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# Study of different facets of electrocution deaths: a 5-year review

Sachin Giri, Avinash Waghmode and Nilesh Keshav Tumram*

## Abstract

**Background:** Deaths due to fatal electric injuries are quite common due to extensive use of electricity in home and industries. Hence, every single case of electrocution should be thoroughly investigated.

**Result:** This study was conducted from 2012 to 2016 to study the manner of deaths, seasonal variations, place of occurrence, source of contact, electrical injury, survival period, autopsy findings, and histopathological findings of skin of contact. During this period, a total of 5431 autopsies were carried out. The ratio of electric burn injuries to total burns was 1:6.5 while the ratio of electric burn injuries to total unnatural death was 1:49. Out of this, 88 cases of electrocution were analysed. In this study, majority of the victims were men (86%) aged between 21 and 40 years (63.6%). In 47.7% cases, victims were electrocuted at home. All these cases (100%) were found to be accidental in manner. Most of these cases were in contact with uninsulated source of electric wire. Out of the total cases, 22.7% cases were alive and got treated in hospital before death whereas 77.2% of people were declared brought in dead condition. Histopathological examination of electric contact skin in 67.04% cases showed all features suggestive of electric injury, i.e., infiltration of inflammatory cells, streaming of nuclei, coagulative necrosis, and epithelial separation.

**Conclusion:** Death due to electrocution is a medico-legal case which demands close attention not only to document the true cause of death of the unfortunate victim but also to detect defective condition which should be remedied in order to prevent future electrocution at the same site. Every such death is potentially avoidable, since every such injury is due to either equipment malfunction or victim error.

**Keywords:** Forensic science, Electrocution, Burns, Electric current, Autopsy, Death

## Background

The thought of modern society without electricity is unimaginable. As electricity has become an integral part of mankind, so have the incidents of electrocution due to electric current. Electrical wounds and burns have caused considerable morbidity and mortality (Kumar et al. 2014; Tirasci et al. 2006; James 2009; Fatovich 1992; Rautji et al. 2003; Accidental and suicidal deaths in India 2018; Shaha and Joe 2010). In India, a total of 9606 person died due to electrocution, in 2016 [2]. Most of the deaths by electrocution are accidental, while homicidal and suicidal deaths are rare or uncommon (James 2009; Accidental and suicidal deaths in India 2018; Lee 1998). Many people are daily exposed to various electrical appliances and sources of electricity.

Electricity is a broad energy agent to which many persons of different professions are daily exposed while performing their day-to-day duties and activities. Many people know the danger caused by non-protective contact with electricity, but very few really understand how minute a quantity of electrical energy is required for causing electrocution-related fatalities. The current drawn by an electric appliance as tiny as a 7.5 W, 120-V lamp, passed from hand to hand or hand to foot across the chest is sufficient to cause death by electrocution (Fatovich 1992). Electrocution is death caused by the passage of electric current. The main concern regarding electricity is that many believes that a normal household current is safe and insulated power lines do not pose a hazard. Electrocutions may result from contact with an object as seemingly innocuous as a broken light bulb or as lethal as an overhead power line (Rautji et al. 2003).

* Correspondence: ntumram@gmail.com; ntumram@rediffmail.com
Department of Forensic Medicine & Toxicology, Indira Gandhi Government Medical College, Nagpur 18, Maharashtra, India

Low-voltage currents and high-voltage currents are equally able to cause electrocution-related fatality. However, most fatalities occurring in a common household or a minor industrial setting happen due to contact with low-voltage currents. The type of power system employed in India is an alternate current (AC) 220–240 V, 50 A.

The present study was conducted to emphasise the extent of electrocution deaths occurring in work places and households in central India. Also, the study was conducted to identify possible risk factors for lethal electrical injury, and to provide recommendations for developing useful safety programs to decrease the threat of electrocution.

