Methods of Indirect Identification in the Hand of a Crisis Manager in the Context of Sociological Aspects

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Abstract – **This paper aims to describe the basic methodological approaches in experimental wounding ballistics, which are methods of indirect identification, especially with an emphasis on the sociological content and perspectives of current trends in security management. The outputs and conclusions presented in the paper result from a thorough analysis of threats and security risks identified in the research work in the context of the IGA project No. 007DTI / 2019 realized at DTI University in Dubnica nad Váhom, arising from the actual security situation in society using conventional weapons systems against human beings, and from the analyze of existing quantitative evaluation criteria for the bullets wounding potential. The main theoretical and experimental output is the conceptual proposal of own bullets wounding potential evaluation criterion.**

Keywords **– wound effect, wounding potential, experimental wound ballistics, physical substitute medium, indirect identification method, ballistic simulation, indirect evaluation method and optic method.**

DOI: 10.18421/SAR54-03
https://doi.org/10.18421/SAR54-03

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Received: 29 October 2022.
Revised: 30 November 2022.
Accepted: 05 December 2022.
Published: 26 December 2022.

1. Introduction

The current assessment tools of a crisis manager working in security management focused on risk assessment in connection with conventional anti-human weapons systems have rather limited use. We find the predominant basis of these evaluation approaches in the use of analytical criteria of bullets or fragments evaluation criteria using a suitably selected physical quantity that meets a particular type of small arms system with a specific structure and ballistic parameters significantly limiting their objective use. This approach corresponds more to evaluation methods of species identification. The real needs of individual identification cannot be logically met in practice.

Experimental research of wound effects and evaluation of bullets and fragments are currently realized mainly on physical substitute media (homogeneous or heterogeneous) made of substitute materials of biological tissue of plastic, elastic and elastic-plastic nature or of a combination of synthetic materials and tissues of biological donors. We apply indirect identification methods in ballistic experiments, where physical substitute media are shelled instead of animals or isolated organs. This technical approach, based on simulating of the bullet effect on vital tissues, is becoming the essential of scientific knowledge in the experimental wound ballistics (EWB), where the real target is represented with physical substitute media in the experiment.

2. Material and Methods

The primary goal of this paper is to describe the basic methodological approaches in the experimental wound ballistics, which are methods of indirect identification, especially with an emphasis on the sociological content and perspectives of current trends in security management.

Relevant secondary goals are:

- to analyze and to describe the position of crisis manager with emphasis on sociological content and perspectives in security management;
- to identify and to specify methods of indirect identification;
- to summarize the relevant conclusions in the context of fulfilling the primary goal.

The outputs and conclusions presented in the paper are based on a thorough analysis of threats and security risks identified in the research work in the context of the IGA project No. 007DTI / 2019 realized at DTI University in Dubnica nad Váhom, arising from the actual security situation in society using conventional weapon systems against human beings, and from analyze of existing quantitative evaluation criteria for the bullets wounding potential, when this analysis was carried out using the ballistic experiments.

During the implementation of ballistic experiments, there are shelled the substitute physical media of own construction, which for ethical reasons in the measuring chain represent a real target of a biological nature. In practice, indirect identification methods are carried out by the injury profile method, the radial crack method (indirect method), and the optical method. The first two methods are static. The optical method which is using a high-speed camera to measure and to record the results is a modern dynamic method.

The main theoretical and experimental output is the proposal of own bullets wounding potential evaluation criterion. The used methods of research and analytical activities are interpreted in accordance with the results obtained inductively, i.e. in the process from individual through abstract to standard generalization. The chosen methodological procedures and practical results are systematically and purposefully developed, possibly expanded, supplemented, innovated and at the same time verified by subjects from professional practice. Given the defined goals, the outputs of the analyzes are not just academic considerations but scientific analyzes capable of their specific life.

3. Position of a Crisis Manager in Security Management

Today's security situation in Europe and around the world is very complex. The number of violent crimes or terrorist attacks carried out by organized criminal groups or individuals, in which the vast majority of small arms were used, is rising. This is sparking controversy in the society about the legal ownership, possession and carrying of weapons in terms of the tolerable range of their numbers. Laws on the licensing of weapons are constantly being tightened and, under the leadership of the European Commission, are also being partially consolidated, yet there is no significant reduction in excesses with weapons in hand. Legally acquired weapons are often used for professional purposes, protection of life, health and property, and for entertainment and sports. On the other hand, there are weapons held and used illegally, which is not negligible.

4. Analysis of the Security Situation in the EU Countries and the World

We can often face the violence against individuals and population groups, or only the violence threat. People should have some knowledge of how to behave in such a situation. There can also be a terrorist attack to provoke fear in order to destabilize the region. The fact that the number of legally held weapons is growing among people and at the same time there is a high number of cases, in which the weapon is involved in the violent crime, indicates that there is a high societal need in the process of categorizing weapons to determine the bullets or fragments wounding potential.

