



Electrical Burns in Albania and their Treatment: A Review of Cases Treated in 2019–2020

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Abstract

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BACKGROUND: Electrical burns, although constituting a small part of the burns treated in a tertiary hospital, remain a constant burden to the medical staff, due to the nature of the causative agent.

PATIENTS AND METHODS: After the Institutional Review Board approval, a retrospective study was performed including all the patients admitted to the Service of Burns and Plastic Surgery, University Hospital Center “Mother Theresa” of Tirana, Albania, from January 2018 to December 2019. Descriptive statistics was used to review the cases for age distribution, body surface area burned, points of entry and exit of the current, acute and late complications, surgical approach, and timing of the latter.

RESULTS: Twenty-six patients were admitted during this period, of which 22 suffered a real electrical burn, four of them having only superficial damage from the flash of the electric arc without direct contact with the electrical source. Mean hospital stay was 58.1 days for true electrical burns and 7.5 days for burns from electrical arc. Each patient underwent three surgical interventions in average, of which 20% were fasciotomies, 30% were eschar excision, 35% were reconstructive procedures, and 15% were amputations. Only one fatal outcome was registered. About 36% of the patients were children and the only death was registered among them. Most of cases were due to neglect of safety measures while working with the electrical power, although being professional qualified workers. Acute complications were myoglobinuria, cardiac rhythm disorders, respiratory acidosis, psychomotor agitation, brain concussion and contusion, and acute bleeding. Anemia is the most common late complication.

CONCLUSIONS: The prevention is still the best treatment, especially for true electrical burns. Working with the corporate that controls the production and transmission of the electrical power could further reduce the incidence of true electrical burns, while moving to more aggressive surgical approach to such burns might avoid long-term complications and degree of invalidity caused by them.

Introduction

Electrical burn is the most aggressive entity of the burn injury, which leads to severe functional and esthetic sequelae. It has always represented one of the most problematic situations that one can encounter in the emergency room of a burns center, due to involvement of the vital organs, as well as the severe functional and esthetic impairment with serious consequences in the active life of the patient. The high incidence of this injury compared with a low incidence of fatal outcomes (after overcoming the early post-trauma period complications) asks for continuous efforts in choosing the proper surgical approaches and in developing and being up to date with the new surgical techniques. On the other hand, most of the cases, at least those of our series, belong to employees of the corporate that controls and manages our national grid system, OSSHE. Stressing this and establishing collaboration with the corporate might increase awareness of the problem and its serious consequences.

Materials and Methods

This is a review of the 2-year experience at the Service of Burns and Plastic Surgery at the Hospital University Center “Mother Teresa” of Tirana in the treatment of electrical burns. After approval of the Institutional Board Review, the medical records of all these patients were analyzed.

The study is a retrospective review, focusing of the following variables:

- Gender distribution
- Age distribution
- Stratification of cases in two major groups: True electrical burns and burns from electrical arc
- Body surface area burned
- Early and later complications
- Final outcome.

Descriptive statistics were used for the above variables.

Results

From January 2019 to December 2020, 26 patients were admitted to our center after having sustained an electrical burn.

About 96.2% of them were male (Table 1). Even among pediatric patients, males predominate. As for all types of burns, this is explained with the fact that boys are more active than young girls and more prone to endanger themselves by being more curious and creating risky situations with their games.

Table 1: Gender distribution

Sex	Number of cases
Male	25 (96.2%)
Female	1 (3.8%)

Age distribution of cases showed that 26.9% were children from 7 to 14 years old, but the majority of cases belonged to the working age group, that is, 31–50 years old (Table 2). About 25% of adult patients reported of having been drunk when the accident occurred.

Table 2: Age distribution

Age groups	Number of cases (%)
7–14 years old	7 (26.9)
15–20 years old	2 (7.7)
21–30 years old	3 (11.6)
31–40 years old	5 (19.2)
41–50 years old	7 (26.9)
51–59 years old	2 (7.7)

True electrical burns were seen in 22 of our patients, and only four of them had burns due to the electrical arc flash (Table 3).

