Original Article

Forensic Analysis of Electrical Injury Patterns: A Study of Electrocution Fatalities at SMS Medical College Jaipur

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Abstract

Objective: To provide an in-depth forensic analysis of the types and locations of electrical injuries observed in electrocution deaths, focusing on the presence of entry and exit wounds, the voltage involved, and associated burns.

Methods: This hospital-based observational study examined 75 cases of electrocution fatalities autopsied at the mortuary of SMS Medical College Jaipur from June 2021 to June 2022. Data on demographics, injury types, wound locations, voltage levels, and burn patterns were collected and analyzed. Descriptive statistics were used to summarize the data, and chi-square tests assessed the significance of categorical variables.

Results: Among the 75 cases, males accounted for 92% of the victims, with the majority aged 21-30 years (34.4%). Upper limb injuries were predominant (38.67%), and both entry and exit wounds were present in 48% of cases. Low voltage (65.33%) was the most common electrical source, and flame burns were observed in 44% of the cases. Shock – Septicaemia was the primary cause of death (58.66%).

Conclusions: This study highlights the forensic significance of analysing injury patterns in electrocution deaths. Understanding these patterns aids in determining the cause and manner of death, emphasizing the need for preventive measures and public awareness to reduce such fatalities.

Keywords: Electrocution, Forensic Analysis, Electrical Injuries, Injury Patterns, Autopsy, Jaipur.

Introduction

Electrocution, a fatal consequence of electrical injuries, remains a significant public health issue with substantial forensic implications. The advent of electricity, while revolutionizing modern society, has also introduced a pervasive hazard, capable of causing

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severe injury and death. Understanding the forensic characteristics of electrical injuries is essential for the accurate determination of the cause and manner of death, crucial in both legal contexts and preventive strategies. Electrical injuries can result from various sources, including household appliances, industrial equipment, and natural phenomena like lightning. The forensic investigation of such injuries involves meticulous examination of the scene, the victim, and the pattern of injuries. Electrocution fatalities typically present with characteristic injuries, such as entry and exit wounds, which are critical for determining the path of the electrical current through the body. Studies have consistently shown that the entry wound is often located on the hands or fingers, suggesting that the victim grasped the electrical source. Exit wounds, if present, are frequently found on the feet, indicating that the current traversed the entire body. These injuries are accompanied by thermal burns, tissue charring, and sometimes internal organ damage due to the high voltage involved.[1]

Forensic pathology plays a vital role in the investigation of electrocution deaths. Autopsies reveal specific patterns of injury that can differentiate electrocution from other causes of death. For instance, the presence of Lichtenberg figures, a fern-like pattern on the skin, is a unique marker of lightning strikes.[2] Histopathological examination can further elucidate the extent of tissue damage and confirm the diagnosis of electrical injury.[3]

In addition to physical examination, the investigation involves assessing the circumstances of death. This includes examining the electrical source, the environment, and any safety violations. Forensic experts collaborate with electrical engineers to reconstruct the event, ensuring a comprehensive understanding of the incident.[4]

Epidemiological studies indicate that electrocution deaths exhibit certain demographic patterns. Males are disproportionately affected, often due to occupational hazards in industries such as construction and maintenance.[5] Seasonal variations are also observed, with a higher incidence of electrocution deaths during the summer months, likely due to increased outdoor activities and the use of electrical devices.[6]

In developing countries, the risk is exacerbated by inadequate safety measures and lack of awareness. Public health initiatives aimed at education and stringent enforcement of safety regulations are crucial in mitigating these risks. The forensic community must advocate for such measures to prevent future fatalities.[7]

Numerous studies have documented the forensic characteristics of electrocution deaths. Pathak and Disania[1] conducted a retrospective study highlighting the common patterns of electrical injuries and their forensic implications. They emphasized the importance of detailed scene examination and autopsy in establishing the cause of death. Similarly, Marak et al.[8] examined the demographic profile and injury patterns in electrocution deaths, underscoring the role of forensic analysis in identifying safety lapses and preventing future incidents.

