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Original Article

High voltage electrical injuries: outcomes & 1-year follow-up from a level 1 trauma centre

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Abstract: Background: High voltage (>1000 V) electric injuries (HVEI) are rare, and dreaded due to profound myonecrosis and fatal arrhythmias. Trauma Centres are well equipped for acute and definitive treatment of injuries. Paucity of burn centres in Himalayan belt make trauma centres a prudent choice for management of HVEIs. We share our experience of HVEIs managed at our Level 1 Trauma Centre. Methods: Study conducted at All India Institute of Medical Sciences, Rishikesh. Patients enrolled from prospectively maintained Trauma Registry. HVEI defined as an electrical shock from a source running current of or more than 1000 Volts. All patients admitted to department of Trauma Surgery with diagnosis of HVEIs, over 17 months (May 2019-Sept 2020) included. Demographics, clinical course, morbidity and management noted. Data is presented descriptively. Results: Prevalence of HVEIs was 0.5% (n=8) among all trauma admissions; all patients were males with median age 25 years. Mode of injury accidental in 6 (75%). Seven patients (87.5%) had entry points in the upper extremity. All patients suffered thermal burns (median BSA 11%). Three patients (37.5%) had secondary fall, no concomitant injury found. Urine myoglobin & creatine kinase measured in all patients. No dysrhythmias detected in index or follow up ECGs. Four patients required emergent escharotomy, four underwent amputation. There was a median of 3 procedures per patient. Fasciotomy (n=6) and grafting (n=3) were commonest operative procedures. Multisystem involvement was seen in 3 patients. In-hospital mortality nil. Conclusions: HVEIs are rare injuries, predominantly affecting upper extremity of young males. Amputation rates approach 50% despite expeditious surgical management of extremity burn due to progressive myonecrosis. Creatine kinase and urine myoglobin did not correlate with renal failure; ECG monitoring wasn't advantageous in patients with normal index ECG in our study. Modest BSA doesnot rule out visceral damage. Delayed hollow viscus perforation is a possibility in HVEIs involving parietal wall. Vocational loss is common due to high amputation rates of affected extremity, most commonly upper limb. Trauma team is well trained to provide acute, definitive and intensive care, and level I trauma centres with their integrated services are well suited to manage victims of HVEIs in LMICs.

Keywords: Electrical injuries, high voltage, burns, level 1 trauma centre

Introduction

Electrical burns account for 0.04-5% of admissions to burn units in developed countries, and up to 27% in developing countries [1]. High voltage (>1000 V) electric injuries (HVEI) are rare but dreaded injuries. They have the potential to inflict multisystem trauma besides profound myonecrosis and arrhythmias. Ideally, such patients warrant admission & treatment in dedicated burn centers [2, 3]. However, designated burn centers may not be as readily available in low & middle-income countries (LMICs). Logistic and financial constraints make intercity travel tedious for such patients, to access specialized care. Hence, many electrical burn patients resort to general practitioners or general surgeons for burn care in LMICs [4, 5].

Trauma Centres are well equipped for initial resuscitation and definitive treatment of electrical injuries. The paucity of burn centers makes trauma centers the ideal place for the management of HVEIs. This is due to the provision of integrated acute, definitive, and intensive care. Due to the lack of designated burn centers in the Himalayan belt region and difficulties of intercity travel in hilly terrain, all HVEIs presenting to the All India Institute of Medical Sciences,

Rishikesh are admitted by the department of Trauma Surgery. We hereby share our experience of high voltage electric injuries (HVEIs) managed at our Level 1 Trauma Centre. HVEIs are rare injuries, and most series report limited experience with small sample size. Our series highlights the atypical presentations, outcomes, follow-up, and pitfalls in the management of HVEIs, in addition to clinical course and routine burn care in these patients.

Material and methods

This is a retrospective review of a prospectively maintained Trauma Registry at Level 1 Trauma Centre, All India Institute of Medical Sciences, Rishikesh (Uttarakhand). An ethical approval waiver was taken given the retrospective nature of the observational study. The registry was searched with terms ["electric" or "electrical"] AND ["burns" or "injury" or "injuries"] OR ["electric injuries"] for all admissions over 17 months (May 2019-September 2020). For this study, HVEI was defined as an electrical shock from a source running current of or more than 1000 Volts. All patients with HVEIs, irrespective of age, gender, and concomitant injuries, admitted to the Department of Trauma Surgery were included. Patients with household electrical accidents were not included. Medical records of patients with HVEIs were studied for demographics, clinical course, morbidity, and management. Follow up was completed telephonically wherever lacking in outpatient records.

