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Original Research Article

A retrospective analysis of electrical burn injuries

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ABSTRACT

Background: Our life is running at a fast pace holding hands of the hi-tech innovations in this ever-developing scenario. Electricity runs the show of the whole technology is potentially dangerous commodity to handle in daily life. Hence, electric burn injuries have been a public health threat. Electrical burns are less prevalent but are the most disastrous. Electrical burn injuries are considered as a unique form of trauma where in morbidity and mortality rates are much higher compared to the other thermal burns. This study is a retrospective analysis of electrical burn injuries that provides an insight to all facts regarding the electric burn injuries.
Methods: This paper is structured upon the patients with electrical burn injuries who were admitted to the hospital. The medical data of all burn patients admitted to our hospital between March 2011 to January 2023 were evaluated for inclusion. Incusion criteria were age 18 years old and above. The patients were divided into two age groups: 18-45 years as younger age and above 45 years old as elder age.
Results: Out of 82 occurrences of electrical burns caused by workplace dangers, 80 involved men. Male patients ranging age from 18 to above 45 years were present, 12 adults above the age of 45 years were there. Accidental electric shocks caused by low-voltage home appliances struck two elderly patients and two female patients.
Conclusions: The cause of electrical burn incidences was work related. The common patient population was consisted of electrical- mechanical workers, industrial workers, agriculture field worker, and construction workers.

Keywords: Electrical burn injury, Electricity, Human body resistance, Electroporation

INTRODUCTION

Since the inception, electricity is inevitable in human life. In the present time, electrical burn injuries are considered as most disastrous public health problem across the globe.[1] Usually, electric burn injury is an under rated trauma but are the ones which account for the highest morbidity and mortality. High voltage burns account for the most predominant cause of physical disabilities due to important amputations along with other complications.[2] Electricity burns are the most destructive and have prolonged physical and mental complications which brings about socioeconomic effects.[3] This retrospective analysis of electrical burn injuries is done on electric burn injured patients in our center.

Etiology

When an arc light flash ignites the clothing of an individual, flame injury takes place. Electric current might or might not travel through the skin in these occurrences. Flash injuries are caused by an arc flash and are referred to as superficial burns because in this case the electric current does not travel through skin. In the case of lightening injury, electrical energy of extremely short but very high voltage is involved. The electric current passes through the entire body of the injured individual.

The true electric injuries are referred when the individual becomes a part of an electrical circuit. In general, an entrance and an exit are found in these cases.[5]

True electric injury

Electrical burns injuries vary from the thermal and chemical burn injuries. In case of electrical injury, there is local generation of heat and the action of the passage of the current being direct through the tissue. Coagulative necrosis of the cells is caused by heating and the current is responsible for the cell membrane disruption that leads to tissue loss and death.[4] The severity of the destruction of human tissue is high due to high voltage electrical burn. The form of energy that has electrons passing from one point to another through atoms is called Electricity. The current is the flow of electrons. Current can hurt and even kill a victim of an electric injury. There are types of electric burns that causes superficial to deep burn injuries.

Types of electrical burns

Electrical injuries are mechanical trauma, broadly caused by four main types which are: Flame, flash, lightening and true.

Electric injuries are often categorized depending upon their intensity, such as high voltage and low voltage. It is important to know for the prognosis of the wounds to make strategic decisions to treat the patients effectively. Electric current of low voltage while travelling through the body of a person which is between the entry and exit site then the electrical energy converts into thermal energy that causes underlying tissue damages. High voltage electric entry wounds are centrally depressed, charred and leathery in appearance whereas exit wounds are mostly exploded as the charr exits.

Incidences

The burden of electrical burn injuries is seen to be different in the developed and the developing countries. The Demographic data shows that most of the electrical injuries occur at work that involves the main working human resource of youth population.

