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MEDICOLEGAL PROFILE AND AUTOPSY PATTERNS OF FATAL ELECTROCUTION: A RETROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Electrocution is an important preventable cause of unnatural death, particularly among young adults exposed to unsafe domestic, occupational, and agricultural electrical installations. Forensic diagnosis may be difficult because electrical contact marks can be absent and internal autopsy findings are frequently non-specific. This study evaluated the demographic characteristics, circumstances, electrical sources, injury patterns, and medicolegal features of electrocution fatalities.

Materials and Methods: This retrospective observational study included 142 confirmed electrocution fatalities autopsied at a tertiary-care medicolegal centre. Demographic, circumstantial, electrical-source, external injury, internal autopsy, histopathological, survival, and manner-of-death data were obtained from autopsy reports, clinical records, and police and scene documents. Associations were assessed using the chi-square or Fisher's exact test, with $p<0.05$ considered statistically significant.

Results: The mean age was 34.9 ± 14.2 years, and 119 (83.8%) victims were male. Domestic incidents accounted for 54 (38.0%) cases, while 62 (43.7%) occurred during the monsoon. Low-voltage exposure predominated in 101/142 (71.1%) cases. Electrical contact marks were identified in 126 (88.7%), most frequently on the upper limbs (78; 54.9%). High-voltage exposure was significantly associated with deep burns, total body surface area involvement >20%, flame burns, contact and presumed exit lesions, and associated trauma (all $p \leq 0.003$). Most victims died at the scene or were brought dead (124; 87.3%). Deep burns, extensive burns, and flame burns were associated with delayed death (all $p<0.001$), whereas a transthoracic pathway was associated with immediate death ($p=0.021$). The manner of death was accidental in 137 (96.5%) cases.

Conclusion: Electrocution fatalities primarily involved young men and resulted from preventable accidental exposure. Low-voltage electricity caused most deaths, whereas high-voltage exposure produced more extensive burns and trauma. Integrated scene investigation, meticulous autopsy, and histopathological assessment are essential for reliable forensic diagnosis. Strengthening domestic and occupational electrical safety, particularly during the monsoon, may reduce mortality.

Keywords: electrical injury; electrocution; electrical contact mark; forensic autopsy; high-voltage injury; medicolegal investigation.

INTRODUCTION

Electrical injury occurs when electric current passes through the body and may cause burns, multiorgan damage, disability, or death. Fatal electrical injury, termed electrocution, remains an important preventable cause of unnatural death, particularly among young adults, electricians, construction labourers, industrial workers, and agricultural workers.[1,2] In India, more than 15,000 deaths due to electrical shocks and electrical fires were reported in 2020, although inconsistencies among police, hospital, and electricity-authority records suggest possible under-reporting.[3] Indian autopsy studies indicate that electrocution constitutes approximately 0.6%–4.0% of medicolegal autopsies, with accidental low-voltage exposure predominating.[4-6]

Injury severity depends on voltage, current strength and type, contact duration, tissue resistance, environmental moisture, and the pathway through the body.[1,7] Although high-voltage exposure generally produces extensive burns and deep tissue necrosis, low-voltage alternating current may cause fatal ventricular fibrillation, particularly when tetanic contraction prolongs contact. Death may result from ventricular fibrillation, asystole, respiratory paralysis, central respiratory arrest, extensive burns, shock, renal failure, or sepsis. Importantly, the extent of external burns may not reflect internal damage or fatality risk.

Forensic diagnosis is challenging because internal findings, including visceral congestion, pulmonary oedema, and petechial haemorrhages, are generally non-specific.[8] A classical electrical mark may appear as a pale, dry, depressed, crater-like lesion; however, it may be inconspicuous or absent. Electrical marks have been reported in approximately 79%–81% of fatalities.[9,10] Histopathology may demonstrate epidermal separation, nuclear palisading, cellular streaming, vacuolisation, and dermal collagen homogenisation. Diagnosis therefore requires correlation of scene findings, electrical-source examination, injury distribution, autopsy, histopathology, and toxicology. The present study aimed to analyse demographic characteristics, circumstances, electrical sources, injury patterns, causes, and manner of death among electrocution fatalities to strengthen forensic interpretation and inform preventive interventions.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based, retrospective observational study was conducted in the Department of Forensic Medicine and Toxicology at a tertiary-care referral centre in North India. All medicolegal autopsies performed for 2 years from June 2023 to May 2025 were screened to identify deaths attributable to electrocution.

