Short reports

Lightning injuries during snowy conditions

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Abstract

Skiers and other snow sports enthusiasts can become lightning casualties. Two such accidents are reported, one being fatal. There are fewer warning signals of impending lightning strikes in winter-like conditions. However, outdoor activists should be aware of at least two suspicious clues: the appearance of convective clouds, and the presence of graupel (snow pellets) during precipitation.

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Skiers and other snow sports enthusiasts face many health hazards. Few think of lightning as one of the dangers that confront them. It is well known that lightning is a threat to the health of those engaged in summer recreational activities, such as golfing, boating, swimming, and mountain hiking.¹ It may come as surprise to many that those participating in skiing and snowmobiling are also at risk of being injured by lightning. Although lightning is less common in the winter months, its electrical power is often more damaging than summer lightning.²

We present the case of a ski patrol member on a snowmobile who received ocular injuries while rescuing another skier who had had a non-lightning injury. Also, we review a previously reported patient who had a fatal lightning skiing injury.³ Since that case was reported, we have learnt additional information about the weather conditions that we detail here.

We describe the meteorological conditions that are necessary for lightning during snowy conditions and provide a few clues that might allow one to suspect an impending lightning storm.

Case report

A 38 year old man was above the timber line at an altitude of 12 500 feet (3800 metres) near Breckenridge, Colorado. He described the weather as cold with sleet and lightning. In a subsequent interview it became clear that what he called "sleet" was actually graupel or snow pellets. He was on a ski rescue mission when he saw a flash of bright light and was thrown about five feet off his snowmobile. It was 4 30 pm on 8 June 1997 and the outdoor temperature was 3.3°C. He was transporting an injured skier

with a broken neck in a fibreglass toboggan on the back of his snowmobile when the lightning struck. He was unconscious for a moment and on regaining consciousness he experienced numbness and weakness in his left arm and leg. He had difficulty swallowing or speaking for a few minutes. He was then able to use his right hand to remove his radiotelephone from his back pocket and call for help.

The search and rescue team reached him in about 15 minutes. At that time his speech was "garbled" and he had difficulty opening his eyes because of extreme sensitivity to light. He was wearing a helmet which covered his head, face, and ears. The visor was up so that he could see. He was taken by ambulance to Centura Health, St Anthony Hospital in Denver, Colorado. In the hospital his neurological examination was normal. His abnormalities were confined to the ophthalmological examination. He had swollen eyelids without ecchymosis. The anterior segments showed chemotic conjunctivae inferiorly in both eyes. The corneas did not stain but showed a stromal swelling reaction in the inferior half of each eye. He was diagnosed as having electrical burns of both corneas and anterior segments. He was treated with cyclopentolate 1% eye drops and topical steroid drops.

Normal study results included an MRI brain scan, with and without contrast, and brain stem auditory evoked responses.

His photophobia and pain gradually decreased. Three months after the accident his corneas were clear. By this time he had developed anterior and posterior cortical cataracts in each eye. His vision was correctable to 20/20 in each eye with a small myopic correction.

Discussion

People engaged in recreational activities are often at risk of being struck by lightning. Most of the lightning injuries and fatalities in people engaged in recreational activities occur during summer-type conditions. The largest numbers of lightning injuries happen to golfers, fishermen and boaters, hikers, and mountain climbers. It is uncommon for skiers and other snow sports enthusiasts to be injured by lightning. However, people on the mountain slopes in snowy conditions are not entirely immune from the dangers of lightning.

Our two patients were struck on the ski slopes during spring months, but in winter-like condi-

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Figure 1 Helmet used by ski patrol. The helmet might have protected the patient from more serious injuries.

tions. The case we report here, as well as the case we reported previously, illustrate that the danger of lightning can apply to snow skiers. The present patient had injuries to his eyes. We believe his helmet (fig 1) might have protected him from additional serious damage. The helmet used by ski patrol members protected the patients head, face, and ears. His tympanic membranes were not ruptured as is common in patients who are struck by lightning. In addition, he might have been protected by his wet ski suit. The helmet might have saved him from a secondary lightning linked traumatic injury when he was thrown in the air.

Ophthalmological sequelae are common after lightning strikes.^{4,5} Conjunctival chemosis and corneal lesions may take days to weeks to clear. Cataracts are the most common ocular complication and may develop after a latency of months to years. Lens opacities may evolve in both the anterior and posterior capsules. Less common complications include retinal lesions, macular oedema, and haemorrhages.

The patient that we had previously reported was a 38 year old man who had a fatal lightning injury while skiing near Vail, Colorado.³ He had

Figure 2 Graupel (snow pellets) on the ground during a lightning storm in Rocky Mountain National Park. The wooden stick in middle of picture is 7.5 cm long. Graupel is typically less than 1 cm in diameter but can grow to sizes similar to hail.

Figure 3 Convective clouds associated with lightning storms. During winter-like conditions, convective clouds are often embedded in large areas of stratiform clouds and are more difficult to identify. © 1991 by C Doswell, used with permission.

just left the ski lift at Eagles Nest Ridge at 10 350 feet (3150 metres). He had a cardiac arrest and secondary cerebral anoxia. We have learnt several additional details about this case since it was first reported. Witnesses on the chair lift heard thunder about 30 seconds before they left the lift. The patient and three companions began skiing towards the tree line. Graupel or snow pellets were falling. The patient stopped to put on goggles when he was struck by lightning. A bright flash and thunderclap were observed at the same time.

