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Lightning injuries: same incident, different injuries - A case series

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Abstract

Singapore, lying near the Equator, has one of the highest lightning activities in the world1. However, injuries related to this weather phenomenon were under-reported and rarely a subject of study. Most reported cases dealt with lightning-caused fatalities, but lightning-caused accidents are not always fatal. We described a case series of five patients seen in our Emergency Department (ED). The circumstances surrounding their injuries and their presentations were reviewed. All our patients survived the ordeal and were discharged well back to their premorbid states. We explored the mechanisms by which lightning had caused their injuries and discussed the complications that might result as a consequence. We also discussed the actions clinician should take when faced with casualties of a lightning accident.

Keywords: Lightning; lightning-caused fatalities; lightning-caused injuries; lightning strike; environmental hazards.

Abbreviations

CK: Creatine Kinase; CTnI: Cardiac Troponin I; ED: Emergency Department; GCS: Glasgow Coma Scale; LOC: Loss of Consciousness; SNHL: Sensory Neural Hearing Loss.

Introduction

Lightning is a spectacular weather phenomenon. It has caused countless injuries to humans and considerable damages to properties. Singapore, lying near the Equator, has one of the highest lightning activities in the world [1]. An average of 171 thunderstorm days is recorded annually, with an average of 0.35 deaths per million populations (year 2000-2003) [2]. Although most reported cases dealt with lightning-caused fatalities, a large portion of lightning-caused accidents are not fatal [3]. Actual reported data showed that about 80% of lightning victims survived, with or without after-effects [1]. We described an incident of five casualties of a lightning strike seen in our Emergency Department (ED). This series is interesting as each victim had a differing presentation although all were in the same incident.

Case Series

Five victims, between the ages of eighteen to twenty-one, were brought to the ED. They were undergoing military training exercise on a knoll when caught in a sudden thunderstorm. They took shelter under a tree that was suddenly struck by a bolt of lightning. Two of them had loss of consciousness instantaneously; two others were knocked down to the ground, while one was unable to stand up from a sitting position. All were attended to by medics on site and military doctors at the Medical Center. All victims were referred to our ED for evaluation and management. All were admitted to the General Medicine Ward for further observation.

Case 1: The patient who fitted

A nineteen-year-old, Indian gentleman with no pre-existing condition presented with loss of consciousness, retrograde amnesia, chest pain, bilateral calf pain with paresthesia, and left ear fullness with tinnitus. Eyewitnesses accounted that he was seen to have jerking movements of his limbs for approximately fifteen seconds and upward rolling of eyes compatible with a seizure. By the time he arrived in ED, patient was oriented with a Glasgow Coma Scale (GCS) of fifteen. Physical and neurological examination revealed a decreased hearing acuity on the right ear. Otoscopic findings were normal. Bilateral calf tenderness was present. Results of laboratory examinations revealed markedly elevated Creatine Kinase (CK) levels of 1695 U/L (*normal range – 50-250 U/L*) on the 1st hospital day, 2043 U/L in the 2nd hospital day, 2038 U/L on the 3rd hospital day and 463 U/L on the 4th hospital day. Cardiac Troponin I (cTnI) levels were however normal. Patient was diagnosed with rhabdomyolysis. While in the ward, his chest pain and ear fullness resolved. He later complained of eye irritation on

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the 2nd hospital day and was referred to ophthalmology service. A diagnosis of conjunctivitis was made. All his symptoms eventually resolved, and he was discharged from the hospital on the 4th day. After discharge, he was followed up with ophthalmology and otorhinolaryngology services after two weeks and one week, respectively.

Case 2: The patient who could not stand

A twenty-one-year-old, Indian gentleman with good premorbid condition presented with bilateral hip pain radiating to the lower extremities. He was sitting about fifteen meters away from the tree when he observed the flash of lightning striking the tree. He was unable to stand up by himself immediately after. He was pulled away from the scene and stretchered out by his fellow servicemen. The pain and weakness eventually resolved after fifteen minutes and he was able to walk on his own unassisted. However, he still complained of paresthesia and pain on his lower extremities on arrival to ED. On examination, patient was alert, coherent, oriented, ambulatory with normal gait, and a GCS of fifteen. Physical and neurological examinations were normal. Laboratory results also revealed markedly elevated CK levels of 1560 U/L (*normal range – 50-250 U/L*) on the 1st hospital day, 2736 U/L on the 2nd hospital day, 1856 U/L on the 3rd hospital day, and 921 U/L on the 4th hospital day. A diagnosis of rhabdomyolysis was also made. Patient's condition continued to improve during his course of hospitalization. He was eventually discharged on the 4th hospital day.

