

Findings in Fatal Lightning Strike Cases

Ölümçül Yıldırım Çarpması Olgularında Bulgular

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Geliş Tarihi/Received: 24.02.2010
Kabul Tarihi/Accepted: 23.09.2010

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ABSTRACT Objective: Lightning is the second most leading cause of weather-related deaths in most of the world. Numerous studies have examined various aspects of lightning-induced injuries and fatalities concentrated on epidemiologic data and cutaneous injuries. This retrospective autopsy study concentrates on morphological findings of lightning strike in relation with demographic data. **Material and Methods:** The autopsy reports of the Council of Forensic Medicine in Trabzon, Turkey were checked for lightning strike fatalities from 2003 to 2007. All cases were reviewed with reference to mortuary admission forms, autopsy and death scene reports. **Results:** Totally 7 reports of lightning autopsy cases were included in this study. All cases were male. The age of victims ranged from 10 to 73. All incidents were at outdoors and in May, June and July. 71% signeing, 63% traumatic lesions, 57% thermal injury, 29% arborization, 14% electrothermal lesions were noted at autopsy. **Conclusion:** Lightning injuries and deaths peak during the summer months. Young people are at greatest risk. Careful and gross and histologic examination of the cutaneous lesions, brain, heart and lung, and otologic inspection should be performed at autopsy of lightning cases. As a result inspection of victim's clothes, death scene analysis and local weather reports are important data to explore death reason with suspicion of lightning.

Key Words: Lightning; death; autopsy

ÖZET Amaç: Yıldırım çarpmaları, dünyada hava şartlarına bağlı ölümler içinde ikinci sırada yer almaktadır. Yıldırım çarpmalarına bağlı yaralanmalar ve ölümlerde, epidemiyoloji ve cilt lezyonları ile ilgili çok sayıda çalışmalar yapılmıştır. Bu çalışmada, yıldırım çarpması olgularının morfolojik bulguları ile birlikte demografik verilerinin retrospektif değerlendirilmesi amaçlanmıştır. **Gereç ve Yöntemler:** Adli Tıp Kurumu Trabzon Grup Başkanlığı'nda, 2003 ve 2007 yılları arasında yıldırım çarpması iddiasıyla otopsisi yapılmış olguların raporları belirlendi. Belirlenen olguların savcılık müzükkeresi, tanık ifadeleri, olay yeri inceleme ve otopsi raporları incelenerek elde edilen bilgiler değerlendirildi. **Bulgular:** Bu çalışmada toplam 7 yıldırım çarpması olgusu yer aldı. Bütün olguların cinsiyeti erkekti. Olguların yaşları 10 ve 73 arasında dağılım gösterdi. Bütün olgularda yıldırım çarpması açık alanda ve Mayıs, Haziran ve Temmuz aylarında olmak üzere yaz aylarında gerçekleşmiştir. Otopsi incelemesinde, olguların %71'inde vücut tüylerinde tütsülenme, %63'te travmatik lezyonlar, %57'sinde yanık lezyonları, %29'unda eğrelti otu manzarası, %14'ünde elektrik çarpması lezyonları saptanmıştır. **Sonuç:** Yıldırım çarpmasına bağlı ölüm ve yaralanma olayları yaz aylarında artış göstermektedir. Özellikle gençler artmış risk altındadır. Yıldırım çarpması otopsilerinde beyin, kalp, akiçiger, cilt lezyonlarının makroskopik ve mikroskopik incelemeleri ile birlikte otolojik değerlendirme dikkatle yapılmalıdır. Yıldırım çarpması şüphesi bulunan olguların ölüm sebebine yönelik araştırmalarda giysi ve olay yeri incelemesi, bölgesel hava durumu bulguları önemli verilerdir.

Anahtar Kelimeler: Yıldırım; ölüm; otopsi

Lightning is the second leading cause of weather-related deaths in most of the world.^{1,2} When a flashover occurs along the whole body, the probability of survival is found to be higher than 50%.³⁻⁶

Lightning can cause injury with direct strike and/or indirect strike when lightning strikes an object which the victim touching, a side flash from a nearby object struck by lightning, a step voltage effect (ground current) from a lightning strike several meters away, upward streamer or a streamer from person's head along with the step voltage effect and/or shock wave (blast) effect. Tertiary blast injury may present as blunt trauma when the victim falls or is thrown away.^{1,2,7,8}

In addition, lightning can cause injuries and death indirectly for example by falling tiles, suffering from burns or smoke inhalation in a fire started by lightning, etc.⁷

Many of people with minor trauma or unaffected by lightning do not seek for further medical attention or receive a detailed medical assessment. Also, death cause remain unknown in many suspected lightning cases which do not have any lightning evidence of death scene or witness comment and any finding of lightning strike at autopsy.

