Lightning Fatalities on the South African Highveld

A Retrospective Descriptive Study for the Period 1997 to 2000

Ryan Blumenthal, MBChB (Pret), dip For Med (SA)

Abstract: A review of the Southern Africa medical literature shows a paucity of published data regarding lightning fatalities. The South African Highveld has a lightning ground flash density of 6 to 9 flashes/km^2/year, with a high incidence of thunderstorm days per year (some 40–70). The Highveld has a largely urban population, many of whom have low socioeconomic status and poor education, housing, and other infrastructures and hence (possibly) are at greater exposure risk. Thirty-eight victims of lightning-related death were identified from the records of the 6 large medicolegal mortuaries on the South African Highveld, serving a population of approximately 7 million, for the period 1997 to 2000. Analysis of the records revealed that 95% of all victims were black, 79% were male, and the average age was 36 years. Lightning strikes occurred from September through to April (normal summer rainfall period), and the most strikes took place in the late afternoon (3:00 PM to 6:00 PM). All except 1 case occurred outdoors. In the autopsy reports, mention was made of singeing of hair in 68% of cases, and mention of damage to clothing was made in 26% of cases. Cutaneous thermal injuries were noted in 34 of the 38 cases, with apparent electrothermal injuries of the feet noted in 4 cases. Fifty-two percent of victims sustained some form of associated blunt-force injury (including abrasions, contusions, etc). Specific keraunopathologic injuries were described in only 2 of the cases. Twenty-one cases had some form of internal organ injury. This study serves to illustrate the relatively high incidence of lightning strikes in the region and calls for a more systematic and detailed investigative protocol in lightning-related deaths.

Key Words: keraunopathology, lightning fatalities, South Africa

(*Am J Forensic Med Pathol* 2005;26: 66–69)

A review of the Southern African medical literature shows a paucity of published data related to lightning injuries and lightning fatalities,[1–5] most reports coming from the lay press. The province of Gauteng is largely composed of the so-called Southern African Highveld, which is composed of a predominantly urban population, many of whom are of low socioeconomic status, with poor education, housing, and other infrastructures. The South African Highveld endures a high incidence (some 40–70) thunderstorm days per year.[6] Furthermore, the South African Highveld has a lightning ground flash density of 6 to 9 flashes per square kilometer per year[6] (Fig. 1). The highest strike rate in the country is on the Drakensberg escarpment in KwaZulu-Natal, with Giant's Castle registering a lightning strike rate of 13 per square kilometer per year.[5]

Eriksson and Smith[3] reported a mean rate of 1.5 deaths per million inhabitants among the largely urban population and 8.8 for the rural population during a 4-year period.[7] Yearly worldwide death rates from lightning range between 0.2 and 1.7 per million of the population.[8]

A lightning strike is initiated when potential gradients within a cloud become high enough to cause air to ionize and break down and a lightning leader starts to advance either towards the ground or to upper-cloud charge concentrations. Flashes to ground usually start in small steps of 50 m in length and are heavily branched or forked, followed by a bright, seemingly upward-moving streamer called the return stroke. This may be followed by 1 or more component strokes, which are not usually branched, and as many as 20 or so components have been recorded. The ribbon appearance sometimes observed is due to the separation of these components when very high wind occurs simultaneously. So-called sheet lightning is seen when the lightning flashes are obscured from direct view by heavy rain or cloud. Intra- and intercloud flashes are more common than flashes to ground, especially in the tropics, and occasionally air discharges occur when a leader emerges from a cloud and discharges without reaching ground (Dr Ralph Blythe Anderson, personal communication). Ball lightning and coronal discharges are poorly understood phenomena that have fascinated humans for centuries.[9–11] Lightning may also strike during a clear blue day, the so-called bolt from the blue.[12] From a

Manuscript received August 11, 2004; accepted November 24, 2004.
From the Department of Forensic Medicine, University of Pretoria, Pretoria, South Africa.
Reprints: Ryan Blumenthal, MBChB (Pret), dip For Med (SA), Department of Forensic Medicine, University of Pretoria, PO Box 2034, Pretoria 0001, South Africa. E-mail: ryan.blumenthal@up.ac.za.