The pediatric and the old aged population suffer electric burn injury takes place at home from the low voltage appliances.[6]

Electrical injuries are observed higher among the boys than the girls. The rates of injury could be seen significantly higher in males than females due to exposure in occupational hazards probably. In a random observation taken, it is seen around 80% are injuries occur in menfolk. The type of the pattern of electrical injuries depends upon the age of the victim. This is seen as in case of low voltage household generally the exposures are among the toddlers. The high voltage exposures are mostly seen among the teenagers and through occupational electricity exposure as well.[7] The prime cause of electric injuries has been seen in the agricultural fields. It occurs mostly due to the lack of proper knowledge and unawareness in the rural area while working with electric devices.

Epidemiology

Being the third largest producer of electricity in the world, India has frequent electric incidences that impact with a high morbidity and mortality. 7 million people in India suffer burn injuries each year with 1.4 lakh deaths and 2.4 lakh people suffer from disability as a morbidity due to electric burns. Electric burn in India is constitute around 24.49%. This is significant when compared to the other parts of the world. Approximately 86% of burns are caused by thermal injury of which 4% are electrical.

Pathophysiology of electrical burns

Electrical burn injuries are devastating and the management poses a serious challenge for the healthcare professionals. The treatment strategy of an electrical burn injured patient entirely depends upon their responses to the pathophysiological aspects at the level of cellular and systemic level.

An electrical burn could take place by direct contact and also by indirect contact as well. Indirect contact burns occur via flash, flame or an arc. Three pathophysiological effects are observed as the consequence: Thermal burn due to carbonation and joule heating, electroporation and protein denaturation.

The severity and the effect of all of the three mechanisms mentioned evidently depends upon the u amount of current, voltage and resistance as expressed in current= voltage/resistance.[8] According to Ohm's Law, the current is directly proportional to voltage whereas inversely proportional to resistance. Hence, there are two important factors contributing to the pattern of the injury and severity of the burn-a. The direction of the entrance of current compared to the body position during the occurrence. b. Duration of the exposure to the electricity

These three mechanisms determine the pathophysiology of how electricity can create a burn in the body.[9]

The three significant mechanisms involved in electrical burn injuries are as mentioned below-Coagulative necrosis (Joule effect) and massive tissue destruction is caused when electrical energy converts into thermal energy. Electrical energy causes direct tissue damage that alters the cell membrane resting potential and induce muscle tetany. There could be mechanical injury with trauma due to violent muscle contraction which might throw off the victim.[6]

Seven factors that affect electric burn injuries are type of current, duration of current, area of contact, resistance of the body, amount of current, pathway of current, voltage.[6]

The question is how and why is the human body susceptible to the electrical current?

Physics of electricity

Electric shocks can be defined as a swift and violent response to the flow of electric current passing through a human body. It is a primary electrical injury when there is a tissue damage produced by voltage or electric current directly. The damage from an electrical burn primarily is due to the passage of electricity across the tissues. The strength of the current along with the time of the contact is responsible for the severity and the degree of damage caused.

Current is the amount of electricity i.e., electrons or ions flowing per second. It is quantified in amperes or milliamperes. [1mA= 1/ 1000 of an ampere].[10]

Ohm's law says that current is directly proportional to voltage and reciprocal to resistance.

The voltage is dependent on the type and nature of the supply of current. It is generally 220 to 250 volts. It is seen according to the Ohm's law; amperage depends directly upon the resistance offered to the current by the body which is represented as: A=V/R. Electricity is a form of energy. It is expressed in the terms of interaction and the movement of electrons which passes from one atom to another which is called the current. It is measured as one ampere current has passed when each time 6.242×10^{18} electrons have passed a given point in 1 second.[11]

Voltage (V)- Generally, electrons move at random in most materials. This is the driving force that direct electrons to move in a uniform direction across the potential difference. This force is reckoned as voltage. Potential difference is termed as Voltage (V). Referring to voltage, electrical injuries are identified into high- voltage and low- voltage injuries. 1000 V is marked as the cut off. Current (I)- Current is measured in amperes (A).

