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X-RAY FLUORESCENT SPECTRAL ANALYSIS IN FORENSIC MEDICAL ASSESSMENT OF INJURIES CAUSED BY ELECTRIC SHOCK DEVICES

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Abstract

Introduction and purpose. Electroshock devices are a type of non-lethal weapon and are widely used. The systematized data concerning the forensic medical assessment of injuries caused by electric shock devices are extremely limited. The purpose of the study was to increase the efficiency of forensic assessment of injuries caused by electroshock devices by using the methods of elemental analysis, namely, X-ray fluorescence spectral analysis. **Methods.** During the experiment, the electric discharges were applied to the skin flaps using electric shock devices under two conditions, namely, in close contact of the ESD electrodes with the skin and from a distance of 3-5 mm. A macroscopic study of skin changes obtained due to the electric impact of electric shock devices was carried out, as well as X-ray fluorescence spectral analysis to establish qualitative and quantitative indicators of the chemical elemental composition of the studied objects. **Results.** It was found that under the condition of causing damage from a distance the

formation of macroscopically visible changes resembling the typical electric burn was observed. No increase in the concentration of chemical elements (metals) is determined in all samples of biological material after the impact of electric discharges of ESD in this condition. Under the condition of close contact of the electrodes of electric shock devices with the surface of the skin no macroscopically distinguishable lesions were found on the skin. The XRF spectral analysis revealed metal deposits in the areas of skin flaps that were subject to ESD. **Conclusion.** The XRF spectral analysis can be useful tool for objective confirmation of the action of electroshock devices.

Keywords: non-lethal weapon; electroshock devices; electric mark; X-ray fluorescence spectral analysis.

Introduction. Nowadays, a non-lethal weapon, i.e. according to the definition of the Department of Defense of United States – the weapon primarily designed for the immediate incapacitation of a person or material, avoiding fatal consequences [1], is becoming widespread. Directives on the development and use of such weapons are being implemented by various countries, including the countries of the North Atlantic Alliance. Ukraine follows the standards of mentioned above countries. Among the wide range of types of non-lethal weapons, there are those which traumatic effect is based on the action of electric current [2]. Among others, this group of devices includes electroshock devices (ESD) of contact and distant type of action. They are adopted by law enforcement agencies in many countries around the world, and sometimes allowed for use by civilians.

It should be noted that the use of electroshock devices is often associated with a high level of danger to health, and sometimes even to person's life. Scientific sources reflect numerous cases of death of people after the ESD usage against them [3]. Numerous reports from international organizations, individual researchers and media sources about the excessive pain caused by ESD, as well as the use of electroshock devices as a means of torture cause a great concern [4, 5].

It is clear that after causing damage by electroshock devices, victims may need a forensic examination to confirm the action of ESD and certain conditions of its action, and identification of a specific device that caused the damage, and so on. It should be noted that at the present

moment, there are extremely small amount of literature sources on forensic assessment of electric shock in living human-beings, including injuries caused by electroshock devices.

This determines the relevance and feasibility of such studies aimed at determining the characteristics of injuries caused by ESD, the mechanism and conditions of their formation, the signs due to which it is possible to identify the device, and other features.

The purpose of the study was to increase the efficiency of forensic assessment of injuries caused by electroshock devices by using the methods of elemental analysis, namely, X-ray fluorescence spectral analysis.

Material and methods of research. To achieve the goal of the study, two models of electroshock devices were selected: WS-704 and 1101 "Police" made in China with the establishment of the design features of their contact electrodes and the elemental composition of the metal of electrodes. With the help of these devices, 120 experimental actions (electric discharges) were performed on biological objects which were fragments of skin pieces from the archival material of the Department of Forensic Medical Criminalistics of the Kyiv City Clinical Bureau of Legal Medicine on the basis of cooperation agreement from 04.01.2021 №01/21/1225. In the course of the experiment, the application of electric discharges was carried out under two conditions, namely, in close contact of the ESD electrodes with the skin and from a distance of 3-5 mm. The duration of the electric discharge ranged from 5-8 seconds. All experimental damage was caused when the electroshock devices were fully charged.

