Lightning-Related Mortality and Morbidity in Florida

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Synopsis

Cases of lightning-related deaths and injuries that occurred in Florida in 1978–87 were reviewed to determine the factors involved, to quantify the morbidity and mortality related to lightning strikes, and to describe epidemiologically the injuries and circumstances involved.

Statewide information on deaths was obtained from death certificates, autopsy reports, and investigative reports. Information about morbidity was obtained from the Florida Hospital Cost Containment Board data base and the National Climatic Data Center data base for all Florida counties, as well as from hospitals in selected counties.

Lightning-related deaths totaled 101 in Florida during the period 1978–87, an annual average of 10.1. Eight percent of the victims were from other States. The overall yearly death rate for State residents was 0.09 per 100,000 population, with the highest rate being that for men aged 15–19 years, 0.38 per 100,000. Thirteen percent of victims were females. The ratio of lightning-related injuries to deaths in Florida was estimated at about four to one. Thirty percent of all deaths were occupationally related.

The first strikes of lightning from a thunderstorm may be the most dangerous, not in terms of impact, but because of the element of surprise. During thunderstorms, people may seek shelter under isolated trees because they believe erroneously that a tree offers protection from lightning, or perhaps because their top priority is to escape from rain rather than lightning. People may not seek adequate shelter during thunderstorms because they do not know the dangers of remaining outdoors or their judgment is impaired by drugs or alcohol.

LIGHTNING KILLS many people despite the fact that danger from lightning strikes is well recognized and prevention measures are extensively publicized, particularly by the National Weather Service.

For the period 1968–85, an average of 113 lightning-related deaths a year were identified from National Center for Health Statistics data based on death certificates *(1)*. During the 18-year period, the States reporting the most lightning-related deaths were Florida with 200, five times the national average, and Texas, with 121. Wyoming had the highest annual risk of death by lightning, 0.196 deaths per 100,000 population, followed by New Mexico, 0.170; Arkansas, 0.159; Mississippi, 0.131; and Florida, 0.120 (three times the national average).

Among all States, Florida ranks first in thunderstorm frequency, 143 days a year with thunderstorms, according to an average of monitoring stations *(2)*. Additionally, Florida has the greatest density of lightning strikes, being the only State in which a mean annual ground flash density of 18 flashes per square kilometer has been observed in certain locations *(3)*. Each year, during the summer months, lightning-related morbidity and mortality are important news topics in Florida.

Because of Florida's unusual lightning activity, we reviewed cases of lightning-related deaths and injuries occurring in Florida during 1978–87. The objectives of our inquiry were to improve understanding of why people become victims of lightning strikes, to quantify lightning-related morbidity and mortality, and to describe epidemiologically lightning-related injuries and their etiology.

Methods

Case definition. A lightning-related victim was defined as anyone injured or killed by electrical energy resulting from being struck directly or indirectly by lightning. We excluded all injuries and deaths that resulted from fires, falling trees, or other indirect effects of lightning.

We searched sources of information for recorded deaths or injuries for which causes were coded as directly related to lightning according to the International Classification of Diseases Codes E907 and 994.0 (*4, 5*).

Mortality data. Information on lightning-related deaths in Florida was obtained by reviewing death certificates, autopsy reports, and available investigative reports. The Florida Department of Vital Statistics provided a copy of death certificates for lightning-related causes from 1978 through 1987. We sought information from all 24 Florida medical examiner districts and potential sources of information, such as police departments, asking for records, such as autopsy, police, and sheriffs' reports, of lightning-related deaths that occurred during 1978–87. Information was abstracted using a standardized questionnaire.

