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Evaluation of the Treatment Protocol of Electrical Injuries in Ain Shams University Burn Unit

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ABSTRACT

Electrical injuries are uncommon type of burn trauma. They represent 1.5% of admissions in our burn unit. In this study, we analyzed retrospectively the epidemiology, the treatment protocol and the outcome of electrical injuries. Twenty-five patients with electrical injuries were treated in Ain Shams University Burn Unit over a 7-year period from 1996-2002. Fifteen patients had low-voltage injuries and ten patients had high-voltage injuries. The study showed that our treatment protocol is satisfactory for resuscitation and prevention of renal failure. Low-voltage injuries are not always minor burns. Reconstructive procedures in the form of skin grafts or flaps are needed to maintain hand function in 50% of cases with contract low-voltage injuries. High-voltage injuries are more devastating and frequently end with a destructive surgery in the form of amputation. The amputation rate of conductive high-voltage injuries is 71.4%. Two cases died from complications of associated thermal burns. One had low-voltage and the other had high-voltage injury. The causes of death were inhalation injury and burn wound sepsis. The factors behind the high morbidity and low mortality are discussed. The surgical attempts at lowering the amputation rate in high-voltage injuries are revised.

INTRODUCTION

Electrical injuries are uncommon type of burn trauma. Misuse of electricity, poor quality control and safety standards and lack of public awareness all contribute to the incidence of electrical injuries **[1]**.

Several factors must be taken into consideration when the effects of the passage of electric current through the body are determined. These are the type of circuit, the voltage of the circuit, the amperage of the current, the body resistance, the pathway of the current through the body and the duration of contact **[2]**. Electrical injuries are classified according to the extent of tissue damage into low-voltage, caused by less than 1000 volts and high-voltage, caused by more than 1000 volts **[3,4]**. Low-voltage electrical injuries are usually associated with minor local wound problems. Experimentally, they were found not to progress more than 48 hours after the injury **[5]**. Surgical treatment includes debridement once or twice and full-thickness or split-thickness graft for definitive coverage in most of the cases **[6]**. Minor amputations of the fingers may or may not be needed **[7]**. High-voltage electrical injuries represent a severe type of trauma. They consist of varying degrees of cutaneous burns combined with hidden destruction of deep tissues and progressive necrosis **[8]**. Extensive limb damage may occur, which frequently requires major amputation of the extremity **[7]**.

Burn trauma carries a low priority in developing countries and burn centers or units have been established in only a few institutions **[9]**. In Ain Shams University Hospitals, a burn unit had been established in 1995. We deliver in-patient and outpatient care for various kinds of burns in all age groups according to certain admission criteria **[10]**. This article presents the epidemiology, the treatment protocol and the outcome of management of electrical injuries in Ain Shams University Burn Unit. The aim of this study is to evaluate the efficacy of the treatment protocol and to put recommendations to improve the outcome of management of electrical injuries.

MATERIAL AND METHODS

This study was done retrospectively on 25 electrically injured patients, admitted to Ain Shams University Burn Unit in the period from 1996-2002. Twenty-four patients were males (96%) and one only was a female (4%). Their ages ranged between 2 and 46 years (average 24.4 years) and the surface extent of burn ranged from 0.5 to 46% TBSA (average 8.86% TBSA). Assessment of the condition of the burned patient is donin the emergency room. The type, surface extent and the depth of burn are recorded **[11]**. The depth is reassessed during subsequent debridements and dressing changes. The presence of inhalation injury is diagnosed by the clinical examination, the presence of facial edema, laryngoscopic findings and blood gases. Bronchoscopic examination for suspected cases of inhalation injury in adults was introduced only in the last four years of this study.

Admission and in-patient treatment, either in the ward or in the intensive care unit is done, provided that the delay after the inception of the burn trauma did not exceed 24 hours, according to the criteria described by Choctaw and his associates [10]. Burned patients who do not fulfill these criteria for admission are treated in the outpatient clinic till healing of their burn wounds or becoming ready for grafting.

