DISABILITY, NOT DEATH, IS THE MAIN PROBLEM WITH LIGHTNING INJURY

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Abstract

Meteorologists and others interested in lightning have, in the past, concentrated their concerns on cataloging and preventing lightning fatalities. However, disability from lightning-strike injuries is a far greater problem. While lightning has been exceeded only by flash floods as a storm killer for the last thirty years, it causes fatal injury to only about 9-10% of those it strikes. While death is devastating, the family eventually can go on. Far more pervasive changes to the family may occur if the survivor is disabled.

Survivors tend to be young, otherwise healthy, productive working people often with families to support. Many survivors are unable to return to work or to resume their previous lives necessitating many changes in the family structure, economic level, and dreams and plans for their future.

The primary areas of disability involve neurocognitive functioning, which manifests itself as deficits in short-term memory, processing of new information, personality changes, easy fatigability, and decreased work capacity. Chronic pain syndromes, sleep difficulties, dizziness, and severe headaches are also often reported. Those who attempt to return to work often find they are unable to carry out their former functions and after a few weeks, when coworkers get weary of 'covering' for them, they either are put on disability (if they are lucky) or fired. Survivors often find themselves isolated because friends, family and physicians do not recognize their disability or feel they are 'faking'.

1. Introduction

Lightning has been one of the main storm killers for the last century (Lopez and Holle 1998; and see Table 1). Lopez and Holle have documented the social and demographic changes in the mortality as well as the changes in the ratio of those killed to those injured but surviving (Holle et al. 1999; Lopez and Holle 1998). The deaths have decreased from 6 per million reporting population early in the century to 0.3 to 0.5 per million in the last decade (Lopez and Holle 1998). They attribute this to better warning systems, population shifts to the urban areas and away from the higher risk rural areas and lifestyles, improved construction of homes, and from improvement in medical care as well as it being more ready available in the urban setting. In the last thirty years, lightning has been the number 2 storm killer (National Weather Service 2001).

2. Scope of Problem

Although the National Weather Service (NWS) uses Storm Data as its official report of the lightning injuries and deaths, the reports are taken from newspaper clippings and necessarily exclude those whose injuries are not published in the newspaper, resulting in under-reporting. While it may be surprising to some, it is not uncommon for survivors to delay medical care until days after their injury when it becomes apparent that their symptoms are not going away or may be worsening. Obviously, their accounts will not show up in the press clippings or NOAA/NWS *Storm Data*.

Even those who seek medical care are admitted to the hospital less than one third of the time so that they will not be counted in hospital admission data banks maintained by most states (Cherington et al. 1999). Studies done during the 1990's that compared Colorado's state data banks of emergency medical visits, hospital admissions, and death certificates with *Storm Data* for the same periods, showed that deaths are under-reported by as much as 11-28% and nonfatal injuries by as much as 42-49% in Colorado (Cherington et al. 1999; Lopez et al. 1993).

In the first organized study of lighting injuries, Cooper (1980) demonstrated that lightning injury was fatal about 30% of the time. Andrews (1993), analyzing similar data for his dissertation, found similar numbers (20%) by using slightly different calculations. Both studies tend to overestimate the fatality rate as they are taken from a compilation of retrospective published case reports, which are usually biased towards the more severe and unusual injuries in order to be acceptable for publication. Cherington et al. (1999) have confirmed what most experts have felt to be a more likely rate of fatality of 9-10% based on 100 injuries they tracked with nine fatalities suffered.

Using Cherington et al. (1999) and Lopez et al. (1993) findings, it is possible to project from the most recent thirty-year numbers (NWS 2001) what may be a more realistic number of injuries and fatalities (Table 2).

a. Causes of death

The only cause of immediate death from lightning is cardiac arrest or the complications of a cardiac arrest (Cooper 1980). Delayed causes include suicide due to depression that can come as a result of the disabilities and life changes that can accompany lightning-strike injuries (Cooper et al. 2001; Lightning Strike and Electric Shock Survivors, International, Inc., 1996, 2000).

b. Causes of disability

Lightning causes primarily a neurological injury. The primary causes of disability are from injuries to the nervous system such as: neurocognitive deficits from brain injury (Cooper et al. 2001; Primeau et al. 1995; Pliskin et al. 1998; Heilbronner and Pliskin 1999), sympathetic nervous system damage and peripheral nervous system injuries regarding sensing pain, temperature, etc. (Cooper et al. 2001).

An analogy that is useful to imagine is of a computer that has had a lightning shock pass through it. The outside of the case will usually appear unharmed (as the person does externally), the boards and circuits within will appear normal to the eye if the case is removed (as CT's, MRI's and EEG's are with people as well) but the 'software', the processing of information, no longer works when the machine is booted up. So it is with people where the neural circuits that they relied on for the basic activities of living such as memory, learning, organization of tasks, personality, sleep patterns, concentration and attention to task are scrambled as well. Lightning injury tends to be a frontal lobe injury, which is where personality resides. One patient related it as being like, 'the office manager of my brain quit.' These deficits have a distinct pattern that has been well characterized with neurocognitive testing (Primeau et al. 1995; Pliskin et al. 1998; Heilbronner and Pliskin 1999).

