

High-voltage Electric Burns: Experience from a Single Centre in North India

Shilpi Karmakar¹,
Rohit Kumar Rai¹,
Gulab Dhar Yadav²,
Pawan Kumar Singh²,
Vijay Kumar³

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ABSTRACT

Electrical injuries account for up to 5% of all burn injuries in developed countries and up to 27% in developing nations. High-voltage burns are more severe and associated with higher mortality and extensive morbidity. A retrospective review of clinical data of all patients admitted to a tertiary care centre in north India, with high voltage electrical injury over a two-year period, was performed. Of the 48 patients, 85.4% were adults; 14.6% were children, 93.8% were males, 37.5% were electricians, 27.1% were laborers, 14.6% were farmers. 62.5% of burns were accidental. Maximum patients sustained burn <30% body surface area, of third or fourth degree. Concomitant injuries were present in 25% of patients. Electrocardiogram abnormalities were observed in 35.4% of patients. The upper limb was involved in 95.8% of patients.

We noted that falling cables are a menace and regulatory authorities need to ensure regular maintenance of overhead cables to safeguard the population. It is equally important to train health personnel in peripheral health centers to perform life support measures. Prompt referral and an effective transport infrastructure are crucial. National programs should be made sustainable and more effective by using data from studies such as ours, to develop targeted community based prevention and management.

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INTRODUCTION

Electrical injuries are one of the costliest and one of the most important public health issues in industrialized societies. Electrical injuries account for up to 5% of all burn injuries in developed countries and up to 27% in developing nations.¹⁻³ Voltage has traditionally been used as a predictor of outcome in electrical injury, with greater than or equal to 1000 Volts labelled as high voltage.

¹ Department of Burns and Plastic Surgery, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India.

² Department of General Surgery, Ganesh Shankar Vidyarthi Memorial Medical College, Kanpur, UP, India.

³ Department of Plastic Surgery, King George's Medical University, Lucknow, UP, India.

*Correspondence: Shilpi Karmakar, drshilpikarmakar@rediffmail.com
Department of Burns and Plastic Surgery, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India.

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Although all electrical burns are serious, high-voltage burns are more severe and associated with higher mortality and extensive morbidity. High rates of amputations, obvious and occult soft tissue destruction, renal injury and cardiac dysrhythmias compound the problem manifold. Even for the survivors of this ordeal, the result is grave in terms of social, psychological and physical consequences. Loss of work days, future unemployment, and social rejection are some of the sordid realities of the victims of high voltage electrical injury (HVEI). In one study, HVEI was associated with heightened anxiety levels and poor sexuality scores.⁴ Our study provides evidence and attempts to shed light on the hazy picture of HVEI managed at a tertiary care centre in north India.

High voltage electricity is different from other trauma as it can cause both superficial (from direct thermal burns) and deep injury. Deep injury derives from one of three mechanisms: heat generated due to resistance (according to Ohm's Law), electroporation (degradation of the integrity of cell membrane increases the cell permeability, finally

leading to influx of calcium ions into the cytoplasm), and electro-conformational protein denaturation (change of polarity of voltage-gated channel proteins). Further injury to tissues is inflicted due to the development of compartment syndrome and rhabdomyolysis.⁵ Fall of the standing person or blast of surrounding objects can complicate the clinical picture.⁵ These multiple insults amalgamate to create the distinct pathology of HVEI. These mechanisms illustrate the multiple pathways of electrical trauma, even if little injury is seen superficially.

METHODS

A retrospective review of clinical data was performed. Institutional Review Board approval was obtained. The records of all patients admitted to our centre with HVEI over a two-year period, were included. Patients who had primarily been treated at another medical facility and referred to our centre, and had complete record of the primary management, were included. Patients presenting beyond 48 hours of injury, were excluded. Patients whose primary mechanism of injury appeared to be flash or explosion (of a high-voltage wire, transformer, or other device), as opposed to direct contact with high voltage, were excluded. Also, those with lightning injuries were excluded because the mechanism of injury differs from that of HVEI.

