

Original Research Article

CLINICO-EPIDEMIOLOGICAL PROFILE AND FACTORS ASSOCIATED WITH ADVERSE OUTCOMES IN PATIENTS WITH ELECTRICAL BURNS: A PROSPECTIVE OBSERVATIONAL COHORT STUDY

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ABSTRACT

Background: Electrical burn injuries are associated with complex local and systemic complications and may result in substantial morbidity, prolonged hospitalization, functional impairment, and mortality. The severity of injury may not be apparent from the external appearance of the burn. This study evaluated the clinico-epidemiological profile of patients with electrical burns and examined clinical and injury-related factors associated with adverse outcomes and mortality.

Materials and Methods: This prospective observational cohort study was conducted over 18 months at Dr. Susheela Tiwari Government Hospital, Haldwani, Uttarakhand, India. All eligible patients presenting with electrical burn injuries during the study period were enrolled using total enumeration sampling. Demographic characteristics, mechanism and voltage of injury, transport time, burn extent, burn depth, clinical course, associated injuries, ECG findings, biochemical parameters, treatment, complications, and outcomes were recorded. Burn extent was assessed using the Lund and Browder chart. The primary outcome was mortality. Associations between clinical variables and outcome were assessed using appropriate statistical tests, with a two-sided p-value <0.05 considered statistically significant.

Results: A total of 120 patients were included. The mean age was 32.18 ± 12.55 years, 81.7% were male, 83.3% were from rural areas, and 65.0% belonged to the lower socioeconomic group. High-voltage injuries accounted for 65.0% of cases. The mean TBSA involved was $22.25 \pm 19.97\%$. Burn depth was significantly associated with voltage ($p = 0.04$), as was TBSA involvement ($p < 0.001$). High-voltage injuries were also associated with longer hospital stay ($p < 0.001$) and greater fluid resuscitation requirements ($p = 0.04$). Overall mortality was 9.2%. Clinical outcome was significantly associated with voltage category ($p = 0.005$). Associated injuries ($p < 0.001$), ECG abnormalities ($p < 0.001$), elevated CK-MB ($p = 0.01$), and WBC count ($p = 0.03$) were also significantly associated with clinical outcome. Cardiac arrest was associated with particularly high mortality, with 4 of 5 affected patients expiring.

Conclusion: Electrical burn injuries predominantly affected males and individuals from rural and lower socioeconomic backgrounds in this cohort. High-voltage exposure was associated with greater burn severity, larger TBSA involvement, prolonged hospitalization, and greater treatment requirements. Systemic complications, particularly cardiac arrest and respiratory failure, as well as ECG and biochemical abnormalities, were associated with adverse outcomes. Early assessment of injury severity and prompt identification of systemic complications are important for risk stratification and management.

Larger multicentre prospective studies are required to further define predictors of mortality and long-term morbidity.

Keywords: Electrical burns; high-voltage injury; low-voltage injury; burn severity; mortality; TBSA; cardiac complications; electrical injury.

INTRODUCTION

Burn injuries remain an important public health problem worldwide and are associated with substantial morbidity, mortality, disability, and socioeconomic consequences. Although advances in emergency care, critical care, infection control, surgical techniques, and burn management have improved outcomes, severe burn injuries continue to be associated with significant mortality, particularly in low- and middle-income countries where access to specialized burn care may be limited.^[1,2,3] In India, burns continue to contribute considerably to mortality and long-term disability, with consequences extending beyond the physical injury to include psychological distress, prolonged hospitalization, loss of productivity, rehabilitation requirements, and financial burden on patients and their families.^[1,3] The burden is further influenced by inadequate safety practices, occupational hazards, limited public awareness, and delayed access to appropriate medical care.^[3]

Electrical burns constitute a distinct category of burn injury because the extent of tissue damage may be considerably greater than that suggested by the appearance of the skin. Unlike conventional thermal burns, electrical injuries may result from the direct passage of electric current through the body, electrical arc or flash, or ignition of clothing following electrical exposure.^[7,8] The classification of electrical injuries commonly includes low-voltage injuries (<1000 V), high-voltage injuries (≥ 1000 V), electrical arc injuries, and lightning-related injuries.^[7] Injuries caused by the passage of current through the body are particularly important because electrical energy can be converted into thermal energy within tissues, producing deep tissue destruction and injury to muscles, nerves, blood vessels, and internal organs despite relatively limited external skin involvement.^[8,9]

The epidemiological pattern of electrical injuries varies according to age, sex, occupation, socioeconomic conditions, domestic and workplace practices, and patterns of electricity use. Electrical injuries in adults are frequently associated with occupational exposure, particularly among construction, electrical, industrial, and utility workers, whereas domestic exposure is an important source of injury among children.^[4,5,6] Previous studies have demonstrated a predominance of males among patients with electrical injuries, reflecting greater occupational and environmental exposure.^[11,12] High-voltage injuries are generally associated with more extensive tissue damage, greater need for surgical intervention, complications, and prolonged hospitalization compared with many low-voltage

injuries.^[4,7] However, low-voltage exposure should not be considered benign, as prolonged contact and specific current pathways can result in serious systemic complications.

