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ELECTRICAL PHENOMENA AND ELECTROCUTION BURNS

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ABSTRACT

Introduction. In Romania the number of electrocutions has risen significantly in the last ten years compared to figures in other European countries. We have a higher number of patients suffering from high voltage burns than low voltage (domestic) injury.
Objective. To establish the current state of management of treatment for electrocution post-burn sequelae in pediatric patients in Romania.
Materials and methods. Observational descriptive single-center study: 1a/electrocution burns on pediatric patients; 2a/the collection of data concerning the treatment of patients inclusive in electrical phenomena.
Results. The study took place over a period of October 2012 – December 2014 at Emergency Hospital for Children Grigore Alexandrescu, Bucharest: 72% developing electrocution post- burn sequelare lesions and 28 patients% non developing electrocution post-burn sequelae lesions.
Conclusion. Too many healthy pediatric patients develop electrocution post-burn sequelae lesions after this exposurefor this kind of event.

Keywords: electrocution, burn, high voltage injury, observational study, sequelae, pediatric patients

INTRODUCTION

In Romania, the number of electrocutions has risen significantly in the last ten years, and compared to figures in other European countries, we have a higher number of patients suffering from high voltage burns than low voltage (domestic) injury. In a proportion of 72%, high voltage burns are considered polytraumatisms, leading to higher mortality rates from secondary trauma. In this article we analyze the effects of our proposed therapeutic algorithm implemented at "Grigore Alexandrescu" Emergency Hospital, over a two year period, for electrocution post-burn sequelae in pediatric patients. An overview of the statistical data collected between October 2012 and December 2014 reveals promising results in terms of the survival rate of the electrocuted patients, evolution of post-electrocution sequelae, amelioration of the patient's psychological trauma, and social reintegration in optimal condit.

Electrocution[3] burns, through the sheer complexity associated with their production (thermal burns – Joule effect, and lesions produced by the passage of electric currents through the body – an incompletely elucidated phenomenon) alongside other lesions caused by electric shocks, represent a topic of vital importance in light of the very elevated morbidity and mortality rates attributed to this type of phenomenon.

From a social point of view, such burns have a negative impact on society, bearing on all aspects typically associated with this type of injury, but having a more devastating effect when they supervene to a patient of pediatric age.

The creation of a diagnostic and treatment guide, with post-burn longitudinal tracking for the pediatric patient from moment zero through to the end of the rehabilitation process, is of imperious necessity. For an optimal recovery, a severe burn (high voltage), supervened to a pediatric patient, necessitates immediate and complex treatment, tailored to the special needs of the patient, and carried out by a multidisciplinary team. The proposed implementation of a therapeutic algorithm for post-burn sequelae resulting from electrocution would raise the survival rate, as well as the quality of life for the pediatric patient reaching adulthood, while amelio-

[3]Note: in this article, the meaning of the term *electrocution* is expanded to also include injury via electric current (the original meaning of the term being restricted to death by means of electricity); interchangeable with electric shock.

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rating the effects of the psychological trauma suffered by the patient, making reintegration into society possible.

OBJECTIVES

1. Child electrocutions are rare, but they have grave consequences.

2. Deep tissue lesions will always be more serious than those at the level of the integument and may have long-term (years) effects, predominantly manifesting cardiac, neurological and ophthalmological lesions.

3. The electrocuted patient must be correctly and rapidly diagnosed, with respect to the occurrence mechanism, the degree of the burn, corporal surface, cardiac function, the onset of the compartment syndrome and evaluation of rhabdomyolysis.

4. High voltage burns from electrocution must be treated in specialized centers and must be approached, without exception, as severe polytraumatisms.

MATERIALS AND METHODS

The study was conducted at the Plastic Surgery Clinic, part of the Emergency Hospital for Children "Grigore Alexandrescu", over a period of two years (between 2012 and 2014) using a sample of 83 patients with electrocution burns, divided into 61 patients exposed to high voltage and 22 patients to low voltage, who were treated using the clinical protocol. The particularity of our study consists of a swap, in terms of occurrence, between high and low voltage injuries, such that in Romania high voltage burns have a higher statistical prevalence compared to low voltage injuries, whereas in other European countries the reverse is true. During this period the clinic did not register any patients struck by lightning. The degree of a burn by electrocution depends on:

- the tension of the electric current U – (Volt);
- the intensity of the electric current I – (Amper);
- tissue resistance to the flow of electric current through tissues R-(Ohm), which depends implicitly on tissue resistivity RO-OhmXm
- t – time of the electric current's passage through the organism
- type of the electric current.

