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EMERGENCY TREATMENT AND EARLY FLUID RESUSCITATION FOLLOWING ELECTRICAL INJURIES

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SUMMARY

Injuries caused by high-tension electrical current are rare, but pathophysiologically unique with destructive effects. As a form of thermal trauma, electrical injuries represent a connection of skin burns and deep tissue destruction unpredictable in its depth which mostly resembles a crush injury.

Emergency treatment measures begin with the separation from the electrical contact if any and prompt transport to the nearest institution with all means for cardiorespiratory resuscitation and complete recovery. Resuscitation of the patient after electric shock continues then with fluid replacement using special formula modified for such cases, correction of acidosis and myoglobinuria and finally with escharotomy and fasciotomy which is most often necessary.

ZUSAMMENFASSUNG

Die urgente Behandlung und die frühe Flüssigkeitsresuszitation bei Verletzungen mit elektrischem Strom

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Die Verletzungen, die durch elektrische Hochspannung verursacht werden, sind zwar selten, aber durch ihre destruktiven Auswirkungen sind sie patophysiologisch bedeutend. Als eine Form des termalen Traumas repräsentiert die elektrische Verletzung eine Verbindung der verbrannten Haut und der Destruktion des Tifgewebes, dessen Tiefe man nicht voraussagen kann. Meistens erinnert die Verletzung an ein zerquetschtes Gewebe.

Die unaufschiebbare Behandlung beginnt mit Trennung des Verletzten von elektrischem Strom (der Kontakt wird aufgelöst) und dann folgt der urgente Transport ins nächste Krankenhaus, in dem sich eine Station zur kardiopulmonalen Resuszitation befindet, und in dem eine komplexe Behandlung garantiert ist. Die Resuszitation des Patienten nach dem elektrischen Schock erfolgt durch den Ersatz von Flüssigkeit nach einer spezielle modifizierte Formula für diese Fälle, Korrektion der Azidosa und der Myoglobinurie. Die Escharatonie und die Fasziotomie sind unbedingt.

Key words: electrical injuries, resuscitation, fluid replacement, fasciotomy

Injuries caused by the electrical power are rare, pathophysiologically unique and have destructive effects. Those injuries are considered a particular field of thermal traumas. Related to the other types of thermal injuries, electrical burn injuries are considered specific due to extreme heat generated by a tissue resistance during electricity flow and unpredictable flow path through a body, as well as specific reaction of certain tissues.

Being unique and destructive form of a thermal trauma, electrical trauma represents a connection of skin burns and of deep tissue destruction unpredictable in its deepness and form. Because of progressive tissue necrosis, mostly it looks like a crush injury.

Concerning diagnostics, most of physicians are ready to call an electrical injury - an electrical burn. In most cases, when body is in connection with the electrical power, a burn is caused. However, part of electrical injury is caused during flow of electricity through deep tissues where much serious damages than a skin burns are caused. This is the reason that an electric injury affects muscles and is followed with the presence of great myoglobin quantities in urine. Similar to it, an electrical injury penetrates into deep tissue causing muscular destruction and is followed with the presence of great myoglobin pigment quantities in urine and with acute tubular insufficiency. Sometimes it is possible to see an electric injury of the extremities that looks like a burn and is treated that way, while underneath a clostridial myositis is developing in two or three days period. Already dead tissues, skin and muscles, enable penetration of the microorganisms and de-

velopment of a destructive clostridial infection (Figs. 1, 2).

Fig. 1.

Figs. 1, 2: Passage of the high-tension electric current over the flexor surfaces from radiocarpal joint to the axilla.

All those facts are pointing out the serenity of the problem we are facing in the century which makes impossible to imagine life without electricity. Electrical power is constantly surrounding us in appearing in different electrical devices in the house, in the offices, even in nature. Increasing industrialization and technological development, as well as the life standard improvement enabled most of the people to use electrical devices. In the past few decades this affected the increase of injuries and fatal results caused by the electric power. On the other side, improvement of a security measures, general education and constant anti hazard warnings against electroinduction represent positive facts in keeping the number of injuries below the level that should be expected.

Those injuries are mainly present in the young population facing the most productive life period and very often they result, if not with fatal end, then with severe and permanent invalidity followed by great economical and social consequences.

TREATMENT

1. Initial Treatment

Initial treatment of an injured person depends upon the type of electrical burning injury. If it is electrocution, separation of the injured person from the contact with electrical power is the first measure to be taken in such situations. Persons involved in this procedure, e. g., rescuers, need to be well-isolated themselves in order to avoid electrical shock during attempting to separate the injured person. If this operation is successfully completed, an urgent evaluation of cardiorespiratory status of the injured person is to be taken as well as resuscitation mesures like ventilation with external heart compression, in case of heart failure. Most survivors begin to breathe spontaneously in 30 minutes, while complete recovery needs continuation of resuscitation measures for at least four hours more. Transportation in the nearest specialized health institution, e.g., an intensive care department, has to be organized in proper way and as soon as possible.

