

# Low- and High-Voltage Electrical Burns: 10 Years of Experience

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## ABSTRACT

**OBJECTIVES:** Electrical burns are devastating, posing development of multiple injuries with high morbidity and mortality. Electrical burn management benefits from a multidisciplinary and multispecialty collaborative approach to improve outcomes.

**MATERIALS AND METHODS:** This prospective study, conducted from January 2010 to December 2020, included 78 patients (75 male and 3 female patients) who presented with a history of electrical burns at the Ain Shams University Hospital (Cairo, Egypt). Patients were interviewed for personal details, cause of burn, percentage of burn, electrocardiogram changes, isolated microorganisms, treatments given, complications, average length of hospital stay, and outcomes, which were analyzed using descriptive statistics.

**RESULTS:** Among the 78 patients, most ranged in age from 21 to 40 years, with ratio of patients with high-voltage versus low-voltage injury of 4.2:1. The most common region involved was the upper limb (88.2%); 29.3% of patients had associated traumatic injuries. Significant electrocardiogram changes were noticed in 25% of patients, and culture was positive for bacterial growth in 76.2% of patients (32/42). Most patients (73.1%) underwent surgery with an average of 2.63 surgeries per patients; 26.9% of patients underwent major/minor amputations. Length of stay ranged from 14 to 28 days. Overall morbidity rate and mortality rate were 2.1% and 2.4%, respectively.

**CONCLUSIONS:** Electrical burns, which are mostly shown in young adult men, can impose a significant burden in developing countries. Electrical burns, especially those due to high voltage, involve multiple organs and have significant residual sequelae, which can benefit from multidisciplinary management. Public awareness and education and proper training of industry workers remain the best way to minimize the prevalence of electrical burns in the developing world.

**KEY WORDS:** *Burn trauma*

## INTRODUCTION

Electrical burn injuries comprise a small fraction of total burn admissions, but they can potentially have disfiguring effects.<sup>1</sup> Most of these injuries are preventable by education programs and safety measures. Electrical burn injuries can be divided into low-voltage (<1000 kV) and high-voltage (>1000 kV) injuries.

In this study, our objective was to investigate epidemiological variables and associated outcomes of electrical injuries at a major burn center in Cairo, Egypt, which could help us to take further preventive measures, improve services in our area, and plan resource allocation.

## MATERIALS AND METHODS

This prospective study included 78 patients (75 male and 3 female patients) who presented with a history of electrical burns caused by electrical currents from January 2010 to December 2020 at the Ain Shams University Hospital in Cairo, Egypt. Patients with electrical arc flash burns only and those admitted for later reconstructive surgery were excluded.

We collected and analyzed data on etiology, age, sex, place of burn, severity of burns, percent of total body surface area (TBSA) burned, electrocardiogram (ECG) changes, anatomical regions involved, associated traumatic injuries,

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**ACKNOWLEDGEMENTS:** The authors have not received any funding or grants in support of the presented research or for the preparation of this work and have no declarations of potential conflicts of interest.

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Burn Care and Prevention 2021/4: 141-146

and length of hospital stay. We also analyzed details of treatment, first aid, initial management (in referred patients), medical care, follow-up results, and mortality.

Electrical burn severity was graded as follows: mild was <5% of TBSA and no third-degree burns, moderate was between 5% and 15% of TBSA or third-degree burn <5% of TBSA, extensive was between 15% and 25% of TBSA or third-degree burn between 5% and 10% of TBSA, and critical was >25% of TBSA or third-degree burn >10% of TBSA. The burn area was estimated by 2 attending physicians at admission to our Burn Department, according to the Rule of Nines and Rule of Palm.<sup>2</sup>

All patients received standard treatment comprising fluid resuscitation, burn wound assessment and management, infection control, diagnosis and treatment of inhalation injury, nutritional support, and rehabilitation.