Treatment protocols

All patients presenting to the Emergency Department are assessed and stabilized following Advanced Trauma Life Support protocols [6]. Life and limb-threatening emergencies are dealt with expeditiously within the primary survey, including operative management for limb threatening compartment syndrome. Fluid resuscitation of burn patients is done per the estimated total burn surface area (BSA; Lund Browder Charts), and fluid rates are titrated to maintain urine output at or above 1 ml/kg/hr. Initial fluid requirements are calculated as 4 ml/kg/% BSA for electrical burns. Urine myoglobin, serum creatine kinase, and electrocardiographic monitoring are done for all patients. Patients with unknown, suspicious, or dangerous mechanisms undergo computed tomography imaging to rule out visceral injuries. Prophylactic antibiotics are not administered unless contamination is present in traumatic wounds/burns [7].

Statistical methods

This is a descriptive study of HVEIs, which are rare events. Data are presented descriptively. Central tendency measures are described with median and range. Frequencies are provided in percentages wherever applicable.

Results

During the study period, the Department of Trauma Surgery admitted 1388 patients, of which 8 patients were admitted with HVEIs (0.5%). All patients were males with a median age of 25 years (range 11-58). Mode of injury was accidental in 6 (75%), recreational in 1, and occupational in 1. Seven patients (87.5%) had entry points in the upper extremity. Pediatric patients (n=2) got electrocuted accidentally from the overhead high tension wires at the terrace, while 5 adults suffered electric injuries at the workplace. All patients suffered thermal burn injuries (median BSA 11%; range 5-27%). Three patients (37.5%) had a history of secondary fall, however, no concomitant head/spine/long bone injury was found. Three patients (37.5%) had visceral involvement as an atypical presentation.

Patient profiles

One 11-year-old child had a deep abdominal wall burn with pneumoperitoneum on CT, without features of peritonism. He was managed nonoperatively with close monitoring, and his abdominal wall wound healed well with secondary intention.

A 45-year man suffered HVEI burns over bilateral hands. There was a brief period of loss of consciousness, but no concomitant physical trauma. ECG monitoring and imaging were unremarkable. He underwent bilateral hand fasciotomies and was discharged later on persistent request. His wounds healed well and he resumed normal activities by 8 weeks.

A 55-year-old man with entry wound over right hand and exit wound over left hand and left foot with normal index ECG was managed with debridement, dressings, and discharged on day 3 with a plan of wound healing with secondary

Figure 1. Improved status of wound of bilateral forearm and hands after 6 months.

intention. At 6 months follow up, patient wounds were healthy with improved range of motion of both hands and no neurovascular deficit (**Figure 1**).

A 12-year boy with accidental HVEI while playing presented with right upper limb thermal burn and compartment syndrome. The entry wound was in the right hand and the exit wound in the left scapula (**Figure 2A**). Urgent escharotomy & fasciotomy of the upper limb were done (**Figure 2B**). However, he eventually landed up with right below elbow amputation due to progressive myonecrosis (**Figure 2C**). The patient also developed nodular scabies at the stump site, which was managed medically.

A 26-year male victim of workplace HVEI was admitted with an entry wound over the left shoulder and an exit wound on left foot. He was discharged after 2 days post debridement and dressing of the wound. Follow-up at 1 month showed satisfactory wound healing and a full range of activities.

Atypical presentations

Three patients of HVEIs had abdominal visceral involvement, two presenting with delayed manifestations.

One 40-year-old male, known case of viral hepatitis (HBV) was referred to our center after 9 days of HVEI with acute renal failure (Serum Creatinine 8.6) and an infected, non-viable upper limb (**Figure 3A**). He underwent hemodialysis and right upper limb amputation. On day 5 of hospitalization, he had hematemesis with hemodynamic instability, which was managed with blood transfusions & medical management of acute upper GI bleed (Octreotide, pantoprazole infusion). Upper GI endoscopy revealed gastric fundal ulcers (**Figure 3B**), and no signs of portal hypertension. The patient went home against medical advice after 2 days and continues to do well in follow-up at 6 months.

