PATTERN OF HIGH VOLTAGE ELECTRICAL INJURIES IN THE KASHMIR VALLEY: A 10-YEAR SINGLE CENTRE EXPERIENCE

ASPECTS DES ÉLECTRISATIONS PAR HAUT VOLTAGE DANS LA VALLÉE DU CACHEMIRE: EXPÉRIENCE MONOCENTRIQUE SUR 10 ANS

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SUMMARY. The objective was to study the clinical profile of high voltage electrical injuries in Kashmir, and various prevention and safety measures to bring down the incidence of such injuries in the future. All patients (176) with high voltage electrical injuries reporting to our centre from January 2001 to December 2010 were included in the study. The most common age group was 20-40 years, with mean age of 29.77 ± 8.98 years. Incidence was higher among the rural population (68.75%) than in urban areas (31.25%), and in the winter months. Electricians comprised 47.16% of victims. The most common mode of injury was touching a live wire directly or indirectly, and was seen in 63.64% of victims. Average total body surface burned was 15.27 ± 10.15 percent. Right upper limb was most commonly involved (64.20% of patients). Compartment syndrome was seen in 40.34% of patients, and fasciotomies on all the affected limbs saved around half of them. An average of 3.91 surgical procedures per patient were performed. Around one-third of the victims required major amputations. Reconstructive procedures were required in 49.43% of patients. Average hospital stay was 26.81 days. Average mortality rate was 2.27%. High voltage electrical injuries are not uncommon in the Kashmir Valley, and electrical workers are at higher risk. The incidence of high voltage injuries would not be so high if the workers were properly trained, hazards of high-tension lines were explained and the use of safety equipment was made mandatory.

Keywords: high voltage, electrical injuries, electrical workers

RÉSUMÉ. *L'objectif de ce travail était d'étudier l'épidémiologie des électrisations par haut voltage au Cachemire pour définir des axes de prévention. Les dossiers des 176 patients s'étant présentés dans notre CTB en raison de ce type de blessure entre janvier 2001 et décembre 2010 ont été étudiés. L'âge moyen était de 29,77 +/- 8,98 ans, avec une majorité de patients de la tranche 20-40 ans. Ils étaient en majorité (68,75%) ruraux et l'accident était plus fréquent en hiver. Les électriciens représentaient 47,16% des patients. Le contact, direct ou indirect, avec une ligne était le mécanisme le plus fréquent (63,64%). La surface brûlée était de 15,27 +/- 10,15% et le membre supérieur droit était atteint dans 64,2% des cas. Un syndrome compartimental a été observé dans 40,34% des cas, des aponévrotomies ayant permis de sauver la moitié des membres atteints. Les patients ont eu besoin d'une moyenne de 3,91 interventions chirurgicales, 1/3 d'entre eux ayant dû être amputés et presque la moitié (49,43%) du total ayant eu besoin de chirurgie reconstructrice. La durée moyenne d'hospitalisation a été de 26,81 jours, la mortalité de 2,27%. Les électrisations par haut voltage ne sont pas rares au Cachemire, les électriciens étant des sujets à risque. L'incidence serait moindre si les professionnels avaient une meilleure éducation sur les dangers de l'électricité et si l'utilisation des équipements de protection était rendue obligatoire.*

Mots-clés*: électrisation, haut voltage, électriciens*

Introduction

Since its inception in 1849, electricity has been used widely in every sphere of life. Electricity use has increased manyfold over the past few decades and so has the risk of injury. High voltage injuries are more common in developing countries.[1,2]

About 0.8-1.0% of accidental deaths are due to electrical injury, and constitute 3-9% of all patients treated in burn centres. Electrical injuries cause around 1000 deaths in the United States each year with a mortality rate of 3-15%.[2,3] They are divided into high or low voltage injuries with 1000V as the cut off.[4] The flow of electrons across the potential gradient is the current.[5,6] 'Let go' is the maximum current at which a person can release the conductor before muscle tetany makes it impossible. For an adult, 'let go' current is 6-9 mA. Blood vessels, muscles and nerves are better conductors of electricity than bone, fat and skin.[7] The three major mechanisms of electricity-induced injury are:

a) direct tissue damage by altering cell membrane potential;
b) coagulative necrosis by conversion of electrical into thermal energy;
c) mechanical injury after violent muscle contraction or fall.

