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ORIGINAL ARTICLE

Electrical burn injuries of 246 patients treated at the University Clinical Center of Kosovo during the period 2005–2010

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Abstract
Background In the developing world, the incidence of electrical injuries has increased in the past few years. Electrical injuries represent approximately 5 % of all burn admissions to burn units in the United States.
Objective The objective of this study is to understand the causes of electrical burns in our population, sex, age, duration of treatment, distribution of electrical burns by season, accompanying other traumatic injuries with electrical burns, entry lesions of high-voltage electrocution, location of injuries, the methods of treatment, duration of treatment, and mortality.
Materials and methods This is a retrospective study that included 246 patients with electrical burns treated in the 2005–2010 period at the Department of Plastic and Reconstructive Surgery in Kosovo. The data were collected and analyzed from the archives and protocols of the University Clinical Center of Kosovo. Data processing was done with the statistical package InStat 3. From the statistical parameters the structural index, arithmetic median, and standard deviation were calculated. Data testing was done with the χ^2 test and the differences were considered significant if $p < 0.05$.
Conclusion The high mortality, 9.1 %, and 7 patients (10.6 %) transferred out of our country for treatment is a reflection of the lack of a burn center in our department.

Keywords Electrical burns · Distribution · Lack

Introduction

In the developing world, the incidence of electrical injuries has increased in the past few years [1]. Electrical injuries represent approximately 5 % of all burn admissions to burn units in the United States [2–4]. Injuries due to electrical currents form a small but important section of all burning accidents [5]. Although electricity is a relatively recent

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invention, humans have always been exposed to electrical injuries caused by lightning. The devastating power of lightning was viewed with awe, and, understandably, it was attributed to supernatural powers. The discovery and widespread use of electricity in the mid-1800s took away the supernatural aura surrounding electrical power but, in return, made electrical injury a common problem at work or at home, with the first electrical fatality recorded in France in 1879 [6].

In considering electrical burns, it is important to differentiate between electrical flash-burns, which are not necessarily associated with the passage of current through the victim, and true electrical burns, in which current has passed through the tissues. The electrical flash-burns are caused by heat from an electric arc—the luminous bridge between two charged electrodes that is separated by a small air space—close to the portion of the patient that is burned. This arc will produce a typical heat burn, usually with partial-thickness skin destruction and a surrounding area of erythema. The second category, true electrical burns, includes lesions caused by direct electrical contact between the body and one or more electrodes. The current passes through the body from the point of contact with the earth or another electrode. The local lesion which is produced depends on the type of current, the skin resistance, and the voltage [7]. Low-voltage injuries are caused by voltage less than 1,000 V. This group includes most injuries caused by household current: the child who bites into the cord producing lip, face, and tongue, as well as occupational injuries resulting from the use of small power tools, or those who become grounded while touching an object that is energized [8]. Burns resulting from high-voltage electric current (>1,000 V) are often associated with a greater degree of deep tissue injury than is initially appreciated [9]. As a result, these rather infrequent injuries, which make up only 3–12 % of burn center admissions [9, 10], are associated with high amputation rates and greater use of resources than comparable percentage total burn surface area (%TBSA) cutaneous burns [9, 11–13]. Electrical injury can result in some of the most devastating thermal traumas. As opposed to thermal burns, the cutaneous burn size does not correlate with the extent of damage seen in high-voltage electrical injuries: electrical injuries result in extensive deep tissue injury in addition to various other systemic complications [14].

According to the 2011 registration, the estimated population in Kosovo is 1,800,000. The plastic surgery department is the only department that treats electrical burns. The plastic surgery department functions within the University Clinical Center of Kosovo. Patients with extensive burns and electrical burns are treated by plastic surgeons in close cooperation with the anesthesiologists, since there is no dedicated burn unit available in our country. These patients are initially admitted to the intensive care unit. After initial resuscitation and after these patients have survived the early complications of extensive burns, they are transferred to our department for further treatment. Emergency resuscitation in our country is not performed properly in many cases, which occasionally leads to early major complications. Delayed transportation and admission to the intensive care unit is responsible for most of the deaths in cases of extensive burns.

