ORIGINAL ARTICLE

An Autopsy Series: Lightning-related Deaths in Van and Hakkâri Provinces, Turkey

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ABSTRACT

Objective: *To report the largest series of lightning-related deaths in Turkey, to review the literature on this subject, and to identify similarities and differences between the autopsy findings in this study and the information available in literature.*

Methods: *In this study, autopsy reports and crime scene investigation data on 11 lightning-related fatalities that occurred in the Van and Hakkâri Provinces, Turkey, from January 1, 2011 to December 31, 2015 were retrospectively reviewed.*

Results: *Of the 1699 fatalities, 11 (2.53%) evaluated by medico-legal autopsy in the Van and Hakkâri Province in a 5-year period died from lightning strikes. Of these cases, 10 (90.1%) were males and 1 (9.9%) was female (*$p < 0.05$*). All cases were in the 11 to 33 years age group. All cases were injured outdoors.*

Conclusion: *We concluded that deaths due to lightning strikes are relatively rare in Turkey, and may be reduced with precautions such as avoiding staying under trees or in the vicinity of high towers, refraining from touching metal objects, avoiding lying on the ground, leaning on walls, and crouching outdoors.*

Keywords: Autopsy, burns, lightning-related deaths, lightning strike

INTRODUCTION

The flash of lightning is one of nature's most deadly incidents, and the number of lightning strikes in a day is approximately eight million on Earth (1–3). The temperature of lightning fire could rise to 20 000ºC which is more than three times the surface temperature of the sun, and the power of lightning is between 20 million and 1 billion volts and 200 000 A (1, 2, 4).

Lightning strikes are the second leading cause of weather-related deaths on Earth (5). The incidence of deaths from lightning strikes has been reported to be 0.2 to 0.8 per million people per year (6). Deaths due to lightning strikes are related to the regional climatic characteristics and seasonality (7). Accidental deaths due to lightning strikes are not uncommon in tropical and subtropical countries, whereas they are rarely seen in other countries (6, 8). Deaths from lightning strikes usually occur during showers of rain in the afternoon or evening hours during the spring and summer months (9, 10).

When lightning strikes, injury occurs by way of six different mechanisms: (a) direct strike effect, (b) contact effect when lightning strikes an object touched by a victim, (c) a side flash effect from a nearby object struck by lightning, (d) a step voltage or ground current effect from a lightning strike several metres away, (e) upward streamer effect, related with injury by a low energy and (f) recently, the so-called sixth mechanism, which can be viewed as an 'electroblast effect' (Fig. 1) (5, 8, 11, 12).

There is much literature available worldwide on many lightning-related deaths, but there are only a few articles written as case reports on lightning-related deaths in Turkey. The aims of this study are to report the largest series of lightning-related deaths in Turkey, to review the literature about this subject, and to identify