A 25-year-old boy was brought after 1 hour of accidental HVEI with limb-threatening compartment syndrome in the left upper limb. There were no associated injuries and FAST was negative. He was taken for urgent escharotomy but eventually landed up with above elbow amputation after 24 hours due to profound myonecrosis. There were no signs of peritonitis or sepsis and the patient was accepting orally well with a functional bowel. The patient was planned for coverage of an exit wound in the left iliac fossa given exposed femoral artery. On day 6 of admission, he developed abdominal pain, distension, and vomiting: USG abdomen revealed free fluid in the abdomen. Enteric discharge was noted from the exit wound in the left iliac region. Exploratory laparotomy revealed jejunal and sigmoid colon perforations, for which jejunal repair and colostomy were performed. On day 36 of injury, the patient had sentinel bleeding from the left common femoral artery blowout. Femoral artery coverage with pedicled right anterolateral thigh flap was done the subsequent day. Partial necrosis of the flap was managed with debridement & dressings, and he was discharged to home care on day 43 of admission, with a plan of raw area coverage (4%) in the outpatient follow-up.

A 27-year-old male was brought after 6 hrs of accidental HVEI (contact of metallic load with

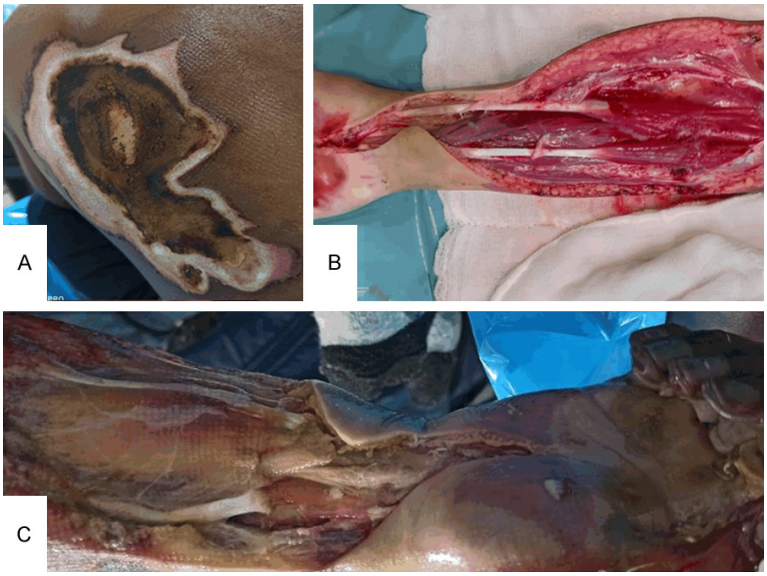

Figure 2. A: Exit wound in the left scapula. B: Fasciotomy of the right upper limb. C: Myonecrosis of the right below amputation stump.

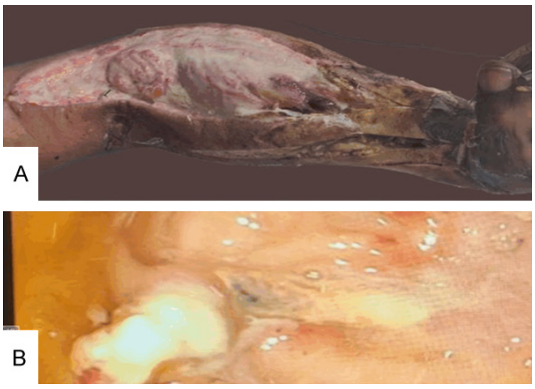

Figure 3. A: Non-viable right upper limb on post injury day 9. B: Gastric fundal ulcers seen on Upper GI endoscopy on post injury day 14.

high tension electric line). He suffered burns over bilateral upper limbs and abdominal wall. Urgent escharotomy along with fasciotomy of the right upper limb was done because of compartment syndrome. Abdominal wall debridement revealed the full-thickness extent of parietal wall burn. Exploratory laparotomy showed full-thickness thermal damage to ileum without perforation, for which resection and anastomosis were done. However, bilateral limbs needed to be amputated after 7 and 10 days respectively due to progressive myonecrosis.

Overall, 4 patient's required emergent escharotomy as a limb-saving procedure. The most common operative procedure was fasciotomy (n=6) and 3 patients required surgery for soft tissue coverage. All patients had normal ECG at presentation and underwent 24 hours of ECG monitoring in a high dependency unit. Serum creatine kinase was monitored in all (**Table 1**); urine myoglobin was positive in one patient. Four patients underwent amputation eventually. There was a median of 3 procedures per patient. Multisystem involvement was seen in 3 patients. There was no in-hospital mortality. There were no ECG abnormalities in any patient, either at presentation or discharge/follow-up.

