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Kusliy Yuriy Yuriyovych Postgraduate of the Department Forensic Medicine and Law, National Pirogov Memorial Medical University, Vinnytsya, Pirohova St., 56, Vinnytsia, 21018, tel.: (0432) 55-39-10, https://orcid.org/0000-0002-3723-5108

Hel Andrey Pavlovich Associate professor of the Department Forensic Medicine and Law, National Pirogov Memorial Medical University, Pirohova, St., 56, Vinnytsia, 21018, tel.: (0432) 55-39-10, https://orcid.org/0000-0003-2612-4530

Vanchulyak Oleg Yaroslavovych Professor of the Department of Forensic Medicine and Medical Jurisprudence, BSMU, Theater square, 2, Chernivtsi, 58002, https://orcid.org/0000-0003-0243-1894

POSSIBILITIES OF "FORT 12R" AND "AE 790G1" PISTOLS IDENTIFICATION USING STEP-BY-STEP DISCRIMINANT ANALYSIS

Abstract. Identification of the instrument of crime is one of the key issues faced by experts. Examinations related to the use of firearms are particularly difficult, where, in addition to this, the issue is establishing the distance of the shot. For the most part, in developed countries, the solution to these issues is achieved through the use of controlled shots with subsequent analysis of the residual components of the shot. However, in addition to them, there are other physical evidences worth paying attention to, such as the specifics of clothing damage, morphological characteristics of body damage, which should also be taken into account. The purpose of the study was to create models using step-by-step discriminant analysis for the identification of "Fort 12R" and "AE 790G1" pistols based on the features of the deposition of the gunshot residue and the features of damage to non-biological simulators of the human body and clothing. In order to achieve the goal, 120 gelatin blocks were made that imitated the soft tissues of the human body and were then covered with one of the types of clothing (cotton fabric, denim or leatherette) or left bare. Shots were fired from "Fort 12R" and "AE 790G1" pistols in the conditions of a shooting range at close range, 25 and 50 cm with further analysis of damage to the block and clothing, laboratory determination of the

residual components of the shot and calculations of the parameters of the temporary cavity. The obtained results were analyzed in the statistical package "Statistica 6.0". Taking into account the specifics of damage to a non-biological human body impersonator and its covering elements in the form of clothing, data on the deposition of the residual components of a shot, reliable discriminant models were built that were correct in 77.5% of cases for identifying a gun and in 99.2% of cases for identifying the distance of a shot. The obtained results will facilitate the work of institutions that directly participate in the examination of gunshot injuries, in particular the bureau of forensic medical examination and scientific research expert forensic centers under the Ministry of Internal Affairs of Ukraine.

Keywords: discriminant analysis, non-lethal weapons, gunshot residue, firearm, gunshot injury.

Куслій Юрій Юрійович аспірант кафедри судової медицини та права, Вінницький національний медичний університет ім. М. І. Пирогова, вул. Пирогова 56, м. Вінниця, 21018, тел.: (0432) 55-39-10, https://orcid.org/0000-0002-3723-5108

Гель Андрій Павлович доцент кафедри судової медицини та права, Вінницький національний медичний університет ім. М. І. Пирогова, вул. Пирогова 56, м. Вінниця, 21018, тел.: (0432) 55-39-10. https://orcid.org/0000-0003-2612-4530

Ванчуляк Олег Ярославович професор кафедри судової медицини та медичного правознавства, БДМУ, Театральна площа, 2, м. Чернівці, 58002, https://orcid.org/0000-0003-0243-1894