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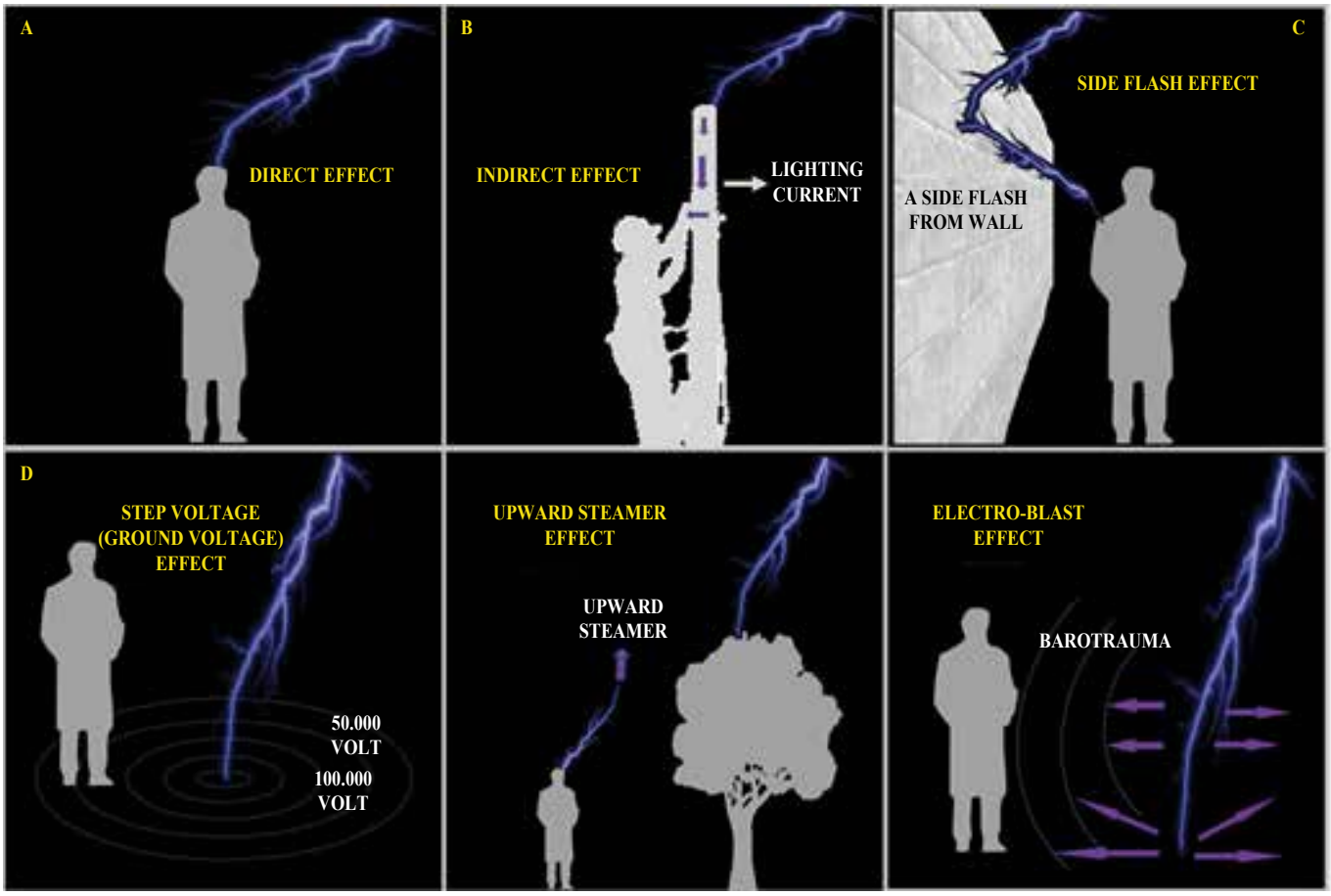

Fig. 1: Six mechanisms of injury to persons exposed to lightning strikes.

similarities and differences between the autopsy findings of this study and the information available in literature.

SUBJECTS AND METHODS

In this study, autopsy reports and crime scene investigation data on 11 lightning-related fatalities that occurred in Van and Hakkâri Provinces, Turkey, from January 1, 2011 to December 31, 2015 were retrospectively reviewed.

Data on the age, gender, occupation of the victims, seasonality of the deaths, crime scene findings, autopsy findings, manner of deaths, and risk factors for lightning strikes were obtained from autopsy records and scene investigation records. All results were compared with the available literature.

RESULTS

Of the 1699 fatalities, 11 (2.53%) evaluated by medicolegal autopsy in Van and Hakkâri Province in a 5-year period died from lightning strikes. The average annual incidence of fatal lightning strikes during the study period in Van and Hakkâri Provinces was calculated as 0.02% per million persons.

Of these cases, 10 (90.1%) were males and 1 (9.9%) was female ($p < 0.05$). All cases were in the 11 to 33 years age group. Two cases were teenagers (18.2%), seven cases were in the third decade of their lives (63.6%) and two cases were in the fourth decade (18.2%). The mean age of the cases was 23.5 years (standard deviation: 6.3; median: 23). All cases were injured outdoors. Four victims were soldiers in fields (36.4%), four victims were farmers in fields (36.4%), two victims were shepherds in grasslands (18.2%), and one victim was a housewife in the garden during the incident (9.0%). Ten cases were exposed to lightning strikes during the afternoon and evening hours (91.0%), whereas one case was at dawn (9.0%). Five cases died in the summer (45.5%), five cases died in the autumn (45.5%) and one case died in spring (9.0%). In all cases, the presence of rain and lightning events in places where the injury occurred and at injury time was confirmed by eyewitness statements and meteorology reports (100.0%). There were environmental evidences of lightning in eight cases (72.7%). Clothing was seen in four cases (36.4%) (Fig. 2). In only one case (9.0%), burned objects and magnetized metal objects were determined (Table 1).

