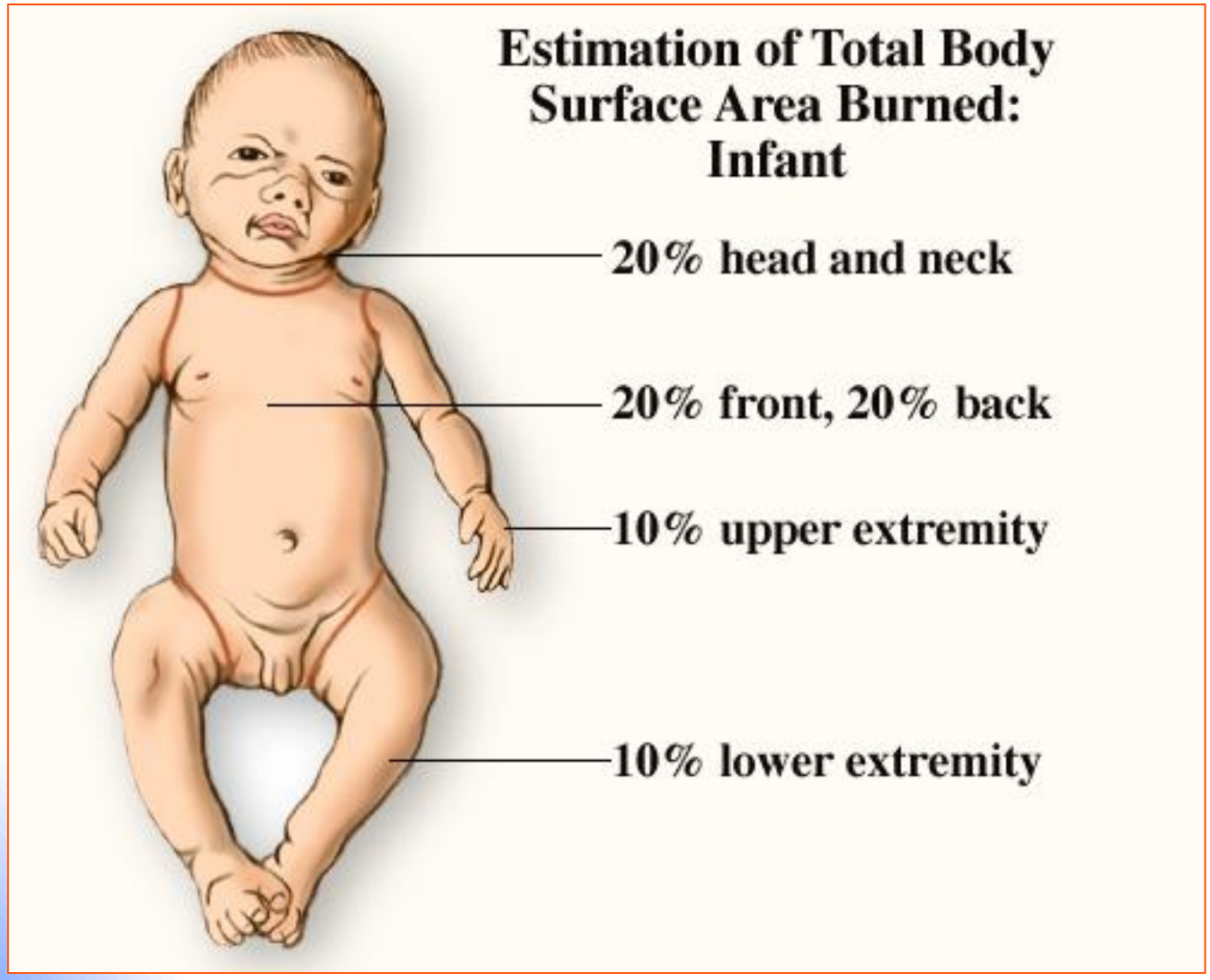
BSA & Resuscitation Formulas

- 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 1st 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

