This chapter will train you to recognize and treat injuries caused by a lightning strike in addition to ways to avoid being struck by lightning according to the following criteria:

- Recognize when and where lightning is more likely to strike in relation to a storm.
- Be able to describe the six mechanisms that one may be struck by lightning.
- Be able to describe the etiology of cardio-respiratory arrest due to a lightning strike and the appropriate management of it.
- Describe common injuries that are caused by lightning for the following organ systems: cardiovascular, CNS, eyes, ears, autonomic nervous system, skin
- Understand the concept of reverse triage in the management of multiple casualties from a lightning strike.
- Understand that all victims of a lightning strike should be evacuated as soon as possible from the back country.
- Be able to list several methods to minimize the potential that one may be struck by lightning while in the back country.
Case 1

A 23 year-old male is leaning against a vehicle with a large whip antenna when the antenna is stuck by lightning. He is thrown back from the vehicle and slightly confused to what actually happened. On your evaluation, he is awake and alert. He remembers a large flash of light then next thing he knew he was on the ground 10 feet away from the vehicle. He is an otherwise healthy man who takes no medications and has no allergies. His vital signs are normal. His physical examination is normal with the exception of an unusual rash on his left chest (pictured below).

1. What is the next step in the management of this patient?
2. Are you at risk of electrical injury from a residual electrical charge if you touch him?
3. Does he require evacuation to a hospital or can he stay in the back country?
4. What are some of the organ systems that may be injured that you must specifically look for?

Rash on the left side of the chest of Case 1
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Case 2

You are watching a football team practice when you see lightning and hear thunder approximately 5 seconds afterwards. The coach sees the lightning as well and calls the team to the center of the practice field to end the practice sooner because of the lightning. As soon as the team breaks to go to the locker room there is a big flash and boom in the middle of the team formation. You run out onto the field to see several players who are dazed and wandering around as well as eight people on the ground. Three of those individuals are moaning, three are unconscious but appear to be breathing on their own. One has a large burn wound to his helmet and is pulseless and apneic. The last person is unconscious, apneic and pulseless with fixed and dilated pupils but does not appear to have any other injury.

1. What is your next step in the management of this multiple casualty situation?
2. Who is the first person you should attend to?
3. What is the prognosis for the individual with the head burn wound?
4. Is there a risk of lightning striking the same area again?

Background

Facts

- Lightning is the 2nd leading environmental cause of death (behind flash floods) in the US with an average of 50 to 300 deaths per year.
- Three to five times as many more patients are injured by lightning, but survive.
- The US has an automatic real-time lightning detection network that has been active for the past decade.
- On the average, 20 million cloud to ground flashes are detected yearly.
- In some summer afternoons, more than 50,000 flashes per hour are detected.
- The most common months for injury are June, July, and August, although lightning strikes may occur during any time of the year to include during snowstorms.
- The most common time of the day for lightning casualties is in the afternoon with more than half of these occurring between 3:00 p.m. and 6:00 p.m. local time. This is the most common time due to the heating of the ground by the sun, which causes vertical cumulus clouds to form, that may be tall enough to produce lightning.
- Florida is the worst state for lightning casualties with nearly 2 times as many casualties than the next state.
- The more dangerous times for a severe lightning strike are before the storm appears and after it has passed.
- Lightning may travel nearly horizontally as far as 10 miles in front of a thunderstorm and seem to occur out of a “clear blue sky” or at least when it is still sunny. In fact, lightning can strike from a storm on the other side of a ridge line.
- Lightning does strike twice in the same place - all the time.
- A lightning bolt is a unidirectional massive current impulse up to 30 million volts.
- A lightning bolt is typically 6 to 10 cm in diameter, but the ionized sheath is much broader, up to 20 cm. The temperature of the sheath is usually about 8000 degrees centigrade.
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Mechanism of Injury

Direct strike

- The patient is hit directly by the bolt of lightning.
- This most commonly occurs to people who are caught in the open and unable to find cover.

Side splash

- The lightning directly strikes another object such as a tree or building but the current flow, which seeks the path of least resistance, jumps from its original pathway onto the victim.
- This is the most common cause of lightning injury.
- These side splashes may also splash indoors from metal objects such as plumbing and telephones.
- Splashes may occur from person to person when several people are standing close together.

