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Epidemiology of pediatric electrical injuries of a tertiary city hospital in Istanbul: Five years of experience

Yakup Çağ[1], Mehmet Tolga Köle[1], Aydan Erdem[1], Kemal Pişmişoğlu[1], Ufuk Yükselmiş[2], Fatih Çiçek[1], Murat Dereli[3], Feyza Esen[4], Yasemin Akın[1]
[1] Department of Pediatrics
[2] Department of Pediatric Intensive Care
[3] Department of Pediatric Surgery
[4] Department of Pediatric Emergency, University of Health Science, Kartal Dr. Lütfi Kırdar City Hospital, Istanbul, Turkey

Abstract

Aim: Despite being preventable with simple measures, electrical injuries are a significant public health issue that can lead to high morbidity and, rarely, death. In this study, the aim was to evaluate the demographic, laboratory, and clinical characteristics of children who presented to our emergency department with electrical injuries, as well as the associated complications.

Material and Methods: Electrical injuries were divided into two groups based on the type of voltage, and the recorded data were compared between these two groups.

Results: A total of 146 patients were included in the study, with 97 of them being male. 62.3% of the patients were under the age of 5. Electrical injuries frequently occurred at home (74.7%) and were often associated with electrical outlets (63.7%). One patient died. Surgical intervention was performed in 15 patients. We identified burns in 83 patients due to electrical accidents. Among the patients, 71 had low-voltage injuries, and 12 had high-voltage injuries. There was a statistically significant difference in burn severity based on voltage status. High-voltage injuries were associated with statistically higher levels of leukocytes, neutrophils, creatine kinase, aspartate aminotransferase , alanine aminotransferase, and creatinine compared to low-voltage injuries. A positive correlation was observed between creatine kinase levels and the total length of hospital.

Discussion: The frequency of high-voltage injuries increased with age, and these patients experienced more severe burns, greater tissue trauma, and required more surgical interventions. To minimize the occurrence of such cases, it is crucial to educate families and implement legal measures by governments.

Keywords

Electrical Injury, Voltage, Burn, Children, Precaution

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Corresponding Author: Yakup Çağ, Department of Pediatrics, University of Health Science, Kartal Dr. Lütfi Kırdar City Hospital, Istanbul, Turkey.
E-mail: yakupcag@hotmail.com P: +90 542 311 88 53
Corresponding Author ORCID ID: https://orcid.org/0000-0002-3855-7280
Other Authors ORCID ID: Mehmet Tolga Köle, https://orcid.org/0000-0002-6055-7746 · Aydan Erdem, https://orcid.org/0000-0001-8541-4699
Kemal Pişmişoğlu, https://orcid.org/0000-0001-7278-309X · Ufuk Yükselmiş, https://orcid.org/0000-0003-1150-2586 · Fatih Çiçek, https://orcid.org/0000-0001-7348-7081
Murat Dereli, https://orcid.org/0000-0002-4433-8922 · Feyza Esen, https://orcid.org/0000-0003-0759-2646 · Yasemin Akin, https://orcid.org/0000-0002-7618-7778
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Introduction

Despite being preventable with simple safety measures, electric injuries (EIs) remain a significant public health issue with high morbidity and, in rare cases, even mortality [1]. Children consitute 20% of the patients presenting to emergency clinics due to EIs [2]. It has been noted that EIs are more commonly seen in boys than girls among children [1, 3, 4]. In studies, EIs have been classified as high-voltage (HV), low-voltage (LV), or lightning injuries [5, 6]. A HVI is defined as contact with a power source delivering 1000 V or more, while a LVI occurs when the power source bears less than 1000 V [7, 8].

The severity of EIs depends on factors such as the magnitude of voltage, intensity, pathway, current type, duration of contact, resistance of tissues at the point of contact, and individual characteristics [8, 9]. In LVI, burns are typically more superficial, and muscle damage is rare. In HVI, life-threatening cardiac arrhythmias can occur, leading to organ loss due to deep burns and compartment syndrome, kidney failure resulting from muscle destruction, multiple organ failure, and even life-threatening respiratory arrest [10].

