

A REVIEW OF ELECTROCARDIOGRAPHY CHANGES IN ELECTRICAL BURN INJURY: IS IT TIME TO REVISE PROTOCOL?

REVUE DES ANOMALIES ÉLECTROCARDIOGRAPHIQUES APRÈS ÉLECTRISATION: VERS UN CHANGEMENT DE PROTOCOLE?

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SUMMARY. This descriptive cross-sectional study aimed to evaluate electrocardiography (ECG) changes in patients with electrical burn injury and determine their predictive extent during hospitalization. The study population consisted of all patients with electrical injury admitted to Velayat Hospital, Rasht, Iran, during 2007-2019. The ECG information of all patients assessed by a cardiologist in terms of dysrhythmic and ischemic changes at the time of admission, demographic information including age, gender, voltage, the severity and path of the current, and degree of burn were recorded in the relevant checklist. The data were analyzed using the SPSS software version 18 (IBM, USA). Out of 192 studied patients, 183 (95%) were male, and the mean age of patients was 32 years. The ECGs of 167 patients were normal (86%), 13 cases had arrhythmia (6.7%), and 12 individuals had ischemia (6.2%). Arrhythmic and ischemic abnormalities in the ECGs of patients had no predictive value during hospitalization ($P < 0.05$). Heart injury caused by electrical injury may be deadly in some cases, and it can be complicated to save the patient. Moreover, the predictive value of ECG in predicting the consequences and duration of hospitalization is weak.

Keywords: burn, electrical injuries, electrocardiography

RÉSUMÉ. Cette étude cas-témoin avait pour but d'évaluer les changements électrocardiographiques (ECG) observés chez des électrisés et leur valeur prédictive d'anomalies survenant durant l'hospitalisation. Elle concernait tous les électrisés admis à l'hôpital Velayat de Rasht (Iran) entre 2007 et 2019. Les données ECG (rythmiques et ischémiques) ont été analysées par un cardiologue. Nous avons en outre relevé l'âge, le sexe, le voltage, le trajet supposé du courant et les caractéristiques des brûlures, analysés ensuite avec SPSS 18 (IBM, USA). Cent quatre-vingt-trois (95%) des 192 patients étaient des hommes, âgés en moyenne de 35 ans. Cent soixante-sept (86%) ECG étaient normaux, 13 (6,7%) étaient arythmiques et 12 (6,2%) ischémiques, ces anomalies n'étant pas prédictives d'une récurrence durant l'hospitalisation ($p < 0,05$). Les conséquences myocardiques d'une électrisation peuvent être mortelles et il est parfois difficile de sauver le patient. Cependant, l'ECG initial ne renseigne pas sur les anomalies subséquentes éventuelles.

Mots-clés: brûlure, électrisation, électrocardiogramme

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Introduction

Nowadays, life is not possible without electricity, and consequently the damages stemming from it are inevitable. About 4% of 40,000 inpatients admitted annually to the burn centers of the United States are due to electrical injuries. This type of injury is the most extensively destructive burn injury and the leading cause of amputation due to burning.¹ Injury can occur both thermally and non-thermally because of the direct effect of electricity on cells. The severity of the injury depends on several factors, including voltage, ampere, current type, current path, contact duration, contact point resistance, and entrance. The most critical factor is voltage, divided into the two main groups of high voltage >1000 and low voltage <1000.

In low voltage cases, injury is usually limited, while in high voltage cases, severe injury is common and is like an iceberg, as injury to the skin is only the tip of the iceberg.^{1,2} The path is important in heart injuries, which are more common in the transverse type (transthoracic) path, with entry from an upper limb and exit from the other upper limb.³ Fifty percent of high voltage electrical injuries are accompanied by loss of consciousness.⁴

