



IN THE NAME OF
GOD



ELECTRICAL INJURY

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Question 1:

- **A 13-year-old girl who was struck by lightning while playing soccer is brought in by EMS...**

The girl was playing soccer in an open field when a thunderstorm started. While trying to take shelter, lightning struck a tree approximately 2 feet away, and she was thrown several feet. An adult observed that she was unresponsive, so he called 911 and initiated CPR. When EMS arrived, an AED was placed and a shock was delivered, with subsequent return of spontaneous circulation. The patient was prepped for transport with a C-collar in place. During transport, her cardiac rhythm was sinus tachycardia, with a palpable pulse, and bag-valve mask ventilation was initiated for no spontaneous respirations

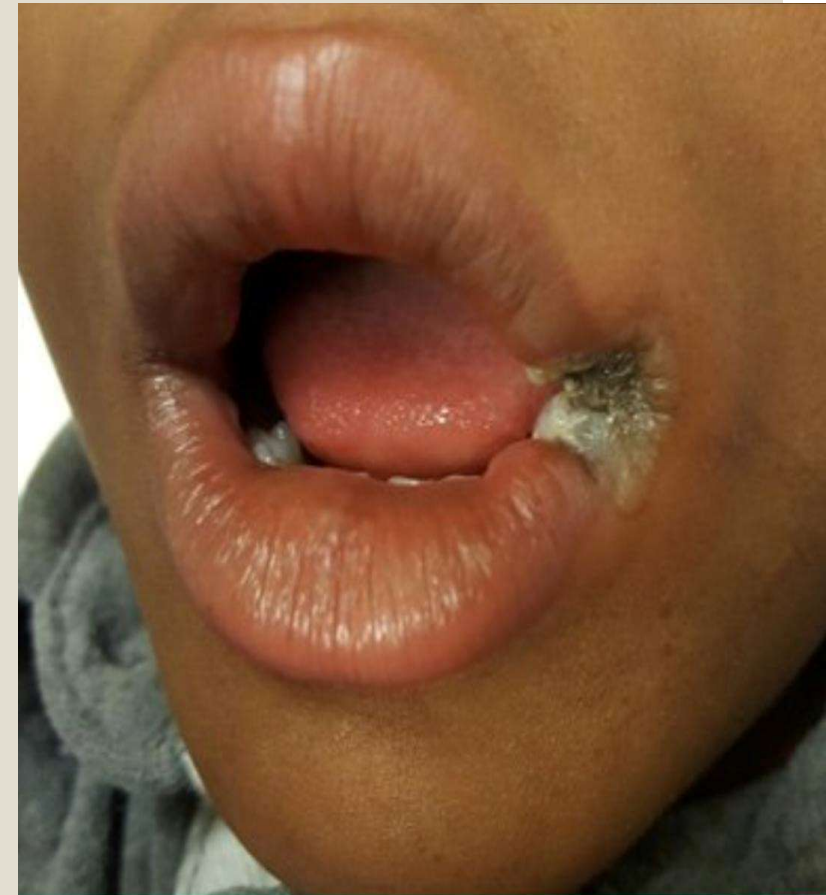
Question 1:

- Upon arrival to the ED, the girl is unresponsive. She has an intact airway but no spontaneous respirations. She has symmetric, clear breath sounds with bag-valve mask ventilation. Cardiac rhythm is sinus tachycardia with a palpable pulse, and her blood pressure is 130/90 mm Hg. She has a GCS score of 3. Her pupils are 4- to 5-mm and nonreactive. She has a Lichtenberg figure across her rib cage, an erythematous irregular patch on the dorsum of her right foot, and there is bloody drainage from her left ear.
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- **How should you evaluate and manage this patient in the ED?**



Question 2:

- **An 18-month-old boy is brought in by his parents after he was found chewing on an electric cord...**
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- The boy is well appearing, with age-appropriate vital signs. He is noted to have grayish-white tissue on the right oral commissure, without bleeding. His dentition and tongue are intact, he has no trouble handling his secretions, and he is able to drink without problem.
- What complication of this injury should you consider? What is the appropriate disposition for this patient? How should you advise the parents?



