An Autopsy Series: Lightning-Related Deaths in Van and Hakkari Provinces
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ABSTRACT

Objective: The aims of this article are to report largest series of lightning-related deaths in Turkey, to review the literature about this subject, to define similarities and differences, between autopsy findings of the presented series and literature information.

Methods: In this article, autopsy reports and crime scene investigation data of 11 lightning-related fatalities that occurred in Van and Hakkari Provinces (Turkey) from January 1st, 2011 to December 31st, 2015 were retrospectively reviewed.

Results: Eleven (2.53%) of 1,699 deaths which evaluated by medico-legal autopsy in Van and Hakkari Province in five years period, died due to lightning strikes. Of these cases, 10 (90.1%) were males and 1 (9.9%) was female (p<0.05). All cases between 11 and 33 age range. All cases was injured outdoors.

Conclusion: We think that, the number of deaths due to lightning strike, that has seen relatively rare in Turkey, may be reduced with additional personal precautions such as to avoid from staying under trees or the vicinity of a high tower, to avoid from touching with metal object, to avoid from to lie on the ground, to avoid from to lie on the ground, to avoid from leaning against a wall, to crouch outdoors or enter indoor such as a building or car.

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

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INTRODUCTION

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 20,000°C which is over three times the surface temperature of the sun and the power of lightning is between 20 million and one billion volts and 200,000 amperes (1, 2, 4).

Lightning strike was defined to be the second leading cause of weather-related deaths on Earth (5). Its incidence was reported to be 0.2-0.8 per million people per year (6). Deaths due to lightning strike is related with the regional climatic characteristics and seasonality (7). Accidental deaths due to lightning strikes are not uncommon in tropical and subtropical countries whereas they have rarely seen in other countries (6, 8). Those deaths are usually occurred during raining at afternoon or evening hours in spring and summer (9, 10).

In the lightning, injury occurs with effect of six different mechanisms; 1) direct strike effect, 2) contact effect when lightning strikes an object during touch of victim, 3) a side flash effect from a nearby object struck by lightning, 4) a step voltage or ground current effect from a lightning strike several meters away, 5) upward streamers effect related with injury by a low-energy and 6) recently the so-called the “sixth mechanism” which can be thought of as an “electro-blast effect” (Figure-1) (5,8, 11, 12).

There are several articles including a large series of lightning-related deaths in the worldwide literature but there are few articles in the style of case reports of lightning-related deaths in Turkey. The aims of this article are to report largest series of lightning-related deaths in Turkey, to review the literature about this subject, to define similarities and differences, between autopsy findings of the presented series and literature information.
SUBJECTS AND METHODS
In this article, autopsy reports and crime scene investigation data of 11 lightning-related fatalities that occurred in Van and Hakkari Provinces (Turkey) from January 1st, 2011 to December 31st, 2015 were retrospectively reviewed. Data about age, gender, job of victims, seasonality of deaths, crime scene findings, autopsy findings, manner of deaths and risk factors for lightning were obtained from autopsy records and scene investigation records. All results was compared with the literature.

RESULTS
Eleven (2.53%) of 1699 deaths which evaluated by medico-legal autopsy in Van and Hakkari Province in five years period, died due to lightning strikes. The average annual incidence of fatal lightning strikes during the study period in Van and Hakkari Provinces was calculated as 0.02 for per million persons.

Of these cases, 10 (90.1%) were males and 1 (9.9%) was female (p<0.05). All cases between 11 and 33 age range. Two cases were teenagers (18.2%), 7 cases were third decade (63.6%) and 2 cases were fourth decade (18.2%). The mean age was 23.5 (SD: 6.3; Median: 23) in cases. All cases was 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 exposed to lightning strikes at afternoon and evening hours (91.0%) whereas one case 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 place where the injury occurred and at injury time was confirmed by witness statements and meteorology reports (100.0%). There were environmental evidences of lightning in 8 cases (72.7%). Clothing
findings were seen in four cases (36.4%) (Figure-2). In only one case (9.0%), burned objects and magnetized metal objects were determined (Table-1).