Objective

The objective of this study is to understand the causes of electrical burns in our population, sex, age, tension of current (voltage), the mechanism of the injury, distribution of electrical burns by years, duration of treatment, distribution of electrical burns by season, accompanying other traumatic injuries with electrical burns, entry lesions of high-voltage electrocution, location of injuries, the methods of treatment, and mortality.

Materials and methods

This is a retrospective study that included 246 patients with electrical burns treated in the 2005–2010 period in the Department of Plastic and Reconstructive Surgery in Kosovo. The data were collected and analyzed from the archives and protocols of the University Clinical Center of Kosovo.

The inclusion criteria in this study were: patients of both genders ranging from 1 to 65 years old; patients hospitalized within 24 h of injury (patients with electrical burns that occur more than 24 h prior to the hospital presentation are not included in this study).

The exclusion criteria in this study were: patients under 1 year old and above 65 years old (five patients above 65 years of age were excluded from the study due to incomplete data) and minor electrical burn injuries (low-voltage electrical burns) below 5 % TBSA (these patients were hospitalized for their tracking but had superficial burns and were excluded from the study).

Data processing was done with the statistical package InStat 3. From the statistical parameters the structural index, arithmetic median, and standard deviation were calculated. Data testing was done with the χ^2 test and the differences were considered significant if $p < 0.05$.

Results

In this retrospective study, 246 patients with electrical burns were included in the 6-year period (low and high

Table 1 Case distribution by age and gender

Age groups (years)	Gender		Total	
	Male	Female	*n*	%
0–9	9	3	12	4.9
10–19	29	5	34	13.8
20–29	63	3	66	26.8
30–39	52	2	54	22.0
40–49	49	2	51	20.7
50–59	24	–	24	9.8
60+	5	–	5	2.0
Total	231	15	246	100.0
Mean ± standard deviation (SD)			33.6 ± 10.0 years	
Range			1–64 years	

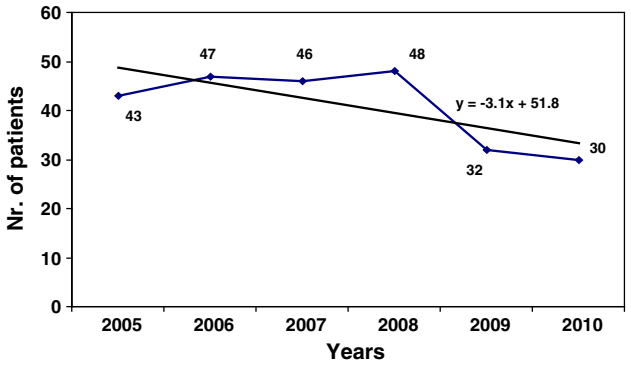


Fig. 1 Case distribution by years

voltage). Electrocution in our population was predominant in male patients, with 231 cases (93.9 %), while only 15 cases were female (6 %) (Table 1). Of the 246 patients with electrical burns, 180 cases or 73.1 % suffered low-voltage electrocution, while 66 cases or 26.8 % were inflicted by high-voltage electrocution.

Regarding age, electrical burns were found to be more predominant in the age group 20–29 years with 66 cases (26.8 %), followed by the age group 30–39 years with 54 cases (22 %), 40–49 years 51 cases (20.7 %), 10–19 years 34 cases (13.8 %), 50–59 years 24 cases (9.8 %), 0–9 years 12 cases (4.9), and over 60 years with 5 cases (2 %). Patients exposed to electrical injuries (low- and high-voltage electrocution) had a very wide age distribution, from 1 to 64 years old, with an average age of 33.6 years. The vast majority of the patients was between 21 and 40 years old (115 cases, 46.7 %) (Table 1).

The distribution of electrocution by year had the following features: year 2008 is the year where the incidence of electrical burns was the highest with 48 cases (19.5 %), 2006 with 47 cases (19.1 %), 2007 with 46 cases (18.6 %), 2005 with 43 cases (17.4 %), 2009 with 32 cases (13 %), and 2010 with 30 cases (12.1 %) (Fig. 1). The duration of treatment ranged from 1 to 111 days. The mean length of the hospitalization was 14.9 days (Table 2). The majority of low-voltage electrocutions occurred in the winter with 77 cases (31.3 %), while high-voltage electrocutions mostly occurred during the summer period with 38 cases (15.4 %).