Epidemiology:

- Electrical burns and lightning injuries result in more than 3,000 admissions to specialized burn units each year in the United States, and they account for 3 to 4 percent of all burn-related injuries
- There is a **bimodal distribution** of environmental electrical injuries with respect to age. The incidence of electrical injuries decreases through the teenage years and increases again as adults enter the workplace
- More than 90 percent of victims are **male**
- **In children, accidental electrical injuries** are twice more common in males compared with females.

Type of electricity exposure:

Low voltage:

<1000V – usually from domestic power supply (UK domestic 230V, workshops 380V).

Alternating Current (AC) - causes **tetany**, patient “locked on” to source, increasing energy delivered to the body

Cutaneous burns from contact points

Less likely to cause deep tissue injury

Cardiac arrhythmias with immediate cardiac arrest possible

High voltage

>1000V - Overhead power lines (380000V) / Railway lines (15-250000V) / Lightning strike (10 to 100 millionV).

Direct Current (DC) - causes single muscle contraction, throwing patient from source increasing risk of trauma.

Risk of significant **deep tissue injury** despite comparatively small cutaneous burn

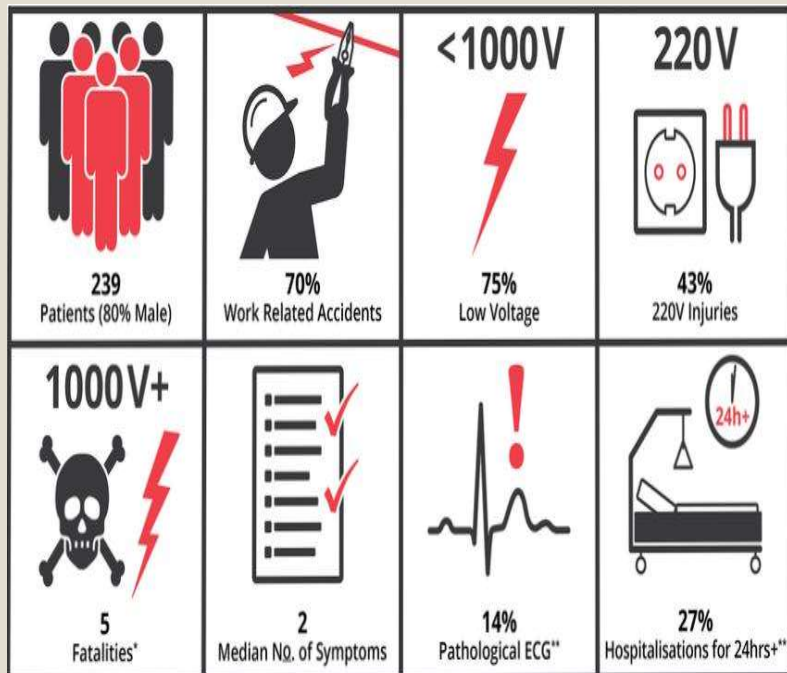
Direct contact with source causes entrance/exit injuries and risk of significant injury.

Full thickness cutaneous burns, rhabdomyolysis, compartment syndrome, periosteal burns, osteonecrosis, myocardial damage and dysrhythmia.

Can often be associated with **trauma** following falls or being thrown by the electrical discharge.

