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Epidemiology and Clinical Outcomes of Electrical Burns in a Burn Center in the North of Iran: A 10-Year Retrospective Study

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Abstract

Introduction: Electrical burns are a less prevalent type of burn injury. However, some acute and chronic complications only occur in this type of burn due to its underlying mechanisms that lead to tissue injury. This study aimed to describe epidemiological patterns of electrical burns in the north of Iran to improve the prevention and management of burns in the area.

Method: All medical records of patients who were admitted to Velayat Burn Center, Guilan University of Medical Sciences, Rasht, Iran, due to electrical burn injuries between March 2010 and March 2020 were studied retrospectively.

Results: A total of 271 patients were included in this study. Occupational accidents (59.78%) were markedly more common than non-occupational injuries (40.22%). High voltage was responsible for 44.6% of the burns. Among the clinical outcomes studied, wound infection and the need for blood transfusion were the most frequent complications, with recorded rates of 17% and 18.5%, respectively. Regarding surgical procedures, limb amputations were performed in 8.1% of patients, 9.6% of cases required a flap, and 56.1% required a skin graft. The rate of transplant rejection was 2.2%.

Conclusion: The higher incidence of occupational electrical burns in men of working age with non-academic education and the significant correlation between high voltage and worse clinical outcomes in this type of injury, compared to other types of burn injuries, indicate the need for employers to raise safety awareness in this area.

Keywords: Electrical burns, Epidemiology, Iran, Voltage.

Introduction

Burn injuries are a significant global disease burden that can be prevented and are responsible for nearly 300,000 deaths per year globally. Millions of victims also suffer from severe physical and psychological effects, mainly in developing countries, where sufficient safety measures are not implemented. According to the World Health Organization, Southeast Asia and the Eastern Mediterranean are high-risk areas. Risk factors for this type of injury include poverty, substandard infrastructure, and low levels of education[1-4].

Electrical burns comprise 5% and 27% of burn center referrals in developed and developing countries, respectively[5]. They are the fourth most common type of burns and the fourth leading cause of occupational traumatic deaths, which result in lifelong disability and a high economic burden to the individual, their family, and the community[6].

Electrical injuries are classified into three categories: high-voltage (≥1000 volts), low-voltage (<1000 volts), and lightning injuries[7]. According to previous studies, the incidence of high-voltage burns is higher than that of low-voltage ones, and the mortality rate of electrical burns widely varies between 2.35% and 26.7%, depending on the severity of the injury and the accessibility of health care facilities[5].

Devastating outcomes of the electric current result from three major underpinning mechanisms. The first one is the direct effects on body tissues, which lead to electropolarization and the electroporation of cell membranes[8]. The second one is the conversion of electrical energy into heat, which causes superficial and deep burns. The final one is a blunt mechanical injury from a lightning strike, which leads to a severe muscle contraction or fall after electrocution[9].

Treatment of high-voltage burns often includes frequent debridement, skin grafts, fasciotomies, local, free, or distant flaps, and in cases where the organ is not viable, amputation[10]. Research has shown that partial or total limb amputation is required in 35% of victims[11].

Electrocution is potentially harmful to multiple organs and tissues. Damage to internal organs might lead to cardiac arrhythmias and dysrhythmias, kidney injuries, visceral perforation, and internal bleeding[12]. Wound and deep tissue infections are also frequent among patients, and in more severe cases, long bone fractures[13] and decreased levels of consciousness tend to occur. There are also long-term complications in rescued patients, such as cataracts, neurological disorders, and psychological complications[14, 15].

This study provides a review of electrical burn prevalence in a burn center in the north of Iran over 10 years to develop evidence for better prevention and management.

Methods

The present study was a cross-sectional retrospective one conducted at Velayat Burn Center, Guilan University of Medical Sciences, Rasht, Iran.

Patient Groups and Definitions

All patients hospitalized due to electrocution between March 2010 and March 2020 who met the inclusion criteria were included in this study. Data were collected anonymously from patients' medical records in the Health Information System (HIS) and through phone interviews. The study was approved by the Research Ethics Committee of Guilan University of Medical Sciences, Rasht, Iran. A researcher-made checklist was designed as a data collection tool. Demographic characteristics, as well as information related to place of residence (urban areas or rural areas) and marital status, were collected from patients' records. The level of education and employment status at the time of injury were inquired about through phone interviews. Other data were collected from medical records in the HIS system, including place of injury (occupational or non-occupational), voltage, total body surface area (TBSA), degree of burn, social history (drug abuse, alcohol consumption, or smoking), length of hospital stay, need for mechanical ventilation, number of total surgeries, surgical procedures (skin grafts, flaps, or amputation), need for blood transfusion, infections (surgical wound infection, pneumonia, sepsis, or infection due to catheterization), cardiac complications, compartment syndrome, acute kidney injury, skin graft rejection, and patient's status at the time of discharge (complete recovery, partial recovery, death, discharged with written consent, or the need for frequent follow-ups).