The effects of electricity on the body are determined by

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type, amount and pathway of current, voltage, duration and area of contact, as well as resistance of the body.[8] Electrical injury results from three kinds of burns: direct contact; flash (= thermal burn injury ± visual injury related to lightning: no real current flow in the body); and electric arc.

Materials and methods

This retrospective and descriptive study was conducted in the Department of Plastic and Reconstructive Surgery at Sheri-Kashmir Institute of Medical Sciences, Srinagar, India, from January 2001 to December 2010. All patients with a history of high voltage electrical injury who attended the emergency department were included in the study. Special emphasis was laid on the victim's profession because most patients with electrical burns are electrical workers, the reason for injury being lack of proper precautions while at work.

As soon as patients with high voltage electrical injury arrived at the emergency room (we have an emergency surgical department with fully equipped resuscitation facilities and a burn unit with burn ICU nearby), airway and circulation were stabilized as per the latest ATLS (Advanced Trauma Life Support - American College of Surgeons) protocol.

After the patients were admitted, fluid replacement was started and titrated to maintain a urine output of 1 to 1.5 ml/kg/hr. Patients were catheterized and urine analysis for myoglobinuria was done. A complete history was taken from each patient, laying emphasis on occupation, cause of electrical injury, site of accident, duration of contact, tension of electrical current (voltage), etc. During initial resuscitation, routine investigations like electrocardiogram, arterial blood gas analysis, chest x-ray and renal function test were performed in all patients. Every patient who had had a fall underwent non contrast computed tomogram (NCCT) of the head, ultrasonogram (USG) of the abdomen and skeletal survey.

Cardiology consultation was sought in all cases with ECG changes to rule out any cardiac complications. Neurosurgical consultation was sought for patients with head injury. Also, general surgery consultation for abdominal trauma, Cardio Vascular Thoracic Surgery (CVTS) consultation for chest trauma, and orthopedic consultation for any fractures was sought and management planned accordingly.

Results

This study included 176 patients with high voltage injuries over a period of ten years. Males were more commonly affected (153 = 86.93%) than females (23 = 13.07%). The age of patients in this study ranged from 10 to 55 years. Mean age was 29.77 ± 8.98 years (*Table I*). The most common age group was 20-40 years, comprising 56.25% of victims.

Table I - Age distribution

Age group	No. of patients	Percentage
1-10 yrs	2	1.14
11-20 yrs	20	11.36
21-30 yrs	79	44.89
31-40 yrs	51	28.98
41- 50 yrs	21	11.93
>50 yrs	3	1.70
Total	176	100.00

About two-thirds (68.75%) of the patients were from rural areas, while less than the one third (31.24%) came from urban areas. The majority of accidents occurred in the winter months (73 = 41.78%), 59 of them from December to February (33.52%).

Another 103 patients (58.52%) were admitted over the rest of the year, with a second peak seen during the summer from May to July with 53 cases (30.12%) (*Table II*).

Table II - Seasonal incidence of electrical injuries

Season (months)	No. of patients	Percentage
Winter (December to February) *	73 (59)*	41.48
Rest of the year (May to July)**	103 (53)**	58.52
Total	176	100.00

The most common occupation of the patients studied was electrical worker (47.16%), followed by farmer (10.79 %). Work-related injuries were seen in around three-quarters of the patients, and this group included electricians, labourers, construction workers, etc. Only 10 electrical workers out of 83 were using insulated tools (12.05%), none were wearing helmets or electricians' gloves, nor had any of them received formal training.