Table 3: True and electrical arc burns and approach to them

Pathology	Number of cases	Treatment
True electrical burns	22 (84.6%)	Surgical
Electrical arc burns	4 (15.4%)	Conservative

Complications in patients with true electrical burns were grouped as “early” and “late” complications. About 18.2% of the patients with true electrical burns had signs of brain involvement, which were cerebral concussion or even contusion, this established after the urgent computed tomography scans.

Three of these patients received conservative treatment for the cerebral edema with anticonvulsants and diuretics (mannitol) which were added to the usual fluid resuscitation regimens that we use for the first 48 h. In all of the patients, neurological symptoms disappeared within the first 72–120 h after the accident. None of the three cases progressed to generalized epileptic seizures. While the fourth case had a concomitant fracture of the frontal bone and was transferred to the neurosurgery department for a better, more specialized treatment, where he stayed for 2 weeks.

Four other patients showed some kind of psychomotor agitation, but no changes were found after cerebral imaging. The agitation persisted for 24–48 h,

and the patients responded well to the use of sedation, diuretics, anticonvulsants, and treatment of acidosis that was present in these patients.

Myoglobinuria was a common finding in the true electrical burned patients: Eight patients (36.4%) had myoglobinuria that lasted from 48 to 72 h. Normal values of myoglobinuria were established soon after adequate resuscitation and maintaining urine output at the level of 50–70 mL/h. In one patient, renal failure was irreversible and the patient could not survive.

The most serious acute complications encountered in electrical burns are cardiorespiratory complications: Cardiac arrhythmias, hypoventilation, and respiratory acidosis are the most common, encountered in two patients (9.1% of the cases). In both cases, the exit point of the present was on the thorax. One of these patients suffered a severe heart attack from the electric shock, leading to death. While the other patient was treated with the help of the cardiologist: Rhythm conversion was achieved with intravenous use of digitalis, maintaining the oxygen levels.

Analysis of the location of the entry-exit points of the present (Table 4) once more confirmed that the most inflicted areas are the upper limbs. In 95.5% of cases (21 patients), at least, one of the contact points is located on the upper limbs. In three cases, two thoracic and one occipital points were identified, and although being exit points, the damage was severe (Figure 1).

Table 4: Acute complications of electrical burns

Post-traumatic complications	Number of cases (%)
Contusio cerebri	4 (18.2)
Psychomotor agitation	4 (18.2)
Myoglobinuria	8 (36.4)
Cardiorespiratory disorders	2 (9.1)



Figure 1: Fatal case with ground contact point on the thorax

The main approach to the electrical burned patients is surgery (Table 5). Fasciotomy to prevent the progression of damage from muscle compression remains necessary and has been applied in 100% of cases with true electrical burns. In our experience, this is followed by either escharectomy, or amputation immediately after reestablishing the hemodynamics and metabolic balances. In nine patients (or 40.9%),

Table 5: Body contact points of true electrical current

Contact points	Number of cases (%)
Upper extremities	21 (95.5)
Lower extremities	2 (9.1)
Thorax	2 (9.1)
Abdomen	2 (9.1)
Cerebral cranium	2 (9.1)
Visceral cranium	1 (4.6)

amputation was applied within 72–120 h from the accident. In four patients (or 18.2% of cases), major and mutilating amputations (extremities amputations) were performed, (Figure 2), while, in five patients (or 22.7%), amputation only of fingers was performed. However, even in cases of minor amputations, post-burn retraction of the skin grafted areas has caused almost complete disability of the interested area.



Figure 2: The application of the amputation in both upper limbs

Twelve patients (or 54.6%) underwent escharectomy. In two cases with electrical burn of cerebral cranium, the escharectomy involved also the outer layer of bone. In another one, the entire occipitoparietal devitalized bones were removed, dura mater was excised too, and aspiration of devitalized brain matter completed the escharectomy. In one case, the excision was limited to the outer layer of the occipital bone reaching to the spongiosa of diploe and left for granulation.

Due to lack of experience in microsurgery in our clinical practice, a limited number of local flaps are applied, exactly only in four patients (18.2% of cases). In two cases with cranial defects, random flaps were applied after laminectomy. While in two other patients, acute abdominal flaps were applied to cover hand defects.

Remaining granulating wounds after escharectomy were grafted after 10–21 days, in 12 cases (54.6%) and immediately after excision in two cases (9.1%), where amputation of the upper limb was done. The defects after excision of dura were reconstructed with fascia lata graft.