ISSN: 0195-7910/05/2601-0066
DOI: 10.1097/01.paf.0000154115.12168.46

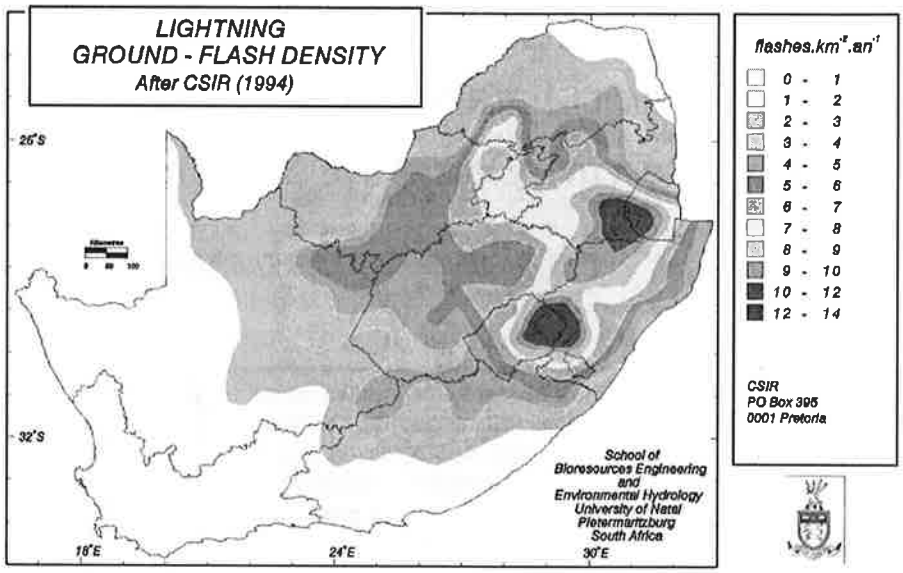

FIGURE 1. Lightning ground-flash density (South Africa).

protection point of view, leaders have been observed to travel very obliquely across the sky, striking ground tens of kilometers away from the originating cloud charge center.

The lightning channel is incandescent but only a few centimeters in diameter. Lightning may heat the surrounding air to temperatures in excess of 30,000°C.[13] The potential between cloud and ground is of the order of 100,000,000 V, and the unidirectional electric current flowing to earth in a component stroke has a peak value which varies between 2 and 300 kA, with a median value of about 30 kA, and has a duration which also varies between a few hundred microseconds to as much as a second. Flashes lasting as long as a second have been called "hot lightning," these reportedly being more dangerous than the short flashes.[14]

Lightning injuries can be explained in 4 ways. These mechanisms of injury are first, a direct lightning strike, and second, an indirect strike by contact with an object such as a pole or tree directly struck. A third mechanism is a side flash that could occur from a stricken object, such as a tree, to a nearby victim standing close by. Finally, a person or animal standing near a stricken object, or close to a flash of lightning to the ground, could be injured by so-called step voltages produced by lightning-induced current flowing through resistance of the soil beneath.[2,10,13,15,16]

Recently, a fifth mechanism of lightning injury has been proposed by Anderson[17] and Anderson et al,[18] namely, that the bodies could be charged sufficiently during the lightning leader process to cause upward streamers to be initiated from them.[17,18]

MATERIALS AND METHODS

For purposes of this study, a lightning-related death was defined as anyone most likely killed by electrical energy resulting from being struck directly or indirectly by lightning. All cases that resulted from fires, falling trees, or other indirect effects of lightning were excluded. All cases referred to the medicolegal mortuaries by the investigating agencies (police officers) as being possibly due to lightning were reviewed with reference to mortuary admission forms, autopsy reports, and case investigation dockets, with cases being included or excluded based on the above criteria. All cases were correlated with the occurrences of electrical storms, using information from the South African Weather Service. According to the autopsy reports, all cases were autopsied, which included external and internal examination of the body.