## Material and methods

The present study was carried out from period 2012 to 2016. It was a prospective study. An in-depth analysis of the epidemiological features and medico-legal aspects was carried out in an effort to more clearly understand the dynamics surrounding these deaths. Data were collected from the hospital records, police, autopsy reports, and relatives of the deceased. The cases were evaluated in terms of age, sex, place and season of occurrence, contact details, survival period, the manner of death, histological features of electrical injury, and potential risk factors for fatal injury if any. Seasonal months were taken as rainy (July–October), winter (November–February), and summer (March–June).

### Inclusion criteria

All the cases of fatal electrocution brought in our tertiary care hospital were studied.

### Exclusion criteria

Dead bodies that were decomposed or that having inadequate history were excluded.

### Observations and results

A total of 5431 medico-legal autopsies were carried out years between 2012 and 2016. There were a total of 4344 cases of unnatural deaths, and out of which, 572 were cases due to burn injuries. The ratio of electric burn injuries to total burns was 1:6.5 while the ratio of electric burn injuries to total unnatural death was 1:49.

Out of these, a total of 88 cases were of electrocution due to electric current. Out of these 88 cases, 76 were male and 12 were female. Their age ranged from 10 to 62 years (Table 1).

Most of the deaths due to electrocution (34%) were seen in the age group 21 to 30 year, while only two cases were seen in the age group of < 10 years.

All (100%) the cases were of accidental nature. Table 2 shows the seasonal incidence of cases of electrocution deaths. The rainy season comprised of 38.6%, followed by summer season 34.09%, and 27.2% cases were from winter season.

**Table 1** Age- and sex-wise distribution of cases

| Age group | Male | Female | Total |
|---|---|---|---|
| 0–10 | 00 | 02 | 02 [2.27%] |
| 11–20 | 12 | 00 | 12 [13.63%] |
| 21–30 | 28 | 06 | 34 [38.63%] |
| 31–40 | 20 | 02 | 22 [25%] |
| 41–50 | 14 | 00 | 14 [15.9%] |
| 51–60 | 00 | 02 | 02 [2.27%] |
| 60 and above | 02 | 00 | 02 [2.27%] |
| Total | 76 [86.4%] | 12 [13.6] | 88 [100%] |

Most of the cases were from urban areas (61.3%) as compared to rural areas (38.6%) (Table 3).

In relation to the place of occurrence, 47.7% cases occurred at home, 29.5% other than workplace or home, and 22.7% cases at workplace (Table 4). Of the total cases of electrocution falling in the category outside of home and work were predominately by overhead wires of trains (14 cases), followed by uninsulated wires in farms for keeping wild animals away, or uninsulated wires in public places which remained accidently open. Considering the source of electrocutions as shown in Table 6, deaths were caused most frequently by touching live electrical wires (22.72%), followed by mishandling of electric rod for water heating (18.1%), overhead wire (15.9%), evaporative water cooler (11.36%), and electric switchboard (9.09%) (Table 5).

In majority of the cases, the entry wounds were seen over upper extremities (61.36%), particularly the palm and fingers, as compared to lower extremities (9.09%). Involvement of multiple sites was seen in 20.5% cases (Table 6).

Direct contact with electricity was seen in 80% of the total cases. Of these, 56.8% cases showed entry wound only, while 10.2% cases showed both entry and exit wound. However, no electric injury was seen in 4.5% cases (Table 7). In cases of flash burns secondary to electrocution, crocodile skin were seen in 14 cases while singeing of body hairs in 8 cases. Amputation/long bone fracture was seen in only two cases.

**Table 2** Seasonal Variation of Electrocution deaths

| | Male | Female | Total |
|---|---|---|---|
| Summer | 25 | 5 | 30 [34.09%] |
| Rainy | 31 | 3 | 34 [38.63%] |
| Winter | 20 | 4 | 24 [27.27%] |
| Total | 76 | 12 | 88 |

**Table 3** Rural versus urban wise distribution of cases

| Place | Male | Female | Total |
|---|---|---|---|
| Rural | 34 | 0 | 34 [38.63%] |
| Urban | 42 | 12 | 54 [61.36%] |

Considering with the medical attention received, 22.7% cases were alive and were treated in hospital before death whereas 77.2% of peoples were declared brought in dead condition (Table 8).

