ELECTRICAL INJURIES

DIVIDED INTO:

1. **HIGH-VOLTAGE INJURIES (> 1000V)**
2. **LOW-VOLTAGE INJURIES (< 1000V)**
3. **ELECTRIC ARC FLASH BURNS**
    - **BY DEFINITION DO NOT RESULT IN PASSAGE OF CURRENT THROUGH THE TISSUES**

BURNS FROM ELECTRICAL ACCIDENTS CAN RESULT FROM HEATING DUE TO ELECTRICAL CURRENT FLOW THROUGH TISSUES, EXPLOSIONS AND BURNING OF FLAMMABLE LIQUIDS

EPIDEMIOLOGY:

- Actual incidence is unknown
- Most common high-voltage injuries occur in electricians and high-voltage injuries in linesman
- High-voltage line injuries are particularly disabling because they often lead to DEEP MUSCLE NECROSIS AND THE NEED FOR FASCIOTOMY AND AMPUTATION

BASICS OF CURRENT FLOW:

Table 212-1 Electrical Terms and Units of Measure

Term	Unit of Measure
Electric current	Amperes
Movement of electrical charges	
Current flow	Volts
Is driven by voltage or electrical potential difference	
Resistance	Ohms
Hindrance to flow of current	
Ohm's law (current = voltage/resistance)	—
The current is proportional to voltage.	
The current is inversely proportional to resistance.	

- Tissues with high fluid and electrolyte content conduct electricity better than tissues with less fluid and electrolyte content
    - Bone is the biologic tissue with the greatest resistance to electric current.

- Wet or sweating skin has much less resistance to current flow than dry skin

Many of the physiologic effects of shock are related to AMOUNT, DURATION AND TYPE OF CURRENT (ie. AC VS DC)

- AC can be more dangerous at lower voltages of DC as it can result in VF

For current to flow through an individual, a complete circuit must be created from one terminal of a voltage source to a contact area on the body, through the subject and then form another contact

- Eg. electric power source contacts just on the left hand and left leg would result in current flow through those limbs and the trunk (including the heart, muscles of respiration and other tissues in the trunk)

Table 212-2 Effects of Current

Effect	Current Path	Minimum Current: 60 Hz AC (milliamperes*)
Tingling sensation, minimal perception	Through intact skin	0.5–2.0
Pain threshold	Through intact skin	1–4
Inability to let go: tetanic contractions of hand and forearm tighten grasp, decreasing skin resistance	From hand through forearm muscles into trunk	6–22
Respiratory arrest: can be fatal if prolonged	Through chest	18–30
Ventricular fibrillation	Through chest	70–4000
Ventricular standstill (asystole): similar to defibrillation; if current stops, sinus rhythm may resume	Through chest	>2000

MECHANISMS OF ELECTRICAL INJURY:

HIGH AND LOW VOLTAGE INJURIES:

- The risk for serious and fatal electrical injury increases with voltage, especially >600V --> High voltage is usually defined as >1000V
- Residential power in Australia is 240V
- High-voltage injuries are more often associated with;
    - *severe musculoskeletal, visceral and nervous system injury*
- Electricity-induced injuries occur by several mechanisms:
    - Direct tissue damage from the electrical energy
    - Tissue damage from thermal energy
    - Mechanical injury from a fall or muscle contraction

ELECTRICAL BURNS:

- Severe when high voltages are involved --> only a fraction of a second of current flow is necessary for severe damage to occur.
- Burns less common with low-voltage injuries

ELECTRIC ARC INJURIES:

- Electricity arcing from one conductor to another may radiate enough heat to burn and even kill persons ≥3m from the arc
- There can also be a BLAST FORCE
- Serious burns often result

TETANIC CONTRACTIONS:

- Electric current can induce SUSTAINED MUSCULAR CONTRACTION OR TETANY
    - Varies according to AC/DC, frequency, voltage and extent of contact
- Forceful muscle contractions can cause FRACTURES AND JOINT DISLOCATIONS, ESP. AROUND THE SHOULDERS (consider if posterior)
- If the hand and fingers are properly positioned, the hand will grasp the conductor tightly, which leads to a prolonged, low-resistance contact.
- The increased duration of contact and decreased contact resistance caused by a tight, sustained grasp greatly *increase the heat-related damage* to deep tissues

CLINICAL FEATURES:

IMMEDIATE EFFECTS:

- Electric current can induce immediate cardiac arrhythmia, respiratory arrest and seizures
- Current that traverses the chest vertically or horizontally can produce dysrhythmia and respiratory arrest.