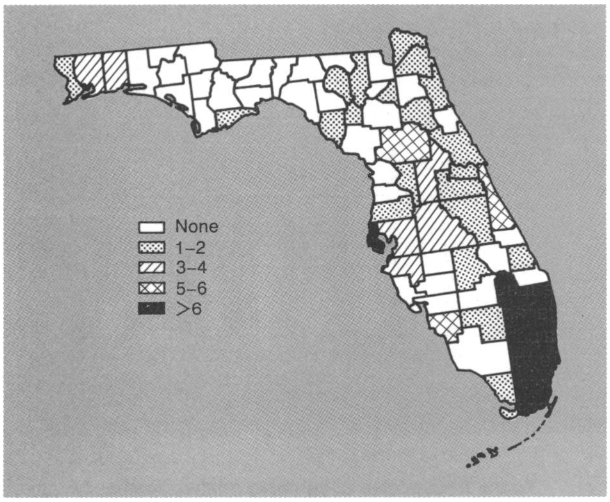
Morbidity data. Information about lightning-related morbidity was obtained by reviewing the Florida Hospital Cost Containment Board data base, the National Oceanic and Atmospheric Administration's National Climatic Data Center data base, and information from those hospitals having emergency rooms in four selected counties, Leon (3 hospitals), Levy (1 hospital), Taylor (1 hospital), and Pinellas (24 hospitals). Levy and Taylor counties were selected for high lightning-related death rates, Pinellas County for a high number of deaths, and Leon County for its accessibility to State health records.

Because a pilot study in the Leon County hospitals suggested the infeasibility of obtaining information about patients who were treated for lightning-related injuries and released without being hospitalized, we requested information only about inpatients hospitalized during 1978–87. However, since lightning has profound effects on the cardiac and neurologic systems, it is probable that most people seeking treatment at emergency rooms would have been hospitalized, at least overnight for monitoring.

The last two quarters of 1987 of the computerized data base of the Florida Hospital Cost Containment Board were reviewed. The data base was established during the third quarter of 1987, when 106 of 227 Florida hospitals were reporting. In the last quarter of 1987, 125 hospitals reported. The data base contains only general and limited information about hospital inpatients, but does allow a case count.

The computerized data base of the National Climatic Data Center was reviewed for the 1978–87. The data base allows identification of deaths and injuries and has limited information on the circumstances of injuries. However, the data base may not be altogether accurate or complete because it consists mainly of information gathered from newspaper articles.

Figure 1. Cumulative frequency of lightning-related deaths, by counties in Florida, 1978–87



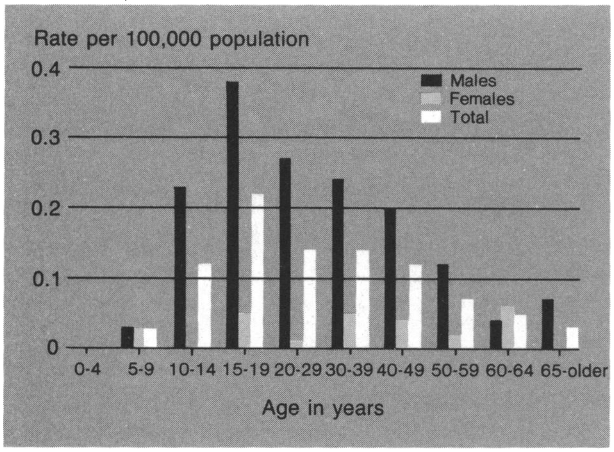
Data analysis. Data were computerized and analyzed using the computer program Epi Info, version 3.0 (*A*). The odds ratio (OR) was used as a measure of the strength of the association between two variables. Exact confidence limits for the OR were computed using the program developed by Metha, Patel, and Gray (*6*). The Fisher's exact one-tailed test was used to test the statistical significance of either a negative or positive association (*7*).

Results

Lightning-related deaths. A total of 101 lightning-related deaths in Florida during the 10-year study period, an annual average of 10.1 cases, was identified and confirmed from various sources. Two deaths coded as lightning related on the death certificate were excluded from our analysis because those deaths were not caused by the person being struck directly or indirectly. One hit her head during a thunderstorm while intoxicated. The other died of electric shock while walking in a pond into which a higher power line had fallen after being struck by lightning. Medical examiners provided detailed information on 79 percent of the 101 cases identified.

