Lightning Safety Guidelines

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On average, lightning causes more casualties annually in the United States than any other storm-related phenomenon except floods. Although 90% of those injured survive, they may have permanent sequelae and disability. Many of these people incur injuries or are killed by lightning because of misinformation and inappropriate behavior during thunderstorms. A few simple precautions can reduce lightning injury risk. To standardize recommended actions during thunderstorms, the Lightning Safety Group (LSG), composed of lightning experts from many lightning-related backgrounds, met at the American Meteorological Society meeting Phoenix, AZ, in January 1998 to collectively address personal lightning safety. This paper is a summary of the recommendations developed by the LSG.

[Zimmermann C, Cooper MA, Holle RL. Lightning safety guidelines. *Ann Emerg Med.* June 2002;39:660-664.]

INTRODUCTION

Lightning has been the second largest storm killer in the United States since 1959.[1] Unfortunately, meteorologic agencies in the United States and around the world, which issue warnings and forecasts with the goal of decreasing casualties and property damage from severe weather, issue warnings for only 3 of the 4 important causes of storm-related fatalities: tornadoes, hurricanes, and floods, but not for lightning.

Because lightning flashes strike the ground an average of approximately 25,000,000 times per year in the United States, it is impractical to expect the National Weather Service to warn every individual of every flash.[2] Depending on where a person lives or recreates, lightning can be considered the most dangerous weather hazard that many will encounter each year.[3] Avoidance of lightning injury usually becomes an individual responsibility, wherein each person must be familiar with and follow lightning safety rules.

Unfortunately, many myths exist in past publications, in the media, and in common belief about lightning, lightning injuries, and advice about their prevention.[4-7] Because of these myths and on the basis of important new findings about lightning and lightning injuries, a group of lightning experts believed it was important to meet and write a consensus statement on recommendations for lightning safety and injury prevention.[8]

The consensus panel is made up of some of the most prominent and well-recognized lightning researchers and leaders in their respective fields with expertise in the demographics and epidemiology of lightning injuries, medical care of lightning casualties, meteorology, atmospheric physics, development of warning and lightning detection methodology, disaster management, lightning safety education, and development of policies for lightning safety (Appendix 1*).

The Lightning Safety Group (LSG) met at the American Meteorological Society's annual meeting in Phoenix, AZ, in 1998 and drafted the Lightning Safety Guidelines.[3] The members of the panel agreed that the guidelines would not be copyrighted and agreed to facilitate their widest distribution in all of their respective fields.

This paper summarizes the LSG lightning safety recommendations. Drafts were circulated from January to May 1998 to LSG members and to lightning researchers, educators, and safety proponents who were not able to attend the meeting. The current authors have added an introduction, references, tables, and more medical information and have updated the original guidelines where appropriate but have not otherwise changed the overall content.

Although there is no guarantee that following these guidelines will prevent all injuries, these guidelines constitute a summary of the safest practices based on the research and experience that are currently available. In addition, these guidelines raise safety issues for large groups that have extended evacuation times, such as students on school playgrounds or isolated playing fields and groups in large stadiums, that have not been adequately addressed in the past.

SAFER LOCATIONS AND LOCATIONS TO AVOID DURING THUNDERSTORMS

Although no place is absolutely safe from the lightning threat, some places tend to be safer than others (Figure 1). Large enclosed structures, such as those with plumbing and electrical wiring, tend to be much safer than small or open structures. Fully enclosed metal vehicles with the windows rolled up provide good shelter from lightning. Some professional golf tournaments place school buses around the course for the evacuation of spectators.

Injuries can occur indoors or in vehicles when a person comes in contact with conducting materials. During a thunderstorm, individuals should avoid touching plumbing fixtures, electrical appliances, and metal frames. Computers should be unplugged before a thunderstorm to avoid damage to the computer and to the person using them. Generic surge suppressors will protect neither people nor equipment from lightning damage. Areas to avoid include those near tall objects, such as towers or trees, and those near water or open areas (Figure 1).

SAFETY GUIDELINES FOR INDIVIDUALS

Generally speaking, if an individual can see lightning or hear thunder, he or she is already at risk. Louder or more frequent thunder indicates that lightning activity is approaching, thus increasing the risk for lightning injury or death.