Security is one of the primary needs of human existence. Security risks, on the other hand, are influences that, by their potential and their eventual implementation, compromise the security. With the development of human knowledge, with the development of science and technology, the world, on the one hand, becomes more accessible and comfortable for human being, and on the other hand, life becomes more complex and even threatening. There are many security risks, and it can be stated without exaggeration that humanity is increasingly threatened, and its existence is undermined.

Today's main threats include international terrorism and organized crime, cyber threats, extremism with the development of the use of small arms weapons systems against human beings, migration, climate change, and pandemics. At present, there are different views on the security situation, threats and risks and ways to manage them (risk management) in terms of political, economic, financial, technological and technical perspective, in the context of security and critical infrastructure protection (CIP), population protection (PP), international terrorism, organized crime, information infrastructure, health, water and the environment in general.

5. Asymmetric Threats of the Modern World

The history has shown us that conflicts which initially appear to be national and insignificant can quickly escalate into a more significant local conflict

with the possibility of spreading to neighboring countries. The current borders of most states are no longer tightly closed and impenetrable, as has been the case in the past. Increasingly, they are becoming vague, somewhat symbolic lines on the maps of Europe and in the world. In addition, globalization and the openness of today's world significantly contribute to reduce the effectiveness of borders.

Conflicts can be divided into two main categories:

1. Conflicts of interest over the territory, raw materials, economic profit or political interest.
2. Values conflicts representing ethnic, religious and ideological disputes. In most cases, the currently involved parties are choosing a non-linear way of fighting to achieve their goals. The reasons can be simple, the possibility to "conquer" a particular area without a real war or eventually due to the aggressor's low chance of success in conventional fighting.

Besides the power ambitions of state and non-state actors, besides the methods and ways of waging a hybrid war, it is about the international terrorism and the fight against it. Even today, defining the concept of terrorism and classifying, what is and what is not terrorism, is not entirely straightforward. Experts and security organizations provide a minor definition of terrorism. The working definition used in UN Resolution 1566/2004 has become one of the most widely used and the most comprehensible definition. It says that "terrorism is a criminal act against civilians committed to intimidate the population or to force the state (international organization) to act or, conversely, to abstain from the act". At the same time, terrorism can be divided into several categories according to the ideological goals it wants to achieve with its mostly armed attacks.

The levels of the fight against terrorism are intertwined, creating a comprehensive system that seeks to be highly effective in joint efforts. All security organizations, of which the Czech Republic is a member, also apply their security policy against terrorism. In particular, the UN has adopted several internationally recognized conventions to increase the effectiveness of the fight against terrorism. At the same time, organizations such as NATO and the EU also lead the physical fight against terrorism through their active participation and effort to stabilize the countries ravaged by conflicts and terrorism [11].

6. The Concept of Security Management for Conventional Weapon Systems

Management is probably as old as humanity itself. With the development of human civilization, the need and the possibility of preserving and developing human existence increased. Management was used for this. "It is a dialectical relationship between things, phenomena and processes of objective reality and their management" [10]. Management can be understood in a dual meaning. The broader meaning lies in understanding the management as a part of the social culture; the narrower meaning is in the use of resources described above. In both sense of words, the primary mission of management is to serve to humanity to preserve its existence and to develop the human society in harmony with nature and its resources.

We distinguish three basic concepts of management:

1. Managers are management;
2. Management represents a range of managerial activities or functions (planning, analytical activities, evaluation, organization, decision-making);
3. Management is a scientific discipline and a practical field.

General management, similarly to general economic theory, implies special branch disciplines (transport economics, healthcare, and construction). Security (crisis) management, like other human activity areas, does not automatically become a unique discipline. In the case of security management, we are talking about a specific topic of management that needs the necessary time and conditions to develop.

With the increasingly aware societal risks of today's global world arising, among other things, from the existence of violent firearms crimes, the security needs to be managed. There are publications and research that signal the need for a systematic collection of security knowledge across the spectrum of security sciences. Furthermore, in this context, security management can thrive for the area of conventional weapon systems and their use against human being.

7. Sociological Content and Perspectives of Security Management

The ballistic effect that a firearm can achieve under certain, predetermined conditions represents the degree of its social danger and its real utility value for the particular purpose of its use.

Violent crime using firearms is very often associated with international terrorism worldwide. In the Czech Republic conditions, it is thus an organized crime, which is a global security threat that ranks among the most destructive threat to the rule of law and democratic society.

According to Professor Michael Maltz, there are 9 attributes making the organized crime from the criminal groups. Particularly speaking about

corruption, and we can add to that violence, sophistication, continuity, structure, discipline, diversity of business activities, legitimate business activities engagement, and reception rituals [9].

Organized crime is a type of group crime committed by an organized criminal group or organization. These groups and organizations usually have a multi-level vertical organizational structure characterized by the systematic commission of a severe coordinated crime. The goal of organized crime is to achieve maximum profit at minimal cost, not only material gain but also, for example, in the form of social, economic and political influence. Therefore, the organized crime poses extraordinary security risks, threatening the stability of the world economic and political system. Organized crime is an evil threatening humanity, which has to be fought hard by all available means and constantly worked on their development, and it is not enough just to know them, but to understand their nature and functioning [1].