County-specific cumulative numbers of lightning-related deaths for the 10-year period are shown in figure 1. The counties with the highest cumulative incidence of deaths were Dade (13), Pinellas (11), Palm Beach (7), Broward (7), and Brevard (6). County-specific death rates are not provided because the numbers of deaths in most counties were very low, and the death

Figure 2. Annual lightning-related death rates in Florida, 1978–87



Yearly frequencies of lightning-related deaths in Florida, 1978–87

Year	Number of persons		
	Date of fatal injury[1]	Date of death[1]	Number killed[2]
1978	12	12	10
1979	9	9	4
1980	7	7	4
1981	8	7	2
1982	12	12	6
1983	14	13	9
1984	12	13	9
1985	8	8	4
1986	9	10	10
1987	10	10	11
Total	101	101	69

[1] Data from authors' survey.
[2] Data from National Climatic Data Center.

rates could be misleading. Only 8 percent of the victims were out-of-State residents.

The ages of victims ranged from 5 to 75 years, with a median of 27.3 years and a mean of 31.8 years. Eighty-one percent of the victims were white, 16 percent were black, and 3 percent were Hispanic. Thirteen percent of victims were females. Age- and sex-specific death rates (excluding nonresidents) are shown in figure 2. The overall death rate was 0.09 per 100,000 population. The yearly death rate was 0.02 per 100,000 for females and 0.18 per 100,000 for males. The highest yearly death rate among various age groups was 0.38 per 100,000 for men 15 to 19 years old. Sex ratios for non-whites were the same as for whites.

Yearly frequencies of lightning-related deaths are shown in the table. The data from the authors' survey are shown by date of the fatal injury and the date of death, compared with data from the National Climatic Data Center.

Fatalities at the time of injury and the time of death are shown in the table, with specific data from the National Climatic Data Center.

The numbers of deaths by month of injury are shown in figure 3. The monthly distribution is similar to the monthly frequency of thunderstorms, which was computed as the average of the averages reported by 19 meteorological stations during 1941–77 (*2*). The monthly injuries follow the monthly distribution of lightning strikes. The distribution of injuries nevertheless has a sharper shape than the distribution of lightning strikes.

Time of injury is shown in figure 4 with the distribution of lightning flashes during each hour as a percentage of all 50,664 flashes detected over a period of 71 days in June, July, and August 1983 in central Florida, as reported by Lopez and Holle (*8*). Most injuries occurred from 1 through 6 p.m. and peaked between 2 and 4 p.m. Work-related injuries, however, were more evenly distributed throughout the day. Six of 10 such injuries occurred in the morning. The hourly distribution of time of occurrence of lightning-related injuries was very similar to the hourly distribution of flashes.

By reviewing eyewitness testimony in the medical examiners' files, we identified 11 of the 101 persons killed (21 percent) who were at a distance from the ground strike and 42 who were hit directly. This information was not available for 48 persons. Twelve of 60 (20 percent) of the victims for which this information is known were moving when hit. Thirty-three of 53 (63 percent) were holding something metallic. Those who were not holding something metallic were less likely to be hit directly by lightning (OR = 0.05, confidence interval (CI) 0.00, 0.42, $P = 0.0009$). Twenty-three of 58 victims (40 percent) were under a tree when they were struck. Those under a tree were less likely to have been directly hit (OR = 0.1, CI = 0.01, 0.66, $P = 0.005$. In nine cases out of the 42 for which detailed weather information was available (21 percent), there was no rain at the time of the strike. When struck, three persons were trying to protect property. Of the 44 people tested for drugs, 3 had traces of cocaine and 6 had traces of alcohol.

The location and circumstances of the 101 lightning-related injuries resulting in death are described in an accompanying box. The available data do not provide more detail on the categories described. No one was injured while swimming. One person died while sheltered under a stable, holding metal wire. A total of 32 persons were killed while on or near water, a river, lake, or ocean.