At autopsies, linear burns were seen in six cases (54.5%) (Fig. 3), and punctate burns in four cases (36.4%), Lichtenberg figures were seen in seven cases (63.6%) (Fig. 4), thermal injuries due to contact with metal objects in three cases (27.3%), thermal injuries due to burning clothing in two cases (18.2%), and thermal injuries due to direct effect of lightning in three cases (27.3%). Singed hairs were seen in seven cases (63.6%) (Fig. 5). Additionally, washerwoman hands were seen in two cases (18.2%) (Table 2).

Fig. 2: Torn and shredded clothing in two cases.

Fig. 3: Linear burn in a case.

Fig. 4: Lichtenberg figure in a case.

Fig. 5: Singed hairs in two cases.

Table 1: Demographic, environmental and clothing features regarding 11 victims who died from lightning strikes

No. of cases	Sex	Age	Job	Month	Witness statements	Meteorology reports	Burned grass	Other damages in scene	Burned clothing	Torn and shredded clothing	Burned objects	Magnetized metal objects
Case 1	Male	23	Farmer	July	+	+	+	+	−	−	−	−
Case 2	Male	16	Farmer	July	+	+	+	+	−	−	−	−
Case 3	Male	11	Farmer	July	+	+	+	−	−	−	−	−
Case 4	Male	31	Shepherd	October	+	+	−	+	−	−	−	−
Case 5	Male	25	Shepherd	May	+	+	+	+	−	+	−	−
Case 6	Female	22	Housewife	June	+	+	+	−	−	−	−	−
Case 7	Male	33	Farmer	August	+	+	+	+	−	−	−	−
Case 8	Male	23	Soldier	October	+	+	−	−	−	−	−	−
Case 9	Male	25	Soldier	October	+	+	+	−	+	+	−	−
Case 10	Male	28	Soldier	October	+	+	−	−	+	+	−	−
Case 11	Male	21	Soldier	October	+	+	−	−	+	−	+	+

Table 2: External findings of autopsies in 11 victims who died from lightning strikes

No. of cases	Linear burns	Punctate burns	Lichtenberg figures	Thermal injuries due to contact with metal objects	Thermal injuries due to burning clothing	Thermal injuries due to direct effect of lightning	Singed hair	Washerwoman hands
Case 1	+	+	+	−	−	−	+	−
Case 2	−	−	−	−	−	−	+	+
Case 3	+	+	−	−	−	+	+	−
Case 4	−	−	+	+	−	−	−	−
Case 5	+	+	+	−	−	+	+	−
Case 6	+	−	+	−	−	+	+	−
Case 7	+	−	+	−	−	−	+	−
Case 8	−	+	−	+	−	−	−	−
Case 9	+	−	+	+	+	−	+	−
Case 10	−	−	+	−	−	−	−	−
Case 11	−	−	−	−	+	−	−	+

In internal examinations, the findings of craniocerebral traumas were seen in two cases (18.2%). In one of the same two cases, there were ruptures on the abdominal walls, and small bowels overflowed out of the abdominal cavity from this rupture. Additionally, lung contusions were seen in both these cases. Internal organ lesions were not seen in other cases, and tympanic membrane rupture was not defined in any case.

DISCUSSION

The annual mortality incidence from lightning strikes was reported to be 0.2 to 0.8 per million people (6). The average annual number of deaths due to lightning per million people was reported to be 0.05 in the United Kingdom (13). The average annual incidence of fatal lightning strikes was 0.02 per million people in Van and Hakkâri Provinces. This rate represents 1/10 to 1/40 of the global average rate. We think that this low rate in the present study may be associated with climatic characteristics of Van and Hakkâri Provinces. Also, the altitudes of these cities are more than 1700 m, and their climate has been defined as arid and semiarid by Aytemiz (14).

It was reported that "males are five times more likely to be struck by lightning than females" (5). In previous studies, the rate of male victims was over 87% (7, 10, 15, 16); it was even found to be 100% in one study (5); despite that relatively lower rates of 50% (17) and 70% (2) have been reported in two studies. In the present study, the proportion of male victims was 90.1%. The mean age of cases ranges from 22 to 31.8 years in several studies (5, 7, 15, 16). Also, the mean age was 23.5 years in this study.

Persons involved in outdoor activities, especially farmers, constructors, campers, hikers, climbers, golfers, hunters, and military personnel are more likely to be struck by lightning than persons indoors (3–5, 12, 13). All the cases studied were injured outdoors. Four victims were soldiers (36.4%), four victims were farmers (36.4%), two victims were shepherds (18.2%), and one victim was a housewife in the garden during the incident (9.0%).