Lightning

Type of electricity exposure:



	Lightning	High voltage	Low voltage
Voltage, V	> 30 x 10 ⁶	> 1,000	< 600
Current, A	> 200,000	< 1,000	< 240
Duration	Instantaneous	Brief	Prolonged
Type of current	DC	DC or AC	Mostly AC
Cardiac arrest	Asystole	Ventricular fibrillation	Ventricular fibrillation
Respiratory arrest	Direct injury	CNS Indirect trauma or tetanic contraction of respiratory muscles	Tetanic contractions of respiratory muscles
Muscles contraction	Single	Single (DC); Tetanic (AC)	Tetanic
Burns	Rare, superficial	Common, deep	Usually superficial
Rhabdomyolysis	Uncommon	Very common	Common
Blunt injury (cause)	Blast effect (shock wave)	Fall (muscle contraction)	Fall (uncommon)
Acute mortality	Very high	Moderate	Low

General mechanisms of electrical injury:

- Direct effect of electrical current on body tissues
- Conversion of electrical energy to thermal energy
- Creations of pores in cell membranes
- Secondary mechanical trauma

Mechanisms of injury specific to lightning:

Lightning transmission methods:

- ● Direct strike
- ● Contact strike
- ● Side-flash or splash
- ● Ground strike

Unique phenomena with lightning:

- Flashover effect
- Keraunoparalysis
- Autonomic dysfunction
- Secondary trauma from shock wave



Injury and clinical features by organ system:

Cardiac:

- Dysrhythmias
- Conduction disturbances
- Myocardial damage

Neurologic:

- Respiratory arrest
- Peripheral nerve injury
- Other common sequelae

Injury and clinical features by organ system:

Eye and ear:

- The blast effect from lightning strikes causes ruptured tympanic membranes in 50 to 80 percent of patients
- Sensorineural hearing loss, tinnitus, vertigo
- Cataracts, hyphema, vitreous hemorrhage, optic nerve injury

Skin:

- Kissing burns
- Oral burns
- Flame burns
- Lichtenberg figures



Injury and clinical features by organ system:

Musculoskeletal and renal:

- Bones and nearby tissue injury
- Compartment syndrome and rhabdomyolysis
- Secondary trauma
- Acute kidney injury

Vascular and related injuries:

- Vascular and thrombotic injury
- Gastrointestinal injury

Prehospital Considerations:

- In a mass-casualty electrocution event the general principles of prehospital triage should be **reversed**: Electrocution victims who do not suffer immediate cardiac or respiratory arrest will likely survive without intervention
- Cardiac dysrhythmia or respiratory arrest, which are usually reversible
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- First responders should evaluate the **safety** of any disaster scene for electrical hazards and not proceed until the scene is safe
- After a lightning strike, prehospital providers should be advised to **leave the scene as soon as possible** and continue resuscitation and stabilizing efforts en route to the hospital

Initial Clinical Assessment in ED

1. Electricity source?
2. Assess voltage – low or high?
3. Contact points and length of contact?
4. Patient thrown from source?
5. LOC? – increase suspicion of head injury or cardiac arrhythmia

Assess Voltage

Low < 1000 v

- * UK household 240v
- * Workshops 380v

High >1000 v

- * Overhead lines 1500v
- * Railway lines 25,000 v
- * Lightning strike 10-200 million v

Low voltage

- ABCDE approach
- All patients require:
 1. 12 lead ECG
 2. Urinalysis
- Patients can be fit for discharge

12 lead ECG:

IF ABNORMAL

- **manage as per high voltage guideline**
- Admit for cardiac monitoring
- Bloods to include troponin and bedside ECHO by cardiology

Urinalysis:

- If myoglobin or blood present requires baseline bloods

Discharge criteria:

- Discuss with senior decision maker
- Absence of syncope
- Normal 12 lead ECG
- No secondary injuries requiring further management
- Safe environment for discharge

High voltage

- APLS approach
- Contact on-call SpR or Consultant for Plastic Surgery to attend
- Trauma call with PEM Consultant and PICU present
- Patient Weight
- Assess for:
 - Cutaneous burns
 - Head injury
 - Dislocation / fracture
 - Compartment syndrome
 - Cardiac injury
 - Spinal cord / peripheral nerve injury
 - Periosteal burns
 - Renal injury

All patients will be admitted to critical care for a minimum of 24 hours

Management:

- FBC, U+Es, bone profile, Mg, amylase, CK, troponin, myoglobin
- 12 lead ECG
- Bedside ECHO by cardiology if ECG abnormality
- IV fluids to aim urine output 1-1.5 mls / kg / hour
- Urinary catheterization
- Monitoring for signs of compartment syndrome

Special considerations:

- **Temperature management;** low threshold for active temperature management above 39 degrees
- **Imaging;** low threshold for multiregional scans due to high risk of trauma
- **Burn Surface Area;** caution when using Lund and Browder charts as cutaneous burn area underestimates subcutaneous tissue injury
- **Analgesia;** high analgesic requirements, likely to require opiates. If pain appears out of proportion, consider compartment syndrome

Initial evaluation and management:

Initial Clinical Assessment in ED

1. Electricity source?
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Initial evaluation and management:

Triage of multiple patients: triage of patients in the emergency department is essentially the same as in the prehospital setting: **patients without signs of life are treated first**

General trauma evaluation:

١. Rapidly assess the **airway, cardiopulmonary** status, and pulses
٢. Evaluate for coexisting **smoke inhalation** or airway burns.
٣. In patients with significant electrical injuries or an **altered mental status**, **immobilize the cervical spine** as appropriate
٤. In a patient with **hypotension**, search for thoracic or **intra-abdominal bleeding** secondary to blunt trauma.
٥. Obtain **brain imaging** in a patient with **altered mental status**
٦. Obtain **radiographic studies** of any region that may have been injured

Initial evaluation and management:

Focused physical examination:

1. Perform a thorough **neurologic examination**
2. Inspect the entire body for **burns**, looking for discoloration, blisters, charred skin, and other lesions. Pay attention to skin creases and areas around joints.
3. In a **young child**, closely examine the **mouth**.
4. **Do not** try to infer presence or **degree of internal injuries based on skin burns**.
5. Inspect and palpate bones and spine for signs of **fracture**. Palpate all compartments and perform passive range of motion of all joints
6. Inspect the **tympanic membranes** for rupture
7. Perform a thorough **eye exam**, including testing visual acuity, inspecting the conjunctiva, and performing a slit lamp evaluation

Initial evaluation and management:

Continuous cardiac monitoring:

Place the patient on continuous **cardiac monitoring**, unless they meet all of the following criteria: **low-voltage exposure, asymptomatic, no reported loss of consciousness, and normal physical examination** (without contact point wounds).

Ancillary testing:

١. **All patients**, even if asymptomatic, should have an **electrocardiogram (ECG)** performed.

٢. A patient with any persistent symptoms or presence of cutaneous burns, should also have a **urinalysis** obtained to evaluate for **myoglobinuria**.

٣. For patients with a high-voltage or lightning exposure, large body surface burns, or concern for deep tissue injury; or those for whom observation or admission to the hospital is anticipated, we obtain: **Basic serum electrolytes (including calcium), CPK, TROP, CBC, BUN, Cr**

Initial evaluation and management:

Wound management

- Wounds are treated in a similar manner to flame or other thermal burns.
- Patients with low-voltage exposure and survivors of lightning strikes typically sustain only superficial burns, while those with high-voltage exposure commonly sustain deep burns.
- Patients with prolonged low-voltage alternating current (AC) exposure may sustain full-thickness skin and local subcutaneous tissue, tendon, and muscle burns.
- Patients with extensive burns should be managed in a burn unit since they often need fasciotomy, escharotomy, extensive skin reconstruction, or limb amputation.
- Topical antibiotic prophylaxis is indicated for non-superficial burns. The value of prophylaxis with intravenous (IV) antibiotics is controversial
- Administer tetanus prophylaxis as needed.

