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Clinical Effects of Voltage Difference and The Factors Affecting Mortality in Electrical Injuries

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Abstract

Background: *The objective of this study is to examine electrical injuries according to high and low voltages and to investigate the factors affecting mortality.*
Methods: *In this study, 370 patients presented with electrical injuries were retrospectively examined. Data in this study included age, gender, cause of electric shock, type of electric shock, electric voltage, falling down from height, burn degree, total burn surface area (TBSA), organ injuries, Glasgow Coma Score (GCS), serum enzymes, creatine kinase- myocardial band (CK-MB), troponin T), developing complications and cardiac arrhythmias. These parameters were compared in terms of low/high voltage electrical injuries and mortality. P values ≤0.05 were considered statistically significant.*
Results: *The mean age was found as 25.81±14.41 (range 1-80, median 24) years. Of the participants, 301 (%81.4) were male and 69 (%18.6) female patients. Gender, occupational accident, burn percentage, burn degree, falling from height, Glasgow Coma Score (GCS), enzymes and complications were significant in terms of low-high voltage difference (p<0.05). In the present study; suicide, the difference of low-high voltage, 3rd degree burn, low GSC and elevation of LDH, ALT, AST, CK and troponin enzymes were the factors affecting mortality (p<0.05). Among the complications; rhabdomyolysis, hyperkalemia, metabolic and respiratory acidosis, pulmonary hemorrhage and edema were found as the factors influencing mortality (p<0.05).*
Conclusion: *To distinguish electrical injury according to low-high voltage difference at the time of first presentation is important in determination of prognosis and mortality. Furthermore suicide cases, 3rd degree burns and elevated levels of LDH, ALT, AST, CK and troponin T enzymes are important in order to predict mortality.*
Key Words: Electrical injury; low voltage; high voltage; mortality.

Introduction

Electricity is an indispensable energy used widely in all areas of our everyday life. Although more infrequently seen, electrical injury is a trauma causing significant damage [1]. In electrical injuries, several factors determine the harmful impact on human body including voltage, current, current type (alternating current, direct current), frequency of current, resistance of the affected tissue against electricity, exposure time and the pathway through which electric current passes through the tissues [2]. Electrical injuries are classified as high-voltage (>1000V), low-voltage (<1000V), lightning strike and electrical arc injuries [3]. High-voltage electrical injuries are important

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prognostic factor that lead to severe damage on the organs and systems of the body, causing complications [1]. Electrical injuries may be a crucial cause of morbidity by prolonged length of stay in hospital, increased need in intensive care and prolonged return to social activities and work secondary to hypertrophic scars and contractures. Electrical injuries may cause mortality by 3% to 15% [4].

The objective of this study is to examine electrical injuries according to high and low voltages and to investigate the factors affecting mortality.

Materials and Methods

This study was conducted by retrospective investigation of the files of 370 patients who have admitted to Dicle University Medical Faculty Emergency Department between January 2010 and September 2014 due to electrical injuries. First intervention to the patients was carried out at the time of presentation by emergency department. All the patients received fluid therapy, monitorization, burn care, analgesia, tetanus prophylaxis, escharotomy and faciotomy depending on the indication and were resuscitated according to the ATLS (Advanced Trauma Life Support) program. Patients in a good condition after the firts 12-hour follow-up were discharged. The other patients were hospitalized in burn unit clinic or intensive care for treatment and follow-up. Patients with missing data and those having lightning strike were excluded from the study.

Data in this study included age, gender, cause of electric shock, type of electric shock, electric voltage, falling down from height, burn degree, total burn surface area (TBSA), length of stay in hospital, organ injuries, Glasgow Coma Score (GCS), serum enzymes (alanine aminotransferase (ALT), aspartate aminotransferase (AST), lactate dehydrogenase (LDH), blood creatine kinase (CK), creatine kinase-myocardial band (CK-MB), troponin T), developing complications and cardiac arrhythmias. These parameters were compared in terms of low/high voltage electrical injuries and mortality.

Statistical analysis

Statistical analysis of the study was performed using “SPSS 18.0 for Windows” statistical software. Quantitative variables are expressed as mean ± standard deviation (SD) and categorical variables are presented as number and percentage (%). Data were analyzed for normality. Comparison of two groups with normal distribution was made using independent t tes. Mann Whitney U Test was used for comparison of two groups with non-normal distribution. Comparison of qualitative variables between the groups was carried out utilizing Chi-square ($\chi2$) test. The hypotheses used were two-sided and p values ≤ 0.05 were considered statistically significant.

Results

A total of 197847 patients presented to Dicle University Hospital Emergency Department between January 2010 and September 2014. Of these patients, 39484 have traumas with 380 of them being electrical injuries. The mean age was found as 25.81±14.41 (range 1-80, median 24) years. Of the participants, 301 (81.4%) were male and 69 (18.6%) female patients.