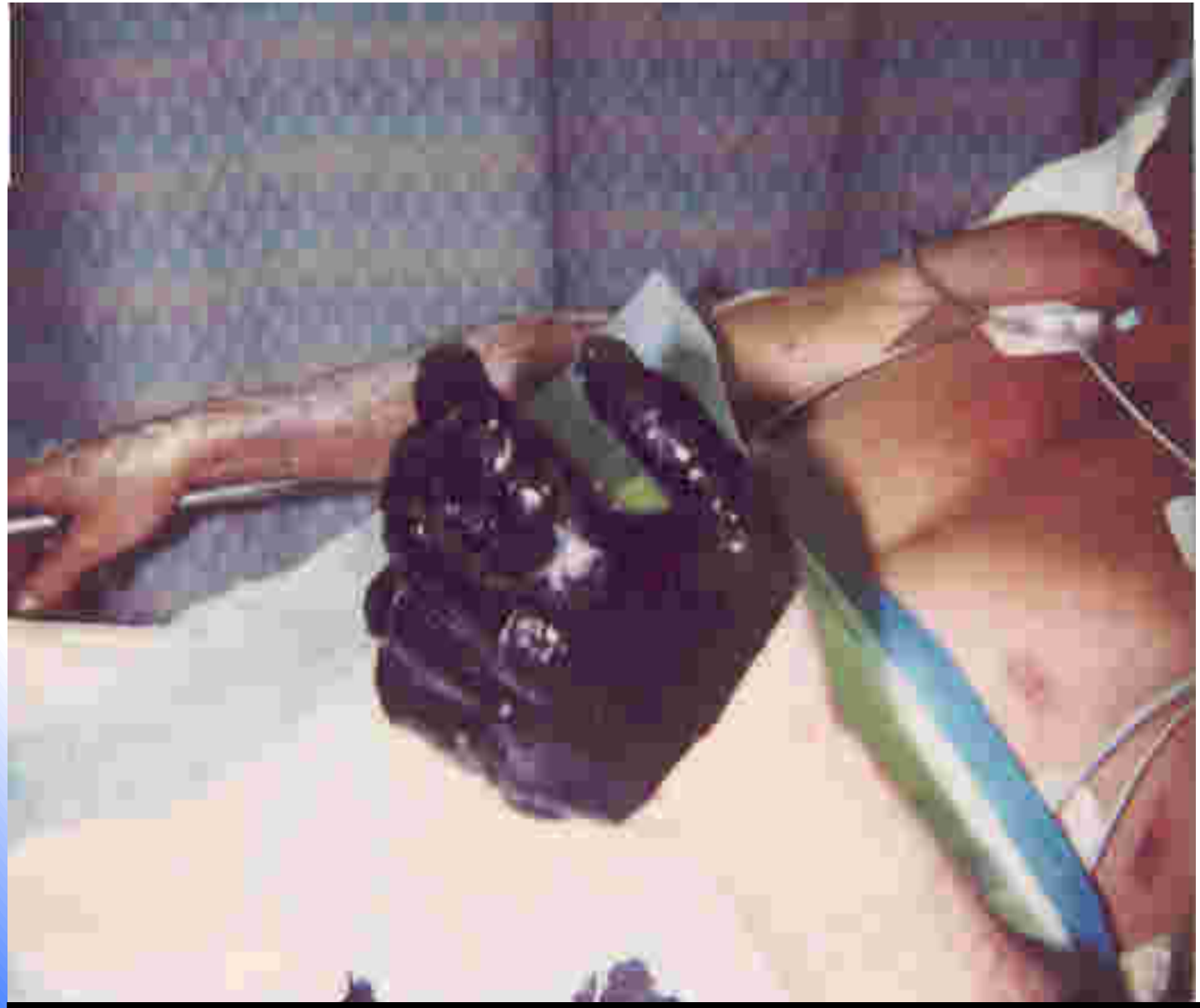
VERY CONSERVATIVE

- 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

Second and Third Degree Burns

Third Degree Burn

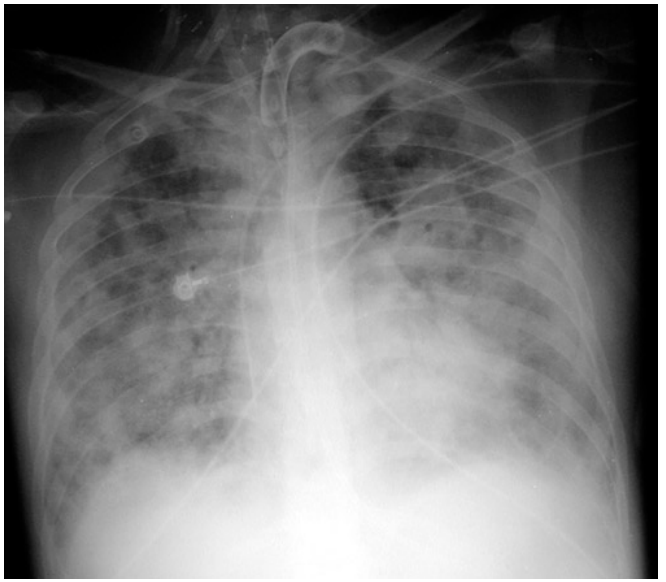
Tar Burn to Hand



Tar Burn to Hand

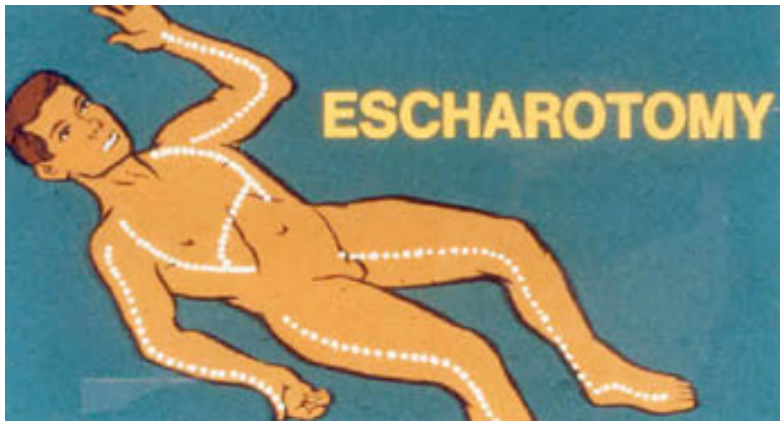
Burn Complications

- 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, 3rd 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 then 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
  } **Heat**
- Ionizing α - least penetrating
  β - 8 mm penetration (burns)
  γ - deep penetration, acute radiation sickness
- Neutrons: fallout
- Radon gas: decay of uranium 238 (α)

