Electrocution-Related Mortality

A Survey of 295 Deaths in Tehran, Iran Between 2002 and 2006

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Background and Aim: Electrical burns are associated with significant morbidity and mortality, which are usually preventable with simple safety measures.

Methods: We conducted a retrospective study of non-lightening electrocution deaths in Tehran, Iran, between 2002 and 2006.

Results: Of 295 deaths, 285 investigated were accidental. The remnants were suicidal. The age range was 11 months to 75 years with a mean age of 28.99 ± 12.58 years. Two hundred seventy-nine victims (96.6%) were males. The upper extremity was the most frequently involved contact site in 185 deaths (66.3%). No electrical burn marks were present in 16 (5.4%) cases. Work-related accidents were responsible for 188 cases deaths (63.9%) and home accident for 85 cases deaths (28.8%). Deaths were caused most frequently by touching an electrical cable (95 cases, 32.2%). There was an increase in electrocution deaths in the summer (119 cases, 40.3%). One hundred seventy-nine cases (60.7%) were dead on the scene of death and 94 cases (31.9%) were dead on arrival at hospital. The unique findings of our study include 10 cases (3.4%) of suicidal electrocution and a high rate of work-related accidental electrocution among Afghan workers.

Conclusion: Death rates from electrocution among all medico-legal deaths were found to be lower in our study than in previous reports, most of them were work-related and preventable. Workers and their employers should be educated to avoid such accidents with safety measures.

Key Words: work-related accident, electrocution, forensic medicine

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Electricity is an integral part of the modern society. Electrical burns are responsible for considerable morbidity and mortality and are usually preventable with simple safety measures.[1,2] Almost all fatalities by electrocution are accidental, while homicides and suicides from electricity are rare or uncommon.[2] Many workers are exposed to electrical energy daily during the performance of their tasks. This study highlights the magnitude of the problem of occupational and home accidental electrocutions in Iran, identifies potential risk factors for fatal injury and provides recommendations for developing effective safety programs to reduce the risk of electrocution.

Electricity is a ubiquitous energy agent to which many workers in different occupations and industries are exposed daily in the performance of their duties. Also many people in different daily activities deal with it. Many people know that the principal danger from electricity is that of electrocution, but few really understand how minute a quantity of electrical energy is required for electrocution. In reality, the current drawn by a tiny 7.5 watt, 120-volt lamp, passed from hand to hand or hand to foot across the chest is sufficient to cause electrocution.[3] The number of people who believe that normal household current is not lethal or that power lines are insulated and do not pose a hazard is alarming. Electrocutions may result from contacts with an object as seemingly innocuous as a broken light bulb or as lethal as an overhead power line and might have affected workers, since the first electrical fatality was recorded in France in 1879 when a stage carpenter was killed by an alternating current (AC) of 250 volts.[4]

Death due to electrocution involves both low and high voltage currents and most of the deaths are due to low voltage currents used in houses and minor industrial settings. The type of power system employed in our country is an AC 220 to 240 volts, 50 amperes.

We describe the epidemiology of electrical fatalities in Tehran, Iran between 2002 and 2006. We hope that this study will serve as a valuable resource for safety and public health professionals, safety and health trainers, researchers, and others who can affect the prevention of accidental electrocutions.

MATERIALS AND METHODS

This study is a retrospective investigation of electrocution deaths in Tehran. Tehran with about 8,000,000 residents is the largest city of Iran. Data for this study was gathered from autopsy reports and hospital records. Victims of lightening were not included into the study. Data was obtained from Tehran's Legal Medicine Organization between January 2002 and December 2006. Records of medico-legal deaths were used in our study. The Legal Medicine Organization surveillance system is composed of information taken from death certificates, autopsy reports and medical records for all decedents of any ages with a diagnosis "deaths due to electrocutions" item.

The cases were evaluated in items of age, sex, type of electric mark, body region distribution, place and season of occurrence, contact details, the duration of hospitalization before death, existence of the multiple trauma due to a fall from a height, the manner of death, nationality of victims, and potential risk factors for fatal injury.

Definitions

Electricity is the flow of an atom's electrons through a conductor. Electrons, the outer particles of an atom, contain a negative charge. If electrons collect on an object, that object is negatively charged. If the electrons flow from an object through a conductor, the flow is called electric current. Four primary terms are used in discussing electricity: voltage, resistance, current, and ground.

