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Clinical and Laboratory Factors Associated with Hospital Admission or Transfer Following Electrical Injury: A Ten-Year Retrospective Study

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Abstract

Objective

This study aimed to identify the clinical and laboratory characteristics associated with hospital admission or transfer following electrical injury and to evaluate the predictive performance of laboratory parameters for these outcomes.

Materials and Methods

This retrospective observational study included 506 patients who presented to the emergency department of a secondary-level state hospital due to electrical injury between January 1, 2016, and December 31, 2025. Patients were divided into two groups: those discharged from the emergency department and those admitted to the hospital or transferred to a higher-level healthcare facility. Demographic, clinical, traumatic, and laboratory characteristics were compared between the groups. Independent factors associated with hospital admission or transfer were evaluated using Firth's logistic regression analysis. The discriminative performance of the model and individual laboratory parameters was assessed using receiver operating characteristic (ROC) curve analysis.

Results

Among 506 patients, 468 (92.5%) were discharged from the emergency department, whereas 38 (7.5%) required hospital admission or transfer to a higher-level healthcare facility. Male sex, occupational injuries, concomitant burns or falls, and acute electrocardiographic (ECG) abnormalities were significantly more frequent in the admission/transfer group (all $p \leq 0.004$). This group also had higher frequencies of serious injuries, including fractures/dislocations, muscle injury/compartment syndrome, rhabdomyolysis, and myocardial infarction (all $p < 0.001$). Laboratory analyses revealed significantly higher white blood cell and neutrophil counts, glucose, urea, ALT, AST, C-reactive protein, CK-MB, CK, and troponin levels among patients requiring admission or transfer. In contrast, the neutrophil-to-lymphocyte ratio (NLR) did not differ significantly between groups ($p = 0.109$). Among individual laboratory parameters, creatine kinase (CK) showed the highest discriminative performance (AUC = 0.837; 95% CI: 0.734–0.921), with 76.0% sensitivity and 80.4% specificity at an optimal cutoff of 276 U/L. In the Firth penalized logistic regression model, a Glasgow Coma Scale score below 15 (adjusted OR = 188.881; 95% CI: 5.668–6294.242; $p = 0.003$) and the presence of skin burns (adjusted OR = 17.448; 95% CI: 7.784–39.108; $p < 0.001$) were independently associated with hospital admission or transfer. The prediction model demonstrated an AUC of 0.848, with 76.3% sensitivity, 89.1% specificity, and a negative predictive value of 97.9%.

Conclusion

The need for hospital admission or transfer following electrical injury is associated particularly with occupational accidents, concomitant trauma, ECG abnormalities, and biochemical markers of muscle and cardiac injury. CK and CK-MB may be useful in clinical risk assessment, whereas NLR alone does not appear to be a significant discriminator of the outcome.

INTRODUCTION

Electrical injuries are important injuries encountered in emergency departments, with clinical manifestations ranging from minor localized skin damage to life-threatening cardiac, neurological, musculoskeletal, and systemic complications (1). The voltage of the electrical current, duration of contact, pathway of current through the body, characteristics of the contact surface, and electrical resistance of tissues are the principal factors determining the severity of injury. Therefore, a seemingly limited skin lesion does not exclude the presence of significant underlying tissue damage. The multisystem nature of electrical injuries necessitates early and systematic assessment in the emergency department (1, 2).

The clinical course of electrical injuries may differ substantially between low- and high-voltage exposures. High-voltage injuries have been associated with more severe burns, loss of consciousness, cardiac arrest, amputation, and the need for intensive care (2). Nevertheless, low-voltage electrical injuries should not be considered entirely benign; patients should be evaluated according to their clinical findings, electrocardiographic characteristics, and associated injuries (2). A recently published retrospective study demonstrated that high-voltage exposure was associated with longer hospital stays and more severe clinical outcomes (2, 3).

The decision to admit a patient following an electrical injury is an important component of emergency department management. High-voltage exposure, electrocardiographic abnormalities, cardiac complications, extensive burns, and systemic involvement are particularly relevant factors when considering hospital admission (3, 4).

Skin burns are important findings in the clinical assessment of electrical injuries. Although the thermal effects of electrical current may cause localized burns, more severe exposures may also result in deep tissue damage, rhabdomyolysis, compartment syndrome, and the need for surgical intervention (4, 5). Among patients with electrical burns, total body surface area burned, renal failure, sepsis, and cardiovascular complications have been associated with longer hospital stays and unfavorable clinical outcomes (4, 5). These findings suggest that burns identified during the initial assessment may provide important information when determining the need for further evaluation and treatment.

The aim of this study was to identify the clinical and laboratory characteristics associated with hospital admission among patients presenting to the emergency department following electrical injury, determine independent predictors of admission using multivariable logistic regression analysis, and evaluate the predictive performance of the developed model using receiver operating characteristic (ROC) curve analysis. This approach may contribute to the earlier identification of patients at high risk of requiring

hospital admission during their initial emergency department assessment and support clinical decision-making.

MATERIALS AND METHODS

Study Design and Patient Population

This retrospective observational study was conducted in the emergency department of a state hospital providing secondary-level healthcare services. Patients who presented to the emergency department because of electrical injury between January 1, 2016, and December 31, 2025, were included in the study.

The primary outcome was defined as the need for hospital admission or transfer to a healthcare facility providing a higher level of care following emergency department evaluation. Patients were divided into two groups for comparison: those discharged directly from the emergency department and those admitted to the hospital or transferred to a higher-level healthcare facility.

Data Collection

Demographic and clinical data were retrospectively obtained from the hospital's electronic medical records system. Demographic variables included age and sex. Injury-related variables included the circumstances in which the electrical injury occurred, whether it was occupational, and the presence of associated traumatic injuries. Clinical assessment included the Glasgow Coma Scale (GCS) score at presentation, electrocardiographic (ECG) findings, and anatomical injury locations.