In all the cases, internal organs showed congestion while petechial haemorrhages were observed over the heart (40 cases), lungs (60 cases), conjunctiva (10 cases), and brain matter (11 cases). In all cases, samples from the contact skin of the electrical injury were preserved for histopathology examination. Out of the total samples, 67.04% cases showed all features suggestive of electric injury (i.e., infiltration of inflammatory cells, streaming of nuclei, coagulative necrosis, and epithelial separation), 9.09% cases showed only coagulative necrosis and epithelial separation while 10.2% cases showed no features (Table 9).

## Discussion

After the advent of electricity and its utilisation as a commercial product, the fatality related to it also started to rise. The widespread use of electricity has been associated with a rapid increase in fatal as well as non-fatal injuries (Peng and Shikui 1995; Beyaztas et al. 2002; Lindström et al. 2006). In India, voltage of 220–240 V alternative current is responsible for causation of fatality due to electric current; however, death due to lower voltage (15 V AC) have also been reported (James 2009; Shaha and Joe 2010; Harvey-Sutton et al. 1992). Males accounted for the most number of deaths, i.e., 86.4% cases. This may be due to more exposure of men to electrical hazards. This is comparable with the study done by Lindstroo et al. (Lindström et al. 2006).

Most fatality occurred in the age group of 21–30 years (38.6%) followed by 31–40 year group (25%); the total number of both age groups goes up to 63.6%. The reason can be due to the fact that a person within the age of 21–40 years is the one which earns for livelihood. Persons of second to fourth decades are more often actively engaged in electricity-dependent works, at either their workplace or home; hence, they are prone to electrocution hazards. These results were consistent with the observations made by Kumar et al. (Kumar et al. 2014), Shrigiriwar et al. (Shrigiriwar et al. 2007), Reddy A (Reddy and Sengottuvel 2014), and Karger et al. (Karger et al. 2002).

**Table 4** Distribution of cases according to place of occurrence

| Workplace | Male | Female | Total |
|---|---|---|---|
| At work | 20 | 00 | 20 [22.7%] |
| At home | 30 | 12 | 42 [47.7%] |
| Outside | 26 | 00 | 26 [29.5%] |

**Table 5** Distribution of cases according to source of electrocution

| Source | Male | Female | Total |
|---|---|---|---|
| Switch board | 12 | 00 | 12 [13.6%] |
| Evaporative water cooler | 07 | 06 | 13 [14.8%] |
| Electric rod for water heating | 13 | 06 | 19 [21.6%] |
| Overhead wire of train or electric pole | 14 | 00 | 14 [15.9%] |
| Live open uninsulated wire | 30 | 00 | 30 [34.1%] |

In this study, all deaths were of accidental in nature, as electrocution is an uncommon cause of death which usually happens accidentally. The analysis of literature confirms the rarity of suicide or homicide by electrocution (James 2009; Fatovich 1992; Rautji et al. 2003; Taylor et al. 2003). However, higher rate of suicide by electrocution was reported by Karger et al. (Karger et al. 2002).

Most of the deaths occurred in the rainy season (July–October) followed by summer (March–June). The high rate of rainy season where similar to the findings of Kumar et al. (Kumar et al. 2014), Fatovich et al. (Fatovich 1992), and Rautji et al. (Rautji et al. 2003). The seasonal variations in electrocution-related deaths are due to differences in humidity, moisture, and individual behaviour. Higher incidents of electrocution deaths during summer may be due to increased humidity and high usage of electric appliances such as coolers, air conditioners, and refrigerators (Reddy and Sengottuvel 2014). Also, excessive sweating caused during the hot and humid season contribute to decrease in skin resistance to the electric current, leading to electrocution.