The severity of an electrical injury is determined by several interacting factors, including voltage, current intensity, type of current, duration of contact, resistance of the tissues, area of contact, and pathway of current through the body.^[8,9] The pathway of the current is particularly important because involvement of the thorax may result in cardiac complications, while passage through the limbs can cause extensive muscle and soft-tissue injury. Alternating current may cause sustained muscular contraction, potentially prolonging contact with the electrical source and increasing the duration of exposure.^[9] Furthermore, electrical injury may be accompanied by secondary trauma caused by falls, involuntary muscle contractions, or being thrown from the electrical source, resulting in fractures, dislocations, head injury, spinal injury, and other traumatic complications.^[8,10]

Electrical injuries may therefore produce a broad spectrum of clinical manifestations ranging from localized burns to life-threatening systemic complications. Cardiovascular complications, including arrhythmias and cardiac arrest, are of particular concern, and electrocardiographic abnormalities such as sinus tachycardia, premature ventricular contractions, atrial fibrillation, conduction abnormalities, and ST-segment changes have been reported following electrical exposure.^[8,10] Extensive muscle injury may lead to rhabdomyolysis, myoglobinuria, acute kidney injury, electrolyte abnormalities, and compartment syndrome.^[8,10] Neurological complications and associated traumatic injuries may further increase morbidity. The discrepancy between external burn appearance and underlying tissue damage makes early clinical assessment and identification of high-risk patients especially important.

Mortality following electrical burns is influenced by the severity and extent of tissue injury as well as systemic complications. Factors such as high-voltage exposure, extensive burns, delayed presentation or transportation, hemodynamic instability at admission, cardiac abnormalities, associated injuries, and systemic complications may contribute to poor outcomes. Previous epidemiological studies have emphasized the importance of understanding the characteristics of electrical burn patients and identifying factors associated with severe morbidity and mortality.^[4,7,11,12,20] However, the relative contribution of these factors may vary between populations because patterns of occupational exposure, infrastructure, emergency transportation,

referral systems, and availability of specialized burn care differ between geographical regions.

In this context, evaluation of the clinico-epidemiological profile of electrical burn patients together with identification of factors associated with mortality is important for early risk stratification and appropriate management. A better understanding of patient characteristics, mechanism and voltage of injury, time to hospital presentation, initial hemodynamic status, electrocardiographic abnormalities, biochemical parameters, associated injuries, and treatment-related factors may help identify patients at increased risk of adverse outcomes. Such information can also contribute to improving emergency response, referral practices, clinical monitoring, and preventive strategies.

The present study was undertaken to evaluate the clinico-epidemiological profile of patients presenting with electrical burns and to identify clinical and other factors associated with mortality among these patients.

Aim

To evaluate the clinico-epidemiological profile of patients with electrical burn injuries and identify clinical and injury-related factors associated with adverse clinical outcomes and mortality.

Objectives

1. To describe the demographic, epidemiological, and clinical characteristics of patients with electrical burn injuries, including high- and low-voltage injuries.
2. To evaluate the association of injury-related factors, including voltage, burn extent, burn depth, transport time, fluid resuscitation, and hospital course, with clinical outcomes.
3. To assess the association of cardiovascular and biochemical parameters, including ECG abnormalities, CK-MB, WBC count, albumin, and serum creatinine, with clinical outcomes.
4. To evaluate the nature and severity of associated injuries and their relationship with adverse clinical outcomes, including mortality.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational cohort study conducted among patients presenting with electrical burn injuries to the casualty department of Dr. Susheela Tiwari Government Hospital, Haldwani, Uttarakhand, India, a tertiary care centre associated with Government Medical College, Haldwani. Patients were managed in the Departments of General Surgery and Plastic Surgery.

Study Duration

The study was conducted over a period of 18 months following approval from the Institutional Ethics Committee (IEC).

Study Population and Sampling

All patients presenting with electrical burn injuries during the study period were considered for

enrolment. Total enumeration sampling was used, whereby all eligible patients presenting to the casualty department during the study period were included.