At autopsies, linear burns were seen in 6 cases (54.5%) (Figure-3), punctate burns in 4 cases (36.4%), Lichtenberg figures in 7 cases (63.6%) (Figure-4), thermal injuries due to contact with metal objects in 3 cases (27.3%), thermal injuries due to burning clothing in 2 cases (18.2%), and thermal injuries due to direct effect of lightning in 3 cases (27.3%). Signed hairs were seen in 7 cases (63.6%) (Figure-5). Additionally, washerwoman hands were seen in two cases (18.2%) (Table-2).

In internal examination, the findings of cranio-cerebral traumas were seen in 2 cases (18.2%). In one of the same two cases, there was ruptures on abdominal wall and small bowels overflowed out of abdominal cavity from this rupture. Additionally, lung contusions were seen in both of these cases. Internal organ lesions was not seen in other cases and tympanic membrane rupture was not defined in any case.

DISCUSSION
The annually mortal incidence of lightning strike was reported to be 0.2-0.8 per million people (6). The average annual number of deaths due to lightning per million people was reported to be 0.05 in United Kingdom (13). The average annual incidence of fatal lightning strikes was 0.02 per million people in Van and Hakkari 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 Hakkari Provinces. Also attitudes of these cities are more than 1,700 meter and their climate was defined 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 defined over 87% (7,10,15,16),
even to 100% in one study(5), despite that low rates to be 50%(17) and 70%(2) in two studies. In the present study, the rate of male victims was 90.1%. The mean age of cases was defined from 22 to 31.8 years of age in the several studies (5, 7, 15, 16). Also the mean age was 23.5 years of age in our study.

People who deal with outdoor activities especially farmers, constructors, campers, hikers, climbers, golfers, hunters and military personnel more likely to be struck by lightning than person indoor(3-5,12,13). Also, all cases was 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 are usually occurred during raining at afternoon or evening hours in spring and summer (9, 10). In our series, 45.5% of cases died in the summer and 45.5% of cases died in the autumn. Of them, ten exposed to lightning strikes at afternoon and evening hours (91.0%) whereas one at dawn (9.0%).

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

Also the findings that obtained from clothing examination is quite valuable. They may be burned, or torn and shredded due to possible blast effect of lightning (16). Torn and shredded clothing was reported in 38 % of cases in study of Akkaya et al (7). In the present study, clothing findings were seen in 36.4% of 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 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 usually localized in axillar region, under of breast region and middle-inferior part of chest associated with high sweat concentration, are usually small burns in diameter from 1 to 4 cm. Linear burns which are probably caused by vaporization 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, circular and 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 also known as keraunographic markings are one of best known “feathering” lesions. They that similar a fern, are pathognomonic for lightning even if they are not seen in many autopsies. Their pathophysiology is associated with extravasation of blood in the subcutaneous tissues and they are generally disappears within 24 hours without known residual effect (3, 18). Lichtenberg figures was reported in 28% of cases in study of Turan et al (5) and in 50% in study of Akkaya et al (7). In the present study, the rate of Lichtenberg figures was 63.6%.

Thermal injury may be due to heat of metal objects (zippers, metal wristwatch, metal clothing buttons, belt buckles, necklaces, coins, etc.) or contact with of burning clothing. In victims who exposed to lightning strikes, extensive tissue destruction or large cutaneous burns are rarely seen. (3, 7, 18). Contact burns was reported in 38 % of cases in study of 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 thermal effect of lightning may be seen in victims (5, 6, 9, 16). Signed hair was reported in 71% of cases in study of Turan et al (5). In the present study, the rate of Signed hair was 63.6%.

Additionally, washerwoman hands were seen in two cases (18.2%). We think that this finding may be related to having a body under the rain for a long time.

Cranio-cerebral trauma may be primary due to “direct effect” of lightning or secondary to blunt head trauma due to “electro-blast effect” of lightning (5, 16). The findings of cranio-cerebral traumas were seen in 2 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 was not cardiac injuries in our series.

Pulmonary contusions was defined to be attributed to lightning strike (16). In our series, pulmonary contusions were seen in 2 cases (18.2%).

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

Tympanic membrane rupture was defined one of most common injuries in lightning victims (3, 16). In the present series it was not defined.