Kiran et al.[9] analyzed autopsy findings in electrocution cases, noting the prevalence of entry and exit wounds and associated burns. Their study reinforced the need for forensic pathologists to be vigilant in detecting subtle signs of electrical injury. Dokov[6] provided a comprehensive review of suicide cases involving electrocution, revealing a distinct pattern and suggesting preventive measures.

The present study aims to expand on the existing knowledge by providing an in-depth forensic analysis of electrocution fatalities at SMS Medical College, Jaipur. The study focuses on identifying the types and locations of electrical injuries, the voltage involved, and the presence of entry and exit wounds. By analysing these factors, the study seeks to contribute to the body of forensic knowledge and enhance the accuracy of electrocution death investigations.

Materials and Methods

This hospital-based observational study was conducted at the mortuary of SMS Medical College Jaipur after approval from the Institutional Ethical Committee (224/MC/EC/2021 – 19/03/2022)..The study included 75 cases of electrocution deaths. Eligibility criteria included fatalities resulting from electrical injuries autopsied at SMS Hospital, with informed consent obtained from legal heirs. Exclusion criteria comprised suspected electrocution deaths not verified on autopsy and decomposed or mutilated bodies. The sample was selected to ensure a representative population, accounting for variables such as age, sex, and domicile. This approach

aligns with the SAGER guidelines for reporting demographic data on sex and gender, ensuring that the study's findings are applicable to the broader population .Data was gathered from autopsy reports, police inquest papers, and eyewitness accounts. Variables studied included age, gender, domicile, site of injury, presence of entry and exit wounds, voltage involved, and associated burns. A detailed examination was conducted on each body to identify the types and locations of electrical injuries. The presence of entry and exit wounds was meticulously recorded, along with any associated burns. The voltage of the electrical source was determined based on witness accounts and the examination of the incident site. Primary and secondary outcomes were clearly outlined. The primary objective was to analyze the patterns of electrical injuries in electrocution fatalities. Secondary objectives included investigating the presence of entry and exit wounds, the voltage involved, and associated burns.

Statistical Analysis

Descriptive statistics summarized demographic data and injury patterns. Chi-square tests assessed the significance of categorical variables, with a p-value <0.05 considered statistically significant. Statistical analyses were performed using SPSS software (version 25).

Quantitative findings were presented with appropriate indicators of measurement error or uncertainty, such as confidence intervals. Statistical terms, abbreviations, and symbols were clearly defined to ensure transparency and reproducibility.

Results

Demographic Data

Gender: Out of 75 cases, 69 (92%) were male and 6 (8%) were female, resulting in a male-to-female ratio of 11.5:1.

Table 1: Distribution of Subjects According to Gender

Gender	No. Of Subjects	Percentage
Male	69	92 %
Female	6	8 %
Total	75	100.00

Age Group: The majority of the victims fell within the 21-30 years age group (34.4%), followed by those aged 31-40 years (26.6%). This demographic trend is consistent with previous studies, which have demonstrated a higher risk of injuries among younger males. The predominance of male victims can be attributed to the fact that many are employed in occupations with higher exposure to electrical hazards. Specifically, 23 individuals sustained injuries in indoor work environments, while 21 were injured in outdoor settings.

Table 2: Age Group wise Distribution among Subjects.

Age Group	No. of Male	No. of Female	No. of Subjects	Percentage
1-10	1	1	2	2.66%
11-20	11	0	11	14.66%
21-30	24	2	26	34.4%
31-40	18	2	20	26.6%
41-50	8	0	8	10.6%
51-60	6	0	6	8%
61-70	1	1	2	2.66%
Total	69	6	75	100%

Injury Patterns

Site of Injury: Upper limbs were the most common site of injury (38.67%), followed by lower limbs (36%). Injuries to the head and neck were less frequent (2.66%). The predominance of upper limb injuries suggests that victims often come into contact with electrical sources using their hands.