Thirty percent of all deaths occurred among persons injured while on the job. None of the females was killed while on the job, although some were involved in domestic tasks. Among the people killed on the job whose occupations were known, nine (30 percent) were farmers or farm laborers, eight (27 percent) were construction workers, three (10 percent) were students employed for temporary duties, three (10 percent) were employed in the tree and nursery business, and two (7 percent) were airline employees. One truck driver, one farming merchant, one jockey, one subscription salesman, and one land surveyor were killed.

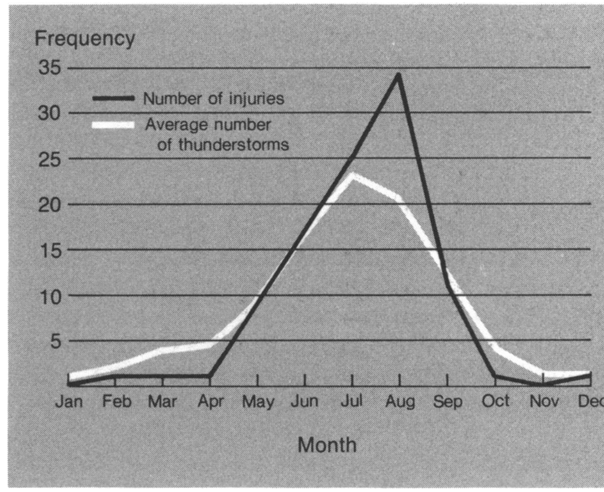
Sixty-seven percent of the victims were not killed instantly. CPR and other resuscitation techniques were applied in 51 of 60 (85 percent) cases for which this information was available. In 23 instances (23 percent of cases), death occurred the day following the injury or later (the following day in eight cases, from 2 to 15 days in seven cases, from 16 to 160 days in seven cases, and in one case, 5 years, during which the victim, who suffered brain damage, remained in a coma). Delayed death was associated mostly with pulmonary infection and brain damage.

Most deaths were caused by cardiorespiratory arrest. In five instances, death was related to complications of bronchopneumonia, in three instances to hypoxic encephalopathy, and in one instance to drowning, after the victim fell unconscious into water after being struck by lightning. Most autopsy findings showed electrical or thermal burns (61 of 83 cases for which this information was available). The burns varied in extent and location on the body; sometimes they had a pathognomonic fern pattern. Burns were particularly apparent on the area of the body near near a metal object, such as a chain or a zipper. In some cases, polyester clothes were melted.

There were 22 cases of specific pulmonary congestion or edema. Other observed respiratory tract problems included five cases of bronchopneumonia, three pulmonary hemorrhages, two of pneumonia, and one pulmonary infarction. There were 10 reports of cerebral edema, four brain injuries, and four cases of anoxic brain damage. Six persons had generalized congestion. Nine victims had ruptured ear drums. One showed a fracture from severe contractions. At least eight autopsies found cardiac predisposition with arteriosclerosis.

Lightning-related injuries. All but one hospital in the four counties agreed to participate. We identified 18 persons struck by lightning during the survey period who were hospitalized and survived. Four additional patients who were admitted to a hospital died. Eight other lightning-related deaths occurred in those counties during 1978–87. This gives an injury to death ratio of 2.5.