Fasciotomies and escharotomies were done by clinical evaluation (tense compartments and pain on passive stretch). Continuous cardiac monitoring and muscle enzymes were requested during the hospital stay. Mannitol and sodium bicarbonate were used for the treatment of myoglobinuria. Cardiac evaluation was done by serial ECG monitoring. Amputations were done after evaluation of the exact vascular status by obtaining a computed tomography angiography of the limbs.

## RESULTS

### Demographics: age

During the study period, 78 patients with electrical burn were admitted to our center. Sixty-one patients ranged in

age from 21 to 40 years (78.2%). Another peak was noticed in the age group that ranged between 11 to 20 years (12 patients, 15.3%). Although the incidence was lower in the age range from 41 to 50 years, which was 2.6% (2 patients), the lowest incidence was observed in patients <10 years, 51 to 60 years, and >61 years (1 patient in each age group range or 1.3%). High-voltage burns and low-voltage burns, respectively, were mainly observed in patients aged 21 to 30 years (35.9% and 7.7%), 31 to 40 years (30.8% and 3.8%), and 41 to 50 years (2.6% and 0%). Figure 1 shows distribution of patients by age.

### Male versus female patients

Male-to-female ratio was 25:1 with electrical burn injuries affecting male patients more than female patients (96.1% vs 3.8% respectively). Both high-voltage and low-voltage burns occurred mainly in male patients (79.5% and 16.7%, respectively). Figure 2 shows distribution of patients by sex.

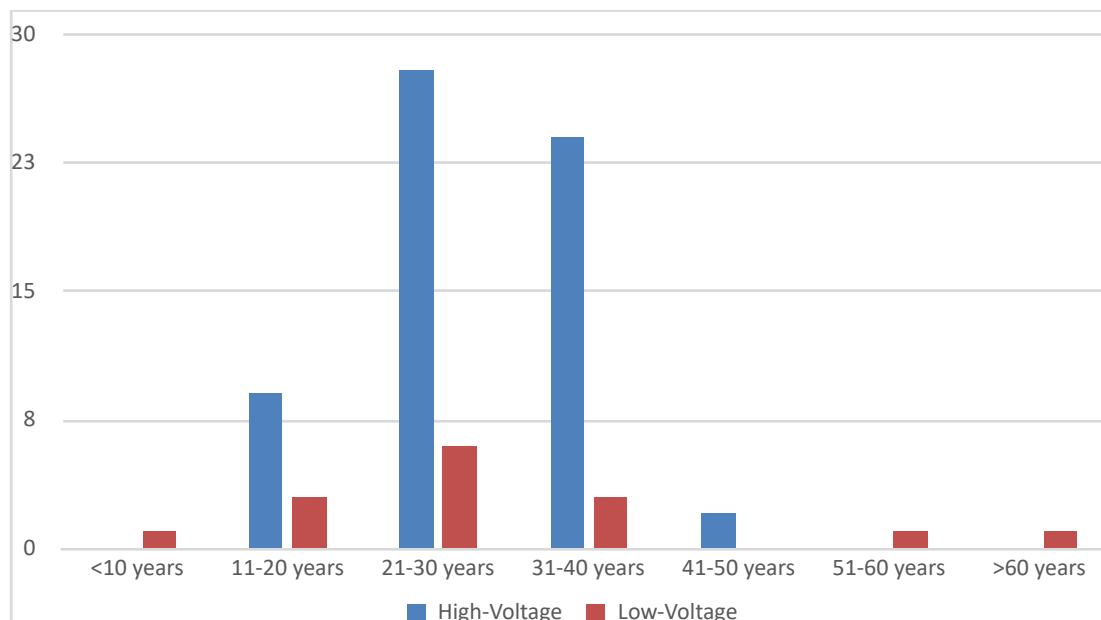
### Season of burn injuries

Most electrical burns occurred from March to November, during which period 88.8% of patients were injured. High-voltage burns were most frequently observed from March to August (65.0%), and most cases of low-voltage burns occurred from June to September (64.8%).

