WHEN LIGHTNING STRIKES...
BEFORE AND AFTER!

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Introduction

To date in 2017, in the United States, 15 people have been killed by lightning, and on average 31 people are killed per annum [1]; in Canada that number is approximately 10 per annum with another 164 people injured.[2] Outdoor recreation activities have accounted for over 70 per cent of those previously killed and over 62 per cent of those injured by lightning in Canada.[3] It is hypothesized that as global temperatures rise, more and more lightning storms will occur. The number of lightning strikes hitting the surface of the earth is predicted to increase 12% for every degree Celsius of warming.[4] If this prediction is proven to be true, that represents a significant increase in risk to those undertaking recreational activities and those working remotely. Preparation and planning will be of utmost importance in avoiding lightning related injuries. In this article we will outline information about lightning, lightning safety, and management of lightning injuries.

Thunder and lightning

Thunder is simply the sound of lightning - if you can hear thunder, there is lightning somewhere. But how do thunderstorms form in the first place? The recipe for a thunderstorm contains three crucial elements: moisture, warm air at the surface of the earth, and a lifting mechanism like a draft or wind. Warm, moisture laden air is forced upward by a vertical updraft, and condenses and cools, forming cumulonimbus clouds. The moisture freezes into ice particles with the rise of these clouds into freezing temperatures. As these ice particles collide and bounce off each other, little pieces break off creating electrical charges. The sum of many of these electrical charge producing collisions ultimately create the bolt of lightning.[5]

In general, if thunder can be heard, the storm is within 16 km. Be wary of blue skies; they don't mean safety, and you can be struck by lightning that is 16 km away. A typical atmosphere to ground lightning strike carries approximately 100 million volts of electricity producing approximately 27,000°C heat.[1] To put this in perspective, that temperature is five times hotter than the surface of the sun.

Approximately 5% of lightning strikes are direct strikes, and 60-80% of strikes are ground current and side flash related strikes. This means that more often than not, lightning strikes an object and then the electrical current is distributed around the object and surrounding area. This distribution may extend to 20m. [6] Although wood is not supposed to conduct electricity, at these extremes of voltage and heat, non-conductive materials like wood can actually become conductive. A large tree gives no protection whatsoever; in fact, large trees become a liability as lightning normally strikes taller objects. Do not seek shelter under a tree in a thunderstorm.

Approximately, 10-15% of lightning strikes are the result of an 'upward leader'.[2] Prior to an atmosphere to ground lightning event, positively charged particles at ground level start to move toward the negatively charged particles in the atmosphere.

Staying safe

First, realize that nothing replaces good planning. If storms are forecast, postpone or modify your activities. If caught in the elements, a building, or a vehicle with a steel roof are the safest places to survive a thunderstorm (Grade 1C).[7,8] The steel construction of the frame of the vehicle will ensure that the electrical current does not pass through you even if it is a direct lightning strike hit (due to its electrostatic shielding, i.e. Faraday cage, properties). Vehicles with soft tops will not afford you the same protection, if any at all. Once inside your vehicle, avoid direct contact with any metal object. It is a common misconception that it is the rubber tires that keep you safe but under such tremendous electrical loads, tires have little to no effect on your safety. If sheltering in a building, stay away from any sources of electricity including phones lines.[7] Some buildings are also protected by conventional lightning protection systems. Many industrial sites also use lightning detectors and when the lightning is within a certain distance (although no obvious signs of a storm may be evident), work may be suspended.

The 30/30 rule is a safety measure often employed in industrial settings. This rule states that you when you see lightning, start counting normally i.e. every second. If you do not get to 30, it means that the storm is within 6 miles or 10 km. Remember, lightning can strike you within 10 miles or 16 km. The second 30 simply refers to the amount of minutes one must wait before returning to the outdoor activities. So when you hear the last thunder or see the last lightning, wait for 30 minutes before returning to activities or work (Grade 1C). [7,8]

Lying down is one of the worst things you can do. As an absolute last resort (and only to be used if you are unable to get to shelter), use the crouching position to protect yourself.[7,8] Crouch down with your heels together on the balls of your feet. Cover your ears as the sound of lightning is extremely loud. The hypothesis (and it is just that) is that even if lightning energizes the area around you, because you are on the balls of your feet (thus minimum contact area) and your heels are together, the current will flow up one foot and exit down the other foot. If this works as expected, the current will not be allowed to pass through the midsection of your body, thereby missing all of the vital organs. There is no guarantee that this will work (Grade 2C), therefore your best protection is to plan ahead and always to seek shelter. It is good to practice the crouch position in advance as it is initially quite difficult to hold.

If you feel your hair standing up or your skin "crawling", or hear hissing, crackling and popping sounds, you are likely near an 'upward leader'; assume the crouched position immediately as a lightning strike is possibly only seconds away.

Lightning injuries

Lightning injuries can exist in a full spectrum from minor to life threatening, and can affect all body systems. Here we will focus on some of the more lethal injury presentations. It is important to state that lightning patients do not hold a residual charge in their bodies, and thus they can be handled safely by rescuers (assuming the storm itself is not placing rescuers at undue risk).

