Electrical current injuries, drowning, hanging injuries

Electrical current injuries

- Mostly in young men at work, small children
- Deaths in low voltage >high voltage
- Burns unit admissions 3-5%
- 1/3 intentional

Mechanism of injuries

- *Direct effect* of electrical current on body tissues
- *Conversion of electrical energy to thermal energy*, resulting in deep and superficial burns
- *Blunt mechanical injury* from lightning strike, muscle contraction, or as a complication of a fall after electrocution
- the primary determinant of injury is the amount of current flowing through the body
- the tissue damage inflicted by most electrical currents can be primarily attributed to the thermal energy (or heat) generated by the current, as predicted by Joule's law: Heat = current (I) x voltage (V) x time of contact (t)

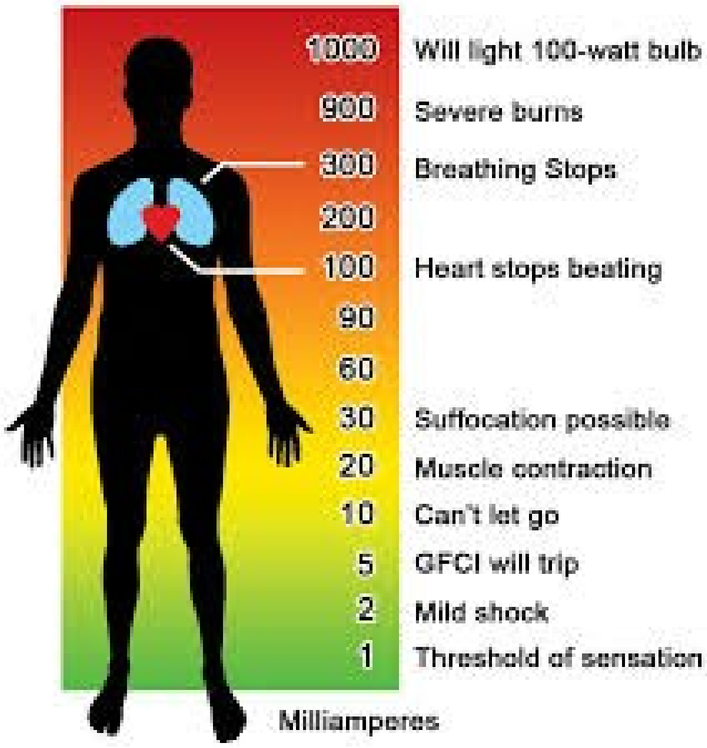
Extent of damage

- Voltage
- Current
- Resistance of tissues
- Duration of contact
- Type of current (AC/DC)
- Path of current flow
- $I = V/R$ (Ohm´s law)

- Resistance- function of the area of contact, pressure applied, and the presence of moisture. Tissues with higher resistance have a tendency to heat up and coagulate, rather than transmit current. high resistances: skin, bone, and fat, lower resistances : nerves, blood vessels
- **Skin:** greatest effect on the severity of an electrical injury- dry skin has a resistance of approximately 100,000 ohms; less than 2500 ohms when the skin is dampened -> lower voltage applied to tissue with low resistance can generate more current and be more damaging than higher voltage applied to tissue with high resistance
- The amount of AC needed to cause injury varies in proportion to its frequency, expressed in cycles per second or hertz (Hz). Skeletal muscle can become tetanic with frequencies between 15 and 150 Hz, and although a 20 mA current may not be perceptible at 10 Hz, the same current may cause respiratory paralysis or ventricular fibrillation at lower frequencies

Effect of AC

-repetitively stimulates muscle contraction



mA	Effect on Human Body
0.5 - 3	Tingling sensations
3 - 10	Muscle contractions and pain
10 - 40	"Let-go" threshold
30 - 75	Respiratory paralysis
100 - 200	Ventricular fibrillation
200 - 500	Heart clamps tight
1500 +	Tissue and Organs start to burn

Shown at (60 hz AC) – Effect will vary with frequency and duration of exposure

DC current

- tends to cause a single muscle spasm that throws the victim from the source -> shorter duration of exposure, but a higher likelihood of associated trauma.
- Often, the site of exposure is at the hand, and because the flexors of the arm are stronger than the extensors, the victim may actually grasp the source, prolonging the duration of contact and perpetuating tissue injury

The ´let go current´

- The amperage at which the human body is able to withdraw from an electrical stimulus
- Once surpassed: tetany, respiratory failure, VF,
- More readily in higher current, alternating current