### Place of injury and occupation

With regard to place of injury, 70.1% occurred in urban areas (cities), with 29.8% occurring in rural areas (villages). Most patients were industrial workers (32%), with high-voltage injuries in 21.8% and low-voltage injuries

**FIGURE 1.** Distribution of Electrical Burns by Age

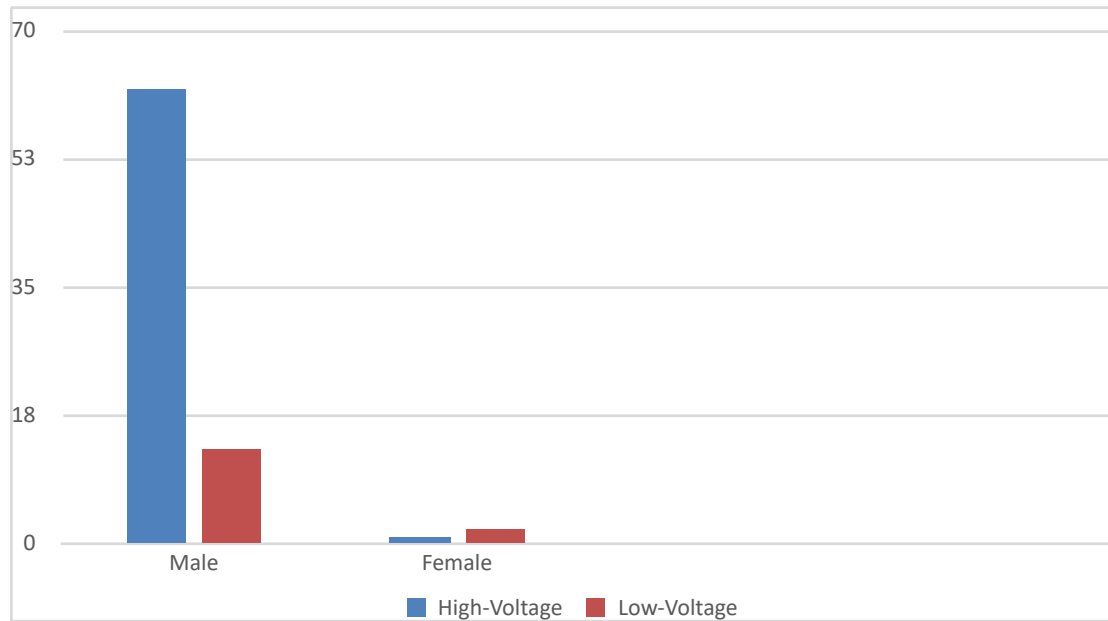


in 10.3%. Homemakers, with injury at home, comprised 16.7% of patients (3.8% with high-voltage and 12.8% with low-voltage burns). Electricians comprised 20.5% of patients injured (18% with high-voltage and 2.6% with low-voltage burns). Preschool children comprised 9.0% of patients (7.7% with high-voltage and 1.3% with low-voltage burns). Figure 3 shows distribution of patients by occupation.