Injury locations were classified as the hand, upper extremity, foot, lower extremity, head and neck, trunk, pelvis, and organ injuries. The use of direct radiography and computed tomography (CT) during patient evaluation was also recorded. Trauma-related clinical findings included fractures/dislocations, muscle injury or compartment syndrome, skin burns, open wounds, renal injury/rhabdomyolysis, myocardial infarction, and pulmonary or hepatic parenchymal injuries.

Treatments administered in the emergency department were recorded, including wound care, cast or splint application, wound suturing, intravenous fluid therapy, tetanus prophylaxis, antibiotic treatment, endotracheal intubation, and cardiopulmonary resuscitation.

Laboratory Assessment

Laboratory results obtained during the initial emergency department presentation were evaluated. The analyzed parameters included white blood cell count (WBC), neutrophil count, lymphocyte count, neutrophil-to-lymphocyte ratio (NLR), hemoglobin, platelet count, glucose, urea, creatinine, alanine

aminotransferase (ALT), aspartate aminotransferase (AST), C-reactive protein (CRP), creatine kinase-MB (CK-MB), creatine kinase (CK), and troponin.

The neutrophil-to-lymphocyte ratio (NLR) was calculated by dividing the neutrophil count by the lymphocyte count. Missing laboratory values were not imputed; therefore, each analysis was performed using the available data for the respective parameter. CK-related analyses were restricted to patients with available CK measurements in the electronic medical records. The number of patients included in each laboratory analysis is reported in the corresponding tables.

Statistical Analysis

Statistical analyses were performed using SPSS Statistics version 21.0. Continuous variables were presented as medians and interquartile ranges (IQRs), while categorical variables were expressed as numbers and percentages. Between-group comparisons were performed using the Mann–Whitney U test for continuous variables and Fisher's exact test or the Fisher–Freeman–Halton exact test for categorical variables, as appropriate.

Firth’s penalized logistic regression was used to identify factors independently associated with hospital admission or transfer to a higher-level healthcare facility. The model included age, sex, a Glasgow Coma Scale (GCS) score below 15, and the presence of skin burns. The results are presented as regression coefficients (β), adjusted odds ratios (ORs), and 95% confidence intervals (CIs). Given the small number of outcome events, Firth’s penalized likelihood approach was used to reduce small-sample bias and address potential estimation problems associated with sparse data.

The ability of individual laboratory parameters to discriminate between patients requiring hospital admission or transfer and those discharged from the emergency department was evaluated using receiver operating characteristic (ROC) curve analysis. The area under the ROC curve (AUC) and its 95% confidence interval were calculated for each parameter. Optimal cutoff values were determined using the Youden index, and the corresponding sensitivity and specificity values were calculated.

Patients with missing laboratory measurements were excluded from the corresponding analyses, and no imputation was performed for missing data. CK analyses were conducted only in patients with available CK measurements. A two-sided *p*-value of less than 0.05 was considered statistically significant for all analyses.

RESULTS

A total of 506 patients who presented to the emergency department following electrical injury were included in the study. Of these, 468 patients were discharged from the emergency department, whereas 38 required hospital admission or transfer to a higher-level healthcare facility. The median age of the patients was 30 years, and no statistically significant difference in age was observed between the

discharge and admission/transfer groups (p = 0.600). In contrast, male sex was significantly more frequent among patients requiring hospital admission or transfer (p = 0.004) (Table 1).

Table 1

Comparison of demographic, clinical, and injury characteristics of patients presenting to the emergency department following electrical injury, according to hospital admission/transfer status

Variable*	**Discharged** **n (%)**	**Hospital admission/transfer** **n (%)**	**p value****
Age, median (IQR), years	29.5 (22.0–41.0)	30.5 (23.0–45.0)	0.600
Sex			
Male	333 (71.2%)	35 (92.1%)	0.004
Female	135 (28.8%)	3 (7.9%)	
Location/circumstances of injury			
Home	391 (83.5%)	10 (26.3%)	< 0.001
Occupational accident	71 (15.2%)	23 (60.5%)	
Outdoor/field setting	6 (1.3%)	5 (13.2%)	
Concomitant trauma			
None	396 (84.6%)	6 (15.8%)	< 0.001
Burn	39 (8.3%)	23 (60.5%)	
Fall	33 (7.1%)	9 (23.7%)	
Glasgow Coma Scale (median [IQR])	15 (15–15)	15 (15–15)	< 0.001
ECG			
ECG performed	290 (62.0%)	36 (94.7%)	< 0.001
ECG not performed	178 (38.0%)	2 (5.3%)	
ECG findings			
Acute abnormal finding*	1 (0.3%)	5 (13.9%)	< 0.001
No acute abnormal finding	289 (99.7%)	31 (86,1%)	

* Abbreviations: IQR, interquartile range; ECG, electrocardiography. Acute ECG abnormalities included atrial fibrillation, ventricular fibrillation, ST-segment elevation, and T-wave inversion. ED: Emergency department

** Statistical analysis: Continuous variables are presented as median (interquartile range, IQR) and were compared using the Mann–Whitney U test. Categorical variables are presented as number (n) and percentage (%). Fisher's exact test was used for 2 × 2 tables, and the Fisher–Freeman–Halton exact test was used for tables with more than two categories. The outcome was defined as hospital admission or transfer to a higher-level healthcare facility.