48 patients met these criteria and were evaluated. The following data was extracted: demographic data (age, sex, occupation, place of injury, mode of injury, occupational injury or non-occupational), primary survey findings, interventions to secure airway and intravenous access, size of cutaneous burn (estimated by means of Wallace Rule of Nine), depth of burn, injured body part, electrocardiogram findings, presence of myoglobinuria, any other injury, additional interventions (neck stabilization, fractured limb splintage, intercostal tube placement), surgical procedures (fasciotomy, escharotomy, amputation, debridement) and outcome (death, discharge, referral)

RESULTS

A total of 48 patients (41 adults, 85.4%; 7 children, 14.6%) were included in the study. 93.8% (45) of patients were male; 6.3% (3) were female. Mean age of the group was 24.8 years (range, 3 to 62 years).

Most of the injuries were accidental (62.5%, 30).

37.5% (18) burns were work-related. The cause of the accident was tripping on live wire lying bare in the field, contact with a live wire while using metallic rod or umbrella or while flying a kite, and contact with a metallic body (train) which was in contact with a live wire. Patients injured at work were either working on power lines, or working on metallic electric poles, when they accidentally came in contact with a live wire. Occupations of patients sustaining HVEI were electrician (37.5%, 18), labourer (27.1%, 13), farmer (14.6%, 7), and others (20.83%, 10).

The mean total body surface area (TBSA) of burn was 21.44% (range, 10% to 65%). All patients sustained third-degree burns. Of the 48 patients, 20 patients (41.7%) sustained <10% TBSA burn, 20 patients (41.7%) sustained 10–30% TBSA burn and the rest 8 patients (16.7%) sustained >30% TBSA burn. The upper limb was involved in burn in 46 patients (95.8%), lower limb in 41 patients (85.42%), head and neck in 13 patients (27%), chest in 11 patients (22.91%), and the abdomen in 5 patients (10.4%).

Concomitant injuries were present in 12 patients (25%). These injuries were thoracic injury in 7 patients (14.58%), traumatic brain injury in 6 patients (12.5%), bone fractures in 3 patients (6.25%), intra-abdominal injury in 2 patients (4.2%) and spinal cord injury in 1 patient (2.08%).

Electrocardiogram abnormalities were observed in 17 patients (35.4%). ECG changes noted were arrhythmias, ST changes, atrial/ventricular atopic beats, alterations in rhythm or rate, and ventricular fibrillation. Creatine phosphokinase was elevated in 25 patients (52%). Myoglobinuria was noted in 32 patients (66.7%). Renal function test was deranged in 32 patients (66.7%).

In the 48 patients, a total 206 surgical procedures were done in 40 sittings (mean 4.29, range 1 to 8). The most commonly performed surgical procedure was venous cut-down (48 sessions done in 48 patients, mean 1/patient, range 0-2), followed by fasciotomy (46 sessions done in 33 patients, mean 1.39, range 1 to 2). Other commonly performed procedures were debridement (35 sessions in 28 patients, mean 1.25, range 1 to 3), amputation (28 sessions in 27 patients, mean 1.03, range 1 to 2) and escharotomy (14 sessions in 14 patients, mean 1, range 0-2). Major amputation was performed in 3 patients (6.25%) and minor amputation in 24 patients (50%). Skin grafting was performed in 12 patients (25%). Intercostal drainage placement was done in 7 patients (14.6%).

Central venous line was placed in 6 patients (12.5%), suprapubic cystostomy and tracheostomy were done in 2 patients each (4.2%).

19 patients (39.6%) were referred to other centres, either on demand of the patient, or because the advanced facilities for the management of patients were not available at our centre. 20 patients (41.7%) were discharged after completing treatment. 9 patients (18.8%) succumbed to their injuries and died. The cause of death was ventricular arrhythmia, multi-system organ failure, septicemia, pneumonia, and renal failure. Length of stay in hospital was <15 days in 25 patients (52.1%), 16 to 30 days in 13 patients (27.1%), and >30 days in 10 patients (20.8%).