Diagnosis of the type of electrical injury either as a low-voltage or a high-voltage injury is made according to the clinical examination and the history given by the patient, an attendant of the accident, or the medical report supplied by the medical facility that provided first aid management and/or transportation. All cases with high-voltage injuries are admitted to the ICU, where they are maintained on 100% oxygen and cardiac monitoring for at least 24 hours. Cardiac monitoring stops only if the ECG wave-pattern is normal or non-specific. Diagnosis of the type and depth is confirmed later intra-operatively during debridement. We had 15 patients with low-voltage injuries (60%) and 10 patients with high-voltage injuries (40%).

In high-voltage injuries, fluid resuscitation is started by intravenous infusion of Lactated Ringer's solution at a rate of 7 ml/Kgm of body weight/each percent of the TBSA burn [3]. The aim of fluid resuscitation is to correct hypovolemia and maintain urine output at approximately 100 ml/hour in order to prevent deposition of hemochromogens in the renal tubules. If this cannot be achieved by fluid infusions alone, diuresis is induced osmotically by Mannitol, 25 gm initially, followed by 12.5 gm/hour. In addition, frusemide as a loop-diuretic or a low-dose dopamine may be given if required. Acidosis from hypovolemia is corrected by intravenous sodium bicarbonate at a rate of 200-400 mEq/hour for 2-4 hours, guarded by the arterial blood pH, which should not exceed 7.5 [12]. This will also lead to alkalinization of urine and prevent precipitation of hemochromogens in the renal tubules.

Escharotomy and fasciotomy were done in the emergency room for all cases with true, conductive high-voltage injuries to the extremities to release the underlying muscle compartments (Fig. 1). Clinical signs of increased compartment pressure are: decreased peripheral pulse, increased muscle turgor and evidence of nerve compression [12]. The later includes pain, tingling and decreased sensation. Motor nerve dysfunction is difficult to assess because muscle damage produces the same effect of motor nerve damage. The vascular status is assessed by palpation for arterial pulse, capillary refilling test, Allen's test, Doppler examination and inspection during operation [13]. In electrical injuries of the hand, the carpal and ulnar tunnels are released to decompress the median and ulnar nerves. The dorsal interosseous compartments are released to prevent intrinsic muscle necrosis. The radial and ulnar sides of the fingers are incised to encourage blood flow to the fingertips.

Debridement of the non-viable skin, subcutaneous tissue and muscles is done in the operating room under anesthesia as soon as the general condition of the patient is stabilized. Conservative approach is adopted for tendons, nerves and any significant vessel. Muscle viability is judged from its color and response to stimulation by electrocautery rather than large vessel bleeding [14,15]. Debridement is repeated as necessary because of the deep, hidden and progressive nature of muscle damage. After hemostasis is secured, the escharotomy and fasciotomy wounds are covered by topical Bovidone lodine ointment. Granulating, viable tissues are covered by a skin graft or flap, depending on the wound bed and functional requirements. Amputation is done for non-viable, functionless extremity by the vascular surgeon.

RESULTS

This 7-year study was conducted retrospectively on 25 burned patients, treated in our burn unit in Ain Shams University Hospitals. Electrical injuries are more common in males (96%) and affect children, young adults and middle aged (range from 2 to 46 years). The data of these patients are summarized in Table (1).

The surgical procedures done for these patients included escharotomy, fasciotomy, STSG, local, regional and distant flaps and amputation. These procedures and their outcome in both low-voltage and high-voltage electrical injuries summarized in Table (2).

Compared with high-voltage injuries, low-voltage electrical injuries are more common (60% of cases). All these cases had hand injuries, with or without associated thermal burn. The later was encountered in 6 cases. The period of hospital stay is shorter (average 12.3 days). They are associated with low morbidity and mortality (0% amputation rate and 6.7% mortality rate). The only patient who died had an associated thermal injury. The cause of death was inhalation injury. Apart from repeated dressings and debridements, surgical intervention was required for 5 cases to resurface deep burns of the fingers or to maintain the web spaces (Fig. 2). These include STSG (2 cases), 1st dorsal metacarpal artery flap (1 case), V-Y advancement flap (1 case) and abdominal flap (1 case).

