MEDICINA AUXILIUM
JUSTITIAE

CULEGERE DE ARTICOLE

al III-lea Congres Internațional al medicilor legiști din Republica Moldova, consacrat aniversării a 70 ani de la fondarea Centrului de Medicină Legală

Chișinău, 2021

MEDICINA AUXILIUM JUSTITIAE

Centrul de Medicină Legală pe lângă Ministerul Sănătăţii al RM

Catedra Medicină legală a USMF ”Nicolae Testemiţanu”

Societatea Ştiinţifică a Medicilor Legişti din Republica Moldova

CULEGERE DE ARTICOLE

al III-lea Congres Internaţional al medicilor legişti din Republica Moldova, consacrat aniversării a 70 ani de la fondarea Centrului de Medicină Legală

8 octombrie, 2021

Chişinău, Republica Moldova

DESCRIEREA CIP A CAMEREI NAŢIONALE A CĂRŢII DIN REPUBLICA MOLDOVA

Congresul Internaţional al Medicilor Legişti din Republica Moldova (3; 2021 ; Chişinău).
Al III-lea Congres Internaţional al Medicilor Legişti din Republica Moldova, consacrat aniversării a 70 ani de la fondarea Centrului de Medicină Legală, 8 octombrie, 2021 : Culegere de articole / comitetul ştiinţific: Andrei Pădure [et al.]. – Chişinău : S. n., 2021 (Bons Offices SRL). – 118 p. : fig., tab. color.

Antetit.: Centrul de Medicină Legală pe lângă Min. Sănătăţii al RM, Catedra Medicină legală a USMF "Nicolae Testemiţanu", Soc. Şt. a Medicilor Legişti din Rep. Moldova. – Text : lb. rom., engl., rusă. – Rez.: lb. rom., engl., rusă. – Referinţe bibliogr. la sfârşitul art. – Implementat de Progr. Naţiunilor Unite pentru Dezvoltare (PNUD) în Rep. Moldova şi Finanţat de Suedia. – 100 ex.

ISBN 978-9975-87-878-4.

340.6(082)=135.1=111=161.1

C 65

Disclaimer:

Prezenta publicaţie a fost elaborată în cadrul proiectului "Consolidarea eficienţei şi accesului la justiţie în Moldova", implementat de Programul Naţiunilor Unite pentru Dezvoltare (PNUD) în Republica Moldova şi finanţat de Suedia. Opiniile exprimate în această publicaţie aparţin autorilor şi nu reprezintă în mod necesar opiniile acestor instituţii.

X-RAY FLUORESCENT SPECTRAL ANALYSIS IN FORENSIC MEDICAL ASSESSMENT OF ELECTRICAL INJURIES

[1]Mishalov V.D.
[1]Petrochak O.Y.
[1]Hoholeva T.V.
[2]Varfolomeiev Y.A.
[3]Voichenko V.V.

[1] Shupyk National Medical Academy of Postgraduate Education
[2] Department of Forensic Medicine "Main Bureau of Forensic Examination of Ministry of the Health of Ukraine"
[3] Municipal Institution "Dnipro Regional Bureau of Forensic Medical Examination"

Abstract

The purpose of the study was increase the efficiency of differential diagnosis of injuries caused by mechanical and electrical influences, using the methods of elemental analysis, namely X-ray fluorescence spectral analysis. Methods. During the experiment, the electric discharges and mechanical pressure were applied to the skin flaps using metal pins with different elemental composition. The X-ray fluorescence spectral analysis was applied to establish qualitative and quantitative indicators of the chemical elemental composition of the studied objects. Results. It was found that under the condition of mechanical pressure of metal pins no increase in the concentration of chemical elements (metals) is determined in all samples of biological material.. Under the condition of electrical discharge via the metal pins the XRF spectral analysis revealed metal deposits in the areas of skin flaps that were subject to the conducting metal. Conclusion. The XRF spectral analysis can be useful tool for differentiation of electrical and blunt injuries.

Key words: forensic medicine, electrotrauma, electrical burns, non-lethal weapon, X-ray fluorescence spectral analysis.

Introduction

The use of sources of electric current, including non-lethal weapons, the effect of which is based on the action of current (electroshock devices) as a means of torturing, has recently become widespread. [1, 2, 3, 4]. It is clear that under such conditions it is very important for forensic examination not only to establish the mechanism of damage to the victim's body due to electric current, but also to establish the possibility of their formation under certain conditions and by a certain device.

In such cases, it is important to use the methods of elemental analysis in the evaluation of the electrical burns, which can act as an additional method of forensic medical examination that confirms the mechanism of damage, and even to some extent to indicate the electrode material that caused the damage.