ELECTRICAL PHENOMENA INVOLVED IN ELECTROCUTIONS

Electrical phenomena:

- electrostatic: stationary electric charges;
- electrodynamic: dynamic electric charges = electric current

Electrocution takes place when the electric current passes through the organism, an action that implies the following phenomena:

1. Contact: an electric circuit (formed by a switch and a consumer – the human) is closed;

2. Electric arc: electric discharge through an electric field caused by a difference of potential between two objects;

a) Atmospheric electric discharges – electric arcs formed in the atmosphere;

i) lightening represents an electrical discharge between two clouds with different electric charges (different electric potentials)

ii) ground lightening represents an electric discharge between a cloud and the earth's surface; convention dictates the electric potential is null, but it can electrify by influence of an electric charge opposite the cloud's surface, creating a large electric potential difference, known as an electric field

Physiopathology of electrocutions

Direct lesions produced by the passage of electric current through the human body are still under intense controversy owing to an incomplete elucidation of the exact biological mechanism involved. Several theories attempt to show immediate and evolving cellular mutations. Some correlate the degree of severity directly with the tissue resistance (from low resistance – blood vessels to higher resistance – bone) resulting in **progressive muscular necrosis** caused by vascular lesions that lead to **progressive vascular ischemia without regard for the caliber of the arteries.** Others (Hunt et al.) doubt the fact that necrosis is caused by ischemia induced by blood vessel lesions (identified by the different tissue resistance theory) and provide experimental proof that **the body behaves as a uniform resistance conductor**, leading to the conclusion that heat dissipates equally in both bones and blood vessels, nerves etc. This theory singles out length (as opposed to resistance) variations as the factor behind severity variations of lesions. It has also been demonstrated that muscular coagulation necrosis is provoked by thrombosis of the small arteries responsible with the metabolic support of various tissues. Arteriography examinations served to corroborate that electrocution does not lead to occlusions of large vessels. In conclusion, necrosis is produced by **progressive ischemia of small caliber vessels (micro vascular lesions).**

All these theories led to the conclusion that electrocution is not solely caused by the heat dissipated by the tissues exposed to electricity. Researchers, such as Lee and Kolodney, have shown using mathematical and electrical models that electrocution positions tissues in parallel, but the tissue with the highest conductivity generates the greatest heat levels. **The most important novelty introduced by Lee and Kolodney** is, however, the realization that basic cellular lesions are caused by **the electric field** whose magnitude relates to **cellular electric short-circuits** that induce cellular lysis through electro-permeabilization, leading to the rupture of bilaminate lipid membranes. As cause of cellular damage, electric fields are more significant than heat dissipated by the passage of electric current. Electric shock lesions are viewed as a **syndrome caused by the intensity of the electric field** resulting in **both immediate and remote cellular lesions, meaning that associated burns are always overestimated.**

By means of an experiment, Arturson has shown that the electrocution lesion is produced when an **arahidonic acid cascade** is set in motion. This is accomplished by activating phospholipase A which lyses the phospholipids in the cellular membranes, leading to cellular **electropermeabilization.**

The Burn Clinic at "Grigore Alexandrescu" Emergency Hospital is dedicated exclusively to pediatric patients, annually treating approximately forty cases of electrocutions, of which more than half are high voltage burns.

The algorithm used at our clinic has the following structure:

– **primary prophylaxis**: measures aimed at reducing the number of electrocutions – raising the social level, raising awareness through mass media, educational programs etc.;

– **secondary prophylaxis**: prehospitalization therapeutic measures (ABC – trauma management); direct referral to a burn centre; hospital therapeutic measures that imply immediate surgical intervention as well as post combustion shock treatment;

– **treatment of sequelae:** the curative therapeutic method consists of customized treatment, in stages, tailored to the specific characteristics of scar lesions, secondary lesions, age and sex of the pediatric patient, social setting, etc, keeping in mind that the fundamental condition of electrocution burn treatment is immediate, precocious intervention.