Discussion

Thermal burns are the most common cutaneous manifestation of HVEIs. The burn surface area (BSA) is misleading in electric injuries, as underlying tissue damage is typically much more extensive than is apparent [2]. In our series on HVEI survivors, we found a median of 11% burn surface area, which is comparable to published literature [8-10]. However, we frequently encountered profound myonecrosis & visceral injuries despite the seemingly modest BSA. It reinforces the need for a thorough assessment of HVEI victims, and the need to observe these patients for a prolonged duration. In our study, visceral complications were diagnosed timely and managed optimally due to provision of direct care by trauma surgeons.

All patients undergoing amputations in our series required revision amputations, more than once. We observed that the myonecrosis of electrocuted extremities evolved over 48-72 hours, as illustrated by pictures. Butler et al also noted an average of 5 procedures per patient in their study [11]. Therefore, we suggest that the prognosis of electrocuted extremities should be kept guarded, even if healthy on index fasciotomy/escharotomy.

Cancio et al (2005) found non-burn injuries in around 25% of electrocuted patients, most commonly fractures [10]. Similar findings were

Table 1. Patient characteristics

Variable	N=8
Median Age (Range)	25 (11 years-58 years)
Sex	
Male	*8/8*
Female	*0/8*
Voltage	
Low voltage	*0/8*
High Voltage	*8/8*
Place of occurrence	
Home	*3*
Workplace	*5*
Mode of injury	
Accidental	*6 (75%)*
Occupational	*1 (12.5%)*
Recreational	*1 (12.5%)*
Burns	
Median body surface area (Range)	*11% (5-27%)*
Entry point	*Upper limb (7/8; 87.5%)*
Exit point	*1. Lower limb 6/8 (75%)*
	2. Chest wall 2/8 (25%)
	3. Abdominal wall 1/8 (12.5%)
Complications	
Associated trauma	*0/8*
Multisystem involvement	*3/8 (37.5%)*
Cardiac arrhythmias	*0/8*
Acute kidney injury	*3/8 (37.5%)*
*Myonecrosis (Creatine Kinase)**	*4/8 (50%)*
Sepsis	*3/8 (37.5%)*
Anemia	*3/8 (37.5%)*
Hypoalbunemia	*3/8 (37.5%)*
Seroma of stump	*3/8 (37.5%)*
Nodular scabies of stump	*1/8 (12.5%)*
Amputations	*4/8 (50%)*
Median CK-MB* (Range)	*406 (88.5-5410)*
Urine myoglobin +	*1/8 (12.5%)*
Median length of hospital stay (Range)	*3 days (1-45 days)*
Mortality in index admission	*0/8*

*Normal lab value: < 170 Units/Litre.

reported by Arnoldo et al in his 20-year review [12]. None of our patients had concomitant injuries in other body regions. This may be due to a small sample size, a low incidence of secondary fall, or even survival bias in severely burnt & injured patients.

The most common rhythm disturbance after HVEI is sinus tachycardia and premature ventricular contractions [13]. We monitored ECG in all patients of the current study, as per ATLS protocol [6]. No abnormality was found in the index as well as follow-up ECGs in our series. Similar to our observation, Srivastava et al found no ECG abnormalities in their study on pediatric electrical injuries [9]. Arnoldo et al did report arrhythmias on admission in 31 patients and late-onset arrhythmias in seven patients, but none of them were related to electrical injury [12]. It is also possible that patients with significant arrhythmias after HVEI do not survive to reach the hospital. Therefore, the practice of prolonged ECG monitoring in HVE patients with normal index ECG needs to be reviewed with larger sample size.

In our study, no patient developed arrhythmia despite elevated cardiac enzymes. Levels of CK-MB in our study are in agreement with other studies, and it has been claimed to be a poor marker of myocardial injury in electrical injury patients [4, 13]. Srivastava et al described elevated CK-MB levels in 29 of 55 patients (54 HVEI), however, none of them had ECG abnormalities [9]. Similarly, Kartas et al in their study of 43 electrocuted patients found only 8 patients with abnormal ECGs (extrasystoles most commonly) and mean CKMB levels of 37.2 ± 6.7 IU/L [15]. Therefore, the practice of monitoring cardiac enzymes to diagnose myocardial damage in HVEI victims needs to be re-examined for clinical significance.