Case 3: The patient who could not hear

An eighteen-year-old, Chinese gentleman, previously well, presented with an episode of loss of consciousness, retrograde amnesia, right ear fullness and tinnitus. He did not experience any chest or calf pain. No abnormal movement of his limbs was noted by eyewitnesses. On examination, patient was alert, coherent, oriented with a GCS of fifteen. Apart from a decreased hearing acuity on the right ear, physical and neurological examinations were normal. Laboratory examinations requested also revealed elevated CK levels of 531 U/L (*normal range – 50-250 U/L*) on the 1st hospital day, 371 U/L on the 2nd hospital day, and 312 U/L on the 3rd hospital day. Its values were not markedly elevated to warrant a diagnosis of rhabdomyolysis. Levels of cTnI were normal. While admitted, patient persistently complained of decreased right ear hearing acuity. He was evaluated by the Otorhinolaryngologist and an audiometry was done. A sensory-neural hearing loss (40-75 dB @ 250 Hz, 2 kHz, 4 kHz, and 6 kHz) on the right ear and a high frequency sensory-neural hearing loss (55dB at 4 kHz) on the left ear were noted. He was eventually discharged on the 4th hospital day and followed up with the otorhinolaryngology service one week later for repeat audiometry.

Case 4: The patient who was knocked over

A nineteen-year-old, Chinese gentleman with no pre-existing condition presented with left leg paresthesia and right ear tinnitus. He saw a flash of light; heard a loud noise and he was knocked and fell to the ground. He was able to stand on his own after the incident unassisted. He denied any loss of consciousness, seizure, and chest pain. The tinnitus eventually resolved but still had left leg paresthesia. On examination in the ED, he was alert, coherent, oriented, and ambulatory with a GCS of fifteen. Pulses were full and equal on both lower extremities. Neurological examination revealed normal lower extremities power, but patient had an antalgic gait. Laboratory examinations also revealed elevated CK levels of 1203 U/L (*normal range – 50-250 U/L*) on the 1st hospital day, 1123 U/L on the 2nd hospital day, 992 U/L in the 3rd hospital day, 597 U/L in the 4th hospital day. Patient improved while admitted with a decreasing trend of CK levels not compatible with rhabdomyolysis. He was eventually discharged on the 4th hospital day back to his premorbid condition.

Case 5: The fortunate patient

A nineteen-year-old, Chinese gentleman with good premorbid condition presented with bilateral ear tinnitus, and pain and paresthesia on both upper and lower extremities. He remained on his feet during the incident but was momentarily paralyzed and was unable to move for about ten seconds. He then felt pain and numbness over both the upper and lower extremities. On arrival in the ED, he was asymptomatic. He was alert, coherent, oriented, and ambulatory with normal gait and a GCS of fifteen. Physical and neurological examinations were normal. Laboratory examination also revealed elevated CK levels of 666 U/L (*normal range – 50-250 U/L*) on the 1st hospital day, 543 U/L on the 2nd hospital day and 329 U/L on the 3rd hospital day. Otorhinolaryngology service evaluated his tinnitus and audiometry performed revealed normal result. He was eventually discharged on the 3rd hospital day.

Table 1: *Outline of clinical presentations of our patients.*

	Case 1	Case 2	Case 3	Case 4	Case 5
Raised CK	+	+	+	+	+
Limb pain	+	+	+	+	+
Limb weakness		+			
LOC	+		+		
Amnesia	+		+		
Seizure	+				
Conjunctivitis	+				
SNHL			+		

Discussion

The acute management of patients with lightning injury presenting to the emergency department could be challenging. Emergency physicians should be aware, well prepared and respond appropriately and adequately to their conditions. The cardinal approach is to perform a thorough history and physical examination. It is also helpful to seek information from bystanders and eyewitnesses, as the patients themselves may not be able to give an adequate description, either because of the severity of injury or because of unconsciousness, confusion, and amnesia. The principle of reverse triage applies, in which the dead are treated first, as they may be resuscitated with rescue breathing alone.

Lightning injuries may occur as a result of six different mechanisms – direct strike; side flash; step voltage (also known as ground current); contact; upward streamer current and lastly blunt or concussive trauma as a result of shockwaves. A direct strike occurs when the lightning directly strikes the victim. It occurs in no more than 3% to 5% of injuries. Even though this mechanism seems intuitive to be the most likely cause of fatalities, this has not been shown in any studies [4, 5, 6]. A more frequent cause of injury, perhaps as much as 30% to 35%, is a side flash [4, 5, 6]. Side flashes occur when a lightning that has hit an object, such as a tree or building, travels partly down that object before a portion of the charge jumps to a nearby victim and cause injuries. More than 50% of the lightning injuries that take place outdoors are caused by side flashes from trees, when the tree is being used as a shelter from rain as in the case of our patients [5, 6]. Contact or touch potential injury occurs when the person is touching or holding the object to which the lightning strikes. It occurs in about 1% to 2% of injuries [4, 5, 6]. Step voltage is when the lightning hits the ground or a nearby object and travels through the ground to injure the victim. A recently identified mechanism is through connecting upward streamer current or leader current. Injury occur when a victim serves as the conduit for one of the usually multiple upward leaders induced by a downward stepped leader and its field during the event of the strike. It is probably a much underestimated mechanism of injury and may account for as much as 30% to 35% of injury cases [4, 5, 6, 7, 8]. Finally, victims may suffer from non-electrical blunt or concussive trauma as a result of shock waves created by the lightning. They may suffer from implosive and explosive forces created by the thunderclap with resulting contusions and pressure injuries, including tympanic membrane rupture and blunt trauma to major organ systems such as the brain, liver, and spleen.