Voltage is the fundamental force or pressure that causes electricity to flow through a conductor and is measured in volts. Resistance is anything that impedes the flow of electricity through a conductor, which is measured in ohms. Current is the flow of electrons from a source of voltage through a conductor, which is measured in amperes. If the current flows back and forth (a cycle) through a conductor, it is called alternating current. In each cycle, the electrons flow first in 1 direction, then the other. In Iran, the

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Figures can be viewed in color at http://amjforensicmedicine.com.

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normal rate is 50 cycles per second (or 50 Hz). If current flows in 1 direction only (as in a car battery), it is called direct current.

AC is most widely used because it is possible to step up or step down (ie, increase or decrease) the current through a transformer. For example, when current from an overhead power line is run through a pole-mounted transformer, it can be stepped down to normal household current.

Ohm's Law (Current = Voltage/Resistance) can be used to relate these 3 elements mathematically.

A ground is a conducting connection, whether or not unintentional, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

RESULTS

Overall, 295 electrocutions deaths occurred from January 2002 to December 2006. The cases represented approximately 0.6% of all autopsy cases received from Tehran's Legal Medicine Organization. An average of 59 persons was electrocuted each year, with an average annual rate of 0.7 per 100,000 persons. Figure 1 provides the frequency of electrocutions by the year of death. The substantial increase is noteworthy (Fig. 1). Two hundred eighty-five cases (96.6%) fatalities were accidental, 10 cases (3.4%) were suicidal and there was no case of homicidal electrocution. The age range of all electrocution deaths in the study period was 11 months to 73 years with a mean age of 28.99 ± 12.58 years (Fig. 2). The majority of the victims (279 cases, 94.6%) were male and male/female ratio was 17.4:1. About 3.7% of the victims (11 cases) were in 0 to 10 age group.

The upper extremity was by far the most common site, involved in 185 deaths (66.3%), followed by chest (43 cases, 15.4%) (Fig. 3). Among the victims, only electrical contact marks were present in 103 cases (34.9%), both electrical contact marks and electrical grounding marks in 176 (59.7%), and no electrical burn marks in 16 cases (5.4%). Work-related accidents were responsible for 188 deaths (63.9%), that 42 cases (22.3% of them) were Afghan workers (Table 1).

Places of occurrence were investigated, 85 of them (28.8%) occurred at home, 64 (21.7%) inside buildings during the electrical work, 52 (17.6%) in the street, 47 (15.9%) in factories, 30 (10.2%) on farmlands/gardens, 13 (4.4%) in shops, 2 (0.7%) in the office, 1 (0.3%) in prison, and 1 (0.3%) in a sport saloon. Considering the contact details, deaths were caused most frequently by touching electrical cables (95 cases, 32.2%), followed by touching electrical wires (67 cases, 22.2%), dynamo at work place (39 cases, 13.2%), water-cooler's dynamo on the roof of buildings (22 cases, 7.5%), refrigerators (16 cases, 5.4%), electrical outlets (12 cases, 4.1%), transformers (7 cases, 2.4%), elevators (7 cases, 2.4%), touching electrical water heaters in the bathroom (7 cases, 2.4%), and by touching electrical washing machines