Study Population and Sampling

All consecutive electrocution fatalities (n=142) satisfying the eligibility criteria were included using census sampling. Cases were eligible when electrical exposure was established from scene information, police inquest records, witness accounts, clinical history, electrical-source examination, autopsy findings, and histopathology, with exclusion of competing causes. Victims who died at the scene, were brought dead, or died after hospitalisation were included. Deaths caused exclusively by lightning or electrical fires without evidence of current passage, cases with advanced decomposition or extensive charring preventing assessment, incomplete records, and uncertain electrical exposure were excluded.

Data Collection

Data were retrieved from autopsy reports, mortuary registers, hospital records, medicolegal documents, police inquest reports, first-information reports, scene photographs, electrical-inspection reports, and laboratory findings. Information was entered into a predesigned case-record form. Variables included age, sex, occupation, residence, place and season of occurrence, activity during exposure, electrical source, voltage category, environmental conditions, survival interval, cause of death, and manner of death.

The place of occurrence was categorised as domestic, occupational or industrial, agricultural, public or outdoor, or other. Exposure sources included defective appliances, exposed wiring, switches, electric poles, overhead transmission lines, transformers, water pumps, agricultural equipment, and energised metallic objects. Wet surroundings, rainfall, waterlogging, damaged insulation, barefoot contact, and use of protective equipment were documented when available.

Classification of Electrical Exposure

Exposure was classified as low voltage (<1,000 V), high voltage (≥1,000 V), or unknown. Where the exact voltage was unavailable, classification was based on the source and electrical-inspection or circumstantial evidence. Injuries were classified as true electrical contact injuries, arc or flash burns, flame burns secondary to ignition, or mixed injuries.

Autopsy Examination

A complete external examination was performed according to the standard medicolegal autopsy protocol. Suspected electrical lesions were documented for number, anatomical location, dimensions, shape, colour, margins, surface, and depth. A typical electrical contact mark was identified as a pale, dry, firm, depressed, crater-like, or parchmentised lesion, with or without an elevated margin. Lesions were primarily recorded as contact points and designated as presumed entry or exit lesions only when supported by their morphology, scene findings, and probable current pathway.

Injury location was categorised as head and neck, trunk, upper limbs, lower limbs, or multiple regions. The probable current pathway was classified as transthoracic, vertical, confined to one limb, cranial, or indeterminate. Burn depth and total body surface area involved were documented. Associated abrasions, contusions, lacerations, fractures, dislocations, head injuries, and injuries caused by falls or tetanic muscular contraction were also recorded.

A systematic internal examination of the cranial, thoracic, and abdominal cavities was performed. The heart, lungs, brain, kidneys, liver, and skeletal muscles were examined for congestion, oedema, haemorrhage, necrosis, and thermal damage. In hospitalised victims, acute kidney injury, rhabdomyolysis, sepsis, pneumonia, and multiorgan dysfunction were documented.

Histopathology and Toxicology

Representative samples from electrical contact lesions, lesion margins, and adjacent normal skin were examined histopathologically wherever feasible. Epidermal separation, vacuolisation, nuclear elongation and palisading, cellular streaming, coagulative necrosis, and dermal collagen homogenisation were recorded. Viscera and body fluids were preserved for toxicological analysis when intoxication, suicide, foul play, or an alternative cause of death was suspected.

Cause and Manner of Death

The cause of death was determined by integrating scene findings, police investigation, clinical records, autopsy observations, histopathology, and toxicology. Deaths were classified as immediate, usually due to fatal arrhythmia or cardiorespiratory arrest, or delayed due to burns, shock, renal failure, sepsis, or multiorgan dysfunction. The manner of death was classified as accidental, suicidal, homicidal, or undetermined.

Statistical Analysis

Data were analysed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median (interquartile range), while categorical variables were presented as frequency and percentage. Associations were assessed using the chi-square or Fisher's exact test, with $p<0.05$ considered significant.

Ethical Considerations

Institutional Ethics Committee approval was obtained. Identifiers were removed, and confidentiality was maintained throughout the study.