A total of 120 patients with electrical burn injuries were enrolled in the study. Patients presenting directly to the hospital as well as those referred from other healthcare facilities were included.

Inclusion Criteria

Patients fulfilling the following criteria were included:

1. Patients with electrical burn injuries of any degree presenting during the study period.
2. Patients who provided written informed consent to participate in the study.

Exclusion Criteria

Patients who were unwilling to participate in the study were excluded.

Data Collection and Clinical Assessment

After obtaining written informed consent, a detailed clinical history and examination were performed for each patient. Demographic, epidemiological, clinical, and outcome-related information was recorded using a structured data collection form.

The variables assessed included age, sex, occupation, socioeconomic status, mode of injury, time since injury, time to hospital admission, transport time, primary treatment received before admission, extent of burn injury, voltage of the electrical source, clinical course during hospitalization, mortality, limb loss, and prognosis.

Particular attention was given to factors potentially associated with mortality, including the voltage of electrical exposure, transport time, hemodynamic parameters at presentation, electrocardiographic abnormalities, biochemical findings, fluid resuscitation, and associated injuries.

Assessment of Burn Extent

The extent of burn injury was assessed using the Lund and Browder chart, and the percentage of involved body surface area was documented.

Clinical Management and Monitoring

All patients underwent initial clinical assessment and appropriate management according to the nature and severity of their injuries. Fluid resuscitation was administered as clinically indicated.

Patients were subjected to continuous cardiac monitoring, and cardiac evaluation included serial electrocardiography (ECG) to identify and monitor cardiac abnormalities associated with electrical injury.

Muscle enzyme analysis was performed as part of the biochemical evaluation of patients with electrical burns.

Local wound management and surgical interventions were performed according to clinical assessment and tissue viability. These included cleaning and dressing, fasciotomy, escharotomy, and debridement, when indicated.

Management of Limb Injuries and Amputation

Patients with severe limb injuries were assessed for tissue viability and for development of a clear line of demarcation between viable and non-viable tissue. Where amputation was required, the level of amputation was determined according to the extent of tissue damage and viability. Minor amputations included finger removal and toe disarticulation, whereas major amputations included below-knee, mid-thigh, mid-forearm, arm, forequarter, and hindquarter amputations.

Outcome Assessment and Follow-up

The primary outcome of the study was mortality among patients with electrical burn injuries.

Other clinical outcomes assessed included limb loss, wound healing, return to work, recovery to a healthy state, and development of contractures resulting in loss of limb function.

Patients were followed for one year to assess their clinical and functional outcomes. Follow-up assessment included evaluation of wound healing, functional recovery, return to work, limb loss, contracture formation, and mortality.

Factors Evaluated in Relation to Mortality

The study evaluated demographic, epidemiological, injury-related, clinical, and investigational variables in relation to mortality.

Particular attention was given to

- Voltage of electrical exposure
- Transport time and time to hospital presentation
- Initial hemodynamic parameters
- ECG abnormalities
- Biochemical findings
- Fluid resuscitation
- Extent of burn injury
- Associated injuries
- Other relevant clinical and epidemiological characteristics

These variables were assessed to identify factors associated with mortality among patients with electrical burn injuries.

Statistical Analysis

Data collected during the study were compiled and analyzed using appropriate statistical methods. Continuous variables were summarized using measures of central tendency and dispersion, while categorical variables were expressed as frequencies and percentages.

The clinical and epidemiological characteristics of patients were analyzed descriptively. Patients were subsequently evaluated according to their clinical outcome, particularly survival and mortality, to identify factors associated with adverse outcomes.

Categorical variables were compared between outcome groups using appropriate tests of

association, while continuous variables were compared using appropriate parametric or non-parametric tests depending on the distribution of the data. The association of variables including age, sex, voltage of electrical exposure, extent of burn, transport time, hemodynamic parameters at presentation, ECG abnormalities, biochemical parameters, fluid resuscitation, and associated injuries with mortality was assessed.

Where appropriate, measures of association with corresponding 95% confidence intervals were calculated. Variables demonstrating an association with mortality on univariable analysis were considered for multivariable analysis to identify factors independently associated with mortality, provided that the number of outcome events and completeness of data were adequate for such analysis. A two-sided p-value <0.05 was considered statistically significant.

Ethical Considerations

The study was undertaken following approval from the Institutional Ethics Committee. The study objectives and procedures were explained to eligible participants, and written informed consent was obtained before enrolment and collection of study-related information.