Table III illustrates mode of injury. In the majority of patients (112 = 63.64%) mode of injury was direct contact with live electrical wires. The second most common mode of injury was touching live wire with a metallic object: iron rods in 27 (15.34%) cases. Live wire fell on 13 victims (7.39%).

Table III - Mode of injury

Mode	No. of patients	Percentage
Touching live wire	112	63.64
Touching with rod	27	15.34
Falling wire	13	7.39
Flash	8	5.68
Touching a tree	7	4.54
Transformer burst	4	2.27
Lightening	3	1.71
Line touching vehicle	2	1.14
Total	176	100.00

Three patients received injuries while attempting suicide (1.7%) and the others accidently (98.3%).

Contact burns were seen in 53.41% patients and a combination of contact with flash in 39.77%. Flash was seen in 6.82% (*Table IV* and *Fig. 1*).

Table IV – Different types of electrical burn

	Contact	Contact + flash	Flash	Total
Number of patients	94	70	12.	176
Percentage	53.41	39.77	6.82	100

Associated injuries were seen in 37 (21.02%) patients, fractures being the most common injury. Total body surface area burned ranged from 2 to 70%, with a mean of 15.27 ± 10.15% (*Table V*).

Myoglobinuria was mostly seen in patients with deep burns (*Fig. 2*). Electrical injuries mostly affected the upper extremities: right (64.20%) and left (64.20%) upper limbs followed by right (44.32%) and left (38.63%) lower limbs. In the upper extremities, most entrance wounds were due to grasping live wires. Most of the exit wounds were in the lower extremities because of the current grounding through the lower limbs (*Fig. 3*). Entrance wounds in the head and neck region were seen in a significant number of patients (26.13%) (*Figs. 4 and 5*).

Compartment syndrome was found in 71 (40.34%) patients. Right upper limb was most commonly involved, in 45 (63.38%) patients. Thirteen (18.31%) patients had compartment syndrome in more than one site.

Different surgical procedures were required in 143 (81.25%) patients. They underwent a total of 560 procedures, with 1 to 9 procedures per patient. Debridement was the most common procedure. Multiple debridements, with an average of 2.3 per patient, were needed in 71.6% of cases (escharotomies formed part of debridement and they are not mentioned separately: while doing fasciotomy on limbs, escharotomy formed part of the procedure if present).

A total of 84 fasciotomies were required in 76 (43.18%)

Fig. 1 - Flash burns involving face and back.

Fig. 2 - Patient with severe high tension electrical burns with pugilistic attitude and myoglobinuria clearly seen.

Table V - Percentage body surface area burned

Total body surface area burned %	Number of patients (176)
<10	38
10-19	62
20-29	36
30-39	22
40-49	8
50-59	5
60-69	4
≥ 70	1

Fig. 3 - Extensive high voltage electrical injury involving lower limbs with exposed, charred knee and ankle joints.