Variable*	Discharged n (%)	Hospital admission/transfer n (%)	p value**
Injury location			
Hand injury	62 (13.2%)	25 (65.8%)	< 0.001
Upper-extremity injury	30 (6.4%)	21 (55.3%)	< 0.001
Foot injury	12 (2.6%)	18 (47.4%)	< 0.001
Lower-extremity injury	11 (2.4%)	15 (39.5%)	< 0.001
Head and neck injury	14 (3.0%)	7 (18.4%)	< 0.001
Trunk injury	11 (2.4%)	12 (31.6%)	< 0.001
Pelvic injury	2 (0.4%)	4 (10.5%)	< 0.001
Organ injury	0 (0.0%)	6 (15.8%)	< 0.001
Radiological imaging			
Plain radiography	57 (12.2%)	21 (55.3%)	< 0.001
Computed tomography	24 (5.1%)	20 (52.6%)	< 0.001
Trauma-related injuries and clinical outcomes			
Fracture/dislocation	3 (0.6%)	6 (15.8%)	< 0.001
Muscle injury/compartment syndrome	0 (0.0%)	10 (26.3%)	< 0.001
Skin burn	50 (10.7%)	27 (71.1%)	< 0.001
Open wound	2 (0.4%)	15 (39.5%)	< 0.001
Renal injury/rhabdomyolysis	0 (0.0%)	5 (13.2%)	< 0.001
Myocardial infarction	0 (0.0%)	5 (13.2%)	< 0.001
Pulmonary/hepatic parenchymal injury	0 (0.0%)	2 (5.3%)	0.006

* Abbreviations: IQR, interquartile range; ECG, electrocardiography. Acute ECG abnormalities included atrial fibrillation, ventricular fibrillation, ST-segment elevation, and T-wave inversion. ED: Emergency department

** Statistical analysis: Continuous variables are presented as median (interquartile range, IQR) and were compared using the Mann–Whitney U test. Categorical variables are presented as number (n) and percentage (%). Fisher's exact test was used for 2 × 2 tables, and the Fisher–Freeman–Halton exact test was used for tables with more than two categories. The outcome was defined as hospital admission or transfer to a higher-level healthcare facility.

Variable*	Discharged n (%)	Hospital admission/transfer n (%)	p value**
Treatments administered in the ED			
Wound dressing	32 (6.8%)	24 (63.2%)	< 0.001
Cast/splint application	4 (0.9%)	9 (23.7%)	< 0.001
Wound suturing	6 (1.3%)	8 (21.1%)	< 0.001
Fluid therapy	287 (61.3%)	36 (94.7%)	< 0.001
Tetanus prophylaxis	12 (2.6%)	21 (55.3%)	< 0.001
Antibiotic therapy	4 (0.9%)	21 (55.3%)	< 0.001
Endotracheal intubation	0 (0.0%)	7 (18.4%)	< 0.001
Cardiopulmonary resuscitation	0 (0.0%)	5 (13.2%)	< 0.001

* Abbreviations: IQR, interquartile range; ECG, electrocardiography. Acute ECG abnormalities included atrial fibrillation, ventricular fibrillation, ST-segment elevation, and T-wave inversion. ED: Emergency department

** Statistical analysis: Continuous variables are presented as median (interquartile range, IQR) and were compared using the Mann–Whitney U test. Categorical variables are presented as number (n) and percentage (%). Fisher's exact test was used for 2 × 2 tables, and the Fisher–Freeman–Halton exact test was used for tables with more than two categories. The outcome was defined as hospital admission or transfer to a higher-level healthcare facility.

The annual distribution of electrical injury presentations showed fluctuations between 2016 and 2025. The annual number of presentations peaked in 2018, with 61 cases, whereas the lowest number was recorded in 2021, with 42 cases. From 2022 onward, an upward trend in the number of presentations was observed, reaching 55 cases in 2025 (Fig. 1). Analysis of the monthly distribution revealed a marked concentration of electrical injuries during the summer months. The highest number of presentations occurred in July, with 82 cases. Notably, the number of presentations increased substantially during June, July, August, and September. In contrast, presentation rates were lower during the winter months, with the lowest monthly counts recorded in January, February, and December, each accounting for 22 cases (Fig. 1).

Regarding the location and circumstances of injury, occupational accidents were significantly more frequent among patients requiring hospital admission or transfer ($p < 0.001$). In contrast, electrical injuries occurring in domestic settings were more common among patients discharged directly from the emergency department. Injuries occurring in outdoor or field settings were also proportionally more frequent in the admission/transfer group (Table 1).

A substantial difference was observed between the groups regarding the presence of concomitant trauma ($p < 0.001$). Electrical injuries accompanied by burns or falls were particularly more frequent among patients admitted to the hospital or transferred to a higher-level healthcare facility (Table 1).

Regarding neurological status at presentation, the median Glasgow Coma Scale (GCS) score was 15 in both groups; however, the distribution of GCS scores differed significantly between the groups ($p < 0.001$). Electrocardiographic assessment also revealed a significant difference. Acute ECG abnormalities were significantly more frequent among patients requiring hospital admission or transfer ($p < 0.001$) (Table 1).

Analysis of the anatomical distribution of injuries demonstrated that multiple and more extensive anatomical injuries were substantially more common among patients requiring hospital admission or transfer. Statistically significant between-group differences were observed for injuries involving the hands, upper extremities, feet, lower extremities, head and neck, trunk, pelvis, and internal organs (all $p < 0.001$) (Table 1).

A marked difference was also observed in imaging requirements. The use of radiography and computed tomography (CT) was significantly higher among patients admitted to the hospital or transferred to a higher-level healthcare facility than among those discharged from the emergency department (both $p < 0.001$) (Table 1).

Evaluation of trauma-related clinical outcomes revealed that fractures/dislocations, muscle injury or compartment syndrome, skin burns, open wounds, renal injury/rhabdomyolysis, and myocardial infarction were significantly more frequent among patients requiring hospital admission or transfer (all $p < 0.001$). Pulmonary or hepatic parenchymal injuries were also significantly more common in the admission/transfer group ($p = 0.006$) (Table 1).

