Electrical Mark in Electrocution Deaths – A 20-Years Study

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Abstract: An electrical mark is one of the crucial morphological findings on the body of a person who received a fatal electric shock and it is often the only evidence of contact between the body and electricity. In cases where the electrical mark on the skin is absent, the cause of death is often established by exclusion of other possible causes and supported by circumstantial evidence.

In our study, the data were obtained from autopsy reports of all persons whose cause of death was electrocution and whose post mortem examination was performed at the Department of Forensic Medicine and Criminology in Zagreb between 1991 and 2010. We collected the data on victim demographics and incident circumstances including sex, age, manner of death, alcohol concentration, place and time of death, and presence and site of the electric mark.

A total of 89 electrocution cases were identified. An electrical mark was detected in 79% of the cases, whereas no detectable changes on the skin were in the remaining 21% of the cases. The entry wound was present in 43% of the cases, both entry and exit wounds were found in 20%, while in 16% of the cases with extensive burns neither entry nor exit point could be detected. Most victims of fatal electrocution were men aged between 20 and 50. Most cases were accidents (83%) and the rest were suicides (14%) or the manner of death was undetermined.

Although inconsistently present on the victims' body, the electrical mark is of great diagnostic value as confirmative evidence in cases of suspected electrocution.

Keywords: Electrocution, electrical mark, electrical current.

INTRODUCTION

Due to improvements in workplace safety measures and quality and safety of electrical installations, the risk of injuries and deaths caused by electricity has been reduced and deaths from electrocution are not common in Croatia [1]. Still, fatal injuries caused by electricity do occur and can present a challenge for the forensic pathologist performing the autopsy. One of the crucial signs on the body of a person who suffered a fatal injury from electric current is an electrical mark, which is often the only evidence of contact with electricity. There is a great diversity in the prevalence and appearance of electrical marks. Due to possible absence of distinctive morphological findings on the body, electrocution as a cause of death is often established by exclusion of other possible causes and supported by circumstantial evidence collected at the scene of the incident. In this study, we analyzed the prevalence of electrical marks on examined victims of electrocution and other available information about the fatal event.

MATERIALS AND METHODOLOGY

We retrospectively investigated all fatal incidents involving electricity in Zagreb County, Croatia, between 1991 and 2010, in which a medicolegal autopsy had been performed at the Department of Forensic Medicine and Criminology. Zagreb County consists of three districts with a total population of 1,243,581. In Croatia, a medicolegal autopsy is required by law in all cases of sudden unnatural death. The material of our study consisted of all cases in which the determined cause of death was electrocution. In the study period, a total of 89 electrocution deaths were identified. Death certificates, autopsy reports, and police records were used as the source of general and forensic information and information related to the site and circumstances of the incident. We collected the data on victim's sex and age, manner of death, alcohol concentration in blood, urine or muscle, place and time of death, and presence and site of electrical mark on the body. Deaths were also grouped according to the electrical voltage involved. Alcohol concentration was measured in the blood and/or urine and/or muscle, depending on the availability of the samples and the state of the body (in case of charring or putrefactive changes, a sample of muscle tissue was analyzed). The Statistics Package for Social Science (SPSS 11.5) was used for statistical analysis of the data and the results were presented as absolute and relative frequencies.

RESULTS

A total of 89 electrocution deaths were identified in area of Zagreb County in the 20-year study period. There were 78 male (88%) and 11 female victims (12%). The age of the victims ranged from 2 to 89 years (median, 38 years); the mean age was 40 years. There were 14 (16%) minor victims under the age of 18 (13 boys and one girl).

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The average number of fatal electrocutions was 4.45 per year, ranging from nine cases in 1996 to only one case a year in 2005, 2009, and 2010. After the exclusion of suicide deaths, the average number of accidental deaths by electrocution was 3.85 per year. The average annual incidence of all electrocution deaths was 0.36 per 100,000 populations, while the average annual incidence of accidental deaths by electrocution was 0.31 per 100,000 populations. Comparing the number of accidental deaths by electrocution among 5-year periods, we found a significantly decreasing trend from 1996 onwards. The annual incidence of electrocution deaths decreased from 0.39 to 0.14 deaths per 100,000 populations. On the other hand, suicides by electrocution showed an increasing trend over the study period, but their number was too low to determine the significance of the trend. The exact number of accidental deaths and suicides by electrocution by 5-year periods is shown in Figs. (**1**, **2**). The analysis of seasonal distribution showed that the incidence was the highest in the summer months (Fig. **3**).

