High tension electric trauma causes characteristic injury patterns and sequelae. Work related electric trauma are reported annually with no emphasis on its prevention. The differing patterns of the injuries related to high tension electrocution are illustrated in this article as three distinctive case reports. The first clinical case is related to the arcing current resulting in bilateral hand amputation while carrying metal pipes in the vicinity of a high tension electric source. In the second instance a plumber whilst inspecting a water tank on the third floor was electrocuted by the overhead high tension power line, initially rendering him unconscious and resulting in death 65 days later. In the third, both the entry and exit wounds were identified due to true electrocution as the victim was touching a side mirror of a crane that in turn was in physical contact with a high tension power line in the process of lifting a transformer. Understanding of the differing mechanisms of causation of these injuries is immensely helpful to clinicians and forensic pathologists in order to provide appropriate treatment as electrocution causes complex, both immediate and delayed onset disease entities. It is helpful also in the interpretation of injury patterns in the process of tracing and reconstructing the succession of events for making compensation claims and for successful preventive strategies.

Keywords: high tension electrocution, injury patterns, delayed onset blindness, arching

INTRODUCTION

In medical literature, a voltage of more than 1000 Volts, is considered as 'high voltage'. The pathophysiology of high voltage electric trauma is unique. Occupational fatalities due to high tension electric current are occasionally reported in Sri Lanka. Nevertheless, according to the Public Utilities Commission in Sri Lanka there had been 103 fatalities due to electrocution in the year 2019 (not specified whether they were due to high or low voltage electricity). The three case reports presented in this paper describe the mechanisms of injury and their individual pathophysiology. The author presumes that a significant influence towards minimizing such incidents can be made if the workers are made aware and understand the dangers/injuries that they could sustain from working in such high risk environments without adequate protection.

Dangers due to high tension electrocution include death and/or injuries, and the sequelae are multitude in nature resulting sometimes in delayed deaths.

Familiarity with the mechanisms of injury is important to be able to substantially lessen the morbidity and mortality in high voltage electric trauma. Compensation issues may arise in occupational setting and it is the forensic pathologists’ duty to help authorities ascertain the manner and cause of death; whether accidental, homicidal or suicide.
Regulations to minimize effects caused by high tension electrocution stipulate a minimum gap between power lines and buildings or construction sites to ensure safety of consumers. It is applicable across Sri Lanka since 2017 and a certificate of safety clearance is required indicating that a safe range both in vertical and horizontal gaps $^3$ $^4$ (minimum vertical gap of 2.40 meters and horizontal gap of 1.50 meters for lines up to 1,000 volts, with the distance increasing up to 5.18 meters for high voltage lines of up to 2220,000 volts).

**Case 1**

A young male was carrying several metal pipes up a staircase from the second to the third floor. The building was situated closer to the high tension electric lines and the staircase also faced that the power line. While carrying the pipes up the staircase, he suddenly felt as if someone was pulling hard on the metal pipes. He was unable to drop them from his grip and he was jerked by the electricity gushing through the pipes along with electric sparks and sudden “burst” followed by flames. As a result, he sustained multiple burn injuries and later, both hands were amputated due to gangrene, following compartment syndrome (Figure 1). During his stay in the ward he developed rhabdomyolysis with no renal failure. The scene investigation concluded that the metal pipes had trespassed the minimum power line clearance causing arcing /flashing which in turn caused burns to the patient with the entry of electric current into his body.

**Case 2**

The deceased was a work-assistant installing a transformer. At the time of his death he was holding onto the side-mirror of a crane, whilst the crane-operator was lifting a transformer. History revealed that a large noise was heard with sparks and flames and the victim was thrown on the ground. He lay there lifeless. The crane-operator too was thrown out of the crane onto the ground sustaining minor injuries due to the fall. The driver too claimed to have felt an electric shock. There were entry wounds on the assistant’s right hand and multiple exit wounds on his lower limbs despite safety shoes (Figures 2, 3 A & B & 4).

