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Detection of gunshot residues in routine CTs

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Abstract The forensic assessment of non-fatal gunshot wounds often proves to be difficult as wounds have usually been cleaned and protected with a sterile bandage by the time of the examination. The aim of our investigation was to test the possible application of computed tomography (CT) for the forensic assessment. Doing so raised the questions whether gunshot residues in the soft tissues, detected by means of 3-dimensional CT, can be used as evidence of a close-range shot and whether conclusions can be drawn pertaining to the range of the shot or the type of bullet used based on the distribution of the radiologically detectable material? In this experimental study 39 shots were fired at fresh pig skin and it was possible to distinguish shots fired from distances of more than 10 cm and contact shots independent of the type of bullet. For unjacketed lead bullets, radiopaque material could be seen in the depth of the entrance wound for firing distances up to 10 cm. In individual cases, CT data and the 3-D reconstruction could provide valuable information in the forensic assessment of patients with gunshot wounds.

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Introduction

In 1996, 1251 firearm deaths were registered in Germany including 178 homicides, 929 suicides, 22 accidents, 5 police shootings and 117 with undetermined circumstances [14]. We have no statistics about the number of non-fatal injuries in Germany, but the Central Bureau of Criminal Investigation in Stuttgart has information on 465 persons injured by shooting (including blank firing guns) in Baden Württemberg in 1996 (personnel communication). In the U.S. the number of firearm-related deaths in 1993 was 39,595 and over 200,000 survived.[3, 15].

Determining the firing distance is of great importance from the point of view of a criminal investigation. In close range shots, there may be deposits from smoke or unburnt powder particles either on the clothes which have been shot through or on the skin. The intensity and distribution of these deposits is related to the firing distance and can therefore be used to estimate it. This range dependency has to be determined for each individual case by experimental shots as it is dependent on the type of weapon and ammunition used.

Conclusions pertaining to the firing distance can also be drawn from the morphological features of the wound or by the morphology of bloodstains [4]. As the primary picture of the injury has usually been changed by surgeons by the time of the forensic examination, the aim of this study was to investigate whether a preoperative computed tomogram (CT) as a routine diagnostic procedure could provide additional information for the assessment of the gunshot.

Case history

A 48-year-old medical doctor committed suicide by a gunshot to the head. The bullet entered through the right side of the neck, 2 cm below the jaw immediately in front of the M. sternocleidomastoideus (Fig. 1) and the bullet finally lodged in the back of

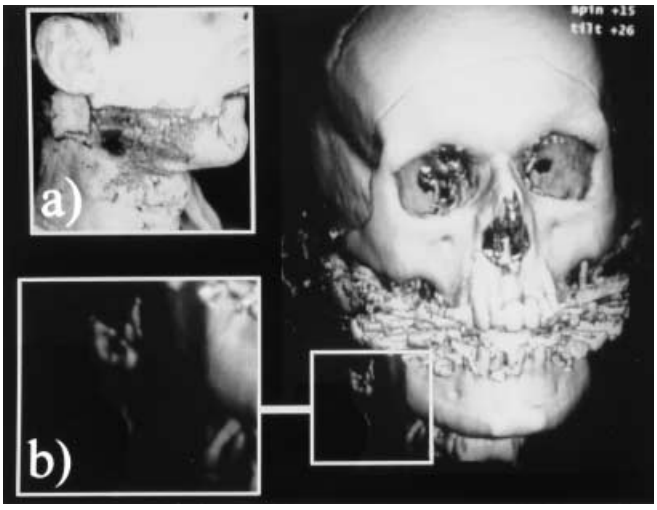

Fig. 1 The suicide of a 48-year-old male where the bullet entered through the right side of the neck. SSD of the skull with shadow-producing material at the entrance wound

head on the left under the galea. In the suicide note, the atypical entrance site was explained by the thought of definitely being able to hit the brain stem and thus vital regions. The weapon used was a double-action Smith & Wesson revolver, model 19-3 (barrel length 6 inches), calibre 357 magnum loaded with three cartridges calibre 357 magnum and with one calibre 38 special with round nose lead bullets. The cartridge fired was the 38 special. The cause of death was the injury of the medulla at the base of the skull. A postmortem CT examination of the head was carried out and the 3-dimensional reconstruction of the skull, radiopaque material arranged in the shape of a ring could be seen on the right side of the neck in the subcutaneous fat which on dissection corresponded to the smoke cavity of the contact shot. Were such findings a phenomenon which could be reproduced? Furthermore, the correlation between detection of substances in the entry wound and the firing distance or the type of bullet or the range of the shot was to be investigated using computed tomography examinations.