The fact that the majority of EIs in children occur accidentally and are preventable highlights the importance of epidemiological data [11]. Nischwitz et al. [12] reported a decline in EIs with education and implementation of necessary precautions.

Our study aims to evaluate the demographic, laboratory, and clinical characteristics of patients who present to our pediatric emergency clinic with EIs, assess the associated complications, and describe the features and outcomes of these EIs.

Material and Methods

Medical records of patients under 18 years who presented to the Emergency Clinic with EIs at our hospital between June 2016 and June 2021 were reviewed retrospectively. The study was conducted following the Helsinki Declaration. Because of the retrospective nature of the study, signed informed consent was not obtained from patients' families. Patients initially treated at other hospitals, those who were admitted for reconstructive surgery later, and those with missing data were excluded from the study. A total of 146 pediatric patients with EIs were included in our study.

The diagnosis of EI was determined based on the patient's history and physical examination. Patients were placed under observation and received fluid resuscitation, burn and wound dressing, EKG, cardiac monitoring, and tetanus prophylaxis as needed. Patients were discharged after following up in the emergency room or admitted to the ward or intensive care unit, which is required depending on their clinical condition. Patients diagnosed with compartment syndrome during follow-up underwent immediate escharotomy or fasciotomy. First-degree and superficial second-degree burns were managed with dressings. The necrotic tissues were debrided, and skin grafts were applied in cases of deep second-degree and third-degree burns. In instances of extensive muscle necrosis, limb amputation was performed.

In our study, the demographic data of patients, causes of damage, location and extent of EI, type of electrical current, laboratory investigations, EKG, length of hospital stay, and clinical outcomes were recorded and evaluated in an Excel file. EIs were classified into two groups based on the type of current: HVI (>1000 volts) and LVI (<1000 volts). The recorded data were compared between these two groups.

Statistics

The data were analyzed using the statistical package program IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, New York, USA). Descriptive statistics were presented as the number of units (n), percentage (%), mean ± standard deviation (mean ± SD), median (M), minimum (min), and maximum values. The normality of numerical variables was assessed using the Shapiro-Wilk normality test. Hematological values were compared between the (LV) and (HV) groups using the Mann-Whitney U test. Age and gender comparisons between voltage groups were performed using Fisher's exact test. Subgroup comparisons for age were conducted using the Bonferroni-corrected two-sample z-test. The relationship between creatine kinase (CK) and length of hospital stay was evaluated using Spearman's correlation coefficient. A p-value of less than 0.05 was considered statistically significant.

Ethical Approval

This study was approved by the Ethics Committee of Istanbul Kartal Dr. Lütfi Kırdar City Hospital (Date: 2022-02-22, No: 2022/514/220/15).

Results

A total of 146 patients presented to our emergency clinics with EIs, and 62.3% (n=91) of patients were preschool-aged (0-5 years), 22.6% (n=33) were school-aged children (6-12 years), and (15.1%) patients (n=22) were adolescents (13-18 years). The incidence of EIs was higher in males (66.4%, n=97) compared to females. EIs occurred frequently at home (n=109; 74.7%) and were frequently associated with contact with electrical outlets (63.7%, n=93) . Among the patients, 91.1%(n=133) were exposed to LV and 8.1% (n=13) to HV. Upper extremities were the most common entry site of the electrical current (83.6%, n=122), followed by the lower extremities (8.9%, n=13.) During EKG monitoring, sinus tachycardia was observed in 4 patients, where non-specific EKG changes were noted in 1 patient. While 36 patients were admitted to the burn unit, 18 patients were admitted to the intensive care unit. One patient died during the follow-up period (Table.1). Surgical intervention was performed in 15 patients (10.3%) following EIs. A total of 5 patients received debridement and subsequent flap surgery to the fingers (all patients), the lip (one patient), the upper extremity (one patient), and the thigh regions (one patient.) Also, four patients underwent escharotomies on the thigh, and two patients underwent escharotomies on the upper extremity, where one patient with extensive necrotic areas required finger amputation.