This retrospective study concentrates on four years autopsy data of morphological findings typical for or indicative of lightning strike. This study has also suggested an autopsy approach to lightning fatalities in relation with demographic data of cases.

MATERIAL AND METHODS

Trabzon, a city by the Black Sea seaside in Turkey, frequently has a rainy lightning wheather all year. Many people living in this region are used to perform outdoor activities like farm, fishing and etc. Trabzon is also an autopsy center which autopsy cases from 14 cities in Northern East region of Turkey are sent.

Ethical permission of the study as a research has been obtained by the Educational Commission of the Council of Forensic Medicine in Turkey.

The autopsy reports of the Council of Forensic Medicine, Trabzon, they have been checked for lightning strike fatalities from 2003 to 2007.

All cases referred to the medicolegal autopsy with a suspicion of lightning strike by local authorities were reviewed already to reference to mortuary admission forms, autopsy and death scene reports. A total of 7 cases were identified autopsy and prosecution records. There prosecution records had included report of police, technical expertise, witness comment and death scene.

All cases had included information about their age, gender, job of cases, season and month of event, witness comment, inspection of clothes, macroscopical and microscopical findings of autopsy.

We could not obtain any information about neither otological examination during autopsy nor local weather report in the day of event.

RESULTS

Totally 7 reports of lightning autopsy cases were evaluated at the Council of Forensic Medicine in Trabzon, Turkey, from 2003 to 2007 years.

All cases were male. The victims' age ranged from 10 to 73 and was at average as 29.85. Over three out of four of the victims were <=40 years of age.

Lightning strike is commonly occurred in summer months. All incidents (100%) were in May, June, July.

The job of victims was as follows: 4 farmers, 2 students, 1 soldier. All the incidents occurred in open area and all were eye-witnessed. All cases were autopsied within twenty four hours after the death, except the third case.

CASE 1 AND 2

Initial two cases were fourteen and ten years old male students were struck by lightning in an open area on July, 2003. There was neither any damage at their clothes, nor was at surrounding of them. At first case victim was wearing wet clothes on. He had traumatic lesions of lightning at left arcus

mandibula and electrothermal lesion at left lumbar region and signed hairs. At second case, traumatic lesions at left scapular and lumbar regions and hemorrhage at subgaleal region were reported.

Hyperemia and edema on brain, subpleural and subepicardial hemorrhages had been reported at autopsy of both cases. In first case, fresh hemorrhages at lung, burn and hemorrhage at skin and in second case, fresh subarachnoidal hemorrhage and ischemic hemorrhagic lung was detected by microscopical examination.

We couldn't find any specific findings related with lightning struck in second case other than nonspecific findings as traumatic lesions at his body, hemorrhage at his head macroscopically and subpleural, subepicardial, subarachnoidal and lung hemorrhage microscopically.

CASE 3

He was a 73 year-old farmer riding on open area when lightning struck him on June, 2004. He and his horse were immediately dead by lightning electricity effect directly with witness statement. 5 days after his burial, he was autopsied. Cutaneous thermal lesions at right glutea and sacrum, echymotic lesions at the skeletal surface of head skin were detected with macroscopical examination. Myocardial hypertrophy and ischemic fibrosis, 30 % coronary obstruction was microscopic findings of autopsy unrelated with lightning struck.

Signed hair was present in following four cases.

CASE 4

23 year-old male farmer having signed hair was a victim of lightning on May, 2005. Multiple traumatic abrasions at left side of face, signed hair at left forearm and scrotum with external examination, ischemic hemorrhagic lung with microscopic examination was noted at autopsy.

CASE 5

He was a 41-years-old farmer in May, 2005. The victim has at an open area near woods when lightning struck him and his brother. His brother was injured. Cutaneous thermal lesions at his left chest and right leg skin, signed hair at left chest and right

leg with macroscopical examination, hemorrhagic lung, separated epidermis from the papillary dermis and nuclear streaming (palisading) at skin samples with microscopical examination was reported.

At two last cases, the presence of an erythematous pattern of arborization was defined during in both autopsies.

CASE 6

A 22 years-old soldier was struck by lightning on June, 2007 during military operation on mountain. He had signed hair, multiple traumatic abrasions at all body, an erythematous pattern of arborization at right and left abdomen and a cutaneous burn in the pattern of the necklace and bracelet was identified with macroscopical examination. Subarachnoidal hemorrhage and hemorrhagic lung, separated epidermis from papillary dermis and nuclear streaming (palisading) at skin samples with microscopical examination was reported.

