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Deaths Caused by Lightning

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ABSTRACT: Though a rare cause of death, lightning is reported to be responsible for more fatalities each year in this country than any other type of natural disaster. Lightning injuries differ significantly from other high voltage electrical injuries because of the high current flow, but extremely short duration, of the lightning stroke. We present a series of cases over the period of 1985 to 1991 in Cook County, Illinois in which lightning was the direct cause of death. Our discussion reviews the nature of lightning, the effects it may have on humans, and the ways in which deaths due to lightning might be prevented.

KEYWORDS: pathology and biology, lightning, death, electricity, electrocution, accidental death

Though statistics vary concerning the exact number of fatalities, lightning causes several hundred deaths in the United States each year [*1–8*]. Like other electrical deaths, these cases are most common in the warmer months of the year. As expected, most individuals struck are engaged in outdoor activities. Examples of such activities include standing under a tree, working on farms or at construction sites, boating, swimming, or participating in field-sports such as golf. Lightning may strike individuals either directly or indirectly. Injury may be caused by either the electrical energy, the high temperature, or the explosive force of the strike. We survey the literature and review lightning deaths during the seven year period from 1985 through 1991 in Cook County, Illinois, which contains the large city of Chicago.

Cases and Methods

Among approximately 25 200 autopsies performed between 1985 and 1991 at the Office of the Medical Examiner of Cook County, Illinois there were five deaths (.02%) directly attributed to lightning strikes.

Case 1 involved a 17-year-old year old boy who was standing under a tree in a park with a friend to avoid the rain when he was struck by lightning. The strike occurred about 6:00 P.M. in late June. He survived in coma for 8 days in the hospital. Single

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thickness burns were present on the head, trunk, and legs. His companion survived the strike.

Case 2 involved a 40-year-old man who fell from a roof after being struck by lightning. He had been at work replacing gutters on a single story house in a suburban residential neighborhood. Witnesses stated he had been hit by an extension of a lightning bolt that had struck in the house's backyard. The strike occurred about 11:00 A.M. in late September. He was dead on arrival at the hospital. There were electrical burns of the head and thorax. A fernlike injury was seen on the abdomen in the emergency room, but had faded by the time the body was autopsied several hours later. Only minimal injuries were caused by the fall. Arc-marks were found on several coins in the victim's pocket.

Case 3 involved a 59-year-old man struck by lightning while fishing on a boat in Lake Michigan. The strike occurred at about 7:00 A.M. in mid May. He survived for 10 h in the hospital in coma with burns of the head, trunk and arm. According to witnesses, his jacket caught fire after he was struck. Lightning arc-marks were found on the boat.

Case 4 involved a 31-year-old man struck while standing under an umbrella on a golf course with several friends during a thunderstorm. Witnesses stated that lightning struck the umbrella and threw all four men to the ground. The strike occurred about 5:00 P.M. in early August. The victim died 21 h later in coma in the hospital. A small electrical burn of the leg was present on the leg of the deceased. The other three men survived.

Case 5 involved a 16-year-old boy struck by lightning while playing in a baseball game. An earlier rain had stopped, but the sky remained cloudy. He was witnessed to be struck on the top of the head by the lightning and knocked to the ground. The strike occurred about 7:00 P.M. in mid July. The victim was dead on arrival at the hospital. The deceased suffered electrical burns on the head, trunk, and legs. Additionally, there was singeing of the hair on the chest. Another player was also struck but survived.

In each of these cases the circumstances of the death were investigated, medical records were reviewed, and a complete autopsy was performed.

Findings

- All our cases involved young adult or middle-aged males. The five deaths occurred in suburban areas of Cook County, none took place in the city of Chicago.
- Seasonally, lightning deaths occurred in late spring, summer, or early fall. The time of day when strikes occurred was in the morning (Cases 2, 3) or early evening (Cases 1, 4, 5).
- Four individuals (Cases 1, 3 to 5) were involved in sporting activities—three in a park or field and one on a fishing boat. In these cases, others nearby either survived their injuries or were not harmed. One case (Case 2) occurred at work on a roof.
- In all cases but one (Case 5) it was raining. Four victims were apparently struck directly and one (Case 2) was struck by a "splash" stroke.
- All victims suffered cardiac arrest. Two victims were dead at the scene (Cases 2, 5) while the remaining three survived from less than 1 day to 8 days in coma.
- Obvious burns were present in four cases. In all of these cases there were multiple burns over various parts of the body, and in one (Case 4) there was a single small burn of the leg. None of the cases demonstrated significant blunt force injury.
- In two cases, examination of nearby objects supported the diagnosis of lightning—there were arc-marks on coins in a pocket (Case 2), and burned clothes and electrical damage to a boat (Case 3).

