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Original Research Article

Diagnosis of electrocution: The application of scanning electron microscope and energy-dispersive X-ray spectroscopy in five cases

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ABSTRACT

Introduction: Deaths from electricity, generally, do not have specific findings at the autopsy. The diagnosis is commonly based on the circumstances of the death and the morphologic findings, above all the current mark. Yet, the skin injury due to an electrocution and other kinds of thermal injuries often cannot be differentiated with certainty. Therefore, there is a great interest in finding specific markers of electrocution. The search for the metallization of the skin through Scanning Electron Microscope equipped with Energy Dispersive X-Ray Spectroscopy (EDS) probe is of special importance in order to achieve a definite diagnosis in case of suspected electrocution.
Materials and methods: We selected five cases in which the electrocution was extremely likely considering the circumstances of the death. In each case a forensic autopsy was performed. Then, the skin specimens were stained with Hematoxylin Eosin and Perls. On the other hand, the skin lesions were examined with a scanning electron microscope equipped with EDS probe in order to evaluate the morphological ultrastructural features and the presence of deposits on the surface of the skin.
Results: The typical skin injury of the electrocution (current mark) were macroscopically detected in all of the cases.
The microscopic examination of the skin lesions revealed the typical spherical vacuoles in the horny layer and, in the epidermis, the elongation of the cell nuclei as well as necrosis. Perls staining was negative in 4 out 6 cases.
Ultrastructural morphology revealed the evident vacuolization of the horny layer, elongation of epidermic cells, coagulation of the elastic fibers.
EDS-microanalysis: In the specimens collected from the site of contact with the conductor of case 1 and 2, the presence of the $K\alpha$ peaks of iron was detected. In the corresponding specimens taken from cases 2, 4, 5 the microanalysis showed the $K\alpha$ peaks of titanium. In case 3, titanium and carbon were found.
Conclusions: In the suspicion of electrocution, the integrated use of different tools is recommended, including macroscopic observation, H&E staining, iron-specific staining, scanning electron microscopy and EDS microanalysis. Only the careful interpretation of the results provided by all these methods can allow the pathologist to correctly identify the cause of the death. Particularly, the present study suggests that the microanalysis (SEM-EDS) represents a very useful tool for the diagnosis of electrocution, allowing the detection and the identification of the metals embedded in the skin and their evaluation in the context of the ultrastructural morphology.

1. Introduction

Death due to electrocution is still a major issue all over the world. It is estimated that 1000 per year people die of exposure to electricity in the United States. Electrocution is a frequent cause of occupation-related death [1] as well as domestic accidents.

In the daily practice of the forensic pathologist, electrocution is one of the most difficult diagnosis. The main reason of this difficulty is the lack of any specific internal finding: in fact, most deaths from electricity are due to cardiac arrhythmia or paralysis of the respiratory muscles, which do not have morphologic

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specific markers at the autopsy (neither macroscopically nor histologically).

An investigation of the scene is a must in the suspicion of electrocution. It should clarify if a relevant current flow was actually possible in that specific situation; a detailed reconstruction can quantify the current flow [2]. Finally, the diagnosis is made on the basis of the circumstances of the death and the external examination, essentially the current mark. Yet, it is difficult to tell the difference between a skin injury due to an electrocution and a common thermal injury. Up to now the literature does not indicate any specific marker useful to attribute a skin lesion to a current mark. Therefore, there is a great necessity for further research about new methods suitable for this purpose, that can allow the pathologist to identify the cause of the death in an electrocution with reasonable certainty. In the present study, the search for the metallization in skin samples using Scanning Electron Microscope equipped with energy dispersive spectroscopy (EDS) probe was tested in five autoptic cases in which electrocution was considered highly probable.

2. Materials and methods

2.1. Specimen collection and preparation

We selected five cases in which electrocution was considered the cause of death, given the circumstances and the presence of typical skin lesions showing the characteristics of the current mark. In each case a forensic autopsy was performed. During the autopsy, specimens of the mentioned skin lesions were collected and then formalin fixed. Some specimens were, instead, fixed with 2% glutaraldehyde overnight for the electron microscopy and microanalysis.

2.2. Histology

After fixation and paraffin embedding, the skin specimens were stained with Hematoxylin Eosin and Perls. Then 4 μm-thick sections were cut, stained with Hematoxylin&Eosin and Perls and observed with Microscope Leica DM RB.

2.3. Scanning electron microscopy

The skin specimens, after glutaraldehyde fixation, were dehydrated with gradient acetone, then dried with carbon monoxide critical point (Critical Point Dryer 7501, Polaron). Then, each specimen was divided in two parts: one of them did not undergo any further treatment and was used for microanalysis using an electron microscope Evo 40 (Zeiss) equipped with EDS Probe (Inca Energy-Oxford); the other one was coated with gold using a metal ion spattering instrument. The samples were examined with a scanning electron microscope XL30 Philips.

3. Results

3.1. Circumstantial data and autopsy findings (see Table 1)

3.1.1. Case 1

A 20-year-old circus performer was traveling in his caravan loaded on a train. During the journey, he went on the roof of the caravan and accidentally touched, with his head, the railway high-tension steel cable (tension of 25 kV).

Lustrous lesions were detected on his scalp and his right foot. The autopsy revealed no distinct injury or disease, except generalized visceral edema and congestion.

3.1.2. Case 2

A 41-year old male was found dead on the ground. The police records revealed that he was stealing the copper from a high voltage trellis (380 kV) and he might had accidentally touched the cables. (the cables were made of ACSR = "aluminum conductor steel reinforced"). Typical current marks were observed on his back and left gluteus and on his right hand (thumb and index). The autopsy revealed severe injuries due to the fall from height, namely subarachnoid hemorrhage, hemopericardium and hemothorax associated with pulmonary contusions, many lacerations at spleen and liver, with scarce blood infiltrates.

3.1.3. Case 3

A 70-year-old man was fishing when his carbonfishing rod touched an high-voltage aluminum cable (380 kV). The external examination showed burning-similar skin lesions on the right hand and on the left foot. The autopsy revealed no distinct injury or disease, except of a generalized visceral edema and congestion.

3.1.4. Case 4

A man in his forties was found dead by his mother in the garret of his house. His mother told the Police that, a few hours before, the man had gone up to the attic in order to fix the TV antenna. At the external examination, typical burned, discolored lesions were detected on his left forearm and chest. The autopsy revealed no distinct injury or disease, except a generalized visceral edema and congestion.

3.1.5. Case 5

A 40-year-old man, at work, was using an electric heat-sealing machine in order to weld some PVC objects. Because of the machine was not working well, he tried to fix it. While he was disassembling some components, he had a direct contact with the electrical parts of the machine (which were examined and resulted made of steel and titanium), which had been connected to the

Fig. 1. Case 2, exit site.