The fundamental concept at the core of our tripartite algorithm requires that the treatment of the post-electrocution sequelae begin with the treatment of the post-electrocution burn.

RESULTS

Between October 2012 and October 2014, the Plastic Surgery Center, part of the Pediatric Emergency Hospital "Grigore Alexandrescu", registered a total of 53 patients with electrocution lesions: 39 patients exposed to high voltage, 14 patients exposed to low voltage.

Case 1

Patient B.C, 16 years old, high voltage electrocution, electric arc at the level of the railway crossing, 20% of the corporal surface, 2nd, 3rd, 4th degree burns.

The patient was hospitalized for a period of 2 months, underwent 9 surgical interventions and was discharged having a stable cardiorespiratory status, surgical wounds healing, patient follow-up in 6 months.

Case 2

Patient R.M., masculine gender, 13 years old, 40% corporal surface, 2nd, 3rd, 4th degree burns, high voltage electrocution (electric arc), at the level of locomotive's (Plaga) tension wires, 1 year old post-electrocution sequelae right shank without substance.

The patient was hospitalized for a period of 2 years and 3 months, underwent 18 surgical interventions, was discharged stable, surgical wounds healed, tegumentary defect covered, continuing patient monitorization.

Case 3

Patient I.F., masculine gender, 12 years old, high voltage burn (high tension post), 25% of corporal surface, 2nd, 3rd, 4th degree burns; entry gate – cranial region temporoparietal right; exit gate – left hand, right suprascapular lesion.

The patient was hospitalized for a period of 2 months, underwent 7 surgical interventions, discharged stable, healed surgical wounds, 1/3 distal forearm (left) amputation, continuing patient monitorization.

FIGURE 1. *Injuries after electrocution burns*

CONCLUSIONS

Prognosis is a function of patient's burned surface and age

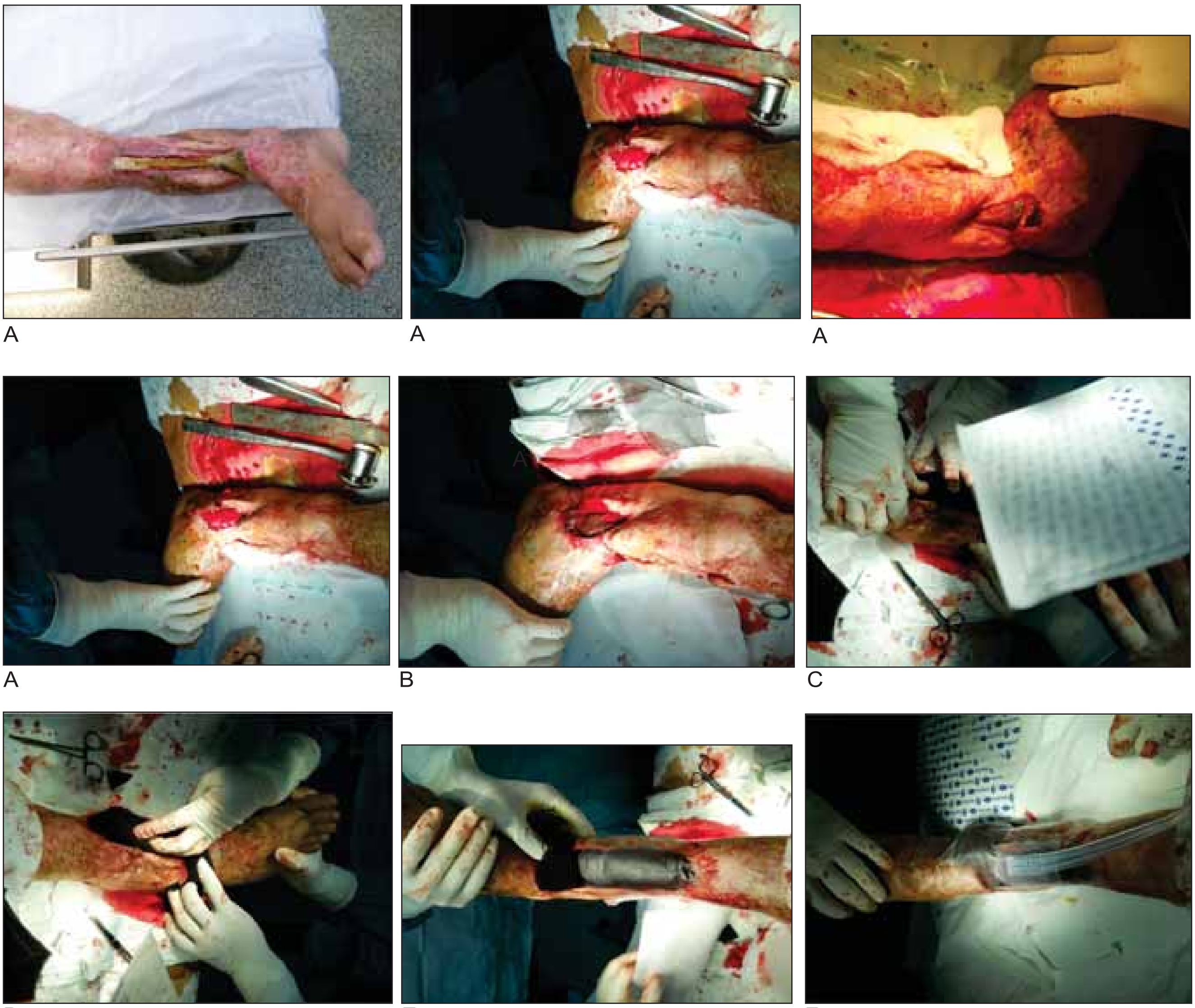
– **M_{50} index** (burned surface with a mortality rate of 50%, for a certain age category); for example, in US, the M_{50} index for a young adult presently situates burned surface at 80% of SC (corporal surface), and even at 90% of SC for an adolescent, in highly performant centers (Schriners).

