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ECG CHANGES IN PATIENTS PRESENTING TO THE EMERGENCY DEPARTMENT WITH ELECTROCUTION INJURIES

Original Research

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ABSTRACT

Background: Electrocution injuries often lead to a spectrum of cardiovascular disturbances, ranging from transient arrhythmias to fatal cardiac arrest. Despite their clinical significance, the frequency and pattern of electrocardiographic (ECG) abnormalities following electrical injuries remain inadequately reported in local healthcare settings. Understanding these cardiac manifestations is essential for early identification of high-risk patients and for optimizing emergency management protocols.

Objective: To determine the frequency and pattern of ECG abnormalities in patients presenting with electrocution injuries and to assess their association with voltage exposure and time to hospital presentation.

Methods: This observational cross-sectional study was conducted in the Emergency Department of Combined Military Hospital (CMH) Rawalpindi from January 2023 to January 2025 following ethical approval (IRB No. 592). Patients aged 12–80 years who presented within 24 hours of electrocution were included, while those with pre-existing cardiac disease, cardioselective drug use, or unrelated trauma were excluded. A structured proforma recorded demographic details, voltage exposure, contact duration, and time to presentation. Standard 12-lead ECGs were obtained and interpreted by emergency physicians and validated by senior specialists. Data were analyzed using SPSS v22 with significance set at $p<0.05$.

Results: A total of 120 patients were analyzed (mean age 34.0 ± 13.4 years; 65.0% male). Low-voltage injuries (<1000 V) constituted 81.7% (n=98), while high-voltage injuries (>1000 V) accounted for 18.3% (n=22). Sinus tachycardia was the most frequent ECG finding (36.7%), followed by normal sinus rhythm (20.0%), atrial fibrillation (10.0%), and T-wave abnormalities (9.2%). High-voltage exposure showed greater association with atrial fibrillation (27.3%) and T-wave changes (18.2%). Mortality reached 40% among patients presenting after six hours, compared with 6.7% in those arriving within one hour.

Conclusion: ECG abnormalities are common following electrocution, with high-voltage injuries predisposing to more severe arrhythmias and repolarization changes. Delayed presentation correlates with poorer outcomes, emphasizing the importance of early triage, ECG evaluation, and continuous cardiac monitoring in all electrocution cases.

Keywords: Arrhythmias, Cardiac monitoring, Electrocution, Electrocardiography, Emergency department, High-voltage injury, Prognosis.

INTRODUCTION

Electrocution injuries represent a significant public health concern and are a relatively common reason for presentation to the emergency department (ED) worldwide, often involving multisystem damage with the cardiovascular system being the most critically affected (1,2). The human heart, due to its intrinsic electrical conduction system, is highly susceptible to even brief exposures to electric current, which can disrupt normal rhythm and lead to potentially fatal arrhythmias (3). The clinical outcome of an electrical injury depends on several factors, including the voltage, current type (alternating or direct), duration of contact, and the pathway traversed through the body, each influencing the degree and distribution of tissue and organ involvement (4). Patients presenting after electrocution exhibit a wide spectrum of electrocardiographic (ECG) changes, ranging from normal sinus rhythm to transient rhythm disturbances and, in severe cases, life-threatening arrhythmias such as ventricular fibrillation or asystole (4,5). Reported ECG abnormalities include sinus tachycardia, bradycardia, conduction delays, premature ventricular contractions, QT-interval prolongation, and ST–T wave changes (5). Timely recognition and interpretation of these findings are imperative for appropriate triage, monitoring, and treatment decisions in the emergency setting (6). The severity of electrical injuries tends to escalate with higher voltage exposure and longer contact duration. Low-voltage injuries (<1000 V) typically result from domestic or occupational incidents, whereas high-voltage injuries (>1000 V) are often industrial or outdoor in nature and are associated with more extensive tissue destruction, cardiac arrest, and higher mortality (7). Electrocution may be accidental, suicidal, or homicidal, affecting individuals of all ages and backgrounds without a distinct gender bias, which adds to the diagnostic and management complexity in clinical settings (8).

