Lightning Injuries

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Abstract

Lightning strikes the earth millions of times every day. Lightning causes serious injuries in 1000-1500 individuals and over 1000 people death every year worldwide. Lightning causes damage to a wide range of body systems including cardiopulmonary, neurological, vascular, cutaneous burns, ophthalmic, and otological injuries. The most common cause of death in lightning strikes is cardiopulmonary arrest. If multiple persons are struck by lightning, triage priorities must be reversed. Those in cardiac and/or respiratory arrest must be treated first. Lightning-injured patients often require a combination of cardiac and trauma care. Care for all persons hit by lightning is aimed at initial immobilization of the spinal column, basic and advanced life support, and then supportive care. Management of burns, cardiac arrhythmias, and blunt trauma injuries should proceed according to standard advanced cardiac and trauma treatment principles. About 70 percent of survivors sustain significant morbidity and permanent sequela. Preventive measures and lightning safety education are the most effective methods to minimize the mortality and morbidity of lightning injury. Familiarity with and implementation of lightning safety guidelines is everyone's responsibility to decrease lightning injuries.*(Ann Disaster Med. 2004;3 Suppl 1:S1-S7)*

Key words: Lightning Injury; Environmental Medicine; Wilderness Medicine

Introduction

Millions lightning flashes occur every day worldwide. Lightning causes approximately 300 injuries each year in the United States with approximately 100 reported deaths each year. [1] Lightning causes serious injuries in 1000-1500 individuals and over 1000 people are estimated to die from lightning every year worldwide. Mortality rates associated with lightning have been estimated to range from 20 to 30 percent but are thought to be overestimated, because medical databases are biased toward collecting information on only the most severe and fatal cases. About 70 percent of survivors sustain significant morbidity and permanent sequela.

Lightning most often occurs during thunderstorms in association with large cumulonimbus clouds. However, about 10 percent lightning occurs without rain and when the sky is blue. [2] In addition, lightning can occur during dust storms, sandstorms, snowstorms, nuclear explosions, and in the clouds over volcanic eruptions. Lightning injuries can occur in outdoors, transportation, water sports, and even

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indoor telephone use.[3]

Pathophysiology

There are five types of lightning strike: (1) *direct strike* that occurs when the victim is struck directly by the lightning discharge. Most fatalities and severe injuries occur after this type of lightning strike. (2) *side flash* that occurs when a nearby object such as a tree is struck and current then traverses through the air to strike the victim. It is usually the underlying mechanism when multiple lightning fatalities occur among persons or animals grouped closely together (Figure). (3) *contact strike* that occurs when lightning strikes an object the victim is holding and current is transferred from the object to the person to the ground. Common contributors to lightning contact are a golf club, an umbrella, or a set of keys in the person's hand. (4) *ground current* that occurs when lightning hits the ground and current is transferred through the ground to a nearby victim. This ground current creates a stride potential or step voltage between the victim's separated feet. (5) A weak *upward streamer* does not become connected to the completed lightning channel.[4]

Lightning is an extremely high-voltage direct current (DC) electrical discharge. When lightning strikes the body, the current travels the path of least resistance to the ground. Because of the extremely limited duration of contact with the body, much of the current passes over the skin in a "flashover" pattern. This flashover effect is protective to the body. Because much of the current passes over the skin causing superficial injury, less voltage penetrates the internal structures; the result is less internal cardiac injury or muscle necrosis. Wet skin may actually decrease the risk of internal injury, helping the current travel though the outside of the body. When current enters the body, it flows through structures that pose the least resistance. Tissues with high fluid and electrolyte content, such as nerves, blood vessels, muscle, and connective tissue are most commonly affected.

Immediate cardiac arrest from lightning strike results from direct current depolarization of the myocardium and sustains asystole. Immediate respiratory arrest after lightning strike is a result of depolarization and paralysis of the medullary respiratory center. Although cardiac automaticity may spontaneously return, concomitant respiratory arrest may persist and lead to a secondary hypoxic cardiac stoppage. The duration of apnea, rather than the duration of cardiac arrest, appears to be the critical prognostic factor.