There are four types of electrical injury, namely actual injury due to current passage, injury due to exposure to an electric arc, injury due to a spark catching fire (flame), and thunderbolt.⁵ In acute patient care, the three following points are particularly important: “Which patients need cardiac electrocardiography (ECG) monitoring, and for how long?”; “Which patients are at risk of limb compartment syndrome and may need surgery?” and “What should the amount of fluid therapy be in cases where there is more damage to deep tissues and myoglobinuria and in cases where there is less damage to superficial tissues?” Numerous studies have shown cardiac abnormalities, including dysrhythmia and myocardial injury following electrical injuries.^{1,2,6-10} Therefore, an initial ECG is necessary to examine these patients.^{1,2,6,7}

The most common cause of death after an electric injury is heart problems, and the most common ECG abnormalities are nonspecific ST changes and dysrhythmias.^{1,6,7} According to some studies, the most prevalent dysrhythmias are sinus tachycardia, sinus bradycardia, and atrial fibrillation in some cases.¹ The

most frequent cardiac arrhythmia that leads to death is atrial fibrillation. There is also direct myocardial injury, which is more similar to myocardial injury due to trauma (bruise) and less similar to the ischemic type resulting in myocardial infarction (MI).^{1,2,6,7}

Nowadays, indications for ECG monitoring are loss of consciousness, ECG abnormality or evidence of ischemia, dysrhythmia recorded before and after hospitalization in the emergency ward, cardiopulmonary resuscitation, and patients with other normal indications. Since the establishment of Velayat Super Specialty Accident and Burn Center in 2007 as the only public burn center in Gilan province, northern Iran, no study has evaluated the consequences of electric injury in electrically injured patients admitted to the mentioned center. Therefore, the present study aimed to investigate ECG changes following an electrical injury at the beginning of hospitalization and determine their relationship with the consequence during hospitalization.

Patients and methods

The present cross-sectional descriptive study was performed on all patients with electrical injury admitted to Velayat Hospital in Rasht, Iran, during 2007-2019. All patients admitted to Velayat Super Specialty Accident and Burn Center due to electrical injury were included in the study. Theoretically, abnormal amounts of potassium can cause both rhythmic and ST changes. In addition, severe injury to soft tissue in electrical burns can be associated with increased serum potassium levels. Therefore, the potassium levels of inpatients were also checked.

The main exclusion criterion was decreased consciousness based on the Glasgow Coma Score of lower than 14 reported in the patient file before arriving at the emergency ward of Velayat Hospital. Other exclusion criteria entailed having a history of any ischemic heart disease or cardiac arrhythmias before the accident, not having an ECG at the time of admission, incomplete information in the file, and severe soft tissue injury.

We collected information related to the age, gender, voltage, hospitalization duration and ECG of all patients at admission for dysrhythmic and ischemic

changes, examined by a cardiologist using the hospital information system. The code of ethics for the present investigation was received from the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1399.313). The researchers adhered to the Helsinki Declaration, and the collected data were anonymous and remained confidential to the researcher.

All data were entered into the SPSS software version 18 and were analyzed statistically. Mean, standard deviation, frequency and relative frequency were used to describe the data. Moreover, to determine the predictive power of ECG at the time of admission, the logistic regression model with a dependent variable of mortality as an outcome and the Poisson regression model with an outcome variable of hospitalization duration and monitoring were used. After regression analysis, the graph and receiver operating characteristic (ROC) index for each of the computational regression models was calculated and plotted to determine predictive power.

Ethical approval

Ethical approval was received from the Ethics Committee of Guilan University of Medical Sciences with the ethics code of IR.GUMS.REC.1399.313.

Results

This cross-sectional descriptive study was performed on 192 patients with electrical injury admitted to Velayat Hospital in Rasht during 2007-2019 to evaluate their ECG characteristics. In this study demographic variables including age and gender, as well as ECGs of all patients at the time of admission, were collected, in terms of dysrhythmic and ischemic changes. Out of 206 patients admitted during 2007-2019, four, three, and seven cases were excluded from the study due to a history of loss of consciousness before hospitalization, a previous history of heart disease, and the absence or impairment of ECG at the time of admission or lack of sufficient information in their files, respectively.