A key challenge in the management of electrocution victims lies in the detection of subtle or transient ECG changes that may be overlooked during initial evaluation, potentially resulting in unrecognized cardiac injury or premature discharge. Even in the presence of a normal initial ECG, delayed arrhythmias or myocardial necrosis have been documented, emphasizing the necessity for continuous cardiac monitoring and serial ECG assessments to ensure patient safety (9). Although several studies have documented ECG alterations in patients following electrical injuries, their findings have been inconsistent. A study, for instance, reported that most patients with electrocution injuries had normal ECGs, with only a minority showing sinus tachycardia (7.8%), bradycardia (2.9%), ST–T changes (3.9%), or ventricular extrasystoles (0.98%) (10). Despite such evidence, regional data remain scarce, particularly in low- and middle-income countries where systematic evaluation and reporting of cardiac manifestations are limited (5–10). Given this gap, there is a compelling need for structured assessment of ECG abnormalities following electrocution to improve early risk identification and guide emergency management. Therefore, this study was undertaken to determine the frequency and pattern of ECG abnormalities among patients presenting with electrocution injuries and to analyze their association with injury voltage and time to presentation. The objective of this research is to generate evidence that supports improved risk stratification, enhances ED monitoring protocols, and promotes safe discharge decisions for patients following electrical injuries.

METHODS

This observational cross-sectional study was carried out in the Emergency Department (ED) of Combined Military Hospital (CMH), Rawalpindi, over a two-year period from January 2023 to January 2025, following approval from the Institutional Review Board (IRB No. 592). CMH Rawalpindi is a 1100-bedded tertiary care teaching hospital equipped with a 50-bed emergency department and an annual patient volume exceeding 220,000 visits, providing a suitable setting for studies on acute emergency presentations such as electrocution injuries. The study population comprised patients aged between 12 and 80 years who presented to the ED within 24 hours of sustaining an electrocution injury. To ensure the accuracy of electrocardiographic (ECG) findings and to minimize confounding factors, patients with pre-existing cardiac conditions such as atrial fibrillation, prior myocardial infarction, or known structural heart disease were excluded. Individuals using cardioselective or antiarrhythmic medications likely to influence ECG interpretation were also excluded, as were patients with major traumatic injuries unrelated to electrocution (e.g., head injury or multi-organ trauma). Written informed consent was obtained from all participants or, in the case of minors, from their legal guardians. The study ensured full autonomy for participants, allowing them to withdraw from the research at any stage without affecting their medical care. The minimum required sample size was calculated using the World Health Organization (WHO) sample size calculator, assuming a 95% confidence level, 80%

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statistical power, and an expected prevalence of ECG abnormalities based on prior literature (11). This yielded a minimum sample size of 120 participants, which was deemed sufficient for statistical analysis (12).

Electrocution injury was operationally defined as any tissue or systemic injury resulting from exposure to an electric current, classified as low voltage (<1000 V) or high voltage (>1000 V). Eligible patients were recruited consecutively upon presentation to the ED. Data were recorded using a structured proforma, capturing demographic details (age, gender, and comorbidities) and electrocution-related characteristics, including voltage exposure, duration of contact, entry and exit sites, presence of external burns, and time elapsed since injury. Data were entered contemporaneously into a Microsoft Excel database to minimize transcription errors and ensure completeness. Each participant underwent a standard 12-lead ECG at the time of ED presentation. The initial interpretation was performed by the attending emergency physician, followed by validation by a senior Emergency Medicine specialist. Any equivocal or atypical ECG findings were reviewed jointly to achieve consensus. This dual-review process enhanced diagnostic reliability and minimized inter-observer variability. Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 22. Quantitative variables such as age were summarized as mean ± standard deviation (SD), whereas categorical variables such as voltage exposure and ECG findings were expressed as frequencies and percentages. Associations between voltage level, time to presentation, and the presence of ECG abnormalities were assessed using the Chi-square test or Fisher's exact test, as appropriate to cell counts. A p-value of less than 0.05 was considered statistically significant. All ethical principles of research involving human subjects were observed, including confidentiality, voluntary participation, and respect for patient autonomy.