The "30–30 Rule" is easy to remember and applies to the warning time before the storm and the time that should be waited before resumption of activities. If the time delay between seeing the flash (lightning) and hearing the bang (thunder) is less than 30 seconds, the individual should be in or should be seeking a safer location

Figure 1.
Locations to seek or avoid during thunderstorms.

Seek safer areas:
Large structures with plumbing and electrical wiring (eg, houses, schools, office buildings).
Fully enclosed metal vehicles (eg, cars, trucks, buses, enclosed farm vehicles).
Important: Roll up windows and avoid contact with metal or conducting surfaces outside or inside the vehicle.
Avoid:
Tall structures (eg, mountains, isolated trees, towers, flag poles, light poles).
Open fields (eg, golf courses, sports fields, parks, school yards, playgrounds).
Open structures or open vehicles (eg, gazebos; rain, sun, golf, or picnic shelters; baseball dugouts; convertibles; golf carts).
Contact with conductive materials (hard-wired telephones, computers, plumbing, electrical appliances or wiring, bleachers, fences, metal window or door frames).
Being near or in water (eg, oceans, beaches, lakes, rivers, indoor or outdoor pools).

*Appendixes can be accessed on the *Annals* Web site at www.mosby.com/AnnEmergMed.

(Figure 1). Unfortunately, this method of ranging has severe limitations, in part because of the difficulty of associating the proper thunder to the corresponding flash. It is probably better to recommend seeking safer shelter when the first lightning is seen or the first thunder heard. "If you can see it, flee it; if you can hear it, clear it" is what we teach to children.[9]

Although high winds, rainfall, and cloud cover often act as precursors to actual cloud-to-ground strikes, many lightning casualties occur before the storm arrives because people ignore these warnings and wait for rain to fall. When thunderstorms are in the area but not overhead, the lightning threat can exist even though the sun is shining, it is not raining, and some of the sky is blue. Lightning may travel more than 10 miles in front of or behind a storm. A flash hits the ground in more than one location nearly 50% of the time and 10% of the time hits when there is no rain in the immediate area and blue sky can be seen.

Other lightning injuries occur after the perceived threat has passed. Generally, the lightning threat diminishes with time after the last sound of thunder or sighting of lightning, but may persist for up to 30 minutes.[8]

Weather warning devices, such as the National Oceanic and Atmospheric Administration (NOAA) weather radio and/or credible lightning detection systems, help warn of lightning danger, but the individual should not let the lack of warning by these systems override common sense and the warning provided by his or her own eyes and ears.

CONSIDERATIONS FOR SMALL GROUPS AND FOR GROUPS WITH AN EVACUATION TIME OF LESS THAN 10 MINUTES

Local weather forecasts, NOAA weather radios, and the Weather Channel should be monitored before any outdoor event takes place to learn whether thunderstorms are forecasted. Numerous Web sites exist on which weather can be monitored in real time (Appendix 2).

If thunderstorms are predicted, the group may decide that it is wiser to cancel or postpone the event or may choose to plan indoor activities. If the group decides to continue the activity, a spotter should be designated to monitor weather forecasts and to observe the sky to keep everyone informed when potential threats develop.

Because neither personal observation of lightning, use of lightning detection systems, nor additional weather information guarantee safety, data from all of these sources are very desirable to ensure consistency, accuracy, and adequate advance warning.

When organized activities involve children, coaches, teachers, camp counselors, lifeguards, and other adults must take responsibility for the safety of the children in their care and take into account the longer time needed to evacuate their group to a safer location. It is advisable to have an action plan that has been agreed on in advance and is known by all responsible persons involved (Figure 2). Although it is not the job of the coach or the referee to watch the sky, they should not obstruct evacuation if the lightning spotter calls the evacuation plan into action. In addition, because lightning safety is also a personal decision, players or employees who elect to leave a situation in which they judge lightning to be a substantial danger should not be penalized for their actions.

SAFETY GUIDELINES FOR LARGE GROUPS AND FOR GROUPS WITH AN EVACUATION TIME OF MORE THAN 10 MINUTES

When large groups, such as those in sports arenas or golf tournaments, are involved, evacuation times may be prolonged and safer areas may not be as well defined or familiar, especially to spectators. These venues should have an established lightning policy.