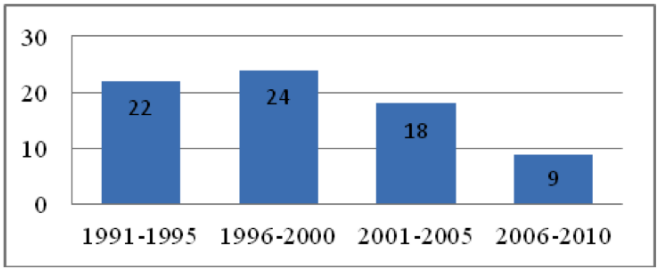

Fig. (1). Number of accidental deaths by electrocution per 5-year period.

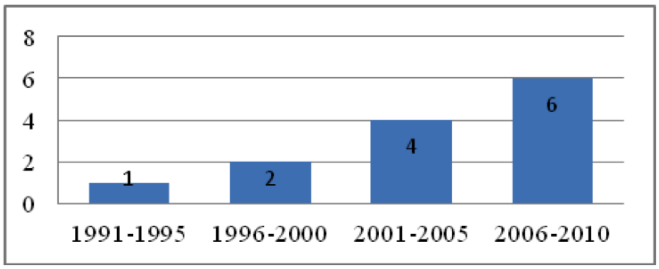

Fig. (2). Number of suicide deaths by electrocution per 5-year period.

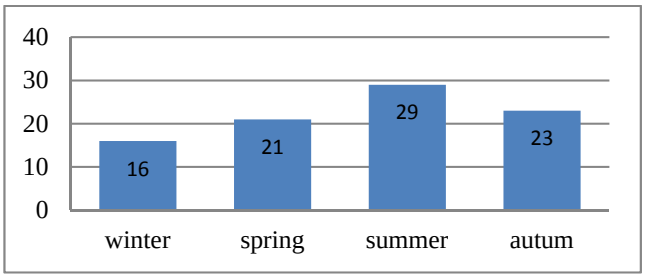

Fig. (3). Number of electrocution deaths by season.

Accident was the predominant manner of death (83%), followed by suicide (14%) and undetermined manner of death in three cases. No electrocution death was found to be a homicide. A significant difference was found in the incidence of suicide between male and female victims: 10 cases were determined as suicide in men (13%) and 2 in women (18%). The only determined manner of death in the population under 18 years of age was accident.

Most cases (75%) were caused by low-voltage electricity, which is used at home and workplaces, whereas high-voltage electricity was the cause of death in 20% of the cases. In 4 cases, the autopsy report contained no information on the voltage.

In 74% of the cases (n=66), fatal electrocution occurred during leisure time and in 25% (22 cases) at the workplace. In one case, the autopsy report contained no information on the place of death. The most common (27%) place of fatal electrocution during leisure time was a bathroom (24 cases, of which 18 occurred in bathtub), followed by other rooms in a house (19%) and a backyard (11%). Railway was the location of fatal electrocution in 5 cases (6%), of which 4 occurred on top of the train carriages; in one case, the specific place remained undetermined. Fatal electrocution in a bathroom was more common among women than men (73% *vs* 21%, respectively). Other rooms in a house and backyard were common places of electrocution during leisure time in men (32% *vs* 18% in women). Low-voltage electricity was the cause in 79% of the cases, and high-voltage in 16% of the cases, while the voltage was unknown or not specified in 5% of the cases. The fatal event occurred while the victim was doing housework or working around the house in 25% of the cases, taking a bath in a bathtub (accidental contact of an electrical appliance with water) in 22% of the cases, doing various outdoor activities in 19% of the cases, or due to faulty electrical appliances in 9% of the cases. In 25% of the cases, the autopsy report contained no information on the exact source and circumstances of electrocution.

In all cases of fatal occupational electrocution (22 cases, or 25%), the victims were men aged between 25 and 66 years (mean age, 38.1 years) and the determined manner of death was accident, except in one case where it was a suicide. Fatal occupational electrocution was more often caused by low-voltage than high-voltage electricity (64% *vs* 32%, respectively). In one case, the voltage could not be determined from the circumstances described in the autopsy report. Most victims were construction workers (36%), followed by electricians (32%), one baker, one carpenter, one track maintainer, one silo worker, and three workers of unknown occupation. Among the construction workers (8 cases), the contact of crane or excavator with the aerial power lines (high-voltage from 10,000 to 50,000 V) was the most common cause of electrocution (4 cases), followed by two deaths due to short circuit as a result of use of electrical heater in a damp basement during construction work. In two cases, the exact activity of the worker at a construction site was not reported. Considering the electrocution among the electricians, the victims were performing their usual job at the time of fatal event. One case of occupational electrocution, which was determined as suicide, occurred in a bakery.

