Risk Management for Outdoor Sports Activities -Especially for Prevention of Lightning Strike Injury

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We need to pay attention to the risk of lightning strike injury for outdoor sports activities, especially in the Japanese summer, which usually has some thundery days. The most important principle in protecting ourselves from lightning strikes is simply to seek refuge in a safe place during a thunderstorm, and as part of this, to be aware in advance when there is an approaching thundercloud. However, as a second level of protection, if one were unfortunately hit by lightning and subsequent cardiac arrest occurred, an immediate cardiac massage can lead to successful resuscitation.

Key Words : thundercloud, lightning injury, strike alert, cardiac arrest, lightning alarm, side stroke, lightning protection manual

The scientific aspects of thunderbolts are described in detail in a booklet published by the Society of Atmospheric Electricity of Japan^{1)~2)}. Here we focus on counter-measures against lightning accidents as part of risk management for outdoor sports activities in sports medicine.

Medical risk management in athletic meetings is wide-ranging. As for counter-measures against common risks such as trauma or heat stroke, setting up a medical office and ensuring a back-up system for transferring to an emergency hospital are necessary essentials. Emergency response plans against rare but serious risks such as disaster including lightning, hurricane, earthquake, fire, or terrorism *etc.* are also recommended. Among these rarer risks, lightning is perhaps the most likely. Dr. K Shiono previously proposed guiding principles for lightning strike accident to Saitama Football Association in 1988 and 2008^{3)~4)}. Saitama Sports Association adopted the proposal⁵⁾.

Although it is difficult to anticipate whether a lightning strike will occur or not, we can predict the

approximation of the thundercloud. Cumulonimbus cloud, wildfire and/or thunderclaps, and sometimes noises on an AM radio, are clues to the phenomenon. In addition, public prediction information such as "Thunderstorm Advisory" from Japan Meteorological Agency, private services for e-mailing information about any "guerrilla lightning storm" delivered by Japan Weather News Inc., or a personal lightning detector such as "Strike-Alert" are also helpful. A personal lightning detector can detect the cloud-to-cloud discharge as far as 60 kilometers away and warns us of lightning strikes. Thus, it can also be used for making a judgment as to whether a thundercloud remains in the vicinity after thunderstorm activity.

And on that point, a word of warning. Because even if we notice lightening at some distance away, and/or a clap of thunder, we tend to think that the place will be safe until it rains, and thus, continue outside sports activity for a while. However, this is wrong and a dangerous way of thinking. In fact, a lightning strike can commonly occur before it starts

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Figure-1 Protective area

If you can find a lightning conductor rod or an object with the height of 4 to 30 meters tall, e.g. building, tree, pall, chimney *etc.*, prostrate yourself at a point where, if you look up at the top of the object, the elevation angle is over 45 degrees and at least two meters away from the object in order to avoid being hit by a side stroke from the lightning that might hit the object itself.

to rain^{6)~8)}.

The characteristics of a thundercloud are as follows :

- a) Tall ; in a formation called cumulonimbus.
- b) Short-lived ; it develops in 10 minutes but lasts only for about 1 hour.
- c) Solitary ; it usually blows over in 30 minutes and consecutive occurrences are rare.
- d) High-speed ; maximum velocity is about 40 km/hr.
- e) Large ; it ranges from 500 m to 20 kilometers.
- f) High-energy ; 100,000,000 volts and 300,000 amperes maximum. One discharge is the equivalent of two month's wattage of a standard home i.e. about 1500,000,000 joules.
- g) Wide range ; one discharge can reach between about one hundred meters to 10 kilometers away.
- h) Thunder clap ; the audible range of a thunderclap is about 10 kilometers.

Therefore, it is possible to be struck by lightning almost immediately after you notice rumbling and/or a flash of lightning. Hence, outdoor sports activities must be stopped immediately when lightning is seen and/or clap of thunder is heard,

even though they might seem far away and faint. For example, there is a famous football game video, which was captured on 26th October 1998 in Johannesburg, South Africa. Several players at the halfway line were struck down immediately after a flash of the lightning while the rest of the players kept playing. A few minutes after this moment, the game was stopped and it began to rain. As can therefore be seen, a lightning strike can occur before rain begins.