МОЖЛИВОСТІ ІДЕНТИФІКАЦІЇ ПІСТОЛЕТІВ «ФОРТ 12Р» ТА «АЕ 790G1» ЗА ДОПОМОГОЮ ПОКРОКОВОГО ДИСКРИМІНАНТНОГО АНАЛІЗУ

Анотація. Ідентифікація знаряддя злочину є одним з ключових питань, з яким стикаються експерти. Особливу складність мають експертизи, що стосуються застосування вогнепальної зброї, де окрім цього частин питанням є встановлення дистанції пострілу. Здебільшого в розвинених країнах вирішення даних питань досягається за рахунок використання контрольованих пострілів з послідуючим аналізом залишкових компонентів пострілу. Проте, окрім них вартими уваги є і інші речові докази, як то особливості пошкодження одягу, морфологічні характеристики ушкодження тіла, які також варто приймати до уваги. Метою дослідження було створення моделей з допомогою покрокового дискримінантного аналізу для ідентифікації пістолетів «Форт 12Р» і «АЕ 790G1» базуючись на особливостях відкладання

залишкових компонентів пострілу та особливостей пошкоджень небіологічних імітаторів тіла людини та одягу. Для досягнення поставленої мети виготовлено 120 желатинових блоків, що імітували м'які тканини тіла людини і в подальшому покривали одним з видів одягу (бавовняна тканина, джинсова тканина чи шкірозамінник) або лишали голими. Постріли виконували з пістолетів «Форт 12Р» і «АЕ 790G1» в умовах тиру з дистанцій впритул, 25 та 50 см з подальшим аналізом пошкоджень блоку та одягу, лабораторним визначенням залишкових компонентів пострілу та розрахунками параметрів тимчасової порожнини. Отримані результати аналізували в статистичному пакеті "Statistica 6.0". Враховуючі особливості пошкоджень небіологічного імітатору тіла людини та його покривних елементів у вигляді одягу, дані щодо відкладання залишкових компонентів пострілу побудовані достовірні дискримінантні моделі, коректні в 77,5 % випадків для ідентифікації пістолету та в 99,2 % випадків для ідентифікації дистанції пострілу. Отримані результати дозволять полегшити роботу установ, що безпосередньо приймають участь в експертизі вогнепальної травми, зокрема бюро судово-медичної експертизи та науково-дослідні експертні криміналістичні центри при МВС України.

Ключові слова: дискримінантний аналіз, нелетальна зброя, залишкові компоненти пострілу, вогнепальна зброя, вогнепальна травма.

Statement of the problem. The problem of the spread of firearms in the world has taken on a threatening form - the number of injuries and deaths as a result of their use is increasing. In Sialkot (Pakistan) from 2008 to 2012, 1,240 cases of injury were recorded, of which 880 were caused by homemade weapons. In 52.2% of cases, the cause of injury was domestic conflicts, in 19.3% robbery, 9.6% accident, 6.1% self-harm, and 6.1% - use by law enforcement agencies [1]. In Colorado (USA) from 2008 to 2018, 308 cases of the use of firearms against children under the age of 18 were recorded. Of these, 34 cases resulted in death. The average age of the victims was 14 years [2].

Taking into account such challenges today, forensic medicine and related specialties are interested in the most scientifically based research that will allow accurate answers to police questions. One of these ways is the use of modern laboratory research methods, such as X-ray fluorescence spectroscopic analysis [3], etc. However, it is equally important to use all available material evidence.

In order to identify such potentially important material evidence, it is most expedient to use controlled shooting with the use of optically transparent substances that mimic human body tissues as much as possible [4]. Further application of powerful statistical processing methods will allow to highlight key parameters that are important for weapon identification and shot distance.

Connection of the publication with planned scientific research works. The work was carried out as part of the research work of the National Pirogov Memorial

Medical University, Vinnytsya at the expense of state funding of the Ministry of Health of Ukraine: "Characteristics of damage to human body tissue simulators caused by non-lethal weapons" (state registration number 0121U107924).

The purpose of the article – based on the data on the deposition of the gunshot residueand the features of damage to a non-biological simulator of the human body and various types of clothing, build models using step-by-step discriminant analysis for the identification of "Fort 12R" and "AE 790G1" pistols.