RESULTS

The mean age of the victims was 34.9 ± 14.2 years, with 84 (59.2%) aged 18–40 years. Most victims were male (119; 83.8%) and from rural areas (82; 57.7%). Construction or industrial labourers (34; 23.9%), agricultural workers (28; 19.7%), and electrical workers (18; 12.7%) constituted the principal occupational groups. [Table 1]

Table 1: Sociodemographic Characteristics of Electrocution Fatalities Included in the Forensic Autopsy Study (N=142)

Characteristic	Frequency (%) / Mean ± SD
Age (years)	34.9 ± 14.2
Age group	
<18 years	12 (8.5)
18–30 years	48 (33.8)
31–40 years	36 (25.4)
41–50 years	25 (17.6)
>50 years	21 (14.8)
Gender	
Male	119 (83.8)
Female	23 (16.2)
Residence	
Rural	82 (57.7)
Urban	60 (42.3)
Occupation	
Construction/industrial labourer	34 (23.9)
Farmer/agricultural worker	28 (19.7)
Electrician/electrical worker	18 (12.7)
Homemaker	16 (11.3)
Student/child	14 (9.9)
Service employee/shopkeeper	13 (9.2)
Unemployed/other	19 (13.4)

Domestic premises were the most frequent location of electrocution (54; 38.0%), followed by construction or industrial workplaces (40; 28.2%). Incidents occurred most frequently during the monsoon season (62; 43.7%). Low-voltage exposure predominated (101; 71.1%), direct contact was the principal mechanism (107; 75.4%), and wet environmental conditions were documented in 59 (41.5%) cases. [Table 2]

Table 2: Circumstances, Location, Environmental Conditions, and Characteristics of Electrical Exposure Among Electrocution Fatalities (N=142)

Exposure characteristic	Frequency (%)
Place of occurrence	
Domestic premises	54 (38.0)
Construction/industrial workplace	40 (28.2)
Agricultural setting	26 (18.3)
Public place/outdoor setting	22 (15.5)
Season of occurrence	
Monsoon	62 (43.7)
Summer	45 (31.7)
Winter	35 (24.6)
Electrical source	
Domestic wiring/appliance	46 (32.4)
Overhead transmission/distribution line	27 (19.0)
Agricultural pump or equipment	21 (14.8)
Industrial machinery/equipment	18 (12.7)
Electric pole, snapped wire, or exposed conductor	17 (12.0)
Transformer/high-tension installation	8 (5.6)
Other electrical source	5 (3.5)
Voltage category	
Low voltage (<1,000 V)	101 (71.1)
High voltage (≥1,000 V)	35 (24.6)
Unknown	6 (4.2)
Exposure mechanism	
Direct contact with live source	107 (75.4)
Electrical arc/flash	24 (16.9)
Energised water or metallic object	11 (7.7)
Wet environmental conditions present	59 (41.5)
Probable unsafe circumstance	
Defective insulation or wiring	47 (33.1)
Unsafe handling or attempted repair	33 (23.2)
Contact with overhead electrical line	26 (18.3)
Leakage from appliance/equipment	20 (14.1)
Snapped or fallen live conductor	11 (7.7)
Deliberate electrical exposure	5 (3.5)

Visible electrical contact marks were identified in 126 (88.7%) cases, while both contact and presumed exit lesions were present in 47 (33.1%). The upper limb was the most frequent primary contact site (78; 54.9%), and a transthoracic current pathway was suspected in 61 (43.0%) cases. Deep burns occurred in 47 (33.1%), TBSA involvement >20% in 29 (20.4%), and associated traumatic injuries in 29 (20.4%) victims. [Table 3]

Table 3: External Injury Patterns, Anatomical Distribution, Burn Characteristics, Probable Current Pathway, and Associated Trauma in Electrocution Fatalities (N=142)