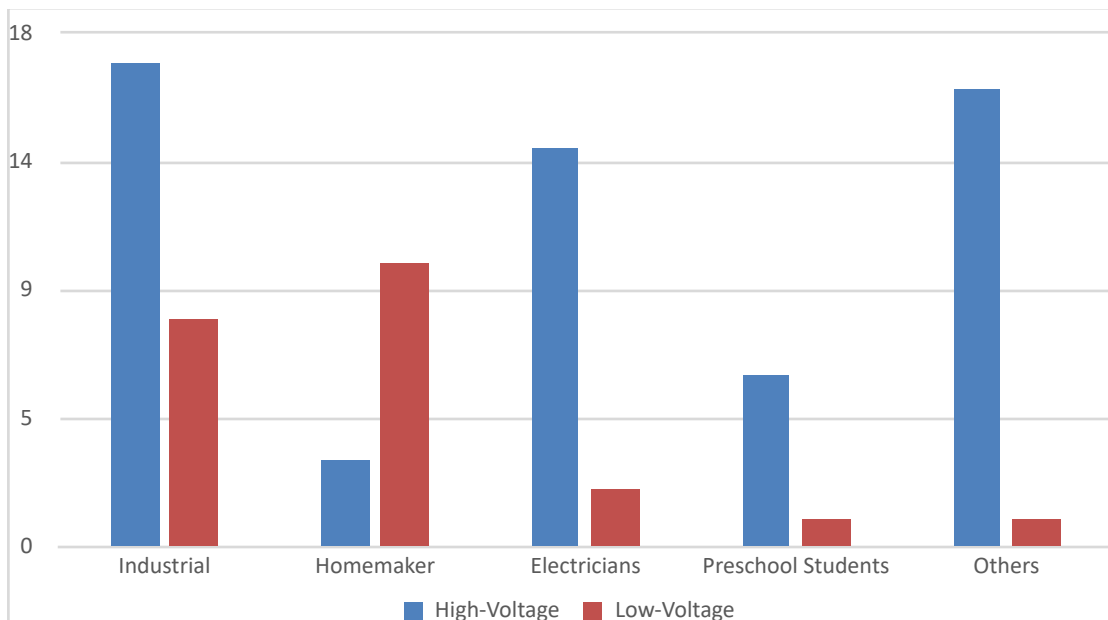
**Burn etiology**

Work-related accidents (46.0%) were the most common cause of electrical injuries, followed by electrical accidents indoors (19.4%). We observed that 15.4% of electrical injuries were the result of electrical accidents outdoors and 11.5% occurred because of electrical operations. Figure 4 shows distribution of patients by etiology.

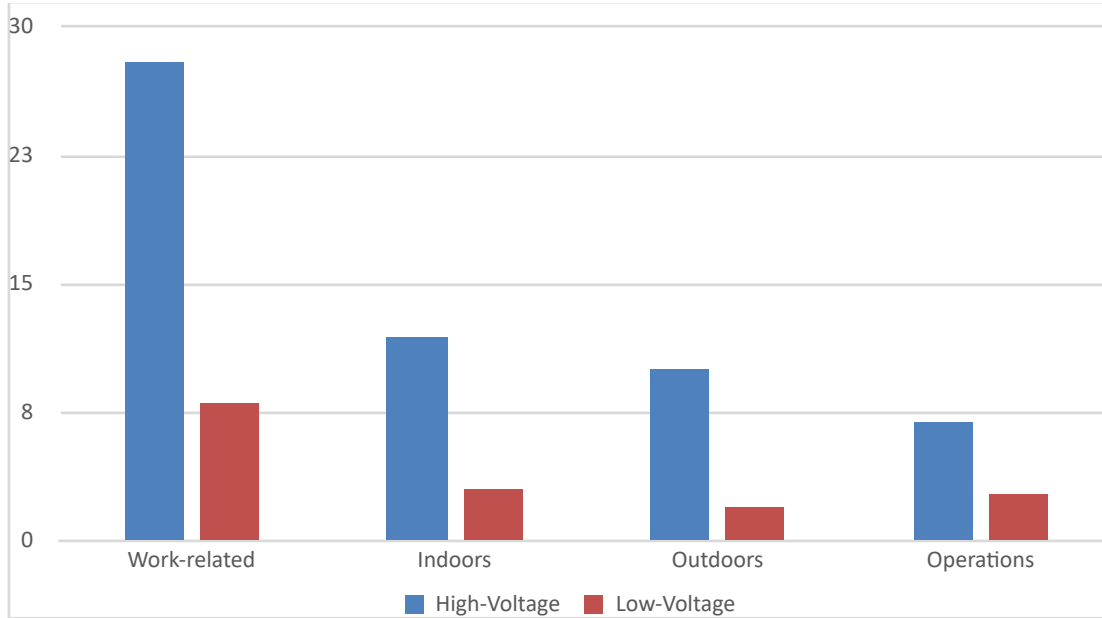
**FIGURE 2.** Distribution of Electrical Burns by Sex



**FIGURE 3.** Distribution of Electrical Burns by Occupation



**FIGURE 4.** Distribution of Electrical Burns by Cause



**Extent of burns**

In our patient group, 63% had third-degree burn injuries, with 25.9% having second-degree burn injuries, 9.3% having fourth-degree burn injuries, and 1.9% having first-degree burn injuries.

