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W. Marty · T. Sigrist · D. Wyler

Determination of firing distance using the rhodizonate staining technique

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Abstract The histological staining technique using rhodizonate is also effective for the determination of the firing distance by examining the distribution and intensity of the staining reaction. The differentiation between absolute close-range shots and long-range shots is generally possible without any doubt. The method is not recommended for routine examinations but it is very useful for cases lacking the possibility to investigate smoke and powder deposits in a criminalistic manner, i.e. surgical skin biopsies of hospitalised victims and skin highly altered by the effects of fire, water or by post-mortem decomposition.

Keywords Skin · Gunshot wound · Firing distance · Rhodizonate · Histochemistry

Introduction

In modern forensic science, technical and immunohistochemical surveys are more and more of prime importance as publications of Stein et al. [11] or Ortmann et al. [8] demonstrate. On the other hand further development of proven methods with new applications make sense, for example the modification of the Hauck procedure by Suchenwirth in 1972 [12] for determination of the firing distance by using the method of rhodizonate staining reaction of particles of gunpowder. However, this procedure fails with the absence of skin, as is frequently the case with bodies damaged by fire, although deeper tissue layers, which may also contain traces of smoke and powder, quite often are still present. The casting procedure described above poses similar problems with bodies altered by decomposition [1]. The same applies to drowned bodies, where the outer skin layers have peeled off. It is true that in a laboratory experimental environment [3] particles of smoke and powder were still detectable on altered skin, however, our experience shows that these will not allow a legally sufficient assessment.

The detection of powder particles on histological tissue sections with the rhodizonate staining technique is easy to perform [6]. Rhodizonic acid (5,6-dihydroxy-5-cyclohexene-1,2,3,4-tetraone) exists as needle-shaped crystals of a dark orange colour and forms a sodium salt which reacts with heavy metal ions (e.g. barium, antimony, lead, tin) with a red precipitate. On histological tissue sections, Na-rhodizonate reacts with heavy metal particles from the primer by generating a finely granular scarlet red pattern which can be assessed with sufficient certainty even under a magnifying glass.

Materials and methods

Materials (weapons and ammunition)

The types of firearms and varieties of ammunition used are listed in Tables 1 and 2.

The barrels, chambers, bolts and magazines were cleaned carefully with hot soapy water and pure benzine prior to the experiments in order to remove potential impurities from previous shooting [14] and to avoid smearing of gun oils [4, 13], which – based on our own findings – may produce rhodizonate-positive precipitates due to additives containing heavy metals. Subsequently, prior to firing on the skin samples, three shots were fired into the backstop in order to assure that the barrels were coated with smoke and powder residues for the whole series of shots into the samples.

Then followed the actual firing onto skin samples stretched and pinned to a synthetic backstop. Next, a 0.5×2.0 cm piece around the impact hole was excised, fixed in formalin and embedded in paraffin and then 3 μ sections were cut and stained with Na-rhodizonate. Identical results are also obtained when using frozen sections.

W. Marty (✉)
Institute of Forensic Medicine, Cantonal Hospital, Loestrasse 170, 7000 Chur, Switzerland
e-mail: walter.marty@ksc.gr.ch,
Tel.: +41-81-2566568, Fax: +41-81-2566544

T. Sigrist
Institute of Forensic Medicine, Cantonal Hospital, Rorschacherstrasse 95, 9000 St. Gallen, Switzerland

D. Wyler
Institute of Forensic Medicine, University, Bühlstrasse 20, 3000 Bern, Switzerland

Table 1 Weapons used in the experiment

Weapon	Manu-facturer	Calibre	Barrel length	Mag-azine
Baby Browning	FN[a]	6.35 Browning	5.4 cm	6
Browning	FN[a]	7.65 Browning	10 cm	7
P-210	SIG[b]	9 mm Luger	12 cm	8

[a] Fabrique Nationale d'armes de guerre Herstal Belgique
[b] Schweizerische Industriegesellschaft Neuhausen

Table 2 Ammunition used in the experiment (*FMJ-RN* full metal jacket, round-nose)

Calibre	Manu-facturer	Bullet type	Bullet mass (g)	V_o (m/s)	E_o (J)
6.35 Browning	Dynamit Nobel AG	FMJ-RN[a]	3.2	255	104
7.65 Browning	Dynamit Nobel AG	FMJ-RN[a]	4.7	305	219
9 mm Luger	Mag Tech	FMJ-RN[a]	7.45	346	446

Staining technique

Tartaric acid (1%) and sodium rhodizonate solution (a few crystals in approx. 5 ml distilled water produce a solution with approx. the colour of brandy or tea). Due to its sensitivity to light, the sodium rhodizonate solution has to be prepared fresh every time.