Inclusion and Exclusion Criteria

All patients who were hospitalized and treated for at least one day due to electrical injuries during the period under study were included. On the other hand, patients with incomplete or distorted records or files were excluded from the analysis.

Statistical Analysis

The statistical values were recorded as mean±SD. Categorical variables were recorded as frequency and percentages. For comparisons between groups, Fisher's exact test was used for dichotomous variables, and the Chi-squared test was used for ordinal and categorical variables. All statistical analyses were two-tailed, and a P-value of <0.05 was considered statistically significant for purposes of this discussion. All analyses were performed using SPSS software (version 24.0).

Results

Over the period of 10 years under study (March 2010-March 2020), 273 patients were admitted to our center, of whom 271 were included in the study.

Study Sample and Demographic Characteristics

Out of 271 patients, 260 were male, and 11 were female (male to female ratio: 26.3:1). The mean age was 31.89±12.81, ranging from 1 to 72 years. Regarding residential areas, 79% of the patients resided in urban areas (n=214) and 21% (n=57) in rural areas. With regard to the level of education, 25.2% of patients had an academic degree. Non-occupational injuries comprised 40% of electrical burns, and the remaining 60% of cases occurred in the workplace. The prevalence of an underlying disease was 13.3% (n=36) among patients. Other characteristics are shown in Table 1.

Table 1 :Patients' demographic characteristics and past medical history.

Variables		Frequency	(%)
Gender	Female	11	4.1%
	Male	260	95.9%
Marital status	Unmarried	110	40.6%
	Married	161	59.4%
Occupation	Employee	31	11.4%
	Construction worker	46	17%
	Self-employed	113	41.7%
	Student	34	12.5%
	Child	14	5.2%
	Miscellaneous	33	12.2%
Education	Illiterate	11	30.3%
	Less than diploma	82	32.1%
	Diploma	87	22.5%
	Post-diploma	61	11.1%
	Bachelor's degree	30	4.1%
Drug abuse	Yes	44	16.2%
	No	227	83.8%
Alcohol consumption	Yes	18	6.6%
	No	253	93.4%
Smoking	Yes	61	22.5%
	No	210	77.5%
Place of injury	Non-occupational/at home	109	40%
	Occupational	162	60%
Age	Minimum	Maximum	Mean
	1	72	31.8

Burn Degree

The majority of patients (44.65%) had second- and third-degree burns simultaneously, followed by 18.08% who only had third-degree burns (Table 2).

Total Body Surface Area

The TBSA ranged from 1-90% with a mean of 10.34±12.17%.

Length of Hospital Stay

The duration of hospitalization ranged from 1-40 days, with a mean of 6.86±7.04 days.

Voltage

The frequency of high-voltage and low-voltage burns is shown in Table 2. In 23.6% of cases, concurrent flame and electrical current led to burn injuries.

Table 2:Burn degrees and electrical injuries

Variables		Frequency	(%)
Burn degree	Second	41	15.13%
	Third	49	18.08%
	Fourth	11	4.06%
	Second and third	121	44.65%
	Third and fourth	43	15.87%
	Second, third, and fourth	6	2.21%
Cause of injury	High voltage	121	44.6%
	Low voltage	86	31.7%
	High voltage and flame	32	11.8%
	Low voltage and flame	3	1.1%
	Unspecified voltage and flame	29	10.7%

The majority of patients (79.3%, n=215) were discharged with partial recovery, 26 (9.6%) were discharged but needed more medical care and frequent follow-up sessions, and 8.9% (n=24) left the hospital with their written informed consent against medical advice. The mortality rate was 2.2% (n=6). There was a significant positive correlation between high voltage and clinical outcomes, including amputation (P=0.028), the need for flap surgeries (P=0.001), skin grafts (P=0.001), blood transfusion (P=0.006), infections (surgical wound infection, pneumonia, sepsis, or infection due to catheterization) (P=0.009), cardiac complications (P=0.000), and intubation (P=0.002) (Tables 3, 4, and 5).