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

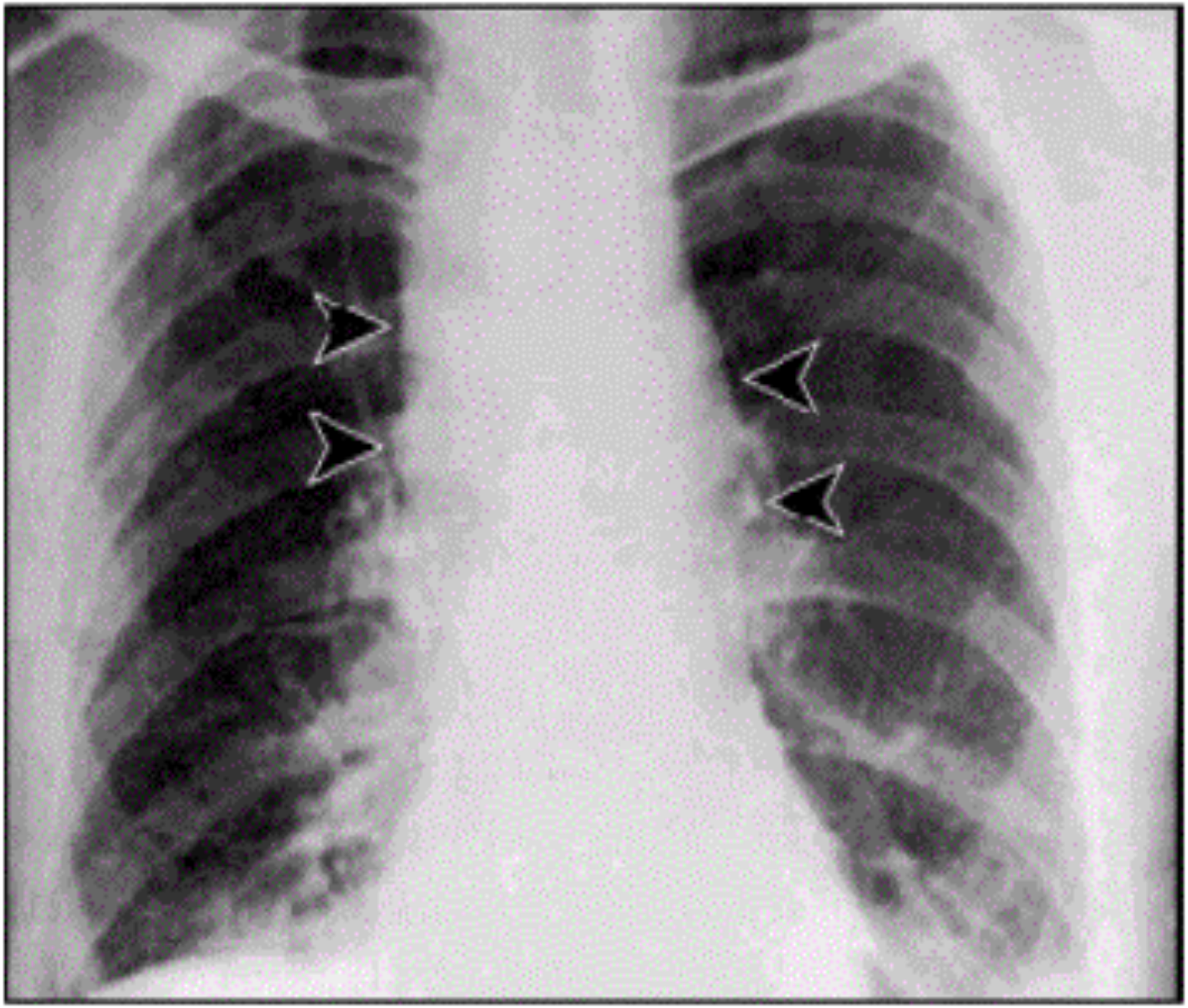
Anthrax (1)