DISCUSSION

HVEI is a devastating and catastrophic injury. There is limited literature discussing the key challenges of HVEI faced in north India. This study aims to meet the need for a thorough examination of issues critical to HVEI and outline the deficits in the existing system, so that clear and thoughtful measures could be taken, yielding the greatest benefit from available resources.

Most of our patient population consisted of adult males. Mean age of the population was 24.8 years. This is similar to the average age of 27.5 years reported by Maghsoudi, 27.9 years reported by Cancio *et al.*, 29.25 years reported by Haberal, 32 years reported by Ferreiro, 33.7 years reported by Handschin, and 34 years reported by Arnoldo.⁶⁻¹¹

In all studies, including ours, males were more commonly affected.^{2,11} These findings are explained by the fact that usually young males work in outdoor and hazardous settings. The male member of the family, also, is called upon to do repair works of the house and may sustain injury with faulty high-tension electricity lines, passing close by. The system of illegal electricity stealing system is rampant in the country, called '*katiya*' in the indigenous language (during the electrical blackout, a temporary wire is hooked on neighboring lines to draw electricity). A miscalculation during the adventure may lead to HVEI. Daily wage-earning labourers are another subset of casualties, working without helmets, rubber gloves, insulated tools in perilous circumstances. Farming, another occupation that engages primarily adult males, is fraught with danger, as farmers work barefoot in fields, where they may trip on a live wire.

A majority of these patients end up with amputated limbs and long periods of illness and unemployment.

These adult men in their prime age, who were supposedly the backbone of the family in traditional societies, are forced to rely on medical care for their morbid complications of HVEI. This along with the financial cost of the treatment adds heavily to the impecunious state of the family.

Interestingly, in our study, 62.5% patients suffered non-work-related injury. In other Indian studies too, 67.9% labourers/ farmers form the most commonly injured group.¹² This is in contrast to most others studies, which find occupational injuries to be commoner.^{10,11,13} Electrical injuries have been reported to be the fourth leading cause of traumatic work-related death.¹⁴ This reiterates the sorry and unsafe state of affairs of the electrical system of the country.

Of note is that 14.6% of our study group comprises of children. Three of them sustained the injury, while in a train compartment, which came in contact with a loosely lying live wire. Two children were flying kites, which got entangled in high-tension lines. Two children were playing with metallic rod-like objects, which came in contact with a high-tension line, passing in the vicinity of the building. All of these injuries are avoidable, with education and awareness amongst the victims and proper planning of construction.

Our population mean of TBSA burn was 21.44%, close to that noted by Cancio *et al.* (17.5%) and Rai *et al.* (16.27%).^{11,15} Most burns were of third and fourth degrees, and were unsalvageable. This is reflected in the high rates of amputations and debridement in the study.

The upper limb was involved in 95.8% patients in our series, compared to 90% patients in the series by Handschin *et al.*¹³ Exit sites were on one or both lower limbs in 85.4% of our patients, compared to 75% patients in the series by Solem *et al.*¹⁶ Most patients got injured due to grasping live wire with hand and then the current grounded through the lower limb. In patients who came in contact with live wire lying bare in fields, the current grounded through the other lower limb or even upper limb and chest, in case the person fell down. One patient, an electrician, was straddling the electric pole with his thighs while doing repairs on the cables when one of the cables went 'live' and he sustained burns to his upper limbs, lower abdomen, perineum, and thighs.

35.4% of our patients were noted to have electrocardiographic abnormalities, in contrast to 11.7% in the series by Arnoldo *et al.*¹⁰ Four patients succumbed to ventricular arrhythmia, soon after

admission. In rest of the patients, alternated rate or rhythm settled with resuscitation. Late-onset arrhythmias occurred in three patients; all of which were related to causes other than the original electrical injury.

Myoglobinuria was noted in 66.7% patients, much higher than 36.5% reported by Arnoldo *et al.*¹⁰ In most patients, it was managed by alkalinizing the urine and overhydrating the patient. In some patients, complete resolution was seen only after amputation and debridement. Persistence of myoglobinuria was an indication for a re-look surgery. In these patients, exploration under anesthesia in the operating room and debridement of all necrosed tissues was instrumental in clearing the pigmenturia.

