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Cranial fractures and direction of fire in low velocity gunshots

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Abstract A total of 59 penetrating contact shot wounds to the head caused by handguns was investigated and a comparison was made between the magnitude and the number of fracture lines at the entrance and exit site of the vault and at the base of the skull. It was noted that in approximately 50% of the cases the extent of fractures at the entrance site exceeded those at the exit wound while in the remaining individuals no relevant differences or even greater exit fractures were found. Furthermore, no close correlation between the fracture patterns of the vault and at the base of the skull occurred indicating that differences in the magnitude and the number of entrance or exit fracture lines cannot provide reliable information on direction of fire. Additionally, no further conclusions on the gun used can be drawn from differences in the entrance and exit fracture patterns. It can only be assumed that the absence of fractures in the cranial fossae points to the use of small calibre handguns (≤ 7.65 mm) while a fragmentation of the skull can as a rule be expected after shots from guns with larger calibres (> 7.65 mm).

Key words Direction of fire · Skull fractures · Firearms

Introduction

In addition to typical features of the skin wound morphology, the interpretation of skull defects can contribute considerably to the estimation of the direction of a bullet from gunshots [1, 2, 4, 10]. Recently, it was suggested that the application of the biomechanics of secondary and tertiary fractures patterns can also determine the direction a projectile has taken through the head independent of entrance or exit beveling [9]. On the other hand, the appearance of gunshot-induced skull fractures seems to be influenced by several parameters such as the type/calibre of the gun used, of the projectiles, and of the cartridges or the localization of the shot (contact or distant) causing the wounds. Therefore, the present study was performed to investigate whether differences in the magnitude of direct and indirect fractures at the entrance and exit site of the vault and at the base of the skull can provide reliable information for the determination of direction of fire.

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Materials and methods

During the period 1991–1994, autopsies were carried out at the Munich Department of Legal Medicine on 59 cases of penetrating contact shot wounds to the head (no direct impact of the projectile at the base of the skull) with known direction of fire. The age of the individuals ranged between 15 and 87 years. The wounds were caused by pistols or revolvers with a calibre of .22 up to 10.4 mm. In 9 cases, no further information on the gun used could be obtained. In all cases except the 10.4 mm revolver (full metal jacketed bullet) typical ammunition was used (see Table 1).

For evaluation, a comparison was made between the fracture patterns at the entrance and exit wound site of the vault and at the base of the skull by estimation of number and length of the fracture

Table 1 Characteristics of the ammunition used (L: lead bullet – J: jacketed bullet)

Type of gun	Characteristics of the projectile				
	Calibre	Weight (g)	Velocity (m/s)	Energy (J)	Type
Revolver	.22	2.56	270	93	L
	.357 mag.	10.2	376	724	L
	.38 sp.	10.2	230	270	L
	10.4 mm	11.5	290	490	J
Pistol	.22	2.56	270	93	L
	6.35	3.2	255	104	J
	7.65 mm	4.8	305/318	219/240	J
	9 mm short	6.0	272	222	J
	9 mm Para	8.0	350	490	J

lines. Additionally, it was investigated whether a correlation between the fracture patterns and the type/calibre of the gun used could be found.

Results

In 27 out of 59 cases (46%) the number and the length of fracture lines at the entrance site of the skull were greater than those of the exit wound and in 8 out of these 27, fractures were exclusively observed at the entrance site but not at the exit wound (calibre of the guns used: .22 up to 10.4 mm). In 9 out of the 27 individuals (33%) the magnitude of the fractures at the base of the skull at the entrance site exceeded that of the exit wound. In 6 cases, however, the magnitude of the exit fractures at the base of the skull was greater and in 10 individuals (37%) no relevant differences could be found. In 2 cases, no fractures were observed in the cranial fossae. No differences in the extent of the entrance and exit fractures of the skull were detectable in 25 out of 59 cases (42%) and in 6 of these individuals, no secondary fractures were found at the entrance or at the exit site (calibre of the guns used: .22 up to 7.65 mm). In 11 out of these 25 individuals (44%) similar fracture patterns could be observed at the base of the skull. In 8 cases (32%) the magnitude of the fractures at the base of the skull was greater at the entrance site and in 4 cases the exit site showed fractures of greater magnitude and number. In two individuals no fractures were detectable in the cranial fossae. Fracture patterns at the exit site exceeding those of the entrance wound were found in 7 out of 59 deceased and 5 of these individuals had fractures at the exit but not at the entrance wound site (calibre of the guns used: .22 up to 7.65 mm). In six out of these seven cases (86%) similar findings were observed at the base of the skull while one individual (14%) showed no fractures in the cranial fossae.