Contact

- Contact exposure occurs when a person is holding onto or touching an object that is either directly hit or splashed by lightning.
- The current passes through the object onto the victim.

Ground current or step voltage

- Ground current is produced when lightning strikes the ground or a nearby object and the current spreads through the ground.
- If a person has one foot closer to the strike, then a potential difference may exist between the two feet and the current will pass up one leg and down the other leg.
- This occurs because the body is of lower resistance than the ground.
- This is a common mechanism for several people being injured at the same time.

Injury by a weak upward streamer

- Electrical streamer heads upward into the sky but does not reach sky lightning, thus not completing a connection.
- The electrical charge passes over and through the involved individual but not nearly at the amount from a direct strike from the sky.

Blunt trauma

- Injury occurs due to the impact of the concussive force of the strike itself or due to being thrown due to the extreme nature of the muscular contraction from the electrical charge.

Pathophysiology

General

- Lighting is neither a DC nor AC current. It is best described as a unidirectional massive current impulse of electrons.
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- In addition to flowing on the outside of the body (flashover), this current may also enter the body through the cranial orifices (eyes, ears, nose, and mouth) and flow through the body. This may explain why some patients have certain injuries such as ocular and/or ear and others do not.
- Although the current flow occurs over a very short period of time the amount of current is significant; on the order of 30 million volts.
- Injuries occur from a “short circuiting” of several of the body’s electrical systems as well as the more direct trauma and indirect trauma due to muscular contraction and being thrown.
- Lightning does not leave a residual charge on a victim of a strike. So there is no need to be concerned of getting shocked or injured by rescuing a person who has been struck by lightning.

Lightning injury by the organ system

Cardiovascular

- The most common cause of death in a lightning victim is cardiopulmonary arrest.
- After the lightning strike the heart initially becomes asystolic. However, due to automaticity, the heart soon begins to contract in an organized manner.
- If concomitant respiratory arrest occurs, the heart may deteriorate back into asystole secondary to the hypoxia. This respiratory arrest occurs because of paralysis of the medullary respiratory center, which usually lasts longer than the cardiac arrest.
- Other complications include:
  - Direct myocardial damage or necrosis
  - Coronary artery spasm
  - Acute global cardiac dysfunction
  - Atrial and/or ventricular dysrhythmias
  - Pericardial effusion
  - The ECG may show ST segment changes consistent with ischemia or infarction as well as prolongation of the QT intervals

Central nervous system

- When current traverses the brain there can be coagulation necrosis of brain substance, formation of epidural and subdural hematomas, intraventricular hemorrhage and paralysis of the respiratory center.
- Those patients who suffer cranial burns are four times more likely to die than those without cranial burns.
- Direct cellular damage to the respiratory and cardiac centers in the 4th ventricle of the brain may occur, especially if current passes through the orifices of the head.
- Seizures may occur secondary to the initial hypoxia from respiratory arrest or due to intracranial damage. These are usually transient, although they may continue for the first few days.
- Confusion and anterograde amnesia are very common.
- Traumatic brain or spinal injury may occur due to being thrown.
- Neuropsychological sequelae are very common.
  - Memory impairment
  - Difficulty concentrating
  - Sleep disturbances
  - Personality change with increased lability and aggression

Autonomic nervous system

- Commonly there is instability of the ANS for several hours after the injury.
- More severely injured patients may have lower extremity paralysis (keraunoparalysis) or in some cases upper extremity paralysis.
  - In these cases, the involved extremities appear cold, clammy, mottled, insensate and pulseless.
  - This is usually the result of autonomic instability and intense vascular spasm, which has been likened to Raynaud’s phenomenon in appearance.
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- Keraunoparalysis usually occurs due to ground current.
- These findings usually resolve spontaneously after a few hours.

Peripheral nervous system

- Peripheral nerve damage is common but recovery is poor.
- Common symptoms include paralysis, pain and paresthesias.
- Symptoms may be delayed by weeks to years

Respiratory system

- Acute respiratory arrest due to the loss of respiratory drive.
- Pulmonary contusion and hemorrhage can occur.