Official data collected at 6 large medicolegal mortuaries serving the metropolitan areas, Province Gauteng, on the South African Highveld were used. The mortuaries involved were the medicolegal laboratories of Pretoria, Diepkloof (Soweto), Medunsa, Roodepoort, Germiston, and Braamfontein. Data were processed using the SAS version 8 statistical software package and were analyzed with the assistance of a statistician from the University of Pretoria. Access to and consent for use of the data were obtained from the Gauteng Department of Health, the University of Pretoria's ethics committee, South African Police Service authorities, and individual mortuary managers. All data were treated confidentially.

These 6 mortuaries serve a population basin of approximately 7.2 million people, of which 79% are black, 17% are white, 0.7% Asian, and 2.4% are of mixed ethnic descent (population census 1997).

RESULTS

Of the 58,927 deaths referred to the 6 large mortuaries on the South African Highveld between 1997 and 2000, 38 fatal lightning strike victims were identified. This suggests an inci-

dence of 64.48 per 100.000 unnatural deaths, or 6.3 per million general population. Australia, on the other hand, has an average of 0.21 lightning-related deaths per million population.[19]

Of the 38 cases identified, 52% (20/38) were witnessed lightning strikes. The South African Weather Bureau could, by means of its database, confirm 15 out of 38 of the strikes. It declared 9 out of 38 of the strikes possible, but it could neither confirm nor deny 14 of the 38 cases.[6]

The ages of victims ranged from 5 to 61 years, and the average age was 36 years (Fig. 2). The majority of cases were of the black race (35/38), and the majority of victims were male (30/38). Lightning fatalities occurred from September through April (the summer-rainfall period). No cases occurred in the winter months (April through September) (Fig. 3). The time of the day was not determined in 9 of the cases. Most lightning strikes happened between 3:30 and 6:30 in the late afternoon (Fig. 4). All except 1 case occurred outdoors. Of the cases that occurred outdoors, the majority (14/38) of victims were located in an open field.

Death was probably immediate in all except 1 of the cases, the latter dying several hours later in hospital. All were single-victim events, except in 3 instances, in which 2 people were involved.

The condition of the clothing was mentioned in the medicolegal autopsy reports in 10 of the cases. The damage ranged from subtle fiber melting to gross burning. Interestingly, 5 of the 10 cases were reported as *torn*, *tattered*, *blown-apart*, and *ruptured*. These defects appeared most prominent laterally.[20]

The condition of personal metallic objects (eg, watches, necklaces) was not mentioned. However, in one case a burn mark was noted on the skin underlying a metallic button, and in another case a burn mark was noted underlying a metallic belt buckle.

Singed hair was mentioned in 38% (12/38) of the cases. Cutaneous thermal injury was noted in 34 of the 38 cases. Of these cutaneous thermal burns, 28% had predominant first-degree burns, 73% had second-degree burns, and 47% had predominant third-degree burns. There was no mention, in this series, of charring of bodies.

FIGURE 3. Lightning fatalities according to month of the year.

Electrothermal injuries of the feet, including the so-called tiptoe sign or blowout-burn,[14,21] were noted in 4 of the cases. These were found chiefly on the plantar aspects of the feet.

Specific keraunopathologic features, such as the presence or absence of arborization or Lichtenburg figures,[12,15] were mentioned in none of the reports. In 2 of the cases, mention was made of electrical-type burns ("crocodile skin" and "arcing injury"). Rupture of the tympanic membrane was mentioned in only 1 case.

Fifty-two percent (20/38) of the cases showed features consistent with associated blunt-force injury (including contusions, abrasions, etc). Fractures were encountered in 2 cases (fractured spine and fractured clavicle, respectively).