As evacuation time increases, the distance at which lightning is noted and considered a threat to move into the area must be increased. Personal observation is not adequate. Additional weather information, lightning strike detection technology, and/or monitoring the distance and direction to lightning is required to ensure consistency, accuracy, and adequate advance warning. Detectors can also be a valuable tool to determine the "all clear" (last occurrence of lightning within a specified

Figure 2.
Components of a Lightning Action Plan.

Develop a Lightning Safety Plan.
Train personnel to be familiar with the plan.
Access up-to-date weather information.
If detection or warning systems are used, train personnel in their use.
Designate safer areas.
Plan for routing and evacuating people.
Display appropriate signage.
Educate the event's participants about the plan.
Use a "warning" signal that is different from the "all clear" signal.
Carry out regular Lightning Action Plan drills.
Review and modify the Lightning Action Plan as needed.

range), providing a time reference for safe resumption of activities.

Management, event coordinators, organizations, and groups should designate a responsible person(s) as lightning spotter(s) to initiate the evacuation process when appropriate. These individuals must be trained in the detection of lightning, including personal observation, and familiar with any detection and warning systems used by the event. Monitoring the weather for the threat of lightning from thunderstorms should begin hours and sometimes days ahead of an event.

Instrumentation can be used to enhance warning during the initial stages of the storm by detecting lightning in relation to the area of concern. Advance notification of the storm's arrival should be used to provide additional time to seek safety. However, extending the range used to determine threat potential also increases the chance that small localized cells of thunderstorms may not reach the area, giving the impression of a false alarm. Too many false alarms can cause individuals to ignore the warnings and cause lost revenue for event organizers.

Lightning is always generated and connected to a thundercloud but may strike up to 10 miles or more from the edge of the thunderstorm cell. Accepting responsibility for larger groups of people requires more sophistication and diligence to assure that safety is considered. Acceptable downtime (time of alert state), lost revenue, and the inconvenience and misinformation that can occur with too many warnings perceived as false alarms have to be balanced with the risk posed by lightning.

COMPONENTS OF A LIGHTNING ACTION PLAN

Lightning safety plans need to be in place and communicated to people before the storm season begins so that all persons at risk from the lightning threat can take appropriate action (Figure 2). For larger events or for events occurring in more open areas, a team of people may be needed to coordinate the evacuation plan.

Monitoring the weather for the threat of lighting from thunderstorms may need to begin hours or days ahead of the event. Persons designated as spotters should be trained in lightning detection, including personal observation and the use and interpretation of reliable lightning detection system information, and should be intimately familiar with the Lightning Action Plan, including the "warning" signal and when it is to be used, the evacuation plan, designated safer areas, and use of the "all clear" signal. The "all clear" signal should be recognizably different than the "warning" signal.

Regular drills of the Lightning Action Plan should be held. The drill schedule might include the beginning of the storm season, when severe weather is predicted, when new personnel are hired, and perhaps when there has been no thunderstorm activity or warnings for long periods of time. The Lightning Action Plan should be periodically reviewed by all personnel and modified when necessary.

Safer sites should be identified beforehand, along with a means to route people to those locations. Strategically placed school buses are an excellent lightning shelter, particularly when large groups of people and large areas, such as golf tournaments, summer day camps, swim meets, military training, or scout groups, are involved.

It may be prudent to consider placing lightning safety tips and/or the action and evacuation plans in publications such as game programs, flyers, and score cards, as well as placing lightning safety placards around the area. This information should clearly describe the sounds that will be used for a lightning "warning" signal and for the "all clear" signal, as well as where safer areas are located. Prominently posted signage warning that structures such as golf, rain, or bus shelters are not safe from lightning should be considered so that individuals, even during good weather, may become used to the idea of where safer locations are and how long it may take to reach them. Lightning signage may be an effective means of communicating the lightning threat to the general public and raising awareness.

MEDICAL RECOMMENDATIONS FOR LIGHTNING VICTIMS

Most lightning victims survive their encounter with lightning, especially with timely medical treatment.[10-12] Individuals struck by lightning do not carry a charge, and it is safe to touch them to render medical treatment.