Evaluation and management by type of electricity:

Assess Voltage

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12 lead ECG:

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Urinalysis:

- If myoglobin or blood present requires baseline bloods

Discharge criteria:

- Discuss with senior decision maker
- Absence of syncope
- Normal 12 lead ECG
- No secondary injuries requiring further management
- Safe environment for discharge

High voltage

- APLS approach
- Contact on-call SpR or Consultant for Plastic Surgery to attend
- Trauma call with PEM Consultant and PICU present
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 - Compartment syndrome
 - Cardiac injury
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Management:

- FBC, U+Es, bone profile, Mg, amylase, CK, troponin, myoglobin
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- IV fluids to aim urine output 1-1.5 mls / kg / hour
- Urinary catheterization
- Monitoring for signs of compartment syndrome

Low voltage:

- **ABCDE** approach – unless suspicion of trauma
- **12 lead ECG** – if abnormal follow management of high voltage injury- will require admission
- Assessment and treatment of **burns** as per burns guideline
- Low voltage injuries can be considered for **discharge** if;
 - Absence of syncope
 - Normal 12 lead ECG
 - No secondary injuries requiring further management (burns or limb injuries etc.)
 - Safe location to be discharged to

Low voltage

- ABCDE approach
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Discharge criteria:

- Discuss with senior decision maker
- Absence of syncope
- Normal 12 lead ECG
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- Safe environment for discharge

Low voltage:

- **Deep skin and local soft tissue burn:**
- Patient with **prolonged alternating current (AC) exposure**, which typically occurs in the **upper extremities** when the victim is unable to release their grasp, may sustain full-thickness skin and local subcutaneous tissue, tendon, and muscle burns
- In these patients, the degree of external injury **does not** always correlate with the extent of local soft tissue injury
- They should be transferred to a **burn center** for evaluation since they will likely need debridement, skin reconstruction surgeries, and rarely digit amputation.

Low voltage:

Mild symptoms :

- Patients with mild persistent symptoms or minor cutaneous burns should have an **ECG** and **urinalysis** obtained, and we observe on a continuous **cardiac monitor** generally for **six hours**.
- If the **initial ECG is normal, myoglobinuria is absent**, and there were no dysrhythmias during the observation, the patient can be **discharged** with appropriate follow-up based upon their injuries
- If there is an **dysrhythmia or myoglobinuria**, admit for at least **24 hours** of continuous **cardiac monitoring** and **serial CK** measurement. **IV fluids** may be needed if the patient develops **rhabdomyolysis**

Low voltage:

- **Asymptomatic:**
- Patients who have **no symptoms** or for whom all symptoms have resolved, did not sustain loss of consciousness, have a normal **physical examination**, and have a normal initial screening **ECG** do not require further ancillary diagnostic tests or cardiac monitoring and can be reassured and **discharged**

High voltage:

1. TRAUMA CALL + inform Plastic surgical

High voltage

- APLS approach
- Contact on-call SpR or Consultant for Plastic Surgery to attend
- Trauma call with PEM Consultant and PICU present
- Patient Weight
- Assess for:
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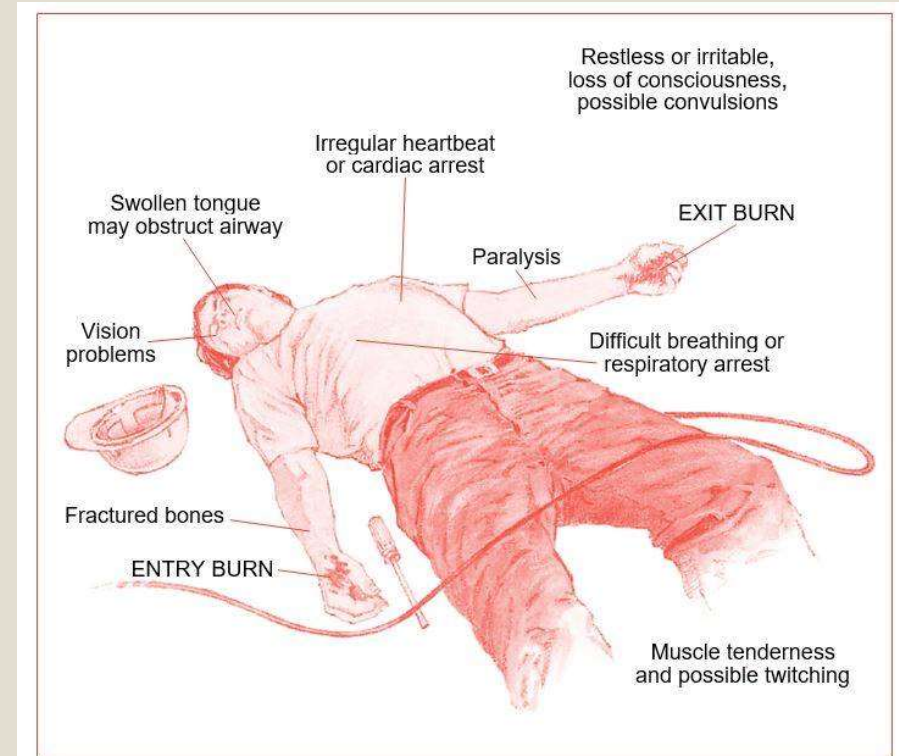
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High voltage:

- **↓.APLS approach:**
- **C-SPINE IMMOBILISATION**
- **AIRWAY + BREATHING:** Supplemental **oxygen**, Early senior anaesthetic review and consider **intubation if evidence airway burns**
- **CIRCULATION:** 12 Lead **ECG**- non-specific ST changes, AF, VF/VT, asystole, Bedside ECHO if ECG abnormal, Continuous ECG monitoring, **IV access** and bloods – FBC, U+Es, bone profile, Mg, CK, troponin, myoglobin, **IV fluid resuscitation** (0.9% NaCL target 1-1.5ml/kg/hr urine output, Urinary catheterisation)
- **DISABILITY: GCS** and hourly neuro observation , If GCS reduced consider head trauma, anoxia from arrhythmia, effect of electricity on brain
- **EXPOSURE:** Assess extent of cutaneous **burns** – manage as per burns guideline, Full exposure including soles of feet and palms, looking for **entry/exit points**, Assess extremity injuries- fractures/dislocations, Assess for compartment syndrome – immediate plastics involvement for consideration of fasciotomies, Careful temperature management- low threshold for active temperature management above 39 degrees

High voltage:

- Imaging as indicated by findings of primary survey
-
- All require **admission**
-
- For **24hr** monitoring in Critical Care
-
- **Echo** if not required in ED
-
- **1** hourly electrolytes/creatinine/CK



High voltage:

- **Assess for deep tissue injury:**

The degree of external skin injury **cannot be** used to determine the extent of internal damage

Patients with any full-thickness skin burn, those complaining of persistent deep ache or pain, and those who have pain with passive range of motion of joints should be presumed to have deep muscle or bone injury

Creatine phosphokinase (CK) elevation greater than 400 U/L is a sign of deep tissue injury and is associated with an increased risk of needing skin grafting or amputation

High voltage:

Fluid resuscitation:

In a patient with signs of muscle necrosis, we recommend **aggressive intravenous (IV) fluid replacement**

Begin initial fluid resuscitation with **isotonic saline**

Physiologic measures, including heart rate, blood pressure, and urine output, are useful in guiding resuscitation. Urine output should be maintained at $1/2$ to 2 mL/kg per hour to minimize intratubular cast formation.

High voltage:

- **Monitor for extremity compartment syndrome:**

Patients should be monitored for the development of acute compartment syndrome of the extremities and rhabdomyolysis. Perform frequent examinations for **tense, painful muscle compartments, pain with passive stretch of muscles, paresthesias, pallor, or diminished sensation, especially in a patient who complains of persistent deep ache, burning pain**, or pain out of proportion to the external signs of injury.

