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ORIGINAL ARTICLE

Forensic investigation of electrocution: Examining electrical injury profiles in Hyderabad, Pakistan

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ABSTRACT

Background: Electrocution-related deaths in Pakistan are a significant public health concern, demonstrating the interplay of electrical safety, infrastructural issues, and socioeconomic status.
Objective: To investigate the forensic characteristics of electrical injuries.
Methods: This cross-sectional study examined 175 electrocution death cases that were autopsied at the Civil Hospital, Hyderabad, Pakistan, mortuary in one year from November 2023 to December 2024. We gathered and examined information on burn patterns, anatomical distribution of injuries, voltage levels, wound sites, injury types, cause of mortality, and gender differences. Information was obtained from eyewitness statements, police inquest documents, and autopsy results using a structured information proforma and checklist.
Results: Out of 175 dead bodies examined, the majority were males (90.3%), and 34.8% were between 21 and 30 years of age. The results indicate a predominance of upper limb injuries (37.8%) and a high incidence of low-voltage injuries (78.3%). Cardiac arrest has emerged as the leading cause of mortality (41.7%), underscoring the critical role of infection in post-injury complications. The gender wise differences of injury location, degree of burns, and mortality cause were found statistically significant ($p<0.05$).
Conclusion: Electrical injuries, particularly those involving low-voltage sources, have a significant impact on specific body areas, notably the upper limbs, and are linked with a high risk of septic complications that can ultimately lead to death.

Key Words: Forensic Medicine, Electric Injury, Profiles

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INTRODUCTION

Electrocution is a serious public health issue with significant forensic ramifications. It can result from accidental or homicidal exposure to electrical currents that cause deadly results. In addition to transforming contemporary civilization, the invention of electricity has brought about widespread risks that can result in serious harm or even death.[1] Accurately determining the cause and method of death is critical in both legal contexts and preventive initiatives, and it requires a comprehension of the forensic features of electrical injuries.[2] Numerous things, like industrial machinery, home appliances, and natural occurrences like lightning, can cause electrical injury. A thorough analysis of the victim, the scene, and the injury pattern is part of the forensic assessment of these injuries.[3]

Electrocution deaths may exhibit unique injuries like entry and exit wounds, which are essential for ascertaining the path the electrical current took through the body. Various studies have indicated that the entry wound is frequently found on the hands or fingers, implying that the victim held onto the electrical source.[4] Exit wounds, when they occur, are usually found on the feet, suggesting that the current moved through the body. These incidents often lead to heat burns, tissue burns, and possibly internal organ injury due to the high voltage present.[5,6]

An essential component of the analysis of electrocution deaths is forensic pathology. Autopsies show particular damage patterns that help distinguish electrocution from other causes of death. For example, a distinctive indicator of lightning strikes is the existence of Lichtenberg figures, a pattern similar to a fern on the skin.[1,7] The diagnosis of electrical injury can be confirmed by histopathological examination, which also offers further information on the degree of tissue damage. In addition to a physical examination, the investigation involves figuring out the cause of death. Examining the surroundings, the electrical supply, and any safety infractions is all part of this. To ensure a thorough knowledge of the situation, electrical engineers and forensic specialists work together to reconstruct the event.[8]

According to epidemiological research, there are specific demographic trends in electrocution fatalities. One Pakistani survey reported that over 70% of electrocution incidents occur inside the home and private premises. People aged 21-30 years are more prone to having electrocution incidents in Karachi alone.[9] One significant factor is the use of generators and water pumps. Men are disproportionately impacted due to work-related risks in sectors including maintenance and construction. In Pakistan, studies have also reported that over 2/3rd of victims reported with electrocution are male.[10] Seasonal changes are also noted, with a larger rate of electrocution mortality occurring in the summer, likely due to more people using electrical equipment and engaging in outdoor activities.[6,11] These cases are more frequently reported from July to September.[9]

Inadequate safety precautions and ignorance increase the risk of electrocution-related deaths in poor nations.[6] Public health programs emphasizing education and strict adherence to safety rules are essential to reduce these dangers.

Keeping this in view, the current study was conducted to add to the body of knowledge by offering a thorough forensic examination of the electrocution victims brought to the Civil Hospital mortuary in Hyderabad, Pakistan. The aim was to enhance the understanding of the factors contributing to electrocution injuries and improve the accuracy of investigations into electrocution deaths, thereby contributing to the body of forensic knowledge.