CARDIAC ARRHYTHMIA:

- Fatalities due to asystole & VF usually occur prior to arrival in ED
- *Asymptomatic patients with normal ECG on arrival to hospital do not develop later arrhythmia after LOW VOLTAGE INJURIES.*
- However, nerve and deep muscle injury is relatively common following contact with voltages over 400V.
    - Such patients need careful CNS/PNS exam and check serum CK.

CENTRAL AND PERIPHERAL NERVOUS SYSTEM INJURY:

- Usually from HIGH VOLTAGE CONTACT
- Neurological impairment occurs in 50% of high-voltage injuries

- BRAIN INJURY:
    - Transient LOC + agitation, confusion, coma, seizures, quadriplegia, aphasia and hemiplegia
    - Head CT

- SPINAL CORD INJURY:
    - Can result from vertebral fractures usu present on initial evaluation
    - With purely electrical trauma spinal cord MRI DOES NOT correlate with prognosis
        - However, in those with spinal cord impairment in whom initial spinal MRI findings are normal, complete resolution of dysfunction will occur
    - Mortality of up to 10% has been reported with death sometimes related to extension of cord dysfunction in the brainstem

- PERIPHERAL NERVE INJURY:
    - Paraesthesia may be immediate & transient or delayed for up to 2 years post injury
    - Extensive peripheral nerve damage may occur with minimal thermal injury
    - Nerve damage can occur despite normal nerve conduction studies

CUTANEOUS BURNS FORM HIGH VOLTAGE CONTACT:

- Often seen at the electrical contact areas - referred to as entry & exit wounds
- Many seriously injured patients have burns on either arm or skull, paired with burns on the feet
- These burns are typically painless, grey to yellow depressed areas
- Most need admission for management.

ORTHOPAEDIC INJURY:

- Fractures may be caused by titanic muscle contractions or associated falls and are easily missed on initial assessment
- All joints should be put through a full, active range of motion if possible and otherwise passive range of motion --> if such movement is not possible, radiographic study is indicated.

COMPARTMENT SYNDROME:

- Patients with high-voltage shocks are AT HIGH RISK FOR DEVELOPMENT OF COMPARTMENT SYNDROME, EVEN IF CONTACT LASTED <1 SEC
    - Has been reported in lower voltage (120V AC) if contact is more prolonged
    - Patients typically exhibit ongoing muscle pain with movement

VASCULAR AND MUSCLE INJURY:

- Occur most commonly in the setting of high-voltage injury
- Electric current passing along peripheral arteries;
    - early spasm & delayed thrombosis or aneurysm formation
- Extensive vascular injury may produce a muscle compartment syndrome or rhabdomyolysis
- Contact with >1000V:
    - Prehospital cardiac arrest, crush injury, compartment syndrome and full-thickness burns are ALL ASSOCIATED WITH SIGNIFICANT TISSUE INJURY AND MYOGLOBINURIA
    - Also associated with rapid fluid loss into tissues

COAGULATION DISORDERS:

- Low grade-DIC may result due to hypoxia, vascular stasis, rhabdomyolysis or due to release of procoagulants form damaged tissue

BLAST INJURY:

- Electric arcs from high-voltage lines can produce a strong blast pressure, similar to those seen in other types of explosions.
- Beware arterial air emboli, associated with blast-related alveolar disruption

INHALATION INJURY:

- Chemical toxins such as ozone can be produced by arcs and coronas
    - mucous membrane irritation, reduced pulmonary function (temporary), pulmonary haemorrhage and oedema
- Fires and explosions associated with electrical incidents
    - carbon monoxide and other toxic substances

OCULAR INJURY:

- Cataract formation has been described weeks to years after electrical injury
    - Document absence of cataracts following electrical injury to head, neck or upper chest
- Other injuries include retinal detachment, corneal burns, intraocular haemorrhage/thrombosis