Despite the generally accepted meaning of organized crime, its description and definition in individual countries are inconsistent and of varying quality. Even the current Czech criminal law does not recognize the concept of organized crime. In this context, the terms criminal association and organized group are appearing in this legislation. The term "criminal association" was embedded into our legal system by Act No. 152/1995 Coll., which amended the Criminal Code No. 40/2009 Coll., effective from January 1, 2010. Until then, this form of crime was prosecuted according to the general provisions on organizing, on association as a form of preparation for a crime and, according to some qualified facts, as an organized group. Section 20 (1) defines a criminal association as a community of several persons with an internal organizational structure that divides functions and activities focused on the continuous commission of an intentional crime. The draft of the new Criminal Code, which in § 405 contains the term organized criminal group, which is characterized as a community of several persons with an internal organizational structure, division of functions and division of activities, which is focused on the continuous commission of an intentional crime, did not eliminate these inconsistencies. On the contrary, the term "organized group" is not defined in the Criminal Code, although it occurs as a feature of some qualified facts in a particular part of this Code.

In the legal literature, the term "organized group" is defined as an association of several persons, in which there is a certain division of tasks between the individual members of the association, and consequences of its activities are the planning and the coordination [12].

The organized crime is a phenomenon of all time, but it is gaining momentum in the sense that it is one of the most severe threats to today's civilization. Transnational organized crime was able to adapt to globalization very effectively and is using it as its advantage making it a phenomenon that threatens states' external and internal security. Of course, this threat also directly affects the Czech Republic, as criminal networks physically exist and operate in our territory, or they use our country as a transit area or to legalize the proceeds of their activities. For this reason, not only the Czech Republic but also other countries of the EU and all countries all over the world have to strive to lead the fight against organized crime.

The organized crime presents a severe and hidden threat to society. The spectrum of activities of contemporary organized crime is vast. It includes, for example, the production, smuggling and distribution of drugs, the arms and human trafficking, thefts, violent crimes, fraud, money laundering, corruption, influencing the politics or economy of the country and infiltrating the state administration for its abuse. Criminal syndicates are governed by their norms, institutions, and bodies and thus represent parallel branches of power in addition to states.

The greatest danger is presented by Russian-speaking groups, which have built bases in our territory and have perfectly established themselves here. For the Czech organized scene in recent years, there is characteristic and significant expansion of Asian criminal structures, especially Chinese and Vietnamese, which deal with smuggling of any goods and financial crime. On the contrary, the situation around the Balkan organizations, which are moving their leaders further west, is positively assessed. However, we must not forget the groups of domestic provenances; those activities have manifested themselves several times in the past in the form of machinations with light fuel oil, groups around businessman František Mrázek, Berdych gang, and groups around Jaroslav Starka. The current situation needs to be solved by new and more modern means of fighting against organized crime, otherwise criminal organizations will unfortunately always be one step ahead all the time, partly due to non-compliance with legal standards, while anti-organized crime authorities have to follow the legal actions. It is about a societal problem and it is therefore necessary to put the interests of the whole community above the interests of the individual in the fight against criminal structures, because it is in the interests of all. Organized crime is essentially a product of the society, and therefore it is up to the people of this planet how the situation will develop in future [1].

The international organizations have put several measures to fight the organized crime, including the UN Convention against Transnational Organized Crime in 2000. All countries need to prevent organized crime structures from entering the country's social systems, primarily politics, justice, police and the media. In its Convention against Transnational Organized Crime, the Ministry of the Interior of the Czech Republic commented on the main areas with certain shortcomings in this fight, according to which the Czech Republic has to improve to increase the fight efficiency.

These problem areas and new challenges for each country include, but are not limited to, these aspects:

- Changes and increase in the effectiveness of the legislative system of the Czech Republic capable to ensure more practical activities for bodies active in criminal proceedings;
- Efforts to improve cooperation and communication between individual security forces within the Czech Republic, but also to strengthen the police and judicial cooperation in the international environment;
- Strength the capacity of the authorities to fight the economic crime and to improve the system for managing of secured property;
- Become more flexible in adapting to new forms and methods of organized crime.

This comprehensive system for fighting the organized crime has to be combined with the promotion of the social and moral consciousness of the population and the introduction of a code of conduct, especially in a state administration environment. The population has to be proactive and aware of the seriousness of the effects of organized crime on society itself and on the economic system of states, which affects the lives of all citizens. This area should be more covered in the media and educational institutions, where organized crime has to be perceived as a threat with a societal impact.