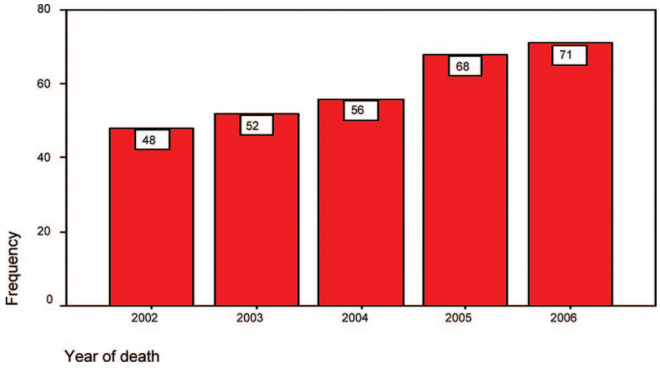

FIGURE 1. Frequency of decedents by the year of death. full color online

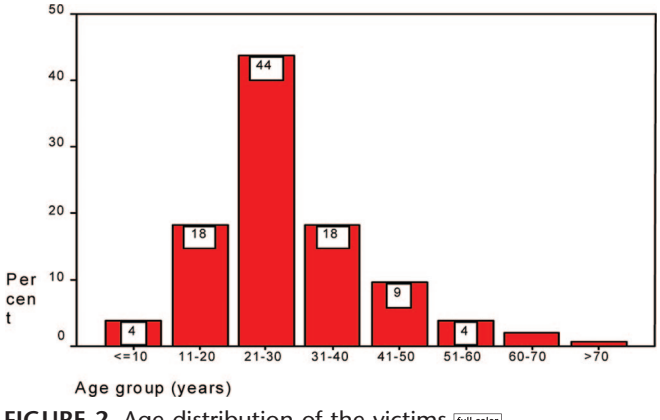

FIGURE 2. Age distribution of the victims. full color online

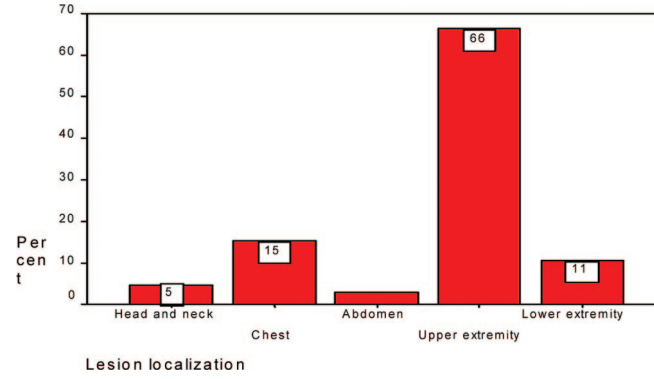

FIGURE 3. Lesion localization of victims. full color online

TABLE 1. Comparison of Victims by Their Nationalities*

Variable	Iranian Victims	Afghan Victims	All	*P*
Mean age (yr)	29.7 ± 13.4	25.3 ± 5.6	29.0 ± 12.6	<0.05
Gender (N [%])				
Female	16 (6.5)	0 (0,0)	16 (5.4)	NS
Male	230 (93.5)	48 (100.0)	279 (94.6)	
Marriage (N [%])				
Single	114 (46.3)	36 (75.0)	151 (51.2)	<0.01
Married	132 (53.7)	12 (25.0)	144 (48.8)	
Types of accidents (N [%])				
Work-related	145 (58.9)	42 (87.5)	188 (63.7)	NS
Home accidents	71 (28.9)	4 (8.3)	75 (25.4)	
Other accidents	20 (8.1)	2 (4.2)	22 (7.5)	
No accident	10 (4.1)	0 (0.0)	10 (3.4)	
Multiple trauma (N [%])				
Positive	43 (17.5)	3 (6.3)	46 (15.6)	<0.05
Negative	203 (82.5)	45 (93.7)	249 (84.4)	
Year of death (N [%])				
2002	35 (14.2)	13 (27.1)	48 (16.3)	<0.05
2003	45 (18.3)	7 (14.6)	52 (17.6)	
2004	44 (17.9)	12 (25)	56 (19.0)	
2005	57 (23.2)	10 (20.8)	68 (23.0)	
2006	65 (26.4)	6 (12.5)	71 (24.1)	

*n = 295, one victim had another nationality.

TABLE 2. Seasonal Distribution

Season	n	%
Spring (March-April-May)	56	19.0
Summer (June-July-August)	119	40.3
Autumn (September-October-November)	72	24.4
Winter (December-January-February)	48	16.3
Total	295	100.0

(5 cases, 1%). There was an increase in electrocution fatalities in the summer (119 cases, 40.3%) (Table 2). Overall, 179 (60.7%) were dead on the scene of death, 94 (31.9%) were dead on arrival at hospital, 15 (5.1%) died during treatment within 24 hours, and 7 (2.4%) died during treatment after 24 hours.

DISCUSSION

Electrocution is an uncommon cause of death and occurs commonly due to accident.[5,6] Electrocution deaths cause approximately 1000 deaths each year in the United States.[5] There was no previous study about electrocution deaths in our country. In our study these deaths were found to account for 0.6% of all medico-legal deaths in our region. Studies were done in other countries reported medico-legal death rate ranging from 1.90% to 3.3%.[2,7–11] This study showed an increase in annual rate of 0.6 per 100,000 people in 2002 to 0.9 per 100,000 in 2006 with an average annual rate of 0.7 per 100,000 people.