Table 3: Correlation between voltage and clinical outcomes

Variables		Low voltage (n=86) n (%)	High voltage (n=121) n (%)	Unspecified voltage and flame (n=29) n (%)	High voltage and flame (n=32) n (%)	Low voltage and flame (n=3) n (%)	P-Value
Mechanical ventilation	Yes	1 (1.2)	19 (15.7)	0	4 (12.5)	0	0.002*
	No	85 (98.8)	102 (84.3)	29 (100)	28 (87.5)	3(100)	
Blood transfusion	Yes	7 (8.1)	33 (27.3)	3 (10.3)	7 (21.9)	0	0.006*
	No	79 (91.9)	88 (72.7)	26 (89.7)	25 (78.1)	3 (100)	
Infection	Yes	7 (8.1)	28 (23.1)	2 (6.9)	9 (28.1)	0	0.009*
	No	79 (91.9)	93 (76.9)	27 (93.1)	23 (71.9)	3 (100)	
Cardiac complications	Yes	5 (5.8)	21 (17.4)	2 (6.9)	12 (37.5)	0	0.001*
	No	81 (94.2)	100 (82.6)	27 (93.1)	20 (62.5)	3 (100)	
Compartment syndrome	Yes	20 (23.3)	48 (39.7)	6 (20.7)	6 (18.8)	0	0.019*
	No	66 (76.7)	73 (60.3)	23 (79.3)	26 (81.3)	3 (100)	
Renal complications	Yes	13 (15.1)	21 (17.4)	3 (10.3)	8 (25)	0	0.520
	No	73 (84.9)	100 (82.6)	26 (89.7)	24 (75)	3 (100)	
Length of stay	Less than 7 days	69 (80.2)	70 (57.9)	23 (79.3)	19 (59.4)	3 (100)	0.023*
	7-15 days	9 (10.5)	29 (24)	5 (17.2)	9 (28.1)	0	
	More than 15 days	8 (9.3)	22 (18.2)	1 (3.4)	4 (12.5)	0	

Table 4: Correlation between voltage and surgical interventions

Variables		Low voltage (n=86) n (%)	High voltage (n=121) n (%)	Unspecified voltage and flame (n=29) n (%)	High voltage and flame (n=32) n (%)	Low voltage and flame (n=3) n (%)	P-Value
Skin grafts	Yes	35 (40.7)	76 (62.8)	13 (44.8)	26 (81.3)	2(66.7)	0.001*
	No	51 (59.3)	45 (37.2)	16 (55.2)	6 (18.8)	1(33.3)	
Flap surgeries	Yes	0	23 (19)	0	3 (9.4)	0	0.001*
	No	86 (100)	98 (81)	29 (100)	29 (90.6)	3 (100)	
Limb amputation	Yes	2 (2.3)	17 (14)	1 (3.4)	2 (6.3)	0	0.028*
	No	84 (97.7)	104 (86)	28 (96.6)	30 (93.7)	3 (100)	
Skin graft rejection	Yes	0	5 (4.1)	1 (3.4)	0	0	0.287
	No	86 (100)	116 (95.9)	28 (96.6)	32 (100)	3 (100)	

Table 5: Analyses of factors associated with electrical injury

Variables		Low voltage (n=86) n (%)	High voltage (n=121) n (%)	Unspecified voltage and flame (n=29) n (%)	High voltage and flame (n=32) n (%)	Low voltage and flame (n=3) n (%)	P-Value
Place of injury	Non-occupational	54 (62.8)	39 (32.2)	1 (3.4)	13 (40.6)	2(66.7)	0.001*
	Occupational	32 (37.2)	82 (67.8)	28 (96.6)	19 (59.4)	1(33.3)	
Concomitant trauma	Yes	14 (16.3)	38 (31.4)	2 (6.9)	10 (31.3)	1 (33.3)	0.016*
	No	72 (83.7)	83 (68.6)	27 (93.1)	22 (68.7)	2 (66.7)	
TBSA	0-25%	44 (51.2)	25 (20.7)	7 (24.1)	6 (18.8)	2 (66.7)	0.001*
	25-50%	20 (23.3)	25 (20.7)	9 (31)	3 (9.4)	0	
	50-75%	12 (14)	37 (30.5)	5 (17.2)	9 (28.1)	1 (33.3)	
	>75%	10 (11.5)	34 (28.1)	8 (27.7)	14 (43.7)	0	
Burn degree	Second	22 (25.6)	9 (7.4)	5 (17.2)	7 (12.5)	1(33.3)	0.004*
	Third	16 (18.6)	26 (21.5)	2 (6.9)	5 (15.6)	0	
	Fourth	6 (7)	3 (2.5)	1 (3.4)	1 (3.1)	0	
	Second and third	35 (40.7)	48 (39.7)	20 (69.0)	16 (50)	2(66.7)	
	Third and fourth	6 (7)	30 (24.8)	1 (3.4)	6 (18.8)	0	
	Second, third, and fourth	1 (1.2)	5 (4.1)	0	0	0	