A set of research methods was used in the work: visual - for a general description of injuries; photographic - to capture morphological changes; X-ray fluorescence (XRF) spectral analysis - to establish qualitative and quantitative indicators of the chemical elemental composition of the studied objects.

The mutual location and morphological characteristics of the lesions were examined visually with the naked eye and with the help of optical devices. The elemental composition of the lesion areas was studied using a spectrometer "M4 TORNADO" of Bruker company (Germany) in the Kiev City Clinical Bureau of Legal Medicine. The X-ray fluorescence spectra of materials were recorded from the areas of electric discharges of electroshock devices (scanning planes contained from 200x400 to 500x400 scanning points), at a radon tube voltage of 50 kV, and a current of 600 μA. The research results are processed by standard methods of variation statistics.

Ethics Commission of the Shupyk National University of Healthcare of Ukraine reviewed the materials of the specified biomedical research approved and gave permission for its implementation, which corresponds to the current legislation of Ukraine, modern ethical norms and principles of scientific research (minutes of the meeting of the commission on ethics № 11 from 26.12.2016).

Research results and discussion. The contact electrodes of the electroshock device WS-704 are made in the form of two metal pins with disc-shaped toothed, rounded extensions in the middle part. The end parts of the electrodes are smoothly rounded, the diameter of the electrodes in the main part is 4.5 mm, in the areas of disc-shaped extensions - 13 mm; the distance between the end parts of the contact electrodes is 30 mm. While studying of the elemental composition of the ESD electrodes, it was found that they consist of a metal alloy which contains iron (Fe), nickel (Ni), copper (Cu) and zinc (Zn). The results of the obtained analysis of the elemental composition of the contact electrodes ESD WS-704 are presented in the table (Table 1).

Table 1

Elemental composition of the contact electrodes of ESD «WS-704»

Element	Net. unn.	C norm (%)	C atom (%)
Fe (iron)	2,98	3,80	4,08
Ni (nickel)	54,48	69,44	70,89
Cu (copper)	15,18	19,35	18,24
Zn (zinc)	5,81	7,41	6,79
Total	78,46	100,00	100,00

Contact electrodes ESD "1101 Police" have got a form of two metal plates that are wavy shape in profile, and form six points of contact (three for each electrode). The end parts of the electrodes (contact points), form a conditional hexagon with a facet length of about 10-11 mm and a distance between oppositely located contact points of about 30 mm. In the course of determining the qualitative and quantitative composition of the alloy of contact electrodes ESD "1101 Police", the presence of iron (Fe), nickel (Ni), chromium (Cr) and copper (Cu) was detected (Table 2).

Table 2

Elemental composition of the contact electrodes of ESD «1101 Police»

Element	Net. unn.	C norm (%)	C atom (%)
Fe (iron)	44,27	82,55	81,98
Ni (nickel)	0,83	1,55	1,46
Cu (copper)	1,13	2,10	1,83
Cr (chromium)	7,40	13,80	14,72
Total	53,63	100,00	100,00

Thus, it is established that the elemental analysis of the metal of the electrodes of the studied models of electroshock devices shows some differences in qualitative and quantitative elemental composition.

Electroshock devices "1101 Police" and WS-704 performed actions (electric discharges) on biological objects under the condition of close contact between electrodes and biological material and from a distance of approximately 3-4 mm. When applying an electric discharge from a distance, the passage of a spark discharge between the contact electrodes and the surface of the skin flap was determined, which was accompanied by the formation of visible injury at the entrance of spark discharges. Thus, the effect of ESD "WS-704" was the formation of two rounded paired lesions on the skin, located on a conditional line with a distance between them of 30 (± 3) mm. In the vast majority of cases (85%) the lesions were in the form of exfoliated epidermis with the formation of empty dry blisters of whitish-gray color, irregularly rounded, 2-4 mm in diameter. In other cases, the formation of rounded, crater-shaped depressions with small pieces of epidermis located along the perimeter with uneven, slightly charred edges was observed; the diameter of these lesions ranged from 3-4 mm.