RESULTS

A total of 120 patients with electrical burn injuries were included in the study. The mean age was 32.18 ± 12.55 years, mean burn extent was $22.25 \pm 19.97\%$ total body surface area (TBSA), mean hospital stay was 10.61 ± 8.56 days, and mean reported transport time was 1.86 ± 1.05 days.

Overall, 68 patients (56.7%) recovered with morbidity, 41 (34.2%) were discharged on request, and 11 (9.2%) expired.

Sociodemographic and baseline characteristics

Most patients were male (98, 81.7%), and the largest age group was 31–45 years (63, 52.5%). One hundred patients (83.3%) were from rural areas. Sixty-five percent belonged to the lower socioeconomic group. The majority of injuries were accidental (116, 96.7%), while 4 (3.3%) were homicidal.

High-voltage injuries predominated, occurring in 78 patients (65.0%), compared with 42 patients (35.0%) with low-voltage injuries. Among occupational groups, labourers constituted the largest group (21, 17.5%), followed by unemployed individuals (20, 16.6%), cooks (18, 15.0%), farmers (17, 14.1%), electricians (15, 12.5%), housewives (13, 10.8%), mechanics (9, 7.5%), and business workers (7, 5.8%).

Table 1: Sociodemographic and baseline characteristics of the study population (N = 120)

Characteristic	n (%)
Age group (years)	
1–15	15 (12.5)
16–30	29 (24.2)
31–45	63 (52.5)

>45	13 (10.8)
Sex	
Male	98 (81.7)
Female	22 (18.3)
Residence	
Rural	100 (83.3)
Urban	20 (16.7)
Socioeconomic status	
Lower	78 (65.0)
Middle	34 (28.3)
Upper	8 (6.7)
Mode of injury	
Accidental	116 (96.7)
Homicidal	4 (3.3)
Voltage	
Low voltage	42 (35.0)
High voltage	78 (65.0)
Mean age, years	32.18 ± 12.55
Mean TBSA, %	22.25 ± 19.97
Mean hospital stay, days	10.61 ± 8.56
Mean transport time, days	1.86 ± 1.05

Burn characteristics

The right upper limb was the most frequently involved anatomical site (40, 33.3%), followed by the chest and abdomen (28, 23.3%) and left upper limb (18, 15.0%). Head and neck involvement was observed in 13 patients (10.8%), right lower limb in 11 (9.2%), left lower limb in 9 (7.5%), and perineal involvement in 1 (0.8%).

Regarding burn depth, 35 patients (29.2%) had superficial burns, 55 (45.8%) had superficial plus deep burns, and 30 (25.0%) had deep burns.

Burn depth was significantly associated with voltage ($\chi^2 = 6.35$, $df = 2$; $p = 0.04$). High-voltage injuries accounted for 48.6% of superficial burns, 69.1% of superficial-plus-deep burns, and 76.7% of deep burns.

TBSA was also significantly associated with voltage ($\chi^2 = 20.942$, $df = 5$; $p < 0.001$). High-voltage injuries constituted 69.2% of burns involving 21–30% TBSA, 76.9% of those involving 31–40%, 85.7% of those involving 41–50%, and 86.2% of those involving >50% TBSA.

Table 2: Pattern and severity of electrical burn injuries according to voltage

Characteristic	Low voltage n (%)	High voltage n (%)	Total n (%)
Anatomical site			
Head & neck	—	—	13 (10.8)
Chest & abdomen	—	—	28 (23.3)
Right upper limb	—	—	40 (33.3)
Left upper limb	—	—	18 (15.0)
Right lower limb	—	—	11 (9.2)
Left lower limb	—	—	9 (7.5)
Perineum	—	—	1 (0.8)
Burn depth			
Superficial	18 (51.4)	17 (48.6)	35 (29.2)
Superficial + deep	17 (30.9)	38 (69.1)	55 (45.8)
Deep	7 (23.3)	23 (76.7)	30 (25.0)
TBSA			
0–10%	17 (63.0)	10 (37.0)	27 (22.5)
11–20%	12 (50.0)	12 (50.0)	24 (20.0)
21–30%	4 (30.8)	9 (69.2)	13 (10.8)
31–40%	3 (23.1)	10 (76.9)	13 (10.8)
41–50%	2 (14.3)	12 (85.7)	14 (11.7)
>50%	4 (13.8)	25 (86.2)	29 (24.2)

Burn depth: $\chi^2 = 6.35$, $df = 2$, $p = 0.04$.

TBSA: $\chi^2 = 20.942$, $df = 5$, $p < 0.001$.

Transport, hospital course and treatment

Transport time was significantly associated with voltage ($\chi^2 = 7.38$, $df = 2$; $p = 0.02$). High-voltage injuries accounted for 59.3% of patients transported within 0–1 day, 54.9% of those transported within 1–2 days, and 81.0% of those with transport time >2 days.