RESULTS

A total of 120 patients who presented with a history of electrocution were included in the study. The mean age of the participants was 34.0 ± 13.4 years, with the age range extending from 18 to 65 years. Males comprised the majority of the sample, representing 65.0% (n=78), whereas females accounted for 35.0% (n=42). The average duration between electrocution and presentation to the hospital was 3.66 ± 1.99 hours. Low-voltage injuries (<1000 V) were predominant, observed in 81.7% (n=98) of patients, while 18.3% (n=22) sustained high-voltage (>1000 V) exposures. At presentation, the most frequent electrocardiographic (ECG) finding was sinus tachycardia, identified in 36.7% (n=44) of patients. Normal sinus rhythm was recorded in 20.0% (n=24), atrial fibrillation in 10.0% (n=12), and T-wave abnormalities in 9.2% (n=11). Other significant findings included asystole in 6.7% (n=8), ventricular fibrillation in 6.7% (n=8), ST-segment deformities in 5.8% (n=7), and premature ventricular contractions (PVCs) in 5.0% (n=6). When stratified by voltage exposure, low-voltage injuries were more frequently associated with sinus tachycardia (42.9%) and normal sinus rhythm (22.4%), whereas high-voltage injuries were proportionally more often linked with atrial fibrillation (27.3%) and T-wave abnormalities (18.2%). Asystole was documented in 6.1% of low-voltage and 9.1% of high-voltage cases, while ventricular fibrillation occurred in 7.1% and 4.5%, respectively. In terms of outcomes, 55.0% (n=66) of patients were discharged from the emergency department, 31.7% (n=38) required hospital admission, and 13.3% (n=16) were declared dead on arrival or died during emergency resuscitation. Mortality was higher among patients exposed to high-voltage electrocution (9 of 22, 40.9%) compared with those sustaining low-voltage injuries (7 of 98, 7.1%). Among the deceased patients, the most frequent ECG abnormalities were asystole (31.3%, n=5) and atrial fibrillation (25.0%, n=4), while normal sinus rhythm, T-wave changes, ST-segment deformities, and PVCs were less common.

Analysis of time-to-presentation demonstrated a clear association between delay in arrival and adverse outcomes. Patients presenting after more than 6 hours had the highest mortality rate (40.0%, n=6/15), while those presenting within the first hour exhibited the lowest (6.7%, n=1/15). The highest admission rate was observed among patients presenting between 3.1 and 6 hours after injury (36.4%, n=16/44). Conversely, early presenters within 1.1–3 hours were predominantly discharged (60.9%, n=28/46). These findings highlight the predominance of low-voltage electrocution injuries and the significance of early presentation in improving survival outcomes. Sinus tachycardia and atrial fibrillation were the most frequent ECG abnormalities, while asystole was strongly associated with mortality. Further analysis was performed to evaluate the correlation between specific electrocardiographic (ECG) abnormalities and patient outcomes stratified by voltage exposure. Among low-voltage injuries (<1000 V), most patients with sinus tachycardia (59.5%, n=25) or normal sinus rhythm (63.6%, n=14) were safely discharged from the emergency department, whereas those exhibiting asystole (42.9%, n=3) or atrial fibrillation (50.0%, n=3) had markedly higher rates of mortality or hospital admission. In contrast, high-voltage injuries (>1000 V) demonstrated a different distribution: 40.9% (n=9) resulted in death, with atrial fibrillation (11.1%, n=1), T-wave abnormalities (22.2%, n=2), and asystole (22.2%, n=2) being the most frequent lethal ECG findings. Patients with high-voltage exposure and normal sinus rhythm had lower mortality but still showed a 16.7% (n=1) death rate, indicating that even apparently benign ECG patterns may not exclude severe myocardial injury. Overall, the data indicate that arrhythmias such as atrial fibrillation and asystole

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were strongly associated with fatal outcomes, particularly in high-voltage exposure. Conversely, sinus tachycardia and normal sinus rhythm were largely predictive of survival and discharge. This relationship underscores the prognostic value of ECG pattern recognition for early risk stratification in electrocution victims.