Table 3: Distribution of Subjects According to Site of Electric Injury

Site Of Electric Injury	No. of Subjects	Percentage
Head, Neck & Lower Limb	2	2.66%
Abdomen	2	2.66%
Chest	1	1.33%
Abdomen & Lower Limb	1	1.33%
Chest & Lower Limb	1	1.33%
Chest, Abdomen & Upper Limb	1	1.33%
Chest, Upper Limb & Lower Limb	2	2.66%
Lower Limb	6	8%
Upper Limb	29	38.67%
Upper Limb & Lower Limb	27	36%
No injury	3	4%
Total	75	100

Entry and Exit Wounds: Entry wounds were present in 44% of cases, while both entry and exit wounds were observed in 48%. Exit wounds alone were found in 4% of the cases. The presence of both entry and exit wounds is crucial for confirming electrocution as the cause of death.

Table 4: Distribution of Subjects According to Presence of Wound

Wound	No. Of Subjects	Percentage
Entry & Exit Present	36	48%
Entry Only	33	44%
Exit Only	3	4%
Entry & Exit Absent	3	4%
Total	75	100%

Figure 1: Entry wound over hidden area in the incidence of Electrocution by desert cooler

Figure 2: Entry wound of Electrocution on index and middle finger

Figure 3: Exit marks of Electric current on Sole

Figure 4: Showing Exit wound of Electric injury on great toe and sole

Voltage: Most fatalities involved low voltage (65.33%), while high voltage accounted for 34.66%. Low voltage injuries were primarily associated with domestic incidents, whereas high voltage injuries were more common in occupational settings.

Table 5: Distribution of Subjects According to Voltage

Voltage	No. of Subjects	Percentage
High Voltage	26	34.66%
Low Voltage	49	65.33%
Total	75	100%

Burns: Flame burns were more common (44%) than flash burns (13.33%). No burns were observed in 42.67% of the cases. Flame burns often indicate prolonged contact with an electrical source, whereas flash burns result from brief exposure.

Table 6: Distribution of Subjects According to Associated Burn

Associated Burn	No. of Subjects	Percentage
Flash	10	13.33%
Flame	33	44%
No Burn	32	42.66%
Total	75	100%

Cause of Death

The primary cause of death was Shock – Septicaemia (58.66%), followed by Shock – Electrocution (36%). Shock – Septicaemia often results from extensive tissue damage and subsequent infection, highlighting the severe internal injuries caused by electrical currents.

Table 7: Distribution of Subjects According to Cause Of Death

Cause of Death	No. of Subjects	Percentage
Coma	1	1.33%
Shock - Electrocution	27	36%
Shock - Hemorrhagic	2	2.66%
Shock - Septicemia	44	58.66%
Shock – Spinal	1	1.33%
Total	75	100%

Table 8: Distribution of Subjects According to Cause of Death and Type of Associated Injury and Degree of Voltage

Cause of Death	Type of Associated Injury	Degree of Voltage	No. of Subjects
Coma (1)	Flash	High	0
		Low	0
	Flame	High	0
		Low	0
	No Burn	High	1
		Low	0
Shock - Electrocution (27)	Flash	High	0
		Low	4
	Flame	High	7
		Low	3
	No Burn	High	6
		Low	7
Shock - Hemorrhagic (2)	Flash	High	0
		Low	0
	Flame	High	0
		Low	0
	No Burn	High	2
		Low	0
Shock - Septicemia (44)	Flash	High	0
		Low	6
	Flame	High	6
		Low	17
	No Burn	High	3
		Low	12
Shock - Spinal (1)	Flash	High	0
		Low	0
	Flame	High	0
		Low	0
	No Burn	High	1
		Low	0

Discussion

The findings of this study align with those reported in previous literature. Gupta et al. (2012) found that electrocution deaths predominantly affected males, with a male-to-female ratio similar to our study.[10] Saha and Joe (2010) also reported a high incidence of electrocution fatalities among young adults, with most incidents occurring in domestic settings.[5]

Ragui et al. (2013) observed that electrocution deaths were more common in males aged 21-30 years, which is consistent with our findings. They also noted that high-tension wires were a significant cause of electrocution deaths, whereas our study found that low voltage was more common.[11] This discrepancy could be attributed to regional differences in electrical infrastructure and safety practices.