Injury characteristic	Frequency (%)
Visible electrical contact mark	126 (88.7)
Pattern of electrical lesions	
Single contact lesion	69 (48.6)
Presumed contact and exit lesions	47 (33.1)
Multiple contact lesions	10 (7.0)
No visible electrical lesion	16 (11.3)
Primary location of contact lesion	
Upper limb	78 (54.9)
Lower limb	24 (16.9)
Trunk	15 (10.6)
Head and neck	9 (6.3)
Not identifiable	16 (11.3)
Burn depth	
Superficial	42 (29.6)
Partial-thickness	36 (25.4)
Full-thickness	33 (23.2)
Mixed-depth	14 (9.9)
No appreciable burn	17 (12.0)
Burned total body surface area	
<10%	89 (62.7)
10%–20%	24 (16.9)
>20%	29 (20.4)
Probable current pathway	
Transthoracic	61 (43.0)
Vertical, non-transthoracic	28 (19.7)

Confined predominantly to one limb	23 (16.2)
Indeterminate	30 (21.1)
Associated traumatic injury	29 (20.4)
Injury attributable to a fall	18 (12.7)
Fracture or dislocation	11 (7.7)
Head injury	8 (5.6)

Generalised visceral congestion (121; 85.2%) and pulmonary congestion or oedema (104; 73.2%) were the predominant internal findings. Most victims died at the scene or were brought dead (124; 87.3%), with fatal arrhythmia or cardiorespiratory arrest being the leading cause of death (105; 73.9%). Accidental deaths constituted 137 (96.5%) cases, and histological features supportive of electrical injury were identified in 103/118 (87.3%) examined specimens. [Table 4]

Table 4: Internal Autopsy Findings, Survival Status, Histopathological Features, Cause of Death, and Manner of Death Among Electrocution Fatalities (N=142)

Finding	Frequency (%)
Generalised visceral congestion	121 (85.2)
Pulmonary congestion and oedema	104 (73.2)
Fine froth in airways	76 (53.5)
Cardiac chamber congestion	95 (66.9)
Petechial haemorrhages	39 (27.5)
Focal myocardial haemorrhage/necrosis	17 (12.0)
Acute kidney injury/rhabdomyolysis changes	12 (8.5)
Survival status	
Died at scene/brought dead	124 (87.3)
Died following hospitalisation	18 (12.7)
Cause of death	
Presumed fatal arrhythmia/cardiorespiratory arrest	105 (73.9)
Shock due to extensive electrical burns	12 (8.5)
Septicaemia/multiorgan dysfunction	10 (7.0)
Respiratory paralysis/arrest	7 (4.9)
Acute kidney injury with rhabdomyolysis	4 (2.8)
Traumatic injury secondary to fall	4 (2.8)
Manner of death	
Accidental	137 (96.5)
Suicidal	4 (2.8)
Homicidal	1 (0.7)
Histopathology performed	118 (83.1)
Histological features supportive of electrical injury	103/118 (87.3)
Electrical metallisation detected	19/118 (16.1)

Compared with low-voltage exposure, high-voltage electrocution was significantly associated with the presence of both contact and presumed exit lesions (57.1% vs 26.7%; p=0.002), deep burns (82.9% vs 17.8%; p<0.001), TBSA involvement >20% (62.9% vs 6.9%; p<0.001), flame burns (54.3% vs 10.9%; p<0.001), and associated trauma (40.0% vs 13.9%; p=0.003). Immediate mortality did not differ significantly between high- and low-voltage exposure (82.9% vs 89.1%; p=0.377). [Table 5]

Table 5: Association Between Voltage Category and Electrical Injury Patterns, Burn Severity, Associated Trauma, and Immediate Mortality (n=136)*

Characteristic	Low voltage (n=101)	High voltage (n=35)	p-value
	Frequency (%)		
Visible electrical contact mark	88 (87.1)	34 (97.1)	0.115
Both contact and presumed exit lesions	27 (26.7)	20 (57.1)	0.002
Deep/full-thickness burn involvement	18 (17.8)	29 (82.9)	<0.001
Burned TBSA >20%	7 (6.9)	22 (62.9)	<0.001
Flame burn component	11 (10.9)	19 (54.3)	<0.001
Associated traumatic injury	14 (13.9)	14 (40.0)	0.003
Died at scene/brought dead	90 (89.1)	29 (82.9)	0.377

Six cases with unknown voltage were excluded. TBSA: total body surface area.