Research objects and methods. To achieve the goal, the authors used a 10% solution of food gelatin type A 270 Bloom (TM "Junca Gelatines SL", Spain), from which standardized gelatin blocks [5] were made in the amount of 120 units. On the basis of the shooting range of the Vinnytsia Scientific Research Expert Forensic Center of the Ministry of Internal Affairs of Ukraine, shots were fired at the blocks using non-lethal pistols "Fort 12R" and "AE 790G1". Previously, the blocks were divided into 4 groups depending on the type of coating: bare blocks, blocks covered with cotton fabric, denim fabric. Microscopic examination was carried out using a MBS-10 microscope under magnification from ×4.8 to ×56.

To detect gunshot residue, the following were used: the chromato-mass spectrometric method on the Shimadzu GC-2010 Plus device and infrared microscopy on the Fourier-transform infrared spectroscopy Nicolet iN10 of the company "Thermo Fisher Scientific" (detection of the components of nitrocellulose gunpowder, namely, diphenylamine and centralites); X-ray fluorescence spectroscopy using the ElvaX Plus device (detection of qualitative and quantitative characteristics of overlapping elements).

The following methods were used to estimate the parameters of the temporary cavity formed when a shot was fired into a non-biological simulator of the human body: according to Fackler and Malinowski [5], Ragsdale and Josselson [6] and Schyma [7], which corresponded to the following values - The total crack length method (TCLM,) The Fackler's wound profile method (FWPM) and The polygon-procedure method (PPM), respectively.

Committee on Bioethics of National Pirogov Memorial Medical University, Vinnytsya (protocol № 11 From 03.12.2020) found that the studies do not contradict the basic bioethical standards of the Declaration of Helsinki, the Council of Europe Convention on Human Rights and Biomedicine (1977), the relevant WHO regulations and laws of Ukraine.

Statistical processing of the obtained results was carried out in the licensed statistical package "Statistica 6.0" using step-by-step discriminant analysis.

Presentation of the main material.

Research results and their discussion. Taking into account the features of damage formation of the "clothing + non-biological human body simulator" complex and individual non-biological human body simulators, as well as trace-forming elements of the structures of the "Fort 12R" and "AE 790G1" pistols when fired from these pistols at close range, 25 cm and 50 cm the discriminant function covers 83.3%

of the parameters characteristic of the Fort 12R pistol and 71.7% of the parameters characteristic of the AE 790G1 pistol. In general, the model is correct in 77.5% of cases.

Among the parameters characteristic of the Fort 12R and AE 790G1 pistols, the discriminant variables are the specific sum of the crack lengths in the FWPM body simulator at a depth of 2 cm (FWPM2), the shot distance (VPOS), the defect area (SD), the non-biological human body simulator without or with the presence of matching (cotton, denim, or leather) clothing (TKAN), presence or absence of centrality (NC), presence or absence of diphenylamine (ND), specific sum of crack length in PPM body simulator at 1 cm depth (PPM1) and presence or absence of soot (K) (Table 1). Among these parameters, the distance of the shot and the area of the defect have the greatest contribution to the discrimination between the pistols. The set of all variables has a slight reliable discrimination (Wilks' Lambda=0.535; $p<0.001$) between the indicators characteristic of the "Fort 12R" and "AE 790G1" pistols (see Table 1).

For each of the groups, we determined the classification indicator (Df), by means of which the indicators of the formation of damage and trace-forming elements shown in Table 1 can be classified as "typical" for "Fort 12R" or "AE 790G1" pistols. Below, in the form of equations, the definition of the classification indicator is given, where assignment to the "Fort 12P" pistol is possible with a Df value close to 160.5; for the "AE 790G1" gun - with a Df value close to 184.5:

Df (*pistol «Fort 12R»*) = -FWPM2×0,255 + VPOS×77,78 + SD×16,93 - TKAN×0,493 + NC×6,327 - ND×14,79 + PPM1×1,382 + K×69,07 - 160,5;

Df (*pistol «AE 790G1»*) = -FWPM2×0,080 + VPOS×83,45 + SD×20,57 + TKAN×0,042 + NC×8,950 - ND×21,29 + PPM1×1,471 + K×72,29 - 184,5;

where (here and in the following), the specific sum of the length of the FWPM cracks in the body simulator is in mm; the distance of contact shot - 1, from a distance of 25 cm - 2, from a distance of 50 cm - 3; defect area - in cm2; bare block without fabric – 1, with cotton – 2, with jeans – 3, with leather substitute – 4; presence – 2 or absence – 1 centrolite; presence – 2 or absence – 1 of diphenylamine; the specific sum of the length of the PPM cracks in the body simulator - in mm; presence – 2 or absence – 1 of soot.