We observed that 183 patients (95%) were male, and the mean age of patients was 32 years with a range of 1-72 years (*Fig. 1*). Among the individuals,

74.07% had academic education. Most of the electrical injuries (36.11%) occurred in summer (*Table I*). The electrical current voltage was high (more than 1000 volts) in 144 patients (75%) and low (less than 1000 volts) in 48 patients (25%). The electricity entrance in 173 (90.1%), 13 (6.7%), 4 (2.1%), and 2 (1%) individuals was the upper limbs, lower limbs, head and neck, and trunk, respectively. The electricity outlet included the trunk, lower limbs, upper limbs, as well as head and neck. It was one of the upper limbs in 43 cases (22.4%), one of the lower limbs in 54 patients (28.1%), and unknown in 95 individuals (49.4%). The potassium level in all patients was in the normal range (3.5-4.5 mmol/L). The ECGs of 167 patients were normal (86%), 13 cases had arrhythmia (6.7%), and 12 patients had ischemia (6.2%). In most individuals of both genders, the ECGs of patients with electrical injury were normal (*Table II*).

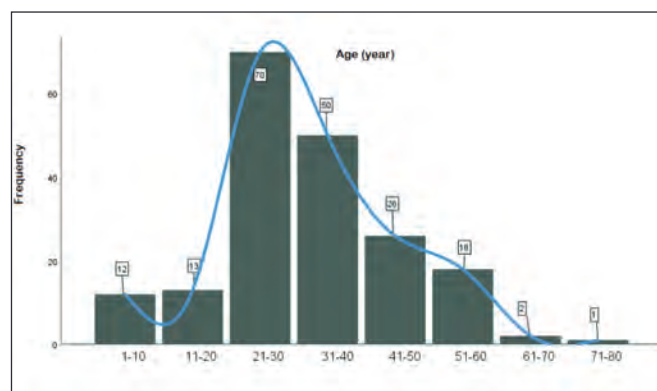


Fig. 1 - Age group distribution in electrical burns

Table I - Baseline characteristics of individuals with electrical injury

	Variable	Percent
Level of education	Academic education	74.7
	Student	3.7
	Illiterate	22.22
Job	Electrical Officer	5.56
	Electricity thief	0.93
	Electrician	25
	Other	68.52
Season	Spring	31.48
	Summer	36.11
	Autumn	23.15
	Winter	9.26

Table II - Characteristics of ECGs of patients with electrical injury by gender

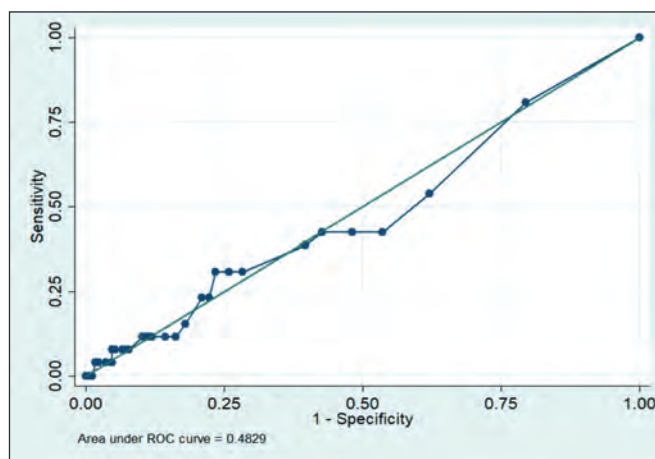
	ECG			Total
	Normal	Dysrhythmic	Ischemic	
Male	(96%) 159	13(100%)	11(91.6%)	183
Female	(4%) 8	0	1(8.3%)	9
Total	167	13	12	192

The mean duration of hospitalization in patients with normal ECG, arrhythmic ECG, and ischemic ECG was 0.66 ± 7.36 (CI=22.6-8.09), 2.3 ± 7.07 (CI=11.2-67.53), and 3.1 ± 8.2 (CI=2.63-14.1) days, respectively. Therefore, the mean duration of hospitalization in patients with ischemic ECG was longer than in other cases. The mean degree of burn in patients was 2.7 and 2.6, with no statistically significant difference between the two groups ($P > 0.05$). The mean percentage of burn was higher in patients with normal ECG than in those with dysrhythmia and ischemic changes (*Table III*).