Monitor serial serum **CK** since it increases as compartment syndrome develops and appears to correlate with need for surgery

- **Cardiac evaluation, monitoring, and management:**

Cardiac monitoring is recommended for 24 hours for patients when high-voltage exposure is suspected, even if they have no apparent injury. Some ventricular dysrhythmias have occurred **up to 12 hours** after the exposure, although they are unlikely to occur if the initial electrocardiogram (ECG) is completely normal

High voltage:

Gastrointestinal prophylaxis and monitoring:

Provide prophylactic therapy to prevent stress ulcer formation, particularly in patients with severe burns

Persistent ileus, abdominal pain, or tenderness should prompt abdominal imaging and surgical consultation due to concern for abdominal organ injury or mesenteric ischemia

The combination of aggressive fluid repletion and restrictive surface burns can lead to the development of increased intra-abdominal pressure and the **abdominal compartment syndrome**. Symptoms and signs include dyspnea, abdominal bloating, abdominal pain, or a tensely distended abdomen

Lightning strike:

- Approximately 30 percent of those struck by lightning die, and up to 24 percent of survivors may have permanent disabilities
- In many victims who survive the acute phase, the prognosis is good and depends mainly on the extent of secondary injury
- Patients with **cranial burns or leg burns** are at higher risk for death than others struck by lightning
- **Interpreting ECG ST segment changes:**
- Lightning strike victims commonly manifest **ECG changes** such as ST elevation, nonspecific ST and T wave changes, and QT interval prolongation
- The initial ECG can mimic **ST-elevation** myocardial infarction but then resolve without sequelae or troponin elevation
- ST segment changes and **troponin/CK-MB elevation, which frequently occur, are poor measures of myocardial injury** and not typically prognostic

lightning strike:

Deep tissue burns are unlikely:

Superficial burns are common in victims of lightning injury, but **deep burns or tissue injury are unusual**

Monitoring of electrolytes and kidney function:

A patient with **hyponatremia** with signs of extracellular volume depletion may be developing **cerebral salt wasting**, which has been reported as a complication of lightning-related injuries

Duration of continuous cardiac monitoring:

A patient with persistent ECG changes, dysrhythmia, cardiac arrest, elevated troponin, other evidence of cardiac dysfunction or suspicion of direct lightning strike should be admitted for 24 hours of cardiac monitoring and further evaluation.

Special consideration:

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- **Temperature management;** low threshold for active temperature management above 39 degrees
- **Imaging;** low threshold for multiregional scans due to high risk of trauma
- **Burn Surface Area;** caution when using Lund and Browder charts as cutaneous burn area underestimates subcutaneous tissue injury
- **Analgesia;** high analgesic requirements, likely to require opiates. If pain appears out of proportion, consider compartment syndrome

Special population:

Pregnant

Obtain **obstetric consultation** and a **fetal heart rate** in a pregnant patient who sustains anything more than mild electrical exposure

Accidental, mostly low-voltage electrical exposure during pregnancy did not appear to pose a major fetal risk. However, **placental abruption** may be associated with even minor abdominal trauma, including electrical injuries.

Effects on the fetus are unpredictable with a lightning strike. Given the risk of significant **abdominal trauma** in the pregnant patient, it is reasonable to obtain continuous fetal heart rate monitoring and ultrasound evaluation of the fetus if potentially viable

Special population:

Pediatric

A child with an **oral commissure burn** can develop **significant bleeding** from the labial artery when the eschar separates, which can occur days to two weeks after the initial burn was sustained

When significant oral injuries are present, admit for intravenous **(IV) hydration, pain control, and plastic surgery evaluation**

A child with a minor burn confined to the oral commissure may be discharged if follow-up with an **otolaryngologist** or **plastic surgeon** can be ensured within two to three days and the parents are warned about the potential for serious, delayed bleeding.

Parents should also be counseled to implement **preventive measures** in the home, such as electrical outlet plugs and keeping electrical cords out of the reach of children.

