ELECTRICAL INJURY

MAIN TOPIC

Description
• Electrical injury produces variable types of adverse effects to organs and vital neurovascular structures, often without outward physical signs of injury
• Potential to cause burns and deep hidden damage
  - Coagulation of arteries proximal to the exit wound
  - Injury may be much more severe than at first thought
  - See ELECTRICAL BURNS
    * Delay excision and grafting until the burn area has fully declared itself
• Children vulnerable to full thickness orofacial burns
  - Pale, painless center of lesion
  - Extends after a few hours
  - Damage to facial and carotid arteries
• Lightning produces a massive voltage of extremely short duration
  - See LIGHTNING INJURY
    * Deep thermal injury is unusual

Clinical presentation
• Cardiac effects
  - Syncope in 33% of pediatric electrical injury
  - Asystole most likely due to direct current or lightning injury
    * 2% of pediatric electrical shock
  - Ventricular dysrhythmia
    * 4% of pediatric electrical shock
    * Case series of 8 patients suffering cardiac arrests due electronic control device use included 3 teenagers
  - Other dysrhythmia
  - Conduction defects (heart block) common, generally resolve without treatment
  - Cardiac contusion far more common than infarction
• Respiratory effects
  - Respiratory paralysis due to injury to medullary respiratory center
  - May persist longer than asystole such that a return to sinus rhythm may degenerate into ventricular fibrillation
• CNS effects
  - Altered level of consciousness: confusion, cognitive or memory defects
  - Seizures
  - Neurogenic shock
  - Brain stem injury with flaccid paralysis
  - Spinal, sympathetic, and peripheral nerve damage
  - Sensory and motor deficits may not match
  - Keraunoparalysis (transient weakness in limb) with autonomic dysfunction after lightning strike
    * Reversible transient paralysis
* Fixed and dilated pupils: not a reason to stop resuscitation

**Vascular effects**
- More common with electrical rather than lightning injury
- **Spasm**: Maximal decrease in blood flow at 36 hours
- **Delayed thrombosis**: due to prolonged decreased endothelial and smooth muscle function

- **Aneurysm**
- Arterial rupture: high voltage
- Subdural, epidural, or intraventricular hemorrhage
- Shock may occur due to vasomotor instability

**Skin**
- Burns are common: more frequently requiring grafting than chemical burns in children
- Small exit, entry wounds may mask extensive damage to blood vessels, muscles, nerves
- Deep burns are uncommon with lightning
- Oral burns occur in children chewing on cords, potentially leading to delayed labial artery bleeding

**Musculoskeletal**
- Rhabdomyolysis and myoglobinuria can produce renal failure
- Fractures or dislocations due to muscle spasm are rare

**Eye effects**
- Cataracts, corneal lesions, intraocular hemorrhages, retinal detachment, optic nerve injury

**Ear effects**
- Tympanic membrane perforation: lightning
- Transient vertigo: electrical
- Sensorineural hearing loss: electrical

**Gastrointestinal effects**
- Rare
- Ulcers or evisceration, stomach and intestinal perforation, esophageal stricture
- Electrocoagulation of liver and spleen

**Blunt trauma** common from secondary fall after injury

**BASIC SCIENCE**
Factors that determine the severity of electrical injury

**Voltage**
- Measurement of the "electrical pressure" in a system
- High voltage
  * > 1,000 volts
  * Usually more damaging than low voltage with tendency to "throw" victim (which may help limit contact)

  * High voltage takes a direct course to ground
Electronic control devices (i.e. TASER) fall in this category

- Low voltage
  - * < 1000 volts
  - * Follows path of least resistance
- Current (amperage)
  - Current more critical than voltage
  - Measure of the rate of flow of electrons
  - As little as 1 milliamp may produce ventricular fibrillation
  - 1 milliamp perceived as a tingling sensation
- AC (alternating current)
  - * Induces tetanic muscle spasm which can prolong contact by interfering with voluntary release
  - * Most common cause of electrocution
  - * Frequency of the AC may precipitate ventricular fibrillation
  - * More dangerous than direct current (DC)
- DC (direct current)
  - * Used for defibrillation etc.
  - Duration of the contact
  - Pathway taken by the current
  - Resistance
  - Measurement of the difficulty of electron flow
  - Increases from nerve, blood, muscle, skin, tendon, fat, and bone
  - Dry skin = 40,000 ohms versus wet skin < 1000 ohms
  - Thin infant skin and oral mucosa = low resistance
  - See TYPES OF ELECTRICAL INJURY

EPIDEMIOLOGY
- Approximately 1500 deaths per year
- Four times more nonfatal injuries
- Bimodal pediatric distribution
  - Exploring toddlers (12 to 24 months) most commonly exposed at home, chewing on extension cords
  - Adolescents climbing utility poles or trespassing into transformer substations

DIAGNOSTIC STUDIES
- Case-by-case based on severity of injuries
- CBC
- CPK
- Cardiac markers
- Electrolytes including calcium, BUN, creatinine, glucose
- ECG
- Urinalysis for myoglobin
- Imaging
- Chest x-ray if current may have passed through thorax
- Cervical spine if AMS
- Relevant long bones for specific injury after high voltage or lightning strike
- Head CT may be indicated for head injury with loss of consciousness

DIFFERENTIAL DIAGNOSIS
- See CAUSES OF ALOC
  - Hypoglycemia
  - Intoxication
  - Drug overdose
  - Cardiovascular disease
  - CVA