We detected burn injuries related to electrical accidents in 83 patients (56.8%), and 71 patients (85.5%) were exposed to LV, while 12 patients (14.5%) were to HV. Among the patients, 54 had 1. degree burns, 14 had 2. degree burns, and 15 had 3. degree burns. A statistical difference was found in terms of burn severity based on the voltage status (p <0.001) (Table.1).

A statistical difference was found in age group distribution based on voltage status. (p=<0.001) (Table 2). The number of 0-5 year old patients in the LV group was statistically higher

Table 1. Demographic data in electrical injury

Variables	n	%
Age groups (year)		
0-5 years	91	62.3
6-12 years	33	22.6
13-18 years	22	15.1
Gender		
Male	97	66.4
Female	49	33.6
Place the injury happened, n (%)		
In the garden	5	3.4
At home	109	74.7
At the workplace	6	4.1
School and kindergarten	5	3.4
Open public areas	21	14.3
Electrical appliance, n (%)		
Electric cable	35	24.0
Electric socket	93	63.7
High voltage line	11	7.5
Others	7	4.8
Voltage, n (%)		
Low voltage	133	91.1
High voltage	13	8.9
Body part, n (%)		
Upper extremity	13	8.9
Lower extremity	122	83.6
Head–Face	5	3.4
Others	6	4.1
Burn degree (n=83)		
1.degree	54	65.1
2.degree	14	16.9
3.degree	15	18.1
Surgery, n (%)		
Yes	15	10.3
No	131	89.7
Emergency service ending, n (%)		
Discharged	92	63.0
Ward	36	24.7
Intensive care unit	18	12.3
Length of hospital stay, day (n=54)	4 (1-84)	
Hospitalization ending, n (%) (n=54)		
Ex	1	1.9
Discharged	53	92.6

n: number of patients, %: percentage, *Median (min-max) values are provided

Table 2. Comparison of gender and age groups according to voltage status

	Low n=133	High n=13	Test value	p
Age groups, n (%)				
0-5	89 (97.8)a	2 (2.2)^{b}		
6.Ara	29 (87.9)ab	4 (12.1)^{ab}	16.635	<0.001†
13-18	15 (68.2)b	7 (31.8)^{b}		
Gender, n (%)				
Male	85 (87.6)	12 (12.4)	4.283	0.061†
Female	48 (98.0)	1 (2.0)		

n: Number of patients, %: Row percentage, †: Fisher exact test, and a and b superscripts indicate the difference between age groups in the same column. Groups with the same superscripts do not show statistically significant differences

than the 13-18 year old group. In the HV group, the number of patients in the 13-18 age group was statistically more than the 0-5 age group. The incidence of HVI increased with age. According to Table 3, we observed that the patients in the HV group have statistically more elevated levels of leukocytes (WBC), neutrophils, CK, aspartate aminotransferase (AST), alanine aminotransferase (ALT), and creatinine compared to the patients in the LV group. Additionally, a positive correlation was observed between CK levels and the total length of hospital stay (rho=0.395; p=0.003).

Discussion

EIs can cause minor tissue injuries at the entry and exit points as well as life-threatening severe tissue damage [4]. The severity of electrical damage varies depending on the magnitude of the current, the resistance of the body, the path of the current through the body, and the duration of contact with the current source [13]. While EIs are more frequently observed in developing countries, a study reported an annual EI rate of 17.5% in Kosovo, 3% in the United States, 3-5% in China, and 3% in Europe [14].