Average timing for debridement surgery and amputations has resulted in 1st week after the accident, mainly on the second to the 7th day after the trauma. The

highest frequency of these interventions was between the fifth and 7th day after the accident. Whereas, for cases complicated by cerebral contusion, the intervention was preferred to be done in the 2nd week after the accident. Only in one case with severe damage of the visceral cranium, (Figure 3) the semi-conservative approach (with chemical debridement) was applied, followed by surgery on the 26th day after the accident, with the aim of maximum preservation of facial structures (Figure 4).



Figure 3: The patient with hemifacial contact electrical point

As for the late complications, significant anemia was found in five patients with severe electrical burns, which has persisted for a period of 2 months, despite the large amounts of blood transfusions, which have varied from 4.5 to 6 units per patient.



Figure 4: The patient with hemifacial contact point, in the 26th day of treatment, after chemical debridement of devitalized tissues

The late occurrence of acute bleeding has been encountered in only three patients, who were treated conservatively, with the aim of preserving as much as possible from the viable tissues. Acute bleeding was always dealt with in the operating theatre. Only in one case with acute bleeding at the level of the femoral artery, where the exit point of the present was located, exactly on the femoral triangle area, amputation of the lower limb was done 3 weeks after the accident. We asked the opinion of the vascular surgeons, if a prosthetic reconstruction of the injured femoral

artery could be done, but they deemed it impossible, justifying this with the lack of guarantee of fixation of the prosthesis in the right inguinal region, where deep destruction would reject it.

Table 6: Surgical treatment

Surgery	Number of cases (%)
Fasciotomy	22 (100)
Amputation	9 (40.9)
Cranial laminectomy	2 (9.1)
Cranial random flaps	2 (9.1)
Acute abdominal flaps	2 (9.1)
Fascia graft for dura reconstruct	1 (4.6)
Skin graft after escharectomy	12 (54.6)
Skin graft after amputation	2 (9.1)

The hospital stay varied widely, depending on the body surface area burned and on the level of destruction at the contact points. The body surface area burned in 22 of our patients varied from 3% to 30% of TBS (total body surface), with an average area of 11.6% (Table 6). The average hospital stay for these patients was 58.1 days. There is a discrepancy between the not too large BSA burned and the long hospital stay, this is due to severity of injury, that is, even why the entry-exit points are small in surface, tissue damage is deep, destructive far beyond what's seen on the surface. Whereas, if we separate from this series four patients with severe amputations and the patient with severe burns of the face, hospital stay results 98–237 days, with an average of 155.6 days, whereas, in four patients with thermal burns from the electrical arc, the hospital stay is 7.5 days.

Table 7: Body surface area burned

Wound surface	Number of cases (%)
<10%	10 (45.6)
10–20%	9 (40.9)
21–30%	3 (13.5)

Discussion

The electrical burn injury can cause two types of tissue damages: Superficial thermal injury and deep ischemic necrosis. The superficial thermal injury caused from the flash of the electric arc must not be confused with the biological ischemic necrosis due to passage of present through the body tissues, because the former is a consequence only of the high temperature of electrical arc flash (about 2500°C). The thermal electrical burns, in most of cases, are not problematic due to a moderate extent in the body surface and due to the superficial damage they induce. This makes their treatment easier, and usually, no severe functional and esthetic sequelae of the involved areas are seen. On the contrary, the true electrical injury is caused by the passage of the electrical present through the body; tissue damage is the result of the thermal energy produced by this passage [1]. Hence, the tissues that are mostly damaged are those with higher conductivity. The severity of this damage will be determined by the amount of heat generation caused by the passage of electricity, which, in turn, can be estimated by the Joule Law:

$$E = 0.24 \times I^2Rt$$

(E-energy, I-intensity of the electric current, R-tissue resistance, t-time of current passage in organism).