**CONCLUSION**

At autopsies of cases who died due to lightning strike, only autopsy findings are not sufficient for determination of manner of death. Examination of clothes and the investigation of event scene offers important clues to forensic scientists for solution of problems about manner of death. Also, witness statements and meteorology reports are important too in the investigation
of manner of death for corpses found in the outdoor especially in fields. Therefore, the diagnosis of death due to lightning strike does not constitute a difficult situation for a forensic expert.

We think that, the number of deaths due to lightning strike, that has seen relatively rare in Turkey, may be reduced with additional personal precautions such as to avoid from staying under trees or the vicinity of a high tower, to avoid from touching with metal object, to avoid from to lie on the ground, to avoid from to lie on the ground, to avoid from leaning against a wall, to crouch outdoors or enter indoor such as a building or car.

AUTHORS’ NOTE

Y Hekimoglu conceived paper, oversaw data collection, conducted data analysis, wrote manuscript and approved final version. M Asirdizer provided oversight to study, participated in study design, data analysis and interpretation, critically revised manuscript and approved final version. U Demir participated in study design, data analysis, and interpretation of data and revision of manuscript and approved final version. A Gur participated in study design, interpretation of data and revision of manuscript and approved final version. Y Etli participated in study design and interpretation of data; critically revised manuscript and approved final version. O Gumus participated in study design and interpretation of data, critically revised manuscript and approved final version. E Kartal participated in study design, interpretation of data and revision of manuscript and approved final version. The authors declare that they have no conflicts of interest.
REFERENCES


Table 1: Personality, environmental and the clothes features in 11 victims who died due to lightning strike

<table>
<thead>
<tr>
<th>NO OF CASES</th>
<th>Sex</th>
<th>Age</th>
<th>Job</th>
<th>Month</th>
<th>Witness Statements</th>
<th>Meteorology Reports</th>
<th>Burned Grass</th>
<th>Other Damage in Scene</th>
<th>Burned Clothng</th>
<th>Torn and Shredded Clothing</th>
<th>Burned Objects</th>
<th>Magnetized Metal Objects</th>
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<td>CASE-1</td>
<td>Male</td>
<td>23</td>
<td>Farmer</td>
<td>July</td>
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<td>+</td>
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<td>-</td>
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</tr>
<tr>
<td>CASE-2</td>
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<td>16</td>
<td>Farmer</td>
<td>July</td>
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<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
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<tr>
<td>CASE-3</td>
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<td>11</td>
<td>Farmer</td>
<td>July</td>
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<td>+</td>
<td>+</td>
<td>-</td>
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<tr>
<td>CASE-4</td>
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<td>31</td>
<td>Shepherd</td>
<td>October</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<tr>
<td>CASE-5</td>
<td>Male</td>
<td>25</td>
<td>Shepherd</td>
<td>May</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>CASE-6</td>
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<td>22</td>
<td>Housewife</td>
<td>June</td>
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<td>+</td>
<td>+</td>
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<tr>
<td>CASE-7</td>
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<td>33</td>
<td>Farmer</td>
<td>August</td>
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<td>+</td>
<td>+</td>
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<tr>
<td>CASE-8</td>
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<td>23</td>
<td>Soldier</td>
<td>October</td>
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<td>+</td>
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<tr>
<td>CASE-9</td>
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<td>Soldier</td>
<td>October</td>
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<td>CASE-10</td>
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<td>CASE-11</td>
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<td>Soldier</td>
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Lightning-related Deaths in Van and Hakkari Provinces

Table-2: External findings of autopsy in 11 victims who died due to lightning strike

<table>
<thead>
<tr>
<th>NO OF CASES</th>
<th>Linear Burns</th>
<th>Punctate Burns</th>
<th>Lichtenberg Figures</th>
<th>Thermal Injuries due to Contact with Metal Objects</th>
<th>Thermal Injuries due to Burning Clothing</th>
<th>Thermal Injuries due to Direct Effect of Lightning</th>
<th>Signed Hair</th>
<th>Washerwoman Hands</th>
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Fig. 1: Six mechanisms of injury in the person exposed to lightning strikes.
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: Signed hairs in two cases.