Blood alcohol concentration was performed in 11 of 38 of the cases. One single case had a level of 0.28 g/100 mL. All the

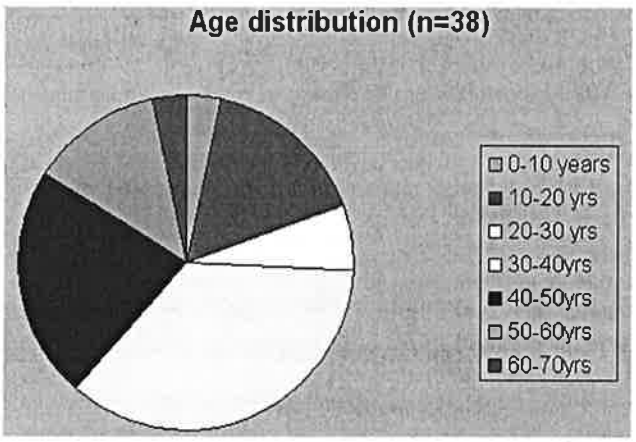

FIGURE 2. Age distribution of victims.

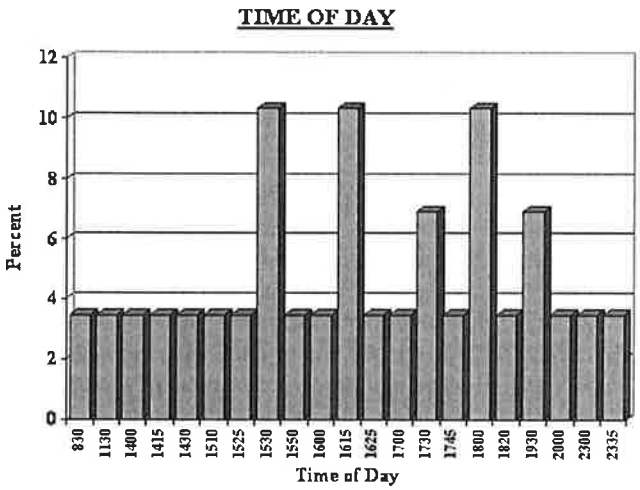

FIGURE 4. Lightning fatalities according to time of day.

other specimens tested negative for alcohol. There was no testing performed for drugs of abuse (cocaine, opiates, etc).

One victim was 8 weeks pregnant.

DISCUSSION

When lightning deaths are witnessed, the medicolegal investigation is greatly facilitated. If there are no reliable witnesses, however, the cause of death may be more difficult to establish. It is therefore critical to do a diligent search for evidence at the scene and a meticulous postmortem investigation.[12] These deaths should involve medical and technical expertise and should include, where possible, scene investigations and examination of instruments, apparatus, etc.

At the scene of a lightning strike, there may be damage to nearby trees, such as splitting or removal of bark. Charred arc marks may be present on the walls of nearby structures. The ground may display a fern pattern and may show so-called fulgurite formation: bore or tubelike substance formed in sand or rock by lightning. When lightning is suspected to have caused the death of a person inside a building, nearby telephone and electrical equipment should be examined by an expert to determine the point of entry of the alleged lightning strike.[22] A history of electrical thunderstorm activity should be ascertained from the local weather bureau. To preserve the case history for scientific purposes, a relevant academic institution or other expert in the field should, if possible, be advised of the incidence of lightning fatalities, especially should there be any suggestion of litigation by a surviving party[7] (also, Dr Ralph Blythe Anderson, personal communication).

Mention should always be made of the clothing of lightning victims, particularly the shoes. Metal objects may have burned underlying skin or been marked by the heat of electrical arcing. Metal objects may show signs of fusing and/or magnetization.

After examination of the clothing, a thorough postmortem examination should be performed. Specific mention should be made of the following:

- The type, pattern, and distribution of any cutaneous thermal injuries, including clusters of punctuate burns, blisters, or charred burns.
- Rupture of tympanic membranes.
- Singeing of hair or scorched hair.
- Eye signs, such as retinal detachment (cataracts can be difficult to demonstrate postmortem).
- Unique arborescent or fernlike injuries (Lichtenburg figure).[23]
- Metallic objects such as tooth fillings, spectacles, and pacemakers.[24,25]

Keraunopathologic findings in this study were consistent with those reported in the international literature.