Discussion

Though a rare cause of violent death, lightning needs to be understood by forensic pathologists and investigators. Two recent fatal lightning strikes at championship golf

tournaments during the summer of 1991 demonstrate that lightning deaths often receive much publicity and may even raise significant legal issues. Lightning strikes, though uncommon, still reportedly cause more deaths in the United States than other natural disasters such as hurricanes, tornadoes, volcanoes, and floods [*1–3*]. The number of lightning deaths has apparently been decreasing in recent years, possibly due to increasing numbers of Americans living in urban areas sheltered by tall buildings. However, precise statistics on the number of persons killed by lightning in this country are difficult to obtain. Available sources place the number of deaths due to lightning each year somewhere between 100 and 600 [*1–8*].

Nationally, fatal strikes are more common in summer and fall, tend to happen in early afternoon and evening, and are more likely to occur in rural than urban environments [*4,6,7*]. In our series, all cases happened between May and September, during daylight hours, and outside the Chicago city limits. Because most lightning strikes occur during thunderstorms, the areas of the country at highest risk are probably in the regions of the Rocky Mountains, the South, and the East, where the numbers of such storms are greatest [*4,6,7*]. The states of New Mexico, Arkansas, Colorado, Delaware, Connecticut, Florida, North Carolina, and Texas are reported to have large numbers of lightning deaths [*4,7*].

Lightning may occur during snowstorms, duststorms, sandstorms, volcanic eruptions, nuclear explosions, and even on clear days [*6*]. However, usually it is associated with the large cumulonimbus clouds formed in thunderstorms. Turbulence causes charge separations to develop in these clouds and results in the lower layers becoming negatively charged. This negatively charged undersurface of the thundercloud induces a positive charge on the surface of the earth beneath the cloud, especially in higher structures like trees and buildings. Unless the differences between the charges becomes great, the air will insulate between the cloud and the earth. However, if the potential gradient becomes sufficiently large, current will arc between the cloud and earth creating a lightning stroke [*1–8*]. In such an electrical arc, current flows through high-temperature ionized air, which forms a pathway composed of positive and negative ions [*1*].

Lightning striking the earth begins as a relatively slow-moving leader stroke traveling from the cloud. This leader stroke is met by a pilot stroke rising from the ground. Once a connection is established, there is a rapidly moving and powerful return stroke as the differences in charge are resolved. Because the leader stroke moves more slowly, lightning is usually perceived as an arc traveling from the cloud to earth, though it actually moves in both directions [*1–8*].

There are various morphologies of lightning. Forked lightning has many branches. Streak lightning travels to the ground with no branches. Ribbon lightning appears as several side-by-side strokes. Additionally, lightning may appear in interrupted beads, as sheet lightning, or as ball lightning. People are primarily affected by lightning which strikes the earth, but lightning may also occur within a cloud or between clouds. Thunder is simply the sound of air that has been explosively expanded by the lightning stroke [*1,4–8*].

Lightning can strike a victim in several different ways. Strikes can be direct, as in most of our cases, when lightning strikes victims themselves or objects immediately overhead like umbrellas or trees being used as shelter from rain. Splash strikes occur when lightning strikes an object like a building then jumps to a nearby person who presents a path to ground of lower resistance. Ground current from lightning strikes may reach individuals standing nearby. These victims may be injured or killed because the stroke creates sufficient difference in potential between their feet to cause current to flow through their bodies [*1–8*]. Finally, individuals may rarely be struck indoors by lightning while using the telephone or electrical appliances. In these cases, the lightning surge may energize a house's structure causing current to flow through the victim into the grounded telephone or appliance. Also, lightning may strike a cable causing connected telephones to become electrically charged [*9*].

Though lightning is essentially very high voltage direct current (between 10 million and 100 million volts), the effects of lightning are much different than those caused by other types of high voltage electricity [*7*]. These differences are principally the result of the extremely short duration of electrical contact in lightning strikes. The comparatively long duration of contact in other high voltage electrocutions usually produces charring of the tissue. Most of the energy of a lightning stroke, however, so quickly flashes over the skin of the victim that severe skin breakdown rarely occurs. Moisture on the skin may vaporize, blowing the clothing off. Also, the clothing may catch on fire, as in one of our cases. Both the hot water vapor and the burning clothing may contribute to whatever skin injury is present [*1,10*].

Surprisingly, despite the vast amounts of energy involved, only 20 to 30% of lightning-strike victims die. Just as other electricity is conducted predominantly along the outer surface of a wire, when a person is struck by lightning most of the current apparently flashes over the skin surface of the victim. Thus, little current may actually pass through the heart and central nervous system—the tissues most vulnerable to electrical disruption. Additionally, if it passes through the body, lightning causes a large direct current (DC) shock to the heart, depolarizing all the heart muscle at once and causing asystole. In contrast, most electricity commonly is alternating current (AC), which tends to induce ventricular fibrillation. With complete cardiac standstill, it is reportedly more likely that the heart's automaticity will cause spontaneous resumption of a normal heart rhythm [*1*].

Individuals who have not arrested after being struck by lightning rarely die. Of those who do suffer arrest, over 75% do not survive. Certain other findings have been associated with death. Victims with leg burns or head burns are reportedly much more likely to die than victims without these injuries—four of our cases had such burns. However, there is apparently no correlation between age, sex, trunk burns, or arm burns, and survival [*1*].