High-voltage electrical injuries are less common than low-voltage injuries (40% of cases). The period of hospital stay is longer (average 21.7 days). They are associated with higher morbidity and mortality (50% amputation rate and 10% mortality rate). The only patient who died had an associated extensive thermal burn. The cause of death was sepsis and multiple organ failure. Surgical intervention included resurfacing with STSG (autografts in 6 cases and homograft in 1 case), rotation flap for exposed calvarial bone (1 case) and major limb amputation (6 major amputations in 5 cases). STSG loss occurred in one case of perineal injury because of infection (Fig. 3). The wound healed by scar formation, which was released and reconstructed later. Major amputation was required for 5 patients, bilateral in one of them (Fig. 4).

Table (1): The age, surface extent, hospital stay, amputation rate and mortality rate for low-voltage and high-voltage electrical injuries.

Type of injury	Age (years)		Extent (% TBSA)		Hospital stay (days)		Amputation		Mortality	
	Range	Mean	Range	Mean	Range	Mean	No.	%	No.	%
Low-voltage N = 15	2-46	20.4	0.5-25	4.4	1-41	12.33	0	0	1	6.7
High-voltage N = 10	14-46	30.4	2-46	15.6	1-51	21.7	5	50	1	10
Total N = 25	2-46	24.4	0.5-46	8.86	1-51	16.5	5	20	2	8

Table (2): Surgical procedures and outcome of different types of electrical injuries.

	Low-voltage injuries		High-voltage injuries	
Type of injury	Contact burns	Flash burns	Conductive injury	Flash burns
Number of cases	10 (1 case had thermal burn)	5	7 (1 case had thermal burn)	3
Surgical procedures	STSG (n = 2) V-Y advancement flap (n = 1) 1st dorsal metatarsal artery flap (n = 1) Abdominal flap (n = 1)	Dressing	Homograft (n = 1) STSG (n = 6) Rotational scalp flap (n = 1) Major amputations (n = 6) (5 above elbow and 1 below elbow)	Dressing
Amputation rate	0%	0%	71.4% (5 cases)	0%
Mortality rate	10% (1 case)	0%	14.3% (1 case)	0%

N.B.: The two cases died from complications of associated thermal burns and not from the electrical injuries.

Fig. (1): Fasciotomies for a case of high-voltage electrical injury of the Rt. Forearm:
A- Fasciotomy at the ulnar side extending proximal to muscle edema.

Fig. (2-A)

Fig. (2-B)

Fig. (2-C)

Fig. (2): Low-voltage electrical injury in the Rt. Hand of a 3 year old boy, with prolonged contact-time.

A- Preoperative view.

B- Abdominal flaps for reconstruction of the 1st web space and ulnar side of the wrist joint.

C- Early postoperative view showing full width of the 1st web space.

Fig. (3-A)

Fig. (3-B)

Fig. (3): High-voltage electrical injury in the medial aspects of the thighs extending to the perineum and the scrotum of a 34 year old male.

A- A view for the injury before debridement.

B- A view for the injury after graft loss and healing by scar formation.

(A)

(B)

Fig. (4): High-voltage electrical injury in a 45 year old male with 5% TBSA surface extent.

A- The entry wound in the Rt. Forearm after debridement. See gangrene of tips of the ring and little fingers.

B- The forearm after below elbow amputation. See the marked edema of the amputation stump.

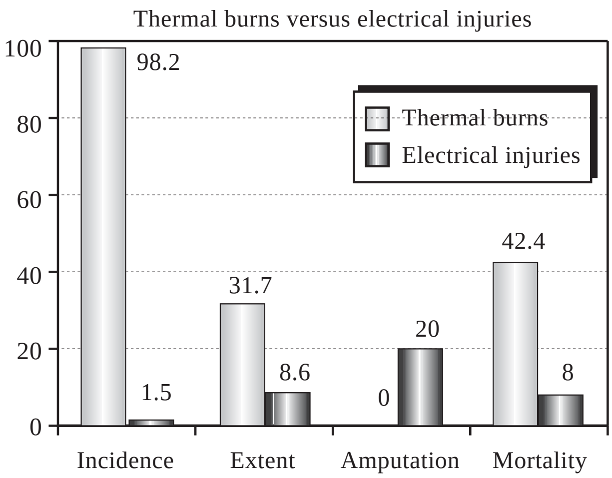

Fig. (5): Diagrammatic representation of the main differences between thermal burns and electrical injuries. Incidence, amputation and mortality are the rates in each group of patients. Extent is the average value of the TBSA burn.