Lightning-related deaths usually occur during rain spells in the afternoon or evening hours in spring and summer (9, 10). In our series, 45.5% of the cases died in the summer and 45.5% of the cases died in the autumn. Of them, 10 were exposed to lightning strikes in the afternoon and evening hours (91.0%), whereas 1 was exposed at dawn (9.0%).

When a death due to lightning is reported to a forensic investigator, the meteorological data about the scene at the time of the incident can be obtained from eyewitness statements and meteorology reports. In the scene investigation, damage to nearby trees or keraunographic markings like the burning of the grass around the body on the ground are important clues (16). In the present study, the presence of rain and lightning events in places where the injury occurred and at injury time was confirmed by eyewitness statements and meteorology reports in all cases, and environmental evidences of lightning was determined in 72.7% of the cases.

Also, the findings that obtain from clothing examination are quite valuable. Clothing may be burned, or torn and shredded, due to the possible blast effect of lightning (16). Torn and shredded clothing was reported in 38% of cases in the study by Akkaya *et al* (7). In the present study, clothing findings were seen in 36.4% of the cases.

Some metallic objects, such as keys and coins, may be charred, fused or become magnetized (16). Also,

burned objects and magnetized metal objects were determined in one case (9.0%).

In the external examination of corpses, four types of skin lesions, including linear, punctate, feathering (Lichtenberg figures) and thermal, can be seen (3, 18). Linear burns, which are usually localized in the axillar region, under of breast region and the middle-inferior part of the chest associated with high sweat concentration, are usually small burns with 1 to 4 cm in diameter. Linear burns, which are probably caused by vapourization of water on the skin's surface, may be present initially, or develop over several hours (3, 18). Linear burns were seen in 54.5% of cases. Punctate burns, which are small, multiple, closely spaced, and circular, with a diameter of less than 1 cm, generally settled to tips of the toes and the sides of the soles of the feet (3, 18). Linear burns were seen in 36.4% of cases.

Lichtenberg figures, which are also known as keraunographic markings, are one of best known "feathering" lesions. They, similar to a fern image, are pathognomonic for the lightning strikes, even if they are not seen in many autopsies. Their pathophysiology is associated with extravasation of blood in the subcutaneous tissues and they generally disappear within 24 hours without known residual effect (3, 18). Lichtenberg figures were reported in 28% of cases in the study of Turan *et al* (5) and in 50% of cases in the study of Akkaya *et al* (7). In the present study, the rate of Lichtenberg figures was 63.6%.

Thermal injury may result due to heat from metal objects (zippers, metal wristwatch, metal clothing buttons, belt buckles, necklaces, coins, *etc*) or contact with burning clothing. In victims who are exposed to lightning strikes, extensive tissue destruction or large cutaneous burns are rarely seen (3, 7, 18). Contact burns were reported in 38% of cases in the study by Akkaya *et al* (7). Thermal injuries due to contact with metal objects were seen in 27.3% of cases, thermal injuries due to burning clothing were seen in 18.2% of cases, and thermal injuries due to direct effect of lightning were seen in 27.3% of cases in the present study.

The singed hair, which occurred by the thermal effect of lightning, can be seen in victims (5, 6, 9, 16). Singed hair was reported in 71% of cases in the study by Turan *et al* (5). In the present study, the frequency of singed hair was 63.6%.

Additionally, washerwoman hands were seen in two cases (18.2%). This finding may be related to the bodies being in the rain for a long time.

Craniocerebral trauma may be caused primarily due to the direct effect of lightning or secondary to blunt head trauma due to the electroblast effect of lightning (5, 16). The findings of craniocerebral traumas were seen in two cases (18.2%).

Cardiac injuries due to lightning were rarely seen in autopsies, but electrocardiographic changes, suggestive of myocardial infarction, were frequently reported by clinicians (2, 16). There were no cardiac injuries in our study.

Pulmonary contusions were defined as attributed to lightning strikes (16). In our series, pulmonary contusions were seen in two cases (18.2%).

Although not previously mentioned in relevant literature, small bowels overflowed out of the abdominal cavity from a rupture in the abdominal wall.

Tympanic membrane rupture is regarded as one of the most common injuries in lightning victims (3, 16); however, in the present study, it was not seen *or* noted.

CONCLUSION

Findings from autopsies on persons who died from lightning strikes are not sufficient to determine the manner of death. Examination of clothes and the investigation of the event scene offer important clues for forensic scientists regarding the manner of death. , Eyewitness statements and meteorology reports are also important in investigating the manner of death of persons found in the outdoor, especially in fields. The diagnosis of death by lightning strike is not a difficult conclusion for a forensic expert to arrive at.