Delayed death was significantly associated with deep burns (83.3% vs 25.8%; p<0.001), TBSA involvement >20% (66.7% vs 13.7%; p<0.001), and flame burns (66.7% vs 15.3%; p<0.001). Conversely, a transthoracic current pathway was more frequent among immediate deaths (46.8% vs 16.7%; p=0.021). Sex, high-voltage exposure, wet environmental conditions, and associated trauma were not significantly related to survival pattern. [Table 6]

Table 6: Factors Associated with Immediate Versus Delayed Death Following Electrical Injury (N=142)

Factor	Immediate death (n=124)	Delayed death (n=18)	p-value
	Frequency (%)		
Male Gender	105 (84.7)	14 (77.8)	0.494
High-voltage exposure†	29 (23.4)	6 (33.3)	0.385
Wet environmental conditions	49 (39.5)	10 (55.6)	0.211
Deep/full-thickness burn involvement	32 (25.8)	15 (83.3)	<0.001
Burned TBSA >20%	17 (13.7)	12 (66.7)	<0.001
Flame burn component	19 (15.3)	12 (66.7)	<0.001
Transthoracic current pathway	58 (46.8)	3 (16.7)	0.021
Associated traumatic injury	25 (20.2)	4 (22.2)	0.768

†Six cases with unknown voltage were retained in the denominator but were not classified as high-voltage exposure. Immediate death included death at the scene or cases brought dead to hospital; delayed death referred to death after hospital admission. TBSA: total body surface area.

DISCUSSION

The present study demonstrates that fatal electrocution predominantly affected young and middle-aged men, with a mean age of 34.9 ± 14.2 years and 59.2% of victims aged 18–40 years. Males constituted 83.8% of cases, reflecting their greater involvement in electrical, construction, industrial, and agricultural work. Gururaj et al., similarly reported that 90.6% of victims were male and 87.5% were aged 11–40 years.[11] A recent Saudi Arabian autopsy study also documented 95.8% male victims, with nearly two-thirds aged 21–40 years.[12] The rural predominance in the present study (57.7%) may be related to unsafe agricultural pumps, exposed distribution lines, informal electrical repairs, and delayed maintenance of electrical infrastructure.

Domestic premises were the most frequent location of exposure (38.0%), followed by construction or industrial workplaces (28.2%) and agricultural settings (18.3%). Comparable findings from Jharkhand showed that 51.9% of incidents occurred at home and 21.1% at workplaces.[13] Low-voltage electricity accounted for 71.1% of fatalities, closely corresponding to the 75% reported in Jharkhand and 65.3% in a Jaipur study.[13,14] The predominance of low-voltage deaths should not be interpreted as indicating low risk. Household alternating current can produce sustained muscular tetany, preventing release from the conductor, while currents traversing the thorax may induce ventricular fibrillation despite limited external injury.

A clear seasonal concentration was observed during the monsoon (43.7%), with wet environmental conditions documented in 41.5% of cases. Gururaj et al. reported 59.4% of fatalities during the late monsoon.[11] Moisture reduces epidermal resistance and increases current transmission according to Ohm’s law. Waterlogging, barefoot exposure, wet clothing, leakage from domestic appliances, and contact with energised metallic surfaces may therefore convert an otherwise limited exposure into a fatal event. This finding supports intensified inspection of wiring, earthing systems, residual-current devices, agricultural pumps, and public electrical installations before and during the monsoon.

Visible electrical contact marks were identified in 88.7% of victims. This is comparable to the 89.4% reported in another Indian autopsy series, although earlier forensic studies documented electrical marks in approximately 79%–81% of fatalities.[9,16,16] The upper limb was the principal contact site in 54.9% of cases, consistent with the 75% limb involvement reported in Ballari and the predominance of upper-extremity lesions in other autopsy studies.[11-13] Hands commonly initiate contact while manipulating switches, wires, appliances, machinery, or tools, whereas the feet frequently provide grounding. Both contact and presumed exit lesions were observed in 33.1%, comparable to the 30% reported in Jharkhand but lower than the 48% reported in Jaipur.[13,14] Differences may reflect voltage, skin moisture, contact duration, footwear, and the difficulty of reliably distinguishing entry from exit lesions.