The proximate cause of death is cardiac arrest at the time of the strike.[12] Anyone who has signs of life is highly likely to survive. When multiple victims are injured, triage rules change, and those in cardiac or respiratory arrest should receive the greatest efforts. Fixed, dilated pupils should not be used to establish death.[12]

During an active thunderstorm, particularly if the victim is located in a high-risk area (eg, mountain top, isolated tree, open field), the rescuers may be placing themselves in significant danger of lightning injury. Because it is relatively unusual for victims who survive a lightning strike to have major fractures or internal injuries unless they have suffered a fall or been thrown a distance, the rescuer needs to decide whether evacuation from a high-

risk area to an area of lesser risk is warranted and should not be afraid to move the victim rapidly if necessary.

If the victim is not breathing or has no pulse, normal advanced cardiac life support (ACLS) protocols may be followed. If it is decided to move the victim, a few quick breaths should be administered before the person is moved. In situations that are cold and wet, putting a protective layer between the victim and the ground may decrease hypothermia, which can further complicate resuscitation.

In wilderness areas and in areas far from medical care, prolonged basic cardiopulmonary resuscitation is probably of little use because the victim is unlikely to recover if they do not respond within the first few minutes. If the pulse returns, the rescuer should continue ventilation with rescue breathing, if necessary, for as long as practical in a wilderness situation. However, if a pulse does not return after 20 to 30 minutes of good effort, the rescuer should not feel guilty about stopping resuscitation.

KEY RECOMMENDATIONS

Individuals are ultimately responsible for their own safety decisions and should take appropriate action when threatened by lightning. They should not be penalized for leaving an area or situation that they deem dangerous. Exposure to the lightning threat during thunderstorm activity should be avoided. Familiarity with and implementation of lightning safety guidelines can decrease injuries.

Teachers, camp counselors, coaches, lifeguards, and other adults must take responsibility for the safety of children in their care.

As groups become larger and evacuation times longer, Lightning Action Plans must become more complex. Use of the "30–30 Rule," designated weather spotters, NOAA weather radios, and lightning detection technology are components of a Lightning Action Plan.

Additional resources are listed in Appendix 2.

Additional resources are listed in Appendix 1 and 2 in the full-text, online version of this article. Access the *Annals* Web site at www.mosby.com/AnnEmergMed. Information is also available at ACEP's home page at www.acep.org/AnnEmergMed.

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APPENDIX 1.

Lightning Safety Group. American Meteorological Society Conference, Phoenix, AZ, January 1998.

Participant	Discipline	Affiliation
Brian Bennett	Athletic trainer	Formerly with the College of William and Mary, Williamsburg, VA
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Collaborators not at meeting		
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Gerald Harwood, PhD	Writer, lightning safety activist	Anubis and Bastet Productions, Tucson, AZ
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Margaret Primeau, PhD	Neuropsychologist	Loyola University, Maywood, IL
Kathleen M. Walsh, PhD	Athletic trainer	Head, Sports Medicine, East Carolina University, Greenville, NC

APPENDIX 2.

Additional sources of information on lightning safety.

Organization	Web Site*
National Lightning Awareness Week (April 28–May 4, 2002)	http://www.lightningsafety.noaa.gov
National Weather Service	http://www.noaanews.gov/stories/images/lightningsafety.pdf
National Severe Storms Laboratory	http://www.nssl.noaa.gov/researchitems/lightning.html
National Lightning Safety Institute	http://www.lightningsafety.com/index.html
Lightning Injury Research, University of Illinois at Chicago	http://www.uic.edu/labs/lightninginjury
Lightning Strike and Electric Shock Survivors International (support group)	http://www.lightning-strike.org/
Lightning Safety for Kids (aka Sabrina's Lightning Page)	http://www.azstarnet.com/anubis/zaphome.htm
Downloadable coloring books on various weather safety topics	http://www.nssl.noaa.gov/edu/bm/bm_main.html http://www.nssl.noaa.gov/edu/bm/bm02_title.html
45th Weather Squadron, US Air Force	https://www.patrick.af.mil/45ws/45og/LightningSafety/index.html
Global Atmospherics, Inc. (North American Lightning Detection Network)	http://www.lightningstorm.com
National Outdoor Leadership School (NOLS)	http://research.nols.edu/wild_instructor_pdfs/lightningsafetyguideline.pdf
University of Florida (Boating Lightning Protection and Safety)	http://www.cdc.gov/niosh/nasd/docs/as04800.html http://www.thomson.ece.ufl.edu/lightning
USA Today	http://www.usatoday.com/weather/thunder/wlightning.htm

*Web sites current as of April 18, 2002.