- "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

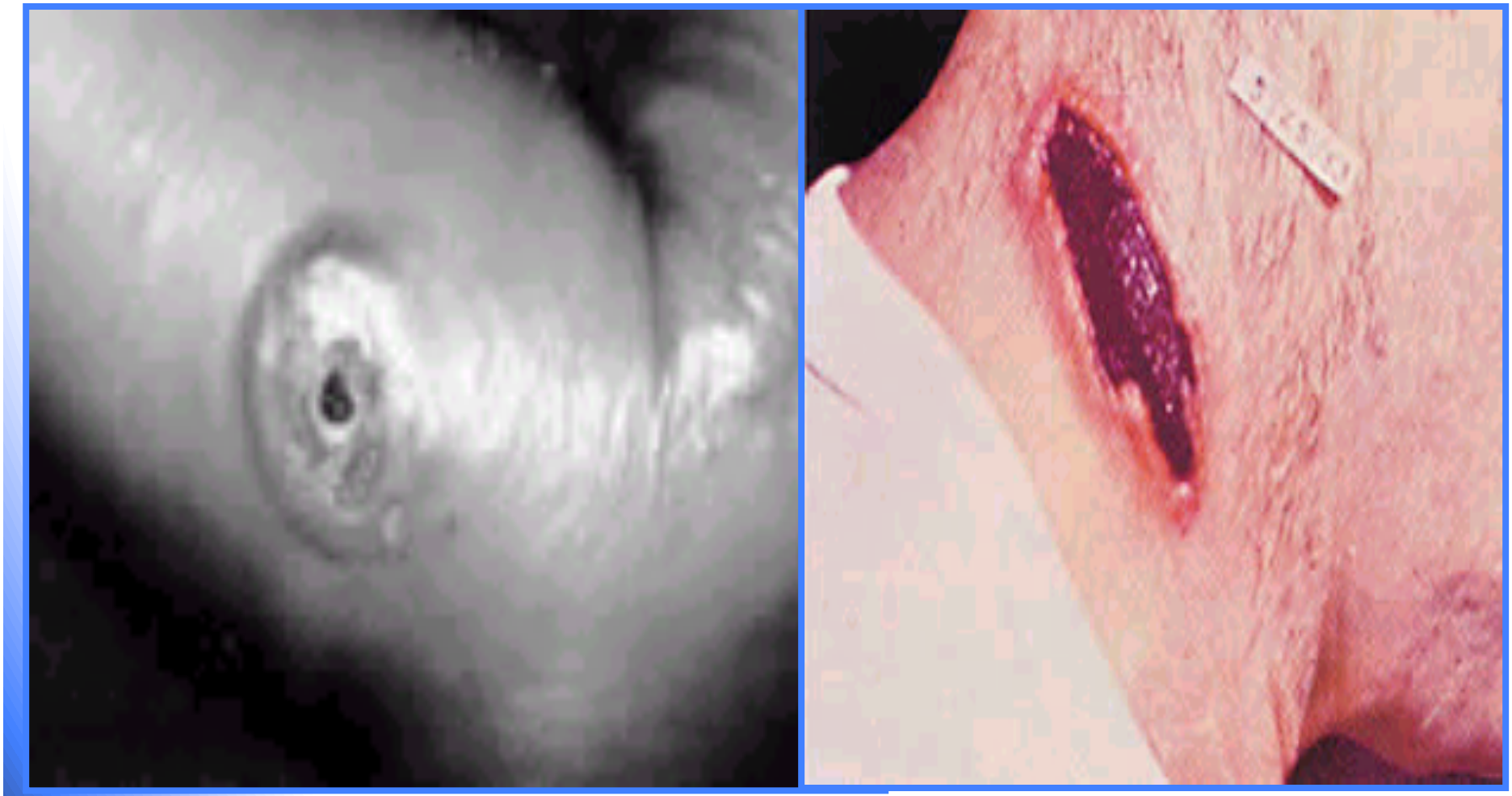


www.CDC.gov

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

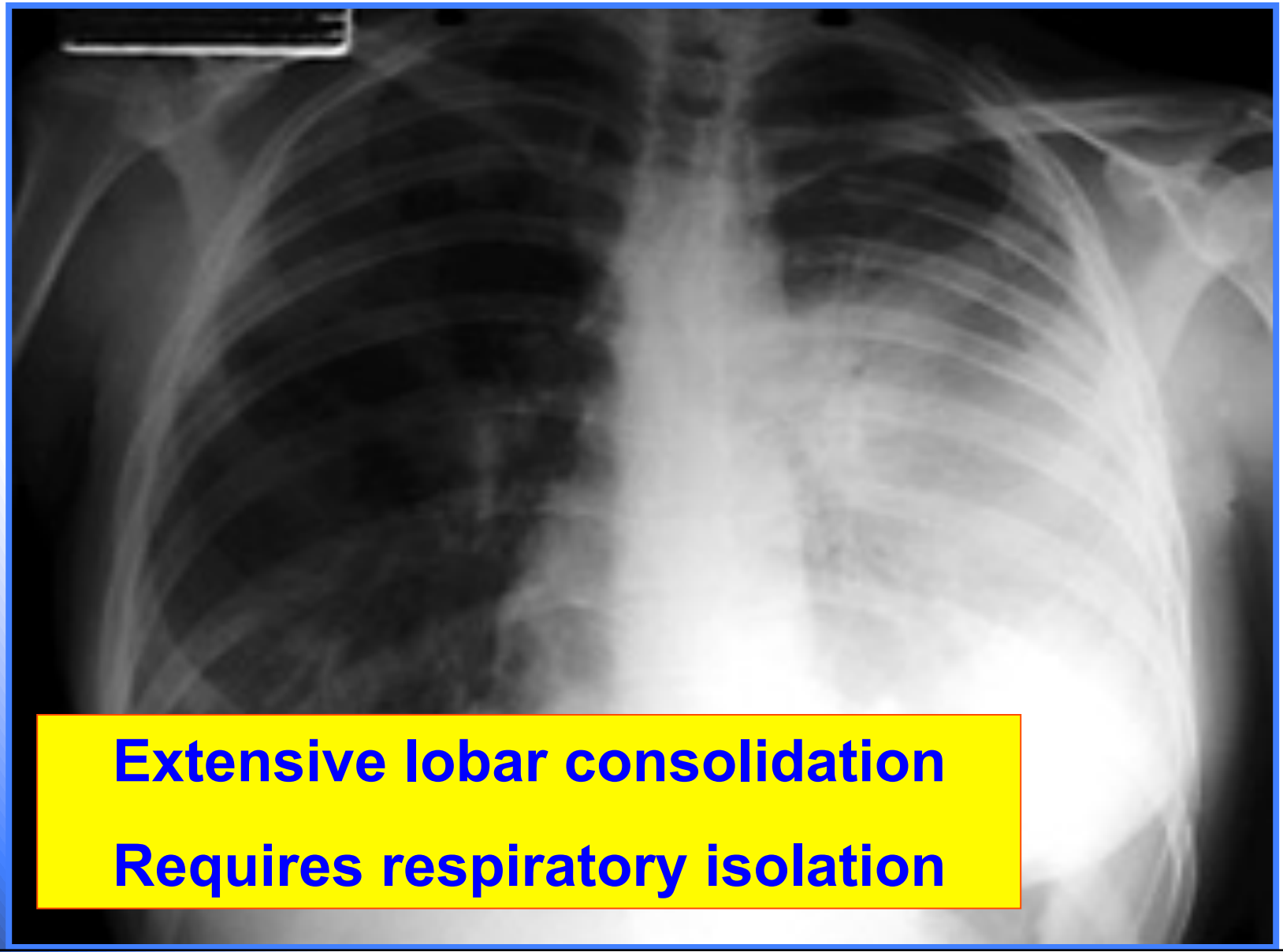


Plague

- *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



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

Auto-inoculation of eyelid with vaccinia virus