Figure. Lightning-shock cows

Clinical Features

Although lightning injuries may involve all organ system, injuries to the cardiovascular system and central nervous system are usually most devastating.[5,6]

Cardiovascular injury

The most common cause of death in lightning strikes is cardiopulmonary arrest. This condi-

tion results from both the direct current to the heart and paralysis of the respiratory center in the brain. Persons who have been hit by lightning and are in respiratory arrest may need only artificial respiration to prevent the secondary hypoxic arrest. Almost all persons hit by lightning who do not have cardiac and/or respiratory arrest at the scene survive, even though they may be seriously injured. If multiple persons are struck by lightning, triage priorities must be reversed.[7] Victims in cardiac and/or respiratory arrest must be treated first. Persons who are conscious after being struck by lightning can wait for treatment, because they will survive. Patient may suffer a variety of other cardiovascular effects, including direct myocardial damage, coronary artery spasm, cardiac contusion from blunt trauma, acute global dysfunction, transient hypertension and tachycardia. The electrocardiogram (ECG) may show acute injury with ST-segment change, prolonged Q-T intervals and premature ventricular contractions. Electrocardiography changes generally resolve within a few days. Although myocardial infarctions do occur, they are rare.

Respiratory injury

Paralysis of brain stem respiratory center may result in apnea, but this central apnea may be temporary and a patient may survive if ventilated until cardiac and respiratory activity return. Other respiratory injuries include immediate and delayed pulmonary edema, pulmonary contusion, adult respiratory distress syndrome, and pulmonary hemorrhage.

Neurological injury

Neurological injury after lightning strike is usually classified as (1) immediate and transient, (2) immediate and prolonged or permanent, (3) delayed, and (4) traumatic lesions secondary to falls and blast effects. Transient effects that typically resolve in 24 hours include loss of consciousness, confusion, amnesia, and extremity paralysis (keraunoparalysis). Immediate and prolonged or permanent injury means that patients have structural lesions that are often seen on imaging studies or on postmortem examination. Post hypoxic encephalopathy is the most common of the major intracranial catastrophes that afflict patients with lightning strike. It is a complication of cardiac or respiratory arrest. Patients struck by lightning can present with intracranial hemorrhages, including intracerebral and subarachnoid hemorrhages. Intracranial hemorrhages in lightning strike patients often appear in two susceptible locations: the basal ganglia and the brainstem. Delayed neurologic disorders attributed to lightning include motor neuron disease and movement disorders. It included seizure, spinal muscular atrophy, amyotrophic lateral sclerosis, parkinsonian syndrome, progressive cerebellar ataxia, myelopathy with paraplegia or quadriplegia, and chronic pain syndrome. This sequela has followed lightning strikes by days to months to years. Lightning bolts can cause trauma secondarily when the patient is thrown or falls. Blast effects related to thunder or vaporization of water on the body can damage the brain and other organs. Epidural, subdural, and subarachnoid hemorrhages result from falls linked to lightning. These patients require usual trauma care.[8]

Vascular injury

Vasomotor spasm in an extremity is seen as a

local response. It may induce by sympathetic nervous stimulation, local arterial spasm, and ischemia of peripheral nerves. Skin color changes from white to blue to red. Severe vasoconstriction may induce loss of pulses, mottling of skin, coolness of extremities, loss of sensation, and paralysis. This calls keraunoparalysis phenomenon.