Detection of chemical elements of metals in the composition of electrical burns is performed in the forensic laboratory by a set of methods and techniques known since the twentieth century. These are X-ray fluorescence analysis, mass spectrometry, atomic absorption analysis, neutron activation analysis, flame emission photometry, emission spectrographic method [5, 6, 7, 8].

The methods are highly sensitive and can detect almost the full range of chemical elements. One of their significant disadvantages is the preparation of the sample, which is accompanied by the inevitable destruction and loss of the object of study. It should be noted that a fairly effective and non-destructive method of studying metals in the areas of electrical burns is X-ray fluorescence spectral analysis. Its essence is the X-ray irradiation of the object of study and the detection of the spectral composition of secondary radiation, which reflects the quantitative and qualitative indicators of the chemical elements of the object under study.

The aim of the study was to increase the efficiency of differential diagnosis of injuries caused by mechanical and electrical influences, using the methods of elemental analysis, namely X-ray fluorescence spectral analysis.

Material and methods of research.

To achieve the goal of the study, the action on biological objects was carried out by metal indentators, which had the shape of rounded pins with a diameter of 4 mm, by pressure (mechanical action of a blunt object), and provided that electric current is passed through them. Three metal alloys (sample №1, №2 and №3) with different elemental composition were selected, which was determined by X-ray fluorescence spectral analysis on a spectrometer "M4 TORNADO", Bruker (Germany). The experiment used electric current sources with low current (up to 10 mA) and high voltage (up to 100 kV) on the electrodes, which corresponds to the electric current in devices that are commonly used as non-lethal weapons. Pieces of skin from the archival material of the Department of Forensic Forensics of the Kyiv City Clinical Bureau of Forensic Medical Examination were selected as objects subject to electric current on the basis of a cooperation agreement dated 04.01.2021 №01 / 21/1225. A total of 120 experimental actions (60 mechanical and 60 electrical) were performed on biological objects. In the course of the experiment, the application of electric discharges was carried out under the condition of close contact of the metal with the skin. The duration of action, both mechanical pressure and electric discharge, ranged from 5-8 seconds.

X-ray fluorescence spectral analysis was used to establish qualitative and quantitative indicators of the chemical elemental composition of the studied objects. The elemental composition of the affected areas was investigated using a Bruker M4 TORNADO spectrometer (Germany) at the Kyiv City Clinical Bureau of Forensic Medicine. X-ray fluorescence spectra from biological objects were recorded from mechanical pressure and electric discharge areas on scanning planes containing from 200x400 to 500x400 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 National University of Health of Ukraine named after P.L. Shupyk 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 their discussion.

In the study of the elemental composition of the alloys of metal pins used for the experimental study, significant differences in the qualitative and quantitative content of metals were established.

Thus, sample №1 contained iron (Fe) - 4.08%, nickel (Ni) - 70.89%, copper (Cu) - 18.24% and zinc (Zn) - 6.79%. The alloy of sample №2 consisted of iron (Fe) - 81.98%, nickel (Ni) - 1.46%, chromium (Cr) - 1.83% and copper (Cu) - 14.72%. When determining the qualitative and quantitative composition of the alloy sample №3 revealed the presence of metals iron (Fe) - 3.66%, nickel (Ni) - 93.94%, copper (Cu) - 1.65% and gold (Au) - 0, 75%. Thus, it was found that the elemental analysis of the metal of the studied samples shows some differences in qualitative and quantitative elemental composition.

When mechanical pressure was applied to biological objects (skin pieces), changes in the form of depressions on the skin surface were determined, which morphologically and in size corresponded to the shape and size of the metal pins with which the action was performed. Namely, the consequence of these actions was the formation of rounded depressions on the skin with a diameter of approximately 4-4.5 mm.

Under conditions of close contact of metal pins with the skin and the passage of an electric discharge was not accompanied by any visible manifestations (spark discharge, electric arc, etc.) of electric current. After cessation of action, changes on the skin surface were determined, which morphologically completely corresponded to the changes formed at mechanical pressure, i.e. had the form of rounded depressions on the skin, with a diameter of approximately 4-4.5 mm.

When observed in the dynamics, these indentations on the skin, formed due to both mechanical and electrical actions of metal pins, persisted for a short period of time (up to 10 minutes), gradually disappearing. After their disappearance, no skin changes visible to the naked eye were detected at the electrodes.

In order to establish the chemical elemental composition in the areas of changes in biological material, a study was performed using X-ray fluorescence spectral analysis. At the same time, there was no increase in the concentration of chemical elements (metals) that are components of metal pin alloys in all samples of damage to biological material caused by mechanical pressure compared to control samples (undamaged areas of biological material).