This study serves to illustrate the relatively high incidence of lightning fatalities in the study region. Furthermore, this retrospective review has demonstrated the need for a more systematic and detailed investigative protocol in lightning-related deaths in urban and periurban areas on the South African Highveld. This study should be seen as a call for greater attention to detail in the medicolegal investigation and reporting of lightning-associated deaths for purposes of better judicial administration and improved understanding and knowledge of keraunomedicine.

ACKNOWLEDGMENTS

The author would like to thank Dr Ralph Blythe Anderson, Tracy Gill (South African Weather Service), Mr J Grimbeek (Statistician University of Pretoria), SAPS Medico-Legal personnel, Prof G Saayman (Department Forensic Medicine).

REFERENCES

1. Castle WM, Kreft J. A survey of deaths in Rhodesia caused by lightning. *Central African J Med.* 1974;20:93–95.
2. South Africa Department of Health. *Salus: Weerlig en Donderstorms.* 1988;11:12–13.
3. Eriksson AJ, Smith MA. A study of lightning fatalities and related incidents in Southern Africa. *Trans SA Inst Elec Eng.* 1986;163–178.
4. Kleinot S, Klachko DM. The cardiac effects of lightning injury. *SA Tydskrif vir Geneeskunde.* 1966;31:1141–1143.
5. Lightning deaths go unrecorded. *The Star* (Independent Newspapers, Gauteng). October 12, 1998; News section:6.
6. The South African Weather Service. Private Bag X097, Pretoria, 001. Available at: http://www.weathersa.co.za/.
7. Carte AE, Anderson RB, Cooper MA. A large group of children struck by lightning. *Ann Emerg Med.* 2002;39:665–670.
8. Wetli CV. Keraunopathology: an analysis of 45 fatalities. *Am J Forensic Med Pathol.* 1996;17:89–98.
9. Andrews CJ, Cooper MA, Darveniza M, et al. *Lightning Injuries: Electrical, Medical and Legal Perspectives.* CRC Press, Inc; 1992.
10. Lifschultz BD, Donoghue ER. Deaths caused by lightning. *J Forensic Sci.* 1993;38:353–358.
11. Cherington M, Yarnell PR. Lightning-induced injury on airplane: coronal discharge and ball lightning. *J Trauma.* 2002;52:579–581.
12. Cherington M, Kurtzman R. Mountain medical mystery. *Am J Forensic Med Pathol.* 2001;22:296–298.
13. Prataap K, Shaw C. Nature's high voltage injuries: sometimes a deadly consequence. *Netherlands J Med.* 1996;49:153–159.
14. Fahmy S, Brinsden MD. Lightning: the multisystem group injuries. *J Trauma.* 1999;46:937–940.
15. Lewis AME. Understanding the principles of lightning injuries. *Patient Care.* 1992;15:535–541.
16. Cooper MA. Electrical and lightning injuries. *Emerg Med Clin North Am.* 1984;2:489–501.
17. Anderson RB. Does a fifth mechanism exist to explain lightning injuries? *IEEE Eng Med Biol.* 2001:105–112.
18. Anderson RB, Jandrell IR, Nematswerani HE. The upward streamer mechanism versus step potentials as a cause of injuries from close lightning discharges. *Transact SA Inst Electric Eng.* 2002:33–43.
19. Editorial: death by lightning. *Med J Austr.* 1973;2:252.
20. Anderson RB, Carte AE. Struck by lightning. *Archimedes.* 1989:25–29.
21. Cooper MA, Cantrill SV. Electrical and lightning injuries. *Patient Care.* 1992;15:158–175.
22. Jumbelic MI. Forensic perspectives of electrical and lightning injuries. *Semin Neurol.* 1995;15:342–350.
23. Resnik BI, Wetli CV. Lichtenberg figures. *Am J Forensic Med Pathol.* 1996;17:99–102.
24. Bernard Knight. Deaths from lightning: electrical fatalities. In: *Forensic Pathology Textbook.* 2nd ed. Arnold Publishing; 1996:330–331.
25. Camps FE. Heat, cold and electricity. In: *Gradwohls' Legal Medicine.* 2nd ed. Bristol: John Wright & Sons Ltd; 1968:387–390.