Studies have emphasized that in children, EIs leading to emergency department visits are more common in boys under the age of 5 [1, 5, 15]. In a study conducted in Turkey by Özdel et al. [10] 74% of the patients presenting to the emergency clinic with EIs were male. In a study by Buja et al. [14] in Kosovo involving 182 patients, 93% of patients were male, while in another study conducted in Austria, 74.1% were male. [16]. Consistent with the literature, our study also revealed a higher incidence of EIs in males (n = 97; 66.4%) compared to females. We believe that the greater interest of male children in electrical and electronic devices may contribute to these injuries.

EIs are more commonly seen between the ages of 4.5 and 8.7 [5, 10, 15]. In our study, the average age was 5.11 years, and in line with the literature, 91 patients (62.3%) were under five years old [10, 17]. Taking domestic precautions during the preschool period, when children have excessive curiosity and a desire to explore, supporting parents with education on this issue, and enforcing legal standards are crucial in preventing EIs. Young children are typically exposed to LVI by coming into contact with electrical cables or electrical outlets. On the other hand, older children may develop EIs by coming into contact with HV power lines in the workplace or industrial electrical currents [17]. Consistent with the literature, our study found that LVI primarily affected preschool and school-aged children, while HVI were also more prevalent among adolescents. In our study, 74.7% of EIs occurred at home, and 63.7% occurred in young children following contact with electrical outlets.

We predominantly observed LVI (91.1%) in our study. Çağlar et al. [1] study in Turkey reported that 92.1% of the cases had LVI. Furthermore, this study revealed that 86.8% of EIs occurred at home, with electrical outlets accounting for 39.5% of the cases. Although EIs constitute approximately 4% of total admissions to burn centers, they are associated with high morbidity and mortality rates [4]. They are the leading cause of amputations performed in burn centers [8]. In our study, we observed electrical burns in 83 patients (56.8%). Among them, 71 patients (85.5%) were exposed to LV, while 12 patients (14.5%) were to HV. We

Table 3. Comparison of blood values according to voltage status

	Low Voltage		High Voltage		Test Statistics	
	±sd	M (min-max)	±sd	M (min-max)	z	p
WBC	9.82±2.95	9.20 (5.00-21.00)	15.86±6.88	12.80 (8.70-29.40)	3.505	<0.001
NEUTROPHILS	4.22±1.84	4.00 (0.00-10.50)	12.95±6.92	10.60 (2.40-25.70)	4.859	<0.001
PLT	328.8±93.6	313.0 (37.0-612.0)	326.8±170.4	304.0 (98.0-747.0)	0.374	0.708
MPV	8.04±1.10	7.90 (5.90-11.20)	8.28±1.01	8.10 (6.80-10.40)	0.883	0.377
CK	179.0±161.2	152.0 (40.0-1174.0)	5704.4±13810.1	830.5 (150.0-48100.0)	4.751	<0.001
LDH	283.5±54.3	280.0 (155.0-447.0)	442.8±339.6	361.0 (208.0-1315.0)	1.884	0.060
GLUCOSE	97.22±15.58	95.00 (67.00-169.00)	106.54±54.25	94.00 (62.00-282.00)	0.158	0.874
AST	31.54±7.99	31.00 (10.00-52.00)	124.46±233.00	49.00 (19.00-889.00)	2.302	0.021
ALT	16.83±5.67	16.00 (8.00-49.00)	46.62±60.61	24.00 (10.00-238.00)	3.029	0.002
UREA	24.56±7.95	24.50 (6.00-45.00)	21.69±8.93	23.00 (6.00-33.00)	0.939	0.348
CREATININE	0.59±2.68	0.32 (0.15-31.00)	0.56±0.20	0.57 (0.31-0.88)	3.550	<0.001
TROPONIN	0.01±0.01	0.00 (0.00-0.08)	0.07±0.19	0.01 (0.00-0.70)	1.621	0.105