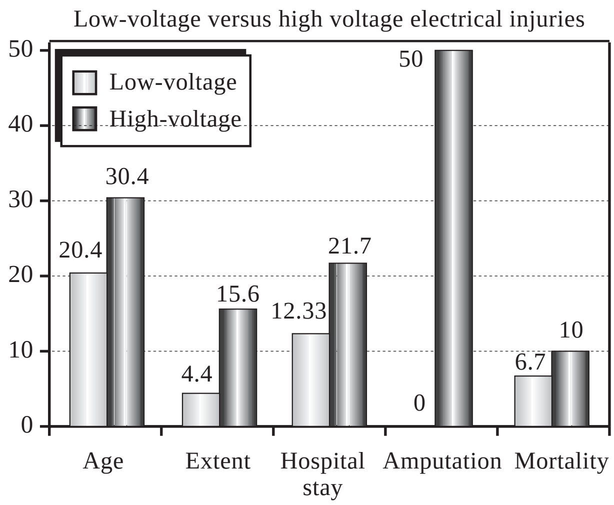

Fig. (6): Diagram showing the main differences between low-voltage and high-voltage electrical injuries. Age, extent and hospital stay are the average values for each group of patients. Amputation and mortality are the rates in each group of patients.

DISCUSSION

Electrical injuries are uncommon type of burn trauma. When compared with thermal burns, they have different patterns of morbidity and mortality (Fig. 5). The incidence of electrical injuries in the literature varies from 3 to 7% of all patients admitted to hospitals for burn treatments **[15,16]**. More than 90% of injuries occur in males and more than 70% of patients are young adults, between 19 and 45 years old **[7,12]**.

The incidence of electrical injuries in our study is less than what was reported in the literature, being 1.5% of total burn admissions to our unit. This may reflect either an increased incidence of thermal burns or underdevelopment of the industry and electrical services in our country. However, the age and sex distributions are nearly the same. The ages of 68% of our patients range between 19 and 46 years and 96% of our patients are males. Children and adolescents represent an important category of our patients. Five patients below the age of 5 years had low-voltage injuries, reflecting the problem of negligence and child abuse. These represent 20% of all cases and 33.3% of cases with low-voltage injuries. Two patients at the age of 14 had high-voltage electrical injuries. One of them died from sepsis and other had bilateral above elbow amputation. They represent 28.6% of cases with conductive high-voltage electrical injuries.

Low-voltage injuries are more common than high voltage electrical injuries **[7]**. They usually occur in the home environment. High-voltage injuries occur more typically in the workplace, near high-voltage installations, or from contact with high power transmission lines **[17]**. Low-voltage injuries lead to limited wounds, which may need minor amputations of the fingers. High-voltage injuries lead to extensive limb damage and frequently require major amputation of the upper extremity **[7]**.

In our study, low-voltage injuries account for 60%, while high-voltage injuries represent 40% of all electrical injuries. This figure is less than the reported incidence of low-voltage injuries in some series, which was 76.3% **[7]**. The to sustained tetanic contraction of muscles in contact with the alternating current. This prolongs the duration of contact with the source of electricity, which is a determining factor in the severity of the injury **[17,20]**. However, none of our cases of low-voltage injuries had oral injury and none of them required amputation, whether minor or major (Fig. 6).

High-voltage electrical injuries include various types of tissue damage. They can be true electrical injuries and/or thermal injuries. The true electrical injury results from the passage of the electrical current through the skin after contact with an electric conductor **[21]**. Prolonged contact with the source of electricity produces extensive damage to the skin, subcutaneous tissue, muscles, tendons, nerves and major blood vessels. Thermal injury may result from ignition of the victim's clothes, electrical flash or arcing of the electric current **[14,16]**.

Our group of patients comprised 7 cases of true, conductive electrical injuries (70%). One of these had an associated thermal injury due to ignition of the clothes and another one had an arc burn in the axilla. Three patients had flash burns (30%). Diagnosis of the last three cases was based on the history of exposure to flashes from high-voltage electrical sources. Clinically, they were superficial burns, requiring 1-3 day's hospital stay without need for skin grafting. There is doubt as regards the actual cause and depth of burn in these patients. In one series, all cases of flash electrical burns were low-voltage injuries **[7]**. There is a belief that high-voltage electrical flash burn are more deep and extensive than low-voltage flash burns and require staged surgical debridement and grafting as for any thermal burn **[16]**.