Skin

- Contrary to popular myth and what is seen in cartoons, deep burns are unusual after lightning injury. At the most, some minor 2nd degree burns may occur from superheated metal objects.
- Often, there are no burns, especially with ground current.
- There are four types of skin effects:
  - Ferning (Case 1): Also called feathering or Lichtenberg figures. These are not actual burns, but an unusual pattern that occurs due to the electron shower. This skin finding is pathognomonic for lightning injury.
  - Linear burns: These are usually 1st and 2nd degree burns that occur from steam production from sweat or water on the victim due to the increased temperatures associated with the lightning strike.
  - Punctate burns: These are multiple, closely spaced but discrete circular burns that individually range from a few millimeters to a centimeter in thickness. These resemble cigarette burns.
  - Thermal burns: These are regular thermal burns that occur when a patient is wearing a metal object, such as a belt buckle or necklace, which heats up due to the electrical current going through it. There may also be thermal burns if clothing ignites.

Musculoskeletal system

- Fractures and dislocations may occur due to intense muscular contraction or from being thrown.
- The significant muscular necrosis and extremity damage seen in electrical injuries is unusual in lightning injuries

Ocular

- One-half of all lightning victims will have ocular injuries.
- Cataracts are the most common ocular injury. These may develop immediately or as late as two years after being struck.
- Transient bilateral blindness of unknown etiology is not uncommon.
- Other injuries: corneal lesions, iridocyclitis, hyphema, retinal detachment, optic nerve atrophy, vitreous hemorrhage.
- Dilated and unreactive pupils can not be used as a sign of death as this may occur after lightning injury.

Ear

- Temporary deafness can occur due to the intense noise and shock wave.
- 30% to 50% of victims will have rupture of one or both tympanic membranes.
- Disruption of the ossicles and/or mastoid bone can occur.
- Facial palsy due to direct nerve damage of the facial nerve as it runs through the auditory canal.
- Victims who were using a conventional (wired) telephone at the time of the strike are at high risk of these injuries, especially if this is a side splash into a dwelling through the telephone.
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Pregnancy

- There are only 11 cases reported of pregnant victims of a lightning strike.
- Maternal outcome is generally good. However, there is a reported 50% rate of fetal death.

Clinical Presentation

Single Victim

The identification of a victim of a lightning strike is easy if the strike was witnessed. However, there may be situations where you will come across a person who is confused, amnestic, disheveled, or possibly unconscious. In those situations, it will take some time and focus to determine the cause of the individual’s symptoms. In the case of the unwitnessed victim, clues that can assist you include the environmental clues such as a recent storm or lightning. For the victim, confusion and amnesia as well as prominent physical findings such as fixed dilated pupils, ruptured tympanic membranes, and the pathognomonic skin rash, ferning.

The patient who is identified as a victim of a lightning strike may present along a spectrum from being unconscious, apneic, and pulseless to being awake and alert without any complaint. The degree that the patient demonstrates signs and symptoms of lightning strike depends upon the type of strike they received with a direct strike causing the most severe symptoms. The typical victim is an individual who was witnessed to be struck by lightning and is amnestic to the event and has some of the previously described sequelae of lightning strike.

Multiple Victims

The typical description of a multiple casualty lightning strike is one of a sudden flash of bright light followed closely by a loud boom and then chaos. There will likely be several people who are ambulatory but confused. There will be people who are lying on the ground but are at least moving or breathing on their own. These first two groups of people do not require immediate attention.

The final group of casualties may include one to several people who are unconscious, apneic, and pulseless. This final group is the one that requires your immediate attention. The fact that you are treating those who appear dead is called “reverse-triage.” The reason for this reverse triage is due to the fact that those victims who are awake or at least breathing have survived the most immediate and potentially critical injury, which is concomitant cardiac and respiratory arrest.

Those patients who are apneic and pulseless require CPR in order to get them to the point where there cardiac pacemakers restart and their intrinsic respiratory drive has started again. These are the patients who may sustain the cardio-respiratory arrest and regain their heartbeat but may still require assistance with breathing for several minutes before their respiratory drive starts.

In attempting to decide on which patients you should start the CPR on, remember that those with head burns are four-times more likely to die from the strike.
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Treatment and Prevention

- Perform reverse triage and initiate CPR on those patients who are pulseless and apneic before caring for those who have spontaneous signs of life. Those with no spontaneous breathing or heartbeat may recover their heartbeat and will require assisted breathing until their respiratory drive returns. Breathing for these patients may prevent a secondary cardiac arrest due to hypoxia. If a victim does not regain a pulse within 20 to 30 minutes then one may discontinue the resuscitation.

- Initial steps follow the ABCs: airway, breathing, and circulation.