Figure 3. Lightning-related deaths by month of injury and average number of thunderstorms by month, Florida, 1978–87



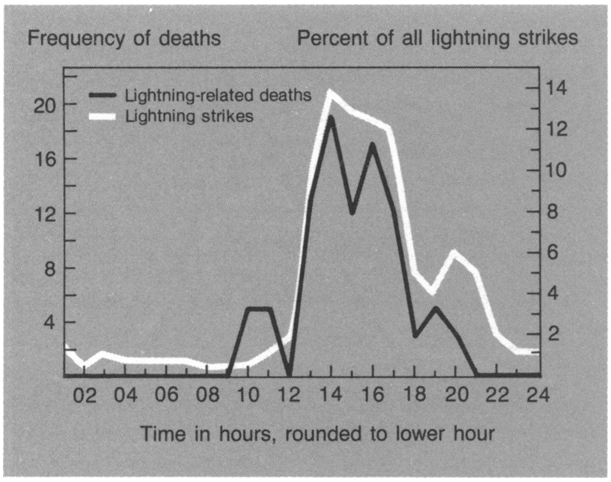
Locations and Circumstances of 101 Lightning-related Injuries Resulting in Death in Florida, 1978–87

13 in yards
10 on farms, ranches, or in fields
9 fishing from boats
7 on beaches
6 on golf courses
5 each on bridges, construction sites, streets, and rural setting
4 near lakes or ocean
3 in parks
2 each on creeks, in vacant lots, on roofs, lifeguard towers, athletic fields, and under trailers or cars
1 each in tree, in grove, on school ground, on parking lot, on trailer or truck, on lake while water skiing, while fishing, at a race track, in open barn, in water while pushing a boat, at a camp, on a motorcycle, while working on a metal tower, under a shade house, and on an airport runway
2 unknown data

We tried to determine if some of the hospitalized patients later died from lightning-related injuries, although they were reported as discharged or transferred from the hospital in which they were identified. Because of the lack of personal identifiers, we tried to compare hospitalized persons with persons who died, matching age, sex, year, and date of injury. Sometimes, however, latency of death is long, and some persons may have died later whom we do not know about.

The ages of the 18 who survived ranged from 14 to 82 years. The median age was 27.0 years, and the mean 30.4 years. Sixty-one percent were male. Thirty-three percent were hit indirectly. Sixty percent were holding

Figure 4. Lightning-related deaths by time of injury and distribution of lightning strikes, Florida, 1978–87



something metallic. Eleven percent were moving. Thirty-eight percent were under a tree. One person was talking by telephone inside a warehouse when struck through the telephone wires. Another person reportedly was inside a kitchen, but we have no detailed information about what the person was doing. Five people (28 percent) were successfully resuscitated. Nine suffered burns. One had a bilateral tympanic perforation. One had an anoxic secondary encephalopathy.

Florida Hospital Cost Containment Board data showed fourteen cases of lightning-related injury occurring during the third quarter of 1987, and five cases in the fourth quarter of 1987. Six of the 19 persons (32 percent) were female. On average, 69 percent of all deaths occurred during the third trimester of the year during the 10-year period (figure 3). Assuming that (*a*) the monthly distribution of deaths is similar to the distribution of injuries, and (*b*) the 106 hospitals which answered for the third quarter were probably not more likely to answer according to the number of lightning-related injuries they treated, we estimated the total number of patients hospitalized for lightning-related injuries in Florida in 1987 at 44. That is 4.4 times the number of recorded deaths. Some of those hospitalized patients, however, might have died later from their lightning-related injuries and, therefore, could have been included in the 10 deaths occurring in 1987, or even at a later period.

Although there were no age and sex matches (we were not provided with personal identifiers) between data from the Florida Hospital Cost Containment Board and the 1987 deaths, we cannot exclude some later deaths. We added the deaths and injuries for 1987 and calculated that Florida residents have an annual risk of 0.54 per 100,000 of being struck by lightning and a cumulative life risk of 38.8 per 100,000 if life expectancy is assumed to be 72 years.

According to data from the National Weather Service, during 1978–87 there was a yearly average of 27.8 nonfatal injuries from lightning in Florida, with 37 injuries in 1987. That is 4.0 times the number of deaths recorded by the National Weather Service over the entire State.

Discussion

Sources of data. Our definition of a lightning-related injury or fatality was restricted to direct causation, which must be taken into account in comparing our results with those of other studies.