Under the action of ESD "1101 Police" for 5-8 seconds was observed the formation of spark discharges that occurred with an uneven frequency between the different protruding points of the electrodes of the device and the biological material. Thus, in most cases (60%) the presence of a spark discharge was determined only in two protruding parts of the plates (electrodes) ESD "1101 Police", which led to the formation of paired skin lesions located at a distance of 12 mm to 30 mm (depending from which protruding points of the electrodes was determined by the formation of spark discharges). In 35% of cases, the passage of a spark discharge between the contact electrodes and the skin was determined at four points of contact, accompanied by the formation of skin lesions located in the corners of a conditional rectangle

with sides 30 and 10 mm long, or trapezoids with an upper base length of about 10 mm bases about 30 mm. In isolated cases (5% of observations), the occurrence of spark discharges was observed in all six protruding points of the contact plates-electrodes of the ESP "1101 Police", which accordingly led to the formation of damage located in the corners of the conditional hexagon with a face length of about 10-11 mm. According to the morphological properties, in all cases, the lesions had the form of empty dry blisters of whitish-gray or yellow-brown color, irregularly rounded (1-2 mm in diameter).

In order to establish the chemical elemental composition in the areas of injuries to biological material, a study was conducted using XRF spectral analysis. No increase in the concentration of chemical elements (metals) is determined, which are components of alloys of contact electrodes of electroshock devices in all samples of damage to biological material caused by electric discharges of ESD from a distance of 3-5 mm compared to control samples (undamaged areas of biological material).

Under conditions of close contact of electrodes ESP WS-704, "1101 Police" with the skin, the passage of the electric discharge was not accompanied by any visible manifestations (spark discharge, electric arc, etc.) of the electric current. After cessation of action, changes in the form of depressions on the skin surface were determined, which in terms of morphological properties corresponded to the design features of the contact surface of the corresponding electroshock devices. Thus, the effect of ESD WS-704 was the formation of two rounded paired depressions on the skin (diameter of 4-4.5 mm) which were located on a conditional line with a distance between them of 30 (± 2) mm. Around these depressions, there were more superficial depressions of a similar nature in the form of a circle with a diameter of approximately 10-11 mm (imprint of the electrode disk), with fine-toothed edges.

Due to the action of ESD "1101 Police", under the condition of close contact of the electrodes with the skin, the formation of a small depression on the skin was determined, which had the shape of a circle, in turn, deeper indentations were determined at the contact points of the protruding parts of contact electrodes. The diameter of this circle was approximately 30-32 mm which corresponded to the diameter of the contact surface of the investigated ESD.

In course of dynamics observation, these depressions on the skin, formed as a result of the actions of the studied ESD under conditions of close contact between the electrodes and the surface of biological material, persisted for a short period of time (up to 10 minutes), gradually

disappeared. After their disappearance, no visible skin changes were detected at the electrodes' places.

We used XRF spectral analysis in order to determine the possibility of metal deposition of electrodes on biological material due to the action of ESD. It was established that in all samples of biological material, which were affected by electroshock devices under conditions of close contact, metal deposits were detected in the areas of contact electrodes of all models of ESD. Their results are shown on the graphical display of the scanning planes of areas of biological material in the form of focal increases in fluorescence intensity.

Thus, the fluorescence spectra of iron, nickel, copper and zinc were determined on the objects damaged by ESD "WS-704" (Fig. 1).

