Case report of an occupational electrocution fatality: histopathological, medicolegal, work safety and insurance implications

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Abstract

When the skin comes to contact with power lines or non-insulated electrical instruments, we have an effect called electrocution. This often occurs in workplace settings.
We report the case of a young man, bricklayer in a yard, that was found unresponsive from his co-worker. Witnesses referred that he was working with an electric arc-welding machine. The external examination performed by a physician, not a forensic one, concluded for a natural death.
A private exhumation performed on the body after two months by a forensic physician found a skin lesion on the left leg that resembled to an electrical mark so the death was classified as an occupational death. Unfortunately, the Italian national worker's insurance company (INAIL) refused the allowance to the family and so the attorney asked us for a definitely opinion.
We weren't able to have a new exhumation but we had the paraffin embedded samples collected during the private autopsy. On these slides, we performed the metallization, choosing the traditional Okamoto-Utamura method. This staining was positive for the presence of copper in the skin: we could conclude the man died for working electrocution.
The case stresses the importance of having forensic pathologists on the scene and of performing a complete autopsy in every case of death happened on a work place, especially if the deceased is very young.
Moreover, we confirm, according to pathological literature, that the electrical mark is detectable in exhumed bodies.

KEY WORDS: electrocution, metallization, occupational death, work insurance.

Introduction

When the skin comes to contact with power lines or non-insulated electrical instruments, we have an effect called electrocution. This often occurs in workplace settings. The effects of the electricity on the body are variable for weightiness and consequences: from the formications in the contact point and pained muscular contractions, not dangerous, to tetanic contraction and spasms of the diaphragm and intercostal muscles, up to ventricular fibrillation and paralysis of the respiratory centres (1). The effects depend on different factors: electrical intensity, high or low-voltage, body tissue resistance and application area. Usually the death is caused by the paralysis of the respiratory centres in the CNS, by the acute respiratory asphyxia or by the cardiac arrest (2). The anatomical results are not specific: the only characteristic finding can be the electrical mark (Joule burn). This is the skin burn resulting from a localized contact with the electricity source (3). It is characterized by a chalky crateriform lesion with raised blistered edges which are bloodless. It is the result of the electricity conversion into heat inside human tissues, with liberation of steam. Microscopic morphology shows the keratin of the stratum corneum focally curled up or clumped and having a yellowish colour in haematoxylin-eosin stained sections. Sub-cellular morphology is characterized by polarization of the nuclei of basal cells of epithelium, cells of the sweat glands and of capillary endothelium: the dark-stained nuclei are enlarged and vesicular, arranged in palisade form (4, 5).

Case report

We report the case of a 23-year-old Caucasian man, bricklayer in a yard, that was found unresponsive from the man who was working next to him. The rescue tried to resuscitate him without success. His co-workers reported the man was welding a drainpipe and his feet were completely under water. The attorney was

alerted and asked a physician to have an external examination on the body. The physician, not a forensic pathologist, in the report described on the left leg an area of dark irregular appearance, that he explained as a skin burned area produced by the worker's arc-welding machine. He didn't describe the clothes and the shoes and didn't specified if the man was wearing or not the gloves. He answered that the death was due to cardiac arrest and classified it as a natural death. The family of the deceased didn't agree with the diagnosis and requested the attorney the permission to have an autopsy performed at their own expenses. It was necessary an exhumation, since two months were already passed. The forensic pathologist entrusted, from the family described, a lesion on the left leg resembled to an electrical mark that he referred to the contact of the leg skin with the uninsulated electric copper wire of the welding machine. The picture he took shows, on the left leg, the dark chalky skin area (Figure 1).
The pathologist didn't have a microscopic analysis, but at least, collected specimens of the lesion, fixed them in formalin and embedded them in paraffin. The rest of the external examination of the body was described as negative, and so was the section. According to the (partial) results of this autopsy, the pathologist concluded that the death was due to electrocution, so the family seek compensation from the National Worker's Insurance Company (INAIL), but the allowance was refused. Then the judge, asked us to establish definitely if it was an occupational death or not.
Unfortunately, we weren't able to have another exhumation, since three years were already passed, so we just had slides prepared from the samples collected from the lesion. The microscopic analysis, with haematoxylin-eosin method, showed that the skin was interested by curling of keratin and vacuolization of the epidermis, epidermal elongated cells and heat artefacts (the cap of the epidermis was detached from dermal layers, with a space beneath): these histological findings were suspected of electrocution (6). Since the tissues were putrefied, it was not possible to detect the increasing of eosinophily or the white necrosis appearance expected in cases of electrocution: to have a confirmation, we performed the metallization on the slides.

Discussion

The metallization is a histological technique used to detect minute particles of metals deposited on the skin. When a current pass from a metal conductor into the body electrolysis occurs, so that metallic ions are embedded in the skin and, even, in the sub-cutaneous tissues (7). In this case, we performed the usual Okamoto Utamura method according to Barka and Anderson (rubeanic acid technique) (8), since the history of the man reported, he was working with an electric machine powered with a copper wire when he collapsed.
The staining was carried out on formalin-fixed paraffin embedding sections of the skin taken from the left leg lesion (4 - 5 µm thick). According to literature the use of other fixatives (e.g. Bouin's solution) is less satisfactory. Acid fixatives, such as mercuric chloride ($HgCl_2$) are contraindicated because may remove copper. Reagent used was 0.1% rubeanic acid (dithio-oxamide) in absolute alcohol 5 cm^3 to which was added 10% aqueous sodium acetate 100 cm^3. Ethanol and xylol were used for dehydratation and clearing.
The staining method provides that paraffin sections are taken to distilled water, placed in a plastic coplin jar filled with the rubeanic-acetate solution for 12 hours at 37°C. Then, they are washed briefly in distilled water, blotted dry, counterstained briefly in 0.5% aqueous neutral red (toluylene red-eurhodin). Then, they are dehydrated in ethanol, cleared in xylol and mounted.
Copper deposits in the epidermal tissues form a chelate with the rubeanic acetate solution. The copper

