VIRGINIA EMS ROCKS !!

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High Voltage
Jesse Bass

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CHESAPEAKE, VA LIGHTING

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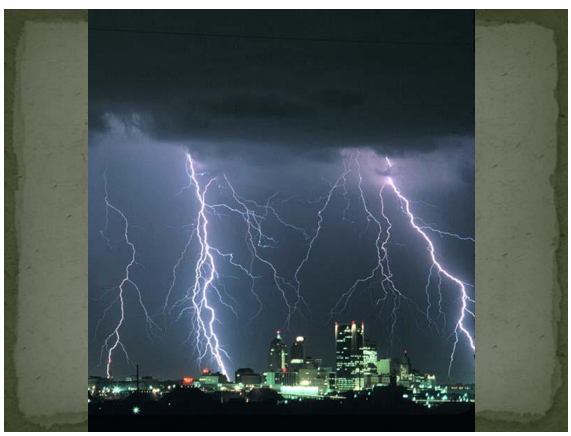

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In this case I only heard a quick crack, but no thunder because the bolt was so close.

35 feet in front of me

"To stand against the deep dread-bolted thunder? In the most terrible and nimble stroke of quick, cross lightning?"

Wm. Shakespeare, "King Lear", Act 4, Scene 7

Myth or Fact?

- Lightning does strike the same place twice.
- FACT

Myth or Fact?

- Lightning only strikes when there are clouds overhead (or when it's raining)

- MYTH

Myth or Fact?

- Carrying an umbrella increases my risk of being hit by lightning.

- FACT

Myth or Fact?

- When someone is struck by lightning, they can be vaporized or turned into a "crispy critter".

- MYTH

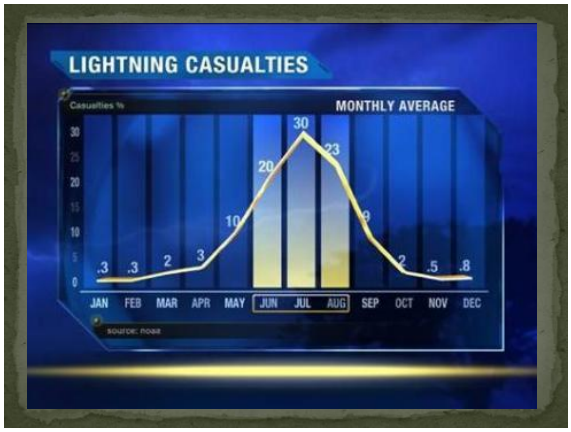
Myth or Fact?

- If multiple persons are struck by lightning, the rules of triage say that you should resuscitate the dead first.

- FACT

General Introduction

- Around the Earth there are 8 million lightning strikes in any given day
- Lightning kills more people in the U.S. each year than any other natural disaster
  - 55% more deaths than tornadoes
  - 41% more deaths than floods and hurricanes combined
- Regions of the U.S. most susceptible to lightning injury/death
  - FL, MI, PA, NC, NY, TX, TN, GA, CO and ....



Epidemiology

- 85% of lightning victims are children and young men aged 10-35
- Lightning injuries commonly tend to involve more than one victim
  - 15% of deaths occur in multiples of two
  - 15% of deaths occur in multiples of three or more

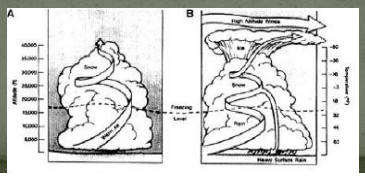
Humans versus Lightning….We Lose .