8. Indirect Identification Methods

Modern experimental methods used in experimental wound ballistic are based on plastic, resp. elastic-plastic substitute media; those with their characteristics are closer to the characteristics of vital soft tissues. Besides to the previously used clay and propellant, the ballistic gelatin, gel, transparent glycerin soap, plasticine, and a mixture of petrolatum and paraffin found the most significant applications in the ballistic experiment. Experimentally obtained characteristics describing the process of bullets penetration through the substitute media blocks became the basis for deriving various criterion and methodologies for quantitative evaluation of the bullets wounding potential [8].

The homogeneous structure of the substitute media sample is advantageous in terms of objective comparison of different types of ammunition. Therefore, this material is considered an optimal substitute for a highly variable human body, whose diverse tissues are characterized by a high degree of "inhomogeneity" from a ballistic point of view. In practice, a relatively narrow group of bullets wound effect evaluation methods based on the shelling of specifically modified substitute media test blocks has proved successful.

The most common indirect identification evaluation methods include:

- Injury profile method;
- Radial crack method (indirect method);
- Optical method - analysis by i-SPEED system.

Each of the above cited methods is a specific expression of the practical experience of its founder and his expert opinion on the bullets human body wound effect evaluation and is usually strictly tied to a specific biological tissue substitute media. For highly plastic non-transparent materials (e.g. clay, plasticine, glycerin soap), it is straightforward possible to determine the parameters of the created temporary cavity directly after shelling without the need to use the special techniques. Conversely, only the permanent cavity can be directly determined for elastic-plastic materials (e.g. ballistic gelatin, gel). Using special techniques, such as high-speed camera recording the parameters of the temporary cavity during the penetration can be determined indirectly with these materials.

Previously used homogeneous biological tissue substitute media blocks were gradually replaced with physical models having a certain degree of inhomogeneity in a ballistic experiment. The experimental representation of a real object with this model, which is as close as possible to it thanks to its geometric structure and physical and mechanical characteristics, forms the basis of the indirect identification method. There is a degree of geometric similarity between the real biological target and the physical model. This type of ballistic experiment is better suited to simulate the conditions of a complicated gunshot wound (involvement of a bone or large vessel) when only soft tissue is not affected.

9. Injury Profile Method

The concept of injury profile is closely related to the analysis of wound - ballistic phenomena in vital tissue [2]. Both authors used this term to describe the graphical representation of the wound effect that can be expected from the bullet of a given structural and ballistic parameters. This profile is formed with a wound track, the core of which is a permanent cavity. Its volume is determined by the amount of lost vital tissue.

From the shape and volume of the wound track temporary cavity we can determine the bullets wounding potential (to some extent also the resulting wound effect) using the so-called injury profile. An injury profile means a photograph (or sketch) of a temporary cavity made by a bullet in a substitute media, which is equipped with a scale and data on the weight, impact velocity and bullet type [4]. Optical methods can obtain the shape of the temporary cavity (e.g. flash photography). The so-called blocks of semi-infinite thickness are preferred for this method [3], when the effort of ballistics is to capture the bullets behavior in the material on the entire trajectory on which the bullet will stop in the test block. Comparing the bullets effects through the injury profiles comparison is a simple orientation method. Together with the data on the total transmitted bullet kinetic energy to the test block, the injury profile provides an idea of the bullet behavior in the material and the distribution of the specific transmitted kinetic energy.

This profile forming can be understood as a specific extension of experimental methods using ballistic gelatin as a simulation tool, where four essential components of the bullets ballistic effect on a gelatin test block representing a real biological target in a ballistic experiment, are monitored:

- the depth of bullets penetration into the gelatin block;
- bullets deformation or disintegration of its body (if they occur);
- volume (diameter) of a temporary cavity;
- volume (diameter) of the permanent cavity (the core of the wound track).

The volume of the temporary and permanent cavity can be read relatively well from the formation and structure (density and length) of the radial ruptures in the penetrated gelatin block, from which it is possible to derive and to construct an illustrative graphic scan of the wound profile (see Figure 1). For further work with this profile, it is advisable to redraw it on a translucent paper and complete it with the millimeter scale.

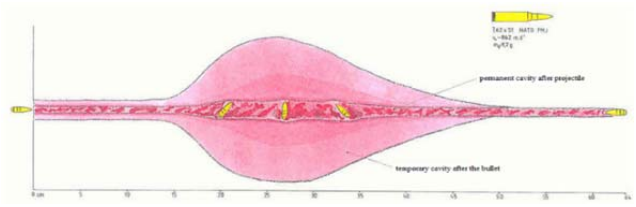

Figure 1. Injury profile typical for bullet of an executive rifle cartridge caliber 7.62 x 51 NATO Standard with temporary and permanent cavity marking formed by the bullet (mq = 9.6 g; v0 = 862 ms-1) after penetrating the ballistic gelatin test block (Source: [3])