Concomitant injuries were present in 25% of our patients, same as Cancio *et al.* (25.1%) and Hsueh *et al.* (29.4%).^{11,17} Srivastava *et al.* noted that HVEI patients had a greater number of associated injuries, due to being thrown from height and with force.¹⁸ Most common injury in our series was blunt thoracic injury (14.58%), followed by traumatic brain injury (12.5%), and bone fractures (6.25%). These three form the majority of non-burn injuries in other studies too, though the proportion varies. 12%, 7%, and 6% of patients in the series of Handschin *et al.* sustained traumatic brain injury, blunt thoracic trauma and fractures of extremities, respectively.⁹ The percentage of patients enduring these injuries in the series by Cancio *et al.* was 4.1, 4.6, and 11.3%, respectively.¹¹

On average 4.29 surgical procedures per patient were performed, similar to 5.2 and 3 surgical procedures per patient reported by Handschin *et al.* and Arnoldo *et al.*, respectively.^{9,10} We did fasciotomy in 68.75% patients and escharotomy in 29.17% patients. The rate of fasciotomy/escharotomy varies greatly in literature, from 9.2 to 54%.^{6,13} Sheridan propagated that patients who had a fasciotomy within 12 hours of the onset of increased compartment pressure regained normal function in 68% of cases, but when surgery was performed after 12 hours, only 8% of patients could recover normal function.¹⁹ Since majority of our patients reached the facility many hours after injury, without proper resuscitation measures enroute, we chose to err on the side of excess. Even though we might have performed a few fasciotomy/escharotomy more (than what may have been required), we attempted to salvage as many limbs and lives as possible.

56.25% of patients in our study underwent amputation surgery, of 1 or 2 limbs. Cancio,

Garcia-Sanchez and Hussmann reported amputation rates of 41, 42 and 49.4%, respectively.^{11,20,21} Frankly gangrenous limb, sepsis with the presence of extensive necrotic tissue and suspicion of deep tissue necrosis with loss of nerves and vessels were our indications of amputation.¹³ Again, our amputation rate was high because of the delayed arrival of the patient to our centre, without proper resuscitation measures. Further delay was caused in performing life-saving procedures and stabilization of vital signs of the patients. Serial debridement is the key to successful treatment, as progression of deep muscle necrosis has been observed even 10 days after injury.¹³ 72.9% of our patients underwent debridement, similar to 82.7% of patients in Thomas *et al.*¹²

Handschin, and Haberal reported mortality rates of 13.1 and 17.2%, respectively, quite similar to our data of 18.8%.^{7,9} This is much higher than that noted in other studies (5.3%),¹⁰ and calls for a reexamination of in-hospital management protocols. At the same time, the undue time stalled in inadequate management of patients at peripheral centres, hindrances in transport and absence of a smooth referral system are reproached.

Our study is not without limitations. This data does not include deaths of patients before they were able to reach our hospital, nor does it take into consideration the follow-up of patients referred to other centres. The hospital data represents only a fraction of total injuries. The study underlines the need for a National Registry in the country, which would elucidate the real magnitude of the problem. We have not studied the long-term physical, physiological and psychological implications of HVEI, in terms of post-traumatic stress disorder, depression, atherosclerosis, nerve palsy, and return to work. The “ripple effect” of the loss of sole working professionals on the family and community appears to be massive but was not part of this study. This study does not take into consideration the financial costs borne by the patients’ family and by the healthcare system. We plan to undertake further studies examining each of these gaps in present knowledge.

CONCLUSION

HVEI is largely preventable. It is important to highlight the need for education in recognizing potential hazards. The Indian Electricity Act, 2003 should be adhered to while laying down power lines. Falling cables are a menace and regulatory

authorities need to ensure regular maintenance of overhead cables to safeguard the population. It is equally important to train health personnel in peripheral health centres to perform life support measures. Prompt referral and an effective transport infrastructure are crucial. National programs should be made sustainable and more effective by using data from studies such as ours, to develop targeted community-based prevention and management.

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