In the current study, it was found that the cases and incidences of electrocution in urban population was more than those in the rural population. Surprisingly, out of the total 38.6% cases of electrocution in rural population, there were no cases in females. Similarly, the female cases were much lower in comparison to males in urban population too. In the rural setup of India and particularly our region, there is less number of electricity

**Table 6** Case distribution according to primary contact site

| Site of contact | Male | Female | Total |
|---|---|---|---|
| Upper extremity | 48 | 6 | 54 [61.3%] |
| Lower extremity | 8 | 0 | 08 [9.09%] |
| Trunk | 0 | 4 | 04 [4.5%] |
| Whole body involvement (multiple sites) | 18 | 0 | 18 [20.5%] |
| No injury | 2 | 2 | 04 [4.5%] |
| Total | 76 | 12 | 88 |

**Table 7** Distribution of cases according to type of electric injury

| | Male | Female | Total |
|---|---|---|---|
| Only entry wound | 44 | 06 | 50 [56.8%] |
| Entry + exit wound | 07 | 02 | 09 [10.2%] |
| Flash burns | 06 | 00 | 06 [6.8%] |
| Electric burns | 17 | 02 | 19 [21.5%] |
| No injury | 02 | 02 | 04 [4.5%] |

connections in households as well as work places than urban places. Also, the supply of electricity to rural area is infrequent and some regions also face 12–18 h of load shedding (periodic stoppage of electric supply by the authorities). This leads to less usage of electric appliances and less degree of contact to it by the users. This might be one of the reasons for such low cases in rural area. Similarly, the social habits of "Early to bed and early to rise" are more prevalent in rural areas leading to early evening meals followed by rest (sleep) than urban areas. This leads to lesser contact of the users with the electrical appliances and electronic gazettes.

In the present study, incidents of electrocution at homes were most common than places of work and others. No female cases were seen at work places or others. All the cases in females were seen at incidents of electrocution occurring at home. This was starkly different than the studies done by other researchers who found work-related fatalities more than home-related ones (Kumar et al. 2014; Taylor et al. 2003). This might be due to the increase in use of electrical appliances at home. Such appliances if not properly used or installed can become a source of electrical hazard. Improper earthing, overcrowded circuits, faulty substandard appliances, etc. all contribute to occurrence of such incidences. Of the total cases of electrocution falling in the category outside of home and work were predominately by overhead wires of trains (14 cases), followed by uninsulated wires in farms for keeping wild animals away, or uninsulated wires in public places which remained accidently open.

In this study, more than half of the fatalities (around 50%) are the result of accidental contact with electricity

**Table 8** Survival period of victims of electrocution

| Survival period | Male | Female | Total |
|---|---|---|---|
| Brought dead | 56 | 11 | 67 [76.1%] |
| 0–6 h | 02 | 01 | 3 [3.4%] |
| 7–12 h | 00 | 00 | 0 [0%] |
| 13–24 h | 04 | 00 | 4 [4.5%] |
| 25–48 h | 02 | 00 | 2 [2.2%] |
| 48–72 h | 00 | 00 | 0 [0%] |
| > 3 day | 12 | 00 | 12 [13.6%] |

**Table 9** Histological findings of contact skin in electrocution

| Histological features | No. of cases (88) |
|---|---|
| Coagulative necrosis + baseline streaming of nuclei | 2 (2.3%) |
| Coagulative necrosis + epithelial separation | 8 (9.09%) |
| Streaming of nuclei | 6 (6.8%) |
| Only infiltration of inflammatory cells | 4 (4.5%) |
| All of the above findings | 59 (67.04%) |
| Negative | 9 (10.2%) |

normally at domestic supply. Except cases of victims catching the overhead wire of a train, which is a high voltage electric current, all other cases were of low-voltage electric current sources. Underestimation of the danger of live circuits and carelessness play a part in work place incidents whereas ignorance, faulty domestic appliances, frayed or broken flex of electric cables, and improper earthing accounts for many of the domestic accidents (Odesanmi 1987; Hussain and Khan 2015; Polson et al. 1985).