Regarding treatments administered in the emergency department, wound care, cast/splint application, wound suturing, intravenous fluid therapy, tetanus prophylaxis, and antibiotic treatment were significantly more frequent among patients admitted to the hospital or transferred to a higher-level healthcare facility (all $p < 0.001$) (Table 1). Intravenous fluid therapy was administered at a particularly high rate in the admission/transfer group, while the use of tetanus prophylaxis and antibiotics was also markedly increased in this group. With respect to advanced resuscitative interventions, endotracheal intubation and cardiopulmonary resuscitation were observed exclusively among patients requiring hospital admission or transfer, with $p < 0.001$ for both variables (Table 1).

Evaluation of laboratory parameters demonstrated that white blood cell (WBC) and neutrophil counts were significantly higher among patients requiring hospital admission or transfer (both $p < 0.001$). In contrast, no statistically significant difference was observed in lymphocyte counts ($p = 0.071$). Similarly, the neutrophil-to-lymphocyte ratio (NLR) did not differ significantly between the groups ($p = 0.109$) (Table 2).

Table 2
Comparison of laboratory parameters according to discharge and hospital admission/transfer status

Laboratory variable*	Discharged Median (IQR)	Hospital admission/transfer Median (IQR)	p value**
White blood cell count (×10³/μL)	8.00 (6.54–9.60)	10.04 (7.80–15.28)	< 0.001
Neutrophil count (×10³/μL)	4.50 (3.50–5.89)	6.15 (4.33–10.24)	< 0.001
Lymphocyte count (×10³/μL)	2.43 (1.86–3.20)	3.04 (1.73–3.90)	0.071
Neutrophil-to-lymphocyte ratio (NLR)	1.84 (1.38–2.60)	2.09 (1.32–4.27)	0.109
Hemoglobin (g/dL)	14.30 (13.52–15.50)	15.00 (13.00–15.90)	0.689
Platelet count (×10³/μL)	258.00 (217.00–299.00)	272.00 (234.50–322.25)	0.233
Glucose (mg/dL)	97.00 (89.00–109.00)	123.00 (98.00–145.00)	< 0.001
Urea (mg/dL)	29.00 (24.00–35.00)	33.50 (28.00–36.00)	0.008
Creatinine (mg/dL)	0.78 (0.60–0.89)	0.85 (0.60–1.00)	0.116
ALT (U/L)	17.00 (14.00–25.00)	27.50 (16.75–61.25)	< 0.001
AST (U/L)	21.00 (16.00–26.00)	30.00 (22.50–71.75)	< 0.001
C-reactive protein (mg/L)	2.00 (0.70–2.40)	2.00 (1.23–5.28)	0.028
CK-MB (ng/mL)	1.84 (1.20–3.00)	6.40 (2.25–16.68)	< 0.001
CK (U/L) ***	154.00 (102.00–241.25)	654.00 (276.00–1469.00)	< 0.001
Troponin (ng/L)	2.30 (1.20–3.50)	2.75 (1.45–8.95)	0.012

* Abbreviations: IQR, interquartile range; NLR, neutrophil-to-lymphocyte ratio; AST, aspartate aminotransferase; ALT, alanine aminotransferase; CK-MB, creatine kinase-MB; CK, creatine kinase.

** Laboratory variables are presented as median (interquartile range, IQR), based on the number of patients with available measurements. Variables were compared using the Mann–Whitney U test. NLR was calculated by dividing the neutrophil count by the lymphocyte count. Missing values were not imputed.

*** CK levels were available only for patients with a recorded CK measurement; results were unavailable for the remaining patients.

Glucose levels were significantly higher among patients admitted to the hospital or transferred to a higher-level healthcare facility ($p < 0.001$). Urea levels also differed significantly between the groups ($p = 0.008$). However, no statistically significant difference was observed in creatinine levels ($p = 0.116$).

Hemoglobin levels and platelet counts likewise showed no significant between-group differences (Table 2).

Regarding hepatic enzymes, both alanine aminotransferase (ALT) and aspartate aminotransferase (AST) levels were significantly higher among patients requiring hospital admission or transfer (both $p < 0.001$). C-reactive protein (CRP) levels also differed significantly between the groups ($p = 0.028$) (Table 2). CK-MB levels were significantly higher among patients admitted to the hospital or transferred to a higher-level healthcare facility ($p < 0.001$). Similarly, creatine kinase (CK) levels were markedly elevated in the admission/transfer group ($p < 0.001$) (Table 2).

Factors Associated with Hospital Admission/Transfer and ROC Analysis

Firth's penalized logistic regression analysis was performed to identify independent factors associated with hospital admission or transfer (Table 3). The analysis revealed that a Glasgow Coma Scale (GCS) score below 15 and the presence of skin burns were significantly associated with hospital admission/transfer. Compared with patients with a GCS score of 15, those with a GCS score below 15 had significantly higher odds of hospital admission or transfer (adjusted OR = 188.881; 95% CI: 5.668–6294.242; $p = 0.003$). The presence of skin burns was also significantly associated with hospital admission/transfer (adjusted OR = 17.448; 95% CI: 7.784–39.108; $p < 0.001$). In contrast, neither age (OR = 1.007; 95% CI: 0.982–1.033; $p = 0.572$) nor male sex (OR = 2.340; 95% CI: 0.714–7.666; $p = 0.160$) was significantly associated with the outcome (Table 3).

Table 3
Firth logistic regression analysis of factors associated with hospital admission/transfer

Variable	β coefficient	Standard error	Adjusted OR	95% CI lower bound	95% CI upper bound	p value
Age (per 1-year increase)	0.007	0.013	1.007	0.982	1.033	0.572
Male sex (reference: female)	0.850	0.606	2.340	0.714	7.666	0.160
GCS < 15 (reference: GCS = 15)	5.241	1.789	188.881	5.668	6294.242	0.003
Skin burn (present; reference: absent)	2.859	0.412	17.448	7.784	39.108	< 0.001

*β, regression coefficient; OR, odds ratio; CI, confidence interval; GCS, Glasgow Coma Scale. ORs were obtained from the Firth penalized logistic regression model. The outcome variable was hospital admission/transfer. The wide confidence interval for GCS < 15 suggests considerable estimation uncertainty due to the small number of events in this subgroup.