During a temporary cavity is formed in soft tissues or their substitution, the temporary cavity pulsates [7]. The total pulsation time τD depends on the extent of the transmitted bullet kinetic energy E_{TR} and can be calculated according to the following empirical equation

$$\tau_D = 2 \cdot \sqrt[3]{E_{TR}} \,. \qquad [\text{ms}] \qquad (1)$$

Graphical profiles of wound tracks (temporary cavities) obtained by shelling of test blocks made of transparent glycerine soap, supplemented by a millimeter scale, allow the mutual comparison of bullet penetration depths, geometric shape (internal layout) and volume of bullet wound tracks for projectiles of different structural characteristics and ballistic parameters. This obtained wound track profiles give some idea about what kind of gunshot injury can be expected from a particular weapon system when certain specific conditions of human intervention are met. The bullet body fragmentation marks, eventual the bullet body deformation together with the amount of damaged tissue, can be compared with a series of gunshot injury profiles to estimate the type of bullet and the type of firearm from which was fired and which caused the injury.

10. Radial Rupture Method (Indirect Method)

To quantify the bullet effect in this environment, J. Knappworst (Dynamit Nobel AG) developed a method of radial ruptures, originally intended for the needs of the military-medical research.

Ruptures created in this way, with their length and density; correspond to the instantaneous amount of the bullet kinetic energy E_{TR} transmitted at a given location of the wound track. The values of the transmitted kinetic energy E_{TR} of selected types of pistol and revolver bullets into gelatine are shown in Table 1.

Table 1. Transmitted kinetic energy to gelatine of selected pistol and revolver bullets

Bullet calibre	Company	Bullet types	m_q	v_I	E_I	E_{TR}	E_{TR}/E_I
			[g]	[m.s^{-1}]	[J]	[J]	[%]
38 Special.	Remington	RN	13,0	202	260	78	30
38 Auto	Remington	FMJ	8,4	315	410	137	33
38 Special	Norma	SP/HP	7,1	407	588	531	92
38 Special	Remington	SP/HP	8,1	288	329	324	99
9mm Luger	DNAG	Cu/RN/P [1)]	5,6	418	489	482	99

9mm Luger	DNAG	Cu/RN/P [2)]	5,65	380	408	300	75
9mm Luger	DNAG	Ms/RN/P [3)]	5,9	380	420	280	67
357 Magnum	Remington	SWC	10,2	363	662	226	34
357 Magnum	S &W	SP/HP	8,1	351	491	380	77
357 Magnum	DNAG	Cu/RN/P	7,5	395	579	520	90
357 Magnum	SFM	Ms/P	2,8	643	568	550	97
357 Magnum	Western	SP/HP	7,1	391	534	533	100
44 Magnum	Remington	SP/RN	15,6	381	1 110	739	67
44 Magnum	Remington	SWC	15,6	385	1 130	862	76
44 Magnum	Remington	SP/HP	15,6	372	1 057	974	82
45 Auto	Remington	FMJ	14,9	248	447	159	35
45 Auto	Remington	SP/HP	12,0	279	460	369	80

Notes:
Comment:
Company name:
S & W: Smith & Wesson
DNAG: Dynamit Nobel AG
SFM: French Ammunition Company
Marking of missiles:
RK: round head
VM: all-coat
SWC: Semiwadcutter
MsS: Fully brass, pointed bullet
TMRK: half-shell, round head
TMHSp: half-shell, hollow tip
CuR / PSp: fully copper bullet with round head and plastic tip
MsR / PSp: fully brass projectile with round head and plastic tip
Usual designation:
Usual designation: ACTION 2
Common designation:
extent of fire = 15 m)

Source: [6]

The method of radial ruptures is suitable for the evaluation of shooting experiments aimed at the shelling of transparent gelatine blocks. Ballistic gelatine behaves differently from other substitute media used in a wound ballistic experiment. The temporary cavity formed by the bullet penetration, collapses during the pulsations, and its volume and shape are represented by a system of radial ruptures along the wound track. Radial ruptures are trapped in cross-section by a ballistic gelatine block (see Figure 2).

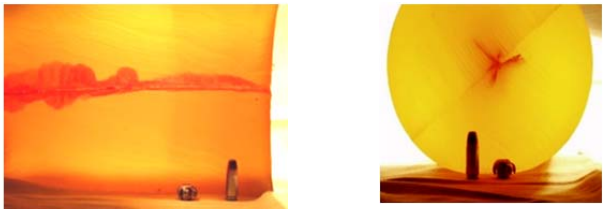

Figure 2. Shape of the temporary cavity defined by the system of radial ruptures after the penetration of the gelatine block by a 9 mm Luger Gold Dot pistol cartridge bullet (Left – horizontal cut of the block at the wound track location, right - view of the cross-section front with star-shaped radial ruptures) (Source: [3])

The radial rupture evaluation method is an indirect method and consists of determining the sum of the rupture lengths in precisely defined sections of the wound track. As a result, a diagram of the dependence of the sum of the rupture lengths on the depth of bullet penetration in the gelatine block is obtained (see Figure 3). If the total transmitted bullet kinetic energy $\boldsymbol{E_{TR}}$ to the gelatine block is known, this energy may be related to the unit of the bullet penetration depth $\boldsymbol{E_{TR/s}}$.