www.cdc.gov

Isolation Recommendations

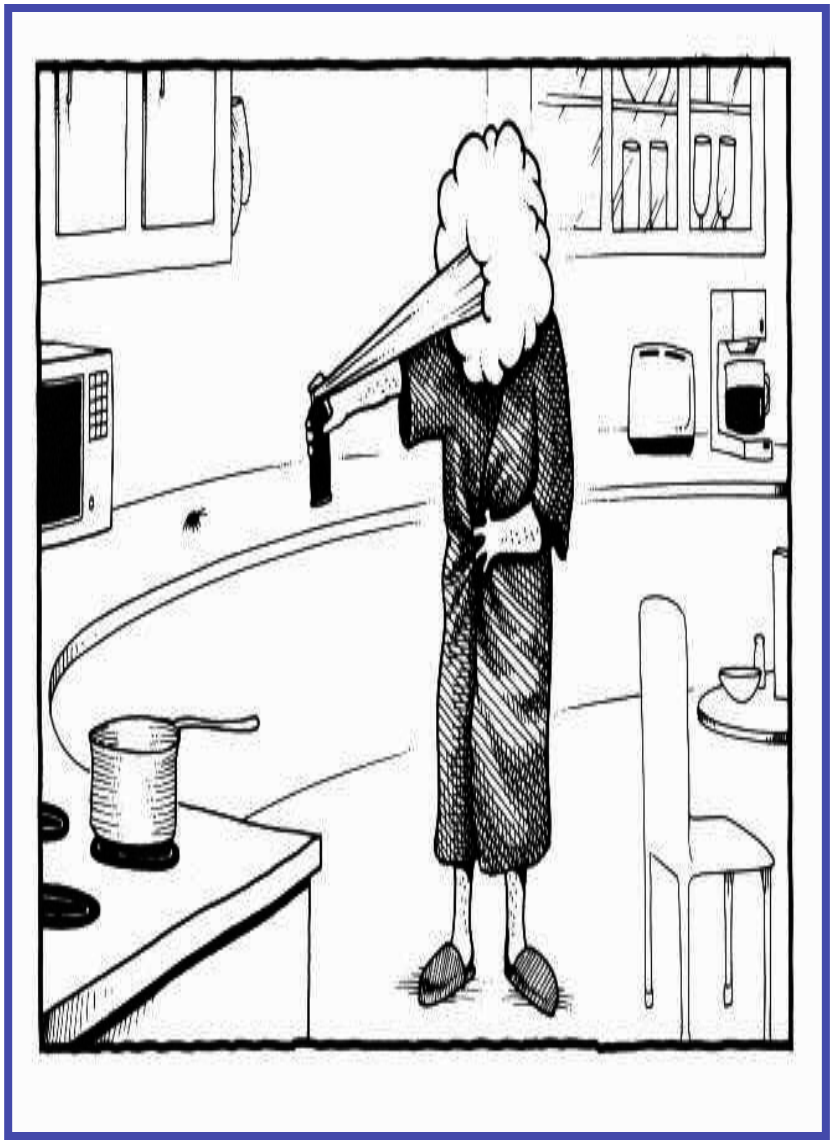
- Isolation is not required for anthrax
- Plague
  - Respiratory isolation (48 hours), sputum and tissue testing, CXR
  - Bubonic plague can disseminate if untreated, and secondary pneumonic plague (contagious) can develop
- Smallpox
  - Strictly quarantined
  - Exposure contacts require respiratory 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
- Human bite
  - Clenched fist
  - Consider in genital wounds
  - **Highest infection risk**
  - Eikenella corrodens
  - Rx: Amoxicillin / clavulanate
- Cat bite (and scratch)
  - Moderate infection risk
  - Pasteurella multocida
  - 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 ¼ 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