The study's objective was to investigate the forensic characteristics of electrical injuries, focusing on the nature and anatomical distribution of injuries, associated voltage levels, wound identification, causes of mortality, and gender differences.

METHODS

After getting approval from the institutional board of Isra University, Hyderabad, Pakistan, a cross-sectional study was conducted from November 2023 to October 2024 in the mortuary of Civil Hospital, Hyderabad, Pakistan. The criteria for eligibility included deaths from electrical injuries that were autopsied at the civil hospital with the legal heirs' informed agreement. Decomposed or disfigured bodies and probable electrocution fatalities that were not confirmed by autopsy were excluded. A sample size of 162 was calculated using the Open-Epi software, keeping a 95% confidence interval, a 5% margin of error, and an electrocution mortality prevalence of 11.9%.[5] However, 175 samples were selected to give a representative population by considering variables like age, sex, and location of residence. A non-probability purposive sampling technique was used. Following hospital and ethics committee guidelines for sex and gender demographic data ensures that the study's findings may be used to a broader population.

Information was obtained from eyewitness statements, police inquest documents, and autopsy results using a structured information proforma and checklist. Age, gender, residence, site of the injury, entry and exit wounds, voltage level, and related burns, cause of death were among the variables studied. Each body had a thorough examination to determine the characteristics of electrical injury. Along with any related burns, entry and exit wounds were carefully examined and documented. Witness reports and an analysis of the scene of the occurrence were used to calculate the electrical voltage of the source.

Ethical Approval

The study was conducted from November 2023 to October 2024 in the mortuary of Civil Hospital, Hyderabad, Pakistan, after taking approval from the Ethical Committee of Isra University, Hyderabad, Pakistan (#IU/RR-10-IRC-23/N/2023/341) on 4th of October 2023.

Statistical Analysis

SPSS version 27 was used to conduct statistical analysis. Demographic data and injury patterns were summarized using descriptive statistics. Categorical variables were analyzed for significant differences using Fisher's exact test. A Fisher's exact test was applied to assess gender differences in the degree of burns due to small expected counts in some categories. p-value ≤ 0.05 was considered statistically significant

RESULTS

A total of 175 forensic examinations of electrocution fatalities were conducted during the study period. The findings revealed a significant gender imbalance, with 158 (90.3%) of the victims being male and only 17 (9.7%) females, resulting in a male-to-female ratio of 11.5:1. In terms of age distribution, the highest frequency of cases occurred in the 21-30 years age group, with 61 victims (34.8%), followed by 35 victims (20.6%) in the 31-40 years age group. Among the victims, 24 (13.8%) were aged 11-20 years, and 24 (13.8%) were aged 51 years and above. Additionally, 21 victims (12.0%) were aged 41-50 years, while 12 (6.8%) were from the 0-10 years age group. Most incidents of electrocution (n=92; 52.6%) took place in home settings, compared to occupational or outdoor environments (n=83; 47.4%).

Table 1: Characteristics of the electrical injuries of the victims

Variables	n (%)
Injury Location	
Upper Limbs	66 (37.8)
Lower Limbs	41 (23.4)
Torso	29 (16.6)
Head and neck	16 (9.1)
Other	23 (13.1)
Type of Electrical Source	
Low Voltage	137 (78.3)
High Voltage	38 (21.7)
Presence of Wounds	
Entry Wounds Only	90 (51.4)
Exit Wounds Only	15 (8.6)
Both Entry and Exit Wounds	70 (40.0)

The most frequent cause of electrocution was attributed to household appliances, accounting for 79 instances (45.1%), followed by high-tension electric lines (n=38; 21.7%), electrical repair work (n=28; 16.0%), water pumps (n=21; 12.0%), and other causes (n=9; 5.1%). The majority of cases (n=88; 50.3%) were reported during the monsoon or rainy season, followed by incidents occurring in clear weather (n=70; 40.0%) and stormy conditions (n=17; 9.7%).

Table 1 shows the characteristics of injuries among the electrocution victims. The findings indicate that the majority of electrocution injuries occurred in the upper limbs, followed by lower limbs and torso injuries, with fewer cases involving the head and other locations. Whereas, regarding the type of electrical source, low voltage accounts for most cases. Regarding the presence of wounds, the data reveal that over half of the cases involved only entry wounds. In contrast, both entry and exit wounds were present, and only a small number of victims presented with exit wounds alone (Table: 1).