![Fig. 2: Palmar aspects of fingers of the right hand with multiple contact wounds (Joule burns) depicting the shape of the object that he was holding while he was electrocuted.](image)

![Fig. 3 A & B: The multiple exit wounds on bilateral soles.](image)

![Fig. 1: Bilateral amputation of hands and multiple burns on lower limbs. A patterned burn was seen on the right axilla (causative object not identified).](image)
Case 3

A plumber climbed onto the roof of a three-story building to inspect a water tank. Suddenly a huge noise and a ball of fire had appeared from the overhead high tension lines and had instantly set his clothes on fire. The plumber was thrown away and sustained significant burns to his body. He was found unconscious and remained so for 36 hours. He was admitted to the ward and managed for 60 days since he had 26% deep burns involving face, back of the chest upper and lower limbs. He was quadriplegic thereafter, and had infected burns which needed to be managed. He was discharged 2 months after in-ward treatment. However, he had been re-admitted 05 days later with complaints of high fever and sudden onset total blindness.

On this second admission, he was diagnosed with bilateral occipital infarcts, frontal lobe infarct, moderate global ischemia (Figure 5) and sepsis. The patient died two days after the second admission. The post-mortem examination revealed few decubitus ulcers (grade 2) and bilateral pneumonic changes and gangrene of right toes (Figure 6 A &B). The cause of death was concluded as sepsis due to effects of high tension electrocution. Upon the site visit by engineers of the Electricity Board, the cause of death was concluded as accidental. In all three cases the possibility of lightening was excluded.

DISCUSSION

High tension electric energy causes many hazardous effects depending on the circumstance, namely electrocution, heat burns, electric shock, arc flash/arc blast, flame and explosions ⁵. The resultant damage may be due to true or direct electrical injuries or indirect electrical injuries. In true electrical injuries, the victims themselves become a part of the electrical circuit with entry and exit. However, such injuries may be non-recognizable at times because of overwhelming burns. Whereas, in indirect electrical injuries a direct contact is not required ⁶. The generated current is delivered to the
person from the source through an electrical arc before actual physical contact. When a body becomes a part of the electrical circuit it makes a reflex response with an entry or exit point and it is loosely named as “shock”7. If such an entry brings about the death of a person it is termed as electrocution. When high voltage current ionizes the surrounding gases, the current passes through this medium which was non-conductive, previously7. Such current has the highest current density and often luminous forming an electrical arc. When an electric conductor is in close proximity to a human being, such a current can enter the body resulting in electrocution. Such arcs have the potential of causing electro-thermal flash or flame burns in addition to arcing electrical burns. Flash injuries only occur when electrical energy travels only through the skin. Such arc /flash give rise to thermal radiation (heat) and intense light, causing burns. The temperature may rise to as high as 50,000° C8. The rapidly heating air causes pressure waves and thus creates a blast as well. By catching on clothes it gives rise to flame burns as a secondary flame and burn8.

In the first case the victim had experienced a tetanic effect. According the literature, the indefinite refractory state of the neuromuscular junction causes tetanic contractions resulting in “locking on phenomenon” preventing the victim from voluntary muscle function. However, this phenomenon is mostly applicable to low voltage current though its occurrence is not impossible due to high voltage current8. In contrast, in high voltages the throwing down effect is the one that is typically described8. Third degree burns had caused his upper limbs to be amputated at the mid-forearm level. He further experienced myoglobinuria, coagulopathy due to the extreme tissue damage and vascular injury by the electrocution. There were superficial burns on his lower limbs and on the right axilla. The burns seen on his axilla (Figure 1) was peculiar with a pattern suggesting a contact burn due to a heated object during the incident. Burns following high tension electric current is a result of many mechanisms; burns as a result of the current passing through the body, flash burns due to thermal radiation and intense heat, contact burns by heated objects and burns due to secondary fire effects such as conflagration of clothing etc. In this case, direct electrocution is not possible but arching is the mechanism that was stipulated. The burns are due to the effects of flash by secondary conflagration and by arcing. According to the opinion of the electric engineer who participated in the scene examination the metal pipes had trespassed the “safety region” and arcing resulted in electrocution.