– **Baux score** is represented by the sum of the percent body surface burned (PBS) and the age of the patient (PBS + age); a Baux score higher than 75 indicates a cautious prognosis, while a score higher than 100 is considered extremely severe.

– **UBS score** (Unit Burn Standard) is an American score; it offers a good representation of the severity of a burn, as a function of surface and depth, and consists of percentage of body surface burned + 3-fold body surface with 3rd degree burns

UBS score = (SB + 3xSB gr III) (For example, a patient with burns covering 50% of the body's surface, out of which 10% SC are total burns, will have a score of UBS = 50 + 3x 10 =80)

According to this score system, a burn is considered severe starting from a score of 50 units, highly



A A A

A B C

D E F

G

FIGURA 2. *Surgical treatment*

severe from a score higher than 100, and extremely severe for a score of 150. We believe this type of evaluation of vital risk is quite reliable, easy to use and adaptive to all age categories.

– **ABSI score** (Abreviated Burn Severity Index) takes into account all factors determining severity of burns and is utilized frequently in specialized burn centers (Table 1).

The implementation of this therapeutic algorithm is based on a prospective study conducted over a four year span (October 2012-2016). The study is composed of two chapters: i) the first chapter is dedicated to fundamental research – cellular and organic lesions, immediate and progressive, produced by the electric current passing through the organism, as well as lesions produced by the **electric field**; and ii) the second chapter is assigned to clinical research – tracking the evolution of patients who registered at the Plastic and Reconstructive Surgery Clinic of the Emergency Pediatric Hospital “Grigore Alexandrescu”.

The age interval, characteristic of a pediatric cohort, offers the ideal timeframe for the implementation of a complete algorithm, because it contains all the stages of development of a postburn traumatic lesion (longitudinal tracking of a lesion), with the final stage overlapping the sequelae lesion of an adult.

The implementation of the 2012 proposed algorithm has improved the survival rate of patients

FIGURA 3. *Post-burn sequelae*

with high voltage burns by more than 55% over a two year period. In addition, it has been registered, albeit over a short period of time, the evolution of post-electrocution sequelae is far superior to the one prior the algorithm.

The post-electrocution sequelae algorithm applied to a pediatric patient mandates immediate treatment, operating under the principle of early surgical intervention, succeeded by the traditional follow-up procedure of post-burn sequelae, irrespective of etiology.