Evaluating exclusively fractures at the base of the skull, it was found that 17 out of 59 cases (29%) showed greater fractures at the entrance site while in 21 individuals (36%) no relevant differences occurred. In 16 cases (27%) the exit fractures exceeded those of the entrance site and in the remaining 5 no fractures at the base of the skull were found. The results are listed in Table 2.

The evaluation of the magnitude of cranial bullet fractures in relation to the type/calibre of the gun used are listed in Table 3.

Table 2 Comparison of the magnitude and the number of exit and entrance fractures of the vault and at the base of the skull in 59 cases of low velocity gunshots to the head

Vault fractures	Fractures at the base of the skull			
	Entrance > exit	Entrance = exit	Entrance < exit	No fractures
Entrance > exit (n = 27; 46%)	9 (33%)	10 (37%)	6 –	2 –
Entrance = exit (n = 25; 42%)	8 (32%)	11 (44%)	4 –	2 –
Entrance < exit (n = 7; 12%)	–	–	6 (86%)	1 –
Total (n = 59)	17 (29%)	21 (36%)	16 (27%)	5 –

Discussion

The diagnostic value of different magnitudes of fracture lines in the skull at the entrance and exit site of the bullet for the determination of direction of fire was studied by Smith et al. [9]. The authors reported that exit radial fracture lines are not as long as those associated with entrance wounds. Furthermore, Smith and coworkers found that tertiary fractures at the exit site have a reduced number of concentric fracture lines which additionally show smaller radii when compared to those localized at entrance

Table 3 Comparison of entrance and exit fracture patterns in relation to the type/calibre of the gun used (n = 59; en: entrance site: ex: exit site).

Calibre (n = 59)	Vault fractures			Fractures at the base of the skull			
	en > ex	en = ex	en < ex	en > ex	en = ex	en < ex	no fractures
.22 (n = 8)	3	4	1	4	2	2	–
6.35 mm (n = 3)	1	–	2	–	–	1	2
7.65 mm (n = 22)	10	9	3	2	11	8	1
.32 (n = 3)	2	1	–	–	2	1	–
9 mm (n = 8)	6	2	–	3	2	3	–
.357 mag. (n = 2)	–	2	–	1	1	–	–
.38 special (n = 3)	–	2	1	2	–	1	–
10.4 mm rev. (n = 1)	1	–	–	–	1	–	–
unknown (n = 9)	4	5	–	4	2	1	2