Victims suffering fatal cardiac arrest due to a lightning strike may not be dead on arrival at the hospital. Three out of our five cases survived in coma as inpatients after being struck. Thus, pathologists handling these cases may need to carefully review medical records for descriptions of any injuries. Some cutaneous burns may become more visible as hours pass after the injury. However, other findings, such as the often described fernlike injuries, found both in lightning strikes and high-voltage technical electrocutions, may fade over time, as occurred in one of our cases. Patients who survive lightning strikes may also suffer ophthalmic, otologic, psychiatric, pulmonary, renal, gastrointestinal, musculoskeletal, and peripheral neurovascular complications. However, though these sequelae may cause morbidity, they are seldom related to death [*1–6,11–18*].

Of particular clinical, and occasionally legal significance, is the observation that resuscitation of lightning victims has a better chance of success than it has with persons suffering cardiopulmonary arrest from other causes. For this reason the American Heart Association includes lightning in its group of special resuscitation situations for Advanced Cardiac Support [*4*]. The triage of multiple lightning-strike victims differs from usual procedures. Typically, treatment of apparently dead victims in a disaster may be delayed in order to focus on those still alive. However, with multiple victims of a lightning strike, treatment is concentrated on those who have arrested and appear dead. This approach is based on the high likelihood that those who have arrested can be resuscitated and on the very low probability that those showing signs of life after the strike will die [*1–4,19*].

When lightning deaths are witnessed, investigation of the circumstances of death is straightforward. If there are no reliable witnesses, however, there may be questions about the cause of death. In such cases a more diligent search for evidence at the scene of the death is needed. Gathering this information may be complicated by delay if the deceased has spent substantial time in coma before death. At the scene of a lightning strike there

may be damage to nearby trees such as splitting or removal of bark. Charred arc marks may be present on the walls of nearby structures. In one of our cases there was visible lightning damage to the victim's fishing boat. The ground may display a fern pattern in the grass resembling the cutaneous discoloration seen on some victims. When lightning is suspected to have caused the death of a person inside a building, nearby electrical and telephone equipment should be examined for signs of lightning damage. Clothing of lightning victims, particularly shoes, may have been torn by the lightning's explosive effects. Finding a victim of lightning in a remote location with the clothing in disarray may even suggest sexual attack. Any metal objects that the victim was carrying or wearing may have burned underlying skin or been marked by the heat of electrical arcing [*7*,*20*].

After careful examination of the clothing, a thorough autopsy should be performed to look for further evidence of injury by lightning. Unlike other types of electrocutions, burns, if present, are most likely to be on the head, torso, or legs rather than on the hands and arms. The skin may show clusters of punctate burns caused by electrical arcing, or may show singeing of hair, as in one of our cases. Unique fernlike or arborescent injuries, in addition to more typical thermal burns, may be present. Rupture of the ear drums may have occurred, due to the explosive blast of the stroke. Also, fractures may have been caused by these explosive effects or by electrically induced muscular contractions [*7*,*20*].

There are a number of preventive measures that reportedly reduce the danger of being struck by lightning. Had these guidelines been followed, probably none of our cases would have occurred. Seeking shelter indoors at the time of a thunderstorm is the safest approach. Even if buildings or automobiles are struck, the lightning will usually pass over the surface of the structure and not injure the occupants. Avoid using the telephone or electrical appliances. Do not stand between two open windows or doors because lightning may cross between them. Outside, individuals may be struck who seek shelter under tall, isolated objects like trees. Also, stay away from isolated equipment, like tractors, and stay away from bodies of water. Put down objects that may act like lightning rods, such as golf clubs, umbrellas, or fishing poles. Seek shelter in dense woods if no buildings are nearby. If caught in the open without shelter, lie in the lowest place possible, preferably on insulating material, such as a raincoat, to reduce electrical grounding [*4*,*7*].

In conclusion, lightning deaths in Cook County show many similarities to other reported cases. In all our examples, the strikes occurred outdoors, in warm weather and in an open area. Most or all of the deaths probably could have been prevented, had precautions been taken. Cardiac arrest with resultant cerebral anoxia was the mechanism of death in all cases. Interestingly, only two victims were dead at the scene—three remained hospitalized in coma for varying lengths of time. Four of our five victims had demonstrable burns at the time of autopsy on the head and legs, which have been associated with poor prognosis [*1*]. Additional lightning damage was documented on the clothing of a victim, coins in a victim's pocket, and on the hull of a fishing boat. Though the diagnosis of death by lightning is often obvious, subtle cases may be missed. Forensic pathologists need to understand the effects of this natural phenomena in order to conduct appropriate investigations and autopsies of suspected lightning fatalities. We support the recommendation of Masselo that death due to lightning should be suspected whenever an individual suffers fatal cardiac arrest during or immediately after a thunderstorm [*7*].

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