# Electrocution fatalities in military personnel in Ankara, Turkey

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## ABSTRACT

**الأهداف:** للتحقق من حالات الوفيات بالكهرباء من بين الأفراد العسكريين .

**الطريقة:** استعراضنا بأثر رجعي السجلات الطبية وتقارير التشريح بين حالات الوفيات الكهربائية في قسم الطب الشرعي خلال الفترة ما بين 1994م و 2013م في أنقرة، تركيا. وتم تحليلها من حيث العمر وحالات محددة من الجنس، والجهد الكهربائي، وتفاصيل الاتصال، وتوزيع منطقة الجسم، مكان وموسم الحدث، موقع وشدة الإصابات التي لحقت، والتغيرات النسيجية المرضية والسُمية.

**النتائج:** 16 ( 3.5٪ ) من حالات التشريح 450 المعنية بالكهرباء. في معظم الأحيان وقعت جميع الوفيات الناجمة عن حوادث في الهواء الطلق ( 75٪ ). توفي8 ( 50٪ ) بسبب الجهد العالي في حين توفي 6 ( 37.5٪ ) وذلك بسبب الجهد المنخفض. في معظم الأحيان تم تحديد الآفات الدخول والخروج في حالات الإصابة مع الجهد العالي. يحدث عادة وفاة الجهد المنخفض في مكان الحدث ( 66.6٪ )، في حين وقعت كل وفيات الجهد العالية في المستشفى ( 87.5٪، P 0.03 =). تم الكشف عن الحروق الكهربائية الأكثر شيوعا في الأطراف العليا ( 32.6٪، N = 14 ).

**الخاتمة:** تبين هذه الدراسة أن الوفيات الناجمة عن ارتفاع الكهرباء بالجهد أكثر حدوثاً من انخفاض الجهد الكهربائي بين الأفراد العسكريين.

**Objectives:** To investigate various cases of death caused by electrical injuries among Turkish military personnel.

**Methods:** We retrospectively reviewed fatality cases of military personnel between 1994 and 2013 at the Department of Forensic Medicine, Gulhane Military Medical Academy, School of Medicine, Ankara, Turkey, the only forensic medicine center for the Turkish Armed Forces. Medical records and autopsy reports of cases of electrical fatalities were reviewed and analyzed in terms of age and gender-specific incidence, voltage, contact details, body region distribution, location, and season of incident, site, and severity of injuries sustained, and histopathological and toxicological findings.

**Results:** Sixteen (3.5%) out of the 450 autopsy cases involved electrocution. All deaths were accidental and most frequently occurred outdoors (75%). Eight (50%) died due to high voltage while 6 (37.5%) died due to low voltage. The entry and exit lesions were determined most frequently in cases with high voltage injury. The low voltage deaths commonly occurred at the scene of the event (66.6%), while almost all high voltage deaths occurred in the hospital (87.5%, $p$=0.03). Electrical burns were most commonly detected in the upper extremities (32.6%, n=14).

**Conclusion:** The present study shows that deaths due to high voltage electrocution are more frequent than low voltage electrocution among military personnel.


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Although electricity is in widespread use as an energy source, electrocution is a relatively infrequent cause of death. Electrical injuries cause a high incidence of mortality and morbidity, but they are essentially preventable with simple safety measures in most situations.[1] While electrical fatalities in domestic environments usually occur due to direct contact with a source of electricity, arcs from high voltage power lines may also lead to electrocution even without direct contact.[2] Most of the fatalities due to electricity are accidental, and result from passage of an electrical current through the body.[1] Most electrical fatalities are caused by accidental direct contact with sources of alternating current. In the United States, the voltage and frequency of the alternating current used at homes are 110 volts (V) and 60 Hertz (Hz), whereas it is 120 volts and 50 Hz in Europe.[3] Electrocutions involving humans may be due to low voltage (<1000 V) or high voltage (>1000 V).[4] Nearly one-third of such deaths are caused by low voltage currents typical for home use (120-140 V).[5] Humans are 4-6 times more sensitive to alternating currents than they are to direct currents. A 100 mA alternating current can lead to ventricular fibrillation and cardiac arrest in less than a fifth of a second. High ampere (>4A) direct currents, on the other hand, can potentially lead to sinus arrhythmias.[6] When considering the total number of personnel of the Turkish Armed Forces, it is one of the largest armies in the world, and to this extent, the present study aims to investigate various cases of death caused by electrical injuries among Turkish military personnel in order to help prevent such injuries. We believe that the present study might contribute to the literature in this respect.