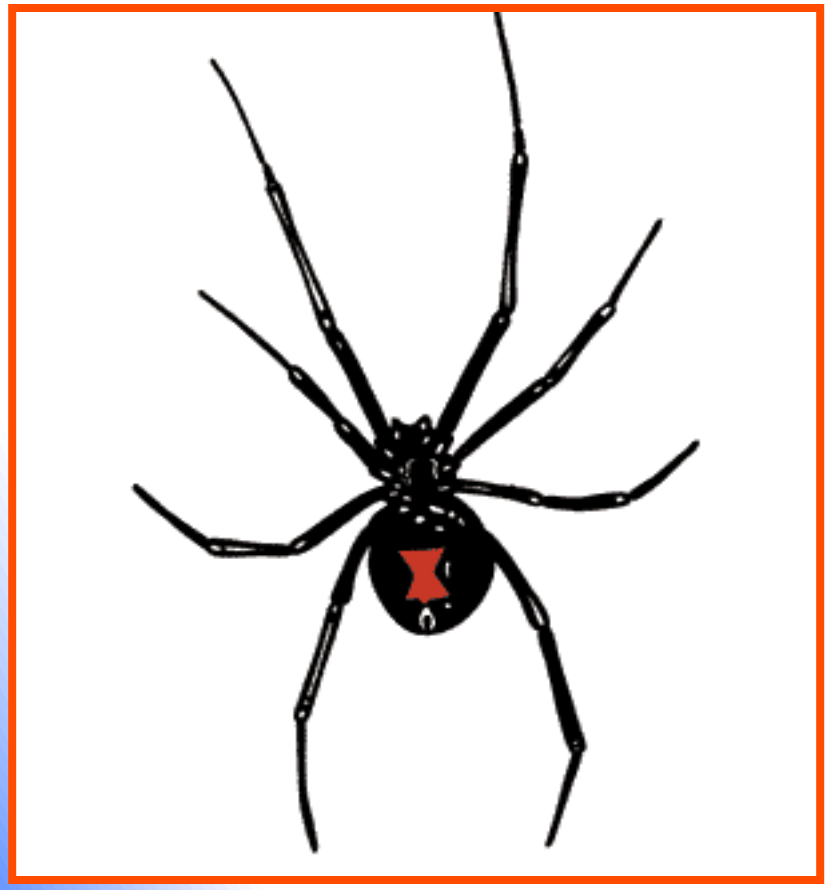
Rattlesnake bite

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 (Loxoscelese)

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
- Areomonas 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 itiching
  - 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

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_2 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_2

E. H_2O_2

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^{o} 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

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^{o}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
2. A
3. D
4. C
5. A
6. B
7. B
8. B
9. C
10. C
11. C
12. A
13. D
14. A
15. B
16. D
17. A
18. A
19. C
20. A