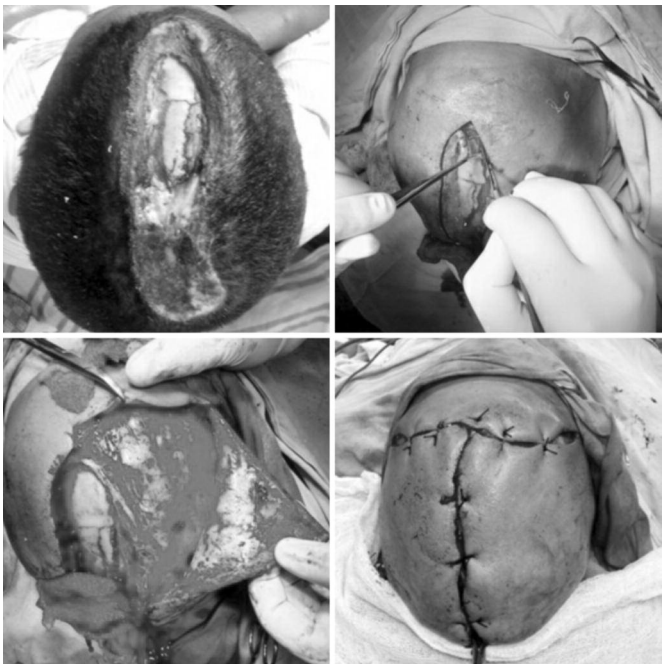

Fig. 4 - Electrical contact burn on the scalp with exposed bone. Defect covered with rotation flap after debridement.

Fig. 5 - Electrical burn on scalp and neck with exposed bone after debridement. Rotation flap covering exposed bone and negative pressure wound therapy applied over raw area on neck.

Fig. 6 - Cataract in left eye as a result of electrical burn on face.

patients, with right upper limb being the most common site (45 patients), followed by left upper limb (31 patients), right lower limb (4 patients), left lower limb (3 patients) and chest (1 patient). Fifty percent of limbs were salvaged by fasciotomies.

Major amputations were carried out on 38 patients (21.59%) with severe injuries. A total of 57 patients (32.39%) underwent amputation. Six patients required more than one major amputation.

A total of 131 reconstructive procedures, namely 70 skin grafts (performed over a period of time as and when required, dictated by the patient's clinical condition – no tangential excision of the skin in any of the cases), 56 different flap procedures and 5 tissue expansions were carried out on 87 patients (49.43%).

Thirty-one patients suffered complications. Early complications included acute renal failure (ARF), septicemia, convulsions, paraparesis and hemiplegia. Among the delayed complications were flap necrosis, stump bleed, empyema lung, paraplegia and cataract. Cataract was seen in one patient four months after the injury occurred (*Fig. 6*).

Four patients died (2.27%). Two of them had acute renal failure secondary to myoglobinuria, one death was sepsis-related and the other patient died from inhalational injury associated with an electrical burn.

Discussion

Electrical injuries have become a more common form of trauma with a unique pathophysiology and with high morbidity and mortality (overall mortality is estimated to be 2-15%,[3] which correlates well with our study).

Males outnumber females with a ratio of 6.6:1, the reason being that males are involved more in outdoor activities, and electricians, construction workers and labourers are exclusively male in this part of the world. Ample evidence of this male predominance can be found in the literature.[7,8,9,10]

We observed that younger adults were most commonly affected, with an overall mean age of 29.77 years: most of the patients (73.87%) were in the 20-40 years age group. Garcia-Sanchez (1999) reported that 60% of patients with electrical injuries were in this age group.[9] Many authors have identified a mean age ranging from 26 to 30 years.[7,8,11]

The higher incidence of high voltage injuries in the 20-40 years age group can be explained by greater risk-taking behaviour and a more aggressive and careless attitude among patients in this group. This age group also includes inexperienced and inadequately trained electrical workers and daily wagers.

The higher incidence in rural areas is mostly due to lack of proper transmission lines. In some places, high-tension transmission lines are laid over trees instead of proper electrical poles, exposing farmers and children climbing trees to greater risk. Farmers are also involved in the illegal use of electricity, thus are again at greater risk. Haberal (1995) too has mentioned higher incidence of high voltage electrical injuries in rural areas.[12]

Increased incidence of high voltage injuries in the winter months is mostly due to heavy snowfall in Kashmir, which causes frequent electrical faults requiring repairs and, thus, puts people at risk. In addition, the increased pace of construction activities during the summer months, with more use of electricity, also puts people at greater risk. Haberal (1986) reported a rise in incidence during the months of May and June.[7]