Table III - Degree of burn by ECG

	Mean	Std. Err.	[95% Conf. Interval]
Burn degree in patients with normal ECG	2.6	0.04	2.2-7.5
Burn degree in patients with arrhythmic ECG	2.7	0.16	3.2-9.4
Burn degree in patients with ischemic ECG	2.6	0.18	3.2-3.2
TBSA in patients with normal ECG	10.3	0.91	12.8-1.5
TBSA in patients with arrhythmic ECG	6.3	1.38	9.3-1.6
TBSA in patients with ischemic ECG	6	1.5	9.2-1.8

In the regression model, the degree of burn was significantly correlated with arrhythmic and ischemic abnormalities in patients ($P = 0.04$). In contrast, voltage and percentage of burn did not affect the cardiac status of patients ($P > 0.05$) (*Table IV*). *Fig. 2* shows the ROC index for the predictive power of ECG for the consequences and hospitalization duration of patients. It indicates the weak predictive power of ECG for predicting the consequences and hospitalization duration of patients.

**Fig. 2** - The predictive power of ECG in the consequences and duration of hospitalization**Table IV** - Multivariate regression model in predicting ECG status

ECG	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
TBSA	0.31	0.37	0.8	0.405	0.42 1.05
Burn degree	-0.08	0.04	-2.03	0.043	0.16 00.002
Voltage	0.74	0.5	1.35	0.176	00.33 1.8

Discussion

The present study was performed on patients with electrical injury admitted to Velayat Hospital in Rasht during 2007-2019 to investigate their ECG characteristics. The highest prevalence of burn was in the age range of 20-30 years. Most patients developed burns with high-voltage electricity (more than 1000 volts). The order of electricity entrance prevalence was upper and lower limbs, head and neck, and trunk. It was found that in most patients the ECG was normal.

Burns are considered one of the most severe health problems throughout the world.¹¹ Electrical burn is the most destructive type of burn, usually affecting both the skin and deep tissues.¹² This type of burn mainly influences young working men and is the most common cause of amputation in burn wards. In addition to power line operators, workers at construction and crane companies are also at particular risk. Electrical burns have several acute and chronic manifestations that are not seen with other thermal injuries, such as cataracts and spinal cord

deficiency that appear later. Illnesses, duration of hospitalization, and the number of surgeries based on burn size are much more than expected.¹³

In burns due to electrical current, several factors damage the injured person, including the passage of electrical current through the body, electric arc, burn caused by sparks, and clothes catching fire.^{6,14,15} In this study, patients who were injured by any of the aforementioned mechanisms were assessed. Electrical injury is mainly caused by accidents in the workplace. In a study by Rezaei et al., the most common cause of burns was workplace accidents. In patients with high-voltage electrical burns, 60% of cases were due to climbing the electric post, and in low-voltage burns, 50% were electrical technicians. Many children also developed burns because of the rising electricity-connected main pipe, which has not been mentioned in other studies and seems specific to the studied area.¹⁶

In patients with electrical injuries, the duration of hospitalization is longer than for other burns, and especially it is considerably longer in high-voltage electrical injuries. In the present study, the duration of hospitalization in both groups with normal ECG and ischemic arrhythmia was 7 days, without a statistically significant difference, while in the study by Mehsoodi et al. the mean duration of hospitalization was 13.9 days.⁶ Rezaei et al. reported the mean duration of hospitalization was 15.2 days, with 16.5 days in high-voltage burns and 11.2 days in low-voltage cases. Hospitalization duration was not significantly different between the latter two groups.¹⁶ The duration of hospitalization in the current study was shorter than in other similar investigations, resulting from the normal ECGs of most of the patients in the present research.