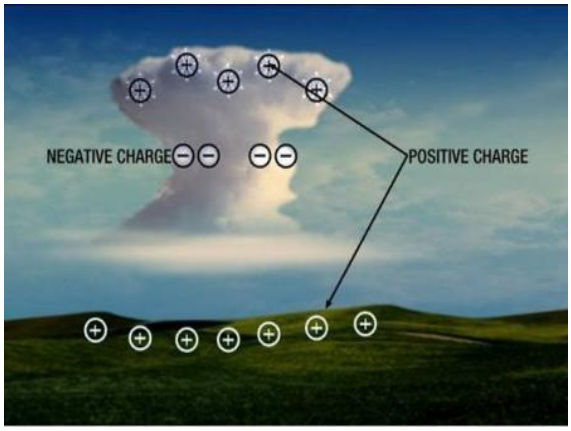
Lightning Production

- Storm clouds are giant capacitors
- Typically cumulonimbus clouds

Lightning Production

- Warm, low pressure air rises through cool, high pressure air
- Lighter ice crystals gain positive charge and are carried by the updraft to the thunderstorm's anvil

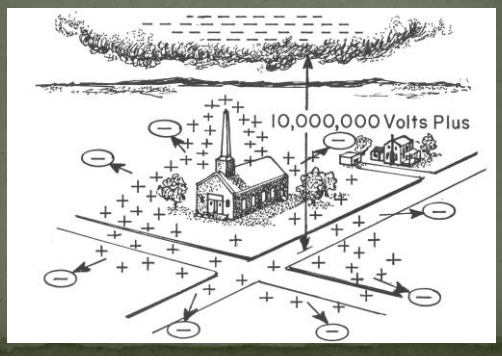




Lightning Production

- This increasingly negative charge in the lower half of the thunderstorm in turn induces a positive charge to increase along the ground
  - And anything attached to the ground

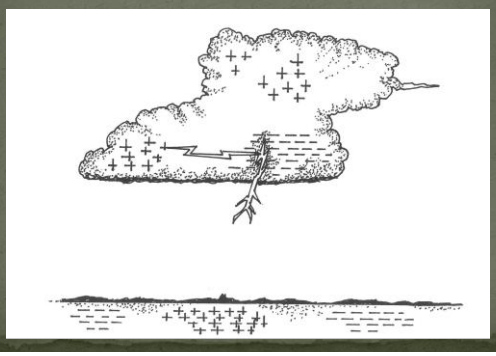
Lightning (1)



Lightning – Part 2

- Follow the Leader
  - A cloud-to-ground lightning strike starts when a negative charge streams from the cloud toward the ground
  - Called a stepped-ladder
    - Negative charge that takes 160 foot steps toward the ground

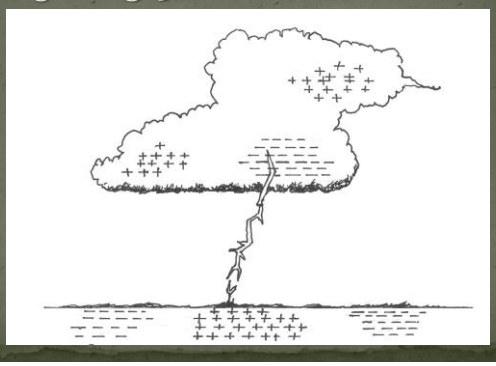
Lightning (2)



Lightning – Step 3

- Opposites attract
  - When the stepped ladder gets within 100 – 300 feet of a tall object, positively charged "streamers" surge upward to meet the stepped ladder

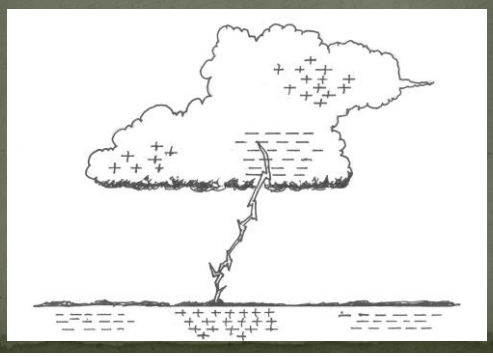
Lightning (3)



Lightning – Step 4

- Making the Connection
  - When the streamer connects with the stepped ladder, electrons in the streamer surge into the ground
  - Immediately, a "return stroke" of positive charge flows toward the cloud

Lightning (4)