Lightning strikes

- Undirectional, instanteous current
- Up to 30% die- 2/3 within 1 hour (arrythmia/ respiratory failure)
- ¾ of survivors have permanent disability
- Injuries different from electrical injuries- different management

Classification of injury

- high voltage (>1000 V) or low voltage (<1000 V)
- Voltage in high-tension power lines is greater than 100,000 V, while the typical voltage delivered to homes is 220 V
- lightning strikes -potential difference between the atmosphere and the ground in excess of 10 million volts
- four classes of electrical injury:
- ●The classic injury pattern develops when the body becomes part of a circuit, usually associated with entrance and exit wounds, which generally do not help predict the path of the current, and the skin findings can significantly **underestimate** the degree of internal thermal injury
- ●Flash (or arc) burns- current arc strikes the skin, but does not enter the body
- ●Flame injuries from clothing catching fire in the presence of an electrical source
- ●Lightning injury is caused by a DC current exposure that lasts from 1/10 to 1/1000 of a second, but often has voltages that exceed 10 million V . Peak temperature within a bolt of lightning rises within milliseconds to 30,000 Kelvin (five times hotter than the sun), generating a shock wave of up to 20 atmospheres induced by the rapid heating of the surrounding air. This shock wave then can be transmitted through the body and result in mechanical trauma.
- Because of the variability of tissue resistance, surface area, and volume of tissue exposed, it is extremely difficult to predict the actual course of current flow and to infer the type and extent of injuries to internal organs

Organ involvement I.

- **Cardiac** — arrhythmia (15%); mostly benign, within the first few hours of hospital admission, cardiac arrest due to asystole (usually with DC current or lightning) or ventricular fibrillation (AC current) prior to hospitalization
- Ventricular fibrillation- most common fatal arrhythmia- in up to 60 percent of patients in whom the electrical current pathway travels from one hand to the other
- Spontaneous return of SR has been noted after asystole, but because respiratory paralysis lasts longer, the rhythm may degenerate to VF due to hypoxia
- Damage to the myocardium is uncommon, but can occur as a result of heat injury or myocardial contusion resulting from the shock wave of a lightning strike
- Cardiac contusion- most common, myocardial infarction is rare
- **Renal** — rhabdomyolysis resulting from massive tissue necrosis and can be complicated by pigment-induced acute kidney injury
- hypovolemia due to extravascular extravasation of fluid can lead to prerenal azotemia and acute tubular necrosis

Organ involvement II.

Neurologic — loss of consciousness, weakness or paralysis, respiratory depression, autonomic dysfunction, and memory disturbances, sensory and motor findings

- manifestations of neurologic damage from high-voltage exposures may be delayed for days to months after the injury
- Keraunoparalysis - temporary paralysis specific to lightning injuries - blue, mottled, and pulseless extremities (lower more commonly than upper)
- Lightning injuries- patients may present with pupils that are fixed and dilated or asymmetric due to autonomic dysfunction- fixed, dilated, or asymmetric pupils should **not** be used as a reason to stop resuscitation!!!
- Complications of lightning strikes: hypoxic encephalopathy, intracerebral hemorrhage, cerebral infarction, cataracts, hyphema, vitreous hemorrhage, and optic nerve injury

Skin — Superficial, partial-thickness, and full-thickness thermal burns can

- 57 % of low-voltage and 96 % of high-voltage victims had visible electrical burns
- Burns are most common at the site of electrical contact and at places in contact with the ground at the time of injury.
- Degree of external injury **cannot** be used to determine the extent of internal damage, especially with low-voltage injuries
- Seemingly minor surface burns may coexist with massive muscle coagulation and necrosis, as well as internal organ injury
- Patients with cranial burns or leg burns from lightning are at higher risk for death than others struck by lightning, possibly because more current has passed directly through the body
- "kissing burn„- at flexor creases, where the flexor surfaces adjacent to a joint touch
- Incidence of superficial surface burns is high in victims of lightning injury, but deep burns are unusual- short duration of contact and the "flashover effect„- the current travels on the skin surface and is discharged to the ground -> formation of branching cutaneous "feather" lesions (Lichtenberg figures)

Organ involvement III.