Some patients, usually after a few months, will develop an absence type of seizure activity where they stare off into space or may even be capable of doing automatic activity without remembering. These are frontal lobe effects as well and not readily picked up on EEG's.

A few patients will complain of palpitations or difficulties with their blood pressure. It is unclear if this is due to direct damage or from nervous system injury since the sympathetic nervous system controls the autonomic (automatic) functions. Clinically, there is no question that there is damage to the sympathetic nervous system and brainstem both from the acute presentation as well as from chronic problems that some victims develop of dizziness, sleep disturbances, and other problems. Some develop a particular kind of intense pain syndrome connected with sympathetic nervous system injury which is difficult to manage and nearly impossible to cure.

Table 1. Annual severe weather fatalities based on data from 1971-2000 (NWS 2001)

Floods	127
Lightning	73
Tornadoes	68
Hurricanes	16

Table 2. Annual fatal and nonfatal injuries from lightning based on data from 1971-2000 (NWS 2001) and estimates from under-reporting based on Cherington et al. (1999) and Lopez et al. (1993).

Documented Annual Average deaths	73
Annual estimated deaths (+28% under-reporting)	93
Annual Estimated Nonfatal Injuries (fatalities x 9)	837
Annual Estimated Total Injuries	930

3. Lightning Injury Is Not Like High Voltage Electrical Injury

High voltage electrical injury can cause devastating deep injuries with destruction of entire extremities. A 'common sense' conclusion would be that lightning, with its tremendously high energies, would cause similar injuries. However, lightning doesn't read electrical engineering treatises or lightning protection code books so that 'common sense' conclusions about lightning's effects, particularly the medical effects, are more often wrong than right (Cooper et al. 2001).

While lightning is certainly an electrical phenomenon and should follow the same laws of physics as other electrical events, several characteristics of lightning including the very rapid rise and fall times make lightning's flow through and around the human body poorly understood. However, physical and neurological effects have been well characterized (Andrews and Darveniza 1989; Andrews et al. 1989, 1992; Andrews 1993; Cherington et al. 1992, 1995; Cooper 1992a, 1992b, 1994, 1995A; Cooper et al. 1992).

As little as 3-5% of lightning injuries will resemble high voltage injuries and burns (Cooper 1995a, 1995b; Cooper et al. 2001). To produce a burn, a heat source must be in contact with the skin long enough to cause skin breakdown. We theorize that the very short exposure time (usually on the order of a few microseconds) is one of the factors that causes the energy that the body actually experiences to be much less than atmospheric measurements of lightning's energy would predict and certainly too short for substantial skin burns to occur. There is good evidence that a great deal, if not most, of the lightning energy courses around the body in an effect called 'flashover' so that the body experiences little internal flow of the energy. Experimental evidence from animal studies suggests that some of the energy may enter through the orifices of the body (eyes, ears, nose, mouth) leading to some internal flow (Andrews 1993).

Burns that occur with lightning are generally quite minor and superficial and sometimes secondary to the flow of current around the body turning sweat or rainwater into steam. This conversion to steam and result-

ing vapor 'explosion' can cause clothing and shoes to be blown off the individual in addition to causing streaking burns or blisters from the steam itself depending on the length of time it is held in contact with the skin by clothing or other objects. Metal worn by the victim can also be heated and cause secondary thermal hot metal burns similar to coming in contact with a hot iron, leaving an imprint that often mirrors the shape of the metal. An odd finding that occurs with no other trauma than lightning is the 'keraunographic markings' or Lichtenberg Figures that appear as a fern-like pattern on skin. It is a brownish skin marking that is not a true burn and usually passes within a few minutes to hours after the strike (Andrews et al. 1992; Cooper et al. 2001).

4. Impact on the Individual and the Family

Death from lightning, however anguishing to the family at the time, will eventually be accepted and the family will go on. However, disability of the breadwinner, the homemaker or a child may be much more devastating to the family.

Often the individual who attempts to return to work finds that their short-term memory is affected and that they may not be able to process new information to the extent they used to. They are not able to understand or retain instructions, organize their work, or 'multitask.' They suffer easy fatigability and are not able to work an entire day. Their co-workers and employer may initially give them some slack and 'cover' for them. However, after awhile, it becomes evident that they will not be able to continue in their employment position. If the injury was work related (over a third of injuries are; Lopez et al. 1993) and the individual is lucky, they may receive workers compensation and disability benefits. For the common worker who often does not maintain separate disability coverage, this compensation is often at a rate that is far below what the individual and their family received when the person was employed, leading to impoverishment of the family.

More often, the worker is fired and receives no benefits. The worker may need to employ an attorney to negotiate for benefits with variable success in finding an attorney who will believe in the victims claims. Some attorneys may 'churn' cases, settling for amounts that are inadequate to buy a new car, much less support a family for years especially when attorney fees and court costs are subtracted. In most states, the workers compensation settlement will cover only the worker's medical expenses, minus the attorney's fee.