wounds. The differences were explained by a loss of energy of the bullet at the entrance site of the skull. Since the magnitude of entrance-associated fractures was assumed to be always greater than that of the exit fractures, such a difference could indicate the direction of fire especially when the lesser exit fractures terminate at those of greater magnitude at the entrance site [9]. There is no doubt that fracture lines terminating abruptly at pre-existing ones are a useful indicator for an estimation of direction of fire. The linear fractures related to the entrance wound travel faster than the bullet and the fracture lines associated with the exit wound according to the rule of Puppe [3, 5–7]. Even though the biochemical explanation for the differences in the magnitude of entrance and exit skull fractures given by Smith et al. [9] seems to be conceivable, some exceptions could be observed in our series obviously limiting the diagnostic value of this parameter. However, 46% of our cases showed fractures at the entrance site unambiguously greater than those of the exit wound of the skull supporting the findings of Smith and coworkers [9]. On the other hand, no relevant differences in the fracture patterns occurred in 42% and in 11% the exit fractures were even greater than those of the entrance site. The absence of apparent differences in the magnitude of entrance and exit fractures can be explained in the majority of our cases by a fragmentation of the skull after the use of large calibre handguns with a high energy of the bullet limiting a further evaluation of the fracture patterns. In the remaining cases, however, different anatomical and technical factors which could have influenced the results must be discussed. In this context, type and calibre of the gun/ammunition used is of particular interest. Considerable differences in the gas pressure, in weight, energy and velocity of the projectile can be observed even though the bullets have similar calibres. Furthermore, it is of interest whether a projectile has a full metal jacket – as commonly observed in pistols – since such bullets show a reduced loss of energy after penetration of the skull when compared to semi-jacketed missiles due to a deformation and/or fragmentation of the projectile. These factors could explain that a bullet can still have a sufficient energy for penetration of the vault at the exit site even though small calibre handguns had been used. On the other hand, the type of the ammunition used cannot totally explain the variations in our results since apparent differences in the fracture patterns at the entrance and exit site occurred even though ammunition with similar ballistic characteristics (weight, calibre, energy and velocity of the bullets) was used. Therefore it must be concluded that anatomical variations in the skull and in particular the localization of the trajectory have considerably influenced our findings. It is of importance whether the skull wounds are caused by contact or distant shots since different shot-induced intracranial overpressures can be expected. In this context it must also be discussed that reduced intracranial overpressures can occur in contact shots localized at the temporal site of the skull since the interposition of the temporal muscle between the muzzle of the gun and the skull can be responsible for a partial muffling of the intracanial over-pressure when compared to contact shots at skull regions with a more direct contact between muzzle and skull.

With regard to these different parameters possibly influencing the features of shot-induced cranial fracture patterns, it seems conceivable that the entrance fractures must not always have a greater magnitude and number than the fractures at the exit site. This is supported by our observation that in 5 of our cases fractures were exclusively present at the exit site. It must be emphasized, however, that in these cases as well as in 6 further individuals with no fractures at the entrance or at the exit site, small calibre handguns (.22 Derringer, 6.35 mm, 7.65 mm) were used. These results are in accordance with those of Sellier [8] who found that secondary fractures can possibly occur after the use of 7.65 mm pistols but are almost regularly observed in handguns with a calibre of at least .38 special or 9 mm Para. In addition, Sellier reported that such fractures frequently originate from the entrance site but not regularly [8].

An evaluation of fractures at the base of the skull revealed that in approximately 30% of the cases with entrance fractures greater than those of the exit site, similar findings could be observed in the cranial fossae. On the other hand, contrasting results without relevant differences or even with exit fractures exceeding those of the entrance wound occurred indicating that the marked degree of fractures at the base of the skull shows no correlation to that of the skull fractures. Comparing the diagnostic value of differences in the fractures of the entrance or exit site between vault and base of the skull, it could be noted that the fracture patterns of the skull provide more reliable information on direction of fire (in our series 46% positive results) than that found at the base of the skull (29% positive results). But it must be concluded that differences in the magnitude and the number of fracture lines at the entrance and exit sites of the skull or at the base of the skull alone are not reliable parameters for the determination of the direction of the bullet. They can only support an estimation of direction of fire performed on the basis of other findings such as the skin wound morphology, the beveling of the entrance and exit skull defect, and the detection of fracture lines abruptly terminating pre-existing (entrance) fractures [1–4, 7, 10]. Even though exit skull fractures exceeding those of the entrance site did not occur after the use of large calibre handguns (> .38 special) almost regularly due to a fragmentation of the skull, such findings were found in the fracture patterns at the base of the skull (in our series after the use of 9 mm pistols). These results and the observation that entrance fractures smaller or greater than those of the exit site were detectable in individuals also shot by guns of larger calibres up to .38 special can be explained by anatomical and technical parameters and indicate that no reliable conclusions on the weapon used can be drawn from the fracture patterns of the vault or at the base of the skull. It can only be assumed that the absence of fractures at the base of the skull points to the use of small calibre handguns with a calibre up to 7.65 mm while a fragmentation of the skull indicates the use of handguns with larger calibre (> 7.65 mm). However, exceptions due to anatomical variations

of the skull and to technical factors of the gun or the ammunition used seem to be possible.

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