Table 1

Report of the discriminant analysis of the identification of guns "Fort 12R" or "AE 790G1" depending on the characteristics of indicators of damage formation and trace-forming elements.

Discriminant Function Analysis Summary (kusliy.sta)						
Step 8, N of vars in model: 8; Grouping: PIS (2 grps)						
Wilks' Lambda: 0,535 approx. F (8,11)=12,06 p<0,0000						
	Wilks' Lambda	Partial Lambda	F-remove -1,111	p-level	Toler.	1-Toler. (R-Sqr.)
FWPM2	0,575	0,931	8,219	0,0050	0,145	0,855
VPOS	0,653	0,819	24,47	0,0000	0,061	0,939
SD	0,621	0,861	17,89	0,0000	0,404	0,596
TKAN	0,545	0,982	2,040	0,1560	0,365	0,635
NC	0,583	0,917	10,05	0,0020	0,661	0,339
ND	0,593	0,902	12,06	0,0007	0,439	0,561
PPM1	0,589	0,908	11,19	0,0011	0,083	0,917
K	0,574	0,931	8,187	0,0050	0,195	0,805

Notes: here and in subsequent similar tables, Wilks' Lambda - Wilks' Lambda statistic; Partial Lambda – the Wilks lambda statistic of the single contribution of a variable to the discrimination between populations; F(8,11)=12,06 – critical (8,11) and obtained (12,06) values of the Fisher test; p – the p-level is related to the overall value of Wilks' Lambda; F-remove – the standard F-criterion associated with the corresponding Partial Lambda; p-level – p-level is associated with the corresponding F-remove; Toler. – tolerance value for each variable; R-Sqr. – coefficient of multiple correlation of a specific feature with other features.

The statistical significance of all discriminant functions was determined using the $\chi 2$ criterion (Table 5.2). The results of this analysis indicate that, taking into account the established indicators of damage formation and trace-forming elements, a reliable interpretation of the obtained indicators of classification between the "Fort 12R" and "AE 790G1" pistols is possible (see Table 2).

Table 2

A step-by-step report including the χ^2 criterion for all canonical roots of the Fort 12R and AE 790G1 pistols, taking into account the indicators of damage formation and trace elements.

Chi-Square Tests with Successive Roots Removed (kusliy.sta)						
	Eigen-value	Canonicl R	Wilks' Lambda	Chi-Sqr.	df	p-level
0	0,869	0,682	0,535	71,32	8	0,0000

Notes: here and in subsequent similar tables, Eigenvalue is the value of the roots for each discriminant function; Canonical R – canonical value of R for different roots; Chi-Sqr. – standard criterion χ^2 of successive roots; Df is the number of degrees of freedom; p-level – p-level of the corresponding χ^2.

Taking into account the specifics of the damage formation of the "clothing + non-biological human body simulator" complex and individual non-biological human body simulators, as well as the trace-forming elements of the "Fort 12R" and "AE 790G1" pistol designs when fired from these pistols, the discriminant function covers 100% of the indicators characteristic of the contact shots, 97.5% of the indicators are typical for shots from a distance of 25 cm and 100% of the indicators are typical for shots from a distance of 50 cm. In general, the model is correct in 99.2% of cases.

