Electrical burns

Because they usually involve the skin and deeper tissues, electrical burns can be devastating.

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Electrical burns are the most devastating of all thermal injuries on a size-for-size basis, usually involving both the skin and deeper tissues. These injuries have multiple acute and chronic manifestations not seen with other types of thermal injury. Morbidities, length of hospital stay and number of operations are much higher than expected, based on burn size alone.[1] The spectrum of injuries ranges from mild injuries due to shock of low voltage (battery-driven radios) to disastrous injuries seen in high-voltage injuries.

Electrical burns are the most devastating of all thermal injuries on a size-for-size basis.

In the Polokwane/Mankweng Hospital Complex, high-voltage burn injuries have been seen in patients who attempt to steal copper wires from high-tension lines transporting electricity. Mortality and morbidity in these patients are very high.[2] In contrast, in low-income households the incidence of acute domestic electrical burns is low despite increased use of electricity and reports of illegal and unprofessional electrical connections. Children presenting with contractures of digits secondary to electrical burns are seen more often.

Pathophysiology

Electrical current (electricity) is the flow of electrons from one atom to another.[3] It is this energy that burns or kills the victim. Voltage is the force that drives electrons in one direction. Electrical resistance is measured in ohms/cm^2. It is a measure of how difficult it is for electrons to pass through material or a body part.

Body resistance to electrical flow

Dry skin resists electrical flow by 40 000 - 100 000 ohms. Calloused skin (mainly on the soles of the feet) is the most resistant. Wet skin resistance is 1 000 ohms, which is 40 - 100 times easier for electrical current to pass through. The skin of a child is thin and less resistant due to high water content. Tissue resistance inside the skin is 500 - 1 000 ohms. Ranging from lowest to highest are nerve, blood vessels, muscle, tendon, fat and bone.[1]

How does electricity burn?

As electrons flow from one atom to another, they collide with each other converting kinetic into thermal energy (heat).[4] This heat (thermal energy) causes protein to coagulate and is called a burn. The released heat is proportional to the resistance of the conductor or body part, e.g. muscle, fat, or blood vessel.

Classification

Electrical burns are classified as low- and high-voltage injuries, with 1 000 volts being the dividing line.

Low-voltage electrical burns (50 - 1 000 V)

This type of electrical burn has a more localised area of tissue destruction and mainly occurs in the domestic environment. Often toddlers are involved. The history is usually that the child grabbed the bar of an electric heater. What is alarming is that these burn injuries are seldom seen in the acute stage at the burns unit. Very often the child presents with contractures of fingers and/or the hands. This burn injury involves small areas of the hand and fingers. Unfortunately it may be severe enough to warrant amputation of digits. Low-voltage alternating current may cause tetany of muscles because it stimulates skeletal muscle contractions.[5] During this contraction, the flexor muscles dominate. This can lead to 'locked-on' effect. As a result the patient cannot release the grip. The duration increases as the current passes through the body and hence causes a more serious injury. Direct current usually produces a single large muscle contraction that throws the patient away from the electrical source. While this reduces the duration of current flow through the body, it may cause fractures.

High-voltage electrical burns (>1 000 V)

These occur mainly in patients who are working in the industry or who (*Izinyoka*) are trying to steal electrical transmission cables (copper) for sale. At high voltage both alternating and direct current have the same effect. These burn injuries can be subdivided into electrical arc/light flash burns, electrical current flow, or lightning.

The extremities are the most frequently injured body part, with severe injury often occurring in the arm and hand.

Electrical arc/light flash burns

The arc is formed between the victim, who is grounded and has low-voltage potential and often carries a metal object or tool, and an electrical source that has high voltage. The arc consists of hot ionised particles and hot surrounding gases, driven by voltage pressure difference between the two. The current from the arc

Fig. 1. Entrance wound (both arms), exit wound (left side of abdomen) and escharotomy on the left arm.

travels outside the body and burns along its path of contact with the patient to the point of grounding mechanism. A temperature of up to 4 000°C can be generated as a flash-type injury.[6] Flame burns result from ignition of the patient's clothing.[7]

Burns caused by electrical current flow

The burn is inflicted by an electric current passing from a power source to an anatomical point of contact with the patient (entry wound) and through the body to an exit point (exit wound) (Fig. 1) from the body to the grounding mechanism. The amount of thermal energy released is proportional to the resistance of body tissues encountered from the contact point (entrance wound) to the exit point or wound. Deep tissue appears to retain heat and hence more severe injury is seen in the peri-osseous tissues, especially between two bones (tibia-fibula, radius-ulna).[8] The most severe injuries are seen at the wrists and ankles, with decreased severity proximally. The extremities are the most frequently injured body part, with severe injury often occurring in the arm and hand. As current follows the path of least resistance it may generate small deep arc injuries in the axilla, groin, popliteal and antecubital fossae.