In our study, 148 (40%) patients have high-voltage and 222 (60%) low-voltage electrical patients. The mean age was found as 26.43±15.58 (range 2-80, median 25) in patients with low-voltage electrical injury and 24.55±12.63 (range 1-56, median 23) in patients with high-voltage electrical injuries. In this study, the mean TBSA was found as 7.5±11,19 (range 0-70, median 2) in all patients, while this value was found as 3.36±6.91 (range 0-55,median 1) in patients with low-voltage electrical injuries and 13.64±13.36 (range0-70, median 10) in those having high-voltage electrical injuries. Fifty-five of the patients fell down from height with 4 of them died and 51 patients survived. The mean height of fall was found as 3.073±2.14 m (range 1m-10m, median 3m) in the cases of falling from height. Among these cases, 23 (41.8%) were low-voltage and 32

(58.2%) high-voltage electrical injuries. Gender, occupational accident, burn percentage, burn degree, falling from height, Glasgow Coma Score (GCS), enzymes and complications were significant according to low and high-voltage difference ($p<0.05$). Clinical findings in terms of low and high-voltage difference are shown in Table 1.
In the present study, 19 (5.1%) patients died and 351 (94.9) survived. The factors affecting mortality are given in Table 2. In the present study; suicide, low-high voltage difference, 3rd degree burns, a low GCS and increases in LDH, ALT, AST, CK and troponin T enzymes were the factors affecting mortality ($p<0.05$). Among the complications; rhabdomyolysis, hyperkalemia, metabolic and respiratory acidosis, pulmonary hemorrhage and edema were the factors influencing mortality ($p<0.05$).

Table1: Relationship between voltage difference and clinical findings in electrical injuries.

Character	High voltage(n:148)	Low voltage (n:222)	P-Value
Age[α]	23(1-56)	25(2-80)	0.501
Gender distribution, n(%)			
Female	5(7.2)	64(92.8)	<0.001
Male	143(47.5)	158(52.5)	
Pregnancy, n(%)	2(15.4)	11(84.6)	0.065
Cause of electric shock, n(%)			
Workplace accident	97(60.6)	63(39.4)	<0.001
Suicide	3(60)	2(40)	0.471
Type of electric shock, n(%)			
Pure electricity	141(39.1)	220(60.9)	
Pure arc	4(80)	1(20)	0.64
Arc and electricity	3(75)	1(25)	
Burn degree, n(%)			
1st degree	67(63.2)	39(26.8)	<0.001
2nd degree	133(48)	144(52)	<0.001
3rd degree	84(77.8)	24(22.2)	<0.001
Total burn surface area [α]	10(0-70)	1(0-55)	<0.001
System injuries, n(%)			
Head	2(66.6)	1(33.3)	0.344
Thoracic	1(100)	0(0)	0.22
Abdominal	3(60)	2(40)	0.316
Extremity	12(100)	0(0)	0.411
GCS[α]	15(3-15)	15(3-15)	<0.001
Mortality, n(%)	15(78.9)	4(21.1)	<0.001
Enzymes [α]			
LDH	250(70-1400)	200(0-2500)	<0.001
ALT	60(40-1000)	40(40-400)	<0.001
AST	67.5(10-1000)	45(10-400)	<0.001
CK	330(50-25000)	150(50-4627)	<0.001
CKMB	12(0-600)	8(0-300)	<0.001
Trponin T	0.06(0-58)	0.04(0-6)	<0.001
Complications, n(%)			
Myoglobinuria	46(80)	13(20)	<0.001
Rhabdomyolysis	60(75)	20(25)	<0.001
Acute renal failure	8(100)	0(0)	<0.001
Escharotomy	7(87.5)	1(12.5)	0.006
Fasciotomy	19(79.2)	5(20.8)	<0.001
Compartment	19(79.2)	5(20.8)	<0.001
Hyperkalemia	14(87.5)	2(12.5)	0.001
Metabolic acidosis	13(68.4)	6(31.6)	0.009
Respiratory acidosis	6(85.7)	1(14.3)	0.013
Pulmonary hemorrhage and edema	2(100)	0(0)	0.082

GCS: Glasgow Coma Score, ALT: alanine aminotransferase, AST:aspartate aminotransferase,LDH: lactate dehydrogenase, CK:blood creatine kinase, CK-MB: creatine kinase-myocardial band, $^{\alpha}$:Median(Max-Min).