In our series, we observed that only one of 3 patients in renal failure had myoglobinuria. Myoglobin induced damage has been described as one of the mechanisms of ARF in electric injuries [14]. Cancio et al (2005) found ARF in just 3.1% of patients despite the high incidence of myoglobinuria [10]. Arnoldo et al too

Table 2. Follow up of high voltage electrocution victims

	TBSA (%)	LoS (Days)	No of surgeries	Follow up duration (months)	Days lost at work	Prosthesis
Patient 1	6	3	0	Lost to follow up	Lost to follow up	Not known
Patient 2	4	1	1	12	1 month	Not required
Patient 3	11	3	0	12	5 months	Not required
Patient 4	13	12	3	8	7 months	No
Patient 5	5	2	0	6	15 days	Not required
Patient 6	12	6	1	8	6 months	No
Patient 7	14	43	6	8	4 months	No
Patient 8	27	32	7	4	2 months	No

TBSA: Total burn surface area; LoS: Length of stay.

found hemochromgenuria in 96 patients but none of them developed pigment-induced acute tubular necrosis [12]. Similar findings were supported by Hanumadass et al (1986) with 44% of patients developing hemochromogenuria but none having renal failure [16]. Levels of myoglobin leading to renal involvement are also not established. Therefore, holistic estimation of myonecrosis with targeted fluid therapy seems better than urine myoglobin status for preventing and/or managing renal failure.

We had one pediatric patient who suffered abdominal wall burn and had pneumoperitoneum, but without features of peritonism. The child was managed non-operatively with close serial examinations. The air speck in the latter case may have entered per abdominal wound. Visceral involvement as a systemic manifestation of electric injuries has been described as a very rare presentation [17, 18]. Interestingly, 3 of 8 patients in our series had visceral involvement. Two of them required surgical management and another required medical management with intensive care. All elements of care in these sick patients including resuscitation, emergency & definitive surgeries, and intensive care were readily provided by the trauma team itself.

Considering HVEI victims as an 'isolated burn patient' is fraught with the danger of missing injuries like hollow viscus perforation and stress ulcerations. An element of immunosuppression in HVEI is also suspected, explaining the relative lack of signs of peritonitis in hollow viscus perforations [19], and this possibility must be kept in mind when admitting HVEI patients. We have published our experience on delayed presentation of hollow viscus perforations in HVEIs earlier [20].

In our study, all victims were males, and most had entry wounds in the upper extremities. A similar trend has been reported by other authors too [8, 9]. The amputation rate in our series approached 50%. As male members are often the dominant bread earners in LMICs, the morbidity of HVEIs, especially upper limbs, is devastating for the patient and the family. In our study, HVEI led to a vocational loss for a median of 5 months (**Table 2**). The resulting financial constraints can very well explain the lack of prosthesis in almost all of amputated patients at a median follow up of 8 months in our study.

Electrical injuries have a mortality of 2.7-5.3% [8, 11]. The causes of death could be electric injuries per se (cardiac arrest), wound-related, or systemic complications [21]. We didn't have any in-hospital mortality in our series. Contributory factors may be natural selection (median injury arrival interval 6 hours), smaller sample size, or both. Nonetheless, the provision of multidisciplinary care round the clock with integrated services of a level I trauma center was instrumental in achieving nil mortality in these patients with dangerous mechanisms and serious injuries.

Limitations

With the current sample size, it is difficult to comment on regional epidemiology and management trends of HVEIs. For true estimation of epidemiology, the number of patients escaping HVEIs with trivial burns attended in the outpatient department, and/or discharged from the emergency department is also desirable.

Strengths

We report on a rare injury with a reasonable sample size, along with one year follow up in

terms of function and rehabilitation. The current study highlights the point that HVEI victims should not be seen as burn victims in isolation, and holistic patient assessment and management are mandatory to achieve optimal outcomes. With the integrated provision of acute, definitive, and intensive care, level 1 trauma centers are ideally suited for the management of HVEIs.

Summary

HVEIs are rare injuries, with a prevalence of 0.5% among all admissions in the current study at level 1 trauma center. Overwhelming male predisposition is there, the median age being 25 years. Entry wounds are commonest in upper extremities and amputation rates approach 50%. Despite expeditious surgical management of compartment syndrome, progressive myonecrosis can lead to a dismal outcome in form of amputation. Creatine kinase and urine myoglobin were not found to correlate with organ dysfunction in the current study. ECG monitoring wasn't advantageous in patients with normal index ECG. Modest burns do not rule out visceral damage; hollow viscus perforation is a real possibility, especially in HVEIs involving the parietal wall, and can present in a delayed fashion. The economic consequences of HVEIs in survivors are unmeasured in LMICs but profound to say the least. Vocational loss is commonly due to high amputation rates of the affected extremity, which is, unfortunately, the upper extremity most of the time. The trauma team is well trained to provide acute, definitive, and intensive care to these patients, and level I trauma centers with their integrated services are the best chance for victims of HVEIs.