Hospital stay was also significantly associated with voltage ($\chi^2 = 38.57$, $df = 4$; $p < 0.001$). High-voltage injuries accounted for 79.2% of patients with a

hospital stay of 15–30 days and 96.7% of those staying >30 days.

Fluid resuscitation volume demonstrated a significant association with voltage ($\chi^2 = 8.56$, $df = 3$; $p = 0.04$).

Debridement was the most frequently performed treatment (61, 50.8%), followed by split-thickness skin grafting (34, 28.3%), flap cover (9, 7.5%), primary/secondary suturing (8, 6.7%), amputation (4, 3.3%), fasciotomy (2, 1.7%), and tangential excision

(2, 1.7%). The distribution of primary treatment did not differ significantly according to voltage ($\chi^2 = 7.29$, $df = 6$; $p = 0.295$). Contracture was the most frequently recorded complication (51, 42.5%), followed by

hypergranulation (21, 17.5%), gangrene (20, 16.7%), and infection (17, 14.2%). The distribution of recorded complications was not significantly associated with voltage ($\chi^2 = 2.049$, $df = 4$; $p = 0.73$).

Table 3: Transport, hospital course, fluid resuscitation and treatment according to voltage

Variable	Low voltage n (%)	High voltage n (%)	Total n (%)
Transport time			
0–1 day	11 (40.7)	16 (59.3)	27 (22.5)
1–2 days	23 (45.1)	28 (54.9)	51 (42.5)
>2 days	8 (19.0)	34 (81.0)	42 (35.0)
Hospital stay			
0–2 days	4 (44.4)	5 (55.6)	9 (7.5)
3–7 days	21 (75.0)	7 (25.0)	28 (23.3)
8–14 days	11 (37.9)	18 (62.1)	29 (24.2)
15–30 days	5 (20.8)	19 (79.2)	24 (20.0)
>30 days	1 (3.3)	29 (96.7)	30 (25.0)
Fluid resuscitation			
<2 L	3 (20.0)	12 (80.0)	15 (12.5)
2–4 L	14 (48.3)	15 (51.7)	29 (24.2)
4–6 L	17 (44.7)	21 (55.3)	38 (31.7)
>6 L	8 (21.1)	30 (78.9)	38 (31.7)
Primary treatment			
Debridement	24 (39.3)	37 (60.7)	61 (50.8)
SSG	13 (38.2)	21 (61.8)	34 (28.3)
Primary/secondary suturing	0	8 (100.0)	8 (6.7)
Flap cover	2 (22.2)	7 (77.8)	9 (7.5)
Tangential excision	0	2 (100.0)	2 (1.7)
Fasciotomy	1 (50.0)	1 (50.0)	2 (1.7)
Amputation	2 (50.0)	2 (50.0)	4 (3.3)

Clinical outcome and factors associated with outcome

Overall, 68 patients (56.7%) recovered with morbidity, 41 (34.2%) were discharged on request, and 11 (9.2%) expired.

Clinical outcome was significantly associated with voltage ($\chi^2 = 10.43$, $df = 2$; $p = 0.005$). Among patients who recovered with morbidity, 32 (47.1%) had low-voltage and 36 (52.9%) had high-voltage injuries. Among those discharged on request, 7 (17.1%) had low-voltage and 34 (82.9%) had high-voltage injuries. Of the 11 patients who expired, 3 (27.3%) had low-voltage and 8 (72.7%) had high-voltage injuries.

Associated injuries were significantly associated with outcome ($\chi^2 = 41.59$, $df = 8$; $p < 0.001$). Cardiac arrest was recorded in 5 patients, of whom 4 (80.0%) expired. Respiratory failure occurred in 10 patients, with 3 (30.0%) deaths. No deaths were recorded among patients categorized with renal failure or neurological deficit.

The reported comorbidity categories were also significantly associated with outcome ($\chi^2 = 32.39$, $df = 10$; $p < 0.001$). Among patients with seizures, 4 of 16 (25.0%) expired. Among patients with psychiatric disorder, 1 of 8 (12.5%) expired, while 1 of 14 patients (7.1%) with alcohol abuse expired. Four of 8 pregnant patients (50.0%) expired.