Table 2 Distribution by location of incidence, surgical interventions, transfers abroad, and duration of hospitalization

	High-voltage electrocution		Low-voltage electrocution		Total	
	n	%	*n*	%	*n*	%
Total	66	100.0	180	100.0	246	100.0
Place						
Workplace	39	59.1	79*	43.9	118	48.0
Home	20	30.3	101	56.1	121	49.2
Other	7	10.6	–	–	7	2.8
Surgical interventions						
Fasciotomy	16	24.2	–	–	16	6.5
Necrectomy plus skin grafting	40	60.6	13*	7.2	53	21.5
Abdominal flap	11	16.7	–	–	11	4.5
Cross-finger	8	12.1	–	–	8	3.3
Transfers abroad	7	10.6	–	–	7	2.8
Mortality	6	9.1	–	–	6	2.4
Duration of hospitalization (days)						
Range					1–111 days	
Mean ± standard deviation (SD)					14.9 ± 10	



Fig. 2 A 22-year-old male with high-voltage electrocution of the *upper right* extremities



Fig. 3 The same patient as Fig. 2 with high-voltage electrocution of the upper left extremities



Fig. 4 The same patient as Fig. 2 with high-voltage electrocution in the right iliac region

Regarding the season, electrical burns had the following features: the winter is the season where the incidence of electrical burns was the highest with 91 cases (36.9 %), followed by summer with 70 cases (28.4 %), Spring with 46 cases (18.6 %), and autumn with 39 cases (15.8 %).

Three cases with high-voltage electrocution were associated with other traumatic injury (one case with subarachnoid bleeding, one case with polytrauma, and one case with spinal cord injuries). The majority of entry lesions in high-voltage electrocution were localized in the upper extremities, 49 cases or 19.9 %; however, no electrical lesions were found in 17 cases or 6.9 %.

Out of 66 cases with high-voltage electrocution, 39 cases (59.1 %) occurred as occupational accidents mostly seen in workplaces (near aerial power lines or factories) (Table 2), 20 cases occurred at home, of which 16 cases were children, three students, and one senior citizen, while a few cases occurred in various other locations. All cases were recorded as accidental, except for two cases who committed suicide. All cases with high-voltage electrocution underwent surgical intervention, of which 16 cases required fasciotomy due to compartment syndrome, 40 cases underwent surgical intervention with early tangential necrectomy followed by skin grafting, 11 cases required abdominal flaps due to the exposure of tendons and joints, while only eight cases with high-voltage electrocution localized in the fingers required cross-finger flaps (Table 2).

Sixteen cases (6.5 %) with high-voltage electrocution underwent surgical amputation. The majority of them, 13 out of 16 cases, underwent amputation of digits at various levels of both extremities, whereas in the three remaining cases, amputations were also performed but they were distal forearm amputations due to the development of progressive necrosis and gangrene (Figs. 2, 3, 4, 5).

Seven cases with high-voltage electrocution were transferred abroad for treatment. All deaths were caused by high-voltage injuries and mortality secondary to high-voltage electrical injury was noted in 6 patients (9.1 %) of the overall patient population studied (Table 2).

Low-voltage electrocution in our country occurred mostly at home (accidental burning) with 101 cases (56.1 %). Quite a significant number of low-voltage electrocutions were also noted in the workplace with 79 cases (43.9 %), mostly as occupational accidents. The most frequent localization in low-voltage electrocution was the face and hands with 146 cases (59.3 %). Out of the total number of patients with low-voltage electrocution (146 cases), only 13 cases required surgical interventions with early tangential necrectomy followed by skin grafting. Nine patients were noted to have deep dermal hand burns and four deep dermal burns of the face. No deaths were recorded from low-voltage injuries in our department.