Dermatologic injury

The six main dermatologic manifestations of lightning injury are Lichtenberg figures, flash burns, punctuate burns, contact burns, superficial erythema and blistering burns, and linear burns. Lichtenberg figures are considered pathognomonic for lightning strike. They demonstrate the superficial ferning or feathering pattern, resulted from electron showering over the skin. They disappear in 24 hours. Flash burns appear as mild erythema and may involve the cornea, and are similar to those found in arc welders. Punctuate burns look similar to cigarette burns with usually smaller than 1 cm full-thickness burns. Contact burns occur when metal close to the skin and the skin is heated from the lightning current. Superficial erythema and blistering burns are usually transient, and superficial skin loss may occur. Linear burns, less than 5 cm wide, occur in areas of skin fold such as the axilla or groin. Entrance and exit wounds, characteristic of electrical injury from human sources, are not commonly seen in lightning injuries. Cutaneous wounds are treated with standard or burn care.

Ocular injury

Half of all lightning victims will have ocular injuries, including cataracts, hyphema, vitreous hemorrhage, corneal abrasion, uveitis, retinal detachment or hemorrhage, and optic nerve damage. Cataracts are the most common injury and may form weeks to years after the lightning injury. Dilated unresponsive pupils may be due to transient autonomic dysfunction and should not be used as a sign of brain death.

Auditory injury

Auditory injuries range from transient hearing loss and vertigo to complete disruption of auditory system. Tympanic membrane rupture is relatively common in lightning injury and may result from the explosive forces of the strike, basilar skull fracture, direct trauma to the ear canal, or direct lightning burn to the canal. Victims sustaining lightning strike along a conventional corded telephone are at higher risk for otologic injury, including persistent tinnitus, sensorineural deafness, ataxia, vertigo, and nystagmus.[3]

Musculoskeletal injury

A variety of musculoskeletal injury can be seen from the blunt force injury associated with lightning strike, including fractures and soft tissue injury. Intense myotonic contractions can produce posterior shoulder dislocation, cervical spine fractures, compartment syndrome, and muscle rupture. Rhabdomyolysis after lightning strike is unusual, so routine forced diuresis and alkalinization of urine is not recommended in lightningvictims.

Psychosocial problems

Lightning victims may suffer from long-term congnitive dysfunction, depression, and anxiety. Posttraumatic stress disorder and storm phobias are known to develop. Anxiety, storm phobias, and recurrent nightmares are more

common in children.

Pregnancy

Although maternal outcome are general good, there is about 50 percent of fetal death, presumably because amniotic fluid serves as a preferential path of current flow. Fetal monitoring and uterine/fetal ultrasonography should be performed on all pregnant lightning-strike victims. Maternal uterine activity and fetal heart rate monitoring is recommended for 4 hours after a lightning strike to a pregnant female.[9]

Diagnosis and Management

Care at the injury scene

Emergency medical service personnel and bystander safety must be the first priority, since lightning can frequently strike twice in the same place. Power lines may fall to the ground as a result of high winds or lightning-related damage to power poles or to the lines. It is important that rescuers visually survey the area. Everyone's safety may be improved by a brief survey looking for burns on the ground or nearby objects, melting of metal objects on or near the person, and unusual sounds, smells, or smoke. If a downed power line is found, safety precautions are important.

Information about the scene of the accident may be more informative than examination of the patient, because physical examination findings suggestive of lightning injury may be subtle or nonexistent. Important information including: history of an electric storm in the area at the time, blast effects on nearby objects, area of burned vegetation, melted or magnetized metal objects, and melted nylon underclothing.

The standard airway, breathing, circulation, disability, and exposure protocols with advanced cardiac and trauma treatment principles are required. Reverse triage is appropriate in the case of multiple lightning-injury victims.[7] In contrast to multiple-victim events caused by mechanical trauma, persons with lightning injury who appear to be dead (in respiratory arrest, with or without cardiac arrest) should be treated first. Such victims often have little physical damage, and they may survive if ventilated until cardiac and respiratory activity resumes. Victims of a lightning strike should be transported in spinal immobilization, due to the possibility of traumatic injuries.