Cardiorespiratory problems of the patient injured with electricity are either fatal or not noticeable after the time of reaching a hospital, but is necessary to continue with monitoring. In this moment, however, it should proceed with an urgent and adequate shock treatment and prevention the of strong ischaemia consequences that appears after sudden swelling, specially on extremities.

1.1. Resuscitation of the Patient After Electrical Shock

Consequence of injury caused by electrical power is sudden, almost immediate lost of body fluids in the area of a damaged tissue and consequent release into myoglobin from damaged muscular cells of circulation. Small quantities of haemoglobin produced by erythrocyte destruction are released as well as other intercellular substances which cause heavy metabolic acidosis. Fast application of a special therapy for any of mentioned abnormalities is helping in decreasing electrical injury complications which are numerous in the first stage.

1.1.1. Fluid Replacement

Fluid replacement is the most important aspect of the initial resuscitation of the electrically injured patient. Patients with conventional thermal injuries, e.g. burns should replace a quantity of fluids that is easy to calculate if using some of the already known formulas by means of calculating body weight and percentage of the TBSA (Evans, Brook, Parkland formula).

However, unpredictable extensiveness and deepness of tissue damages are the factors that make more difficult evaluation of the lost fluids. In such situation percentage of the burned surface cannot be an indicator for the quantity of fluid which should be replaced. Some authors are

recommending the increasing of this quantity three times if the burned skin surface is below 20% of the TBSA. It should be increased twice or even less considering increasing of a burned skin percentage. According to this, patient with upper extremity electrical burn needs 7 - 8 litters of fluids per day in order ot get adequate reanimation. Anyway, taking into account that a surface of a burned skin cannot be an adequate parameter for evaluation of a lost fluids, it is considered that the most important is fast fluid replacement until a stabile urinary output of 50-100 ml per hour is achieved. It is necessary to maintain the urinary output achieved in this way. The isotonic balanced saline solution such as Ringer-lactate is the ideal solution because intercellular fluid, that is the most similar, represents the most part of the lost fluids.

As in any other process of a patient reanimation process, a permanent monitoring is necessary as well as constant measurement of urinary output per hour, haematocrit, osmolality of plasma and a central venous pressure. Diuresis of 50-100 ml/h and gradually decreasing of haematocrit are usually the signs of an adequate fluid replacement.

Sometimes it is not possible to make a precise calculation of the fluid quantities needed for adequate resuscitation. That is the consequence of an inadequate primary treatment in the health institution that is having the first contact with the patients or because not keeping a precise evidence of the given fluids. Despite of those problems, we succeeded to establish some kind of protocol for fluid replacement at those patients:

* A fluid replacement should start according to Parkland's formula increased two or three times depending on the surface of electrical injury (three times if the surface is 20% and twice or less according to the increasing percentage of a burned skin)

* In the first 24 hours exclusively cristalloids should be used as well as energetically important hypertony solutions with constant checking of a serum sodium that should be maintained between 145 and 160 meq/l.

* Alternative hyperbaric oxygen therapy should start as soon as possible, e.g., immediately after completing the initial treatment.

* Intensive use of hypertony crystalloid solutions gives a possibility of using colloids (4-20% albumins, fresh frozen plasma) in the first 18-24 h after injury. Hyperbaric oxygen with its vasoconstrictive effects decreases protein loss.

* Fluids replacement should be intensified, if necessary for the stimulation of diuresis that should be 50 - 100 ml/h and with the control of the color of urine because of the presence of haemachromogens.

* In case of myoglobin appearance some instant measures should be taken giving great quantities of fluids and osmotic diuretics, choosing manitol preferably.

* To exclude threatening hyperkaliemia after 24 h a constant potassium control should be maintained as well as control of sodium, urea and creatinine.

* After peristaltic appearance during second day it should be started with nasogastric hyperalimentation.

* Blood transfusion may be used starting second or third day.

* Taking of vitamin C (500-1000 mg per day) is a contribution for the wounds healing.

1.1.2. Acidosis

With electrical injuries the fall of blood pH is much bigger than with purely thermal injuries, e.g., burns. This is the result of great quantity of acid disintegration products from devascularized and devitalized tissues. Blood pH fall cannot be in correlation with injury extensiveness because blood vessel thrombosis often stop the comeback of acid products into circulation system. Patients having electrical injuries with 10 - 20 % TBSA and not having big blood vessels' thrombosis, often have arterial pH between 7,20 and 7,24 in the first few hours after being injured and having thrombosis of big blood vessels can have arterial blood pH within the normal limits.

More than half of patients suffering mioglobinuria face extreme acidosis that makes reanimation process more complicated. For the proper treatment of this actual or potential problem arterial blood should be constantly checked to pH, pO_2 and pCO_2. Correlation of acidosis demands a special alkalized therapy. 100-300 mEq of sodium bicarbonate should be included in the first 2-3 litters of fluid as a prevention of further blood pH fall. It should be constantly kept under control.

A further phase requires dozes of 80 - 120 ml of sodium bicarbonate to keep and achieve stabilization of pH at acceptable level, e.g., above 7,35. A total quantity of sodium bicarbonate needed for a complete stabilization of acidity is individually variable. Considering that most of the patients having tissue destruction show the signs of acidosis, the usage of sodium bicarbonate as an early treatment is the right preventive therapeutical approach.