CASE 7

Last case was a 26 year-old farmer with his brother struck by the lightning on July, 2007. He died in one hour after lightning strike although he had been carried to hospital by his brother. His clothes were described as "Blown into fragments" or shredded. An erythematous pattern of arborization at right shoulder, 2nd degree burn (cutaneous thermal injury) at left part of his body, signed hair, brain edema, hemorrhage and edema of lung at autopsy, hemorrhagic lung, palisading at skin samples with microscopic examination was determined (Table 1, 2, Figure 1).

Any eardrum examination of cases in order to possible traumatic perforation was not performed. Nor blown out shoes were reported in any case.

DISCUSSION

Lightning injuries and deaths occur most often in individuals who work outside or participate in outdoor recreational activities during summer months.^{1,7-9}

At studies, it has been stated that men are five times more likely to be struck by lightning than women. People with outdoor activities especially

TABLE 1: Death scene and autopsy findings of lightning cases.

Findings Cases	History	Damage in Clothes	Any Damage at Death Scene	External Injuries	Internal Injuries (Macroscopic)	Histopathology at skin samples
Case 1	+			+	+	
Case 2	+			+	+	
Case 3	+		+	+		
Case 4	+			+		
Case 5	+		+	+		+
Case 6	+	+		+		+
Case 7	+	+		+	+	+

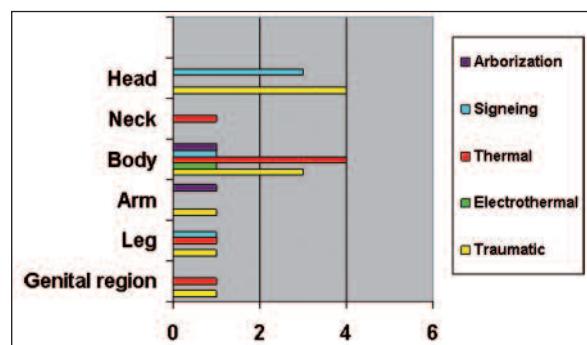
TABLE 2: External body findings of lightning cases.

Findings Cases	Traumatic lesions	Electrothermal injury	Burning	Signeing	Arborization
1	+	+		+	
2	+				
3	+		+		
4	+			+	
5			+	+	
6	+		+	+	+
7			+	+	+

farmers, constructors and military personnel appear to be at particular risk.^{1,7,8,10} All cases were male and the victims were struck by lightning at outdoor or open area in present study.⁵ It has been assumed that males are more prone to lightning strike because male are more engaged in outdoor activities than females.

Young people (over $\frac{3}{4} \leq 40$ years of age, average age 29.85) are also at greatest risk. The demographical findings in these data have been found similar to those reported by others. At a study by Wetli, average age of cases was 32.6 and by Blumenthal was of 36.^{8,9} In UK, a study from 1993 to 1999, the average age being 30 years correlated with average age of present study.⁷

If witness exists during lightning strike, history of case can be obtained. Witness statements are especially important if physical evidence of lightning strike is absent at the scene. All cases in present study were witnessed about lightning although any evidence of lightning struck was not

**FIGURE 1:** Cutaneous lesions of lightning cases in comparison with body region.

reported by technical expert. Injury of nearby person and a dead horse at scene were detected in two cases. Witness statement and lightning findings at scene would be followed by suspicion of lightning strike.

The condition of the clothing may range from subtle fiber melting to gross burning. The damage of clothing was mentioned in 3 cases. In one, the clothing was described as "blown into fragments".

In other case, the clothes were wet but any damage in them was not described. There may be no obvious sign of damage in clothes by lightning strike, if surroundings or clothes are wet. Burn mark is sometimes detected on the skin underlying a metallic substance like watch, necklace etc.^{5,8,9,11}

In one case of a personal metallic object was mentioned. About this case, a cutaneous burn in the pattern of the necklace and bracelet was also identified at autopsy.

Many external lesions without internal organ harm in lightning struck cases have been reported at literature.^{1,2,4-6,9}

Because of the blast overpressures generated by lightning strike, it is found frequently that victims present with tympanic membrane rupture and many abrasions on the skin tissue.^{1,2,12} 5 of all cases (63%) had traumatic lesions (abrasions and echymosis) besides other specific findings (burning, arborization, singed hair, palisading at skin samples etc.). In second case, multiple abrasions without any other lesion of any significance were identified (Figure 2). The rupture of tympanic membrane would be a more specific finding than any traumatic lesions on the skin in the autopsy of lightning strike. So, it is recommended that otological examination should be performed in all cases of suspected lightning strike.