Suicide was determined as the manner of death in 12 cases (14%), two women (18% of all female deaths) and 10

men (13% of all male deaths). The age range in this group was 30 to 82 years (mean age, 61.8 years). One suicide occurred at workplace and the rest of them at home (5 in a bathroom and 6 at other places in a house). In 7 cases (58%), electrical wires were found wrapped around the parts of the body. In 4 cases, victims were found in a filled bathtub with an electrical appliance (hairdryer in two cases, electrical heater in one case, and undetermined appliance in one case) in the water. Persons who committed suicide by electrocution were of different professions and educational level, but none was a professional electrician.

Among the minor victims (14 cases, or 16%), 13 were boys. The age range of the victims was 2 to 17 years (mean age, 11.4 years). Twelve minors were between the age of 2 and 10, one boy was 15, and one girl was 17 years old. In 7 cases, electrocutions occurred in a bathroom; in 6 of these cases, the cause was a hairdryer that fell into a bathtub filled with water. In four cases, the place of electrocution was a railway site and the incident happened while the minor was climbing on the train carriages. One case of electrocution occurred during fishing when a fishing rod came into contact with aerial power line, and one fatal electrocution occurred in an electrical substation. One incident took place in a house and no other specific information was obtained. High-voltage was more fatal in this age group than in the general population of fatally electrocuted (43% and 20%, respectively). All victims of high-voltage electrocution were boys aged between 13 and 15. In 11 cases, electrocution was the only determined cause of death, while in three other cases additional causes of death were reported (submersion in two cases and head trauma in one). The only determined manner of death in this subgroup was accident.

Alcohol concentration was measured in 80 cases. In 73 of these cases (82%), the samples were either negative for alcohol or alcohol concentration was less than 0.5 g/kg, which is considered sober. All samples with alcohol concentrations higher than 0.5 g/kg (7 samples, 8%) were collected from male victims. The alcohol concentration ranged from 0.53 g/kg in muscle tissue to 3.91 g/kg in blood and 5.81 g/kg in urine. None of the victims of occupational electrocution and none of the minors were positive for alcohol.

An electrical mark or burns were recorded in 79% of cases, and no detectable changes on the skin were found in the remaining 21%. Entry injury was found in 43% of the cases, both entry and exit injuries were present in 20%, and extensive burns were recorded in 16% of the cases in which neither the exact entry nor exit injuries could be detected. Entry injuries were most commonly found on the palms (58%). If the forearm (12%) and upper arm (4%) were taken into account, the upper extremity was the most common site of entry wound - 74% of the cases. Other sites were the head and neck (11%), lower leg (7%), trunk and feet (4% each), and upper leg (2%). Obvious exit wound was found in 18 cases and it was most commonly placed on the soles of the feet (7 cases, 39%) followed by palms (5 cases, 28%), trunk (4 cases, 22%) and thigh (2 cases, 11%). No electrical marks or burns were recorded in 19 cases, 9 of which happened in a filled bathtub and two occurred in a humid environment. Obvious multiple entry wounds (extensive burns excluded) were found in 9 cases, 6 of which were suicides with electrical wires wrapped around various parts of the victim's body (the head, neck, hands, and legs). Electrical mark and/or burns were found in all cases of high-voltage electrocution. In 10 cases (56%), the exact entry and exit wounds could not be found due to extensive burns (in four cases, charring of the body prevented further analysis). In three cases (17%) with extensive burns, the exit wound was found on the feet (in two cases on one foot and in one case on both feet). The only obvious entry wound was present in 5 cases (28%) and it was always located on palms.

DISCUSSION

Electrical work has traditionally been considered a "man's job". Accordingly, we have found a strong predominance of male population among the electrocution victims (male-to-female ratio was 7:1), similar to other studies [2, 3]. However, the proportion of male victims in our study was somewhat lower than in other studies [4-6]. The age range in our study sample was very broad, indicating potential hazards of electricity for any age group. As reported previously [4, 7, 8], the majority of deaths occurred due to low-voltage electricity, i.e. exposure to voltage of 220 volts at 50 Hz, which is commonly used in households and at workplaces in Croatia. The remaining deaths were caused by high-voltage electricity, which is used in industrial facilities, on construction sites, in aerial power lines, railway, and similar. High-voltage electricity used in transmission power lines ranges from 10,000 to 50,000 V, while railway uses a direct current with voltage ranging from 1500 to 3000 V. Majority (74%) of investigated deaths occurred during leisure time, while the rest occurred at workplace. The group of low-voltage incidents roughly overlaps with the group of incidents at leisure time, whereas high voltage contributed more to the occupational electrocution deaths. Other studies reported a similar finding [2, 5]. The only exception is the subgroup of accidental deaths of minors at railway sites.