- Call for evacuation to the closest medical facility.

- Stabilization such as splinting of fractures, and spinal precautions should be performed as determined on your secondary assessment.

Evacuation Guidelines

- Any patient who is a victim of a lightning strike should be evacuated as soon as possible.

- Even if the individual does not have any overt evidence of damage, there is a high likelihood of some sort of injury that is not served best by staying in the back country.

Avoiding Lightning Injury

The 30-30 rule

- The 1st “30” --> When the time between seeing the lightning and hearing the thunder is 30 seconds or less then people are in danger and should be seeking appropriate cover.

- The 2nd “30” --> Outdoor activities should not be resumed until 30 minutes after the last lightning is seen or the last thunder is heard.

Seek shelter in a substantial building or in an all metal vehicle

- Small shelters such as golf, bus, and rain shelters may increase a person’s risk of being struck due to side splash as the lightning flows over the building.

- All metal vehicles are safe because the metal will diffuse the current around the occupants to the ground. A convertible is not a safe alternative. It is a myth that the rubber tires provide insulation.

If you are caught in a storm outside without a safe building or vehicle

- Stay away from metal objects and those items that are taller than you.

- Avoid areas near power lines, pipelines, ski lifts, and other large steel objects.

- Do not stand near or under tall isolated trees, hilltops, or at a lookout or other exposed area.

- In a forest seek a low area under a growth of saplings or small trees. Seeking a clearing free of trees makes a person the tallest object in the clearing.

- If you are totally in the open, stay far away from single trees to avoid lightning splashes and ground current. A good position is to squat down with your knees fully bent and your feet together or to sit cross-legged or kneeling on the ground.

- If you are in a group of people spread far apart so that a single lightning strike will not take out the entire group.

- If on the water seek the shore and avoid being the tallest object near a large body of water.
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If indoors

- Avoid open doors and windows, fireplaces and metal objects such as sinks and plug in electrical appliances
- Do not talk on the telephone (even a cordless one) as telephone lines are usually not grounded like electrical wires.

Questions

1. What is the most dangerous time to be struck by lightning in relation to the storm?
   a. At the first time you hear thunder
   b. In the middle of the storm when the rain is the hardest
   c. The period of time right before the storm actually hits
   d. Thirty minutes after the storm ended
   e. You are at the same risk regardless of the storm

2. In which one of the following situations is somebody least likely to get injured by lightning?
   a. Crouching near the top of a ridge line
   b. Sitting inside a rain shelter on a golf course that is open on the front
   c. Sitting under a large tree that provides protections from the rain
   d. Sitting in an all-metal automobile with the windows rolled up.
   e. Standing upright in the middle of an open field

3. A 30 year-old male is struck by lightning and is pulseless and apneic. Which one of the following is correct in regards to the management of this patient?
   a. CPR is not necessary as his heart will start beating on its own
   b. CPR is not helpful as his heart likely sustained irreversible damage
   c. CPR should be initiated until he begins breathing on his own, then you may stop
   d. CPR should be initiated until he regains his pulse, then you may stop
   e. CPR should not be initiated as the patient may have a residual charge from the lightning

4. Which one of the following is not an injury commonly seen with lightning strike?
   a. Amnesia
   b. Cataracts
   c. Dislocated tympanic membranes
   d. Seizures
   e. Third degree skin burns

5. You observe lightning strike a large group of people with the following casualties:
   A. Awake, alert and sitting up with obvious dislocated shoulder
   B. Awake, moaning and confused
   C. Unconscious, apneic, pulseless, no evidence of injury
   D. Unconscious, apneic, pulseless, obvious burn to the head and face
   E. Unconscious, breathing on own, palpable pulse
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What is the correct order that you should triage and care for these patients?

a. A, B, E, D, C
b. B, E, D, C, A
c. C, D, E, B, A
d. D, C, E, B, A
e. E, C, D, B, A

6. Which one of the following is a method to minimize being struck by lightning?
   a. If caught in the open squat down with your feet together
   b. Seek shelter under the largest tree in the open, ensuring you are leaning against it
   c. Laying supine if you are caught in the open
   d. Seeking shelter when you see lightning and hear thunder within 10 seconds
   e. Sitting under large electrical towers as they are grounded and protected from lightning

Answers:
1. c
2. d
3. c
4. e
5. c
6. a