The most common occupation associated with high voltage electrical injuries in our study was electrical worker (electricians), accounting for 83 (47.16%) patients. Work-related injuries in the present study were found in 73.3% of patients. This corresponds well to the results of many studies in the literature.[13,14] One of the main reasons for higher incidence among electrical workers was recruitment of inexperienced and inadequately trained daily wagers. We observed that most of the workers had not taken or had not been advised to take any safety measures, like wearing a helmet, using safety belts, electrician's gloves, properly insulated tools, etc. Only 10 patients used insulated pliers. Higher incidence in electrical workers could also be attributed to lack of a proper transmission system. Farmers were mostly injured during attempts to steal electricity for agricultural activities, or household members while stealing electricity by throwing wires (hooking) onto high-tension lines. The most common mode of injury was touching live wires while working on electricity poles, grids or climbing trees (mischievous children) with overhead lines. Construction workers received injuries while operating heavy machinery re-

quiring high voltage current and also while carrying long iron bars to construction sites, which carries a risk of touching overhead high-tension lines. This is in agreement with the study by Craige and Wilkinson.[15]

Entry site was most commonly located in the upper limbs - right more than left. The reason could be grasping wires while working on live wires, or touching live wires with a hand-held conductive object. Right-handedness is dominant, so this is the limb that is most commonly involved. Exit site was mostly seen on the lower limbs as grounding is through them. Our study is in agreement with Haberal[7], Craige and McDonald[15] and Hussmann.[17] However, there was more involvement of the head and neck region than in the literature, due to helmets not being worn. Compartment syndrome also was seen more in the right upper limb, followed by the left upper limb.

Associated injuries (most common injury being fracture followed by intracranial injury and blunt abdominal trauma) were mainly caused by falling from an electricity pole or the patient being thrown aside by a high voltage shock. Hanumadass reported that the majority of associated injuries were due to falling from electricity poles, as we found also.[16]

An average of 3.91 procedures per patient were required, in agreement with studies by Marshall[10] and Handschin.[13] Fasciotomies were required in 43.18% of patients to salvage the limb by relieving any compartment syndrome, as mentioned by Handschin.[13] Fifty percent of limbs were salvaged by fasciotomies alone. Amputations were required in 32.39% of patients when fasciotomy failed to save the limb or if the limb was severely charred. This corresponds well to many studies in the literature.[7,18,19,20]

Different reconstructive procedures were required in 49.43% of patients to cover raw areas or reduce disabilities, which corresponds well to studies in the literature.[9,13,17]

Though less frequent than flame or scald burns, electrical burns give rise to a series of very complex problems. Overall mortality is estimated to be 2-15%,[3,19,21] which correlates well with our study. Morbidity and mortality are largely affected by the type of electrical contact involved in each exposure. Extensive burns, extent of muscle necrosis and subsequent development of multi-organ dysfunction determine morbidity and long-term prognosis.[22] Patients are at high risk of sepsis (due to large necrotic load and also to subsequences of hypercatabolism) and renal failure (due to myoglobinuria**).** Cataract was seen in one patient four months after injury (ocular lesions such as cataracts are often related to the light effects of UV radiation in electrical flashes without any entry of current on the head). Burns are often ultimately much worse than they appear in the emergency room.

Conclusion

We concluded that high voltage injuries are not uncommon in the Kashmir Valley, and that electrical workers are at a greater risk of exposure to them. Fasciotomy was the most useful limb salvage procedure, and saved limbs in 50% of patients.

The incidence of high voltage injuries would not have been so high had the workers been properly trained and the hazards of high-tension lines explained. Moreover, emphasis must be laid on safety measures like helmets, electrician's gloves, safety belts and insulated equipment. Fiberglass link can be used in ladders thereby providing insulation, so that electricity does not have a path to the ground. An alternative could be to cover the top half of extension ladders with an insulating material like Teflon. Upgrading the transmission system, especially in rural areas, can also decrease such accidents. Mass media awareness programs on electrical safety aimed at the general public are necessary. Proper and quick referral after initial resuscitation at peripheral centers can save many lives.

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