Discussion

Electrical burns are still an important and challenging problem in burn centers [15, 16], with a higher incidence in developing countries [15–17]. The exposure of joints, tendons, and bones remains a major problem for soft tissue surgeons. Several effective reconstructive measures have been developed, such as partial and full-thickness skin grafts, local rotational flaps, pedicle advancement flaps, tissue expansion, and free vascular pedicle flaps. Nevertheless, extremity amputation continues to occur too often, especially in patients with electrical burns caused by high-

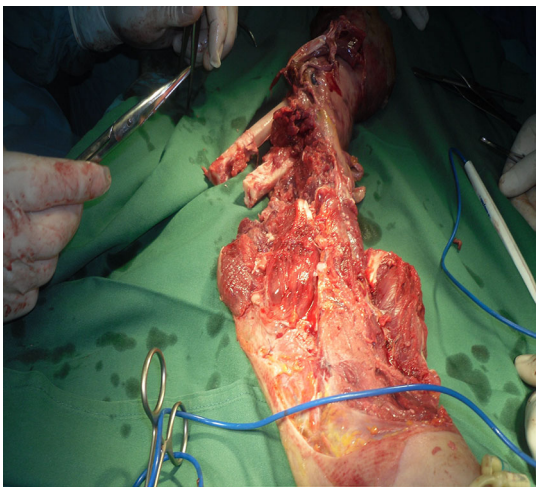


Fig. 5 Amputation of the right forearm in the same patient as Fig. 2 with high-voltage electrocution

voltage electricity and characterized by extremity muscle necrosis, bone, and tendon exposure [18].

In this retrospective study, we included 246 patients in 6-year period with electrical burns (low- and high-voltage electrocution). Electrocution in our population were dominant in male patients with 231 cases (93.9 %), while only 15 cases were female (6 %). A similar study of 84 patients with electrical injuries by Patil et al. [1] reported male predominance; 71 patients were male and 13 were females.

This predominance of the male gender in our population is related to the socioeconomical and cultural habits in our country; the male gender in our country are the main carriers of heavy physical works; also, the families in our country are dependent upon the financial aspect of this gender, while women, especially in rural areas, are mainly housewives (Fig. 5).

The age of patients with both sorts of electrical injuries (low- and high-voltage electrocution) ranged from 1 to 64 years, with an average age of 33.6 years; however, most patients were between 21 and 40 years old (115 cases, 46.7 %).

A similar study of 115 patients with electrical burns by Kidd et al. [2] reported that the average patient age was 34.9 years.

The majority of low-voltage electrocutions occurred in the winter with 77 cases or 31.3 % of the total number of patients, while high-voltage electrocutions mostly occurred in the summer, with 38 cases (15.4 %). In our study, we found the incidence of electrical burns to be higher during winter and summer months. This is due to several reasons. Because of the significant drop in temperatures during the winter period, the electrical power supply is not able to meet the high demands and, therefore, is not a reliable source of energy. Thus, people are forced to utilize alternative means of energy for their households. This can lead to accidents associated with electrical burns and other means of injuries.

The majority of construction projects in our country take place during the summer time. The installation of high-voltage electrical cables is frequently performed by inexperienced personnel, leading to a variety of accidents, including severe electrical burns. This explains the high incidence of severe electrical burns mostly during this period of time.

Electrical burns have usually been more frequent in undeveloped countries with an inefficient electric energy system and a low social and economic level, as in our country, Kosovo. The consequences of the Kosovo war (1998 to June 1999) included the destruction of the country's production infrastructures and disruption of the electricity supply system. With the deterioration of the electricity supply system in Kosovo, the number of patients with electrical injuries increased, reaching the highest rate in Europe. In Kosovo, the electricity supply system consists of two old power stations that are unable to satisfy all the needs for electric current, as is normally the case with outdated electricity distribution systems [19].

After 1999, our country emerged from the war and our population was confronted with frequent reductions of electricity, especially during the winter season due to overloading of the electricity network; at the same time, our population within households were forced to find other alternative electricity sources (aggregates with fuel for the production of electricity, gas canisters for the preparation of food, etc.). As a result we have this dominance of low-voltage electrical burns during the winter season. Simultaneously, low-voltage electrocution dominated at home during various improvisations in the electricity network.