FIGURE 2: Traumatic lesions at chest, left inguinal and pelvis region (Case 6).



FIGURE 3: Singeing and traumatic injury at chest (Case 6).



FIGURE 4: Electrothermal injury.



FIGURE 5: Arborization at right shoulder (Case 7).

Singed hair which occurred by thermal effect of lightning was mentioned in 71% (5/7) of cases (Figure 3).

There are four types of skin lesions that result from lightning strike: linear, punctuate, “feathering,” and thermal.

Linear burns preferentially follow areas of high sweat concentration, such as under the breasts and arms, and down to the chest. They are generally from 1 to 4 cm in diameter.

Punctate burns (electrothermal lesions) are small, multiple, closely spaced circular burns. The "Tip-toe sign" is one example of a punctate burn; it consists of small circular full-thickness burns of the tips of the toes and the sides of the soles of the feet.^{1,8} The exit wounds due to electrocution can be seen in the literature but exit wound by lightning current is a rarity. In a previous reported case, electrothermal lesions were present over the occipital, and groin area (Figure 4) while one case of electrothermal exit lesion in lomber region was reported in this study.

The vast majority of the victims had easily discernible thermal injuries generally involving the head and neck area and the lower extremities in literature.^{2,9} Severe burns have been found rare, as being very minimum less than 20% of the total body surface area, and confined to the skin.^{1,4,9,13} In present study, cutaneous thermal injury was noted in 57% of cases. Of these cutaneous thermal burns, one had predominant second degree burn, other cases had predominantly first-degree burn. This finding suggests that burn at lightning struck is not the main cause of death in most cases.

Lichtenberg figures or arborization do not represent a thermal injury, and the epidermis and dermis are normal. Upon pathophysiologic examination they consist of extravasation of blood in the subcutaneous tissues.^{1,6,9} Arborization which is a pathognomonic finding of lightning strike, usually disappears within 24 hours without known residual effect.^{1,3,11,13} Arborization in branching pattern was found in 2 of 7 cases (28%) which were autopsied in first 24 hours after death (Figure 5).

Histopathologically, the epidermis separated from the papillary dermis, and nuclear streaming (palisading) which is occasionally seen, were present in 3 cases (43%). The keratin with pattern of palisading had vacuoles and was adherent to foreign clothing in volar skin at microscopic examination.⁹

Other microscopical findings of cases were 6 hemorrhagic lung, two subarachnoidal hemorrhage, one myocardial fibrosis and hypertrophy (unspecific to lightning), and one unspecific burning at skin sample.

Electrical lesions from lightning can result in massive and global lesions similar to patterns seen in crush injuries with internal examination of autopsy.¹⁴ The most profound harm associated with lightning exposure is often neurologic and cardiac in nature.^{1,15} In a minority of patients, fatal lightning harm may occur in the absence of burns or other obvious external or internal lesion. This finding is attributed to the induction of current by strong magnetic fields, sufficient to cause cardiac arrest.^{1-4,11}

Head lesions were documented in 6 cases (86%) with macroscopical and microscopical examination. In one, it has not been resolved whether the individual fell on a ground after struck by lightning because he had only abrasions on head at autopsy. Cranio-cerebral trauma is generally regarded as secondary to blunt trauma from falling or being thrown to the ground. In cases of craniocerebral trauma after lightning strike, witness statements, scene investigation, and post-mortem examination to be mechanical blunt-force injury to the head has been occurred.

Pulmonary contusion and haemorrhage are also reported with lightning injury.⁴ Pulmonary contusions attributed to lightning strike were observed in these cases as 2 subpleural and 2 lung hemorrhages macroscopically. Also, in one case, cardiac injury was noted as subepicardial hemorrhage.

In conclusion, special attention to external injuries, careful examination of the brain for lesions and detailed gross and histological examination of the heart and lung would possibly help to clarify the nature of harm to these structures. The tympanic membranes should be inspected otologically.^{8,9,12,13}

Witness statements and knowledge of the weather conditions are obvious values. These deaths should involve medical and technical ex-

pertise and should include also scene investigation and examination of instruments, apparatus, etc.^{8,13}

Burned, ruptured clothing and shoes are important signs that point to the likelihood of a lightning strike. Another important data comes from the National Lightning Detection Network, which provides information on the location and time of lightning strikes in the region searched for.¹³

Lastly, climate models suggesting global warming may lead to increased lightning activity in some countries which need to pay greater attention to taking actions to minimize the risk of being struck.⁷ This may become more important to take preventive measures and to develop new diagnostic tools for lightning deaths in the future as increasing numbers of people participate in outdoor recreational and sport activities.

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