Discussion

Data from around the world indicate that electrical burns account for an average of 5.8% of all burns. However, this type of burn is of particular importance due to the complications involving multiple organs and the high mortality rate[14].

In the present study, work-related electrocutions (59.78%) were more frequent than non-occupational injuries (40.22%). However, a considerable number of accidents occurred outside working environments, which might be due to low safety standards or the carrying out of technical work at home by non-professionals. Moreover, occupational injuries significantly correlated with high voltage (P=0.001), which was consistent with the findings of previous studies, including the study by Elloso et al.[15].

The mean TBSA observed in patients was 10.34±12.17%, and the most common degree of burn was second- and third-degree burns simultaneously (44.65%). Both indicators were statistically correlated with voltage in this study. The severity of electrical injuries depends on several factors, including current intensity, type of current, body tissue resistance, as well as skin moisture, and is positively correlated with the duration of exposure and the ignition of clothing[16, 17].

Overall, 17% of the studied patients suffered from a type of infection, as a major complication of burns, detected by sample collection from wound tissue, exudates, or body fluids. There was a significant correlation between high voltage and the incidence of infections (P=0.009). In some cases, the culture results were reported as negative by qualitative measures or after necessary antibiotic therapy. Numerous studies have also reported differences in qualitative and quantitative bacterial counts depending on the sampling technique, namely wound swab or biopsy culture [9].

In this study, the transplant rejection rate was relatively low (2.2%), considering the proportion of patients who needed skin grafts (56.1%), and the graft rejection rate was not correlated with voltage (P=0.287). Reddy et al. noted that skin graft rejection in the lower extremities is more common than in other body areas. Increased BMI, peripheral vascular disease, and immunosuppressive drug administration were considered risk factors in their study [18].

In a study by Elloso et al., out of 76 skin grafts, 5 (0.7%) were rejected [5]. Skin graft rejection occurs as a result of improper vascularization of the wound bed, hematoma, seroma, infection, and mechanical separation forces. In order to prevent it, proper preparation of the wound bed, homeostasis, graft placement, and appropriate dressing are required. Moreover, underlying diseases, such as diabetes, and the administration of medications, including immunosuppressive drugs, steroids, and anticoagulants, are important risk factors [19, 20]. In our survey, 36 patients (13.3%) had an underlying disease (including diabetes, hypertension, hypothyroidism, favism, a medical history of seizures, epilepsy, or psychiatric diseases). Additionally, the rates of tobacco, alcohol, and drug abuse in the present study were 22.5%, 6.6%, and 16.2%, respectively, which were previously mentioned as contributing factors for wound healing [21].

We also found a significant correlation between voltage and the need for flaps (P=0.000), grafts (P=0.000), and amputations (P=0.028). Consistent with the results of this study, in the study by Kym et al., which was conducted on 625 patients with electrical burns, in the low-voltage group (n=185), limb amputation surgery was performed on 15.6% of patients, and 17.8% of burn victims needed flaps. In the high-voltage group (n=440), the limb amputation rate was 74.7%, while 74.7% of patients needed flaps [22]. In another study by Arnoldo et al. on 700 patients with electrical burns, amputation rates were significantly higher in the high-voltage group than in the low-voltage group [23]. In the study by Srivastata et al., however, the need for reconstructive surgery (including grafts and flaps) was not statistically different between the two groups [24]. A possible explanation is that the type of reconstructive surgery will vary depending on the flap repair guidelines, the anatomical area involved, as well as the extent of damage to adjacent tissues, such as the arteries and periosteum [18].