There are two types of currents based on the pattern of electron-flow:

Alternating current (AC): The direction of flow of electrons follows a cyclic pattern of change. Hence it is expressed in cycles per second or hertz (Hz). 50- 60 Hz is the standard AC current for household purposes. At the same exposure of the voltage, AC is three times more dangerous compared to direct current (DC) which is responsible for high morbidity and mortality.

Direct current (DC): Here, the direction of flow of electrons remains constant. DC current is used in railway tracks, automobile electric system, batteries and lightening as well. Skin is more resistant to DC than that to alternating current.

Resistance and the human body as a conductor

The interior of the human body serves as an excellent conductor (low resistance) due to the fluid content of the tissue, blood plasma and interstitial fluids in particular. The important variability factor of resistance (R) lies in the skin and the pathway of the source of electricity making contact with the body.[13] Externally human body is covered by skin. The skin is structured in layers. The outermost layer of epidermis, Stratum corneum acts as the insulator for the body offering the main resistance for the skin. Next is the layer called dermis, offers very low resistance like other internal parts of the body. Only bones offer high resistance, hence are poor conductors.

The skin resistance varies based on different factors- Skin's moisture content, thickness of the outer derma and the cleanliness of the skin

Main concern of high voltage accidents

Medical literature defines high- voltage exposure is greater than 1000 V. In most cases of high voltage incidences, the victim is thrown away far from the electric circuit that causes traumatic injuries, like, fracture, brain hemorrhage. In general, 4 types of burns injuries are categorized that are caused due to contact with high- voltage electric circuits: Injuries from electric arc, injuries from an electric current, burn injury from flame and flash burn injuries.

Complications in electrical burn injuries

The occurrence of neurologic complications is most common in case of electrical burn injuries. High-voltage electric current many a times might be the reason for cardiac arrest from asystole and ventricular fibrillation as well. There are disastrous, almost lethal traumatic injuries due to thrown away falls by the force of electricity. Within the reported cases, an array of visceral complications is observed after the high- voltage electrical injury. Around 25% of the patients develop adynamic ileus. In case high voltage accidents, bone lesions are of frequent occurrence. Bones have high resistance to the passage of electric current that causes periosteal necrosis. Melting of calcium phosphate matrix is also occurs due to this.

Sometimes electric current passes through the victim's head due to an accident when the eye might be injured dangerously.[6]

Prognosis

It is an evident fact that electrical burn injuries are responsible for quite complicated internal multi- organic issues that demand a strategic therapeutic approach on the right time. The mortality and morbidity are directly related to the prognostic factors of the burn caused by electric current. The mortality is associated to refractory

myoglobin- uric renal failure, cardiac involvement, sepsis. This mortality differs from country to country on the basis of the socio- economic level. In the developed countries it is seen to be quite low as 3-16% whereas the developing countries has 21-27%. The frequency of amputations, neuropsychological and the sensory sequels are the factors related to morbidity by Habouchi et al.[14]

Diagnosis

Appropriate diagnosis is the most essential and pivotal step for the electric burn injuries to strategize effective assessment followed by treatment procedure. The severity and the degree of the electric burn is first determined by the healthcare provider in a clinical environment. There are processes to follow to estimate the percentage of burn and the depth of burn experienced by the body. Once classified, the burn wounds are taken care of to treat the best. Following table-2 shows the diagnosis with the proposed treatment strategies in accordance to the extent of the electric burn.[18]

Diagnosing unconscious patient in a clinical setting

In the differential diagnosing procedures, electrical injury symptoms should be included. Safe airway, breathing and continued circulation has to be ensured with the activation of Advanced trauma life support. It is important to calculate the total body surface area (TBSA) of the skin burn. Compartment syndrome should be detected by monitoring neurovascular status. All organ systems of the unconscious patient should be examined with care.