The voltage-stratified analysis demonstrated a biologically coherent pattern. High-voltage exposure was significantly associated with deep burns (82.9% vs 17.8%), TBSA involvement >20% (62.9% vs 6.9%), flame burns (54.3% vs 10.9%), both contact and exit lesions (57.1% vs 26.7%), and associated trauma (40.0% vs 13.9%). All associations were statistically significant ($p \leq 0.003$). High-voltage current produces greater Joule heating, coagulative necrosis, vascular thrombosis, and deep muscle damage, while electrical arcs may ignite clothing. Violent muscular contraction or being thrown from the electrical source can additionally cause falls, fractures, and head injuries. Nevertheless, immediate mortality did not differ significantly between voltage categories (p=0.377), underscoring that voltage alone cannot predict lethality. Low-voltage transthoracic alternating current may cause rapid ventricular fibrillation without extensive burns, whereas some high-voltage victims initially survive despite severe tissue destruction.[17]

Most victims died at the scene or were brought dead (87.3%), and fatal arrhythmia or cardiorespiratory arrest was the leading attributed cause of death (73.9%). Earlier Indian studies reported on-scene mortality ranging from 60.8% to 95.9%.[6,11] The predominance of sudden death is consistent with the electrophysiological effects of alternating current on the myocardium and respiratory musculature. Generalised visceral congestion (85.2%), pulmonary congestion or oedema (73.2%), and cardiac chamber congestion (66.9%) were common but non-specific findings. Consequently, these internal changes cannot independently establish electrocution and must be interpreted alongside scene evidence, electrical contact lesions, and exclusion of competing causes.[18]

Delayed death was strongly associated with deep burns (83.3% vs 25.8%), TBSA involvement >20% (66.7% vs 13.7%), and flame burns (66.7% vs 15.3%), all with p<0.001. Extensive electrical injury may continue to evolve because of microvascular thrombosis, progressive muscle necrosis, compartment syndrome, rhabdomyolysis, acute kidney injury, infection, and multiorgan dysfunction [19]. Conversely, a transthoracic pathway was significantly more frequent in immediate deaths (46.8% vs 16.7%; p=0.021), supporting sudden arrhythmic death when the current crosses the cardiac axis. High voltage itself was not significantly associated with delayed death (p=0.385), suggesting that the extent and depth of tissue injury may be more informative than voltage classification alone.

Histological features supportive of electrical injury were found in 87.3% of examined specimens, whereas metallisation was detected in 16.1%. Epidermal separation, nuclear palisading, cellular streaming, coagulative necrosis, and collagen homogenisation may strengthen the diagnosis; however, these changes are not individually pathognomonic and may overlap with thermal burns or artefacts.[8,20] The absence of a visible electrical mark in 11.3% of cases therefore does not exclude electrocution, emphasising the need to integrate autopsy, histopathology, toxicology, scene investigation, and electrical-engineering evidence.

Finally, 96.5% of deaths were accidental, consistent with the 96.5%–100% reported in Indian studies and 98.6% in the Saudi Arabian series.[11,12,15] Suicidal and homicidal electrocution remained uncommon. Collectively, these findings indicate that fatal electrocution is largely preventable. Improved earthing, residual-current circuit breakers, maintenance of domestic and public wiring, enforcement of occupational lockout procedures, use of personal protective equipment, and focused monsoon-season surveillance could substantially reduce mortality.[21]

Limitations

This study has several limitations. Its retrospective, single-centre design limits generalisability and depended on the completeness of autopsy, police, clinical, and scene records. Exact voltage, current pathway, contact duration, environmental conditions, and protective-device use could not be established in every case. Histopathology was unavailable for some victims, and fatal cases alone were examined, preventing comparison with survivors. The relatively few delayed, suicidal, and homicidal deaths restricted subgroup analysis.

CONCLUSION

Fatal electrocution predominantly affected young men and was usually accidental, with domestic, occupational, and agricultural exposures contributing substantially. Low-voltage contact was most frequent, particularly during the monsoon, demonstrating that household electricity may be lethal when moisture, prolonged contact, or a transthoracic pathway facilitates current transmission. High-voltage exposure produced significantly deeper, more extensive burns and greater associated trauma, whereas transthoracic pathways were linked to immediate death. Delayed mortality was mainly associated with extensive deep and flame burns. Careful integration of scene investigation, autopsy findings, histopathology, toxicology, and electrical examination is essential. Improved wiring, earthing, circuit protection, workplace safeguards, and monsoon surveillance could prevent many fatalities.

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