In high-voltage electrical injuries, acute renal failure may occur due to undiagnosed hypovolemia because a minimal cutaneous injury usually masks large volume of underlying dead tissue **[22]**. It is an alarming sign to find the color of urine turns deep red-to-red brown due to hemochromogens. A massive pigment load presented to the ischemic renal tissue will produce acute tubular nephropathy and renal failure **[4,17]**. The incidence of renal failure was drastically reduced over the last decades due to vigorous fluid supplementation. Conventional burn formulae call for crystalloid replacement in the first 24 hours at a rate of 2-4 ml/kgm/% TBSA burn. Patients with deep conductive electrical injury will require 8-12 ml/kgm/% TBSA burn, two to three times the usually estimated amount to effectively maintain fluid balance and renal output, particularly when blood and muscle pigments appear in urine **[17,23]**. The blood pressure and circulating blood volume must be stabilized by running crystalloid infusion at a rate to maintain urinary output at 100 ml/hour or greater until urine is clear.

In our study, cases with high-voltage electrical injuries are resuscitated by Lactated Ringer's solution at a rate of 7 ml/kgm/% TBSA burn. The rate may be increased to maintain urine output around 100 ml/Kgm/hour. If urine output is not satisfactory, mannitol and frusemide, are given to induce diuresis. Since metabolic acidosis is not uncommon in massive electrical injury and predisposes to tubular precipitation of hemochromogens, alkalinization of urine by sodium bicarbonate is done to maintain urine pH above 7, avoiding blood pH to exceed 7.5 **[4,17]**. Surgically, the injured muscle must be removed to avoid renal shut-down. With this regimen, the incidence of renal failure in our cases is 0%.

Several investigations were tried to diagnose compartment syndrome and muscle and vascular damage in cases of electrical injuries, both pre- and intra-operatively **[12,14,24-27]**.

In our study, diagnosis of muscle and vascular injuries is based on the clinical examination, supported by direct inspection intraoperatively during debridement. Doppler examination was done to support the clinical findings before any amputation surgery. It is difficult to transfer electrically injured patients to the nuclear medicine unit for scanning with Technetium 99 or Xenon 133. Arterial obstruction is usually obvious by simple examination methods other than arteriography, which may accelerate thrombosis in the damaged vessels [13].

There is a controversy as regards the pathophysiology of electrical injury as well as its management. Different surgical regimens failed to prove superiority of one regimen over the other. The concept of progressive wound necrosis had been introduced by Baxter and Skoog [28,29]. According to this concept, the non-viable tissues of the electrical burn wound are serially debrided till the wound bed becomes ready for closure, usually within two weeks [22]. This conservative approach may be preferred for exposed nerves, tendons and bones. Coverage by a flap can save thee structures even in the presence of infection [3,20,30]. The second surgical concept is based on the consideration that muscles and vessels are damaged from the beginning resulting in immediate muscle coagulation necrosis and small nutrient artery thrombosis. This is favored by Quinby et al., Hunt et al. and Luce & Gottlieb [26,31,32]. According to this concept, an aggressive surgical approach is favored. Early radical debridement is done followed by coverage of the wound actual incidence of low-voltage injuries may be higher because many cases of the low-voltage injuries are mild and do not present to medical centers [4]. Healthy children with small partial-thickness burns and no initial evidence of cardiac or neurovascular injury do not appear to need hospital admission [18]. The average extent of low-voltage injuries is 4.4% TBSA, while the average extent of high-voltage injuries is 15.6% TBSA.

Low-voltage electrical injuries are almost exclusively of the contact type and are localized to the hands or the mouth [3]. Although low-voltage injuries are limited in surface extent, injuries to the hand can produce significant damage requiring early debridement and wound coverage to maximize function [4]. A severe burn in the hand due to prolonged contact time with a low-voltage electric coil, that required coverage by cross-arm flap and fillet-flap from the little finger was reported [19]. In one series, amputations were necessary in 17.9% of patients with low voltage electrocution burns [7]. A special type of low-voltage injuries in children is the full-thickness skin burn of the mouth and lips due to combination of contact burn, flash burn and an electric arc. It accounts for 27-40% of pediatric low-voltage injuries [3,18].