Diagnosing tests done to confirm the treatment strategy

The retrospective analysis was done on the basis of the all the entries of electrical burn patients in our center. The cascade of treatment followed once the overall diagnosis tests of external and the internal organs were carried out on the victims. Skin burn (Cutaneous), heart- Arrhythmia cardiac arrest, musculoskeletal-Muscle necrosis, compartment syndrome, fractures, pulmonary-respiratory arrest affects the patients due to tetany of respiratory muscles. Vascular system-aneurysm, ischemia, renal-in case of extensive muscle necrosis myoglobinuria causes renal failure. Neurological-Spinal cord injury, peripheral neuropathy, paralysis and paresthesia.[17]

Lethal complications due to third-degree electrical burns

When the third- degree burns are deep and cover a large portion of the skin it could be dangerous in terms of mortality. If the electric burn runs deep in the inner tissue strata, then it is possible to be life threatening. The complications observed in those cases are: Arrythmia and dehydration, contractures and deep scars, edema- excess fluid and swelling in the tissues, internal vital organ failure, pneumonia, serious infection when sepsis sets in which might lead to amputation and extremely low blood pressure-hypotension.[18]

Treatment

Only once the patient's correct diagnosis and the type of electric current exposure have been established is a cascade of therapy ensured. First aid and a brief stay at the care facilities could be necessary.

Depending on how severe the burn is, it may require surgery or require a lengthy hospital stay under observation.

Burn wound management

To treat the wounds in a clinical setting must- include procedures are: Debridement of loose tissues, moisturize the wounds early epithelial regeneration and antimicrobial agent application to avoid sepsis. According to their function, ointments are prescribed by the healthcare provider- a. Sulfadiazine b. Mafenide cream c. Silver-nitrate cream.

METHODS

This an original research paper. The medical data of all burn patients admitted to Pune international burns and cosmetic centre, Bhosari, Pune between March 2011 to January 2023 were subjected to a retrospective scrutiny. We used patient information on the types of electrical burns (low or high voltage), the proportion of burns, and the total body surface area (TBSA) burned to conduct the analytical investigation. Retrospective examination of the demographic and pathophysiological characteristics of electric burn wounded patients in the urban area was regarded to have been supported by the record of the length of hospital stays and the applied treatment for the injuries. This is a retrospective study, hence sample and ethical approval is not applicable. Inclusion criteria were age 18 years old and above. The patients were divided into two age groups: 18-45 years as younger age and above 45 years old as elder age.

Results are expressed in percentages (categorical variables). It is a dichotomous (or binary) data.

RESULTS

The entire number of electrical burn patients admitted to our centre from March 2011 to Jan 2023 underwent a conventional descriptive retrospective study. The electrical burn patients were found to have the most superficial to deep burns among all the burn patients.

Following factors were considered to perform the analysis: length of hospital stays, total body surface area burnt (TBSA), complications, non-surgical or surgical treatment strategies taken, amputations and mortalities related to the different exposures of voltages.

Table 1: Dangerous effects of electric shock.

Effects	Explanation
Electrocution	Lethal effect as the electric current sent through the human body.
Damage of heart	Myocardial injuries (heart attacks and cardiac arrest) and arrythmias (irregular heart rhythms) are the most common forms caused by the human body coming into contact with electric current.
Damage of brain	Electric shock results into neurological and neuropsychological damages. This is responsible for memory loss, reduced visuospatial reasoning, disability to perform daily routine work, depression and sometimes coma.
Electrical burns	Burns caused due to electric shock on the body is evidently painful It is potentially disfiguring and often causes disability. To reduce the damage of internal organs or loss of blood flow resulting in amputation, immediate medical intervention is required.
Effect on muscles	Contact with electric current mostly results in violent contraction and seizures that causes severe pain. To avoid even more serious internal damage, prompt medical attention is necessary.
Arm pain	Electric shock injuries are often serious than it looks on the external. Arm pain might be the symptom of deep burn, tissue necrosis or nerve damage.
Damage of nerves	Nerve damage due to electric shock injury can be disastrous and lethal. It can disrupt- a. cardiac function b. pulmonary function c. to decipher the pain signals of the body d. speech and walk ability.
Miscarriage	A pregnant woman might have a miscarriage due to electric shock passing through her body.