Lightning burns

This involves a single massive current impulse of greater than 2 000 volts during an extremely short duration of 0.1 - 1 ms. This is the direct strike. The short duration minimises thermal injury. The patient may be burnt by a side flash, i.e. a discharge from an object near the victim, or by flash-over, in which case energy passing outside the patient's body causes vaporisation of surface water and a blast effect on clothing.

Lightning may cause cardiac arrest due to massive depolarisation of the heart leading to asystole. However, due to its automatic rhythm, normal sinus rhythm may occur as the heart restarts. Cardiac arrest may also occur due to massive depolarisation of the brain that stuns the respiratory centre, leading to longer central apnoea. In this situation artificial respiration is necessary for the patient to survive. In areas where lightning is not usually severe this is an uncommon injury but in neighbouring countries (e.g. Zimbabwe) up to 300 lightning deaths are reported each rainy season.

Management

The best way to treat electrical burns is prevention. At home, burns can be prevented by:

- using plug blockers that prevent children from placing their fingers in the outlets
- insulating damaged electrical cords
- keeping electrical kettle and cords out of reach of children
- unplugging appliances before attempting repair
- not using electrical devices near bathtubs or other bodies of water.

In public, teenagers should be discouraged from climbing electrical poles, and criminals stealing electrical cables should be discouraged and made aware that mortality from high-voltage electrical burns is extremely high.

The acute care situation should be handled by:

- switching off the power if possible
- disengaging the victim by using a dry wooden pole while standing on dry ground
- assessing for airway patency
- sending the patient to the nearest health facility.

Ventricular fibrillation is the most common cause of death at the scene of injury. Arrhythmias are treated using the same indications and modalities as for medical causes.

At the health care facility

The patient should be examined and an adequate history of the accident obtained. Where possible get information on the voltage (low or high), type of current (direct or alternating), and whether the patient froze or was thrown away.[5] The burn injury should be evaluated for entry, exit, extent and depth. The extent or total body

Fig. 2. High-voltage electrical burn: amputation of right arm at shoulder level and above-knee amputation of right leg.

surface area burnt may be difficult to calculate because deep structures that are burnt may be covered by normal skin between the entry and the exit wound.

Depending on the extent of the burn and the general condition of the patient, the patient may be treated as an outpatient or an inpatient at general hospital or referred to a specialised centre.

Investigations include routine emergency room tests. Analgesics should be given in adequate doses. Fluid resuscitation in the first 24 hours should be crystalloids tailored to urine output of 1 - 1.5 ml/kg body weight. High-voltage burns (>1 000 V) cause rhabdomyolysis and myoglobinuria. In the presence of haemochromogenes (myoglobinurea) sodium bicarbonate may be added to an intravenous drip, to increase the solubility and clearance of myoglobin.

The wounds may need special or routine dressings depending on availability.

Surgical treatment

Surgical treatment of electrical burns involves repeated evaluation of the burn wound and early escharotomies on digits and extremities when needed. Fasciotomy and excision/debridement of all dead tissue should be done early to prevent rhabdomyolysis, renal failure, loss of limbs and death. In high-voltage burns amputations of extremities are common (Fig. 2). Split skin grafting for burn surfaces not overlying deeply burnt tissues may be done at the time of debridement (Fig. 3).

We have also noted loss of lips in our high-voltage burn injury patients (Fig. 4).

Fig. 3. Postoperative split skin graft to exit wound.

Fig. 4. Electrical burns with loss of left side of lips and ectropion.

Reconstruction of lips on these patients is unfortunately unsatisfactory. In our setting all our high-voltage survivors lost a limb, a lip, an ear or a digit.

Conclusion

Electrical burns are the most devastating of all thermal injuries. These injuries have multiple acute and chronic manifestations. Our patients have gone home with an everlasting memory. They have all been adult male, attempting to steal copper wires that they claim to sell at R12 000 a metre to jewellery manufactures and dealers. Mortality is very high.

References

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In a nutshell

- In our setting, we see increasing numbers of patients with high-voltage electrical burns.
- Most patients are men who are trying to steal electrical cables (copper wires) for sale.
- Morbidity and mortality are high.
- Low-voltage electrical burns have high morbidity among toddlers.
- Fluid resuscitation in electrical burns should be tailored to urine output.
- Calculation of total body surface area burnt does not fit in the usual formulae and charts methods.
- The entry wound does not have to be smaller than the exit wound.
- Early escharotomies and fasciotomies prevent amputations of limbs and digits.
- Prevention of electrical burns should be our first-line approach.