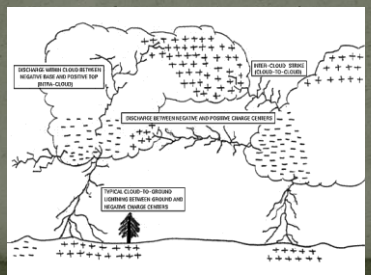


Lightning – Step 5

- Too fast for the Human Eye
  - The upward flow of charge produces the flash we see as lightning
  - However, the eyes see the bolt go from the cloud to the ground

Lightning Caveats

- Roughly 80% of lightning actually occurs *within the cloud, never reaching the ground*



Lightning Caveats

- A small fraction of lightning cloud-to-ground flashes occur up to 15 miles away from a thunderstorm
  - Due to positive charge buildup in the anvil
  - "Bolts from out of the Blue"
    - Typically contain higher currents than the more ordinary lightning

Lightning Specifics

- Thermal energy causes a rapid, explosive heating of air in a lightning channel
- Explosion =THUNDER !

Lightning Mechanisms of Injury

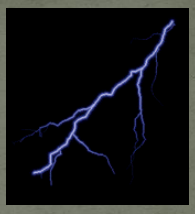
- Heat Production
- Indirect Effects
  - Fires, falling objects
- Concussive Force
- Electrical Effects

Concussive Force

- Results from shock wave
  - Acoustic injury
  - Internal organ contusion
- Propulsion of victim
  - From displacement of air
  - Blunt Trauma

Electrical Effects

- Direct Strike
- Splash Injury
- Ground Strike (Step Voltage)



Direct Strike

- Most dangerous
- Hitting the victim or some object the victim is holding
  - Golf club
  - Umbrella

Splash Injury ("Side Flash")

- Lightning hits a nearby tree or other object
- Splashes onto a nearby victim
- Can be person to person
- Indoors
  - Plumbing, telephone, wiring

Ground Strike (Step Voltage)

- Strike occurs near the victim causing a difference of potential in the ground
  - Amounts to several thousands Volts/foot
- Wave – like radiation outward toward the victim
- Usually involves the lower extremities
  - Circuit made by legs rather than staying in the ground

Lightning Mechanisms of Injury

- Factors that affect type and severity of an injury
  - Duration
  - Voltage
  - Amperage
  - Resistance of Tissues
  - Pathway
  - Frequency

Duration, Voltage , Amperage

- Duration
  - Duration of a strike is 1/10,000th to 1/1000th of a second
    - Actual amount of energy delivered is very small
- Voltage
  - 100 million to 1 billion Volts
- Amperage
  - Current in a single bolt is as high as 20,000-100 million Amps

Resistance of Tissues

- Tendency of a material to resist flow of electric current
- Resistance of body tissues (least -> greatest)
  - Nerves
  - Blood
  - Mucous membranes
  - Muscle
  - Dry skin
  - Tendons
  - Fat
  - Bone

Pathway

- Takes a finite amount of time for skin to breakdown
- Duration of strike not long enough
- Flash-Over effect
  - Diminishes energy dissipation within the body
  - Thought to be cause of a commonly seen blast effect
    - Vaporizes moisture on the skin
    - Blasts apart clothes, shoes, etc.
- Portions of the current may still "leak" into the body through cranial orifices

Frequency

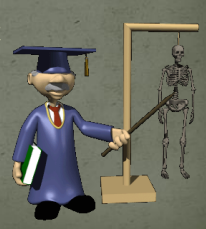
- Massive unidirectional current impulse
- In essence, similar to Direct Current (DC)
- Has the effect of cardioversion
  - Leads to asystole

Frequency

- Cardiac automaticity results in spontaneous return to RSR in many cases
- The concomitant respiratory arrest often persists
  - Thoracic muscle spasm, suppression of respiratory center
  - Secondary hypoxic cardiac arrest develops

What organs are commonly injured?