Table 1: Frequency and distribution of ECG changes inpatients by voltage level with electrocution injury (n=120)

ECG Changes	Low Voltage Injuries (< 1000V) (N = 98)	High Voltage Injuries (< 1000V) (N = 22)	Total (n)	Percentage (%)
Sinus Tachycardia	42 (42.9%)	2 (9.1%)	44	36.7
Normal Sinus Rhythm	22 (22.4%)	2 (9.1%)	24	20.0
Atrial Fibrillation	6 (6.1%)	6 (27.3%)	12	10.0
T- wave abnormality	7 (7.1%)	4 (18.2%)	11	9.2
Asystole	6 (6.1%)	2 (9.1%)	8	6.7
Ventricular Fibrillation	7 (7.1%)	1 (4.5%)	8	6.7
ST Segment Deformity	6 (6.1%)	1 (4.5%)	7	5.8
Premature Ventricular Contractions (PVCs)	6 (6.1%)	0 (0.0%)	6	5.0

Table 2: Outcomes by Voltage and ECG Pattern DOA= dead on arrival

Parameter	Low-Voltage (n=98)	High-Voltage (n=22)	Total (n=120)
Discharged	59	7	66 (55.0%)
Admitted	32	6	38 (31.7%)
Deaths (DOA or in ED)	7	9	16 (13.3%)
Common ECG Findings among those who died	Low-Voltage (n=7)	High-Voltage (n=9)	Total (n=16)
Sinus Tachycardia	0	0	0
Normal Sinus Rhythm	1	1	2
Atrial Fibrillation	3	1	4
T- wave abnormality	0	2	2
Asystole	3	2	5
Ventricular Fibrillation	0	0	0
ST Segment Deformity	0	1	1
Premature Ventricular Contractions (PVCs)	0	2	2

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Table 3: Correlation of ECG Patterns with Clinical Outcomes by Voltage Exposure (n = 120)

ECG Pattern	Low Voltage Injuries (<1000 V)	High Voltage Injuries (>1000 V)	Total (n)	Predominant Outcome
Sinus Tachycardia	Mostly discharged (≈59.5%)	Predominantly discharged (≈50%)	44	Recovery / Discharge
Normal Sinus Rhythm	63.6% discharged, 9.1% deaths	50% discharged, 16.7% deaths	24	Recovery / Mild involvement
Atrial Fibrillation	50% admitted, 25% deaths	22.2% admitted, 11.1% deaths	12	Moderate to severe cardiac involvement
T-wave Abnormality	45% admitted	22.2% deaths	11	Myocardial stress / Variable outcome
Asystole	42.9% deaths (n=3)	22.2% deaths (n=2)	8	High mortality risk
Ventricular Fibrillation	Rare, all resuscitated	None fatal in this cohort	8	Severe but reversible if early treated
ST-Segment Deformity	28.6% admitted	11.1% deaths	7	Moderate risk / Ischemic changes
PVCs	33% admitted, no deaths	22.2% deaths (n=2)	6	Arrhythmic instability (variable prognosis)