**Methods.** We retrospectively reviewed fatality cases of military personnel between 1994 and 2013 at the Department of Forensic Medicine, School of Medicine, Gulhane Military Medical Academy, the only forensic medicine center for the Turkish Armed Forces in Ankara, Turkey. There was a total of 450 autopsies performed during this period, where only 16 were electrocution cases. Victims of lightning strike are excluded in the study. All of the 16 electrocution cases were active military personnel in the Turkish Armed Forces. Medical records and autopsy reports of the cases were reviewed and analyzed in terms of age and gender-specific incidence, voltage, contact details, body region distribution, location, and season of incident, site, and severity of injuries sustained, and histopathological and toxicological findings. We considered a voltage of <1000 V as low voltage, and >1000 V as high voltage. The required approval for the study was obtained from the Ethics Committee of the School of Medicine, Gulhane Military Medical Academy. Autopsy findings including details of electrical burns, complications, and pertinent medico-legal findings were also noted.

Data were analyzed using the Statistical Package for Social Sciences for Windows version 15 (SPSS Inc., Chicago, IL, USA) statistical package program. Descriptive statistics were provided as mean ± standard deviation for continuous variables, and as frequency for discrete variables. Differences between groups were evaluated using the chi-square test. $P<0.05$ was considered statistically significant.

**Results.** Among the 450 autopsy cases, 3.5% (n=16) cases were caused by electrocution. All of the victims were male, and aged between 20 and 36 years (mean age: 23 ± 4.1; median age: 21 years). Among the 16 cases, 87.5% were private (n=14), 6.3% was officer (n=1), and 6.3% was military servant (n=1). All events were accidental. Of these cases, 37.5% (n=6) died in spring (March to May), 25% (n=4) in autumn (September to November), 18.8% (n=3) in winter (December to February), and 18.8% (n=3) in summer (June to August). Eight (50%) of these cases died due to high voltage electrical currents, 6 (37.5%) died due to low voltage electrical currents, whereas the voltage was unknown for the remaining 2 cases (**Figure 1**). Twelve (75%) of 16 cases were in an outdoor location, 12.5% (n=2) were indoors, and 12.5% (n=2) were at an unknown location (**Figure 2**). Considering the contact details, the deaths were caused most frequently by touching an electrical cable, or a high voltage line (**Table 1**). The upper extremity was the most common site involved (32.6%) followed by the lower extremity (**Table 2**). No metallization was observed in any of the cases. Injuries associated with arcs originating from high-tension lines were identified in 2 (12.5%) cases. The entry and exit lesions were most frequently detected in cases with high voltage injury (**Table 3**). The low voltage deaths commonly occurred at the scene of the event (66.6%), while almost all high voltage deaths occurred in the hospital (87.5%, $p=0.03$). The cause of death in 7 cases was electrocution, and in 9 cases were electrocution and its complications. The survival time for hospitalized cases varied between 6 and 217 days (mean duration: 20.6 days, median: 7.5 days). Burn percentages were lesser in low voltage deaths while burns covered a larger area in high voltage deaths. The relationships between burn percentages and the survival times of the cases are shown in **Table 4**.