The discriminative performance of laboratory parameters for predicting hospital admission or transfer was evaluated using ROC curve analysis (Table 4). The highest area under the curve (AUC) was observed for CK (AUC = 0.837; 95% CI: 0.734–0.921). The optimal cutoff value determined using the Youden index was 276 U/L, corresponding to a sensitivity of 76.0% and a specificity of 80.4%. CK-MB also demonstrated relatively high discriminative performance (AUC = 0.772; 95% CI: 0.679–0.857). At a cutoff value of 5.1 ng/mL, its sensitivity was 57.9% and specificity was 89.2%.

Table 4
ROC analysis of laboratory parameters for predicting hospital admission/transfer

Laboratory parameter*	n	AUC*	95% CI*	Optimal cutoff*	Sensitivity (%)*	Specificity (%)*	Interpretation*
White blood cell count (×10³/μL)	483	0.704	0.599–0.805	12.5	39.5	96.2	Moderate
Neutrophil count (×10³/μL)	483	0.684	0.576–0.785	7.39	44.7	91.5	Poor
Lymphocyte count (×10³/μL)	483	0.588	0.477–0.699	3.39	44.7	79.6	Poor
Neutrophil-to-lymphocyte ratio (NLR)	483	0.578	0.471–0.689	3.77	31.6	91.2	Poor
Hemoglobin (g/dL)	483	0.520	0.417–0.620	14.7	57.9	53.5	Poor
Platelet count (×10³/μL)	483	0.558	0.456–0.657	245	73.7	42.7	Poor
Glucose (mg/dL)	483	0.712	0.608–0.804	123	52.6	88.1	Moderate
Urea (mg/dL)	483	0.630	0.545–0.713	32	65.8	59.6	Poor
Creatinine (mg/dL)	483	0.577	0.467–0.685	0.85	52.6	68.8	Poor
ALT (U/L)	483	0.716	0.620–0.812	22	68.4	68.3	Moderate
AST (U/L)	483	0.714	0.601–0.816	26	68.4	72.6	Moderate
CRP (mg/L)	483	0.606	0.505–0.703	3	39.5	79.1	Poor
CK-MB (ng/mL)	482	0.772	0.679–0.857	5.1	57.9	89.2	Moderate

AUC, area under the ROC curve; CI, confidence interval; CK, creatine kinase; CK-MB, creatine kinase-MB; AST, aspartate aminotransferase; ALT, alanine aminotransferase; CRP, C-reactive protein. Hospital admission or transfer to a higher-level healthcare facility was considered the positive outcome. Optimal cutoff values were determined using the Youden index. The 95% confidence intervals for the AUC values are reported in the table. Missing laboratory values were not imputed. CK analysis was restricted to the 209 patients with available CK measurements.

Laboratory parameter*	n	AUC*	95% CI*	Optimal cutoff*	Sensitivity (%)*	Specificity (%)*	Interpretation*
CK (U/L)	209	0.837	0.734–0.921	276	76.0	80.4	Good
Troponin	482	0.623	0.523–0.720	8.5	31.6	96.6	Poor

AUC, area under the ROC curve; CI, confidence interval; CK, creatine kinase; CK-MB, creatine kinase-MB; AST, aspartate aminotransferase; ALT, alanine aminotransferase; CRP, C-reactive protein. Hospital admission or transfer to a higher-level healthcare facility was considered the positive outcome. Optimal cutoff values were determined using the Youden index. The 95% confidence intervals for the AUC values are reported in the table. Missing laboratory values were not imputed. CK analysis was restricted to the 209 patients with available CK measurements.

Glucose (AUC = 0.712; 95% CI: 0.608–0.804), ALT (AUC = 0.716; 95% CI: 0.620–0.812), AST (AUC = 0.714; 95% CI: 0.601–0.816), and WBC count (AUC = 0.704; 95% CI: 0.599–0.805) demonstrated moderate discriminative performance. The AUC for neutrophil count was 0.684 (95% CI: 0.576–0.785), whereas urea, CRP, troponin, lymphocyte count, NLR, creatinine, platelet count, and hemoglobin had AUC values ranging from 0.500 to 0.700 (Table 4). The ROC curves of laboratory parameters for predicting the need for hospital admission or transfer among patients presenting to the emergency department following electrical injury are presented in Fig. 2.

DISCUSSION

Electrical injuries are important injuries that require systematic evaluation in emergency departments because their clinical manifestations range from minor localized tissue damage to life-threatening cardiac complications, deep muscle injury, and multiple organ involvement (6, 7). Although the voltage of the electrical current, duration of contact, and pathway through the body influence injury severity, externally limited lesions do not always reflect the extent of underlying tissue damage (6, 7). Therefore, early identification of the need for hospital admission or transfer to a higher-level healthcare facility following electrical injury is important for patient management. In a recent emergency department study conducted in Türkiye, electrocardiographic changes, high-voltage exposure, and certain biochemical markers were reported to be associated with hospital admission (8). Similarly, a study involving patients treated for electrical injuries at burn centers demonstrated that creatine kinase (CK) and myoglobin levels were associated with injury severity and a more complicated clinical course (7). Nevertheless, further evidence is needed regarding the ability of clinical and laboratory variables obtained during the initial emergency department assessment, when evaluated together, to predict the need for hospital admission or transfer. Accordingly, the present study examined the clinical and laboratory characteristics of patients presenting to the emergency department following electrical injury over a 10-year period, identified factors associated with hospital admission or transfer, and evaluated the discriminative performance of individual laboratory parameters and a multivariable prediction model.