In our series, all cases of low-voltage injuries affected the hands. Nine cases were of the contact or conductive type (60%) and six cases were thermal due to flash or flame burns (40%). The flash burns were superficial, though their surface extents were relatively great. Surgical intervention in the form of STSG, local or regional or distant flap was required in 6 cases with low-voltage electrical injuries of the contact type of avoid contractures, joint stiffness and to maintain the 1st web space. The severe nature of some cases of low-voltage injuries may be attributed to the non-release phenomenon due to any available reconstructive method from skin graft up to free-flaps [7,33]. Aggressive debridement and early definitive coverage interrupts the cycle of desiccation, infection and tissue damage [6,15]. Sepsis may provoke a number of secondary events such as adult respiratory distress syndrome, coagulopathy, immune system depression and Curling's ulcer [3].

In our study, we followed the conservative approach of serial debridements followed by wound coverage by a graft or a flap. Although, this proved useful in cases of low-voltage injuries and cases of high-voltage injuries not involving the hand as an entry point, the outcome of conductive high-voltage electrical injuries involving the upper limb as sites of entry is disappointing.

Electrical injuries frequently affect the extremities. Less commonly, they involve other parts of the body including the scalp, the chest, the abdomen or the perineum [17].

In this study, the upper limb was involved in all cases of conductive, high-voltage electrical injuries. In addition, we had two cases involving the scalp and the perineum.

The classic management of deep electrical burns of the scalp, including the skull bones, is waiting until sequestration is complete and followed by reconstruction [34]. However, this is frequently followed by the development of epidural or subdural abscess. Therefore, the alternative approach includes early removal of the devitalized tissue, followed by flap coverage [35].

The case of high-voltage electrical injury of the scalp in our series was treated by serial debridements followed by coverage of the exposed calvarium by a rotation flap. No evidence of bone sequestration or epidural abscess was detected during the course of hospital stay. The patient did not present later with any of these complications. Recently, a case of skull bone sequestration and infection underneath a viable, free, vascularized muscle flap was reported [36]. Therefore, follow up by C.T. scan is recommended for electrical injuries of the scalp to exclude he development of epidural or subdural fluid collection and to detect late sequestration of bone [35].

Surgical management of electrical burns to the genitalia has not been standardized as well. In absence of trauma to the pelvis, attempt at passing a small silastic Foley's catheter for drainage of urine may be done [37]. Some authors stated that all patients suffering from burns to the genitalia require suprapubic urinary diversion [38]. Debridement of the penile and scrotal tissues may be delayed to preserve as much as possible of these structures to maintain function and minimize hormonal disturbances [39]. However, delayed intervention in the perineal region may lead infection and ultimately increases tissue loss. Therefore, early debridement of the devitalized tissue followed by either immediate or delayed skin grafting after topical application of antimicrobials was suggested [40-41].

We had one case of high-voltage injury to the upper thigh and perineum, extending to the scrotum. There was no injury to the deep pelvic structures. Urinary drainage was achieved by urethral catheter. Split-thickness skin graft applied onto the perineal wound was lost because of infection. However, the perineal wound ultimately healed by scar formation, which was released and reconstructed later.

The extremities frequently exhibit disastrous effects of high-voltage electrical trauma and the amputation rates remain high regardless early attempts at debridement and decompression [3,6,20]. Indications of amputation in burned patients are either septic focus that cannot be eradicated without amputation, or non-viable, non-functioning limb [17,22]. The later was defined as an extremity with exposed deep structures such as bones or nerves, which would require a free tissue transfer for salvage in a patient who is not a candidate for such procedure [42].

In high-voltage injuries, the rate of major limb amputation reported in the literature is high, ranging between 45-71% [6]. It was reported that 75% of the amputations were in the upper limb and 25% were in the lower limb. This correlates closely with the reported wounds of entrance and exit, since 80% of the entrance wounds involve the upper extremity, whereas 70% of the wound exits are in the lower extremity [17]. Non-viable limb due to vascular destruction of non-functioning limb due extensive muscle necrosis is amputated in the first week. Infection in large volume of necrotic muscles is also managed by emergency amputation [6,7,22,43]. Amputation contributes to survival by, reducing the burn size, eliminating septic foci, decreasing the metabolic requirements and enhancing the healing process of the remaining burn wound [42].