Table 2 shows that the flame burns are the most prevalent type of injury in the study victims, accounting for nearly half of the cases (n=76; 43.4%). Flash burns follow the flame burns (n=57; 32.6%), while no burns were observed in some victims (n=20; 11.4%).

The data on causes of mortality indicate that cardiac arrest was the leading cause of death. Neurological damage was the second most common cause of death, accounting for a significant proportion of cases, which highlights the potential for electrical injuries to impact brain function. Respiratory failure was noted in some cases, indicating that respiratory complications can also arise from severe injuries. Additionally, a limited number of cases fall under "other" causes, suggesting a variety of less common factors contributing to mortality (Table: 2)

Table 3 shows the gender-wise differences in the anatomical distribution of electrical injury and the presence of wounds among the victims studied. There was a statistically significant gender difference in the anatomical distribution of electrical injuries (p 0.011). Among males, the upper limbs (39.2%) and lower limbs (24%) were the most frequently affected sites. In contrast, in females, the majority of injuries were classified under the "Other" category (41.2%), followed by upper limbs (23.5%). This suggests the

potential differences in exposure patterns or contact points during electrical injury between males and females.

However, no statistically significant difference between males and females was observed in the presence or type of electrical wounds (p=0.112). Entry wounds were more frequently observed in males (53.8%), whereas more females exhibited both entry and exit wounds (53.0%).

The differences in degrees of burns and causes of mortality among males and females are shown in Table 4. A significant gender difference was observed in the distribution of burn severity (p=0.001)

First-degree burns were more common among females than males, whereas second-degree and third-degree burns were more frequently reported in males than in females (Table 4).

In males, cardiac arrest was the leading cause of mortality, followed by neurological damage and respiratory failure, with significantly higher frequencies (p=0.014) compared to females (Table: 4).

Table 2: Degree of burns and causes of mortality among victims

Variables	n (%)
Degree of Burns	
No Burns	20 (11.4)
First degree	53 (30.3)
Second degree	72 (41.2)
Third degree	30 (17.1)
Cause of Mortality	
Neurological damage	52 (29.7)
Cardiac Arrest	73 (41.7)
Respiratory Failure	35 (20.0)
Other	15 (8.6)

Table 3: Gender wise differences in anatomical distribution of electrical injury and the presence of wounds

Variables	Males n (%)	Females n (%)	p value
Injury Location			
Upper Limbs	62 (39.2)	04 (23.5)	
Lower Limbs	38 (24.0)	03 (17.6)	
Torso	27 (17.2)	02 (11.7)	0.011*
Head and neck	15 (9.5)	01 (6.0)	
Other	16 (10.1)	07 (41.2)	
Presence of Wounds			
Entry Wound	85 (53.8)	05 (29.4)	
Exit Wound	12 (7.6)	03 (17.6)	0.112
Both Entry Exit wounds	61 (38.6)	09 (53.0)	

*Chi-square test applied. *p<0.05 statistically significant.*

Figure 1: Electrocution injuries among the victims

Table 4: Gender differences in the degree of burn and causes of mortality

Variable	Males n (%)	Females n (%)	p value
Degree of Burn			
No Burns	18(11.4)	02 (11.7)	
First degree	41(26.0)	12 (70.6)	0.001*
Second degree	70(44.3)	02 (11.7)	
Third degree	29(18.3)	01 (6.0)	
Mortality Cause			
Neurological damage	48(30.4)	04 (23.5)	
Cardiac Arrest	68(43.0)	05 (29.4)	0.014*
Respiratory Failure	32(20.2)	03 (17.6)	
Other	10(6.4)	05 (29.4)	

*Chi-square test applied. *p<0.05 statistically significant.*

DISCUSSION

This study explores and offers important new information on the types of burns, electrical injury characteristics, and the causes of victim death. The results add to a more complex understanding of electrocution episodes by methodically examining data on wound existence, electrical source type, and damage location.

Historically, electrical work has been regarded as a "man's job." Previous studies have reported a significant prevalence of male victims based on this understanding.[12,13] In this study, 90.3% of the victims were male compared to their counterparts. These findings are consistent with a previous study by Prasad et al. that reported a higher number of male victims (92%) in their research.[14] It is widely acknowledged that males engage with electricity more frequently, whether at home or in the workplace, which explains the higher incidence of electrical accidents among them.