Table 2: Factors affecting mortality and clinical features in electrical injuries

Character	Survived N=351	Died N=19	Total N=370	P-Value
Age$^{\alpha}$	24(1-80)	29(4-48)	24(1-80)	0,795
Gender distribution, n(%)				
Female	65(94.2)	4(5.8)	69(100)	0.782
Male	286(95)	15(5)	301(100)	
Pregnancy, n(%)	13(100)	0(0)	13(100)	0.392
Cause of electric shock, n(%)				
Workplace accident	152(95)	8(5)	160(100)	0.967
Suicide	3(60)	2(40)	5(100)	0.002
Type of electric shock, n(%)				
Pure electricity	342(94.7)	19(5.3)	361(100)	
Pure arc	5(100)	0(0)	5(100)	0.852
Arc and electricity	4(100)	0(0)	4(100)	
Electric voltage, n(%)				
Low voltage	218(98.2)	4(1.8)	222(100)	<0.001
High voltage	133(89.9)	15(10.1)	148(100)	
Fall from height, n(%)	51(92.7)	4(7.3)	55(100)	0.308
Burn degree, n(%)				
1st degree	105(99.1)	1(0.9)	106(100)	0.134
2nd degree	266(96)	11(4)	277(100)	0.357
3rd degree	100(93.5)	8(6.5)	108(100)	<0.001
Total burn surface area $^{\alpha}$	2(0-70)	2(0-55)	2(0-70)	0,664
System injuries, n(%)				
Head	3(100)	0(0)	3(100)	0.686
Thoracic	1(100)	0(0)	1(100)	0.816
Abdominal	4(80)	1(20)	5(100)	0.129
Extremity	12(100)	0(0)	12(100)	0.411
GCS$^{\alpha}$	15(3-15)	3(3-6)	15(3-15)	<0.001
Enzymes $^{\alpha}$				
LDH	200(70-2500)	250(70-1100)	200(70-2500)	<0.001
ALT	40(30-1000)	200(30-600)	40(30-1000)	<0.001
AST	50(10-1000)	170(10-400)	50(10-1000)	<0.001
CK	200(50-12000)	1500(50-25000)	200(50-25000)	0.001
CKMB	8(0-500)	40(0-600)	8(0-600)	0.056
Trponin T	0.04(0-58)	0.2(0-7)	0.04(0-58)	0.001
Complications, n(%)				
Myoglobinuria	54(91.5)	5(8.5)	59(100)	0.439
Rhabdomyolysis	69(86.2)	11(13.8)	80(100)	<0.001
Acute renal failure	7(87.5)	1(12.5)	8(100)	0.340
Escharotomy	8(100)	0(0)	8(100)	0.506
Fasciotomy	22(91.7)	2(8.3)	24(100)	0.463
Compartment	22(91.7)	2(8.3)	24(100)	0.463
Hyperkalemia	12(75)	4(25)	16(100)	<0.001
Metabolic acidosis	13(68.4)	6(31.6)	19(100)	<0.001
Respiratory acidosis	4(57.1)	3(42.9)	7(100)	<0.001
Pulmonary hemorrhage and edema	0(0)	2(100)	2(100)	<0.001

GCS: Glasgow Coma Score, ALT: alanine aminotransferase, AST:aspartate aminotransferase,LDH: lactate dehydrogenase, CK:blood creatine kinase, CK-MB: creatine kinase-myocardial band, $^{\alpha}$:Median(Max-Min).

Table 3: ECG findings according to the voltage difference.

Character	High voltage N=148	Low voltage N=222	Total	P
Right bundle branch block	3	1	4	0.538
Left bundle branch block	9	4	13	0.489
Asystole	15	3	18	<0.001

1st degree block	1	1	2	0.772
Ventricular extrasystoles	1	0	1	0.220
Bradycardia	1	3	4	0.538

Table 4: ECG findings according to mortality.

Character	**Survived N=351**	**Died N=19**	**Total**	**P-Value**
Right bundle branch block	4	0	4	0.640
Left bundle branch block	12	1	13	0.671
Asystole	4	14	18	<0.001
1st degree block	1	1	2	0.004
Ventricular extrasystoles	1	0	1	0.816
Bradycardia	4	0	4	0.640

Discussion

Electrical injuries are among the causes of severe morbidity and mortality that occur as a result of negligence and imprudence, with a numerous factors affecting morbidity and mortality, involving multiple systems.

Electrical injuries usually occur in younger segments with a mean age between 20 and 30 years [5]. In a study, 81% of electrical injuries have occurred in men and 19% in women with about 1/3 being due to low-voltage and 2/3 high-voltage injuries [1]. In our study, distribution of age, gender and low-high voltage were consistent with the literature.

In a study by Karadaş et al. [6], 84 of the cases (57.1%) were due to low-voltage and 63(42.9%) high-voltage electrical injuries. Of women, 85.7% have injured by low-voltage electricity, while 51.8% of men have injured by high-voltage electricity. , in a study by Arnoldo et al. [3], 143 of the cases were due to low-voltage and 263 high-voltage injuries. Male to female ratio was found as 4.5/1 in low-voltage and 130/1 in high-voltage injuries. Gender distribution by low-high voltage difference in our study was closer to that of the study by Karadaş et al. Accordingly, we can say that, women get injured more commonly by low-voltage, while men are more commonly affected by high-voltage electrical injuries.