One of the important findings of our study was that acute ECG abnormalities were significantly more frequent among patients requiring hospital admission or transfer. This finding is consistent with the study by Durdu et al., which identified ECG changes as a factor associated with hospital admission following electrical injury (8). Karray et al. likewise emphasized the importance of ECG abnormalities in assessing cardiac involvement in electrical injuries (6).

Although the distribution of GCS scores at presentation differed significantly between the groups, the median GCS score was 15 in both groups. This finding is noteworthy because it suggests that neurological impairment or concomitant trauma may be present in some patients even when the level of consciousness is preserved in most cases at initial presentation. Therefore, evaluating only the median GCS score may not adequately reflect the clinical differences between the groups. Previous studies have also reported that loss of consciousness and neurological complications may occur more frequently following high-voltage exposure (5, 8).

Among the laboratory parameters evaluated in our study, CK demonstrated the highest discriminative performance (AUC = 0.837), supporting the clinical relevance of muscle injury in electrical injuries. This finding is consistent with the study by Durdu et al., which evaluated 327 patients presenting to the emergency department following electrical injury (8). In that study, the median CK level was 282 U/L among hospitalized patients and 135 U/L among discharged patients, with a statistically significant difference between the groups ($p < 0.001$) (8). Similarly, Struck et al., in a study of 162 patients treated at two burn centers, demonstrated that CK and myoglobin levels at presentation were associated with clinical outcomes, including burn extent, the need for surgical intervention, amputation, renal replacement therapy, and mortality (7).

However, elevated CK levels should not be considered a standalone criterion for determining the need for hospital admission in every case of electrical injury. In a small emergency department study examining low-voltage electrical injuries, all patients with elevated CK levels were discharged from the emergency department, and CK elevation did not alter clinical management (9). Likewise, in another retrospective study involving 465 patients, elevated CK levels were observed in 6.5% of patients. Although CK elevation was more frequent following high-voltage exposure, no serious arrhythmias or in-hospital deaths were observed in that study (4). The differences between these studies and our findings may be explained by variations in patient populations and clinical outcomes.

The significantly higher CK-MB levels observed in the hospital admission/transfer group and the AUC of 0.772 obtained in the ROC analysis suggest that this biomarker may contribute to clinical risk assessment. However, because CK-MB is associated with skeletal muscle as well as myocardial tissue, it should not be interpreted as an isolated indicator of cardiac injury in patients with electrical injuries. Supporting this consideration, a 2026 study evaluating 83 patients hospitalized for electrical burns found that CK-MB, CK, AST, ALT, and lactate dehydrogenase levels were higher among patients who underwent amputation (10).

Regarding troponin, although higher levels were observed in the admission/transfer group in our study, its discriminative performance for predicting the need for hospital admission or transfer was more limited than that of CK and CK-MB. Differences in study endpoints are important when interpreting this finding. In a multicenter study by Douillet et al. involving 785 patients from five French hospitals, major cardiac events occurred in only six patients (0.76%). Initial troponin elevation demonstrated a specificity of 97.7% and a negative predictive value of 99.9% for predicting these events (11).

The significantly higher AST and ALT levels observed among patients requiring hospital admission or transfer in our study are also consistent with previous research. In the study by Durdu et al., the median AST level was 34 U/L in hospitalized patients and 24 U/L in discharged patients, whereas the corresponding median ALT levels were 27.5 U/L and 23 U/L, respectively. The differences in both parameters were statistically significant ($p < 0.001$) (8). A more recent study investigating amputation outcomes among patients hospitalized for electrical burns likewise found significantly higher AST and ALT levels in patients who underwent amputation (10).

Findings in the literature suggest that the clinical significance of the neutrophil-to-lymphocyte ratio (NLR) may vary according to the patient population and the outcome being evaluated. In a study published in 2026 by Yavuz et al., which included 83 patients hospitalized for electrical burns, neutrophil counts and NLR were significantly higher among patients who underwent amputation; the reported AUC for NLR was 0.725 (10). However, none of the variables was confirmed as an independent predictor of amputation in the multivariable analysis (10). This finding suggests that inflammatory markers alone may be insufficient to explain clinical outcomes. Differences between that study and our findings should be interpreted in the context of the respective patient populations and outcome measures.

Our findings regarding seasonal distribution are consistent with studies reporting an increased incidence of electrical injuries during warmer months. Çomçalı et al., in a study evaluating 419 hospitalized patients with burns, reported that electrical and chemical burns were more frequent during spring and summer (12). Similarly, a study examining eight years of occupational accident records among employees of an electricity distribution company in Iran found that most electrical injuries occurred during the summer months (13). A forensic study examining 386 fatal electrocution cases in Türkiye between 2015 and 2019 also reported that 44.56% of deaths occurred during summer and that 53.89% of cases took place in occupational settings (14). Nevertheless, the seasonal distribution of electrical injuries appears to vary across regions. In a 10-year emergency department study involving 112 patients, Adalı et al. reported that electrical injuries occurred most frequently during winter, with 33.9% of cases presenting in that season (15). These differences suggest that seasonal patterns may be influenced by regional factors, including climatic conditions, local occupational activities, electricity-use practices, and patterns of hospital presentation.

The median age of 30 years in our study indicates that electrical injuries remain an important health concern, particularly among young and working-age individuals. However, no statistically significant difference in age was found between patients admitted to the hospital or transferred to a higher-level

healthcare facility and those discharged from the emergency department (p = 0.600). Previous studies have reported varying findings regarding the relationship between age and clinical outcomes. In a study of 327 patients in Türkiye, Durdu et al. identified age as one of the variables associated with hospital admission, whereas the 10-year emergency department study by Adalı et al., which included 112 patients, demonstrated that cases were concentrated particularly among young adults (8, 15).