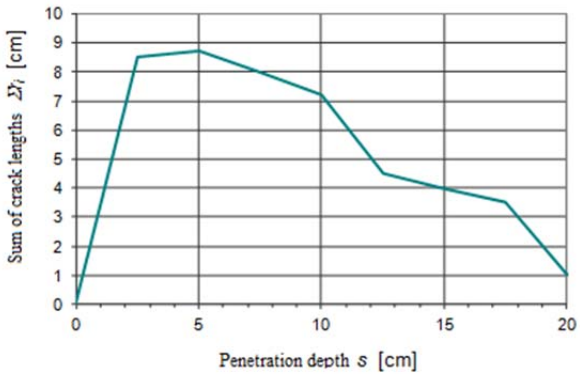

Figure 3. Diagram of the dependence of the sum of ruptures lengths Σri on the depth of a bullet penetration into a gelatin block (Source: [3])

This method consists of determining the sum of the lengths of radial ruptures in given sections of a block. From the total length of radial ruptures, it is possible to obtain a diagram of the total length of ruptures $\boldsymbol{\Sigma r_i}$ dependence on the bullet penetration depth s into the gelatine block. Figure 4 shows a part of such a diagram of the total length of radial ruptures as a function of the bullet trajectory in a gelatine block. Sections by block i and i+1 delimit the i-th bullet trajectory interval. The lengths of individual radial ruptures corresponding to these sections are measured in the individual sections and their sum $\boldsymbol{\Sigma r_i}$ and $\boldsymbol{\Sigma r_{i+1}}$ is determined. Height of gelatine *i - th* disc (the length of resp *i-th* interval) is $\boldsymbol{\Delta s}$.

The average total radial rupture length of the *i-th* interval can be calculated according to this equation [4].

$$\sum_i r = 0,5 \cdot (\sum r_i + \sum r_{i+1}) \qquad [\text{cm}] \qquad (2)$$

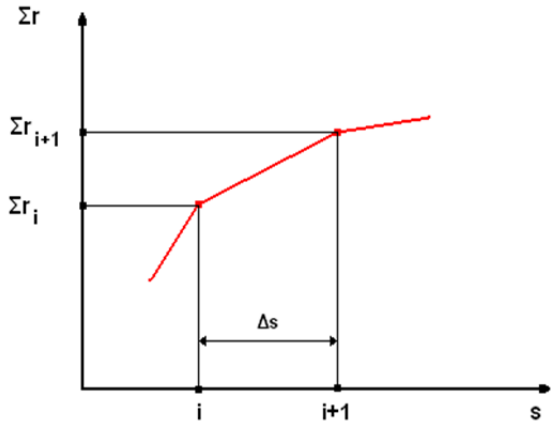

Figure 4. Construction of the dependence of the total length of radial ruptures on the bullet trajectory (Source: [3])

It applies, with careful execution and evaluation of the experiment, that the area under the curve of the total radial rupture length at a given interval is proportional to the total transmitted energy $\boldsymbol{E_i}$ at that interval. It applies:

$$\Delta s \cdot \sum_i r = c \cdot E_i, \qquad [\text{cm}] \qquad (3)$$

where $\boldsymbol{c}$ [cm2.J^{-1}] is a constant that characterizes the characteristics of the used gelatine.

Height, respectively the thickness of the gelatin discs (cutting plane distances) $\boldsymbol{\Delta s}$ is chosen most often between 2.5 or 5 cm. With the choice of smaller disk thicknesses, it is possible to obtain a more accurate course of the total radial ruptures' length on the bullet trajectory, but at the expense of a disproportionate increase in the laboriousness of the own evaluation.

The partial level of specific transmitted energy $\boldsymbol{E_i}'$ on a given interval can be then calculated according to the equation:

$$E_i' = \frac{E_i}{\Delta s} = \frac{\sum_i r}{c}. \qquad [\text{J.cm}^{-1}] \qquad (4)$$

While evaluating the experiment it is necessary to know the bullet impact velocity and the value of its firing velocity after block perforation. From these velocities and the known bullet mass, the total transmitted energy $\boldsymbol{E_{TR}}$ to the block can be calculated. From the area under the curve of the total radial ruptures' length depending on the bullet trajectory and from the total transmitted energy, the constant $\boldsymbol{c}$ for a given block can be calculated from the equation:

$$c = \frac{0,5 \cdot \sum_1^n (\sum_i r \cdot \Delta s)}{E_{Př}}, \qquad [\text{cm}^2.\text{J}^{-1}] \qquad (5)$$

where $\boldsymbol{n}$ is the number of disks of the same thickness to which the gelatine block has been cut.

The bullet trajectory in the diagrams of the specific transmitted energy is usually given in cm. The value of the constant $\boldsymbol{c}$ is valid only for a particular gelatine block and has to always be evaluated. As the gelatine concentration, its structure, or the block tempering temperature changes, the value of this constant changes as well.