Table 4: Clinical outcome according to voltage and major associated factors

Variable	Recovered with morbidity n (%)	Discharge on request n (%)	Expired n (%)	Total
Voltage				
Low voltage	32 (76.2)*	7 (16.7)*	3 (7.1)*	42
High voltage	36 (46.2)*	34 (43.6)*	8 (10.3)*	78
Associated injury				
Cardiac arrest	1 (20.0)	0	4 (80.0)	5
Respiratory failure	3 (30.0)	4 (40.0)	3 (30.0)	10
Renal failure	3 (60.0)	2 (40.0)	0	5
Neurological deficit	2 (40.0)	3 (60.0)	0	5
No associated injury	59 (62.1)	32 (33.7)	4 (4.2)	95
Selected comorbidities				
Seizure	4 (25.0)	8 (50.0)	4 (25.0)	16
Psychiatric disorder	5 (62.5)	2 (25.0)	1 (12.5)	8
Alcohol abuse	7 (50.0)	6 (42.9)	1 (7.1)	14
Diabetes	5 (83.3)	1 (16.7)	0	6
Pregnancy	3 (37.5)	1 (12.5)	4 (50.0)	8
Undernutrition	44 (64.7)	23 (33.8)	1 (1.5)	68

For voltage, percentages in this subsection are calculated within each voltage group to show outcome-specific proportions.

Voltage $\times$ outcome: $\chi^2 = 10.43$, df = 2, p = 0.005.
Associated injury $\times$ outcome: $\chi^2 = 41.59$, df = 8, p < 0.001.

Comorbidity $\times$ outcome: $\chi^2 = 32.39$, df = 10, p < 0.001.

The thesis reports comorbidity categories separately; they should not be interpreted as mutually exclusive categories.

ECG and biochemical findings

A normal ECG was recorded in 90 patients (75.0%). Sinus arrhythmia was present in 8 (6.7%), bradyarrhythmia in 7 (5.8%), ST elevation in 8 (6.7%), and T-wave changes in 7 (5.8%).

ECG findings were significantly associated with clinical outcome ($\chi^2 = 41.2$, df = 8; p < 0.001). Four of the 7 patients with bradyarrhythmia (57.2%) expired, while 3 of 8 patients with sinus arrhythmia (37.5%) expired.

Elevated CK-MB was present in 40 patients (33.3%) and was significantly associated with outcome ($\chi^2 = 8.706$, df = 2; p = 0.01). Seven patients (17.5%) with elevated CK-MB expired compared with 4 (5.0%) with normal CK-MB.

WBC count was significantly associated with outcome ($\chi^2 = 11.19$, df = 4; p = 0.03). Mortality was 8.3% among patients with WBC counts of 4–10 $\times 10^3/\mu\text{L}$, 4.8% among those with counts of 10–19 $\times 10^3/\mu\text{L}$, and 15.6% among those with counts >20 $\times 10^3/\mu\text{L}$.

Albumin category showed a borderline association with outcome ($\chi^2 = 9.59$, df = 4; p = 0.05).

Mean serum creatinine was 1.14 ± 0.348 mg/dL among patients who recovered with morbidity, 1.26 ± 0.434 mg/dL among those discharged on request, and 1.29 ± 0.489 mg/dL among those who expired. No inferential statistical test for serum creatinine was reported; therefore, this finding is presented descriptively.

Table 5: ECG and biochemical parameters according to clinical outcome

Parameter	Recovered with morbidity n (%)	Discharge on request n (%)	Expired n (%)	Total
ECG				
Normal	57 (63.3)	29 (32.2)	4 (4.4)	90
Sinus arrhythmia	2 (25.0)	3 (37.5)	3 (37.5)	8
Bradyarrhythmia	2 (28.6)	1 (14.3)	4 (57.2)	7
ST elevation	4 (50.0)	4 (50.0)	0	8
T-wave changes	3 (42.9)	4 (57.1)	0	7
CK-MB				
Normal	52 (65.0)	24 (30.0)	4 (5.0)	80
Elevated	16 (40.0)	17 (42.5)	7 (17.5)	40
WBC ($\times 10^3/\mu\text{L}$)				
4–10	8 (66.7)	3 (25.0)	1 (8.3)	12
10–19	43 (68.3)	17 (27.0)	3 (4.8)	63
>20	17 (37.8)	21 (46.7)	7 (15.6)	45
Albumin (g/dL)				
0.8–1.5	23 (74.2)	7 (22.6)	1 (3.2)	31
1.6–3.0	20 (50.0)	18 (45.0)	2 (5.0)	40
>3.0	25 (51.0)	16 (32.7)	8 (16.3)	49

ECG: $\chi^2 = 41.2$, df = 8, p < 0.001.

CK-MB: $\chi^2 = 8.706$, df = 2, p = 0.01.

WBC: $\chi^2 = 11.19$, df = 4, p = 0.03.