Regarding sex, the significantly higher proportion of male patients in the hospital admission/transfer group in our study (p = 0.004) is consistent with the epidemiological characteristics of electrical injuries. In the study by Durdu et al., 74.6% of patients were male, and the hospital admission rate was higher among men than among women (8). Similarly, Adalı et al. reported that 91 of 112 patients (81.3%) were male (15). An earlier emergency department study conducted in Türkiye by Al et al., involving 165 patients, also found that male cases substantially outnumbered female cases (16). The greater representation of men among patients with electrical injuries may be related to the distribution of occupational exposures, particularly in electrical installation, construction, maintenance, and repair work.

The significantly higher frequency of concomitant trauma among patients requiring hospital admission or transfer to a higher-level healthcare facility in our study (p < 0.001) suggests that electrical injuries should be assessed not only in terms of direct tissue damage caused by electrical current but also with regard to secondary traumatic effects. The greater frequency of associated burns and falls in the admission/transfer group indicates that these patients may require more comprehensive evaluation and treatment. Similar findings have been reported in the literature. Gökdemir et al., in a study of 152 patients with high-voltage electrical injuries, demonstrated that falls from height and second- or third-degree burns were significantly associated with mortality (17). In a study of 706 patients conducted at a burn center in the Philippines, concomitant trauma was identified in 11.3% of cases, including fractures, cranial injuries, spinal cord injuries, and multiple trauma (18). More recently, Yavuz et al. reported multiple trauma in 19.3% of 83 patients with electrical burns (10). These studies support the importance of not overlooking associated mechanical trauma in patients with electrical injuries. The higher frequencies of fractures/dislocations, muscle injury or compartment syndrome, and multiple anatomical injuries in the admission/transfer group in our study are also consistent with this view.

CONCLUSION

Among patients presenting to the emergency department following electrical injury, the need for hospital admission or transfer to a higher-level healthcare facility was associated particularly with occupational accidents, concomitant trauma, acute ECG abnormalities, and biochemical changes. Among the laboratory parameters, CK demonstrated the highest discriminative performance, while CK-MB, AST, ALT, and glucose also emerged as potentially useful markers for clinical assessment. In contrast, NLR did not differ significantly between the groups. The developed Firth logistic regression model demonstrated good discriminative performance. These findings suggest that early risk assessment following electrical injury should integrate clinical findings, ECG abnormalities, and laboratory results to support clinical decision-making.

Study Limitations

This study has several limitations. First, its retrospective, single-center design may limit the generalizability of the findings. Second, data on important exposure characteristics, including electrical voltage, duration of contact, and the pathway of current through the body, were unavailable. Third, missing laboratory measurements may have introduced bias, and the analyses were based on available cases without imputation. Fourth, hospital admission and transfer were combined into a single outcome, preventing the assessment of factors associated with each outcome separately. Finally, the prediction model was developed and evaluated in the same cohort and has not been externally validated. Therefore, its predictive performance and potential clinical utility should be interpreted cautiously and confirmed in independent, preferably multicenter, cohorts.

Declarations

Ethics Committee Approval

Ethical approval for this study was obtained from the Non-Interventional Clinical Research Ethics Committee of Nevşehir Hacı Bektaş Veli University on September 26, 2025 (Decision No. 2025.09.03). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Informed Consent

Informed consent was not required for this study because of its retrospective design and the use of anonymized patient data. The requirement for informed consent was waived by the relevant ethics committee.

Conflict of Interest

The authors declare that they have no conflicts of interest related to this study.

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Use of Artificial Intelligence

Artificial intelligence tools were not used for data analysis, interpretation of results, or the generation of the scientific content of this study. AI-assisted tools were used during manuscript preparation solely for language editing, including grammar and expression refinement. The author(s) take full responsibility for the scientific content and accuracy of the final manuscript.

Data Availability

The data used in this study are not publicly available due to patient confidentiality requirements and restrictions imposed by the ethics committee. Where appropriate, the corresponding author may be contacted for access requests, subject to relevant ethical and institutional approvals.