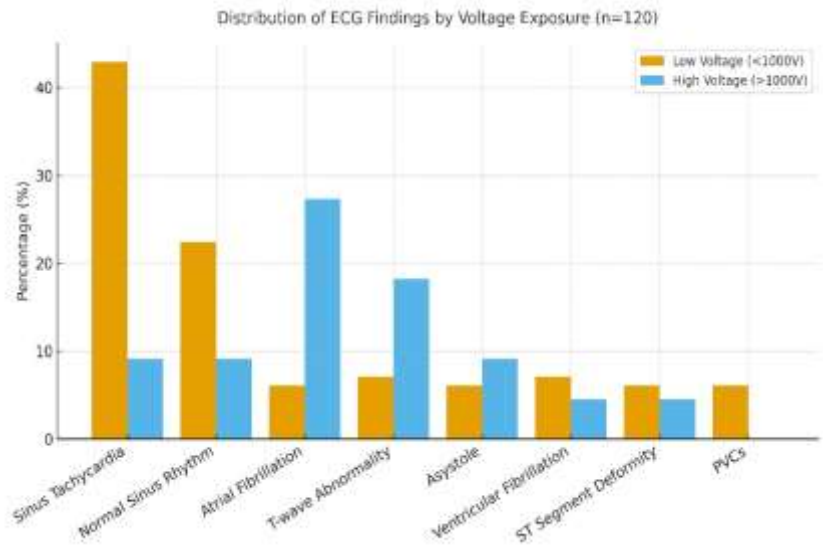

Figure 1 Distribution of ECG Findings by Voltage Exposure (n=120)

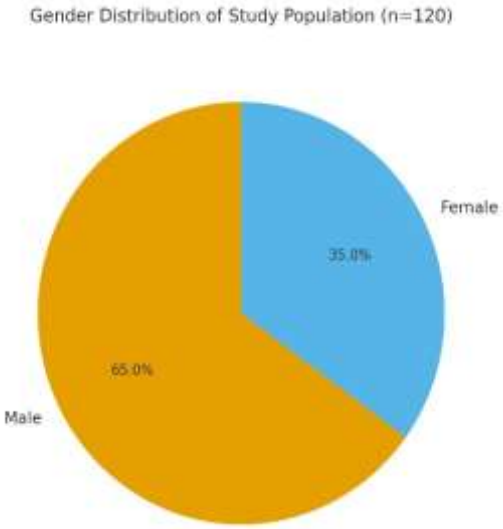

Figure 2 Gender Distribution of Study Population (n=120)

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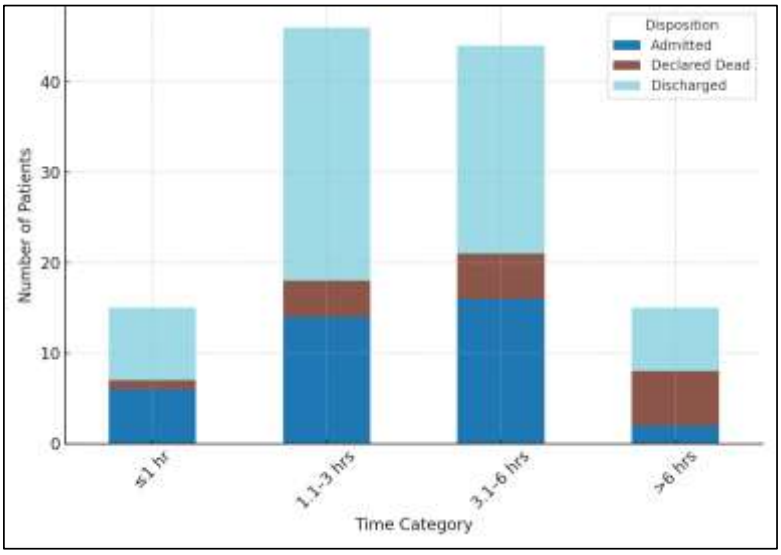