It is noteworthy that victims of lightning strike are likely the result of multiple combinations of these mechanisms. It is the reason why victims present differently, and thorough evaluation is mandatory. In our series, the likely mechanism of injury was through a side flash as they were all sheltering under a tree struck by lightning. The concussive forces of the shockwaves produced by the lightning could also be considered as they complained of tinnitus and hearing loss. Those patients who complained of lower extremity cramps and numbness could be caused by step voltage mechanism wherein the lightning after hitting the tree, had traveled into the ground where our victims were sitting and standing.

The seizure experienced by one of the patients could be explained by the sudden large burst of electrical current into the nervous system disrupting the normal electrical activity of the brain. Seizures could also result from hypoxia and hemorrhage as a result of cardiorespiratory arrest and blunt trauma to the brain respectively. However, it is unlikely to be the cause in our case as our patient did not suffer from any of both events. The lightning victim may also experience loss of consciousness for varying periods [4, 12]. In a study conducted by Cooper, loss of consciousness occurred in about 72% of cases [4]. The lightning current can also affect the memory of the victim producing amnesia [4, 12].

Lightning can cause other minor symptoms that self-resolve, for examples, weakness, numbness and paresthesia [9, 11]. All of which were present in our patients. These symptoms could be due to intense vasospasm and vasoconstriction of blood vessels and restriction in blood flow (and thus oxygen) to a part of the body. The high current flow is thought to cause damage to the small blood vessels accompanying the nerves that control the muscles of the extremity involved, along with ischemia of these muscles [1]. It resolves spontaneously and requires no intervention [1]. This could also explain the mechanism of rhabdomyolysis as the case in two of our patients. The ischemia to the lower extremities as a result of vasospasm and the direct effect of the electrical current flowing into the muscle can result in muscle injury and eventual necrosis resulting in the release of muscle breakdown products such as CK11. In our study, all patients have elevated levels of CK. However, not all their CK levels were significantly elevated to warrant a diagnosis of rhabdomyolysis.

Our third patient suffered serious otologic injury in the form of sensory-neural hearing loss on the right ear and a high frequency sensory-neural hearing loss on the left ear. None of them have ruptured tympanic membrane that occurs in about 20–50% of lightning-injured victims as a result of the shock wave created by the lightning flash [1, 13, 14, 15]. In some reports, even if the tympanic membrane remains intact, the victims may still suffer from varying degrees of permanent hearing loss and tinnitus [1, 9, 13, 14]. This is probably caused by the damage to the hair cells and nerves in the cochlea either from the shock wave or by the flow of current through it. The blast can also cause damage to ossicles that will result in conductive deafness, especially at high frequency [1, 13, 14, 15].

The current passing through the head and the strong radiation produced by the channel may cause a series of medical problems in the eyes of patients struck by lightning. It can cause inflammation, edema, burns, opacities, and ulcers leading to iritis, conjunctivitis, uveitis and cataract formation [16]. Development of cataract is the most common long-term injury reported [17]. It can occur in either or both eyes as a result of heat produced due to the current flow or due to exposure of the eye to very strong optical radiation including ultraviolet light [17]. It may occur days or years after the injury. Many eye problems develop over a long period, and so prolonged surveillance of a lightning strike survivor is necessary [1, 16, 17].

Follow ups on all the patients after they were discharged from the hospital showed no permanent disabilities except for the patient who suffered sensory neural hearing loss as repeated audiometry showed persistent abnormal results. On the other hand, the patient who had mild conjunctivitis had recovered without any complication. Likewise, those patients who suffered from rhabdomyolysis had decreasing CK levels. As of the date of writing this paper, there have been no further ED attendances from these patients related to lightning injury.

Why should an emergency physician be aware of this?

Our case series showed that victims struck by lightning could present differently although involved in the same strike. This is the result of interplay of the different mechanisms. It also demonstrated that lightning caused incidents are not always fatal and that victims may survive with little or no side effects given proper medical treatment and management. It is however noteworthy to mention that victims of lightning strikes can have severe immediate and long-term complications, therefore follow ups are necessary. Given the magnitude of

injuries that can be sustained, these patients are best managed multi-disciplinarily.

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