- Any organ has the potential of being injured
  - Pathway of current
  - Site of entry



Dermatologic Effects

- Superficial burns (partial thickness)
- Less than 5% suffer full thickness burns
- 4 types of superficial burns
  - Linear
  - Punctate
  - Feathering
  - Thermal

Linear Burns

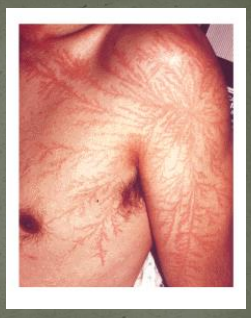
- From steam production and flash-over
- 1 – 4 cm wide
- Follow heavy sweat concentrations
  - Folds
  - Beneath breast tissue
- Usually 1st or mild 2nd degree
- May develop late

Punctate Burns

- Multiple, closely-spaced, discrete circular burns
- May be full-thickness
- Few millimeters -> centimeters in diameter
- Resemble cigarette burns

Feathering Burns

- Not a true burn
  - RBC extravasation into superficial layers of the skin
- Secondary to the breakdown of the skin from electron showering
  - Does not follow vascular or nerve pathways



Thermal / Explosive Burns

- Clothing ignited by lightning
- Metal jewelry, carrying coins, necklaces
- Can be 2nd and 3rd degree burns

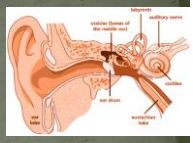
Opthalamic Effects

- Corneal Lesions
  - Intense brightness
- Vitreous hemorrhage
- Retinal detachment
- Hyphema
- Diplopia
- Cataracts (late)

In this case I only heard a quick crack, but no thunder because the bolt was so close.
35 feet in front of me

Otological Effects

- Tympanic membrane rupture
  - Secondary to barotrauma
- Temporary deafness/tinnitus/vertigo
- CSF otorrhea
- Burns to external auditory canal



Musculoskeletal Effects

- Direct or indirect injuries from strike
- Contusions
- Fractures
- Muscle/ligament tears
- Compartment syndrome (rare)

Cardiopulmonary Effects

- Dysrhythmias (PVC's, a-fib., VF/VT, asystole)
- Pulmonary contusion
- Pulmonary edema
- Myocardial injury
- Apnea
- Transient HTN
- Vascular instability

Neurologic Effects

- Keraunoparalysis
  - Temporary paraplegia and occasionally quadriplegia secondary to lightning strike
  - Lower and upper extremities are blue, mottled, cold and pulseless
    - Due to vascular instability and sympathetic dysfunction
- Few people are left with permanent paresis or paresthesias

Indications of Lightning Injury - Physical Exam

- Cold, pulseless extremities (vasomotor instability)
- Confusion, amnesia, LOC are result of direct passage of current through the brain
- Temporary hearing loss caused by shock wave of thunder
  - 50% of patients rupture at least 1 tympanic membrane

Indications of Lightning Injury - Physical Exam

- Hypotension most likely signals:
  - Intra-abdominal or thoracic hemorrhage
  - Fractured pelvis
  - Rupture of internal organs
  - Spinal cord injuries
- Prolonged paresis/paralysis of extremities indicates possible spinal cord injury
- Fixed and dilated pupils typically result from transient ANS disturbances, not serious head injuries

Actual Case

- Eight -year-old boy struck by lightning. Had no vital signs for 13 minutes, pupils fixed and dilated, and no bleeding with a thoracotomy.
- He responded to CPR and intracardiac epinephrine.
- He suffered no permanent dysfunction.

Initial Resuscitation

- Scene safety
- Remove smoldering clothing and/or jewelry
- C-Spine stabilization
- ABC's per BLS/ALS
  - Watch for rapid soft-tissue swelling

Initial Resuscitation

- H/P exam, if possible
- I.V. access and fluids
  - Fluid resuscitation to prevent hypovolemia and to maintain diuresis of myoglobin, potassium and toxic by-products
- Pharmacological therapy prn
- Wound care

Treatment

- Cardiovascular therapy
  - Same indications for antiarrhythmics and pressors
  - Transient HTN may be short-lived and require no action
    - Responds well to conventional therapy
- CNS
  - Thorough head to toe exam

Treatment

- Pronouncing the victim dead
  - Exclude other causes of dysfunction before death is declared
    - MI
    - CVA
    - Intracerebral bleeds
    - Metabolic
    - Toxicologic

Questions?

Thanks for Listening!

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Resources

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