If the victim was injured in a non-work related activity, initial applications for social security (SS) are often rejected. Simkins, an attorney who has befriended the Lightning Strike and Electric Shock Survivors, International, support group reported in a 1996 lecture that SS routinely denies 90%+ of initial claims in a simple attempt to cut down its paperwork; only about 30-40% of people appeal the initial denial.

The child who is injured may exhibit personality changes, which may manifest as behavior problems, often covering the learning deficits that they have developed. For the younger patient, parents have difficulty getting schools to understand or accept that lightning may cause brain injury and learning disability. It becomes difficult to obtain the rehabilitation and extra educational resources required by federal law for learning disabled individuals, particularly in school districts with limited resources.

For the adolescent survivor with brain injury, parents and schools may have difficulty separating injury-related personality changes and behavior problems from the normal changes in behavior, sleep patterns, and family relationships that may occur in teenagers. Added to the 'normal' rebellion and nonverbal nature that some adolescents develop it becomes a difficult problem for all involved when the brain-injured teenager reacts to his/her frustrations with anger and self-isolation.

Self-isolation is a problem even with adults. The survivor often encounters a resistant medical profession who sees their complaints as attempts to receive undeserved compensation or pain medications. Most of the injuries (neurocognitive, pain, frontal lobe seizures) are not easily documented or quantified with standard medical tests. They do not show up on CT scans, MRIs, EEGs or EMGs for various technical reasons. The unrelenting post-traumatic headaches are not amenable to the normal pain medications.

Socially, the survivor's former friends may no longer invite them along because, for example, they get lost in the fields hunting or they don't know how to keep score at bowling anymore. The personality change, self-isolation and depression of the individual may be seen as the cause rather than the affect of the person's disability. Family members may insist that the person 'just snap out of it'.

Some adult victims with more severe injuries may be unable to be left unsupervised. The spouse or guardian may not be able to continue to work because of fear that the injured person will leave the stove on and burn down the house, wander away from the home, or do other socially inappropriate things. The change in family dynamics, financial pressures from unemployment or inadequate compensation, and increased burden to the caretakers bring a tremendous amount of pressure to the family, sometimes causing breakups or even suicides (Cooper et al. 2001; Lightning Strike and Electric Shock Survivors, International, Inc., 1996, 2000).

5. Conclusion

While the death of any individual from lightning is regrettable, in reality, the disability suffered by many lightning survivors is a much bigger problem. Whether it is the breadwinner of the family, the homemaker or a child that is disabled, it can be devastating to the family. Their dreams for the future change and much of the family's plans and daily activities must be centered around the disabled person who may not be capable of returning to work or the child who is unable to pursue their education to become the independent and productive citizen their parents had hoped.

Prevention of injury, survived or not, should be the goal. Education of broadcasters and other operational meteorologists about the importance of warning the public of severe weather in their daily broadcasts, perhaps revision of lightning and severe weather warning practices by the National Weather Service, inclusion of lightning safety guidelines by parks, recreational facilities, schools and organized sports events, and education of the public of the risks of lighting injury will all help to prevent injuries.

Author

Mary Ann Cooper, MD, received her BS in Biochemistry from Michigan State University in 1971 and continued at Michigan State for her medical degree in 1975. Her residency training was in Emergency Medicine (1978) at the University of Cincinnati, the first emergency medicine program in the US. During her residency she developed an interest in electrical injuries and progressed to lightning injuries for which she is considered one of the world's experts in this narrow field.

In addition to her continuing clinical duties as an online emergency physician at the University of Illinois Hospital, her role as an Associate Professor at the medical school involves teaching medical students and residents, serving as a senior faculty member on university and medical school committees and directing the Lightning Injury Research Program. Her research interests span prevention to clinical interventions to development of an animal model of lightning injury. In addition to Emergency Medicine, her primary specialty, she also holds faculty appointments in the Departments of Neurology and Bioengineering.

The Lightning Injury Research Program at the University of Illinois at Chicago does basic research into the cellular mechanisms of lightning injury, hoping to eventually improve diagnostic and treatment methods. It also attempts to assist in understanding and prevention of these injuries by participating in documentaries and media interviews, answering technical medical questions about lightning, networking inquirers and lightning victims and their families, working with individual physicians, communicating with other lightning researchers (meteorologists, physicists, engineers, etc.), and encouraging injury prevention. The Lightning Injury Research Program's Web site is at: www.uic.edu/labs/lightninginjury.

Dr. Cooper recently received a Special Recognition Award from the Lightning Strike and Electric Shock Survivors, International, support group for 'wisdom, mercy, gentility, and humanity' in serving on their board of directors, initiating an endowment fund and gathering donations for it, publicizing the group and providing support, advice, and guidance for the officers and members of the organization. In addition, she was recently awarded a "Special Award" from the American Meteorological Society "for outstanding work on the medical effects of lightning which has enhanced the treatment of lightning strike victims and revolutionized lightning safety worldwide."

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