Albumin: $\chi^2 = 9.59$, df = 4, p = 0.05.

Serum creatinine

Figure 1. Mean serum creatinine according to clinical outcome.

Mean serum creatinine increased numerically across the outcome groups, from 1.14 ± 0.35 mg/dL in patients who recovered with morbidity to 1.29 ± 0.49 mg/dL among patients who expired. Error bars represent standard deviation.

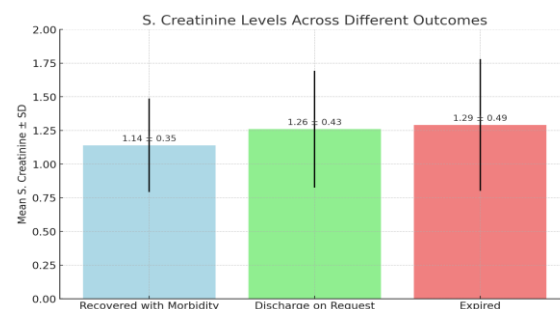


Figure 1: Mean serum creatinine according to clinical outcome

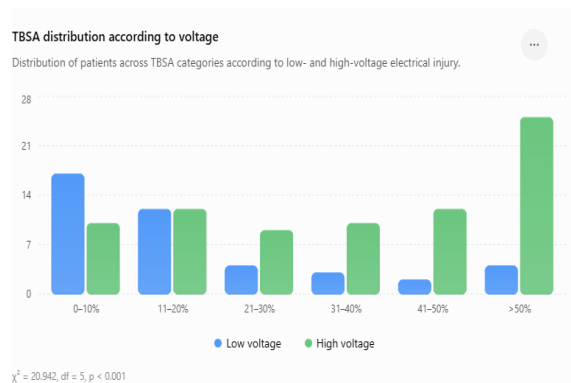


Figure 2: TBSA according to voltage

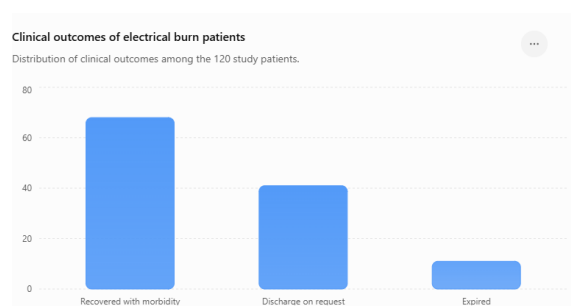


Figure 3: Clinical outcome

DISCUSSION

The present study evaluated the clinico-epidemiological profile and factors associated with adverse outcomes among 120 patients with electrical burn injuries. The study population was predominantly young and middle-aged adults, with a mean age of 32.18 ± 12.55 years and 52.5% of patients belonging to the 31–45-year age group. A marked male predominance was observed (81.7%), consistent with previous studies reporting a predominance of young men among patients with electrical injuries.^[11,12] The predominance of rural residents (83.3%) and patients from lower socioeconomic groups (65.0%) suggests an important role of occupational and socioeconomic circumstances in the occurrence of electrical injuries. Similar associations between burn injuries and lower socioeconomic status have been reported previously.^[14,12]

Accidental injuries accounted for 96.7% of cases, consistent with previous reports in which electrical injuries were predominantly unintentional and frequently related to occupational exposure or contact with exposed electrical sources.^[13,12] High-voltage injuries constituted 65.0% of the present cohort, comparable to the high proportion reported by Ghavami et al.^[15] The right upper limb was the most frequently involved anatomical site (33.3%), followed by the chest and abdomen (23.3%), similar to previous studies reporting frequent upper-limb involvement in electrical injuries.^[41,59]

An important finding was the significant association between voltage and severity of burn injury. High-

voltage injuries constituted 76.7% of deep burns compared with 48.6% of superficial burns ($p = 0.04$). Similarly, high-voltage injuries accounted for 86.2% of patients with burns involving >50% TBSA, and the association between voltage and TBSA was highly significant ($p < 0.001$). These findings are consistent with previous studies demonstrating deeper and more extensive tissue injury following high-voltage exposure.^[16-18] Thus, voltage category appears to be an important marker of injury severity in electrical burns.

High-voltage injury was also associated with longer transport time, longer hospital stay and greater fluid resuscitation requirements in the present study. Patients with transport times >2 days were predominantly in the high-voltage group (81.0%), while 96.7% of patients hospitalized for >30 days had sustained high-voltage injuries. Fluid requirements were also greater among patients with high-voltage injuries. Similar relationships between high-voltage injury, severity, treatment requirements and prolonged hospitalization have been reported previously.^[15-17] These findings emphasize the importance of early referral and appropriate management of severe electrical injuries at specialized centers.