: average, sd: Standard deviation, M: Media, z: Mann-Whitney U test

observed third-degree burns in 10 patients who had HVI. In our study, a statistical difference was found in terms of burn severity according to the voltage status (p=<0.001). Another study conducted in our country, based on eight years of data, yielded similar results to our study, indicating that HVI resulted in more profound and broader burn areas compared to LVI [18]. Lack et al. [5] reported similar findings, highlighting larger burn areas with HVI in South Africa. In HVI, patients underwent more surgical interventions, amputations, and flap surgeries, resulting in prolonged hospital stays [19]. Compartment syndrome can develop in the extremities as a consequence of EIs. Early escharotomy/fasciotomy should be performed to prevent amputations and achieve decompression [4]. In our study, one patient underwent amputation, and six underwent escharotomy as a preventive measure against compartment syndrome.

Electric current can lead to injuries in specific organ systems, including cardiac arrhythmias, skin injuries, rhabdomyolysis, and acute kidney injury [5]. Maghsoudi et al. [20] have noted that renal failure can develop in these patients due to the deposition of myoglobin and cellular fragments as a result of severe damage to deep tissues and muscles. Rapid and aggressive resuscitation, fluid support therapy, and urine alkalization have prevented renal failure. Furthermore, studies have indicated long-term complications following EIs include cataracts, transverse myelitis, amyotrophic lateral sclerosis, post-traumatic stress disorder, depression, and psychological and neurological disorders [21, 22]. After EIs, EKG changes such as sinus tachycardia, non-specific ST changes, heart blocks, prolonged QT interval, supraventricular-ventricular arrhythmias, and atrial fibrillation are commonly observed, while asystole and ventricular fibrillation are the life-threatening consequences of EIs [23]. Studies have emphasized that tissue damage increases as the voltage exposure increases [10]. Following up on patients with EIs for 24-hour cardiac monitoring as a standard practice is no longer recommended. Research has indicated that even in cases with HV current, patients with stable heart rhythm and no risk factors do not require cardiac monitoring during the 24 hours following the injury [20]. We did not observe significant cardiac damage or rhythm abnormalities during the monitoring. While passing through the pathway, electrical current can cause damage to deep tissues, leading to elevated levels of particular laboratory markers. Yılmaz et al. [24] found significantly higher levels of CK, CK-MB (creatine kinase myocardial band), AST, and ALT in patients with HVI compared to those with LVI, suggesting that these parameters could serve as indicators of tissue damage. Another study conducted in Turkey also reported significantly higher levels of CK, CK-MB, AST, and ALT in patients exposed to HV compared to those exposed to LV [10]. Additionally, markers of rhabdomyolysis, such as myoglobin and CK, have been associated with injury severity, amputation rate, and mortality [18]. Shih et al. [25] in a comprehensive study encompassing 41 studies and 5,485 patients worldwide, reported that patients presenting with HVI had prolonged hospital stays, more EKG changes, and a higher incidence of myoglobinuria and kidney failure. We observed that the levels of CK, AST, ALT, and creatinine in the HV group were statistically higher than those in the LV group in our study. Additionally, a positive correlation was observed between CK levels and the total length of hospital stay (p=0.003).

Limitation

It is a single-center and has a retrospective nature. Also, we could not assess long-term morbidity, neurological sequelae, psychological impact, and social adaptation issues following EIs. However, Having 5 years of data from our hospital, which is one of the major burn centers in the region, is a strong aspect of our study.

Conclusion

EIs continue to be a grave concern in children. They range from minor injuries to life-threatening multiple organ injuries. In our study, when considering the age groups, EIs were predominantly observed in the home environment and among boys aged ≤5 years. It is crucial to address them as a public health concern and design national strategies to reduce EIs. Preventative measures and regular education programs for families and children play a significant role in preventing EIs.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or compareable ethical standards.

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Conflict of Interest
The authors declare that there is no conflict of interest.

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