Another study also reported that electrocution deaths were more common in men, with a male to the female ratio comparable to the present study. Low-voltage power, which is often utilized in homes and businesses, was the cause of over 70% of fatalities.[15]

The greater accessibility of residential low-voltage and alternating current power lines, which people are more accustomed to and can reach more readily, may be the cause of this.[15] High-voltage electricity, which is utilized in railroads, industrial facilities, building sites, aerial power lines, and other similar applications, was the cause of the different occurrences, which led to cardiac arrest.[13] Whereas, young adults also experienced a high rate of electrocution deaths, with the majority of these instances taking place in homes.[16]

In the present study, we observed that the majority (34.8%) of victims were between 21 and 30 years of age. Also, our study found that low voltage (64.5%) was more prevalent. Data is available suggesting that most participants in their research were younger males.[14,17]

According to Khalid et al., their study on electrocution revealed no discernible gender disparity. They discovered that more than half of the fatalities were between the ages of 39 and 59 years.[11] Regional variations in electrical infrastructure and safety procedures may cause this disparity.

Seasonal fluctuation in electrocution mortality was noted by different researchers, with a greater number during the monsoon period. Although seasonal trends were not particularly examined in the present study, the prevalence of domestic events raises the possibility that weather-related factors could impact the incidence of electrical injuries.[18] The autopsy-based investigation discovered that entry wounds on the upper limbs were responsible for the majority of electrocution deaths; these findings are consistent with our study findings.[14,17] Both entry and exit wounds were frequently seen, highlighting the significance of these indicators in establishing electrocution as the source of death.

Our results are consistent with Begum et al., who found that contact with low-voltage sources was a factor in most electrocution deaths in their study.[19] The upper limb electric injuries were more predominant in the present study, indicating that this may have been caused by handling electrical devices, which is in line with the findings of Dash et al.[20] Another important factor is the location of injuries. This pattern implies that victims frequently touch electrical sources with their hands, emphasizing the necessity of taking precautions when working with electrical equipment.

Electricity causes mortality predominantly by the flow of current, which can induce ventricular fibrillation, cardiac arrest, and arrhythmias.

In the present study, most (41.7%) deaths resulted from cardiac arrest. Different national and international studies also reported a similar proportion of deaths due to the mentioned factors.[5,11,14,21,22] The results of the present study are in line with Prasad et al. and Manjunatha et al., who discovered that flame burns were more frequent in electrocution deaths.[14,17] Their study also highlighted the need to examine burn patterns to ascertain the cause of death forensically. Important information about the cause of death can be gleaned from the forensic examination of electrocution injuries.

CONCLUSION

The findings indicate that the upper limbs are the most commonly affected area in electrical injuries, primarily from low-voltage sources, with notable instances of entry and exit wounds. Second-degree burns are the most prevalent, while causes of mortality show a concerning prevalence of cardiac arrest and neurological damage. Additionally, gender differences reveal that males are more likely to experience severe injuries, as evidenced by higher rates of third-degree burns and related mortality.

Limitations of study and future recommendations

The study's shortcomings include a limited sample size, which limits its applicability to other settings or areas. The study occurred at a single mortuary, which may have resulted in location-specific biases and reduced the diversity of the cases analyzed. Moreover, the study focused solely on deceased individuals, limiting the ability to examine the circumstances surrounding electrocution in living subjects. Finally, the cross-sectional research design does not allow for the identification of causal links, making it impossible to make firm conclusions regarding the elements that contribute to electrocution deaths.

To build on the findings of this study, future research should include a larger and more geographically diverse sample to improve the generalizability of results. Multi-center studies, involving multiple mortuaries and forensic units, would help minimize location-specific biases and capture a broader range of electrocution cases. Additionally, incorporating data from surviving electrocution victims could

provide valuable insights into risk factors, circumstances, and preventive measures that cannot be assessed through dead victims alone. Finally, prospective or case-control study designs may allow for better understanding of causal relationships and help identify specific occupational, environmental, or behavioral factors contributing to electrocution-related injuries and deaths.

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AUTHOR'S CONTRIBUTIONS:

- **SAK:** Conception of study, study design, data acquisition & analysis, manuscript drafting
- **NAQ**: Conception of study, study design, interpretation of data, critical review
- **AM:** Data collection, critical review, manuscript drafting
- **IB:** Conception of study, data acquisition & analysis, manuscript drafting, critical review
- **WAN:** Data collection, interpretation of data, manuscript drafting
- **MOQ:** Data collection and manuscript drafting
- **KR:** Data collection, critical review, manuscript drafting

All authors approved the final version to be published and agreed to be accountable for all aspects of the work, ensuring that any questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

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