Generously coat the section set on a slide with rhodizonate solution (approx. 5 drops on a preparation of 1 cm^2). Then add 1 drop of tartaric acid solution per 5 drops of rhodizonate solution and leave for a reaction time of 1 min. Pour off the solution and seal with a standard sealant. For large numbers of sections, a staining bath is recommended, whereby the ratio of rhodizonate to tartaric acid remains unchanged at 5:1.

Criteria for the assessment of smoke and powder residue on the surface

The histological preparations stained with rhodizonate were independently assessed by two examiners who had no prior knowledge of the method of firing. The following classification, which was subsequently assigned to the firing distances given by the experimental set-up was defined and illustrated in Figs. 1, 2, 3 and 4.

Fig. 1 Contiguous deposits on the surface from an absolute close-range shot with a Baby Browning, cal. 6.35

Fig. 2 Scattered deposits on the surface from a shooting distance of 5 cm with a P-210, cal. 9 mm Luger

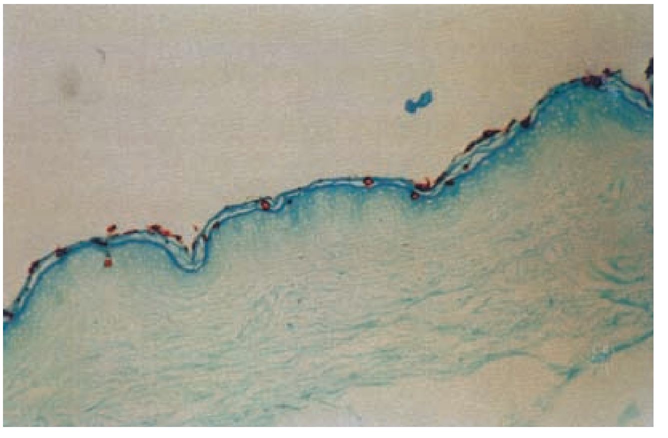

Fig. 3 Dotted deposits on the surface only from a shooting distance of 10 cm with a Browning, cal. 7.65 Browning

Fig. 4 Flag-like fold of the epithelium with deposits of gunpowder residues (close-range shot with a Browning, Cal. 7.65 Browning)

Table 3 Results of the assessment of smoke and powder deposits from a Baby Browning, calibre 6.35 Browning, barrel length 5.4 cm (n = 29)

Firing distance (cm)	Contiguous deposits	Scattered deposits	Dotted deposits
0	+	–	–
1	+	–	–
2	+	+	–
3	+	+	–
4	+	–	–
5	+	+	–
6	–	+	+
7	–	+	+
8	–	+	+
9	–	+	+
10	–	+	+
20	–	–	+

Table 4 Results of the assessment of smoke and powder deposits from a Browning, calibre 7.65 Browning, barrel length 10 cm (n 34)

Firing distance (cm)	Contiguous deposits	Scattered deposits	Dotted deposits
0	+	–	–
1	+	–	–
2	+	–	–
3	+	+	–
4	+	–	–
5	+	+	–
6	–	+	–
7	–	+	+
8	–	+	+
9	–	+	+
10	–	–	+
20	–	–	+
30	–	–	+

Table 5 Results of the assessment of smoke and powder deposits from a p-210, 9 mm Luger, barrel length 12 cm (n = 30)

Firing distance (cm)	Contiguous deposits	Scattered deposits	Dotted deposits
0	+	–	–
1	+	–	–
2	+	–	–
3	+	+	–
4	+	–	–
5	+	+	–
6	+	+	–
7	+	+	–
8	–	+	–
9	–	+	+
10	–	+	+
20	–	+	+
30	–	–	+
40	–	–	+

Results

The results of the experiments are listed in Tables 3, 4 and 5.