The mechanical characteristics of the ballistic gelatine depend on its temperature. So, the gelatine blocks have to be tempered to the same temperature. The temperature of the test blocks varies; in most sources the temperature of 20° C is recommended (for gelatine with a concentration of 20%). When comparing the results of different authors, it is necessary to keep this fact in mind.

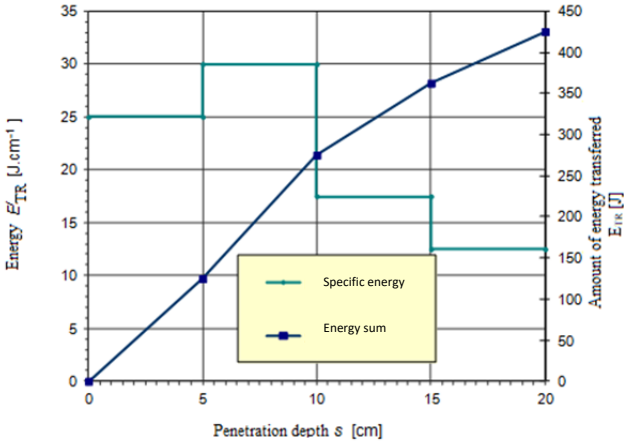

Figure 5. Transmitted energy (E_{TR}) and transmitted energy per gelatin trajectory function of the offending section of the bullet trajectory in the gelatin block. (Source: [3])

With the help of equation (4), the y-coordinate calibrated in cm (= $\boldsymbol{\Sigma_{ri}}$) in Figure 3 can be transformed into [J.cm^{-1}] in Figure 5. In this diagram, not only (left scale) is plotted, but there is also plotted the total transmitted bullet kinetic energy $\boldsymbol{E_{TR}}$ (correct scale).

Thus, on the penetration track of 0 to 5 cm, the value is 24.5 J.cm^{-1} and thus $\boldsymbol{E_{TR}}$ = 24.5 J.cm^{-1}. 5 cm = 122.5 J. When the bullet penetrates the gelatin block for the first 5 cm, it transmits the kinetic energy $\boldsymbol{E_{TR}}$ = 122.5 J to the penetrated environment. This value of the transmitted bullet kinetic energy to the block in the first section s = 5 cm is plotted in Figure 5. The remaining courses of both curves and their construction are carried out gradually but separately for other equally long sections of the depth of bullet penetration.

The method of radial ruptures is also suitable for describing the fragmenting bullets wounding potential. However, in the experiment, it is necessary to determine the bullet mass loss, and to calculate it into the calculation of total transmitted energy.

11. Optical Method. I-SPEED Analysis

The most modern method is connected with the use of the modern high-speed camera, which records the bullet interaction with the test block of transparent substitute medium. Using the high-speed camera, that allows tens of thousands scans per second, and thanks to its software, it is possible to determine the course of bullet velocity in the substitute medium block and then to calculate the partial levels of specific transmitted energy to the block on each precisely determined sections of the penetration bullet trajectory [5].

With using the high-speed camera software, it is possible to construct an approximate course of the environmental resistance against the bullet motion. From the definition of the wounding potential and of the relationships cited above, it is clear, that the area under the environmental resistance curve $\boldsymbol{R = f\,(s)}$ corresponds to the wounding potential (the transmitted energy to the block, i.e. the work that $\boldsymbol{R}$ spent on slowing the bullet on the trajectory). The optical quantification method of the wounding potential is currently the subject of interest of our professional workplace. Some results of experiments realised at the Department of Weapon Systems were published in [5]. Within in the past performed experiments, there was used the high-speed camera Olympus i-SPEED borrowed with the necessary accessories by the Faculty of Electrical Engineering, the University of Technology in Brno [4]. We used the type designation of the used high-speed camera, we came out, when naming the optical method with the working title "i-SPEED system analysis".

The records analysis of high-speed cameras using their software is the most modern method of evaluation of a ballistic experiment, in which all known transparent substitute medium can be shelled (i.e. even those, that do not form apparent radial ruptures, e.g. ballistic gel). High-speed camera records are enabled to monitor the whole bullet interaction with the substitute medium block, the formation, and the pulsation of the wound track temporary cavity, eventually the deformation or fragmentation of the bullet body (if any). The software of high-speed camera allows determining the course of the bullet velocity on its trajectory, which is the default for calculating the dependence of the specific transmitted energy. It is also possible to determine the course of the bullet trajectory in the block as a function of time for the transmitted pulse calculation, or to determine the course of resistance against the bullet motion in the material. The great importance for the evaluation of the ballistic experiment has also the determination of the increase rate of the radial dimensions of the wound track temporary cavity (see Figure 6).