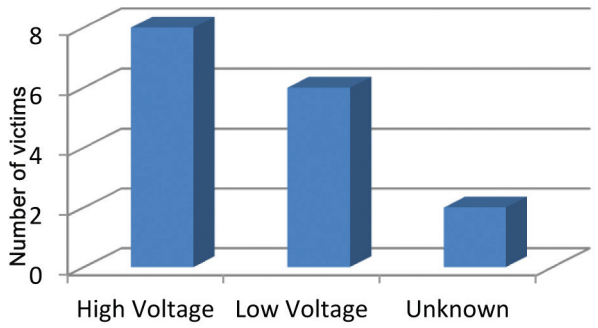


**Figure 1 -** Type of voltage in fatal electrocution cases.

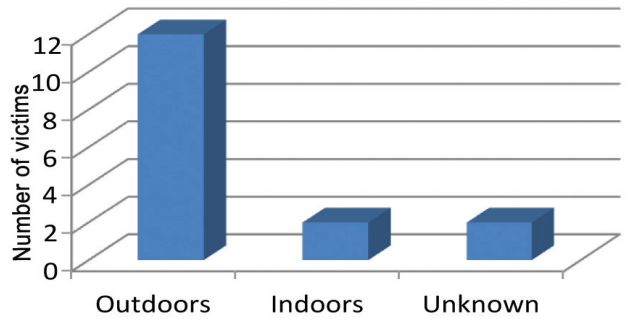


**Figure 2 -** Places of incident or location of electrocution among fatalities in Turkish military personnel.

**Table 1 -** Sources of contact of electrocution among fatalities in Turkish military personnel.

| Causes of electrocution | n (%) |
|---|---|
| Contact with a cable | 4 (25.0) |
| Arc from a high voltage line | 2 (12.5) |
| Contact with a high voltage line of train | 3 (18.7) |
| Contact with a high voltage line while operating a crane | 1 (6.2) |
| Electric water heater | 1 (6.2) |
| Contact with a high voltage line | 2 (12.5) |
| Contact with current from a water filled pool | 1 (6.2) |
| Unknown | 2 (12.5) |
| **Total** | 16 (100) |

**Table 2 -** Location of lesions of electrocution among fatalities in Turkish military personnel.

| Location | n (%) |
|---|---|
| Head and neck | 7 (16.4) |
| Thorax | 8 (18.6) |
| Abdomen | 3 (6.9) |
| Upper extremity | 14 (32.6) |
| Lower extremity | 11 (6.2) |

***Histopathological findings.*** Histopathological examination was performed in 12 of the 16 cases. Ten cases were positive for typical electrical burn lesions (coagulation necrosis, carbonization of collagenous fibers, swelling, and hemorrhages of the dermal zone beneath the injury, general burn findings). In 2 of the cases who had died due to low voltage electrical currents, skin samples from suspected regions of the body did not reveal any findings of electrical damage.

**Table 3 -** The relationship between voltage and entry/exit lesions.

| Location of lesions | High voltage | | Low voltage | |
|---|---|---|---|---|
| | Entry | Exit | Entry | Exit |
| Head and neck | 1 | - | - | - |
| Thorax | 1 | - | - | 1 |
| Right upper extremity | 2 | - | - | - |
| Left upper extremity | 1 | - | 3 | - |
| Right lower extremity | - | 3 | - | - |
| Left lower extremity | - | 2 | - | 2 |
| Undetermined | | 3 | | |

**Table 4 -** Burn percentages and the survival time of cases among fatalities in Turkish military personnel.

| Variables | Burn percentage (%) | | | | | Total |
|---|---|---|---|---|---|---|
| | 0-10 | 11-20 | 21-30 | 41-50 | 61-70 | |
| *Voltage* | | | | | | |
| Low | 4 | 2 | - | - | - | 6 |
| High | 2 | 2 | - | 2 | 2 | 8 |
| Unknown | 1 | 1 | - | - | - | 2 |
| *Survival time* | | | | | | |
| 0 days* | 4 | 3 | - | - | - | 7 |
| 1-10 days | - | 1 | | 1 | 1 | 3 |
| ≥11 days | 3 | 1 | | 1 | 1 | 6 |
| **Total** | 7 | | - | 2 | 2 | 16 |

*death at the scene of the event

***Microbiological findings.*** *Staphylococcus aureus* (*S. aureus)* and *Pseudomonas aeruginosa (P. aeruginosa)* were identified in the blood culture of a case who died 13 days after hospitalization. In another case who died after 217 days of treatment, coagulase (-) *S. aureus* was identified in the cerebrospinal fluid culture, while *Enterobacter spp.* and *P. aeruginosa* were identified in the blood culture.

***Toxicological findings.*** Toxicological analyses revealed ethyl alcohol in only one (6.3%) case, of which the blood ethyl alcohol level was 39 mg/dL.

**Discussion.** Electrocution is an uncommon cause of death, and it is usually due to accidents.[1,3,7,8] In the United States, approximately 1000 individuals die every year as a result of electrocution.[9] In the present study, which covered the past 20 years, electrocution accounted for 3.5% of all the evaluated forensic cases in military setting. All our cases occurred accidentally. Previous studies reported that 0.6 to 3.3% of all

medicolegal deaths were due to electrocution.[1,10-12] The rate of our study is essentially similar to those reported previously.

Deaths due to electrocution are predominantly in males.[1,10,11] This is probably due to different working conditions of men, and to their use of more powerful and varied electrical tools. All our cases were male, and this result is similar to those reported previously.[1,7,10,11] The fact that military service is mandatory for men in Turkey should be taken into account when dealing with the rate reported in this study. Most of the electrocution occurred in these mandatory recruits (87.5%).