Figure 1 - Suspected electrical mark, at first explained as a burned skin lesion on the left leg.

is chelated between the sulphur and nitrogen groups:

$H_2NCSCSNH_2 \leftrightarrow Cu$

The salt resulting, the copper rubeanate, appears under the light microscope as greenish black particles in the skin in contrast with the pinkish cytoplasm of the cells. Copper forms a chelate with rubeanic acid as do some other metals: of these, nickel or cobalt may be confused with copper, so sodium acetate is added to the solution to inhibit them.
In the slides prepared, were detected, under light microscope, green-blackish round-shaped granules, some microns in diameter: they formed dark clusters embedded between the fibres of the stratum corneum and Malpighian of the epidermis (Figure 2, see black arrows). Scant isolated granules were found in deeper dermal tissues, according to Kerbach-Wighton et al. (9) (Figure 2, see red arrows).

Conclusions

According to the results of the staining, we concluded the death was due to an electrocution. The story was consistent with this hypothesis: the man was contacted by the uninsulated electrical copper wire on the left leg, and the current could have pass through the chest and then to the upper limb or on the other leg and then the ground, anyway it could have reached the heart. Since the shoes were not described we couldn't know if they were the accident-prevention ones but we can presume they were, anyway they couldn't protect him. The man's feet were completely under water when he was welding, and this could favourite the exit of the current from the feet. No exit electrical mark was described on the feet. Even the clinic expression of the fatality was consistent with an electrocution: in fact, the man didn't complain of anything before he was found unresponsive.
An accurate review of the literature revealed that an average of 6,359 traumatic work-related deaths occurred each year in the United States from 1980 through 1989, and that an estimated 7% of these fatalities were due to electrocutions (10): the industries with the highest percentage of electrocutions were construction (40%), in fact the construction industry had a rate of 2.4 per 100,000 workers dead by electrocution (11). This stresses the importance of having a forensic expert on the scene when these fatalities happen, in order to analyze the exact position of the body and how far it is from any source of electricity, the influence of current voltage and skin contact duration (12), the body conditions (damp, soaked or wet skin can favourite electrocution), the influence of the climate. A careful look at the clothes would be very important too, since they can express signs of the electrocution.
Moreover, the present case shows how is demanding to have a complete autopsy in all the death happened on work, especially in case of very young persons. It is not acceptable anymore that the death of a 23-year-old person in a work place is investigated by an external examination performed by a not specialist physician, and that a forensic autopsy is concluded without a microscopic analysis. In fact, in these cases is essential to be able to diagnosis an incontrovertible cause of death (13, 14), for all the legal implications (the respect of working place safety rules), the insurance and the social and economical aspects (compensations for the family).
At last, we confirm that the method of the metallization can be used even in skin showing early or advanced signs of decomposition. Okamoto Utamura histological staining is important to validate the presence of the copper in the skin (15): whilst not particularly sensitive (*Rhodanine method* is more sensitive but less specific), this staining gives clear-cut results and it is

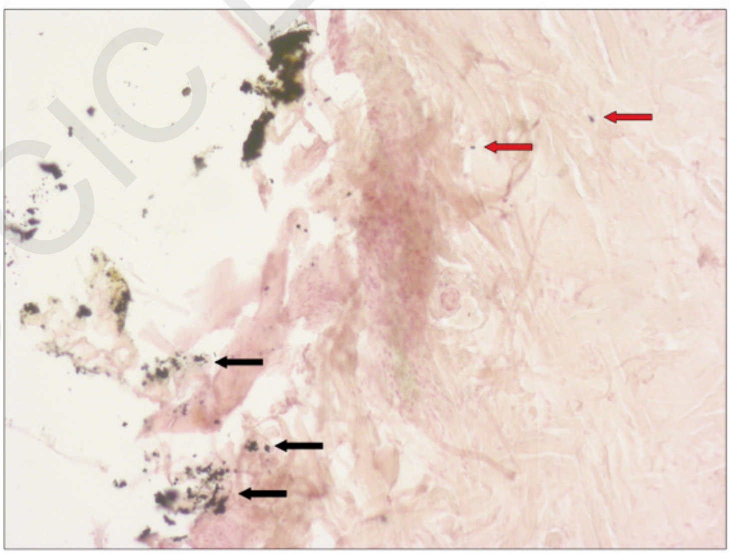

Figure 2 - Okamoto-Utamura histochemical staining (light microscope at magnifications of 200x with bright field illumination): green-blackish granules clustered in epidermis (black arrows) and isolated granules in dermal layers (red arrows).

the method of choice, although it was established in 1937 (16). Usually, at macroscopic examination, can be difficult to distinguish between a cutaneous burn, an electrical mark or the presence of the soot that can be found on the surface of skin. In the case, we examined, using this histochemical technique, since the body was exhumed, there was no doubt that the blackish particles in the skin were due to copper deposition.
The traditional staining method of Okamoto Utamura is still useful for copper traces detection in the skin, also in putrefied corpses, although new and expensive methods (like scanning electron microscope, electrography, atomic absorption spectroscopy or ICP-AES spectroscopy) can be used nowadays (17).

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