Debridement was the most frequently performed procedure (50.8%), followed by split-thickness skin grafting (28.3%). Although high-voltage injuries accounted for a greater proportion of several surgical procedures, the overall association between voltage and primary treatment was not statistically significant ($p = 0.295$). Similarly, the distribution of recorded complications was not significantly associated with voltage ($p = 0.73$). This finding differs from some previous studies reporting greater complications and more extensive surgical intervention in high-voltage injuries,^[16] although Tiryaki et al. reported comparable complication frequencies between voltage groups.^[18]

Overall mortality was 9.2%. Clinical outcome was significantly associated with voltage ($p = 0.005$), with 8 of the 11 deaths occurring among patients with high-voltage injuries. However, mortality within the voltage groups was 10.3% for high-voltage and 7.1% for low-voltage injuries; therefore, the distribution of deaths should not be interpreted as a 72.7% mortality rate for high-voltage injuries. Previous studies have similarly reported poorer outcomes among patients with high-voltage electrical injuries.^[17,18,20]

Associated injuries were strongly associated with outcome ($p < 0.001$). Cardiac arrest was particularly important, with 4 of 5 patients with cardiac arrest expiring. Respiratory failure was also associated with adverse outcomes. ECG abnormalities showed a significant association with outcome ($p < 0.001$), and bradyarrhythmia was associated with a high proportion of deaths. These findings are consistent with previous reports emphasizing cardiovascular and systemic complications as important determinants of prognosis following electrical injury.^[15,18]

Biochemical parameters also showed significant associations with outcome. Elevated CK-MB was associated with a higher proportion of deaths than normal CK-MB (17.5% vs. 5.0%; $p = 0.01$). WBC count was similarly associated with outcome ($p = 0.03$), with mortality being highest in patients with WBC counts $>20 \times 10^3/\mu\text{L}$. These findings are broadly consistent with previous observations linking biochemical and inflammatory abnormalities with greater severity and poorer outcomes in burn patients.^[15-17] Albumin showed a borderline association with outcome ($p = 0.05$), although the pattern in the present dataset was not sufficiently consistent to support its interpretation as an independent prognostic marker. Mean serum creatinine was numerically higher among patients, who expired, but no inferential statistical test was reported and therefore this finding should be considered descriptive.

Overall, the findings indicate that high-voltage electrical injuries in this cohort were associated with greater burn depth, larger TBSA involvement, prolonged hospitalization and greater treatment requirements. Clinical outcome was additionally associated with associated injuries, ECG abnormalities, CK-MB and WBC count. These findings highlight the importance of early assessment of burn severity, cardiovascular status and systemic complications in patients with electrical burns.

The study was limited by its single-centre design, relatively small sample size and small numbers in some clinical subgroups. The observational design also limits conclusions regarding causality and independent predictors of mortality. Nevertheless, the study provides useful clinical and epidemiological information and identifies several factors associated with adverse outcomes among patients with electrical burn injuries.

CONCLUSION

Electrical burn injuries continue to cause substantial morbidity and mortality, particularly when associated with high-voltage exposure, extensive burns, and serious systemic complications. In this prospective cohort of 120 patients, electrical injuries predominantly affected males, rural residents, and individuals from lower socioeconomic groups, with the largest proportion of patients belonging to the 31–45-year age group.

High-voltage injuries were associated with greater burn depth, larger TBSA involvement, longer hospital stay, and greater fluid requirements. Clinical outcome was also significantly associated with voltage category, with adverse outcomes observed more frequently among patients with high-voltage injuries. Major associated injuries, particularly cardiac arrest and respiratory failure, were strongly associated with mortality. Abnormal ECG findings, elevated CK-MB levels, and higher WBC counts were also associated with poorer clinical outcomes.

Contractures and other complications contributed substantially to morbidity and prolonged care.

These findings emphasize the importance of early assessment of injury severity, prompt identification of systemic complications, continuous cardiovascular monitoring, appropriate resuscitation, and timely surgical and multidisciplinary management in patients with severe electrical burns. Recognition of high-risk clinical features may assist in early risk stratification and treatment planning.

The study was limited by its single-centre design, relatively small sample size, limited study duration, and small numbers within some clinical subgroups. The observational design also limits the ability to establish causality or determine independent predictors of mortality. Further multicentre prospective studies with larger sample sizes and longer follow-up are required to validate these findings and better define predictors of mortality and long-term functional morbidity following electrical burn injuries.

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