**Anatomical regions involved**

The most frequently injured anatomical area was the upper limb (88.2%) followed by the lower extremities, head, and neck.

**Total body surface area burned**

The TBSA observed for high-voltage burn group ranged from 1% to 45%, which was significantly more extensive than observed for the low-voltage burn group (1% to 27%).

**Initial management**

Initial management included management of airway, breathing, and circulation, fluid resuscitation, burn wound assessment and management, infection control, diagnosis and treatment of inhalation injury, nutritional support, and rehabilitation.

**Medical care and follow-up results**

A total of 73.1% of patients underwent surgery with an average of 2.63 surgeries per patients; 26.9% of patients required major/minor amputations.

**Length of hospital stay**

The length of hospitalization for the high-voltage burn group ranged from 2 to 60 days, which was significantly

longer than the hospital stay for the low-voltage burn group (range, 2-21 days).

**Complications and outcomes**

There were more complications in patients with high-voltage burns than in those with low-voltage burns (80.8% vs 19.2%). There were more major amputations in patients with high-voltage burns than in those with low-voltage burns (25.8% vs 5.0%). We observed that 29.26% of patients had associated traumatic injuries. Complications in patients are shown in Table 1.

**TABLE 1.** Main Complications and Combined Injuries of Electrical Burns

Complications/ Combined Injuries	High-Voltage Burns, % (No. of Patients)	Low-Voltage Burns, % (No. of Patients)
Coma	87.3 (55/63)	66.7 (10/15)
Shock	1.6 (1/63)	0.0 (0/15)
Peripheral nerve injury	1.6 (1/63)	0.0 (0/15)
Glaucoma	0.0 (0/63)	0.0 (0/15)
Brain trauma	1.6 (1/63)	0.0 (0/15)
Fracture	3.2 (2/63)	0.0 (0/15)
Electrical arc burn	1.6 (1/63)	0.0 (0/15)
Bruises and laceration	3.2 (2/63)	6.7 (1/15)
Lung injury	1.6 (1/63)	0.0 (0/15)
Cardiac injury	50.8 (32/63)	6.7 (1/15)
Liver injury	47.6 (30/63)	6.7 (1/15)
Acute renal failure	1.6% (1/63)	0.2 (3/15)
Compartment syndrome	9.5 (6/63)	6.7 (1/15)

Culture was positive for bacterial growth in 76.19% of patients caused by multidrug-resistant *Pseudomonas aeruginosa*. We observed that compartment syndrome occurred in 9.5% of those with high-voltage burns versus 6.7% of those with low-voltage burns.

Overall morbidity rate and mortality rate were 2.1% and 2.4%, respectively. The mortality rate was 2.4% versus 0% in the high-voltage versus low-voltage electrical burn groups.

## DISCUSSION

Although not common, electrical burns deserve special attention. They comprise approximately 0.04% to 5% of all admissions to burn centers in developed countries and up to 27% in developing countries.<sup>3</sup> During our study period, annual electrical burn injuries accounted for 1% to 3% of all annual admitted burns, suggesting a relatively low incidence of electrical burns in Cairo.

