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How Lightning Kills and Injures

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1. INTRODUCTION

Although lightning fatalities continue to decrease in the United States (Fig 1), lightning continues to be one of the leading causes of weather fatalities (Fig 2). The only acute cause of death from lightning is cardiac arrest at the time of the injury even if the actual pronouncement of death is delayed for a few hours or days by resuscitation efforts (Cooper 1980).

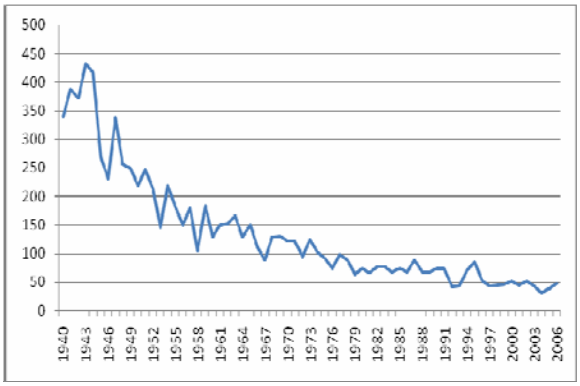

Figure 1. Lightning fatalities for the United States from 1940 through 2006 (NOAA 2007).

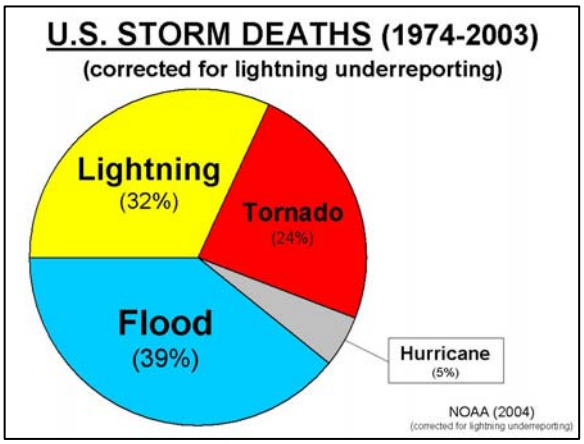

Figure 2. Weather related deaths in the US (1974-2003) by weather phenomena. (NOAA 2004). Lightning is the 2nd leading cause of storm deaths over this 30 year period (From Roeder, 2008).

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Due to underreporting of injuries as well as deaths (Cherington 1999; Duclos 1990,1990a; Holle 2003), it is difficult to pinpoint an exact percentage of deaths vs. injuries. However, 10% has long been used as the common 'rule of thumb' mortality rate for the United States. Of the 90% who survive, many may suffer significant disabilities.

2. MECHANISMS OF INJURY

Mechanisms of lightning injury are more complex and varied than usually assumed by the general public and reported by the media. While it is difficult in many cases, given the reporting, to be sure of the exact mechanism, on review of hundreds of cases, Cooper (2007) estimated the distribution of mechanisms as listed in Table 1. The 'direct' strike, although dramatically ascribed as the cause of injury in most media reports, probably occurs in as little as 3-5% of cases. Contact potential, where the person is touching an object that is hit such as plumbing, hard wired electronics, headsets or telephones, occurs in as little as 1-2% of the cases. Side flashes from other objects such as trees or towers are much more common and are estimated to be the causative mechanism in approximately one third of the cases. Ground potential or earth potential rise, whether ground arcing or ground current, is by far the most common mechanism, occurring in as much as half of the cases. Injuries caused by an upward streamer that does not attach to the main lightning account for the remainder of the injuries, perhaps as much as 20-25% but are probably the hardest to document (Cooper 2002). It is not unlikely that there is a combination of these mechanisms occurring, especially when multiple victims are involved (Anderson 2001).

Table 1. Mechanisms of Lightning Injury

Mechanism	Frequency
Direct	3-5%
Contact Potential	1-2%
Side Splash	25-30%
Earth Potential Rise / Ground Current	30-50%
Upward Streamer	20-25%

3. PRESENTATION OF LIGHTNING INJURY

Unlike gunshot wounds where a specific entry and exit wound may be found, or high voltage electrical burns, where massive internal injuries and external burns are often extensive and deep, lightning generally causes few significant external signs of injury in the majority of cases. This is due to several factors, including the physics of lightning, flashover, the decreased or modified energy levels that occur with the most common mechanisms of injury (Table 1), inadequate exposure time for burns and other skin damage to occur, and perhaps other factors not yet described (Cooper 2007).