TREATMENT
- Ensure safety of first responders
- Separate victim from source of current
- Reverse triage if multiple victims especially with lightning strike
  - Focus on those appearing dead first due to high survival
- Advanced life support and trauma protocols
- CPR if necessary
  - Prolonged efforts may be indicated at discretion of treating physician as most victims are young and good outcomes reported even with asystole
    - See BASIC CPR
    - See RESUS: ASYSTOLE
- Oxygenation and ventilation
- Treat dysrhythmia
  - ECG and enzymes poor predictors of cardiac injury
    - See RESUS: VENTRICULAR FIBRILLATION
    - See DYSRHYTHMIAS
- Treat seizure
    - See RESUS: STATUS EPILEPTICUS
- Maintain circulation
  - Fasciotomy or amputation if necessary
- Assess for multiple trauma
- Volume expansion for thermal burns
  - Titrate to urine output
  - May require more fluid that predicted by burn formulas
- Fluid restriction if CNS injury
  - Watch for and treat cerebral edema
- Maintain urine output to treat myoglobinuria if present
  - Lasix or mannitol
- Alkalinize the urine
- See RHABDOMYOLYSIS AND MYOGLOBINURIA
• Comprehensive physical examination
- Pay particular attention to the head and neck
- Careful exam of the skin and pulses
- Cranial, cerebellar, and peripheral nerve exam
• Clean and dress burns
- Early referral to plastic surgeons but delay excision and grafting until the area declares itself
- See BURNS
• Address obvious injuries
• Tetanus prophylaxis and antibiotics
• High voltage or lightning strike
- Admit for observation and cardiac monitoring
- Repeat examination over days

COMPLICATIONS
• Considerable muscle damage may produce myoglobinuria
• Long term sequela from electrical and lightning injuries include
- Paralysis
- Dysesthesia
- Peripheral mono- or polyneuropathies
- Disturbances in mood, affect, and memory
  * up to 78% develop Diagnostic and Statistical Manual of Mental Disorders psychiatric diagnoses

DISPOSITION
• All children with oral injuries require plastic surgery or dental consults
• Neurosurgical, ophthalmological, and ENT consultations may be needed
• Transfer to a burn center may be needed
• Admission not required for any nontransthoracic low voltage injuries in an asymptomatic child without ECG abnormalities
• Admit all high voltage injuries for 12 to 24 hours
• Admit all lightning injuries except those with a normal exam, normal lab tests, normal ECG plus adequate home supervision and close follow up care
• Admit those presenting with syncope for cardiac monitoring

EDUCATION/PREVENTION
• Regulations requiring safety switches on power and lighting circuits
• Keep extension cords in good repair
• Cover unused outlets with dummy plugs
• Keep electrical appliances away from sinks and bathtubs
• Supervise electrically operated toys

TIPS
• Amount of skin injury is not a reliable predictor of overall severity of injury
• Beware of other injuries particularly fractures caused by immense muscle spasm
• All victims of electrical burns must be evaluated

LIGHTNING INJURY
Description
• Lightning produces a massive voltage of extremely short duration
  - Deep thermal injury is unusual
Clinical presentation
• Usually obvious clinical presentation due to patient or witnesses reporting a lightning strike
  - See ELECTRICAL BURNS
• Consider lightning strike in unwitnessed falls, cardiac arrests, or unexplained coma in the outdoor setting
• Feathering (Lichtenberg figures)
  - Pathognomonic of lightning injury
  - Cutaneous imprints form electron showers that track over the skin
  - Resolve within 24 hours
Types of lightning injuries
• Direct strike
  - Most serious form of injury and occurs when carrying or wearing metal objects
• Contact injury when lightning strikes object victim is touching
• Side flash or splash when victim near an object that is struck
• Ground current
  - Lightning strikes ground close to victim, travels through body from one foot to the other
• Thermal flash
• Blast injury: assess for concomitant shrapnel injuries\textsuperscript{21}
  - Shock wave from lightning channel can cause tympanic membrane perforation or blunt trauma from the victim being thrown
• Upward streamer
  - Weak streamer that does not become completed lightning channel
Complications
• High incidence of death or morbidity
  - 30 percent mortality
  - 75 percent of survivors have permanent sequela
  - See TYPES OF ELECTRICAL INJURY

TYPES OF ELECTRICAL INJURY
TYPE
Lightning
High Voltage
Low voltage

DURATION
1/1000 sec
Brief
Prolonged
ENERGY
100,000,000 volts
> 1,000 volts
< 1,000 volts
TYPE
DC
DC or AC
Mostly AC
SHOCK WAVE
Present
Absent
Absent
CARDIAC
Asystole
V Fibrillation
\textit{Atrial or Ventricular} Fibrillation\textsuperscript{14}

BURNS
Superficial & minor
Deep & severe
Superficial
RHABDOMYOLYSIS
Rare
Very common
Common
FASCIOTOMY
Rare
Extensive
Rare
MORTALITY
Very high
Moderate
Low

REFERENCES
Topic supported by DynaMed Systematic Literature Surveillance

SEE ALSO
- See CENTRAL VASCULAR ACCESS
- See ELECTRICAL BURNS
- See HAND INJURIES
- See PERIPHERAL VASCULAR ACCESS
- See RESUS: ASYSTOLE
- See RESUSCITATION DRUGS
- See RHABDOMYOLYSIS

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