Electrical injuries are much more common in young men in the community. In the present study, the mean age of patients was 32 years, and 95% were men. In other studies, the mean age of inpatients was 27.5 years, and 98.5% were male.^{7,15,17} According to Rezaei et al., 97% of the cases with electrical injuries were men with a mean age of 26 years.¹⁶ We observed that the mean age of patients was high, but the proportion of men was similar to previous studies.

Although most patients in our study had normal ECG, numerous investigations have shown cardiac abnormalities, including dysrhythmia and myocardial injury following electrical injuries.^{1,2,6-10} As a result, an initial ECG is necessary to examine these patients.^{1,2,6,7} Hosinger et al. revealed that the levels of creatine kinase and its MB form do not help predict cardiac complications in those with normal ECG.¹ In contrast, other studies have demonstrated that the increased levels of these enzymes are associated with a higher mortality rate. Regarding troponin, the studies are incomplete.^{1,2,7} Myocardial injury and dysrhythmia occur very soon after electrical injury, and the most common cause of death following an electrical injury is cardiac arrhythmia. The most common ECG abnormalities are nonspecific ST changes and dysrhythmias.^{1,6,7} The results of the present study indicated normal ECG in both genders with electrical injury. In addition, we found that most arrhythmias and ischemia cases were caused by the passage of electric current through the upper limbs and the exit of electric current from the upper limbs and trunk. Although the mean hospitalization duration in normal and abnormal ECG conditions was not significantly different in this study, the duration of hospitalization in ischemic ECG patients was longer than in other cases. In the present investigation, the mean degree of the burn was 2.6, and there was no statistically significant difference between patients with ischemic and arrhythmic ECGs and those with normal ECGs. However, the mean percentage of burns in patients with normal ECG was higher than in arrhythmic and ischemic patients.

Degree of burn was significantly related to arrhythmic and ischemic ECG abnormalities. In contrast, voltage and percentage of burns did not affect cardiac status. Consequently, arrhythmic and ischemic abnormalities in the ECGs of patients did not influence their duration of hospitalization. Bert Arnoldo et al. found that ECG was necessary for the initial examination, the most common abnormality was nonspecific ST-T changes, and the most prevalent dysrhythmia was atrial fibrillation.⁷ Barreny et al. and Arrowsmith et al. reported that all cardiac dysrhythmias occurred during admission to

the emergency ward or in the early hours after admission.¹⁸

In another study, David et al., in patients with electric injury, observed two cases of arrhythmia with clinical manifestations in cardiac monitoring as AF and regular supraventricular tachycardia improved with the vagal maneuver. The ECG was interpreted before and during hospitalization by two separate cardiologists without knowing the type of study. They stated that most cardiac arrhythmias were detected after an electrical accident in patients by ECG at the time of admission and concluded that cardiac monitoring of individuals with normal ECG was unnecessary.¹ Furthermore, Searte et al. reported brief cardiac arrhythmias (sinus tachycardia-sinus bradycardia and isolated extra systole) in patients, and no arrhythmia required intervention.¹⁰

Conclusion

Electrical burn injury is one of the problems of today's society and is accompanied by deep and extensive tissue damage. Consequently, this group of patients should be managed appropriately in terms of initial treatment measures and the required surgeries to minimize complications. On the other hand, heart problems that are caused by electrical burns can sometimes lead to death, and in some

cases it will be challenging to save the patient. Therefore, providing excellent and appropriate information through mass media can effectively reduce the number of patients and the resultant complications.

In this study, there was no significant difference between cardiac complications and the outcomes of patients with electrical injury between groups with normal ECG, dysrhythmia, or ischemia at the time of admission. As a result, paying attention to the ECG at the time of admission may not help determine the way and duration of cardiac monitoring in patients with electrical injury. In other words, the ECG at admission does not change the treatment plans for patients, and further investigation is required. It is recommended that future studies evaluate the impact of electrical burn injury on ECG changes, as well as the relationship between pre-hospital factors or the effect of factors preventing the occurrence of such accidents, which can be helpful in appropriate prevention or treatment.