In the present study, the renal complications rate was 16.6%, and 14.8% of patients suffered from cardiac complications (myocardial injury or arrhythmias). The results showed that there was a significant correlation between voltage and cardiac complications (P=0.000) but not renal complications (P=0.520). In a study by Arnoldo et al., complications such as cardiac arrest, arrhythmia, and renal failure were more common in the high-voltage group than in the low-voltage group [23]. Furthermore, in the study by Srivastata et al., the events of the first hours of admission, including the rise of creatine phosphokinase, myoglobinuria, and renal failure, were significantly higher in the high-voltage group than in the low-voltage group (P<0.001). Furthermore, cardiac complications (sinus tachycardia or arrhythmias) were significantly higher in the high-voltage group [24]. The overall estimate of the incidence of arrhythmias following electrocution is about 15%. Most cases are benign and can be detected in the early hours of hospital admission. However, cardiac arrest and death before reaching a hospital can occur due to asystole or ventricular fibrillation [9].

In electrical burns, rhabdomyolysis, as a result of extensive tissue necrosis, can lead to acute kidney injury in 15-50% of cases. Other risk factors include dehydration, sepsis, and acidosis [9]. High voltage, cardiac arrest before hospitalization, full-thickness burns, and compartment syndrome are among the predictor factors of acute renal impairment in patients with electrical burns [25].

In this study, 18.5% of patients needed blood transfusions, which was significantly correlated with high voltage (P=0.006). Anemia occurs in more than 10% of burn victims during the first two weeks after injury, mainly due to blood loss from the burned area, dilution following resuscitation, concomitant traumatic injuries, and multiple surgeries [26]. In later stages, anemia worsens due to frequent dressing changes, venous blood extravasation, malnutrition, and reduced erythropoiesis. According to previous studies, 75% of patients with TBSA of more than 20% need to receive packed red blood cells [27]. Since several factors evaluated in our study, including some demographic characteristics and clinical outcomes, affected the need for blood transfusions, the blood transfusion rate was consistent with other findings in this study.

Conclusion

This study provides an overview of electrical injuries in a 10-year period from 2010 to 2020 in a major burn center in the north of Iran. Most of the patients were men of working age without academic education, and a significant number of cases were occupational accidents due to high voltage. Most of the patients lived in urban areas. There was a significant correlation between high voltage and the burn outcomes studied. In this study, deaths following electrocution at the site of the accident were not reported due to the fact that those cases were not referred to our tertiary care center. Therefore, more studies are needed to elucidate electrical burn mortality rates in this region. Nonetheless, this study illustrated an epidemiological pattern that highlights the most common complications of electrical injuries for our health system to be notified of. This pattern also could be used for the purpose of raising safety standards by our electrical industrial sector managers.

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Conflict of Interest Disclosures

None to declare.

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Authors' Contributions

A.K. collected data, prepared the data for analysis, and wrote the manuscript. M.M. developed the idea and revised the manuscript. R.Z. performed the statistical analysis. All the authors reviewed the results and approved the final version.

Ethical Statement

The study protocol was consistent with the ethical principles of the Helsinki Declaration and was approved by the Research Ethics Committee of Guilan University of Medical Sciences, Rasht, Iran, with the ethical ID: IR.GUMS.REC.1399.534.

References

1. Al-Shaqsi S, Al-Kashmiri A, Al-Bulushi T. Epidemiology of burns undergoing hospitalization to the National Burns Unit in the Sultanate of Oman: A 25-year review. *Burns*. 2013;39(8):1606-11.

2. Nnabuko R, Ogbonnaya I, Otene C, Ogbonna U, Amanari O, Opara K. Burn injuries in Enugu, Nigeria-aetiology and prevention. A six-year retrospective review (January 2000-December 2005). *Ann Burns Fire Disasters*. 2009;22(1):40.

3. Oladele A, Olabanji J. Burns in Nigeria: a review. *Ann burns fire disasters*. 2010;23(3):120.

4. Sarbazi E, Yousefi M, Khami B, Ettekal-Nafs R, Babazadeh T, Gaffari-Fam S. Epidemiology and the survival rate of burn-related injuries in Iran: a registry-based study. *Ann Burns Fire Disasters*. 2019;32(1):3.

5. Elloso MS, Cruz JJV. A review of electrical burns admitted in a Philippine Tertiary Hospital Burn Center. *Burns Open*. 2017;1(1):20-4.