In order to determine the possibility of metal deposition on biological material due to the action of electric discharge, when using the above metal pins as conductors, by applying X-ray fluorescence spectral analysis determined the elemental composition at the sites of electric current on the skin flap. It was found that in all samples of biological material exposed to electric current, metal deposits were found in the areas of contact of metal pins with the skin surface. 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 (fig. 1). Thus, the fluorescence spectra of iron, nickel, copper and zinc were determined on biological objects with changes caused by the action of electric current using the sample №1 as a conductor.

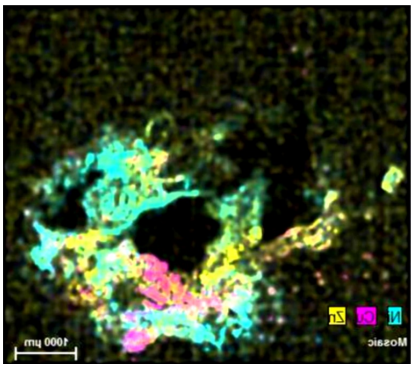

Figura 1:
Fluorescence of Ni, Cu and Zn in the area electric current impact via metal conductor (sample 1)

Instead, fluorescence spectra of chromium, copper and iron were determined at the objects exposed to electric current through the sample №2 at the points of contact of the metal pin with the biological material, and at the action of the current through the sample №3 only nickel and iron were deposited at the biological objects. It should be noted that the deposition of some metals, the share of which in the alloy was insignificant was not observed.

On the graphical display of the scanning planes, local deposits of these metals were determined, which in general corresponded in location to the area of contact of the metal pin (sample №1) with the biological material. In this case, the elemental composition of the metal pins, which acted as electrodes, corresponded to the metals deposited in the areas of damage to the biological material.

Conclusions

1. The mechanical action (pressure) of metal pins on biological objects was not accompanied by deposits of metals in the contact areas. Instead, under the condition of contact of the metal pins with the skin during the passage of electric current through them, the X-ray fluorescence spectral analysis detected metal deposits in the areas of the skin flaps.
2. It is established that under the action of electric current on biological objects through conductors with different qualitative and quantitative metal composition, a relationship is established between the composition of the conductor alloy and the composition of metal deposits on biological material, which can be objective confirmation of electric current through a conductor with a certain elemental alloy composition.

Bibliography

1. UN Committee Against Torture (CAT). Conclusions and recommendations of the Committee against Torture Portugal, № CAT/C/PRT/CO/4 [Internet]. Portugal: UN Committee Against Torture (CAT); 2008. Available from: https://www.ref world.org/docid/4804a62e2.html.
2. Amnesty International (USA). Pain Merchants: Security Equipment and Its Use in Torture and Other Ill-treatment, ACT 40/008/2003. México: Ciudad de México; 2003. Available from: https://www.amnesty.org/download/Documents/ 100000/act400082003en.pdf.
3. Council of Europe. Report to the Polish Government on the visit to Poland carried out by the European Committee for the Prevention of Torture and Inhuman or Degrading Treatment or Punishment (CPT) from 5 to 17 June 2013 [Internet]. Report No.: CPT / Inf (2014) 21; 2014 Jun 25. Poland: Council of Europe: Committee for the Prevention of Torture; 2014. Available from: https://www.refworld.org/docid/53aa83ed4.html.
4. Council of Europe. Report to the Bulgarian Government on the visit to Bulgaria carried out by the European Committee for the Prevention of Torture and Inhuman or Degrading Treatment or Punishment (CPT) from 24 March to 3 April 2014 [Internet]. Report No.: CPT/Inf (2015)12; 29 Jan 2015. Bulgaria: Council of Europe: Committee for the Prevention of Torture; 2015. Available from: https://www.refworld.org/docid/54d1f2a84.html.
5. Subramanian KS. Determination of metals in biofluids and tissues: sample preparation methods for atomic spectroscopic techniques. Spectrochimica Acta Part B: Atomic Spectroscopy [Internet]. 1996;51(3):291-319. Available from: https://doi.org/ 10.1016/0584-8547(95)01425-X.
6. Direct analysis of biological samples by total reflection X-ray fluorescence. Lué-Merú MP, Herna´ndez-Caraballo EA. ChemInform [Internet]. 2004;36(8):1077-90. Available from: https://doi.org/ 10.1016/j.sab.2004.05.017.
7. Megan LM. Novel biological, forensic, and historical applications of inductively coupled plasma-mass spectrometry [dissertations]. Ames, Iowa: State University Ames; 2012. 107 p.
8. Rahil-Khazen R, Bolann BJ, Myking A, Ulvik RJ. Multi-element analysis of trace element levels in human autopsy tissues by using inductively coupled atomic emission spectrometry technique (ICP-AES). J. Trace Elem. Med. Biol. [Internet]. 2002;16(1):15-25. Available from: https://doi.org/10.1016/S0946-672X(02)80004-