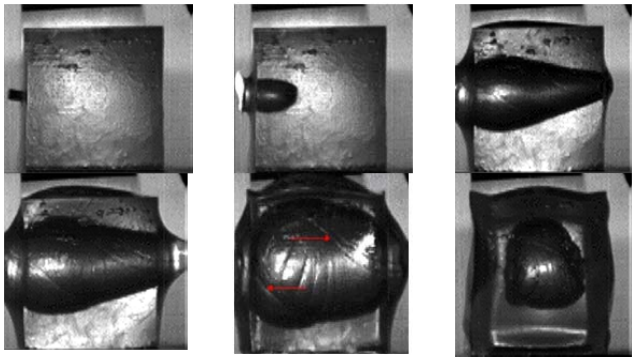

Figure 6. A series of selected images from the continuous recording of the gelatine block penetration with an bullet of a calibre 40 S & W (frame rate 20,000 sn.s^{-1}) (Source: [3])

This method is very demanding on the technical equipment. The accuracy of the obtained results is influenced by the quality of the recording. The material block has to be shone through for recording. That is why; the relatively powerful reflectors are used, which light is scattered by a semipermeable barrier [3].

For the analysis of high-speed camera records, it is necessary to calibrate the recordings, mostly with using the knowledge of the exact block parameters. The accuracy of the record calibration determines the accuracy of the calculation of the average bullet velocity at the specified intervals of its trajectory. After calibrating the record, the bullet velocities at given points are calculated and the functional dependence of the bullet velocity along the block is approximated by the selected curve. The choice of the approximation curve type has a major influence on the resulting dependence of specific transmitted energy on the bullet trajectory. This curve is chosen based on the experience concerning the assumed course of bullet velocity on its trajectory in the block. The most commonly used curves are polynomials of the second and third-degree or exponentials.

From obtained dependence

$$v = f(s), \tag{5.5}$$

where $\boldsymbol{v}$ is the bullet velocity and s its trajectory in the substitute medium block, we calculate the bullet velocity at nodal points, i.e. at points on the bullet trajectory, which lie at the boundaries of the intervals and at which the specific energy is calculated (these

intervals are most often chosen between 2.5 or 5 cm)[1].

From the obtained bullet velocities at these points and from the known bullet mass we are able to calculate the specific transmitted energy at a given interval according to the equation

$$E' = \frac{0,5 \cdot m_q (v_n^2 - v_{n+1}^2)}{\Delta s}, \quad (5.6)$$

where m_q - bullet mass, v_n – bullet velocity at the beginning of the examined interval, v_{n+1} bullet velocity at the end of the examined interval, Δs - trajectory segment (the length of the examined interval). The value of E' is given in [J.cm^{-1}]. In this way, the levels of specific transmitted energy are determined at individual sub-intervals along the entire block. The resulting dependence of the specific transmitted energy depending on the bullet trajectory gives a concrete idea of the bullets wounding potential.

12. Conclusion

Presented paper dealt with three basic empirical methods of quantified bullets (fragments) wounding potential evaluation, which have their origins in experimental wound ballistics. Based on indirect identification, these evaluation procedures represent a suitable evaluation tool for the manager's analytical work for the current practice of a crisis manager working in security management in connection with problems associated with the use of conventional anti-human weapon systems.

The experimental method of injury profile requires relatively extensive experience in processing the results obtained by the ballistic experiment. The authors of this quantitative method strive to capture the total wound track from the examined bullets in the test block. To meet this condition, it is necessary to select test blocks made of substitution of biological tissue of infinite thickness, which will allow the capture of permanent and temporary cavities and their graphical display in the correct scale and proportions for further description of the volume and geometry of the wound track.

The radial rupture method is a relatively simple but time-consuming and laborious evaluation method. The accuracy of this indirect evaluation method depends on the correct tempering of transparent test blocks before the actual firing, mainly on the accuracy of the radial ruptures total length measuring in all selected sections of the wound track. The wounding potential of fragmenting bullets can be described relatively well through this method as well.

The last method, the optical method based on i-SPEED analysis is a modern ballistic experiment evaluation method. It is a dynamic evaluation method suitable for shelling of all physical substitute media of transparent nature. The course of the specific transmitted bullet kinetic energy can be easily determined based on the found dependence of its velocity on the test block penetration trajectory. The accuracy of the achieved results is decisively affected by the setting of the high-speed camera scanning frequency and by the choice of the mathematical function, in which is the actual course of the bullet velocity decrease approximated. The i-SPEED program analysis record results depend to a large extent on the experience of the operator and on the quality of the technical equipment to illuminate the transparent test block. For this purpose, synchronized lightning systems are currently being developed, which are triggered by non-contact gates responding to the passage of the bullet, the systems illuminate the block with an intense flash lasting several thousandths of a second.

It is up to the specific experience of the crisis manager and the technical equipment of his workplace, which of the above methods he chooses for the wounding potential quantification, and thus for the evaluation of the social danger of the assessed conventional weapons system.

[1] The extent of intervals is chosen as low as possible for accurate calculations, for common use, we choose the thickness of the interval similar to the radial rupture method.

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