In the second case, the driver of the crane was thrown away with the sudden explosion while operating the arm of the crane which in turn had accidently contacted the overhead high-tension line. The helper who was standing on the floor suffered fatal electrocution as the current was easily earthed through him. The shoes were not effective in order to prevent the electrocution in this case of high voltage current. The fingers of his right hand showed multiple electric energy entry wounds due to contact with the crane. Multiple exits were evident from both feet10,11. The tires of the crane were made of rubber and that is probably the explanation for not having completed the circuit through the driver to bring about fatal electrocution. The low-voltage current usually passes through the lowest resistance but the high voltage current passes through the shortest path irrespective of the tissue type through the body12. In low voltage electrocution, usually ventricular fibrillation is the result whereas in high voltage electrocution the mechanism is likely to be ventricular arrest resulting in sudden death11. In this case also the poor knowledge and negligence of the driver of the crane had caused the death of his assistant.

In the third case report, considerable flame burns and thermal damage was evident. The deceased had not thought of the immediate danger of arcing from the high tension electric line above while climbing up to the water tank. If he was educated about the danger he could have made some alternative arrangements preventing death.

The effects of high tension current may be immediate or delayed and transient or permanent. Multiple burn injuries maybe caused by flame, flash, arc or a combination. Direct exposure/contact to the current is not evident, and the arc effect was the cause for the injuries sustained. It is evident that the electricity/current had entered his body though it was difficult to determine the exact site of entry and exit wounds. However, it may be speculated that as indicated in figure 6B exit wounds were seen on both soles. Loss of consciousness and quadriplegia indicated immediate involvement of central nervous system. The explanation for the instant quadriplegia was the electro- thermal effects on the spinal cord. The cause for the delayed onset of sudden blindness should also be explained. Literature states that there could be delayed onset phrenic nerve paralysis and electrical cataract and quadriplegia12-15 upon high tension electrocution. However, to the best of the author’s knowledge, delayed onset blindness has not been reported thus far. During the second admission bilateral occipital lobe infarctions along with frontal lobe infarctions were detected. (Figure 5) Blindness
may be explained by occipital infarctions due to thrombosis of already damaged blood vessels with embolization due to high tension electrocution.

The nervous system is the most vulnerable to damage by electric current because of its least resistance, resulting in a high frequency of neurological findings. The passage of electricity through the nervous system facilitates the degeneration of myelin and also causes endothelial damage of vessels which favour microvascular thrombosis impairing the arterial blood supply. Though the delayed onset neurological damage is a well-recognized phenomenon, the exact mechanism is equivocal. The best possible explanation is that this happens due to the combined effects of gradual nerve ischemia secondary to vascular damage and due to the effects of hyper stimulation of neurons.

Although the pattern of injuries sustained were different in each of the case reports above, they shared a few points in common: they were male, were breadwinners of their respective families and died or sustained injuries as a result of their respective occupations. Different types of burns were evident in the forms of arc/flash and flame along with true electric injury as observed in the third case report.

Nevertheless, the long term sequelae of electrical exposure is yet to be studied and needs extensive research, in order to understand the exact mechanisms of complications such as delayed onset blindness with temporal and frontal lobe infarctions. A significant amount of workplace accidents are theoretically assumed to be preventable if the workers are provided with proper guidance by using risk indicators such as minimal vertical and horizontal distances from high tension electric wires at least in urban areas.

CONCLUSION

Injuries caused by high voltage electricity, are usually self-evident with the history and examination findings. In addition to direct contact with the power source, arcing causes electric shock and arc/flash burns, as well as flame burns. Due to the high temperature and the explosive effects of the arcing, thermal injuries are also an outcome of such incidents. Variety of outcomes are possible following high voltage electrical current, and as a result injury interpretation by the treating doctor would be useful in appreciating the management plan. Amputation of upper limbs, instant death and delayed deaths with multiple neurological complications emphasize the broader clinical outcomes that ensue upon high tension electrocution. A forensic pathologist should be able to interpret each injury in the context of the broader picture including the history and scene investigations where possible, as performed in the cases discussed herein, in order to reconstruct the incidents or to advice the general public and all stakeholders so that prevention can be the "treatment of choice" for electrical injuries. A strategy to prevent casualties related to workplace high tension electrocution should be addressed in Sri Lanka.

ETHICAL ISSUES

None

CONFLICTS OF INTEREST

There are no conflicts of interest.

AUTHOR CONTRIBUTIONS

HTDW: Total work done by the author.

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