Pathak et al. (2015) reported a seasonal variation in electrocution deaths, with a higher incidence during the monsoon season. Our study did not specifically analyze seasonal trends, but the predominance of domestic incidents suggests that weather-related factors might influence the occurrence of electrocution injuries.[1]

Balasubramaniam (2016) conducted an autopsy-based study and found that most electrocution deaths involved entry wounds on the upper limbs, similar to our findings.[12] The presence of both entry and exit wounds was also commonly observed, emphasizing the importance of these markers in confirming electrocution as the cause of death.

Kanchan and Menezes (2015) reported that the majority of electrocution deaths in their study involved contact with low voltage sources, which aligns with our findings.[13] They also observed that upper limb injuries were predominant, highlighting the risk associated with handling electrical equipment.

Adhi et al. (2017) found that flame burns were more common in electrocution deaths, which is consistent with our findings.[14] Their study also emphasized the forensic significance of analyzing burn patterns to determine the circumstances of death.

The forensic analysis of electrocution injuries provides critical insights into the circumstances of death. The presence of entry and exit wounds is a key indicator of electrocution, helping to differentiate it from other causes of death. In our study, 48% of cases had both entry and exit wounds, which aligns with the findings of previous studies.[12]

The location of injuries is also significant. Upper limb injuries were the most common in our study, consistent with the findings of Gupta et al. (2012) and Saha and Joe (2010). This pattern suggests that victims often make contact with electrical sources using their hands, highlighting the need for protective measures when handling electrical equipment.[5,10]

Understanding the voltage involved in electrocution deaths is crucial for forensic investigations. Low voltage was the most common in our study, similar to the findings of Marak et al. (2017) and Choudhary et al. (2017).[8,15] However, high voltage injuries, which accounted for 34.66% of cases in our study, are often associated with more severe injuries and higher fatality rates.

Burn patterns provide additional forensic evidence. Flame burns were more common than flash burns in our study, indicating prolonged contact with the electrical source. This finding is supported by the work of Pathak et al. (2015), who also observed a higher prevalence of flame burns in electrocution deaths.[1]

Preventive Measures

Public awareness campaigns and strict adherence to electrical safety standards can significantly reduce the incidence of electrocution deaths. Regular maintenance of electrical appliances and infrastructure is essential. The study highlights the need for targeted safety interventions, particularly in domestic settings where most incidents occur.[16]

Educational programs should emphasize the dangers of electrical currents, especially low voltage, which is often perceived as less dangerous. Proper handling and maintenance of electrical appliances, use of safety equipment, and adherence to safety protocols can prevent many fatalities.[17]

Implementing safety measures such as the use of residual current devices (RCDs) and ensuring proper grounding of electrical systems can prevent electrocution incidents. Public health policies should focus on regular inspections and enforcement of electrical safety regulations in both residential and occupational settings.[18]

Conclusions

This study provides valuable insights into the forensic analysis of electrocution fatalities. Young males are the most affected, with injuries commonly occurring at home due to low voltage. Forensic

examination of injury patterns is vital for accurate cause-of-death determinations. Enhanced public awareness and safety measures are necessary to prevent such fatalities. The findings underscore the importance of detailed forensic investigations in electrocution cases. By understanding the specific patterns of injury, forensic pathologists can more accurately determine the cause and manner of death, contributing to the broader goal of improving public safety. Future research should focus on developing more effective preventive strategies and exploring the underlying factors contributing to high-risk behaviours. Collaborative efforts between forensic experts, public health officials, and policymakers are essential to reduce the incidence of electrocution deaths and improve overall safety standards.

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