Diffuse and deep burn skin occur in high-voltage electrical injuries, while skin burns are less diffuse and superficial in low-voltage electrical injuries [7]. In a study, mean TBSA was found as 30± 23 in high-voltage injuries and 6± 8 in low-voltage injuries [4]. Another study have reported the mean TBSA as 6.4± 0.6 in high-voltage electrical injuries and 0.4± 0.1 in low-voltage electrical injuries [3]. The rates were different in the present study, although the results were parallel with the literature. Burn degree and area were increased with voltage.

Even if different part of the body expose to the same voltage, current and tissue damage occurring will be different due to the resistance difference [8]. Clinical manifestation occurs with 3 mechanisms in electrical injuries. These include direct trauma due to electric current, injuries resulted from the conversion of electrical energy into thermal energy and the mechanical effect including falling from height and severe muscular contractions [9]. Electrical injuries result in multiple system and organ injuries [7]. System injuries are more commonly seen in high-voltage electrical injuries [3,6]. In this study, system injuries were higher in high-voltage electrical injuries, although the difference was not significant between low and high-voltage difference. This can be attributed multifactorial nature of organ injuries and clinic picture in electrical injuries.

In the study by Karadaş et al. [6], elevations in LDH, ALT, AST, CK and CKMB enzymes were significant in terms of low-high voltage difference. In our study also increased levels of enzymes were consisted with the literature.

Numerous conducted studies have demonstrated a significant correlation between the developing complications and low-high voltage electrical injuries and reported that complication rates are higher in high-voltage electrical injuries [6,10]. In the present study, complications were markedly

increased in high-voltage electrical injuries. This finding can be explained by that high-voltage causes more severe tissue damage due to greater current and height of falling is higher in this type of electrical injuries.
Mortality rate has been reported up to 21.7% in electrical injuries [11]. In a study by Al et al. [12] mortality rate was 9.1% with 80% of these case being high-voltage injuries and there was a positive correlation between the complications observed and mortality. Arnoldo et al. [3] found mortality rate as 2.8% in low-voltage and 5.3% in high-voltage electrical injuries. In another study with 58 cases of high-voltage electrical injuries, mortality rate was reported as 15.52% [13]. In our study, mortality rate and the correlation between voltage difference and mortality were consistent with the literature. As expected, the correlation between high-voltage and mortality was significant.
Electrical injuries usually consist of occupational accidents, while suicide cases are extremely rare [10,14]. In the present study, correlation of suicide cases with mortality was significant. Both high-voltage electrical injuries and falling from height were observed in the patients who committed suicide and died. This significant correlation between suicide cases and mortality might be related to be exposed to two different high-energy traumas at the same time.
Central nervous system injuries are one of the important causes of death from electrical injuries. Death may occur due to damage in respiratory center or upper motor neuron [7,15]. In a study investigating low-voltage electrical injuries in children, a GCS value lower than 13 was reported that it was significantly correlated with mortality [16]. Similarly, in our study low GCS was a factor affecting mortality.
Several complications may develop as a result of electrical injuries such as organ injuries related to the systems including head, thoracic, abdominal and extremities, escharotomy, fasciotomy amputation, rhabdomyolysis, acute renal failure and coma that may lead to death [7,10,12]. In the present study, the correlation between mortality and rhabdomyolysis, hyperkalemia, acidosis, pulmonary hemorrhage and edema was significant.
Monitorization is not recommended in the patients without loss of consciousness, tetania, an abnormal ECG or rhythm recorded in the scene or at the time of first admission and having no history of high-voltage electrical injury. If these factors are present, monitorization is recommended for the first 12 hours. Arrhythmias due to electrical injuries are generally seen in the early period. Late arrhythmias are rare and usually do not result in death [17,18]. Cardiac arrhythmias and dysrhythmias that develop due to necrosis of myocardium, nodes, electrical conduction paths and coronary arteries are another important cause of death in electrical injuries. The higher the voltage, the higher degree of myocardial damage occurs [19]. In this study, 9 patients died at the time of first presentation due to asystolia, while asystolia due to acidosis and mortality were seen in 5 patients in the late period. Majority of the patients who died were those with asystolia due to high-voltage electrical injuries.
To distinguish electrical injury in terms of low-high voltage difference at the time of first presentation is important in determination of prognosis and mortality. Furthermore suicide cases, 3rd degree burns and elevated levels of LDH, ALT, AST, CK and troponin T enzymes are important in order to predict mortality. However, electric shock is a multiple trauma and despite a multidisciplinary approache, complications developing in the late period may cause mortality.

Conflicts of interest

There is no conflict of interest

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