Among the parameters characteristic of shots at close range, from a distance of 25 cm or from a distance of 50 cm, the discriminant variables are the specific sum of the length of cracks in the TCLM body simulator at a depth of 2 cm (TCLM2), the presence or absence of soot (K), the specific sum of the length of cracks in the body simulator TCLM at 1 cm depth (TCLM1), specific sum of crack lengths in FWPM body simulant at 2 cm depth (FWPM2), specific sum of crack lengths in FWPM body simulant at 3 cm depth (FWPM3), presence or absence of diphenylamine (ND), non-biological a human body simulator without or with the presence of appropriate (cotton, denim or leather) clothing (TKAN), a gun model (PIS) and the specific sum of the length of cracks in the PPM body simulator at a depth of 1 cm (PPM1) (Table 3). Among these indicators, the presence or absence of soot has the greatest contribution to discrimination between shot distances. The set of all variables has a pronounced reliable discrimination (Wilks' Lambda=0.012; $p<0.001$) between indicators characteristic of different shot distances (see Table 3).

For each of the groups, we determined the classification indicator (Df), with the help of which the indicators of the formation of damage and trace-forming elements shown in Table 5.3 can be classified as "typical" for shots at close range, from a distance of 25 cm or from a distance of 50 cm. Below, in the form of equations, determination of the classification indicator, where classification as contact range shots is possible with a Df value close to 94.53; for shots from a distance of 25 cm - with a Df value close to 62.68; to shots from a distance of 50 cm - with a Df value close to 36.21:

Df (*contact shot*) = -TCLM2×0,209 + K×59,24 + TCLM1×0,587 - FWPM2×0,760 + FWPM3×1,012 + ND×4,643 - TKAN×2,049 + PIS×0,468 + PPM1×0,345 - 94,53;

Df (*shot distance 25 cm*) = -TCLM2×0,524 + K×43,30 + TCLM1×0,462 + FWPM2×0,265 + FWPM3×0,016 + ND×24,57 - TKAN×0,484 + PIS×6,756 + PPM1×0,128 - 62,68;

Df (*shot distance 50 cm*) = -TCLM2×0,380 + K×16,26 + TCLM1×0,240 - FWPM2×0,180 + FWPM3×0,052 + ND×36,39 + TKAN×1,527 + PIS×10,02 - PPM1×0,046 - 36,21;

where, the specific sum of the length of TCLM cracks in the body simulator is in mm; pistol model "Fort 12R" - 1, and "AE 790G1" - 2.

Table 3

The report of the discriminant analysis of the identification of the distance of the shots depending on the characteristics of the indicators of the formation of damage and trace-forming elements from the "Fort 12R" or "AE 790G1" pistols.

Discriminant Function Analysis Summary (kusliy.sta)						
Step 9, N of vars in model: 9; Grouping: VPOS (3 grps)						
Wilks' Lambda: 0,012 approx. F (18,22)=97,30 p<0,0000						
	Wilks' Lambda	Partial Lambda	F-remove -2,109	p-level	Toler.	1-Toler. (R-Sqr.)
TCLM2	0,017	0,719	21,28	0,0000	0,239	0,761
K	0,050	0,243	169,9	0,0000	0,460	0,540
TCLM1	0,014	0,872	8,025	0,0006	0,207	0,793
FWPM2	0,017	0,724	20,77	0,0000	0,193	0,807
FWPM3	0,016	0,760	17,18	0,0000	0,311	0,689
ND	0,015	0,818	12,10	0,0000	0,624	0,376
TKAN	0,014	0,885	7,085	0,0013	0,745	0,255
PIS	0,014	0,890	6,746	0,0017	0,598	0,402
PPM1	0,013	0,939	3,571	0,0315	0,186	0,814

The statistical significance of all discriminant functions was determined using the $\chi 2$ criterion (Table 4). The results of this analysis indicate that, taking into account the established indicators of damage formation and trace-forming elements from the "Fort 12R" or "AE 790G1" pistols, a reliable interpretation of the obtained classification indicators between different shot distances is possible (see Table 4).