Musculoskeletal — bone- highest resistance -> generates the greatest amount of heat when exposed to an electrical current -> areas of greatest thermal injury are often the deep tissue surrounding long bones, potentially resulting in periosteal burns, destruction of bone matrix, and osteonecrosis

- fractures from falls, blast injuries, under the stress of repetitive tetanic muscle contractions (need of imaging studies of the cervical spine)
- tissue necrosis, edema, acute compartment syndrome, leading to rhabdomyolysis

Vascular, coagulation system, other injuries — from acute compartment syndrome/ electrical coagulation of small blood vessels.

- Delayed arterial thrombosis, aneurysm formation and rupture due to medial coagulation and necrosis
- Damage to internal organsis uncommon

Physical examination

- Airway, breathing, circulation
- Cardiovascular function: cardiac rhythm; pulses
- Skin: burns; blisters, charred skin, and other lesions; pay attention to skin creases, areas around joints, and the mouth (particularly in young children)
- Neurologic function: mental status, pupillary function, strength and motor function, sensation
- Ophthalmologic: visual acuity; inspect the eyes, including a funduscopic examination
- Ear, nose, and throat: tympanic membranes; hearing
- Musculoskeletal: inspect and palpate for signs of injury (eg, fracture, acute compartment syndrome), examine the spine

Management

- **Cardiopulmonary resuscitation** — prolonged CPR regardless of the initial rhythm (most victims are young, good outcomes even among patients with asystole)
- Patients can have spontaneous cardiac activity but paralysis of the respiratory muscles -> prompt restoration of gas exchange via secure airway (prevention of secondary cardiac and neurologic dysfunction)
- Lightning injury may cause fixed and dilated pupils- may not accurately reflect the patient's neurologic status
- **Trauma resuscitation and neurologic evaluation** — smoke inhalation or airway burns must be excluded, cervical spine immobilization and clearance, tetanus prophylaxis
- Coma or neurologic deficit- prompt brain and spine imaging
- careful secondary survey once the initial resuscitation is complete.
- **Cardiac injury** —ECG, cardiac and hemodynamic monitoring
- Serum CK-MB measurements and ECG changes are poor measures of myocardial injury following electrical trauma

Management II.

- **Fluid resuscitation** — aggressive IV fluid replacement, especially if there are signs of muscle necrosis; those with lightning injuries typically require less volume than patients with thermal burns
- approach to fluid resuscitation is similar to that used for the prevention of acute kidney injury from heme pigments (ie, myoglobinuria)
- Fluid resuscitation for patients with severe soft tissue injuries comparable to that used for major crush injuries. Given the risk of hyperkalemia, IV fluids containing potassium should be avoided
- Acute hypotension should prompt a search for thoracic or intraabdominal bleeding secondary to blunt traum
- Large fluid shifts can occur following electrical injury, and clinicians should pay close attention to volume status and electrolytes throughout the course of management
- heart rate, blood pressure, urine output central venous pressure monitoring- in patients with more severe injuries
- Urine output in adults over 100 mL per hour; serum electrolyte concentrations- every two to four hours early during management
- The combination of aggressive fluid repletion and restrictive surface burns can lead to the development of increased intraabdominal pressure and the abdominal compartment syndrome
- Cerebral salt wasting - complication of lightning-related electrical injuries
- **Myoglobinuria** — acute compartment syndrome, rhabdomyolysis, acute kidney injury- to maintain adequate urine output to minimize intratubular cast formation until pigment has cleared from the urine
- **Skin wounds** — treated in a similar manner to flame or other thermal burns
- Patients with burns may require transfer **to a** burn unit and treatment with fasciotomy, escharotomy, extensive skin reconstruction, or limb amputation, topical antibiotic prophylaxis is indicated for non-superficial burns.
- greater chance of developing gastric ulcers following electrical burns (Curlings ulcers)

Disposition

- Severely injured patients are admitted to an intensive care setting
- Patients with significant electrical burns should be transferred to a burn center when stable
- When exposure to high-voltage (>1000 V) is suspected, 12 to 24 hours of cardiac monitoring is prudent despite the apparent absence of injury. Additional indications for monitoring - history of cardiac disease, active chest pain, documented loss of consciousness or arrhythmia in a patient exposed to lower-voltage
- Asymptomatic patients after a low-voltage exposure with a normal physical examination do not require ancillary diagnostic tests and can be reassured and discharged
- Patients with mild persistent symptoms or minor cutaneous burns and a normal ECG and urinalysis (no hemoglobinuria) can be observed for a few hours and discharged with appropriate follow-up based upon the severity of their wounds and any comorbidities
- Obstetric consultation for pregnant-placental abruption may be associated