There is little other information in the medical literature about lightning injuries in skiers or other outdoor winter sports activists. Holle *et al* reported on a patient who was injured while indoors during a winter cloud-to-ground lightning flash in Connecticut.² There is also a reference in ancient Chinese literature to snow thunderstorms as ominous military omens.⁶

The current thinking on how clouds become electrified explains the rarity of lightning during winter-like conditions when surface temperatures are relatively cold. From laboratory measurements we know that a mixture of ice crystals, supercooled cloud droplets, and larger ice particles called graupel form a potent environment for electrical charge to separate onto different sized particles.⁷ The meteorological term graupel defines a type of frozen precipitation that is sometimes referred to as snow pellets or soft hail (fig 2). Graupel is smaller (typically less than 1 cm in diameter) and more spongy (less dense) than hail. Ice crystals colliding with graupel particles, in the presence of supercooled water, can lead to substantial and opposite charges being left on each particle. Under most natural cloud conditions the ice crystals charge positively and the graupel charges negatively. The different sized and charged particles separate by falling at different speeds, eventually developing preferred regions of accumulated charge in a cloud. Lightning occurs when the charge accumulation and separation creates enough electrical potential to overcome the resistance of the air.

Fairly strong updrafts in clouds are necessary to allow substantial supercooled droplets to exist and to be collected onto the graupel particles, resulting in sufficient charge building up. Convection results in strong updrafts in response to steep vertical temperature gradients. Temperature gradients that are unstable

to convection are most prevalent when surface temperatures are warm. The resulting convective clouds are also known as cumulus clouds, and are characterised by enhanced vertical growth and cauliflower-like puffs (fig 3). Convective instability occurs only occasionally during winter-like conditions, often associated with a front or other large scale phenomenon. Under these conditions the cumulus clouds or cumuliform elements are often embedded in a larger layer of clouds. Also, winter convection is often shallow and the clouds tend to be tilted owing to stronger upper level winds. Consequently, winter thunderstorms tend to have infrequent lightning.² In addition, they have a higher percentage of positive lightning flashes as opposed to the more common negative lightning flashes of summer. Positive flashes have larger and longer lasting currents, and are more damaging.⁸

Thunderstorms in winter-like conditions are rare and are associated with only one or a few lightning events.² For this reason there is less warning from visual or other detection methods that allow the outdoor activists to seek

shelter than there is during the summer. Two clues that suggest possible cloud electrification are (a) the appearance of convective clouds; unfortunately, convective clouds are more difficult to see in winter conditions because they are often embedded in large areas of more stratiform clouds; and (b) the observation of graupel or snow pellets during precipitation.

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- 1 Cherington M, Vervain C. Lightning injuries—who is at greatest risk? *Physician and Sportsmedicine* 1990;18:58–61.
- 2 Holle RL, Lopez RE, Howard KW, et al. An isolated winter cloud-to-ground lightning flash causing damage and injury in Connecticut. *Bulletin of the American Meteorological Society* 1997;78:437–41.
- 3 Cherington M, Yarnell PR, Hallmark D. MRI in lightning encephalopathy. *Neurology* 1993;43:1437–8.
- 4 Lagreze WA, Bomer TG, Aiello LP. Lightning-induced ocular injury. *Arch Ophthalmol* 1995;113:1076–7.
- 5 Noel L-P, Clarke WN, Addison D. Ocular complications of lightning. *J Pediatr Ophthalmol Strabismus* 1980;17:245–6.
- 6 Wang P-K, Chu J-H. Unusual lightning events in ancient Chinese literature. *Weatherwise* 1982;35:119–22.
- 7 Saunders CPR. A review of thunderstorm electrification processes. *Journal of Applied Meteorology* 1993;32:642–55.
- 8 Brook M, Nakano M, Krehbiel P, et al. The electrical structure of the Hokuriku winter thunderstorms. *Journal of Geophysical Research* 1982;87:1207–15.

Take home message

One is not immune to lightning strikes in winter-like conditions. Warning signs include the presence of (a) convective clouds and (b) graupel (snow pellets) during precipitation.

Commentary

The authors draw attention to the rare phenomenon of lightning discharge under wintery conditions. This is of special interest because skiing, snowboarding, and ice skating are gaining enormously in popularity.

Of special interest is the formation of sleet and graupel under certain meteorological conditions, which may indicate the presence of high differences in potential in the atmosphere. Sportsmen should be trained to recognise this typical form of precipitation.

It is well known that Faraday's cage protects those within the cage from an electrical discharge. In this way occupants of cars, metal ships, and so on are protected from lightning injuries. It is questionable whether wearing metal objects like hairpins, zippers, necklaces, and bracelets has any protective influence in this respect. Kitagawa discussed this question in several articles, but it is uncertain whether wearing such metal objects is beneficial.^{1 2} They may facilitate a discharge over the body's surface so that a lightning current will not flow through the body. On the other hand, it is possible that metal objects attract a lightning discharge. A polyester helmet or a ski suit in which no metal strips have been incorporated cannot act as a Faraday cage. But a wet skin surface (for example, a wet ski suit) may facilitate a discharge over the surface of the body, thus preventing an internal current from flowing.

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- 1 Kitagawa N, Kinoshita K, Ishikawa T. Discharge experiments using dummies and rabbits simulating lightning strokes on human bodies. *Int J Biometeorol* 1972;17:239.
- 2 Ohashi M, Kitagawa N, Ishikawa T. Lightning injury caused by discharges accompanying flashovers: a clinical and experimental study of death and survival. *Burns* 1986;12:496–501.