Based on the above physical interpretation, the factors of aggressiveness on tissue structures are:

- Type of electrical current: The alternative current causes more serious tissue damages in the electric frequency 50–60 Hz (the normal frequency of the grid current) than the direct electric current. The mechanism of this aggressiveness is the deionizing of the cells membranes from the alternative current potential.
- Electrical current voltage: Calculated as $V = IR$ (V-voltage, I-intensity, and R-resistance). Higher voltages result in more serious tissue damages, because the higher the voltage the higher the heat produced by the passage of the current through tissues.
- Intensity of the electric current: The tissue damages and functional alteration of vital organs are proportional to the increase of the current intensity. A current with an intensity of 8–12 mA causes only muscular contractions; intensity higher the 20 mA causes burn; over 25 mA it causes ventricular fibrillation, at 100 mA unconsciousness; and 200–1200 mA cardiorespiratory arrest.
- Tissue resistance: Tissues possess different resistance characteristics to electrical current. According to resistance, tissues are listed in an ascending order: Nerves, blood vessels, muscles, skin, fat, and bones. The higher the tissue resistance, the more devitalizing are the damages caused by the passage of electricity. Due to the high electrical resistance (about 100,000 Ω), the skin areas in contact with the electrical current exhibit profound necrosis.
- Exposure time to voltage: The longer the time of exposure to voltage, the more severe are the tissue damages from the electrical current.
- Tissue conductor cross-sectional area: The smaller cross-sectional area of tissue conductor, the higher is the tissue resistance to electricity, and consequently, the higher is the heat generated by the electricity passage. The blood vessels suffer severe damage, because they accumulate thermal energy due to blood ionic environment.* In the meantime, the nerves undergo reversible changes due to their high conductivity and non-energy accumulation.

*The blood vessels damages from electrical current cause ischemic tissue damage of the type "iceberg," or "sandwich." However, the tissue damages caused by vascular necrosis should not be confused with secondary damage due to blood vessels thrombosis.

Only 3.2% of severely burned patients admitted to our intensive care unit (ICU) were

electrical burns. This number of does not indicate, in statistical terms, the low incidence of such injury, but is related to the decline in industrial activity in the post-communist period [2], [3]. This study found a decrease in the incidence of electrical burns in children (0.9%), compared to a 10 year study (1993–2002), where electrical burns in children accounted for 2% of severe burns treated in our ICU. This testifies for a better standard of living in general, but also for better safety measures at the electrical power stations, which are less accessible nowadays, but, in the previous study, was reported to be site of the accident even for children, because they could enter them easily and use them as part of their playground.

All the studies on electrical burns report for an absolute predominance of males among electrical burned patients [4]. This is confirmed by our study too, where 96.2% of the cases were male. All the high voltage burns were all males and all from the same profession: They work in the maintenance of our national grid system, employees of the OSSHE the corporate that manages the production and transmission of the electric power in Albania [5].

Electrical burns are usually classified as being either “true electrical burns” (caused by direct contact with the electric current) or electrical arc flash burns (caused by the flashing during the short circuit) [6]. This has both practical and theoretical value. A wrong diagnosis between these two types of combustions, mainly due to the lack of attention in the emergency room has consequences in the management and treatment of these combustions. Clinically, burns caused from electric arc are superficial, although caused by a temperature of up to 2500°C, because the time of exposure to such temperatures is extremely short. In 100% of our cases, burned after an electrical arc, healing was completed only with conservative treatment, and this testifies to what we said above. Furthermore, this type of burns does not induce serious and vital complications in the acute phase; the injury is confined locally and does not disturb body’s metabolic balances. Thus, thermal combustion from the electric arc cannot be confused with the electrical burn in all components, including its aggressiveness, course of the disease, prognosis, and treatment. For this reason, the series of patients analyzed in this study has been reduced to 22 cases, which manifest genuine electrical burns caused by the passage of current in the body.

Due to its systemic assault toward organism, electrical burn is characterized by severe acute complications, a situation that calls for attention to a careful management of the disease starting straight from the moment of accident [7].

Myoglobinuria is one of the most common complications encountered among electrical burned patients [8]. The mechanisms of this go beyond the scope of this article but having this in mind does increase the need for better resuscitation. In such patients, the

amount of fluids administered during the resuscitation phase always exceeds that calculated by the common formulas of rehydration. The aim of the latter is to maintain a urine output at the level of 50–70 mL/h, and this is the guide of the resuscitation no matter what the calculated amount of fluids.