1.1.3. Mioglobinuria

Myoglobin presence in urine is not rare in patients who have significant electrical injuries. Its value can reach up to 6 gr. on 100 ml. This is representing a sign of massive muscle destruction. The greatest part of pigment excretion is myoglobin. The haemoglobin can be noticed in very small quantities representing a destruction of red blood cells. Presence of coloured urine, with color variation from red to black despite of relatively good diuresis (> 50 ml), is a reliable sign of massive muscle destruction. At C. Baxter's serial, all the patients that suffered mioglobinuria over six hours had to have either an amputation of one or more extremities or extensive necrectomy.

The hemohromogen appearance in urine demands a special treatment in order to prevent tubular insufficiency development as a result of pigment excretion in the presence of hypovolemia and acidosis. Therapy consists of great quantities of fluids and osmotic diuretics and manitol is the diuretic of choice. Depending on an author, the concentrated dozes may be applied for a short period (initial dose of 25 g, than 12,5 g per hour in the period of few hours, results usually with diuresis of 200 - 300 ml/h - according to Baxter or even smaller dozes of 5 - 20 mg/h for several days).

Mioglobinuria that is maintained several hours, even several days, after having an adequate fluid replacement, as already has been stated, is a sign of a great muscles destruction. In those cases an early amputation or extensive necrectomia represents the only safe choice. Permanent monitoring of arterial blood pH is obligatory because hemohromogens are giving paradoxical alkaline urine that cannot be the criterion for therapeutical decisions.

1.2. Escharotomy and Fasciotomy

Fasciotomy has therapeutical and diagnostic role in the treatment of electrical injuries. An intensive swelling of injured extremity, usually present at the beginning and during first several hours, obviously gives a first indication for fasciotomy in order to normalize a blood flow. Impaired circulation distal from the injured area represents a big therapeutical problem. It can be the result of a constrictive effects of the strong eschar that circumferently takes full skin thickness (Fig. 3).

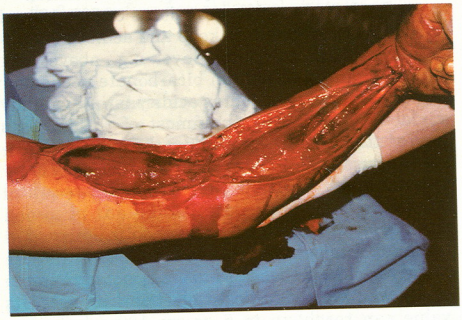

Fig. 3: Fasciotomy after electrical injury of the upper extremity.

It can also be the result of compressive effect of venous obstruction and/or subfascial oedema of the swollen muscles. It is very difficult to achieve a complete certainty of etiology of distal vascular collapse during electrical injury of an extremity. It is specially difficult in a situation when the injury is combined also with a flame burn. In case of impared circulation the adequate, prompt and full treatment is necessary. After removal of a solid eschar if there is still no expected blood flow, a fasciotomy is indicated if manifested by swallowed, oedematous muscles under the fascia. If there is even any sign that a subfacial swelling is a cause of an impared circulation then we have a definitive indication of fasciotomy. The muscles' appearance which is to be expected is going to give us an answer about an amputation necessity. However, in that moment, it is not definitively a reliable factor because a progressive arterial and venous thrombosis can provoke a muscular necrosis in a period 2 - 3 weeks after being injured. This is pointing out the problem of an early necrotomy in electrical injury cases (Fig. 4).

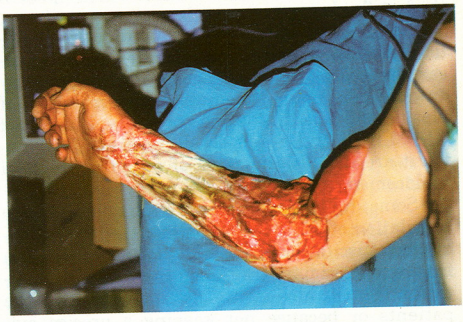

Fig. 4. Extensive muscle necrosis of the forearm following high-tension electrical injury.

Even in cases of extreme carbonification when the necessity for amputation is obvious, an initial fasciotomy will enable the lowest possible level of amputation. On the other hand, with patients who have minimal surface swelling very often the heaviness of injury can be overlooked. Careful fasciotomy of certain muscles' compartments can lead us to their swelling even in cases when skin is not hard and swelled enough to point out a fasciotomy necessity.

Fasciotomy can be very important in determinating the area and extensiveness of necrotic muscular masses. If those necrotic masses remain unnoticed, in a period of 3 - 5 days they become toxic, susceptible to liquefaction and abscesses formation that leads to sepsis. Muscular damage can sometimes be limited to only one group of extremities while in a further development muscular necrosis may spread selectively either into deep or superficial muscles of the one or several compartments.

An adequate fasciotomy requires a skin and subcutaneous incision as well as incision of all muscular groups. Still it is not a guaranty for survival of damaged muscular masses because intravascular thrombosis during the first two weeks may only postpone the indicative signs of