6. Najmi Y, Kumar P. A retrospective analysis of electric burn patients admitted in King Fahad Central Hospital, Jizan, Saudi Arabia. *Burns Open*. 2019;3(2):56-61.

7. Karimi H, Momeni M, Vasigh M. Long term outcome and follow up of electrical injury. *Journal of Acute Disease*. 2015;4(2):107-11.

8. Schulze C, Peters M, BaumgΔrtner W, Wohlsein P. Electrical Injuries in Animals: Causes, Pathogenesis, and Morphological Findings. *Vet Pathol*. 2016;53(5):1018-29.

9. Pinto DS, Clardy PF, Moreira ME. Environmental and weapon-related electrical injuries. *Up to Date* (http://www. u*ptodate.com/contents/environmental-and-weapon-related-electrical-injuries*. 2016:1-112.

10. Tondineli T, Rios J, Candelario K, Ribeiro R, Junior L, Freitas M. High-voltage electrical burns: five-year epidemiological analysis and updated surgical treatment. *Revista Brasileira de Cirurgia Pl6stica*. 2001;31(3):380-4.

11. Singerman J, Gomez M, Fish JS. Long-term sequelae of low-voltage electrical injury. *J Burn Care Res*. 2008;29(5):773-7.

12. Waldmann V, Narayanan K, Combes N, Jost D, Jouven X, Marijon E. Electrical cardiac injuries: current concepts and management. *Eur Heart J*. 2018;39(16):1459-65.

13. Stueland DT, Stamas P, Jr., Welter TM, Cleveland DA. Bilateral humeral fractures from electrically induced muscular spasm. *J Emerg Med*. 1989;7(5):457-9.

14. Chudasama S, Goverman J, Donaldson JH, Van Aalst J, Cairns BA, Hultman CS. Does voltage predict return to work and neuropsychiatric sequelae following electrical burn injury? *ANN PLAST*. 2010;64(5):522-5.

15. Latifi N-A, Karimi H. Acute electrical injury: A systematic review. *Journal of Acute Disease*. 2017;6(3):93.

16. Karamanli H, Akgedik R. Lung damage due to low-voltage electrical injury. *Acta Clin Belg*. 2017;72(5):349-51.

17. Duggirala P, Sarabahi S, Tiwari V, Annapareddy SNR. To Study the Incidence of Electrical Contact Burns and To Evaluate the Pattern of Injury in a Tertiary Burn Care Centre.

18. Reddy S, El-Haddawi F, Fancourt M, Farrant G, Gilkison W, Henderson N, et al. The incidence and risk factors for lower limb skin graft failure. *Dermatol Res Pract*. 2014;2014.

19. Rowan MP, Cancio LC, Elster EA, Burmeister DM, Rose LF, Natesan S, et al. Burn wound healing and treatment: review and advancements. *Crit Care*. 2015;19:243.

20. Leon-Villapalos J, Dziewulski P, Jeschke MG. Skin autografting. *Up To Date*. 2020.

21. Avishai E, Yeghiazaryan K, Golubnitschaja O. Impaired wound healing: facts and hypotheses for multi-professional considerations in predictive, preventive and personalised medicine. *Epma j*. 2017;8(1):23-33.

22. Kym D, Seo D, Hur G, Lee J. Epidemiology of electrical injury: differences between low-and high-voltage electrical injuries during a 7-year study period in South Korea. *Scandinavian journal of surgery*. 2015;104(2):108-14.

23. Arnoldo BD, Purdue GF, Kowalske K, Helm PA, Burris A, Hunt JL. Electrical injuries: a 20-year review. *J Burn Care Rehabil*. 2004;25(6):479-84.

24. Srivastava S, Patil A, Bedi M, Tawar R. Paediatric electrical burn injuries: experience from a tertiary care burns unit in North India. *Ann Burns Fire Disasters*. 2017;30(3):185.

25. Rosen CL, Adler JN, Rabban JT, Sethi RK, Arkoff L, Blair JA, Sheridan R. Early predictors of myoglobinuria and acute renal failure following electrical injury. *The Journal of emergency medicine*. 1999;17(5):783-9.

26. Pham TN, Gibran NS. Thermal and electrical injuries. *Surg Clin North Am*. 2007;87(1):185-206, vii-viii.

27. Koljonen V, Tuimala J, Haglund C, Tukiainen E, Vuola J, Juvonen E, et al. The use of blood products in adult patients with burns. *Scandinavian Journal of Surgery*. 2016;105(3):178-85.