The most severe acute complications encountered in electrical burns are cardiorespiratory complications, accompanied by cardiac arrhythmias and respiratory acidosis, with hypoventilation of the pulmonary fields [9]. Such complication is life-threatening and quick diagnosis and immediate treatment is lifesaving.

Analysis of points of entry and exit has shown that the upper limbs are often the sites of at least one of these points. Theoretically, the point of entry as a rule exhibits more damage than the point of exit of the current, or the ground point [10]. Nowadays, they are addressed as contact points, implying that the degree of tissue damage does not correspond with the fact that it is the entry or the exit point of the current, but is related to the tissue characteristics, their condition at the moment of the accident, and the characteristics of the current causing the accident. From the practical point of view, when treating electrical burn, differentiating which is the entry and which is the exit point is of no value. In two of our patients deep, destructive damage was seen, respectively, on the thorax and the head, although being exit or ground point. On the chest, the thoracic cage is entirely bony and presents high resistance to electrical current, consequently, the heat produced is high and the damage induced very severe. The same phenomenon occurs on the skull, where the cranial skeleton lies quite close to the surface, lined with a thin layer of soft-tissue highly fragile to the heat generated by electricity.

The surgical treatment in electrical burns is the main approach to them [11]. Prompt and careful management of electrical burns is important to avoid or at least smoothen the post-burn sequela. Besides systemic treatment of the patients, local care is addressed immediately with the ultimate aim of protecting any viable structure at the damaged area. This is accomplished by escharotomy/fasciotomy, serial debridement, early coverage of the wound by all means: Skin grafts, random flaps, pedicled flaps, and even free flaps. Amputation is sometimes necessary and other times lifesaving. In spite of all that, especially when skin grafts are used to cover granulating wounds, severe contraction of the inflicted areas is unavoidable [12], [13].

Rarely, more than above-mentioned procedures are needed: When electrical burns involve the head, partial- or full-thickness excision of skull bones are done and in extreme cases even necrotized dura and brain matter are removed [14], [15], [16].

Nowadays, microsurgery is often found as the best solution to severe electrical burns. Because we still do not have the possibility of using free tissue

transfer, limited number of flaps are listed in the surgical procedures. Scarcity of viable tissues around the defect, and not being able to transfer tissue by microsurgery is the reason why even old methods like acute abdominal flaps transferred in stages, are listed in the procedures used by us: In two patients, acute abdominal flaps were applied to cover hand defects [17], [18].

When it comes to timing of the surgical treatment of electrical burns, the period starting 5–7 days results the preferred one [19]. Whereas, for cases complicated by cerebral contusion, the intervention was delayed until the 2nd week after the accident, to prevent intra- and post-operative complications. When surgical excision seems impossible to be done, other ways must be tried, for example chemical debridement, and this is mainly true when facial structures are burned, and where radical excision is better avoided to prevent disfigurement [20].

Anemia is a common complication after true electrical burns. It is related to massive destruction of tissues by the initial injury, but abrupt destruction of significant blood vessels at the burned areas might cause serious bleeding and acute anemia. Sometimes prolonged anemia may be encountered in large burns and may persist for more than 2 months after the initial trauma, in spite of considerable amounts of blood units given to the patient. Depression of the bone marrow is added to the losses due to surgical procedure and daily debridement of the deep wounds [21], [22], [23].

Electrical burns are notorious also for the long hospital stay of the injured patients. Long hospital stays have been reported in the literature that may exceed even 5 months [24]. This proves once more that severe electrical burn is one of the most serious and expensive traumas, with a long hospital stay, numerous surgical procedures, and high possibility for permanent invalidity.

Conclusions

Burns caused by the passage of the electrical current through the human body is one of the most devastating injuries that humans may sustain. Both functional and esthetic consequences are expected after such an accident, especially after true electrical burns.

Mortality rate between electrical burns is low, (4.5%), but the invalidity it causes is high, 40.9%.

As always, prevention is the best treatment and knowing that most of true electrical burns are encountered among professional workers that maintain the national grid, working together with the corporate might further reduce the incidence of true electrical burns.

Surgery is the mainstay of treatment in electrical burns. Application of more flaps might prevent long-term complication after such burns.

Successful treatment of electrical burns often requires a team approach to them, vascular, orthopedic surgeons, neurosurgeons, and prosthetists being a few to mention.

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