Table 4

A step-by-step report including the χ^2 criterion for all canonical roots of shot distance when considering the rates of damage formation and trace elements from the Fort 12R or AE 790G1 pistols.

Chi-Square Tests with Successive Roots Removed (kusliy.sta)						
	Eigen-value	Canonicl R	Wilks' Lambda	Chi-Sqr.	df	p-level
0	21,60	0,978	0,012	497,4	18	0,0000
1	2,612	0,850	0,277	145,1	8	0,0000

Thus, on the basis of the features of damage formation of the complex "clothing + non-biological human body simulator" and individual non-biological human body simulators, as well as trace-forming elements of the structures of the "Fort 12R" and "AE 790G1" pistols when fired from this weapon, reliable discriminative models of the possibility were built for identification of "Fort 12R" or "AE 790G1" pistols and distances of shots at close range, from a distance of 25 cm or from a distance of 50 cm.

The data we obtained are perfectly consistent with the results of A.M. Perebetyuk's work. with co-authors [8], who discovered patterns of deposition of soot and gunpowder elements when fired from different distances using Fort 9R and Fort 17R pistols.

The results of the research of the team of authors led by G.O. Legin are interesting. [9] in which changes in the macroscopic pattern of eyeglass lens damage during shots from different distances were detected under the condition of using non-lethal pistols (gas pistols) of different manufacturers. Not only the area of the defect is specific, but also the quantitative and qualitative characteristics of the cracks formed on the glass.

Foreign authors focus on the analysis of gunshot residue, namely such elements as Pb, Ba, Sb, and Sn, which play a key role in the identification of the weapon [10]. Elements such as copper and nickel are also found less often [11]. Data from the literature indicate that these nanoparticles can be detected when fired at a distance of up to 45 cm [12], however, in our study, soot and gunpowder particles were detected at a firing distance of 50 cm and were included in the models that can be used to identify the firing distance. Such discrepancies can be explained by the distinctive features of both the design of the pistols and the ammunition for them used in other studies and ours.

In general, gunshot residue [13] is still the most important piece of physical evidence that has a greater influence on expert opinion [13], which, however, should not prevent research that can reveal a significant influence of macroscopic indicators, as our research results showed.

Conclusions. Taking into account the features of damage to a non-biological human body simulator and its covering elements in the form of clothing, data on the deposition of the residual components of the shot, reliable discriminative models were built, correct in 83.3% for the identification of the "Fort 12R" pistol and 71.7% for the "AE 790G1" pistol and is correct in 99.2% of cases for identifying the shot distance for the above pistols.

The discriminant variables for identifying the shot distance or gun model were mostly parameters of the temporal cavity of the shot, the presence or absence of gunpowder components, while the elemental composition or the frequency of occurrence of the temporal cavity were not used at all in the created models.

References:

1. Hussain S, Shirwany TA, Din IH. Epidemiology of gunshot injuries in district Sialkot. Jszmc. 2013;4(4):504-8.

2. Phillips R, Shahi N, Bensard D, Meier M, Shirek G, Goldsmith A, Recicar J, Haasz M, Schroeppel T, Moulton S. Guns, scalpels, and sutures: the cost of gunshot wounds in children and adolescents. Journal of trauma and acute care surgery. 2020 Sep 1;89(3):558-64. doi:10.1097/TA.0000000000002766

3. Mikhailenko OV, Roshchin HH, Dyadik OO, Irkin IV, Malisheva TA, Kostenko YY, Gunas VI, Hel AP. Efficiency of determination of elemental composition of metals and their topography in objects of biological origin using spectrometers. Indian Journal of Forensic Medicine and Toxicology. 2021;15(1):1278-84. doi: 10.37506/ijfmt.v15i1.13592

4. Gunas V, Bobkov P, Plakhotniuk I, Olhovenko S, Solonyi O. Specifics of fire damage to cotton clothing while shooting point-blank at a human torso simulator from a Fort-12RM pistol. Theory and Practice of Forensic Science and Criminalistics. 2021 Jul 27;23(1):175-87. doi: 10.32353/khrife.1.2021.13

5. Fackler ML, Malinowski JA. The wound profile: a visual method for quantifying gunshot wound components. The Journal of trauma. 1985;25(6):522-9. PMID: 4009751

6. Ragsdale BD, Josselson A (1988) Predicting temporary cavity size from radial fissure measurements in ordnance gelatin. J Trauma 28(1 Suppl):S5-S9

7. Schyma C (1998) "Die" polygonale Modellierung des Schusswundkanals: eine experimentelle Untersuchung der traumatischen Schusswirkung in Gelatine (Doctoral dissertation).