Among the electrocution deaths, 279 of 295 cases (94.6%) were male-perhaps due to more exposure of men to electric hazards compared with 69.9%, 92.5%, and 90.3% in previous reports from other countries.[2,12,13]

Some results of this study are similar to previous studies done in other countries. Similarly, we found that the upper extremity was the most common site involved (66.3%).[2,10,12,14,15] In our study, only electrical contact marks were present in 103 cases (34.9%) and both electrical contact marks and electrical grounding marks in 176 cases (59.7%), whereas there were no electric burn marks in 16 victims (5.4%) who died of electrical shocks in water or moist places. Because water lowers both the skin resistance and the density of electrical current, no burn marks would be expected in these cases. These results are partly similar to the findings of other studies.[2,6,10,16] Deaths due to electrocution had also occurred most frequently in summer months in our study (119 cases, 40.3%) compared with even higher rates of summer deaths reported by Fatovich (62.7%)[6] and Rautji et al (74%).[10] This may be attributable to increased sweating in the summer which decreases skin resistance and increases current flow through the body.[17] In our study, the decedents were predominantly from 21 to 30 age group and 285 cases (96.6%) of fatalities were accidental. Ten cases (3.4%) were suicidal and there was no case of homicidal electrocution. Thus almost all electrocution deaths had occurred by accident. However, higher rate of suicide by electrocution were reported by Karger et al 2002 in 10 cases among 37 deaths (27%).[18]

Work-related electrocution deaths were the most common form of accidents (188 cases, 63.7%) in our study. There were 48 foreign (Afghan) workers, which 87.5% of them were victims of work-related electrocution deaths, compare with 59.2% of work-related electrocution deaths among Iranian workers. The observation that there is a high rate of electrocution in Afghan workers has a mildly interesting sociological value. Almost all Afghan workers were forced into the most dangerous jobs without effective safety measures. Many workers are unaware of the potential electrical hazards present in their work environment, which makes them more vulnerable to the danger of electrocution. Thus, it seems that the high rate of work-related electrocution mortality in our country can be due to low safety training for workers and their employers. The most comprehensive study ever conducted in the United States has shown that electrocution continues to be a major cause of death among workers, because workers and their employers do not recognize the importance of safety training and implementing safe practices.[19]

Individuals who try to steal from a power utility are at the risk of electrocution. There are a few cases of death during theft from electric utilities in developed countries.[20] In our study, deaths during theft from electric utilities were seen in 8 cases (2.7%). All decedents were men, who were residents of the suburb.

The National Electrical Code describes high voltage as greater than 600 volts AC.[21] Most utilization circuits and equipments operate at voltages lower than 600 volts, including common household circuits (220/240 volts); most overhead lighting systems used in houses, industries or office buildings and department stores; and much of the electrical machinery used in industries, such as conveyor systems, and manufacturing machinery such as weaving machines, paper rolling machines or industrial pumps. Voltages over 600 volts can rupture human skin, greatly reduce the resistance of the human body, allow more current to flow and cause greater damage to internal organs. The most common high voltages are transmission voltages (typically over 13,800 volts) and distribution voltages (typically under 13,800 volts). The latter are the voltages transferred from the power generation plants to houses, offices, and manufacturing plants. Electrocution deaths occur mostly at a voltage between 110 to 380 volt, which is the voltage range of houses and industrial electricity. In this study we didn't observe any electrocuted cases from high voltage current and all cases were caused by low voltage current. Electrocution occurs when a human is exposed to a lethal amount of electrical energy. To determine how contact with an electrical source occurs, characteristics of the electrical source before the time of the incident must be evaluated (pre-event). For death to occur, the human body must become a part of an active electrical circuit, having a current capable of over stimulating the nervous system or causing damage to internal organs. The extent of injuries received depends on the current's magnitude (measured in amperes), the pathway of the current through the body, and the duration of current flow through the body (event). The resulting damage to the human body and the emergency medical treatment ultimately determine the outcome of the energy exchange (postevent). Electrical hazards represent a serious, widespread occupational danger; practically all members of the workforce are exposed to electrical energy during the performance of their daily duties, and electrocutions occur to workers in various job categories.

The electrocution fatality data helps us to illustrate the magnitude of the electrocution problem nationally and allow a comparison of the potential risks in various situations. Further investigations must focus on more detailed information on electrocution hazards, such as contact with overhead power lines, contact with exposed conductors, inadequate personal protective equipment, and nonexistent lockout/tagout procedures or other measures necessary for working around energized conductors and equipment. This research was done on Iranian cadavers in Legal Medicine Organization. Legal Medicine Organization of Iran with more than 1.5 million clinical forensic referrals and 50,000 autopsies per year is an appropriate field for such research and training.[22–28]

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