Discussion

Clouds of smoke and powder residues are not symmetrical, homogeneous phenomena [9]. Even from repetitive shots from the same firing distance and using the same weapon and ammunition, one cannot expect identical residue patterns. At close ranges, lands and grooves produce a residue fallout pattern similar to a star or a blossom which, in the absence of the weapon, may even occasionally allow deductions regarding the number of lands, grooves and the direction of twist and spin, thus giving clues to the weapon used, e.g. the manufacturer (most modern handguns have 5, 6 or 8 lands and grooves and run clockwise, while Colts traditionally have 6 grooves and run counter-clockwise). On rare occasions, even body movements of the victim can alter residue patterns, as has been shown in a 1989 report on a homicide by Hochmeister and Dirnhofer [2] who noticed crow's feet within the residue pattern.

Interpretation of the results

A residue pattern centred very tightly around the impact hole is typical for an absolute close-range shot with contiguous deposits of gunpowder residues (Fig. 1). When the barrel is pressed forcibly against the skin, the pattern can have a very small diameter, however, in these cases one finds residue particles pressed massively into tissue fissures, obviously an effect of the vortices and turbulence within the residue jet. When flag-like folds of the epithelium are formed at the rim of the bruise [10] (Fig. 4), one will find residue deposits in the surrounding folded tissue. Depending on the ammunition used, there will also be thermal damage in the path of the projectile through the tissue due to the gas temperature [5, 7].

With relative close-range shots one will, as expected find deposits of the scattered tip (Fig. 2).The distinction between a closer and a relatively more distant close-range shot also manifests itself in the density of residue deposits, whereby with the closer one contiguous deposits are detected, while with the more distant one they are more scattered.

With the long-range shot, one may at best observe dot-shaped, finely or coarsely granulated and non-contiguous rhodizonate-positive particles (Fig. 3).

The finding that smoke and powder particles from long-range shots can also be detected in deeper tissue layers was rather surprising. We explain this phenomenon by assuming that the perforated skin could not entirely "clean" the projectile surface from impurities because the radial acceleration of the skin at impact by the bullet will cause a hole which is temporarily wider than the projectile calibre. Hence, the particles still clinging to the projectile surface are wiped off only in the first part of the path of the bullet.

Using histological sections, absolute close-range shots and long-range shots can be indisputably differentiated. The rhodizonate-positive particles are not only distributed characteristically on the surface of the skin, but they also appear in a cloud-like pattern within the gaps between connective tissue fibres along the rim of the cavity where smoke and powder residues settle. This differentiation is generally rather uncomplicated when done macroscopically on the body, on the other hand, with excised surgical wounds fixed in formalin it is not always very easy. This is where this method has its big advantages. The differentiation between a relative close-range shot and a long-range shot is possible only under certain conditions. However, histologically we were able to demonstrate that with increasing firing distance the density of rhodizonate-positive particles on the surface on the skin decreases analogous to the known model of the casting procedure. Close co-operation between forensic morphologists and crime lab technicians can be of help when histological diagnosis is inconclusive or in borderline cases. In these cases, we recommend firing comparison shots, first from distances increasing each time by 1 cm and then in increments of 10 cm. This method of a calibration series is rather time-consuming, but it will fulfil its aim in almost all unclear cases provided the suspected weapon is available. Weapons not relevant to the crime, even when of the same or, worse, only similar type, should not be used. Altered deposit patterns can be a result of wear and tear of the barrels. By the same token, ammunition from different batches is of only limited use for comparison shots, since formula modifications in primer and propellant are not uncommon.

Conclusion

Histologically, differentiating between absolute close-range shots and long-range shots is generally possible with the assessment of the distribution of rhodizonate-positive primer particles on and in tissue. Relative close-range shots cause a characteristic histological distribution pattern of the particles on the surface, however, an unequivocal attribution is rather difficult which is why a series of comparison shots is needed.

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