Potentialities of scanning electron microscopy and EDX analysis in bullet wounds

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Abstract: Since the development of electron microscopy, it opened new horizons for medical and physical research. In forensic medicine, scanning electron microscopy with energy dispersing microanalyser (EDX) provides valuable information about the morphology of injuries, and injury implements. In the paper, we aim to confirm the potentialities of the use of scanning electron microscopy together with the X-ray microanalyzer EDX for evaluating the interaction of a bullet passing through tissues of the human body. We performed SEM and EDX analysis from skin tissue samples taken from bullet wound sites, and brain tissue from the depth of the bullet wound in head firearm injuries. We demonstrated the presence of light particles on the sample surface and in the depth of the bullet wound canal. Analysing the compositions of the particles we detected Mg, Al, Si, P, S, Cl, Ca, Cu and Zn in both skin and brain samples. Microparticles were most expressive at the bullet wound site, while deeper in the wound canal, they were present in minimal amounts. We conclude that scanning electron microscope together with EDX analysis, are suitable for forensic investigation of firearm wounds, as they enable the determination of projectile parameters and an approximate estimation of the firearm distance.

Key words: SEM, EDX, Firearm wound, Projectile, Microparticles

The fundamentals of scanning electron microscopy were first described by von Ardenne in 1938 [1]. It is use in medicine began later on. Scanning electron microscopy (SEM) together with energy dispersing microanalyser (EDX) was used by Raso et al in 1999, to examine the bioreactivity of silicon implants [2]. In forensic medicine, Kim et al. used both in 2000, SEM and EDX them to analyse remains after bullet wounds [3]. SEM together with EDX are used in toxicology and pathology for determining exogenic and endogenic toxic substances [4, 5, 6].

From a forensic viewpoint, it is of a significant value, that the use of SEM is not limited by autolysis to an extent such as for example in transmission electron microscopy. Therefore, SEM is convenient for the study of various types of wounds [7] particularly in the study of bullet wounds [8, 9, 10, 11]. When a bullet passes through a living tissue, both thermal and mechanic changes of tissues take place [12, 13]. The effectiveness of bullet wounds is based on the mechanic effect of the large pressure of gases released after the combustion of the explosive charge.

These gases, under large pressure push the bullet out of the gun barrel. The barrel of a firearm gun contains a helix shaped system of spiral grooves. These grooves are 0.1–0.2 deep. These grooves cause the projectile to confer a rotation around its long axis while passing through the gun barrel, which improves its aerodynamic stability and accuracy. When passing through the gun barrel, both

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surfaces of the projectile and the gun barrel are abraded. Micro and macroscopic defects are formed on the surface of the bullet. These defects can be used for the identification of the gun used. When the bullet passes through animal tissue, microparticles are released from the surface defects and deposited into tissues. In case of coated bullets, deposits consist of Dutch metal Tombac (Zn, Cu), in non coated bullets, they contain heavy metals (mainly Pb). The aim of this paper is to confirm the potentialities of the use of scanning electron microscopy together with the X-ray microanalysis EDX for evaluating the interaction of a bullet passing though tissues of the human body.

**Materials and Methods**

We performed SEM and EDX analysis from skin tissue samples taken from sites of gun shots, and brain tissue from the depth of the bullet wound in head firearm injuries. Samples were fixed with formol. Then dehydrated in alcohol with increasing concentrations, and dried at the critical temperature of CO₂ using a CPD 040 (Balzers Union, Vaduz, Liechtenstein) apparatus. Samples were covered with a carbon layer using the Agar SEM Carbon (Agar, London, England) apparatus.

We used brain tissue samples from cases of sudden death following a myocardial infarct as a negative control. For a positive control we used samples of animal tissue obtained from shooting control. In shooting control, we used commercially available pork skin with subcutaneous fat tissue as a target. For the positive control samples, we used the revolver Taurus cal. 22 and Glock 17 cal. 9 mm Luger.

For the revolver we used non coated ammunition cal. 22 LR, manufacturer Sellier & Bellot, projectile weight 2.6 g. For the Glock 17 we used coated ammunition 9 mm Luger, manufacturer PS, projectile weight 7.5 g with Tombac coat composed of 90% Cu, 10% Zn.

We used the scanning electron microscope JXA 840A (Jeol, Japan) with the EDAX 3205 – 1200 (Kevex, Valencia, USA) analyser with 20 kV accelerating voltage. Spectral gain time was 200s, the energy range of 0.160 to 10.230 keV. The resulting image was recording with the digital camera Tescan (Tescan, Brno, Czech Republic).

**Results**

Scanning electron microscopy demonstrates the presence of microparticles of different sizes on the surface of skin samples (Fig. 1).
Using scanning electron microscopy we recorded particles on the surface of brain tissue samples (fig. 2).

**Fig. 2.** The surface of brain tissue from the taken from the wall of the bullet wound canal after a head shot. Light bright particles on the tissue surface are from the bullet passing through the tissues. SEM.

Using EDX analysis of element composition, we determined the presence of Mg, Al, Si, P, S, Cl, Ca, Cu and Zn particles, the composition of elements present on the skin surface samples and the brain surface samples were identical (fig. 3).

**Figure 3.** EDX analysis of particles present in figure 2. The EDX spectrum shows zinc and copper.

On the sample surface of control samples, where firearm wounds were implicated from short distances we detected particles, with element composition corresponding to the gunpowder charge.
Using EDX analysis, we detected the presence of Si, Pb, K, Ca and Ba in the bullet wound canal, and in the vicinity of the wound (fig. 4). The presence of microparticles was most expressive at the bullet wound site, while deeper in the wound, it was minimal.

Discussions

We conclude from the presence of particles on the surface of skin and brain tissues, that scanning electron microscopy provides explicit evidence of the bullet wound site. Brazeau, Wong and Havel [8,14], described the potentialities of the use of SEM together with EDX analysis for characterising the bullet wound site. They found that analysing the presence of firearm residue around the wound site can assist in more accurate interpretation of the events. EDX analysis of surface tissue from the wound site confirms the presence of material from projectile coatings, as well as non coated projectiles.

These materials in the above described pattern do not occur in animal tissues in normal circumstances.

Cardinetti et al. described the presence of lead-antimony-barium particles in workers of the automobile industry [15]. He stated that X-ray mapping technique is not a persuasive method for differentiating firearm residua and particles coming from the working environment. He concludes, that SEM, together with EDX analysis can provide explicit information in bullet wound investigations.

From the analysis of the bullet wound site, and the wound canal, we deduce that the presence of microparticles is most expressive in at the wound site. While deeper in the wound...
canal it is minimal. Dubrovin and Dubrovina (2003) described a significant increase in the size of the bullet wound depending on the distance of the firearm [16].

It would be possible to calculate the distance of the firearm by measuring the size of the bullet wound. Brozek-Mucha et al. (2003) describes the presence of lead, barium and antimony on the surface of examined tissues [17,18].

By analysing the amount of particles found on the tissue surface they confirm the possibility of identifying the manufacturer of projectiles. By analysing 7 different groups of Luger projectiles by different manufacturers, they found that there is no statistical difference between the amounts of detected particles.

Conclusion

The use of EDX analysis is a suitable apparatus for studying the relation of „foreign inert materials”, penetrating the animal tissues and organs. Scanning electron microscope together with EDX analysis, enables in certain circumstances the determination of projectile parameters in firearm wounds, and an approximate determination of the firearm distance.

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References