Our search was limited to the last 10 years because we believe that, in most cases, it would have been difficult to obtain detailed and accurate information for incidents that occurred before 1978. Because of time and money constraints, our search for injuries among hospitals was limited to selected counties. The morbidity figures obtained for hospitalized patients in the selected counties are only crude estimates of the true morbidity in those counties because some patients may have been injured in another county and some of the persons injured in those counties may have been treated in another location.

Our search for lightning-related injuries was probably incomplete because we only looked for inpatients. In addition, one hospital did not participate in our survey and some hospitals were unable to provide us with data for all 10 years. Therefore, our figures probably slightly underestimated the true number of victims. We missed all minor injuries or shocks for which people did not seek medical treatment or checkup. We believe, however, that inpatient records probably give a good estimate of the total number of serious injuries. Since being struck by lightning is a rare event, we believe it is not feasible to review all log books to identify conditions such as lightning-related injuries. In addition, a lightning-related injury might be reported in emergency room log books as a burn or an electrical shock.

We found instances of deaths unduly attributed to lightning on death certificates. In addition to a lack of information, data from death certificates can be misleading. For example, a person might be reported as hit while playing baseball, but actually was hit while taking cover off the playing field. Certificates usually do not contain information on protective actions taken or on preexisting medical conditions, such as cardiovascular diseases.

The National Climatic Data Center records only a fraction of all lightning-related deaths and injuries (68 percent of all identified deaths during 1978–87). Better understanding of the lightning strike problem depends upon improved recordkeeping.

National Weather Service records need to be more precise, particularly in classifying locations where injuries occur and the activities of the victim, and revised to reflect factors that are important for prevention efforts. More specificity is needed about locations and activities in regard to lightning strikes.

Improvement of recordkeeping may be difficult to achieve because the sources of information for the National Weather Service data base have many limitations. All our sources have limitations and none provides very detailed information in all cases. The best single source of data appears to be medical examiners' records, whose narratives, however, are inconsistent in the amount of detail contained. Autopsies and laboratory tests have not always been performed. These and other factors could introduce biases. When we present, for instance, the proportion of people taking shelter under a tree, results have to be interpreted, not as a true proportion, but rather as an indicator.

Risk factors. The large male-to-female ratio of persons killed by lightning is consistent with previous findings. The month and time of injury figures are consistent with outdoor activities being a major risk factor for lightning-related injury. Time of injury, however, is related to the hourly distribution of thunderstorms and, therefore, lightning strikes, which are more likely to occur in the afternoon at the hottest time of the day (*8*).

A comparison of the month and time distribution of occurrence of fatal lightning-related injuries with respect to the month and time distribution of lightning strikes must be interpreted cautiously because the frequency of lightning strikes varies according to location. In particular, our lightning strike distribution does not represent a geographic or a yearly average (*8*).

It is important to acknowledge that some people are killed although they are at some distance from the ground strike, ranging up to 30 feet, according to our survey. Factors contributing to deaths from indirect strikes may include the nature of the soil, the victim's posture, the intensity of the strike, and individual variability. Being under an isolated tree or near any other structure that attracts lightning increases the risk of an indirect strike.

Some risk factors for being struck by lightning include age, sex, and location. People can be hit while moving. The risk of being struck seems to increase if a person is under a tree or holding something metallic. However, the lack of denominator data about the proportion of persons being sheltered under trees versus being outside in other locations prohibits a detailed

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analysis of locations as risk factors. The overall large number of water-related injuries might be explained by lack of shelter, the large part of water-related activities among all outdoor activities in Florida, or a genuine increased risk from being near water, related to an increased number of lightning strikes, or increased electrical conduction.