High-voltage electrocution was more prevalent during the summer season, and the majority of these electrical injuries occurred in workplaces near high buildings under construction near electrical cables carrying high voltages.

A higher incidence of electrical burns in our country was recorded during 2005, 2006, 2007, and 2008, while in 2009 and 2010, the incidence of electrical burns was lower. This decline may likely be explained by the stabilization of the electricity supply in our country.

Three cases with high-voltage electrocution were associated with other traumatic injury (one case with subarachnoid bleeding, one case with polytrauma, and one case with spinal cord injuries).

The majority of entry lesions in high-voltage electrocution were localized in the upper extremities (49 cases, 19.9 %). However no electrical lesions were found in 17 cases (6.9 %). From 66 cases with high-voltage electrocution, 39 cases (59.1 %) occurred as occupational accidents mostly seen in workplaces (near aerial power lines or

factories), 20 cases occurred at home, of which 16 cases were children, three students, and one of them was a senior citizen. A few cases occurred in various other places. All cases were recorded as an accident, except for two cases who committed suicide.

Seven cases with high-voltage electrocution were transferred for treatment abroad in other countries, since a burn center has not yet been established in our country. We do not have data concerning the outcome of these patients.

All deaths were caused by high-voltage injuries, comprising 6 cases (9.1 %). In four cases, the cause of death was the development of acute renal failure, while in the other two cases, the cause was cardiac arrest due to ventricular fibrillation. Respiratory arrest is one of the most common causes of acute death in serious electrical injuries. There was no fatal case associated with respiratory arrest noted in our institution. Low-voltage electrocution in our country was mostly accidental seen at home with 101 cases (56.1 %), while 79 cases (43.9 %) occurred as occupational accidents mostly seen in workplaces. This high incidence of electrical burns caused by low-voltage electricity is attributed to the postwar period. We inherited a totally destroyed and dysfunctional electrical power supply system. There was a massive power supply shortage, especially in the immediately postwar period. People were living without electricity for up to 12 h a day for the first 7 years postwar. The situation got better after 2007. There are still shortages in the electricity supply at present; however, it is far less common compared to the early postwar period. In view of this hugely dysfunctional electrical power system, people were forced to look for alternative means of electrical supply. This, of course, led to numerous accidents.

The second factor which has contributed to increased incidences of electrical burns was the fact that over 200,000 houses were burned during the war; therefore, after the renovation and reconstruction of these houses follows the installation of the electrical network, in most of cases from the non-professionals and unskilled people that ensues such a high incidence of electrical burns in the household.

A similar study of 100 patients with electrical injuries by Akçan et al. [20] reported that 71 cases of electrical burns occurred as occupational accidents. This discrepancy in our country is connected to postwar period problems with the electricity supply in our country. This incidence of electrical burns is a consequence of the war in Kosovo (1998–1999), the low social and economic level of the population, the inefficiency of the electricity network, the amortization of electricity network dispersions, the misuse of electric current, and repair work on the electricity network done by non-professionals. A marked relationship was found between inefficient electric energy supply and the incidence of electrical injuries [19].

The most frequent localization in low-voltage electrocution was the face and hands with 146 cases (59.3 %). From 146 cases with low-voltage electrocution, 13 cases underwent surgical interventions with early tangential necrectomy followed by skin grafting, of which there were nine cases with deep dermal hand burns and four cases with deep dermal burns of the face. No deaths were reported from low-voltage injuries in our department.

Conclusion

On the basis of the results of this study, we can conclude that:

- Electrical burns are deep tissue lesions caused by the passage of electric current through the human body that are characterized by higher morbidity and invalidity than burns of any other etiology. They constitute one of the most severe medical problems in our country;
- The high mortality, 9.1 %, and 7 patients (10.6 %) transferred out of our country for treatment is a reflection of the lack of a burn center in our department;
- Our department, in collaboration with the Ministry of Health, should endeavor to establish a burn center because of the highest incidence of electrical burns in Kosovo, reflecting the inefficiency of the electric energy system and the population's low social and economic level;
- The high electrical burn amputation rate (6.5 %) is also a reflection of the lack of a burn center in our department.

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Ethical standards Not required.

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