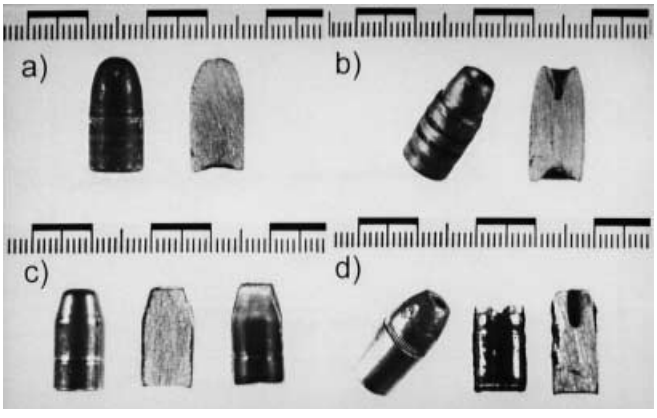

Fig. 2 **a** Lead round-nose bullets, **b** lead hollowpoint bullets **c** jacketed flatnose bullets and **d** semi-jacketed hollow-point bullets

Materials and methods

A total of 39 shots were fired at fresh pig skin with a thickness ranging from 1.5 to 4 cm, with subcutis attached which in part included a thin layer of muscle and was either covered with coarse cotton material or left uncovered. These included 26 lead, 2 semi-jacketed and 11 full-metal-jacketed bullets of the calibres 38 special, 357 magnum and 22 lr (Table 1, Fig. 2).The weapon used by the suicide victim in this case was used to fire 33 of the bulletsand the 6 other bullets were fired from a submachine gun copy, cal. 22 lr of another suicide victim. The pieces of skin measuring approx. 25×35 cm were stretched over a wooden frame and bullets were shot from a range of 0 cm to 100 cm. Afterwards they were examined in a clinical computed tomograph Siemens SOMATOM Plus 4 in the spiral mode with 3 mm layer thickness, pitch 1.5 and a reconstruction increment of 1.5 mm. Then the 3-D surface shaded display (SSD) and maximum intensity projection (MIP) were carried out in which the SSD limiting values of –50 HE, 100 HE and 150 HE were selected as the lower threshold values and 3071 HE as the upper threshold value. Then the skin was photographed and the entry wounds prepared. Material from the smoke cavities and the entry wounds was examined for elements in a scanning electron microscope (Zeiss DSM 960, 25 kV, 27 mm) using energy dispersing radiological microanalysis.

Results

Independent of the type of bullet, all contact shots resulted in a circular, occasionally interrupted ring of radiopaque material. From the side view this ring was under the dermis in the fatty tissue (Fig. 3 a). In connection with this a variably clear cone-shaped distribution of smaller particles could be seen (Fig. 4). On dissection of the entry wound, the remains of the smoke cavity in the shape of a stretchable defect perpendicular to the direction of the shot could be seen in the subcutis. The subcutaneous fat of the pig consists of several layers of fat whereby the smoke detectable on dissection tended to be in the outer fat layers along the thin lines of connective tissue.

For shots with a range between 2.5 cm and 10 cm, the radiological detection of the particles decreased with in-

Table 1 Bullet and weapon information

	Calibre 38 Special			Calibre 357 Magnum		Calibre 22 LR
Manufacturer	Remington/USA	Winchester/USA	Norma	Norma	S&B	–
Bullet	Round nose lead bullet	Hollow-point lead bullet	Semi-wadcutter jacketed	Part- cased hollow-point	Cased wadcutter	Hollow-point lead bullet
Bullet diameter	9–14 mm	9–14 mm	9–14 mm	9–12 mm	–	2–6 mm
Bullet weight	10–24 g	10–20 g	10–20 g	10.24 g	–	2.55 g
Weapon	S&W, barrel length 152 mm	S&W, barrel length 152 mm	S&W, barrel length 152 mm	S&W, barrel length 152 mm	S&W, barrel length 152 mm	Machine pistol copy

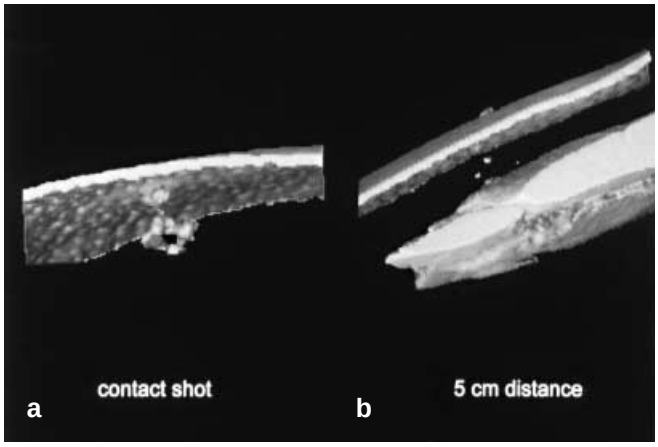

Fig. 3 **a** SSD of a contact shot (range –50 to 3071 HE) lateral view without muscles **b** SSD of a 5 cm distance shot (range–50 to 3071 HE) lateral view with muscles

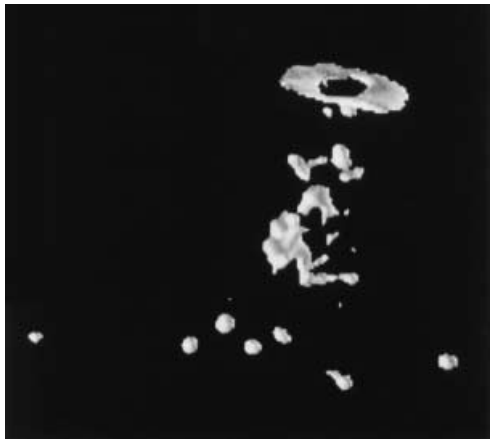

Fig. 4 SSD of a contact shot (150–3071 HE) lead bullet, cone-shaped distribution of smaller particles

creasing firing range; individual small particles formed various distribution patterns in the entrance hole (Fig. 3b). In this group it was possible to distinguish between the types of bullet.

