Electrical Injuries

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Epidemiology

- Relatively common, almost always accidental, and generally preventable.
- Electrical burns and lightning injuries result in ~3000 admissions to burn centers per year.
  - 3-4% of all burn-related injuries
- Up to 40% of serious electrical injuries are fatal.
  - ~1000 deaths per year.
Lightning Injuries

- Small subset of electrical injuries
- 300 injuries requiring 100 hospitalizations/year
- Death from lightning injuries:
  - 2/3 occur within 1 hr of injury, mostly from fatal arrhythmia or respiratory arrest
Physics of Electricity

- **Definition**: The flow of electrons from high to low potential

- Ohm’s Law: \( V = I \times R \)

- Joule’s Law: \( \text{Heat} = I^2 \times R \times T \)
What influences extent of injury? (1)

- **Current:** type, magnitude, and pathway
  - **Type:** Alternating vs Direct
  - **Magnitude:**

| Tingling sensation from household current | 1–2 |
| Let-go current                           |     |
| Man                                      | 7–9 |
| Woman                                    | 6–8 |
| Child                                    | 3–5 |
| Tetany (freezing to circuit)             | 10–20 |
| Respiratory arrest from thoracic muscle tetany | 20–50 |
| Ventricular fibrillation                 | 50–100 |
What influences extent of injury? (2)

- **Voltage**
  - Up to 1,000 V – increased resistance limits further passage of current and heating of tissue
  - >1,000 V – passage of current is not limited, and tissue injury can continue
    - *Lightning*: 10,000,000 volts
    - *High tension power lines*: 100,000 volts
    - *Household*: 110 volts

- **Resistance**
  - Dry skin = 100,000 ohms
  - Wet skin = 2,500 ohms

- **Duration of contact**
Classification of Injury

- Classic injury pattern
- Flash (aka Arc) burn
- Flame injury
- Lightning injury
Classic Injury Pattern

- **Body becomes** part of a circuit.
- Usually occurs when >1000 volts.
- Can usually see entrance (source) and exit (ground) wounds.
Flash/Arc Burn

- Current arc strikes the skin but **does not enter the body**.
- Current ignites surrounding particles, which cause the burn.
- Temperature ~2500 °C
- Usually results in superficial partial thickness burns

Current arcs, causing flash
No current goes through patient
Flame Injury

- These occur when the electrical source sets the person’s clothing on fire.
Lightning Injury

- DC exposure that lasts from 0.001-0.1 sec.
- Voltage > 10,000,000 volts (!)
- Peak temperatures ~30,000 K
  - 5x hotter than the surface of the sun!
  - Rapid heating and cooling of surrounding air
Mechanisms of Injury

1. Direct effect of electrical current
2. Blunt mechanical injury
3. Conversion of electrical to thermal energy
1. Direct Effect of Current

- Cardiac arrhythmias
- Respiratory arrest

2. Blunt Mechanical Injury

- Avulsion fracture from tetanic muscle contraction
- Trauma from falling, explosive/implosive force of lightning
3. Conversion to Thermal Energy

- **Joule’s Law:** \( \text{Heat} = I \times V \times T = I^2 \times R \times T \)

- Tissues with higher resistance tend to heat up rather than transmit the current.
  - *High resistance:* skin, bone, fat
  - *Low resistance:* nerves, blood vessels

- Deeper tissue cools more slowly, so may actually be more severely damaged than surface tissue.
  - Surface wound is only the beginning.
Skin Involvement

- **20 seconds** in contact with:
  - 20-35 mA/mm² → raises skin temp to 50°C → blistering & swelling
  - 75 mA/mm² → raises skin temp to 90°C → charring and more severe burns
- Cranial or leg burns higher risk of death
  - Rationale: More current passes directly through body
Cardiac Involvement

- Incidence of documented arrhythmia ~15%

- High voltage or DC current: **asystole**
  - Respiratory arrest typically lasts longer than cardiac arrest: may lead to secondary V-fib from hypoxia.

- **AC current: ventricular fibrillation**
  - 60% of people where current goes from one hand to the other

- Cardiac contusion
Musculoskeletal involvement

- **Compartment syndrome**
  - Swelling of the injured extremity with pain, paresthesia, pallor, pulselessness, poikilothermia, paralysis.
  - Impairs circulation, compresses nerves

- **Bone = highest resistance of any body tissue**
  - Areas of most thermal damage = adjacent to bones

- **Fractures from falls or repetitive tetanic muscle contraction**
  - Flexors of forearm and hand are stronger than extensors, so person may actually grab on to the source.
Organ Involvement

- **Renal**
  - Rhabdomyolysis $\rightarrow$ myoglobinuria $\rightarrow$ ATN
  - Burn edema $\rightarrow$ hypotension $\rightarrow$ ATN

- **CNS**
  - LOC, weakness/paralysis, respiratory depression, autonomic dysfunction, memory disturbances, seizure disorder, psychiatric sequelae

- **Vascular**
  - From compartment syndrome or from electrical coagulation of small vessels
Organ Involvement (cont’d)

- **Ophthalmologic**
  - Cataracts, hyphema (hemorrhage into anterior chamber), vitreous hemorrhage

- **Otologic**
  - Hearing loss, tinnitus, vertigo
Causes of Death

In Temporal Order of Occurrence:

- Cardiopulmonary arrest
- Overwhelming injuries
- Cardiac arrhythmias
- Hypoxia and electrolytes
- Intracranial injuries
- Myoglobinuric renal failure
- Abdominal injuries
- Sepsis
- Tetanus
- Suicide
Management

- ABC’s!
- Cervical spine immobilization, tetanus vaccine
- Assess for coexisting smoke inhalation
- If comatose/neuro deficit: brain +/- spine imaging
- Fluid resuscitation
  - Parkland formula is not rigorously tested in this setting.
  - Extent of surface burns don’t tell the whole story.
  - Goal UOP 1-1.5 cc/kg/hr in setting of myoglobinuria
  - Goal UOP 0.5-1.0 cc/kg/hr otherwise
Management (cont’d)

- Assess for **myoglobinuria** with UA
  - If present, treat with: IVF, alkalinize urine, mannitol diuresis

- Assess for **rhythm disturbances** with EKG
  - Monitor for 12 hours for presence of arrhythmias
  - May need to monitor for longer if pt had LOC, known cardiac disease, chest pain, hypoxia, etc.

- Assess for **electrolyte imbalance** with chem
  - Hyperkalemia $\Rightarrow$ calcium gluconate, insulin/glucose, beta-agonists
Management (cont’d)

- Monitor for development of **compartment syndrome**
  - Escharotomy or fasciotomy if $P > 30$ mmHg
- Prophylaxis
  - NG tube for ileus
  - PPI’s for Curling’s ulcers
- Once stable:
  - Ophthalmologic eval, esp if injury above shoulders
  - Otologic & audiologic eval
Wound Management

- Aggressive debridement of necrotic tissue
  - Necrotic tissue is a great medium for bacterial proliferation
- Skin grafting
  - Allografting: encourages granulation tissue formation
  - Autografting
Long-term sequelae

- **Psychiatric complaints**
  - Phobias, depression, irritability, PTSD

- **Neuropsychological signs**
  - Memory deficits, attention problems

- Scarring

- Cataracts