Follow up care:

Patients who sustain high-voltage or lightning injury should be encouraged to arrange the following follow-up care:

- **Otolaryngologist** for otologic examination and audiometric testing
- **Ophthalmologist** for evaluation of delayed cataract formation, which generally develops days, weeks, or even months after injury.
- **Cardiologist** for a patient who has developed electrocardiogram (ECG) changes or atrioventricular (AV) or bundle branch blocks.
- Any child discharged with an **oral commissure burn**, needs to follow up with an otolaryngologist or plastic surgeon within two to three days

Question 1:

- **A 13-year-old girl who was struck by lightning while playing soccer is brought in by EMS...**

The girl was playing soccer in an open field when a thunderstorm started. While trying to take shelter, lightning struck a tree approximately 2 feet away, and she was thrown several feet. An adult observed that she was unresponsive, so he called 911 and initiated CPR. When EMS arrived, an AED was placed and a shock was delivered, with subsequent return of spontaneous circulation. The patient was prepped for transport with a C-collar in place. During transport, her cardiac rhythm was sinus tachycardia, with a palpable pulse, and bag-valve mask ventilation was initiated for no spontaneous respirations

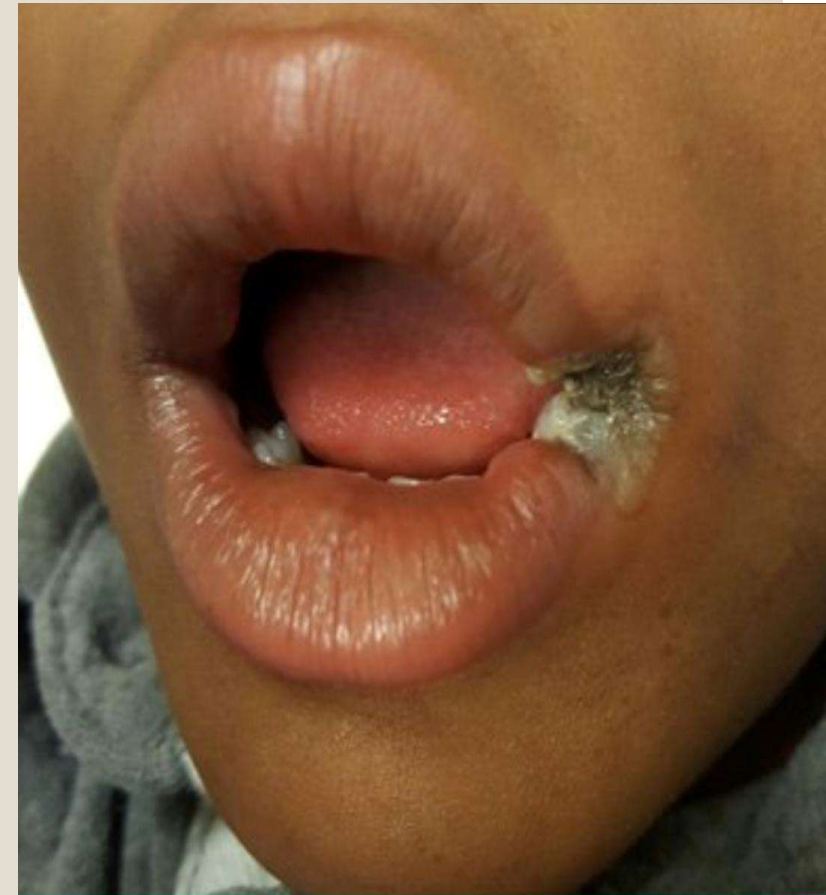
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Question 2:

- **An 18-month-old boy is brought in by his parents after he was found chewing on an electric cord...**
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- The boy is well appearing, with age-appropriate vital signs. He is noted to have grayish-white tissue on the right oral commissure, without bleeding. His dentition and tongue are intact, he has no trouble handling his secretions, and he is able to drink without problem.
- What complication of this injury should you consider? What is the appropriate disposition for this patient? How should you advise the parents?





REFERENCES:

Textbook of nelson
Up-to-date
Electrical injuries guidelines(NHS, EBM)



THANK YOU