The mechanism of electrical burn damage is complex and can include combined thermal and electroporation with an electrical force that can generate temperatures over 100 °C. This can drive water into the lipid membrane and cause cell rupture. The mechanism of electrical burn damage depends on several factors, such as damaged area, contact time, and electrical current intensity.<sup>4</sup> The severity of tissue damage can be classified according to the electrical intensity (low voltage or high voltage), the type of current (direct or indirect), the affected part of the body, the contact time, and simultaneous secondary damages.<sup>5</sup> Alternating current (AC) is 3 times more dangerous than direct current (DC) for the same voltage exposure. A DC injury can throw the patient, thus limiting the exposure to the source but inflicting traumatic injuries and cardiac rhythm disturbances. An AC injury can induce continuous muscle contractions and tetany. Thermal damage to the tissues and subsequent coagulative necrosis is caused by high-voltage injury.<sup>6</sup> Electrical burn injuries can also be classified into 2 main groups: burns with current above 1000 volts and burns with current below 1000 volts.<sup>7</sup>

Low-voltage burns result in destruction of the affected site tissue, whereas high-voltage burns cause systemic damage.<sup>8</sup> These types of injuries have immediate consequences in the short-term and require extensive medical intervention, and their complications are much deeper and more difficult to detect in the long run.<sup>9</sup>

In our study, there were more patients with high-voltage electrical burns than low-voltage electrical burns (ratio of 4.1 to 1), which was similarly previously reported.<sup>10</sup> However, it has also been reported that low-voltage currents are responsible for most electrical injuries.<sup>11</sup> In the present study, high-voltage burn injuries were more

frequent between March and August (spring and summer), whereas low-voltage burns peaked between June and September (summer). This may be associated with intense industrial output and domestic electricity usage in these seasons in Cairo.

There were more male patients with electrical burn in our study, which is similar to a previous finding.<sup>12</sup> This may be because men often engage in high-risk jobs, as reported previously.<sup>13</sup> Our results showed that almost 75% of the total injuries occurred in young and middle-aged people, an energetic and active group. In addition, there were a substantial number of low-voltage burns in young children. Young children obviously are less able to judge danger and protect themselves and may not always be protected by their families.

Comparable to several previous studies, we found that a high percentage of burns occurred in industrial workers and electricians at work or homemakers at home.<sup>14</sup> These accidents mainly resulted from unsafe machine operation and electricity manipulation and protection equipment. Thus, preventive strategies are crucial to reducing the incidence of electrical burns. We found that patients with high-voltage burns had longer hospital stays and more extensive TBSA of burns than those with low-voltage burns, a finding consistent with other studies.<sup>15,16</sup> High-voltage burns are characterized by greater energy release and deeper, more extensive tissue damage, resulting in longer hospital stays. These 2 factors are directly related to mortality rates.<sup>17</sup>

Electrical injuries can lead to many complications. Our results and those of others have indicated that high-voltage burns tend to result in complications.<sup>18,19</sup> In the present study, coma was the most frequent one, but usually resulted in transient loss of consciousness and left few mental or physical sequelae. Cardiac and liver injuries were easily identified from elevated levels of creatine kinase isoenzyme-myocardial band and liver enzymes and abnormal ECG results. After symptomatic treatment, these injuries substantially improved in our patients. Shock and acute renal failure are life-threatening conditions but rare. It is important to use resuscitation as early as possible to avoid various complications, indicating the importance of intensive care and comprehensive treatment.

Electrical burns are still a major risk factor for amputations. Amputations are generally performed because of massive necrosis of deep tissues caused by the current. There were more major amputations in patients with high-voltage burns than in those with low-voltage burns (25.8% vs 5.0%). In addition, high-voltage burns involved more amputations of one upper limb, probably because that upper limb was the most common current entry point.<sup>20</sup>

Amputations not only cause physical disabilities but also psychological problems. Thus, a major challenge is to how to reduce amputations and reconstruct the function of the injured limbs.

In conclusion, electrical burns are an important public health problem. Their prevention should be emphasized in male adults, especially with respect to industrial workers, incidents in the spring and summer, and high-voltage injuries. Information about the use of outlet covers for connection elements and arc-fault circuit interrupters, rules for the standardization of the manufacturing electrical devices, use of warning signs, knowledge about electrical injuries and proper use of electricity, and awareness of self-protection could be enhanced via public education programs in schools, companies, and communities. Workers exposed to electrical equipment must be fully trained and certified.

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