Table 2: Burn type, diagnosis and treatment.

Burn type	Diagnosis	Treatment
Minor	Mostly, categorized as first-degree burns those which affect less than 10% of the body. This is categorized as minor and requires hospitalization in very rare occasions.	First degree burns could be treated or attended with first aid and a burning pain could be treated taking pain medication, like, Acetaminophen or NSAIDS.
Moderate	The electric burns where 10% body is affected is categorized as second degree burns and considered as moderate. Although the burns on face, hands, feet and genitals might be moderate to severe.	First and second- degree burns might ask for the same treatment strategy more or less. Often-prescribed antibiotic cream is silver sulfadiazine as it is strong and kills bacteria reducing the probability of infection.
Severe	The most disastrous and lethal electrical burn injuries are third degree burns. Third degree burn is referred to as the deep thick burn. In this type of burns the outer layer of the skin is destroyed along with the dermis.[19]	These deep wounds frequently need skin grafting.

Table 3: Hospital stay classification.

Hospital stays (days)	Male	Female
01-20	68	02
21-40	06	00
41-60	03	00
61-80	03	00
81-100	00	00

Table 4: TBSA classification.

TBSA (percentages)	Male	Female
01-20	28	02
21-40	26	00
41-60	18	00
61-80	08	00
81-100	00	00

Figure 1: Electricity accident.

Figure 2: Incidences (Electric burn at workplace).

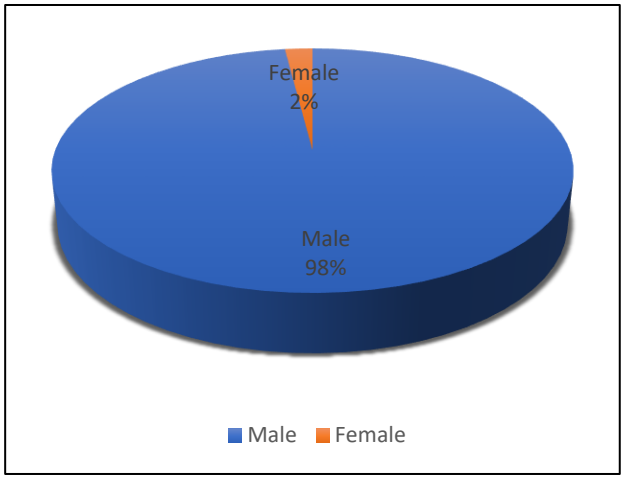

Figure 3: Sex prevalence-male 98% and female 2%.

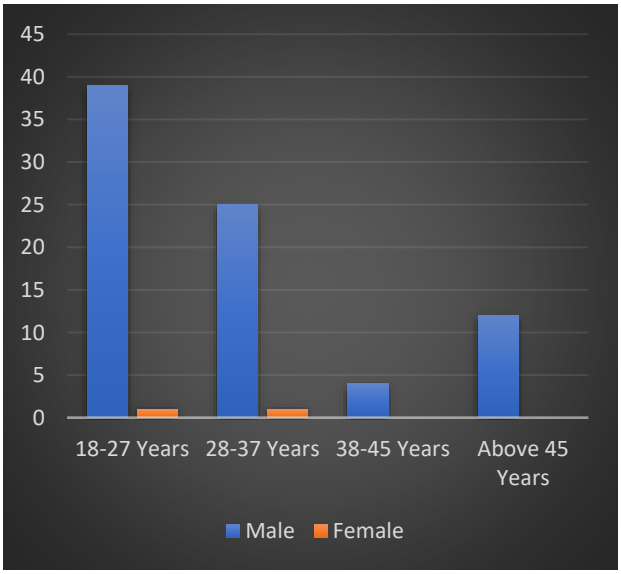

Figure 4: Age distribution of electrical burn patients admitted in our burn care center.