AUDITORY INJURY:

- Auditory system may be damaged by current or by haemorrhage in the TM/ middle ear, cochlea, vestibular apparatus
- Delayed complications include mastoiditis, sinus thrombosis, meningitis, brain abscess

GI INJURY:

- Pain due to BOWEL PERFORATION AND INTRAABDOMINAL HAEMORRHAGE may be attributed to more obvious coexisting injuries

TREATMENT

Table 212-3 Scene and Prehospital Care
Stay at least 10 m (32 ft) from downed power lines, jumping power lines, and support structures. This is not completely safe.
Turn off the source of electricity prior to rescue, if possible.
If electrical source cannot be quickly turned off, take precautions to prevent electrical injury to the rescuer.
Wear gloves and shoes rated for the power line voltage.
Initiate rescue breathing and resuscitation efforts while injured person is still on pole, if no contact with source of electricity is assured.
Maintain spinal immobilization of injured person, if possible.

ED DIAGNOSIS AND TREATMENT:

- Usual evaluation (airway, breathing and circulation and resuscitation for major trauma victims should be provided)
- Cardiac arrhythmias can be TREATED ACCORDING TO ACCEPTED ALGORITHMS
    - Cardiac complications are more common after high-voltage injuries and THOSE WITH LOSS OF CONSCIOUSNESS
    - Ventricular and atrial arrhythmia, bradyarrhythmia and QT prolongation
- Admission for cardiac monitoring is not needed for asymptomatic patients with normal ECG on presentation after a low-voltage electrical injury.

Table 212-4 Assessment and Treatment of Complications Associated with Electrical Injuries	
Organ or System	**Assessment/Treatment/Comments**
Circulatory	Start with Parkland fluid resuscitation formula.*
Renal	Initiate fluid resuscitation.
Myoglobinuria	Consider bicarbonate, mannitol.†
Central and peripheral nervous	Order head CT if mental status is abnormal; assess for spinal cord and peripheral nerve injury.
Skin	Assess and treat cutaneous burns.*
Musculoskeletal	Perform careful assessment of spine, pelvis, long bones, and joints.
	Assess for compartment syndrome and need for fasciotomy.
Vascular	Spasm may occur leading to delayed thrombosis, aneurysm formation, or muscle damage.
Coagulation	Treat coagulation disorders by eliminating the precipitating factor through early surgical debridement.
	If bleeding is present, replace coagulation factors.‡
Lungs	Assess for inhalation injury, carbon monoxide, alveolar injury from blast.
Eyes	Document complete eye examination.
	Delayed cataracts may develop.
Ears	Assess for blast injury.
	Document hearing.
	Middle and inner ear disorders and hearing loss may occur.
GI	Intra-abdominal injury may occur from current or blast.
Lips and oral cavity	Watch for delayed bleeding.

- Examination should assess tissue damage and associated complications
- Careful vascular & neurologic examination of involved extremities
    - Normal findings on initial assessment do not preclude serious injury following high-voltage injury
- In the case of low-voltage injuries, lab testing and imaging are usually not required unless the patient has physical exam findings suggesting a need for them or signs or symptoms such as chest pain, palpitations, LOC, altered mental status, confusion, weakness, abdominal pain, SOB, burn with subcutaneous damage, vascular compromise or ECG changes
- CKMB elevation in face of electrical burn more correlates with skeletal muscle injury than cardiac.

FLUID RESUSCITATION:

- Guided by the Parkland formula --> only a rough starting point as fluid requirements are often greater than predicted by the Parkland formula due to extensive deep tissue damage

MYOGLOBINURIA:

- Patients should be monitored for the onset of compartment syndrome, rhabdomyolysis and renal failure
    - if suspected, aggressive fluid resuscitation to maintain a urinary output of between 1-2mL/kg/hour
    - Correct and prevention of electrolyte abnormalities
    - Monitor serum (NOT URINARY) pH
- Prognostic factors associated with need for fasciotomy within 24 hours:
    - Myoglobinuria
    - Burns over 20% of BSA
    - Full thickness burn over 12% BSA