Options for a safe restart of playing are as follows :

- a) About 30 minutes passage of time after the last clap of thunder ;
- b) Confirming by inquiry to public meteorological office is better if possible ;
- c) Confirming by inquiry to private service such as "Kaminari alarm" (043-274-5504) run by Japan Weather News Inc ;
- d) Confirming by personal lightning detector

Then, hereafter we discuss about escape from lightning strike. The most important thing is simply to seek refuge into an absolute-safe place such as the inside of a concrete building, train, and car *etc.* if you are outside. If the building is made of wood, you

have to stay 2 meters away from lamp cables, aerial cables, earth leads, water pipes, gas pipes, or walls, sails, electric equipment, and plugs which include those cables. If you cannot get enough distance away from such lines or pipes, all you can do would be to sit down at the center of the room temporarily and seek a safer place when there is a break or lull in the lightning.

How to move and evacuate from outdoors are as follows :

- i) Move within the protective area of a lightning conductor rod (i.e. within an area where if you look up at the rod, the elevation angle is greater than 45 degrees, but at least 2 meters away from the structure holding the rod : Figure-1).
- ii) If you can find an object with the height of 4 to 30 meters tall, e.g. building, tree, pole, chimney *etc.*, prostrate yourself at a point where, if you look up at the top of the object, the elevation angle is over 45 degrees (so if the height is 20 meters, an area 20 meters in radius would be a protective area) and at least two meters away from the object in order to avoid being hit by a side stroke from the lightning that might hit the object itself (Figure-1). If you were group in such situation, you should take shelter separately if possible. This is so that the rest of the people in the group, who have evacuated to another place separately, can perform cardio-pulmonary resuscitation (CPR), and hence, may achieve successful resuscitation of anyone hit by side strike of lightning. It is rare that the lightning take place in the area within 100 meters from the former strike point repeatedly.
- iii) If you cannot find i) or ii), prostrate yourself on the ground until the thundercloud goes away. It used to be said that for up to one minute after a lightning strike is safe because the interval time between lightning strikes seemed to be usually 1 to 3 minutes. However, this is no longer thought to be the case since lightning can recur as little as 15 seconds, or even 0.1 second, after a previous strike.

Here, we introduce some experimental evidence about lightning (all evidence below are from Prof. Shinichiro Kitagawa, Department of Science, Saitama University) :

- a) All kinds of objects of the same height have the same probability of lightning strike regardless of the material ;
- b) Lightning invariably strikes a taller object in preference to a shorter one ;
- c) Being made of metal does not influence the risk of lightning attack. Indeed, because metals absorb the electrical current from a lightning strike as a "creeping discharge", it is actually preferable to wear metal materials. The injury resulting from wearing metal materials is limited to a burn on the skin surface under the metal. It is not critical. Further, the absorption of the electric current by the metal's creeping discharge would tend to be protective for us, as a way of diverting the flow of electricity from our brain or heart towards the metal material.
- d) Insulating materials such as rain capes or rubber boots do not influence the probability of lightning strike either. Because the human body itself has an electrical resistance of 300 ohms, such insulating materials are irrelevant in the context of a huge energetic thunderbolt of 100,000,000 joules.

Lastly, we discuss death by lightning strike. 50% of fatal cases resulted from a direct hit in a large area such as an athletic field. 20-27% were from a side strike from a tree whilst taking cover under it from the rain. 12% were from a side strike from a ridge or spur whilst taking cover from the rain in mountain climbing. 11% were none of the above. We therefore have to bear in mind that taking shelter from rain under a tree is a relatively frequent method of attempting to avoid lightning, and can itself be dangerous. The causes of death are (1) cardiac arrest, (2) critical arrhythmia, (3) respiratory failure, (4) central nervous damage by direct hit on the head. Although a huge power current passing throughout the body will cause cardiac arrest, the heart itself does not undergo a severe impairment as in the case of an electric shock accident, which causes direct damage to heart. Therefore immediate cardiac massage (CPR) can lead to resuscitation. Of course, you can use an automated external defibrillator (AED) for critical arrhythmia such as ventricular fibrillation if possible. Sequelae of lightning strike are (1) central nervous damage - memorial impairment is the most frequent, (2) burn - mostly burn index of I or II degrees, (3) hypo/hyperkalemia, (4) renal failure *etc.*

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