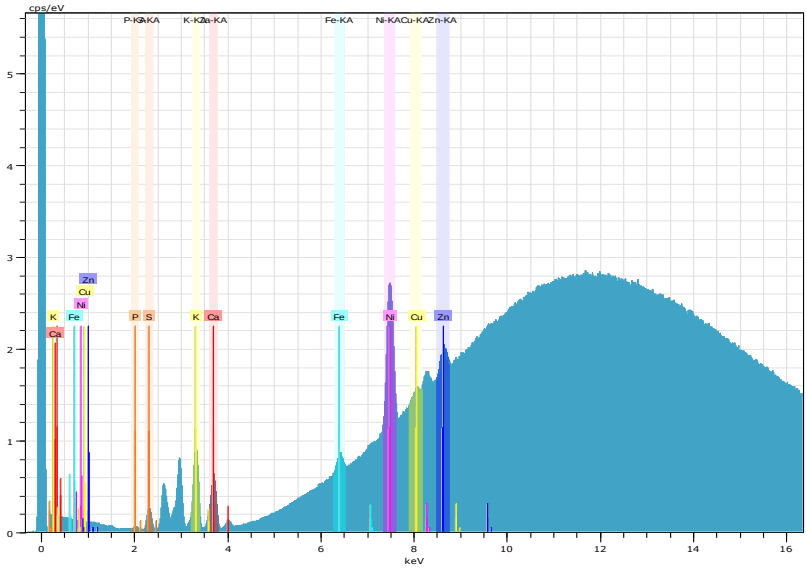

Fig. 1. Fluorescence spectra of iron, nickel, copper and zinc in the area of contact with electrodes of ESD "WS-704"

On the graphical display of the scanning planes, local deposits of these metals were determined, which in general corresponded to the size and shape of the contact area of the ESD electrodes with biological material. Moreover, metal deposits were noted in the form of two circles: a central one with a diameter of about 4 mm, which corresponded to the end part of the contact electrode of the electroshock device, and an outer circle with a diameter of about 11 mm, which corresponded to the diameter of the contact electrode disk (Fig. 2).

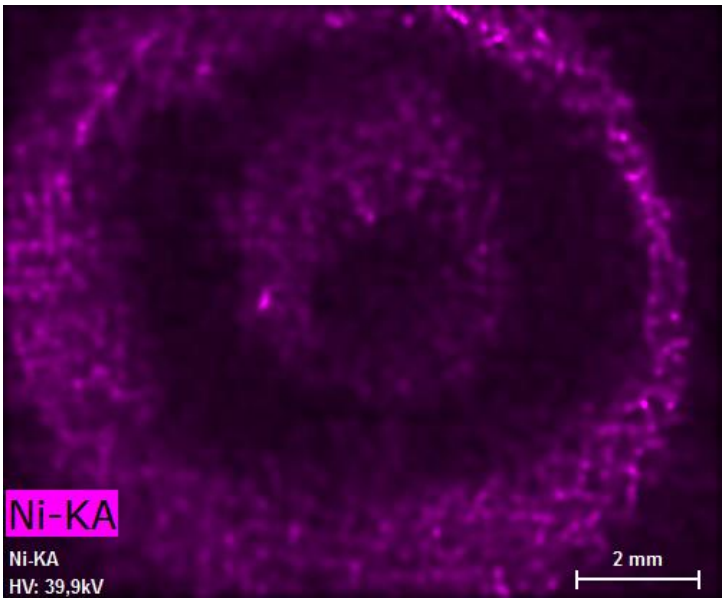

Fig. 2. Nickel deposition on the skin in the area of contact with electrodes of ESD "WS-704"

In this case, the elemental composition of the contact electrodes corresponded to the metals deposited in the damaged areas of biological material, the presence of iron, zinc and nickel, with small deposits of copper that are the main components of the alloy contact electrodes of ESD "WS-704"were determined.

Fluorescence spectra of chromium and iron (metals which are the main constituent metals of the contact electrodes of the investigated electroshock device) were determined on the objects on which the ESD "1101 Police" acted under the condition of close contact of the electrodes with the biological material at the points of contact (Fig. 3).

On the graphical display of the scanning planes, local deposits of these metals were determined at the points of contact of the protruding electrodes with the skin, as well as in some places between them (Fig. 4).