8. Perebetyuk A, Prokopenko S, Fomina L, Gunas I, Terekhovska O. Peculiarities of additional shot factors deposition when firing from "FORT 9R" and "FORT 17R" pistols. Forensic medical examination. 2022(2):43-9. doi:10.24061/2707-8728.2.2022.6

9. Legin GO, Bondarchuk GO, Perebetiuk AM, Mokanyuk OI, Magdiy AY, Zagryzla NO. Characteristics of damage to glasses when fired from air weapons. Forensic Bulletin. 2012;1(17):145-51.

10. Li X. Measurement of gunshot residues with inductively coupled plasma mass spectrometry from a 9 mm× 25 mm police revolver and 7.62 mm× 25 mm type 64 pistol. Microchemical Journal. 2021 Jan 1;160:105678. doi:10.1016/j.microc.2020.105678

11. Sahu KI, Kennao P, Gupta AK, Saran V, Waghmare NP. Study of 9mm Improvised Pistol Pattern & Gunshot Residue with respect to Different Range. Int. J. Comput. Sci. Eng. 2018;6:155-60.

12. Ananth V, Ahmad UK, Tong SM. Detection of organic gunshot residues for the estimation of firing distance. Malaysian J. of Forensic Sci. 2011;2(1):36-45.

13. Kaur J, Sodhi GS. Forensic importance of gunshot residue analysis: A review. International Journal of Medical Toxicology & Legal Medicine. 2022;25(1and2):14-21. doi:10.5958/0974-4614.2022.00004.3

Література:

1. Hussain S, Shirwany TA, Din IH. Epidemiology of gunshot injuries in district Sialkot. Jszmc. 2013;4(4):504-8.

2. Phillips R, Shahi N, Bensard D, Meier M, Shirek G, Goldsmith A, Recicar J, Haasz M, Schroeppel T, Moulton S. Guns, scalpels, and sutures: the cost of gunshot wounds in children and adolescents. Journal of trauma and acute care surgery. 2020 Sep 1;89(3):558-64. doi:10.1097/TA.0000000000002766

3. Mikhailenko OV, Roshchin HH, Dyadik OO, Irkin IV, Malisheva TA, Kostenko YY, Gunas VI, Hel AP. Efficiency of determination of elemental composition of metals and their topography in objects of biological origin using spectrometers. Indian Journal of Forensic Medicine and Toxicology. 2021;15(1):1278-84. doi: 10.37506/ijfmt.v15i1.13592

4. Gunas V, Bobkov P, Plakhotniuk I, Olhovenko S, Solonyi O. Specifics of fire damage to cotton clothing while shooting point-blank at a human torso simulator from a Fort-12RM pistol. Theory and Practice of Forensic Science and Criminalistics. 2021 Jul 27;23(1):175-87. doi: 10.32353/khrife.1.2021.13

5. Fackler ML, Malinowski JA. The wound profile: a visual method for quantifying gunshot wound components. The Journal of trauma. 1985;25(6):522-9. PMID: 4009751

6. Ragsdale BD, Josselson A (1988) Predicting temporary cavity size from radial fissure measurements in ordnance gelatin. J Trauma 28(1 Suppl):S5-S9

7. Schyma C (1998) "Die" polygonale Modellierung des Schusswundkanals: eine experimentelle Untersuchung der traumatischen Schusswirkung in Gelatine (Doctoral dissertation).