In the previous studies which focused on deaths related to electrocution, cases due to low voltage injury were more frequent.[1,10,11,13] However, in research series conducted by Mellen et al,[7] which contained cases predominantly of military origin, high voltage electrocutions were more frequent (51%). This issue suggests that the military environment has its own specific conditions with regard to the risk of electrocution. Preventive approaches with a focus on household safety may not be entirely applicable in reducing injuries due to electrocution in a military setting.

Sheikhazadi et al[10] reported 60.7%, and Rautji et al[11] reported 98% electrocution-related deaths took place at the scene of the event. In the present study, 43.7% (n=7) of cases died at the scene of the event, while 56.3% (n=9) died at the hospital during their treatment. The low voltage deaths commonly occurred at the scene of event (66.6%), while almost all high voltage deaths occurred in hospitals (87.5%, $p$=0.03).

A characteristic of low voltage alternating current injury is its propensity to induce a "no let go" state, which lengthens the period of exposure. This can result in ventricular fibrillation, which is a major cause of death at the site of electrocution.[3,6] High voltage electrocutions are associated with temporary paralysis of the respiratory muscles and electrical burns. The prolonged survival in these results in an increased frequency of deaths in hospitals. Our results support this situation with more deaths on site in the low voltage cases (37.5%), and prolonged survival in cases with high voltage electrocution (50%). Similar to previous studies,[1,10,12] we found that the upper extremity was the most common site involved in accidental electrocution (32.6%). This is a natural consequence of using hands for the use of tools.

In cases of electrocution, it is recommended to examine the deceased's body and clothes for signs of metallization.[5] No gross sign of metallization was observed in any of our cases. Likewise, "crocodile flash burns," which can accompany burns from high voltage arcs,[6,9] were not seen in our series.

Exposure to high voltages may result in "primary high-tension injuries" due to direct contact with the current, and also cause "secondary burn injuries" due to indirect burns. Low or high voltage electrical exposures may also occur without detectable morphological consequences, depending on a multitude of factors.[6,11] In our series, burn percentages were lesser in low voltage and higher in high voltage deaths consistent with previously reported observations.[3,6]

In many electrocutions, entry and exit wounds might be identified after careful inspection.[1,5,8,11] Shaha et al[1] found typical electrical burns in 93.3 % of cases in their series. Rautji et al[11] was able to identify entry wounds in 86.27 % and exit wounds in 13.73 % of their cases. In 75 % of our cases, grossly visible or suspected entry/exit wounds were examined histopathologically. Most of these were in the high voltage group. Interestingly, histopathological examination failed to reveal any morphological findings in 2 cases with low voltage injury. Based on the histopathological evaluation of tissue samples in our series, we determined that 10 of presented cases had cutaneous and subcutaneous findings associated with electrical damage.

Intoxications are well-known contributors to all sorts of accidents including electrocution. Lindström at al[14] reported that 20% of the evaluated cases had ethyl alcohol in their blood and urine. In a study conducted by Mellen et al,[7] ethyl alcohol was detected in 31% of the electrocution cases that were predominantly of military personnel. In the present study, ethyl alcohol was identified in only one case. The relatively low incidence of alcohol as a contributory factor in our series can be ascribed to the difficulty in accessing alcoholic beverages in local military facilities.

Mortality in survivors of electrocution is usually due to multiple organ failure and sepsis.[1,15] Electrical burns can also be sources of bacterial infections. In our study, the cause of death in 9 cases was electrocution and its complications. Blood cultures were positive for bacteria (*S. aureus* and *P. aeruginosa*) in only 2 of the cases, which may be related to the relatively short duration of hospitalization in our series.

Our evaluations are limited by the relatively small size of our series. However, the findings are still important as they pertain to a very specific population at risk for electricity related death; namely, the military personnel.

In conclusion, based on the results of the present study, it was determined that deaths due to high voltage electrocution were more frequent than low voltage electrocution among military personnel. We believe that providing military personnel with training regarding the potential hazardous sources of high voltage current in their particular environment is of crucial importance for their safety. Measures to prevent electrical accidents in military settings should be taken into account with emphasis on the differences in exposures related to high/low voltage currents.

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Acquisition of funding, collection of data, or general supervision of the research group, alone, does not justify authorship.

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