Care in emergency department

Standard advanced cardiac and trauma principles should be followed. Intravenous access, supplemental oxygen, and continuous cardiac monitoring should be instituted. Lightning victims in cardiac arrest have a better prognosis than those in cardiac arrest from acute myocardial infarction, so aggressive resuscitative efforts are indicated.[10] Hypotension is not an expected finding from lightning injury. Occult hemorrhage, such as intra-abdominal or intrathoracic hemorrhage, and pelvic or long bone fracture should be searched.

Once the primary survey is completed, a careful head-to-toe examination should be performed to identify occult injuries.[10] Cutaneous burns may help determine the path of the current and locate potential organ injury. A careful neurologic examination should be performed to detect motor and sensory deficits. Ophthalmologic and otologic examinations should be done to rule out visual and hearing disturbances. All patients should have a completed ECG performed to evaluate for arrhythmias and injury pattern. Laboratory tests include blood counts,

coagulation studies, serum electrolytes, calcium, magnesium, blood urea nitrogen, creatinine, CK, CK-MB, arterial blood gas, and urine myoglobin level. Imaging studies (plain radiography, ultrasound, or computed tomography) should be obtained for suspected injuries. A chest X-ray should be obtained to evaluate for aspiration, pulmonary edema, pulmonary contusion, rib fractures, and pneumothorax. Cervical spine films should be obtained in patients with suspected spinal injuries or trauma secondary to falls. Computed tomography of the head should be performed in patients with an altered or deteriorating conscious level or evidence of head injury.

Disposition

The majority of lightning-strike victims will have moderate to severe injuries that require admission for specialized care. Conditions associated with serious mortality and morbidity include cardio respiratory arrest, cranial burns, leg burns, ECG changes and arrhythmias, any CNS lesions or loss of consciousness, any neurological injuries without rapid resolution, and myoglobonuria.[11] For patients with minor injuries, admission for observation is recommended for the potential delayed sequela. For the rare patient with no neurologic injuries and normal cardiovascular evaluation, a period of observation in emergency department is recommended. Discharge may be considered if no new abnormal symptoms or sign develop, and neurologic and ophthalmologic referral should be arranged.

Prevention

Many of these people incur injuries or are killed by lightning because of misinformation and inappropriate behavior during thunderstorms. Few people really understand the dangers of lightning. The first step in solving this problem is to educate people so that they become aware of the behavior that puts them at risk of being struck by lightning, and to let them know what they can do to reduce that risk. [12,13] Individuals are ultimately responsible for their own safety decisions and should take appropriate action

Table. Guidelines for prevention of lightning injury during thunderstorm

1. Do not touch the telephone, a computer with a modem, or electric appliances, and stay out of the shower and bathtub.
2. Seek shelter in a building with plumbing and electrical wiring or a closed, all-metal motor vehicle. Do not touch any metal objects in the buildings and vehicles.
3. Avoid open fields. Do not lie flat. Present the smallest “target” possible.
4. Do not seek shelter under a lone tree or other tall object or under any isolated shelter. A thick forest is considerably safer.
5. Put down metal objects such as golf clubs, fishing rods, and umbrellas. Stay away from metal objects. Remove shoes with metal cleats.
6. Get out of the water immediately, and stay away from it.
7. Avoid hills or mountain peaks, metal fences, or aboveground pipes.

when threatened by lightning. Each person must be familiar with and follow lightning safety rules. There are safer locations and locations should be avoided during thunderstorms. Large structure with plumbing and electrical wirings (e.g., houses, schools, office buildings) and fully enclosed metal vehicles (e.g., cars, trucks, buses, enclosed farm vehicles) are safer areas. It is important to roll up windows and avoid contact with metal or conducting surfaces inside or outside the metal vehicle. Fully enclosed metal vehicles with the windows rolled up provide good shelter from lightning. Areas to avoid include those near tall objects, such as towers or trees, and those near water or open areas.[2] The lightning safety rules are listed in Table. Exposure to the lightning threat during thunderstorm activity should be avoided. Familiarity with and implementation of lightning safety guidelines can decrease injuries.

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