An overview of the statistical data collected between October 2012 and December 2014 reveals promising results in terms of the survival rate of the electrocuted patients, evolution of post-electrocution sequelae, amelioration of the patient's psychological trauma, and social reintegration in optimal conditions.

TABLE 1

Factors determining severity	Variable	ABSI Score
Sex	Feminine/Masculine	10
Age	0-20 years	1235
	21-40 years; 41-60 years	
	61-80 years	
	> 80 years	
Inhalation trauma	1	
Full thickness burn	1	
TBSA burned (%)	1-10% SC	1
	11-20% SC	2
	21-30% SC	3
	31-40% SC	4
	41-50% SC	5
	51-60% SC	6
	61-70% SC	7
	71-80% SC	8
	81-90% SC	9
	91-100% SC	100
ABSI burn score	**Threat to Life**	**Probability of Survival**
2 - 3	Very low	99%
4 - 5	low	98%
6 - 7	Moderate	80-90%
8 - 9	Significant	50-70%
10 - 11	Severe	20-40%
>11	Maximum	< 1%

For an electrocution victim to die it takes 7 milliamperes for a period of 3 seconds!!!! Volts burn, amperes kill!

1. Although in high income countries there is a downward trend in the number of electrocutions, in favour of low voltage electrocutions, in Romania we are registering an upward trend, in favour of high voltage electrocutions.

2. Between October 2012 and October 2014, The Plastic Surgery Clinic registered 652 patients with hot liquid burns, 154 patients with contact burns, 137 patients with lesions produced by flames and flame-explosion, 6 patients with chemical burns and 83 electrocutions

3. Low voltage electrocutions, also known as domestic voltage, is typically associated with children between 1-6 years old, while the age group for high voltage victims is between 9-10 years (which represents a significant drop compared to previous years). This can be explained by the fact that the majority of victims belong to unfavoured social categories, as well as by a lack of interest at the level of the general population with respect to prevention campaigns and household accidents.

4. Between October 2012 and October 2014 a total number of 83 patients were hospitalized, 61 of the patients were exposed to high voltage, 22 to low voltage, a difference of 8.1% compared to western countries.

5. The patients who underwent grafting, in spite of administering the correct treatment, suffered from acute renal insufficiency, acute cardiac insufficiency, progressive neurological lesions, irreversible, leading to cardiorespiratory arrest (unable to resuscitate).

6. The physical effects of the electric field, produced by the passage of the electric current through the organism, proved to be the cause of death for the stabilized patient, who underwent a delayed surgical intervention.

7. All the lesions resulting from high voltage electrocutions were polytraumatisms, with associated internal organ contusions, not requiring surgical intervention, but those associated with fractures necessitating immobilization.

8. The novelty of the phenomenon at the root of electrocution lesion formation of internal organs, with major implications at the cellular level, in the absence of associated secondary traumatism, consists of the *physical effect* determined by the electric field produced by the passage of the electric current through the organism, such that the thermal burn (Joule effect) plays only a small part in the physiopathology of cellular lesions, at the level of teguments, but even less so at the level of the affected internal organs.

9. Post-treatment tracking of electrocuted patients discharged from the hospital, who need to undergo future interventions based on age, is difficult; under 50% of the electrocuted patients (especially those with high voltage) who have survived return for corrective surgery.

10. Hospital records for these patients show cardiac lesions, nervous system lesions as well as ophthalmologic lesions may occur even 5-10 years after the initial treatment for high voltage burns.

11. In a much smaller proportion, the same types of lesions have been observed for low voltage electrocutions.

12. Until this moment, electrocution is a type of burn with very high mortality rates, in part through the direct lesion produced by the passage of the electric current through the organism, as well as through the polytraumatisms (high voltage electrocutions) associated with it, in a proportion of 85%. Low voltage electrocutions (domestic) have a smaller risk of immediate mortality, but over the long term may evolve in cardiac, neurological and / or ophthalmological lesions.

13. The key to success is prevention: social (markings, education in schools, TV campaigns), familial (protection measures for electric devices, ulterior familial education) and restricting access

for children to high tension sources: railroad tracks, electrical trains, high tension posts, toughen laws that address trespassing of potentially dangerous areas, for hired personnel responsible for supervising these areas, as well as for persons responsible for the welfare of children.

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