Disclosure of conflict of interest

None.

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References

[1] Shih JG, Shahrokhi S and Jeschke MG. Review of adult electrical burn injury outcomes worldwide: an analysis of low-voltage versus high-voltage electrical injury. J Burn Care Res 2017; 38: e293-e298.

[2] Henry S, Brasel K and Stewart RM. Thermal Injuries. In: Advanced trauma life support for doctors, ATLS, student course manual (10th ed.), Chicago, Ill.: American College of Surgeons, Committee on Trauma (2018). 179-180.

[3] American Burn Association. Advanced Burn Life Support provider manual 2018.

[4] McLeod JS, Maringo AE, Doyle PJ, Vitale L, Klein JD and Shanti CM. Analysis of electrocardiograms associated with pediatric electrical burns. J Burn Care Res 2018; 39: 65-72.

[5] Zikaj G, Xhepa G, Belba G, Kola N and Isaraj S. Electrical burns and their treatment in a tertiary hospital in albania. Open Access Maced J Med Sci 2018; 6: 835-838.

[6] American College of Surgeons. Advanced Trauma Life Support Student Course Manual 2018.

[7] Ramos G, Cornistein W, Cerino GT and Nacif G. Systemic antimicrobial prophylaxis in burn patients: systematic review. J Hosp Infect 2017; 97: 105-14.

[8] Kasana RA, Baba PU and Wani AH. Pattern of high voltage electrical injuries in the Kashmir valley: a 10-year single centre experience. Ann Burns Fire Disasters 2016; 29: 259.

[9] Srivastava S, Patil AN, Bedi M and Tawar RS. Paediatric electrical burn injuries: experience from a tertiary care burns unit in North India. Ann Burns Fire Disasters 2017; 30: 185.

[10] Cancio LC, Jimenez-Reyna JF, Barillo DJ, Walker SC, McManus AT and Vaughan GM. One hundred ninety-five cases of high-voltage electric injury. J Burn Care Rehabil 2005; 26: 331-40.

[11] Butler ED and Gant TD. Electrical injuries, with special reference to the upper extremities: a review of 182 cases. Am J Surg 1977; 134: 95-101.

[12] Arnoldo BD, Purdue GF, Kowalske K, Helm PA, Burris A and Hunt JL. Electrical injuries: a 20-year review. J Burn Care Rehabil 2004; 25: 479-84.

[13] Housinger TA, Green LA, Shahangian SH, Saffle JR and Warden GD. A prospective study of myocardial damage in electrical injuries. J Trauma 1985; 25: 122-4.

[14] Waldmann V, Narayanan K, Combes N, Jost D, Jouven X and Marijon E. Electrical cardiac injuries: current concepts and management. Eur Heart J 2018; 39: 1459-1465.

[15] Karataş MB, Onuk T, Güngör B, İpek G, Özcan KS, Kaplangöray M, Çanga Y, Durmuş G, Çakıllı Y and Bolca O. Assessment of electrocardiographic parameters in patients with electric injuries injury. J Electrocardiol 2015; 48: 809-14.

[16] Hanumadass ML, Voora SB, Kagan RJ and Matsuda T. Acute electrical burns: a IO-year clinical experience. Burns Incl Therm Inj 1986; 12: 427-31.
[17] Marques EG, Júnior GA, Neto BF, Freitas RA, Yaegashi LB, Almeida CE and Júnior JA. Visceral injury in electrical shock trauma: proposed guideline for the management of abdominal electrocution and literature review article in international journal of burns and trauma. Int J Burn Trauma 2014; 4: 1-6.
[18] Sharma M, Kaundal P, Sharma P and Chaudhary R. Electric current causing sigmoid perforation: case report. Annals of International Medical and Dental Research (AIMDR) 2015; 1: 39-40.
[19] Blears E, Sommerhalder C, Toliver-Kinsky T, Finnerty CC and Herndon DN. Current problems in burn immunology. Curr Probl Surg 2020; 57: 100779.
[20] Goyal D, Dhiman A, Jagne N and Rattan A. Delayed bowel perforation in electrocution: an unpredictable foe. Monaldi Arch Chest Dis 2020; 30: 100377.
[21] Sokhal AK, Lodha KG, Kumari M, Paliwal R and Gothwal S. Clinical spectrum of electrical burns-A prospective study from the developing world. Burns 2017; 43: 182-9.