Cardiovascular System

Injuries can range from minor ECG disturbances to lethal arrhythmias such as ventricular fibrillation. While earlier studies demonstrated asystole was the most common presenting rhythm [9], recent research has shown that ventricular tachycardia (VT) and ventricular fibrillation (VF) are significantly more prevalent than previously thought.[10] Wetli (1996) demonstrated that in half of cases the initial presenting rhythm reported by paramedics was VF with asystole accounting for 40%. This highlights the need for prompt resuscitative efforts.

Less deadly arrhythmias like atrial fibrillation are also possible, but rarer.[11–13] One other potential cardiovascular change that is reported is QT interval prolongation, including a case of QT interval prolongation of 500 ms two days after being struck [14], and a case of QT interval prolongation of 680 ms which normalized after 1 month.[15] These cases highlight the importance of initial and continued cardiovascular monitoring in the lightning victim.

Finally, it is important to stress the need for immediate, high-quality resuscitation despite the fact that some patients may present in asystole or pulseless electrical activity (PEA). Lightning strike victims tend to be younger with little to no underlying medical problems, and therefore prolonged resuscitation can lead to success regardless of initially presenting rhythm.[16,17] Mortality is lower in lightning victims when compared to the cardiac arrest in the general population.[8]

Nervous System

Neurological injuries can again range from benign to life-threatening [18], and have been categorized into four distinct groups.[19,20] Anyone that has suffered a lightning injury that should be subjected to a thorough neurological exam.[8]

a) Immediate onset but transient. One of the most typical manifestations is "kerauno-paralysis" which is a transient paralysis that has been theorized to be the result of on overstimulation of the autonomic nervous system, causing vascular spasm.[18,21] Some of the more commonly encountered signs and symptoms include pallor, cyanosis, coolness of the effected limb, and in some cases severe vasoconstriction, at times so severe that the pulse in that limb will be undetectable.[20,22] Luckily in most instance the effects of keraunoparalysis are short lived, and resolve with a few hours.[8]

b) Immediate onset and prolonged or permanent. The most devastating neurological injury sustained by lightning strike victims is hypoxic encephalopathy due to cardiac arrest.[18] Subarachnoid and intracerebral hemorrhage may also occur immediately, especially in cases of a direct lightning strike.[19] Other possible immediate onset, permanent injuries include cerebral infarct, cerebral lesions and 'cerebral salt wasting syndrome' which can lead to significant cerebral edema.[23–25]

c) Delayed onset with progressive complications. In this category it becomes increasingly more difficult to link to the lightning injury as the causative factor of some of these neurological conditions especially in the case of much later onset symptoms (i.e. years).[26,27] The associated mechanisms and pathophysiology of progressive complications over time are not well understood.

d) Nervous system injuries due to secondary trauma or blast effect. It is also possible for victims to sustain secondary trauma if thrown by the lightning strike. Serious head and neck injuries are common when sustaining this type of trauma. The information gathered at scene and passed on to the receiving facility is crucial for the recognition, treatment and continued monitoring of the patient for both short and long term.[8]

Integumentary System

There are six types of burns caused by lightning that have been identified: punctuate, linear, thermal, contact, flash and feathering.[28] Despite the fact that the temperature associated with lightning is extremely high, skin burns are often superficial in nature.[29] Pre-hospital management of lightning burns should follow standard burn management guidelines. As with any burn, the possibility of infection is great and caution should be exercised when bandaging these types of burns.

Linear burns, classified as partial thickness burns, will be more frequently found in areas of the body with a high concentration of moisture like the armpits and underneath the breasts. As the lightning travels over the skin, moisture trapped close to the body (such as sweat) is turned into steam causing the burn.[8] Full thickness burns after a lightning strike are quite uncommon and are usually associated with the victim wearing some type of metal jewelry.[30]

Lichtenberg figures, also known as "lightning flowers", that may be present on lightning victims' skin are not burns.[31] Previous literature proposed that the pattern represents a rupture of capillaries as the lightning current passes over the skin.[32] However, to date there have been no pathophysiological changes of the skin identified using tissue biopsy. Lichtenberg figures are also apparent when lightning hits other objects such as grass. See http://bit.ly/2yNItlv for a case image of Lichtenberg figures.

Conclusion

Lightning injuries can range from minor to fatal, and can affect multiple body systems. It is important for paramedics to thoroughly assess and continuously monitor patients who have suffered a lightning strike. Paramedics working remotely in industrial settings may be responsible for providing cover to work crews in the field, and we propose that it is prudent for paramedics providing medical cover for recreational activities such as adventure races and other non-industrial events to be aware of the risks of thunderstorms and lightning. Providing practical advice on lightning safety to those undertaking such activities may aid in reducing the occurrence of lightning injuries. CP

Resources

The Wilderness Medical Society (WMS) Guidelines for the Prevention and Treatment of Lightning Injuries: 2014 Update is available from http://bit.ly/2haGBfc (open-access).

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