According to the results of the present study, ECG at admission has no predictive value for cardiac complications. Therefore, the design and timing of cardiac monitoring based on it cannot be logical and principled. It should be noted that the current protocols for monitoring patients with electrical injury based on ECG at the time of admission should be revised.

BIBLIOGRAPHY

- 1 Herndon DN: "Total burn care", Fifth Edition, 365-380, Saunders, Elsevier, 2018.
- 2 Song DH, Neligan PC: "Plastic Surgery E-Book, Vol. 4: Trunk and Lower Extremity", 325-339, Elsevier Health Sciences, 2018.
- 3 Haddad S: Electrical burn - a four-year study. *Ann Burns Fire Disasters*, 21(2): 78, 2008.
- 4 Haisley K, Hunter J: "Schwartz's Principles of Surgery", 1: 251-70, 2019.
- 5 Tolouie M, Farzan R: A six-year study on epidemiology of electrical burns in northern Iran: is it time to pay attention? *World J Plast Surg*, 8(3): 365, 2019.
- 6 Maghsoudi H, Adyani Y, Ahmadian N: Electrical and lightning injuries. *J Burn Care Res*, 28(2): 255-61, 2007.
- 7 Arnoldo B, Klein M, Gibran NS: Practice guidelines for the management of electrical injuries. *J Burn Care Res*, 27(4): 439-47, 2006.
- 8 Pilecky D, Vamos M, Bogyi P, Muk B et al.: Risk of cardiac arrhythmias after electrical accident: a single-center study of 480 patients. *Clin Res Cardiol*, 108(8): 901-8, 2019.
- 9 Waldmann V, Narayanan K, Combes N, Jost D et al.: Electrical cardiac injuries: current concepts and management. *Eur Heart J*, 39(16): 1459-65, 2018.
- 10 Searle J, Slagman A, Maaß W, Möckel M: Cardiac monitoring in patients with electrical injuries: an analysis of 268 patients at the Charité Hospital. *Deutsches Ärzteblatt International*, 110(50): 847, 2013.
- 11 Jafaryparvar Z, Adib M, Ghanbari A, Leyli EK: Unplanned readmission after hospital discharge in burn patients in Iran. *Eur J Trauma Emerg Surg*, 45(2): 365-71, 2019.
- 12 Hunt JL, Mason Jr AD, Masterson TS, Pruitt Jr BA: The pathophysiology of acute electric injuries. *J Trauma*, 16(5): 335-40, 1976.
- 13 Lee RC: Injury by electrical forces: pathophysiology, manifestations, and therapy. *Curr Probl Surg*, 34(9): 677-764, 1997.

- 14 Maghsoudi H, Pourzand A, Azarmir G: Etiology and outcome of burns in Tabriz, Iran: an analysis of 2963 cases. Scand J Surg, 94(1): 77-81, 2005.
- 15 Arnoldo BD, Purdue GF, Kowalske K, Helm PA et al.: Electrical injuries: a 20-year review. J Burn Care Rehabil, 25(6): 479-84, 2004.
- 16 Rezaei E, Motamedoshariati M, Safari H: A study of electrical injuries in Emam Reza Burn Center of Mashhad. MJMS, 52(2): 107-12, 2009.
- 17 Bailey B, Gaudreault P, Thivierge RL: Experience with guidelines for cardiac monitoring after electrical injury in children. Am J Emerg Med, 18(6): 671-5, 2000.
- 18 Arrowsmith J, Usgaocar R, Dickson W: Electrical injury and the frequency of cardiac complications. Burns, 23(7-8): 576-8, 1997.

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Declaration of competing interests. The authors declare that they have no conflicts of interest.

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