For various reasons, people are hit by lightning despite the fact that lightning is a recognized danger. No one reason explains all cases. Lightning strikes some victims when they seek shelter or are under shelter. Some victims are struck when they have not sought shelter, either because it was not raining at the time, or because the lightning had just begun. The first strikes of lightning in a thunderstorm may be more dangerous, not in terms of impact, but because of the surprise element. Many people seek shelter under isolated trees during thunderstorms in the erroneous belief that a tree offers protection, or they may seek shelter from rain rather than from lightning. Someone might ignore safety rules because their judgment is impaired by drugs or alcohol. A case control survey would address some questions and test some hypotheses, such as for example, why some people do not seek appropriate shelter during electrical storms.

Job-related injuries are an important and frequent issue with respect to lightning strikes. Working may be an incentive to stay exposed or workers may be forced to continue working. On-the-job injury prevention may require regulations and recommendations different from National Weather Service safety rules. In Florida, 4.0 percent of the work force is employed in agriculture and 8.5 percent in construction. Therefore, the highest risk by profession is for farm laborers. The National Institute for Occupational Safety and Health ought to consider investigating why lightning victims did not stop work to seek shelter from lightning.

Estimates of the death-to-injury ratio obtained by three different methods are fairly similar and coherent. From those figures, we estimated the true death-to-injury ratio for lightning-related casualties in Florida to be about four. It is difficult to determine why some people are only injured and others killed. According to our data, nothing in the circumstances in which they were injured distinguishes injured and dead persons,

Recommendations for Lightning Strike Preventive Measures

When a storm threatens, get inside a home or large building, or inside a vehicle.

When inside, avoid using the telephone and close contact with plugged electrical appliances.

If outside with no time to reach a safe building or vehicle, do not stand under a tall, isolated tree in an open area.

Avoid projecting above the surrounding landscape.

Get out of and away from open water.

Get away from tractors and other metal farm equipment.

Get away from motorcycles, scooters, golf carts, and bicycles.

Put down golf clubs.

Stay away from any metallic object which could be a path for lightning, such as a drainpipe, metal stairs, or an antenna.

Avoid standing in small, isolated sheds or other small structures in open areas.

In a forest, seek shelter in a low area under a thick growth of small trees.

In open areas, go into a ravine or valley.

SOURCE: Adapted from National Weather Service recommendations.

with the exception that 20 percent of those injured versus 11 percent of those killed were indirectly hit. Differences between a fatal and nonfatal issue might have to do with the lightning strike and its severity. Persons who die might have risk factors, such as arteriosclerosis. Survival might be determined by the availability of appropriate resuscitation.

Age does not seem to be a risk factor for lightning-related death. The mean age of lightning victims was 31.8 for those who died and 30.4 years for those injured. When comparing those figures, we must be aware that the number of persons injured is small and that the mean age for those killed is based on their age at death and not at the time of injury. A matched case-control study could be undertaken to determine why some people are uninjured, others injured, and others killed.

The proportion of males in lightning-related deaths was 87 percent versus 61 percent in nonfatal injuries. These figures may suggest that males are at a higher risk of dying than females. However, a selection bias for people seeking hospital treatment cannot be excluded.

The frequent finding of cerebral edema on autopsy may indicate some direct effect of lightning on membranes. The perforation of ear drums, although inconstant, appears as common and specific to lightning-related injuries. Although the major cause of death among those struck by lightning is cardiac arrest, delayed deaths can be attributed to bronchopneumonia or encephalopathy secondary to cerebral anoxia. Therefore it appears very important to carefully monitor the pulmonary status of lightning victims who are hospitalized. Resuscitation methods need to be applied within 4 minutes or less to people who are not breathing.

Protective factors. Our findings confirm the appropriateness of the National Weather Service's recommendations, which are outlined in the accompanying box.

We emphasize the importance of observing the National Weather Service recommendations and urge that people act quickly in impending thunderstorm situations. Precautions against lightning strike should be taken even if the main thundercloud is not directly overhead because people can be struck on the edges of storms and outside the area where it is raining. Further, we recommend that specific advisories be provided to farmers and posted at outdoor recreation sites, such as golf courses, marinas, and beaches.

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Equipment

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