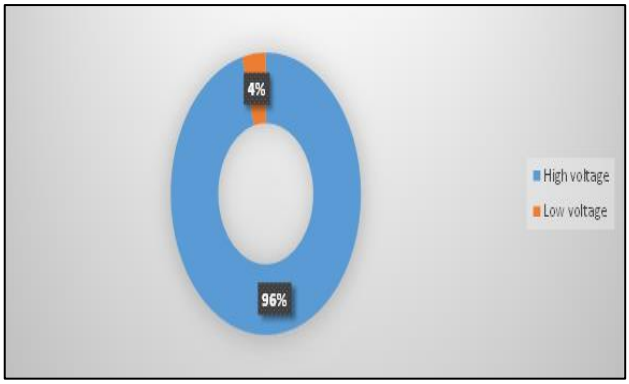

Figure 5: Comparison between high voltage and low voltage electrical burns.

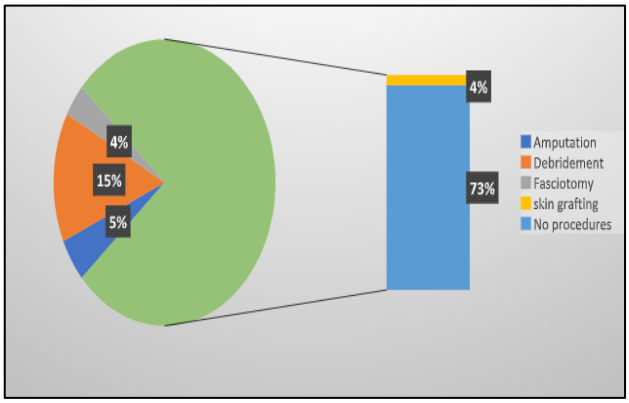

Figure 6: Classification of non0surgical or surgical treatment strategies and amputation.

DISCUSSION

India is the most populated country in the world at present with over a billion people. It is estimated that India has an estimated annual burn incidence of 6-7 million.

Electrical burns especially high voltage burns reported to hospitals are mostly accidental occurrences. In this study the most common etiology is occupational hazard that makes almost 90 % of our study. Ninety percent of the electric burn victims in our study are in productive age group of 16 to 40 years and most of the patients belong to poor socioeconomic strata. The work force is majorly consisting of male who sustained injuries working on transformers, high- tension wires and in the construction sites. Hence, our retrospective analysis revealed that the cause of electrical burn incidences was work related. The common patient population was consisted of electrical-mechanical workers, industrial workers, agriculture field worker, and the construction workers.

Males make up the majority of the working-age population, and electrical injuries continue to cause long-term morbidity and mortality. The musculoskeletal,

neurologic, behavioral, and neuropsychiatric systems have all been linked to well-documented consequences.

Analysis has established the fact that treatment in our clinical facility was successful to treat for the debridement, skin grafting and surgical procedure for the patients. It has also taken care of the long-term sequels to bring the patients back to mainstream daily routine. There was only one death occurrence with 90% burn.

The overall survival was confirmed by 99% of the admitted patients. The required measures like, immediate fluid resuscitation, initiation of haemo-dynamic and metabolic support and the timely surgical intervention helped to battle the complications to success.

Our study is a retrospective case control study of electrical burn injuries for around 12 years, this is longest study reported.

There are very rare studies till date which showed importance of high voltage electrical burns at workforce. Our result indicated the same. Since most patients sustain burns from high-voltage electricity while at work, occupational safety guidelines can help lower the number of these injuries. Updated standards should be followed by a skilled medical team in well-equipped hospitals because to the high rate of complications in electrical burns.[19]

The limitations for study was difficulty in arterial colour doppler due to edema, poor economics strata in view of long term treatment so, patient could not complete follow up.

CONCLUSION

A multidisciplinary team comprising a burn surgeon, neurologist, neuropsychiatric specialist, and rehabilitation therapist ought to assess every patient with an electrical damage in a methodical manner. It is necessary to create registries to monitor these.

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