Disposition by Time to Presentation

Figure 1 Disposition by Time to Presentation

DISCUSSION

The present study identified consistent demographic and clinical characteristics among patients presenting with electrical injuries, aligning closely with trends reported in the existing literature. The predominance of young males, with a mean age of 34 years and a male representation of 65%, reflects occupational exposure patterns, particularly in electrical and industrial work environments (12,13). This demographic trend underscores the occupational hazard associated with electricity-related work and highlights the importance of safety education, enforcement of protective regulations, and preventive measures for high-risk populations. Electrocardiographic abnormalities were frequent and diverse, with sinus tachycardia emerging as the most common finding, followed by normal sinus rhythm, atrial fibrillation, and T-wave abnormalities. These findings mirror those reported in prior studies that described sinus tachycardia and repolarization disturbances as common early ECG manifestations after electrocution (14-16). Although atrial fibrillation is generally infrequent in the context of electrical injury, its transient occurrence is clinically significant as it may indicate temporary disruption of atrial conduction or myocardial irritation. Other conduction and repolarization changes, such as QT prolongation or fragmented QRS complexes, have been described in earlier research as potential predictors of malignant arrhythmias and adverse cardiac outcomes (17,18). These patterns highlight the diagnostic value of early ECG assessment as a non-invasive tool to identify patients at higher cardiac risk. Voltage level demonstrated a strong association with the nature and severity of ECG abnormalities. High-voltage injuries, although less prevalent, were disproportionately linked to atrial fibrillation and T-wave abnormalities, suggesting a greater degree of myocardial insult due to deeper tissue penetration and stronger current amplitude (19,20). The pathophysiological explanation for this relationship lies in direct electrical interference with cardiac myocyte depolarization and necrosis, which predisposes to arrhythmogenic substrates. This observation reinforces the need for heightened vigilance and extended monitoring of high-voltage exposure victims, even in the absence of overt symptoms or major external burns. The timing of presentation was another determinant of prognosis in this cohort. Patients who presented within the first hour after injury had the lowest mortality, while those presenting beyond six hours had substantially worse outcomes. This time-dependent trend is supported by prior evidence indicating that early recognition and management of arrhythmias improve survival and reduce complications (21-23). Timely intervention allows for immediate stabilization, correction of electrolyte imbalances, and early cardiopulmonary support.

The study's findings therefore emphasize that delayed presentation to the emergency department remains a critical risk factor for mortality, particularly in high-voltage injuries or when initial ECG changes are present. The clinical implications of these results are significant. Early ECG evaluation, combined with serial monitoring, can serve as a cost-effective triage strategy in emergency settings, helping clinicians identify high-risk individuals who require inpatient observation. Patients with high-voltage exposure or abnormal

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ECG patterns should be prioritized for telemetry and echocardiographic assessment to exclude structural or functional myocardial injury. Furthermore, standardized post-electrocution monitoring protocols should be developed and integrated into emergency practice guidelines to minimize preventable cardiac deaths. The study possessed several strengths, including consecutive patient enrollment that minimized selection bias and standardized operational definitions for voltage exposure, which enhanced internal validity (24,25). The sample size, although moderate, was adequate for a single-center observational study and provided meaningful insights into ECG variability and clinical outcomes. Nevertheless, certain limitations were identified. The cross-sectional design precluded causal inference and limited the ability to evaluate long-term cardiac sequelae. As a single-center investigation, the findings may not be generalizable to rural or resource-limited healthcare settings where injury patterns and access to timely medical intervention differ. Additionally, the study was restricted to ECG analysis at the time of presentation. Serial ECGs and extended Holter monitoring were not performed, which may have led to under-detection of delayed arrhythmias or transient conduction abnormalities. Future studies should aim to include multicenter designs with longitudinal follow-up to assess the persistence of ECG abnormalities and late cardiac complications. Incorporating biomarkers such as troponin or cardiac MRI could further delineate the extent of myocardial injury and improve prognostic stratification. Despite these limitations, the study adds valuable regional data to the growing body of literature on the cardiovascular impact of electrocution and underscores the importance of early ECG evaluation and timely medical intervention for optimizing patient outcomes.

CONCLUSION

This study concludes that electrocardiographic abnormalities are frequent among patients presenting after electrocution, with sinus tachycardia being the most prevalent pattern. While low-voltage injuries account for the majority of cases, high-voltage exposure is more often associated with atrial fibrillation and T-wave abnormalities, indicating deeper myocardial involvement and higher cardiac risk. The timing of presentation emerged as a crucial determinant of outcome, as delayed arrivals were linked to increased mortality. These findings emphasize the importance of early ECG evaluation and continuous cardiac monitoring in all electrocution victims—particularly those exposed to high-voltage currents—to enable timely detection of arrhythmias, guide clinical management, and ultimately improve survival outcomes.

AUTHOR CONTRIBUTION

Author	Contribution
Amer Iqbal*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Tamkeen Pervez	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Ashfaq	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Riaz Ahmad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Anees Ur Rehman	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Zeeshan Munir	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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