As expected, and in accordance with other studies [4-9], majority of fatal electrocutions in our study were accidental. However, improvements in occupational safety standards and safety measures at in households have shown to be effective, since there is a significant decrease in the incidence of accidental electrocution deaths after 1996 in comparison with previous years. On the other hand, the number of suicides by electrocution is increasing; however, it was too low to calculate the statistical significance of this increase. This increasing trend is in contrast with a slight decline in the overall suicide rate in Croatia during the same period [10].

Minors represented 16% of the total number of electrocution victims autopsied at our Department, which is considerably lower than the number reported for Diyarbakir in Turkey, where 31.7% of fatally injured were younger than 10 years of age [9]. Still, their proportion in our study was higher than in other studies where minors constituted a rather

small proportion of electrocution victims [11]. Sex distribution among minor victims was similar to that among adults, with the number of male victims being quite higher than in other studies investigating electrocution deaths in childhood [11, 12]. Although chewing on an electric cord [13] and direct or indirect contact with low-voltage electrical outlets or faulty equipment [12, 14] have been the most common causes of fatal electrocution reported among children, in our study, the combination of a bathtub and electrical equipment (mostly hairdryers) was the most frequent finding, especially for younger minors. On the other hand, almost all boys aged 13 to 15 years were electrocuted by high-voltage electricity while playing on railway carriages and railway sites. High-voltage electricity has already been identified as especially dangerous for male minors [15]. These two typical circumstances of death among minors have one important feature in common – they could have easily been prevented, at least theoretically. Increasing parental awareness of the danger and need to adjust their own behavior in the presence of their children (*e.g*. not to use and/or leave electrical appliances in the bathroom) should lead to a significant decrease in the number of these tragic events among younger minors. Older boys should continuously be warned against playing extreme adventurous games at dangerous places (*e.g.,* on train carriages). As expected, accidents were the exclusive manner of death in this subgroup, which is similar to the reports of other authors [11, 12].

Although alcohol consumption before the lethal event was exclusively reported in male adults in our study, it was a rare finding and distributed evenly between accidental deaths and suicides. Other studies reported various proportions of victims of occupational electrocution who were under the influence of alcohol [2]. However, we found no cases of alcohol consumption among the occupational electrocution victims in our study.

Electrical injuries to the skin may range from superficial erythema to full-thickness burns and charring involving deep tissues. Also, under some circumstances, no obvious electrical injury may be present. In our study, some extent of skin damage was observed in 79% of cases, while in remaining 21%, there were no detectable changes on the skin. Upper extremities were by far the most common site (74%) of primary contact with the electrical source, which is consistent with findings reported elsewhere [6, 7, 9, 11, 12, 16]. On suicide victims, other entry sites as head and neck, trunk and lower extremities were more commonly found, obviously reflecting inventive suicide procedures. Unusual site of the electrical mark was not the only difference between suicide and accidental deaths. Multiple entry wounds were also a finding strongly associated with a suicide rather than an accident. The existence of a primary contact wound was proven to correlate with the voltage of electrical current. High voltage more often causes the appearance of electrical marks [4, 7, 17] than low voltage. In our study, high-voltage current caused some sort of thermal damage to tissue in all victims. Most of these victims (56%) had severe burns, which made it impossible to discern the entry and exit wounds (grounding marks). Both entry and exit wounds were found in one-fifth of the cases, with the soles of feet most commonly affected, as reported in other studies [16, 18]. All victims without any skin lesions that could be characterized as an electric mark (21%) were electrocuted by low-voltage electrical current. Among those with no obvious electrical mark, 47% were electrocuted in a bathtub and another 11% on damp construction sites. This finding is not surprising, since water decreases the skin resistance and reduces the density of electrical current [4, 8, 18]. When performing an autopsy, an examiner should not neglect less obvious types of skin marks, *e.g*., collapsed blisters on the palms of the hands. Careful external examination should be followed by a thorough microscopic examination aimed to reveal discrete changes in the skin.

CONCLUSION

Our findings are in accordance with the results of similar studies in this field. Decreasing the number of electrical fatalities should be the responsibility of legislators, communities, and individuals involved in the activities that include contact with electricity. When preventive measures fail and a fatal incident occurs, a thorough investigation should be carried out, including careful examination of both the scene and the body. Electrical mark is a guiding sign for a forensic pathologist attempting to establish the cause of death, especially when the findings and the scene are not informative enough.

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CONFLICT OF INTEREST

Declared none.

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