The distinct injury marks formed at the place of contact with electric current (entry mark) and joule burns can be considered as a classical external sign of electrocution. Entry mark alone was seen in nearly half of the autopsied cases while both entry and exit marks were noticed in nearly 10% cases. The findings were similar to those of Di Maio (DiMaio and DiMaio 2001) and Bailey et al. (Bailey et al. 2001). The production of electrical injury depends on voltage, amount of current flow, the area of the contact, and duration of contact. An electrical burn occurs only if the temperature of the skin is raised enough for a sufficiently long period to produce damage (Spitz 1993). On the other hand, a glancing contact or fall against conductor results in break in the circuit; in cases of high-tension supplies, the victim is usually repelled violently. Nevertheless, there can be enough current to make it difficult for a person to remove his body parts (Erkol 1995). In four cases, no electric burn was found. In all these cases, the victims were in contact with water. Unlike dry skin, wet skin offers less resistance to the passage of electric current, thus producing no visible electric burn mark at the site of contact. In such cases, circumstances such as having eyewitnesses and faulty earthing of the electrical appliances or circuits help in forming an opinion regarding electrocution.

The hands and fingers of the upper extremities are the most common sites for electrical injuries (entry marks), while exit wounds were usually located on the soles and toes of the lower extremities, because extremities are the most common sites of contact with the source of electric current. The findings were similar with the studies of Erkol (Erkol 1995) and Byard et al. (Byard et al. 2003).

Out of all, 77.2% people were brought in dead condition whereas 22.7% died during treatment. It is well known that the electric current is particularly more dangerous when it uses one of the circuits involving the heart muscle, and in this study, upper extremity was involved in 61.3% cases. The high percentage of electrocutions at the scene is due to the catch-on effect of low-voltage AC current (220–240 V) used in homes and small-scale industries in India.

The electric marks and joule burn are important features of electrocution when low- or medium-voltage current is involved. Often, electric marks are not produced in cases of electrocution. In such cases, histological examination of the skin from the electric wound was done to support the findings of death due to electrocution. It has been observed that histological examination could be an important aspect in diagnosis of electrocution, as observed in 89.7% of cases that were indicating signs of electrical injuries. Of these changes, all findings suggestive of electrical injuries were found in 67.04% of cases. Electrical injuries produce high-temperature burns in many cases, leading to production of distinctive findings of severe thermal denaturation of collagen causing it to stain blue with haematoxylin. Separation of the epidermis with formation of micro-blisters within squamous epithelium as well as in the horny layer was seen. There is stretching and narrowing of the contour of the nuclei of epidermal cell at the site of an electrical burn resulting in a palisade type of appearance. This change is often referred to as streaming of the nuclei (Spitz 1993).

## Conclusion

Death due to electrocution demands close attention not only to document the true cause of death of the unfortunate victim but also to detect defective conditions which should prevent future electrocution. Usually, such deaths are accidental which can be avoided if proper safety measures are adopted. Caution should be advised while using malfunctioned equipment, uninsulated wiring, damaged appliances etc. Children should be prevented from using electrical appliances or gadgets which they cannot handle. Electric switchboard should always be kept away from the reach of children. In our study, water coolers were found to be a growing electrical hazard. This can be easily prevented by adopting proper earthing to it. Also, while filling water in the water cooler, one should remove the plugs and keep it in off mode. People residing near high-tension wires or persons climbing on the roof of the railway bogie are at particularly high risk of getting electrocuted. So, such contact should be avoided. At the end, if one can practise safety measures for handling electrical instruments, one can remain safe.

### Abbreviations

AC: Alternate current

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### Availability of data and materials

The data and necessary material is available from the authors.

### Authors' contributions

All the authors were equally involved in the process of the data collection and the preparation and editing of the manuscript. All authors read and approved the final manuscript.

### Ethics approval and consent to participate

As the paper did not reveal the identities of the participants who are subjected to medico-legal autopsy, the ethical approval was waived off under the institutional ethics committee. Necessary consent were taken from the relatives of the deceased.

### Consent for publication

Necessary consent were taken from the relatives of the deceased.

### Competing interests

The authors declare that they have no competing interests.

## Publisher's Note



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