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Figures

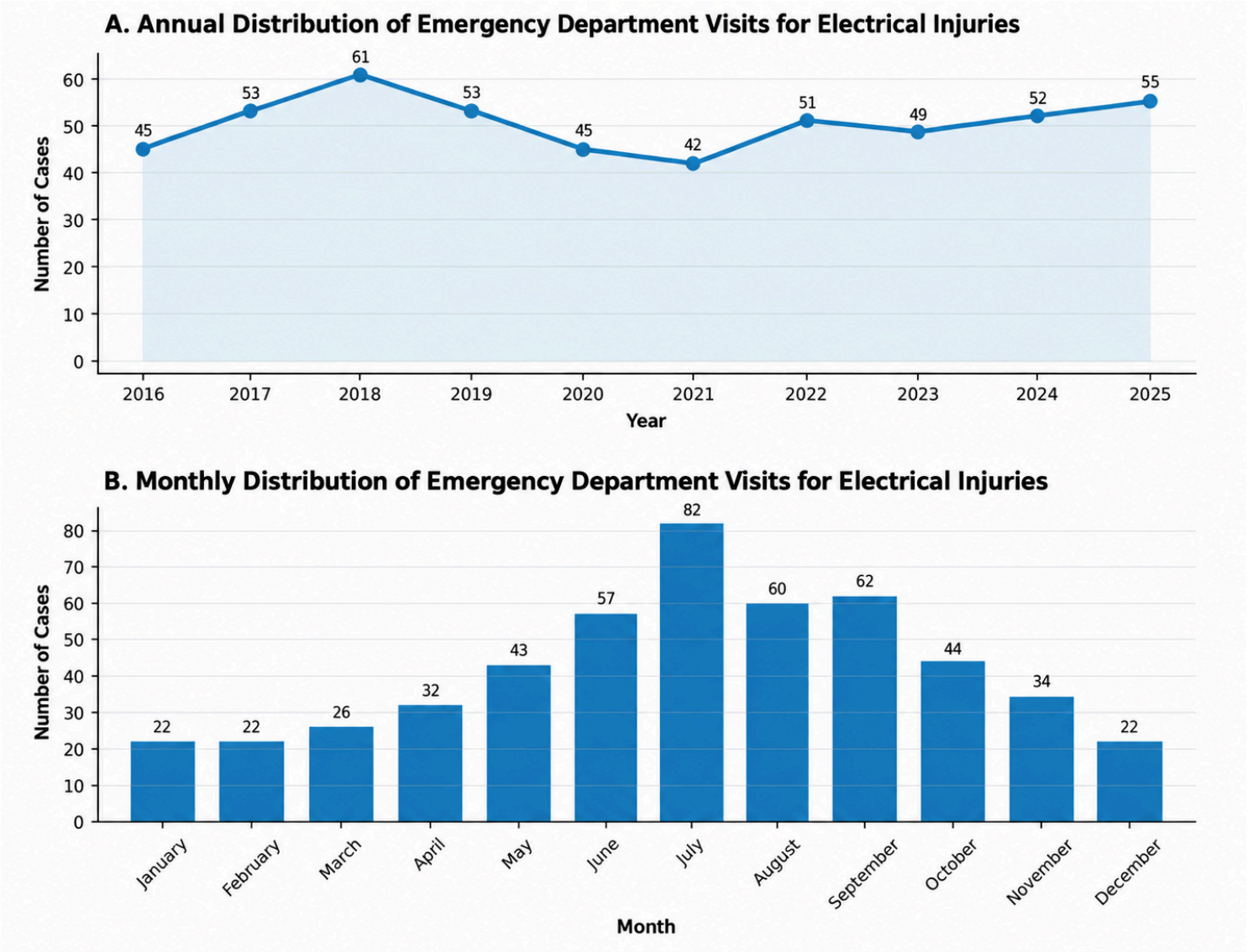

Figure 1

Annual (A) and monthly (B) distribution of emergency department visits for electrical injuries.

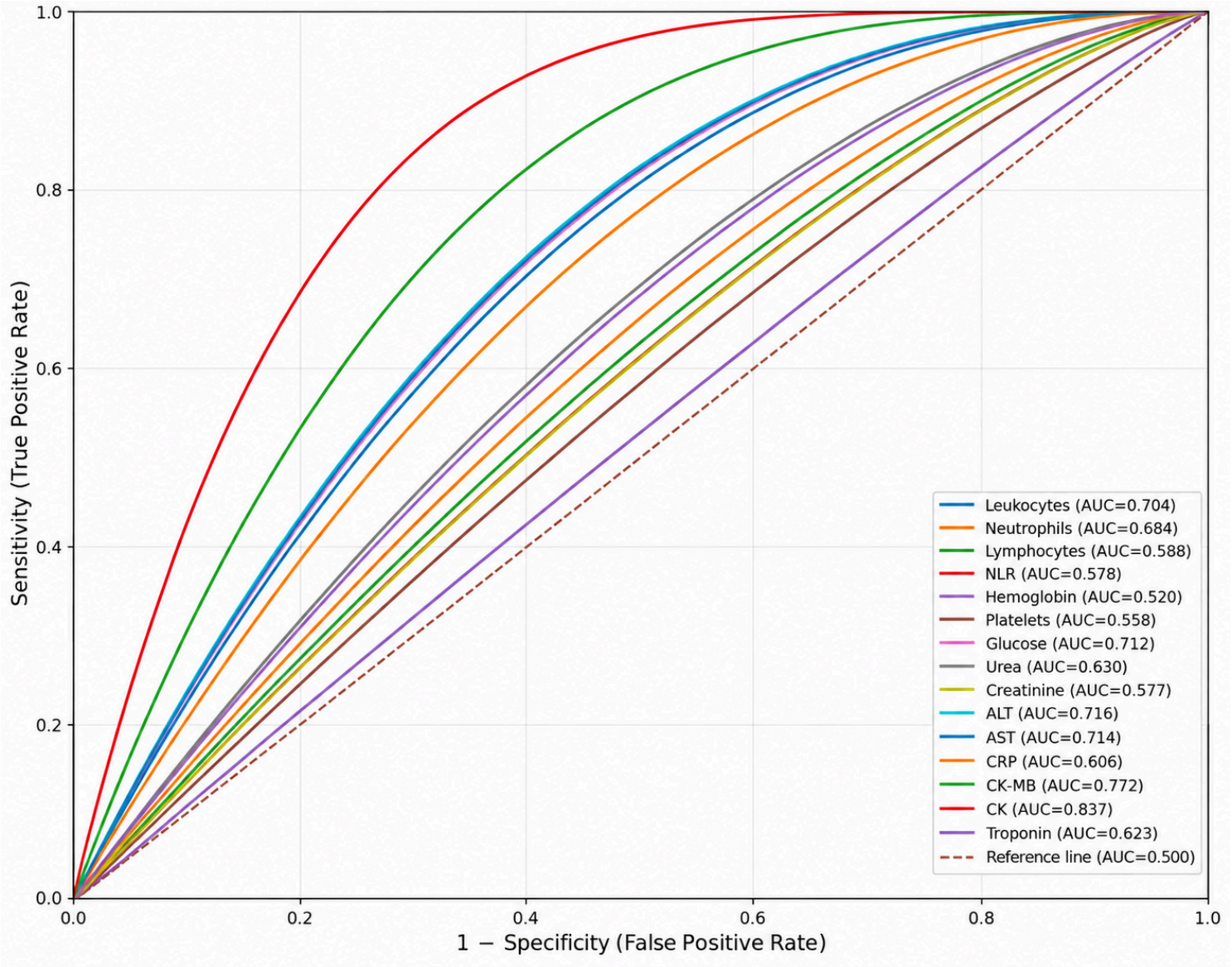

Figure 2

Receiver operating characteristic (ROC) curves of laboratory parameters for predicting the need for hospital admission or transfer among patients presenting to the emergency department following electrical injury.