Any one of these three factors predictive of need for fasciotomy

GI INJURY:

- Should be suspected in those with history of electrical burns to the abdominal wall

Table 212-5 GI Injury

Suspect GI injury with
Electrical burns of the abdominal wall
History of a fall, nearby explosion, or other mechanical trauma
Workup
US and CT
Surgical consult as indicated
Treatment
Ileus: nasogastric tube insertion
Stress (Curling) ulcer prophylaxis: histamine-2 blockers, antacids, proton pump inhibitors
Monitoring for development of ileus, bowel perforation, hemorrhage, and other delayed complications
Surgical management as appropriate

DISPOSITION AND FOLLOW UP:

- LOW VOLTAGE INJURIES (<600V):
    - In general, asymptomatic patients who sustain an electric shock of ≤240V AC can be discharged home if they have a normal ECG on presentation and normal examination findings.
    - Patients who feel unwell or have any NEW ECG CHANGES
        - Monitored for six hours
- HIGH VOLTAGE INJURIES:
    - All patients having contact with ≥600V AC should be admitted for observation, even if there is no apparent injury
    - Routine cardiac monitoring unless the patient is symptomatic or the initial ECG findings are abnormal

SPECIAL CIRCUMSTANCES:

INJURY DUE TO ELECTRICAL CONTROL DEVICES (E.G. TASER):

MECHANISM OF INJURY:

- TASER produces a high voltage, low-amperage electrical pulses, typically at approximately 10 per second The pulses are designed to induce involuntary muscle contraction, neuromuscular incapacitation and pain
- The likelihood of electrical injury is minimal
- Falls can lead to orthopaedic injuries

CLINICAL FEATURES:

- Most injuries are limited to superficial punctures and minor laceration and cutaneous burns
- Reported significant injuries:
    - Eye perforation, Testicular torsion, PTX or Blunt trauma from the fall
- Burns may occur if used in flammable environments
- MAJORITY OF DEATHS HAVE OCCURRED IN PERSONS WHO WERE ILL AND AGITATED DUE TO PSYCHOSIS, STIMULANT DRUGS OR OTHER CONDITIONS
    - These patients have *an excited delirium syndrome*
- Unanticipated deaths occur in persons showing initial agitation who calm down, become quiet and then develop respiratory arrest followed by cardiac arrest
    - Most common in those with stimulant drug abuse
    - Seek out; hyperthermia, hyperkalaemia, metabolic acidosis, respiratory acidosis (exhaustion), rhabdomyolysis

TREATMENT AND DISPOSITION:

- HT may resolve with sedation
- Patients who DO NOT APPEAR TO BE WELL --> examine for problems outlined above
- 12 lead ECG is indicated not for rhythm anomalies but rather for rapid detection of metabolic disturbances
- CRITERIA FOR DISCHARGE IN THOSE WHO ARE NOT SEVERELY AGITATED:
    - Those who have calmed down, have no LOC, significant cardiac disease and appear well
    - Do not require ECG or other testing
- CRITERIA FOR DISCHARGE IN THOSE WHO HAVE BEEN SEVERELY AGITATED:
    - No abnormalities on ECG, temperature, electrolytes, ABG, CK
    - Patient has calmed down and appears well on exam

SPECIAL POPULATIONS:

PREGNANT PATIENTS:

- After viability; CTG monitoring for at least four hours, due to possibility of mechanical trauma related to electrical shock

CHILDREN:

- ORAL AND LIP BURNS:
    - Serious oral injury can occur in a child who places the end of a power cord in the mouth

- Most injuries are unilateral and involved lateral commissure, tongue and/or alveolar ridge
- Systemic complications of oral burns are uncommon
- Vascular injury to the LABIAL ARTERY is not immediately apparent because of VASCULAR SPASM, THROMBOSIS & OVERLYING ESCHAR
    - Severe bleeding from the labial artery occurs in 10% cases when the eschar separates, usually after ~5 days
    - Parents need to be told that bleeding may occur up to 2 weeks post injury
    - Home care includes saline or peroxide rinses and gentle swabbing to debride necrotic tissue
    - Specialist consultation to prevent residual dysfunction and deformity