The unjacketed lead bullets left much more material in the fatty tissue than the semi-jacketed or full-metal-jacketed bullets but this difference could not adequately demonstrated after dissection. For shots fired from a distance of over 10 cm, no material could be shown to be in the depth of the entry wound either radiologically or by dissection. The element analysis using a scanning electron microscope identified the radiopaque material as lead. Antimony could also be found in traces which together with lead and barium originates from the igniting charge of the cartridges. A quantification of the elements was not carried out in this study.

Discussion

For non-fatal gunshot wounds, computed tomography is often used to diagnose the injury and to plan the surgical

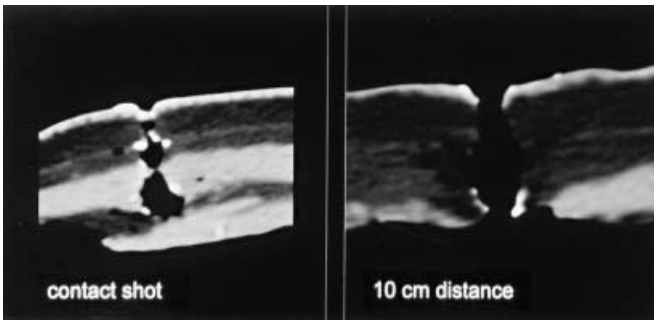

Fig. 5 Sectional views of the entrance wound from a lead bullet

treatment [3, 7, 8, 12, 13]. After excision of the bullet wound it is then often impossible or at least difficult to carry out a forensic assessment. In addition, to ensure that the wound heals well, the freshly operated area should not be manipulated so that a precise examination of the gunshot wound is contraindicated from a medical point of view.

Schyma described material which can be detected by microradiography after shooting pigskin whereby the localisation in the depth of the wound could only be determined in the second section (i.e. on radiation of the tissue sample on the edge of the section) [personnel communication, 10, 11]. In surviving victims, microradiography can only be carried out on excised tissue samples. Pluisch and Sellier [9] examined whether metal particles could be detected by radiology if vertebral bodies had been hit by unjacketed small calibre lead bullets. They were able to show that for all shots with such bullets so called “lead paths” were present along the intravertebral bullet track.

Within the context of our study, small particles from the unjacketed lead bullets could be detected on computed tomographic sectional views in the dermis (Fig. 5a,b). The small size of the particles, however, was a limiting factor in the 3-dimensional reconstruction. The examination parameters intentionally corresponded with normal clinical routine and were therefore subject to certain limitations concerning the resolution. Very close-range shots could be distinguished from shots from a range of more than 5 cm using the 3-D method. In contact shots, regular and reproducible radiopaque rings in the fatty tissue could be seen which showed a conical form penetrating into the depth. For unjacketed bullets, radiopaque material could be seen after firing ranges of up to 10 cm, for jacketed bullets the radiopaque material was completely missing in the wound after firing ranges of 5 cm and above.

In future a problem will be the examination of gunshot wounds where modern lead-free primer has been used. The lack of shadow-producing material means that it will be impossible to differentiate between contact shots and distance shots using radiographic systems.

Scanning electron microscopy (SEM) has become an excellent method for detection of gunshot residues [1, 2]. The major primer elements are lead (Pb), barium (Ba), or antimony (Sb) and usually all three are present. According to Kijewski and Klewe [6] antimony can always be

detected in the shooting ranges examined here if it is an element in the primer. The results of our shooting experiments indicated that the radiologically detectable particles essentially consist of smoke which is supported by the scanning electron microscope detection of antimony but not of lead.

There are two possible reasons for the differences in the particle deposition between lead bullets and jacketed bullets:

1. The smoke cloud from lead bullets contains a higher density of lead than the smoke cloud of a jacketed projectile.
2. Particles adhere more strongly to the comparatively rough surface of an unjacketed bullet than to the smooth surface of a jacketed bullet and are thus carried along further.

The possibility of attributing the radiologically detectable particles to material loss from the bullet when entering the skin can be excluded. Finds of this kind would have been detectable independent of shooting range.

In summary it can be said that CT records of the entry wound are suitable before excision of the wound to differentiate between a contact shot and firing ranges of more than 10 cm. Determination of the shooting range, however, is not possible. For shooting ranges of less than 5 cm within the context of the shot experiments, radiopaque particles could always be detected, and are interpreted as being smoke particles. Due to these correlations, it is recommended that a layer thickness of 3 mm is selected for the primary diagnostics using computed tomography in the area of the wound of entry. The method has the advantage over microradiography in that it can be carried out on the patient within the context of a routine examination and also makes the calculation of pictures in different sections possible.

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