The number of deaths due to lightning strikes, though relatively rare in Turkey, may be reduced with additional precautions such as avoiding staying under trees or in the vicinity of a high tower; avoiding touching metal objects, and refraining from lying on the ground, leaning against a wall, and crouching outdoors.

AUTHORS' NOTE

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Y Hekimoglu conceived the paper, oversaw data collection, conducted data analysis, wrote the manuscript and approved the final version. M Asirdizer provided oversight to the study, participated in the study design, data analysis and interpretation, critically revised the manuscript and approved the final version. U Demir participated in the study design, data analysis and interpretation of data and revision of the manuscript and approved the final version. A Gur participated in the study design, interpretation of the data and revision of

manuscript, and approved the final version. Y Etli participated in the study design and interpretation of data, critically revised the manuscript and approved the final version. O Gumus participated in the study design and interpretation of data, critically revised the manuscript and approved the final version. E Kartal participated in the study design, interpretation of data and revision of manuscript, and approved the final version. The authors declare that they have no conflicts of interest.

REFERENCES

1. Chamber of electrical engineers KTMMOB [Internet]. Lefkosa, IL: Bilgekul H. Wild electricity: lightning (Turkish web pages); [rev 1 Nov 2016; cited 30 Nov 2016]. Available from: http://www.ktemo.org/uploads/documents/23-03_vahsi_elektrik_-_simsek_ve_yildirimlar.pdf
2. Islamoglu Y, Cil H, Basturk M, Tekbas E, Elbey MA. Noninvasive electrophysiological effects of lightning strike: case series. Eurasian J Emerg Med 2011; **10:** 97–9.
3. Ritenour AE, Morton MJ, McManus JG, Barillo DJ, Cancio LC. Lightning injury: a review. Burns 2008; **34:** 585–94.
4. Dogan KH, Denirci S, Gunaydin G. Deaths caused by lightning strike: case report of three cases. Genel Tıp Derg 2007; **17:** 217–22.
5. Turan N, Birincioglu I, Butun C, Can M. Findings in fatal lightning strike cases. Turkiye Klinikleri J Foren Med 2011; **8:** 59–65.
6. Eriksson A, Ornehult L. Death by lightning. Am J Forensic Med Pathol 1988; **9:** 295–300.
7. Akkaya H, Karbeyaz K, Kokcuoglu MA, Urazel B. Lightning associated deaths during 1997–2011 in Eskisehir. J For Med 2013; **27:** 94–9.
8. Murty OP. Lightning fatality with blast, flame, heat and current effects: a macroscopic and microscopic view. J Forensic Leg Med 2009; **16:** 162–7.
9. Butun C, Yucel Beyastas F, Yilmaz R. Lightning-related death. Turk Arch Ped 2012; **47:** 60–3.
10. Murty OP, Kian CK, Ari Husin MH, Nanta Kumar RK, Mohammed Yusuf WY. Fatal lightning strikes in Malaysia. Am J Forensic Med Pathol 2009; **30:** 246–51.
11. Cooper MA. A fifth mechanism of lightning injury. Acad Emerg Med 2002; **9:** 172–4.
12. Blumenthal, R. The forensic investigation of fatal lightning strike victims, Reconsidered and Revised, 31st International Conference on Lightning Protection, ICLP 2012, Vienna, Austria; 2012.
13. Elsom DM. Deaths and injuries caused by lightning in the United Kingdom: analyses of two databases. Atmos Res 2001; **56:** 325–34.
14. Turkish State Meterological Service MGM [Internet]. Ankara, IL: Climatology Division. Climate Classifications; [rev 1 Nov 2015; cited 7 Nov 2015]. Available from: http://www.mgm.gov.tr/FILES/iklim/iklim_siniflandirmalari.pdf
15. Duclos PJ, Sanderson LM, Klontz KC. Lightning-related mortality and morbidity in Florida. Public Health Rep 1990; **105:** 276–82.
16. Meel BL. Lightning fatalities in the Transkei sub-region of South Africa. Med Sci Law 2007; **47:** 161–4.
17. Wetli CV. Keraunopathology. An analysis of 45 fatalities. Am J Forensic Med Pathol 1996; **17:** 89–98.
18. Price TG, Cooper MA. Electrical and lightning injuries. In: Marx J, Walls R, Hockberger R, eds. Rosen's emergency medicine—concepts and clinical practice, 8th ed. Philadelphia: Elsevier Health Sciences, 2013:1906–14.