With the conservative approach to high-voltage electrical injuries of the extremities, we had 50% incidence of major limb amputations. If true, conductive high-voltage injuries were only considered, the incidence of major limb amputations rises up to 71.4%. All were upper limb amputations including, a below elbow amputation (1 case) and above elbow amputations (4 cases), one of which was bilateral.

There are several explanations for the high rate of major limb amputation in our cases of true, conductive high-voltage injuries. The duration of contact may be increased by tetanic contraction of the long flexor muscles of the forearm. This results in a non-releases phenomenon or inability to let-go off the current source [14,17]. The dependence of heat generated on the cross-sectional area of the volume conductor explains the high frequency of severe injury in the extremities, with small cross sectional areas and the relative rarity in the trunk [44]. Because of the compositional difference between patient groups reported by different authors, Shen and his group believe that the amputation rate neither reflects the effectiveness of the measures taken to rescue the injured hands nor reveals the success of treatment [13].

Surgical attempts at reducing the amputation rate were described. Early aggressive excision of the necrotic tissue and flap coverage of wounds are important factors in decreasing the incidence of amputation and preserving the length of the amputation stump [7]. Wang et al., reported on the use of early vein graftings as arterial and venous bridges between the hand and forearm to avoid distal limb necrosis and amputation [45]. None of our patients was subjected to microvascular surgery, whether for free-tissue transfer or to bypass vascular obstruction at the wrist region. This may be another explanation for the high rate of major limb amputation in our cases.

The mortality rate in electrical injuries ranges from 3-15% in different series [12,46]. Early serial debridement and adequate fluid resuscitation decrease mortality and morbidity [47].

The mortality rate among electrically injured patients in our series is 10% in cases of high-voltage injuries and 6.7% in cases of low-voltage injuries. However, this does not reflect the actual mortality rate from electrical injuries because, some patients die at the site of the accident [17]. The two cases that died had electrical injuries associated with thermal burns. The first one had high-voltage injury and 46% TBSA thermal burn. The cause of death was burn wound sepsis and multiple organ failure. It was reported that thermal injuries carry a higher risk of mortality when compared with electrical injuries [42]. It was also estimated that 75% of deaths following burns are due to infection [48]. In one series, mortality rate from electrical injuries was reported as 0% [7]. This was attributed to early excision of the necrotic tissue, which decreases the risk of invasive infection and decreases the load of muscle pigment to the ischemic renal tissue. The other case that died had a low-voltage electrical injury and an associated thermal burn. The cause of death was inhalation injury, established determinants of the outcome of thermal injury [49]. Another reason for the low-mortality rate among high-voltage injured patients in our series is the absence of serious visceral injuries, apart from one case of gangrenous cholecystitis. Although severe visceral injuries by electricity are rare, they commonly result in fatal outcomes if not diagnosed and managed early [50]. A third reason for the low mortality rate is successful fluid resuscitation and absence of renal failure among our patients. Patients with electrical injuries who develop acute renal failure may have a mortality rate as high as 50% [51].

Conclusion:

Low-voltage electrical injuries are usually minor burns. Some cases do not present for hospital care, while others are deep enough to require early debridement and wound coverage to maximize function.

High-voltage electrical injuries represent a devastating type of trauma. Our treatment protocol is satisfactory for resuscitation and prevention of renal failure. The mortality rate is low, but the amputation rate remains high regardless early attempts at debridement and decompression. The high incidence of major limb amputation in this kind of injury may be due to the length of contact with the electric source, but this is difficult to quantify and is unknown in most of the patients. Another reason is the frequent current pathways from the upper to the lower extremities, with increased thermal effect due to the small cross-sectional area. Microvascular arterial and venous bridges between the hand and forearm, may be considered in selected cases to avoid distal limb necrosis and to decrease the frequency of amputation.

Because a high percentage of patients with high-voltage electrical injury require one or more major amputations, care should be taken to preserve the maximal length of the amputation stump and provide stable soft tissue coverage for adequate prosthetic fitting in the future. Rehabilitation and psychological support must be provided for these patients with major limb amputations. Attention should be directed for preventive efforts.

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