In a study of survivors, less than one third suffered any external marks or burns (Cooper 2007). Although occasionally deep burns similar to high voltage injury can occur, they are rare in the population seen in the US and other economically developed countries. Occasionally, blunt trauma can be seen either from the person falling, being thrown by involuntary muscle contraction induced by lightning energy or perhaps barotrauma from the stroke itself.

Lightning is primarily a nervous system injury, involving injury to any or all of the three divisions of the nervous system. Since nerve tissue does not heal well, survivors may have permanent damage or disability including chronic pain due to peripheral injury or thought processing and attention problems due to brain injury. Autonomic injury has also been described with positive tilt tests, dizziness, changes in sweat and temperature patterns, hypertension and rarely cardiac arrhythmias. The discussion of nerve injury, healing, cell death, scarring and resulting change in function is far too complex to include in this paper.

A more extensive discussion of the medical presentation of lightning injury as well as a complete bibliography of lightning injury publications is available at www.uic.edu/labs/lightninginjury.

4. DIAGNOSIS AND CARE OF LIGHTNING INJURY

The physics of lightning is far better understood than the pathophysiology of lightning injury. There is no 'gold standard' or unequivocal test that can validate lightning injury in all who claim it nor are there easily available, inexpensive, simple or easily interpreted tests that can measure the extent of injury. While similar brain and cognitive injury has been well documented with technical electrical injury where more research and funding has been available, it is unclear how these deficits occur, particularly when the brain is not in any way in the pathway of electrical current.

Care and rehabilitation is also far from well-defined or exact. It varies with the clinical judgment and expertise of the professionals involved, family or patient self-advocacy and follow-through, patient resources, resource management and availability as well as the severity and range of injury suffered by the survivor.

5. STUDIES OF LIGHTNING INJURY

Research on the medical consequences of lightning injury has been sparse, in large part because of lack of funding as well as few injuries and deaths relative to areas such as cancer, heart disease and HIV. One of the current more active research groups is the Chicago Electrical Trauma Program which performs multidisciplinary evaluations of survivors of electrical and lightning. Unfortunately, the funding for the majority of these evaluations comes primarily from cases in litigation, obviously biasing the sample.

One of the areas of investigation involves use of a powerful research magnet to perform functional MRI (fMRI) of the brain. The commonly available clinical diagnostic MRI is merely an anatomic or static picture. An fMRI differentiates between actively functioning vs resting areas of the brain, 'lighting up' based on the concentration of oxygenated hemoglobin. By using activities or tests designed to target language perception, for instance, areas of language processing can be differentiated from those used simply to hear verbalized nonsense sounds.

In the case of lightning injury, a test was developed to study attention deficit, a large factor in the cognitive deficits that lightning and electrical survivors often suffer. Normal, matched controls performed the same tasks. Preliminary findings were initially surprising but, in fact, also supported another frequent problem of easy mental fatigability that many survivors find incapacitating. Since the majority of the study subjects were injured by electricity, more lightning survivors need to be studied before the findings can be generalized.

6. STAGES OF LOSS AND RECOVERY

Survivors of lightning injury suffer the same stages of loss initially described by Elizabeth Kubler-Ross in her landmark study, 'On Death and Dying'. In fact most people who have serious loss, whether a job, a disability, or the loss of a loved one suffer these same stages to a more or less extent.

These stages are:

1. **Denial** -- 'This can't be true; it didn't happen to me; I'll wake up tomorrow and it will be gone and I'll be like I was before.'
2. **Anger** – Since it is hard to be angry at lightning, anger is often displaced to the family, to physicians or comes out as an angry 'I'm going to lick this' attitude.

3. **Bargaining** – 'If I can just find the right pill / right exercise / right doctor, etc, this will all go away.' This stage can lead to desperate searching for magic answers that do not exist.
4. **Depression** – From experience, we expect that most problems such as a sprained ankle or laceration will resolve in a specific and finite time. When symptoms do not resolve or improve in a few weeks or a few months, the patient must face the reality that they may never resolve, resulting in despair and depressive symptoms.
5. **Acceptance** – With good support, and depending on the survivor's personality and other factors, many learn to accept their limitations, put them in their place and move on with the rest of their lives.

None of these stages are 'clean' but overlap and recur during the post-injury and recovery period. They are a normal physiologic response to loss and, like physical and mental recovery from other illness or injury, take their own time and cannot be rushed. The acceptance stage, for instance, rarely occurs before two to three years post-injury.

7. SUMMARY – PREVENTION OF INJURY IS ALWAYS BETTER THAN TREATMENT

Since there is no medical therapy or intervention that is known to stop the cascade of injury and disability once it is set in motion with the initial insult, it is far better to prevent the injury than to treat the survivors.

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