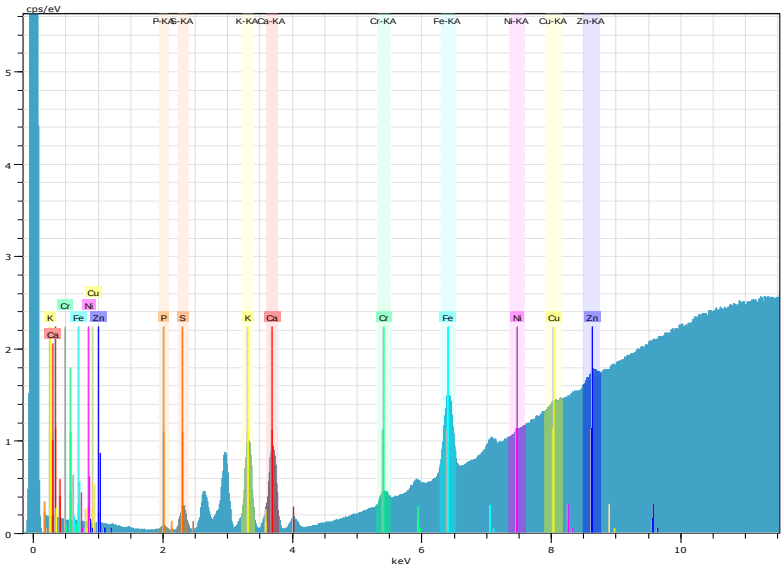

Fig. 3. Fluorescence spectra of iron, nickel, copper and chromium in the area of contact with electrodes of ESD "1101 Police"

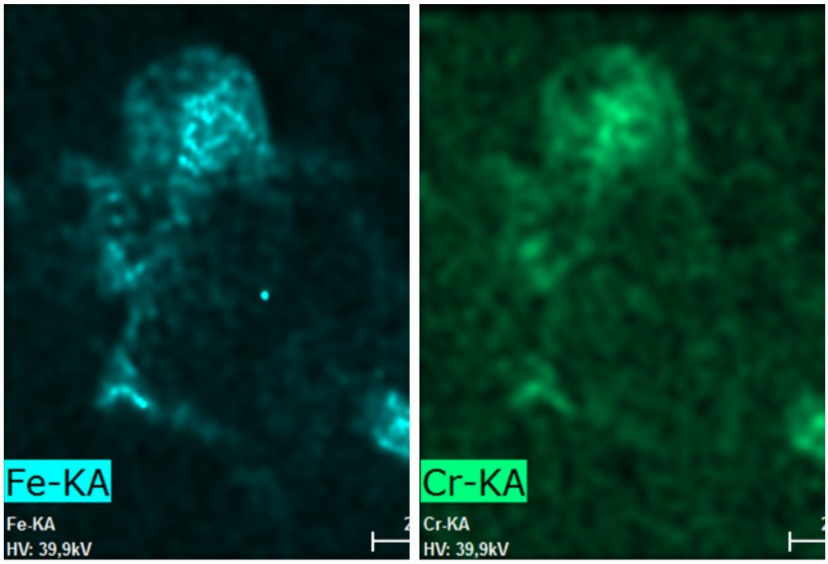

Fig. 4. Iron and chromium deposition on the skin in the area of contact with electrodes of ESD "1101 Police"

Nickel and copper deposits were not determined, which can be explained by the extremely low content (less than 2%) of these elements in the electrodes of ESD "1101 Police".

CONCLUSIONS

1. The action of the electroshock device from a certain distance was accompanied by the formation of a gas spark discharge and caused the formation of visible injuries to the skin, which corresponded to the classical morphological pattern of electrical and thermal damage. The main traumatic factor under these conditions was ionized gas (plasma), which is the substrate of the spark discharge and the temperature which can reach significant values; therefore, it acts as a main cause of morphological changes in the skin. Therefore, the XRF spectral analysis did not detect metal deposits in the areas of spark discharge of electroshock devices on the skin flaps under the above conditions.

2. The action of electroshock devices under the condition of close contact of the electrodes with the skin with an electric discharge (5-8 seconds) did not cause visible changes in the skin, which can be explained by the extremely low value of electric current. According to Joule law (the amount of heat dissipated from a current carrying conductor is proportional to the resistance of the conductor, the square of the current and the time needed for the current to pass through the conductor), short-term electric current action leads to a slight exothermic reaction. Thus, the amount of thermal energy, which generated by the passage of electric current from the contact electrodes directly into the skin at the specified time of action, is insufficient to form significant morphological changes in the biological material. However, the XRF spectral analysis revealed metal deposits in the areas of skin flaps that were subject to ESD. In this case, a relationship between the qualitative composition of ESD electrodes and the composition of metal deposits in these areas of biological material was established. It can be an objective confirmation of the action of electroshock devices with a certain elemental composition of the contact electrode alloy. Therefore, this acquires a special forensic significance, taken into account the absence of external visible damage under the action of electroshock devices under mentioned above conditions.

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