Death from electrical arc flash burns

A report of 2 cases

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Summary

Two cases of fatal accidental electrocution involving high-tension cables are reported in which autopsy revealed the presence of flash burns and, more significantly, multiple circumscribed and cavitated lesions associated with arcing. Attention is drawn to the danger of 'near-contact' with high-tension cables. The autopsy findings of severe internal injuries, which may be associated with the blast of the electrical discharge or occur secondary to a fall are discussed.

In the absence of an adequate history, the autopsy findings may help to elucidate more accurately the circumstances of death and the type of electrical injury involved in fatal electrocution.

Case reports

Case 1

The body of a 25-year-old black man was found at the base of a high-tension electric cable pylon on the outskirts of Johannesburg. Police investigation and eye-witness statements indicated that the man had been climbing the pylon but had not yet reached the level of the cable when a blue flash of current was seen, causing him to be flung to the ground from a height of some 7 metres.

Autopsy revealed numerous round, crater-like areas with slightly raised edges over the right arm and as well as severe charring of the skin and subcutaneous tissues of the right arm, shoulder and right lateral thoraco-abdominal wall (Fig. 1). Internal injuries comprised subdural haemorrhage over both parasagittal parietal areas, contusion haemorrhages of the grey matter and subcortical white matter of the inferior aspect of the right temporal pole and central midbrain haemorrhages. Bilateral subpleural pulmonary contusions were noted as well as adventitial haemorrhages of the thoracic aorta. A full-thickness rupture of the descending thoracic aorta extending to part of the circumference was present.

Histological examination of the skin lesions revealed honeycomb vacuolation of the keratin together with separation of dermis and epidermis (Fig. 2). In addition, the nuclei of the basal epidermal cells as well as those of some of the higher-lying cells at the edge of the lesion were distorted, fusiform and hyperchromatic, creating a 'streaming effect' (Fig. 3). The dermal collagen showed homogenisation due to coagulation necrosis.

Case 2

According to the police investigation docket based on two eye-witness accounts and a visit to the scene of the accident, the deceased, a black man, was standing on top of a brewery truck unloading empty beer crates. He threw up a canvas side-cover attached to the vehicle, which contained a heavy steel wire along its edges. This cover came into contact with an overhead high-tension cable 5 - 6 metres above the ground. An explosive sound was heard accompanied by a flash and the man was thrown onto the ground next to the truck. The earth surrounding the truck's wheels was scorched and the deceased's clothing was burnt and charred.
Electric burn is simply a thermal injury. 6.7 However, previous reports have focused on the mechanism of sudden death, and fluid and electrolyte alterations rather than on an elucidation of the pathophysiology of the injury. However, the results of animal experiments appear to indicate that a low-voltage (≤ 1000 V) electric burn is simply a thermal injury and that tissue temperature is the critical factor in determining the magnitude of tissue injury. 4 Tissue damage occurs when electrical energy is converted to thermal energy or heat. While high-voltage currents or electrical arcs can generate temperatures in excess of 3000°C, which may result in flash burn injuries or burns due to the ignition of clothing, high-voltage discharges, like lightning strikes, exert an electromechanical effect on the tissues. Total energy transfer, being in the range of 10^7 J or more, cannot be locally absorbed as each molecule is able to absorb only a certain amount of energy in accordance with the principles of quantum mechanics. The energy is therefore dissipated in the form of an explosion (and some in the form of heat) with resultant mechanical trauma and blast-like air displacements resulting in severe disruptive injuries of internal organs. A similar phenomenon is observed with laser beams. 3

While the explosive effects of high-voltage current may indeed have been responsible for the internal injuries noted, it is impossible to exclude the concomitant contributing factor of a fall to the ground. Lending support to this inference was the finding of contusion haemorrhages situated in the grey matter of the frontal and temporal poles facing the posterior orbital lobes, classic sites of injury in falls to the ground. As 6 However, the multiple circumscibed crater-like lesions noted on the skin in both cases are highly suggestive of electric arc injuries seen in association with high-voltage currents; their multiplicity may be due to current 'dancing' on the skin surface or to multiple points of current entry.

When examined histologically electrical arc burn injuries show a very sharp demarcation of the damaged area from the adjacent tissues without the progressive gradation seen in regular burns. In addition, the high temperatures evolved during passage of electrical current through tissues may produce coagulation necrosis not only of underlying dermis but also of small blood vessels remote from the cutaneous burn. 9, 10

From the forensic viewpoint, it is important to realise that associated arc and flame burns may obscure or obliterate the microscopic features of ordinary electrical burns 11, and that current marks may also be induced post mortem; it is only the histological or histochemical manifestation of a vital reaction in the surrounding tissues which can provide evidence of the ante-mortem nature of the lesion.

We sincerely thank Professor N. J. Schepers for reviewing this manuscript, and also Dr V. D. Kemp, Head of the Department of Forensic Medicine, University of the Witwatersrand.

REFERENCES

Discussion

Electrical burns constitute a unique type of thermal injury and previous reports have focused on the mechanism of sudden death, and fluid and electrolyte alterations rather than on an elucidation of the pathophysiology of the injury. However, the results of animal experiments appear to indicate that a low-voltage (≤ 1000 V) electric burn is simply a thermal injury and that tissue temperature is the critical factor in determining the magnitude of tissue injury. Tissue damage occurs when electrical energy is converted to thermal energy or heat. While high-voltage currents or electrical arcs can generate temperatures in excess of 3000°C, which may result in flash burn injuries or burns due to the ignition of clothing, high-voltage discharges, like lightning strikes, exert an electromechanical effect on the tissues. Total energy transfer, being in the range of 10^7 J or more, cannot be locally absorbed as each molecule is able to absorb only a certain amount of energy in accordance with the principles of quantum mechanics. The energy is therefore dissipated in the form of an explosion (and some in the form of heat) with resultant mechanical trauma and blast-like air displacements resulting in severe disruptive injuries of internal organs. A similar phenomenon is observed with laser beams. While the explosive effects of high-voltage current may indeed have been responsible for the internal injuries noted, it is impossible to exclude the concomitant contributing factor of a fall to the ground. Lending support to this inference was the finding of contusion haemorrhages situated in the grey matter of the frontal and temporal poles facing the posterior orbital lobes, classic sites of injury in falls to the ground. However, the multiple circumscibed crater-like lesions noted on the skin in both cases are highly suggestive of electric arc injuries seen in association with high-voltage currents; their multiplicity may be due to current 'dancing' on the skin surface or to multiple points of current entry.

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