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TECHNICAL NOTE

Effect of shortening the barrel in contact shots from rifles and shotguns

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Abstract In a suicidal gunshot fired to the chest from a carbine, the barrel of which had been shortened to half its original length, an unexpectedly large degree of destruction of the anterior thoracic wall with extensive undermining of the subcutis was found. This phenomenon was investigated for reconstructive purposes by firing test shots from two different long guns (caliber 7.92×57 repeating rifle with full-jacketed pointed bullet and caliber 12/70 single-barreled shotgun with shotgun slug) into blocks of soap (38×25×25 cm). The contact shots were fired before and after shortening the barrels (repeating rifle from 60 to 30 cm and single-barreled shotgun from 72 to 36 cm). The volume of the cavities in the simulant was visualized three-dimensionally with the help of a multislice computed tomography (CT) scanner and calculated sectionally. With the repeating rifle and the single-barreled shotgun, the shots from the sawed-off barrels produced significantly larger cavity diameters in the first section of the bullet track. This effect is attributable to the fact that, with a shortened barrel, the gas pressure at the muzzle is higher, thus, leading to increased expansion in the initial part of the wound track in contact shots.

Keywords Contact shot · Shortened barrel · Rifle · Shotgun · Computed tomography

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Introduction

Long guns with shortened barrels are mostly used in connection with criminal offences. Especially, shotguns are shortened for criminal purposes to make it easier to carry them unnoticed [1–3]. In contrast, suicidal acts are rarely committed with shortened long guns. When investigating a suicide of this type, it could be demonstrated that a contact shot from a sawed-off barrel may cause atypical findings in the gunshot entrance region [4]. In the reported gunshot to the chest, several abnormalities were found:

- An unusually large stellate entrance wound,
- An oversized powder cavity with extensive undermining of the subcutis and destruction of corresponding parts of the precordial thoracic wall,
- A perforation of the skin near the entrance wound caused by a rib fragment displaced contrary to the direction of the shot, and
- A disproportionately small exit hole.

For experimental investigation of this phenomenon, comparative test shots with two different weapons were fired to blocks of soap (before and after shortening the barrel).

Table 1 Technical data of arms and ammunition

Weapons	Ammunition	Test shots fired from
Repeating rifle Model carbine 98 k Manufactured by Mauser, Oberndorf/Germany Caliber 7.92×57 Weapon no. 5382	Centerfire cartridges FNM with full-jacketed pointed bullet of Fabrica Nacional de Municoes de Armas, Chelas/Moscavide/Portugal: caliber, 7.92×57; bullet mass, 12.7 g; bullet length, 35.0 mm; powder mass, 2.87 g	Original barrel length, 60 cm; v_o, 745 m/s Shortened barrel length, 30 cm; v_o, 604 m/s
Single-barreled shotgun Model 18 M Manufactured by Izhevsky-Baikal, Izhevsk/Russia Caliber 12/70 Weapon no. 8841224	Shotgun slug cartridges Rottweil Brenneke of Dynamit Nobel (now RUAG Ammotec) Fürth/Germany: caliber, 12/70; slug mass, 31.0 g; slug length, 31.0 mm; powder mass, 1.84 g	Original barrel length, 72 cm; v_o, 430 m/s Shortened barrel length, 36 cm; v_o, 400 m/s

Materials and methods

Test shots

For the test shots, a repeating rifle, make Mauser (caliber 7.92×57, carbine 98 K), and a single-barreled shotgun, make Izhevski-Baikal (caliber 12/70, model 18 M) were used. The contact shots to blocks of soap measuring 38×25×25 cm (Permatin, Stein am Rhein, Switzerland) were fired with the ammunition described in Table 1 before and after sawing off the barrels. In all the shots, the same force was applied for the contact between the muzzle and the soap block serving as target medium (approximately 25 N). In addition to the actual test shots, muzzle velocities were determined with a measuring device using a photoelectric barrier type BMC 12 (Mehl, Diebach, Germany).

The 60-cm long barrel of the repeating rifle was shortened from 60 to 30 cm. The muzzle velocities measured were 745 m/s (with a barrel length of 60 cm) and 604 m/s (with a barrel length of 30 cm; Table 1).

For the shotgun, the 72-cm long original barrel was shortened to 36 cm; before sawing off the barrel, the shotgun slugs reached a muzzle velocity of 430 m/s, and after shortening the barrel, it was 400 m/s (Table 1).

CT examinations

To visualize the cavities and to determine their volume, the soap blocks were examined by means of computed tomography (CT).

CT method

The examinations were performed on a multislice CT scanner (Somatom 16 VolumeZoom, Siemens, Erlangen,

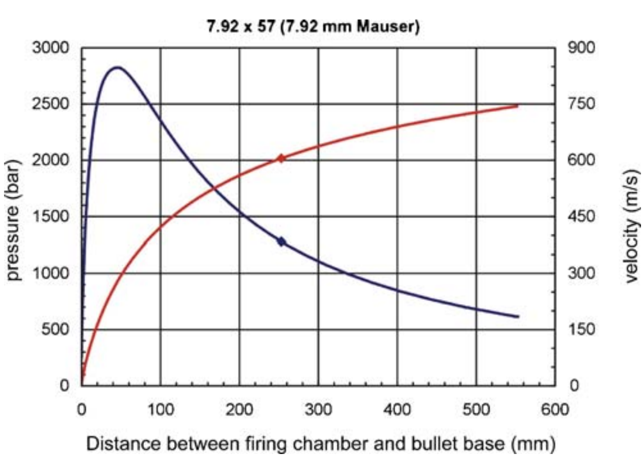

Fig. 1 Pressure (*black line*) and velocity (*gray line*) in the barrel of the caliber 7.92×57 repeating rifle. The *marked points* indicate the values achieved with half the barrel length

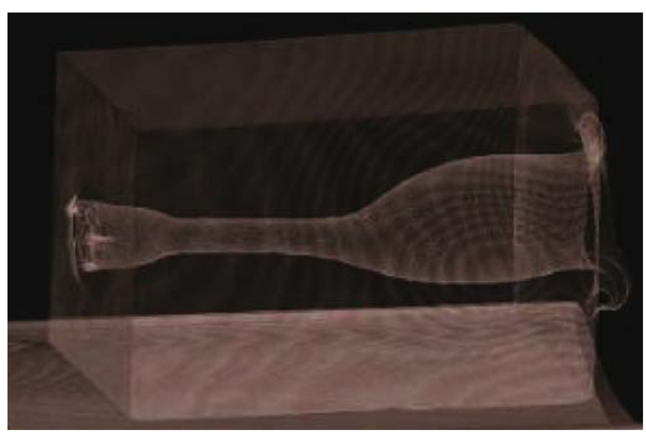

Fig. 2 Three-dimensional CT image of the cavity the shot produced in the simulant. The entrance hole is on the *left*, the exit hole on the *right* side of the soap block. Contact shot from the caliber 7.92×57 repeating rifle (with original barrel) using a full-jacketed pointed projectile

Germany). Scan acquisition parameters were identical in all objects (140 kV; 120 mAs; collimation, 0.75 mm). Axial scans were reconstructed with 0.75- and 5-mm slice thicknesses. Axial, sagittal, coronal (5-mm slice thickness), and 3D projections and animations were reconstructed on an external workstation (Aquarius Net, Terra Recon, Sun Mateo, CA, USA).

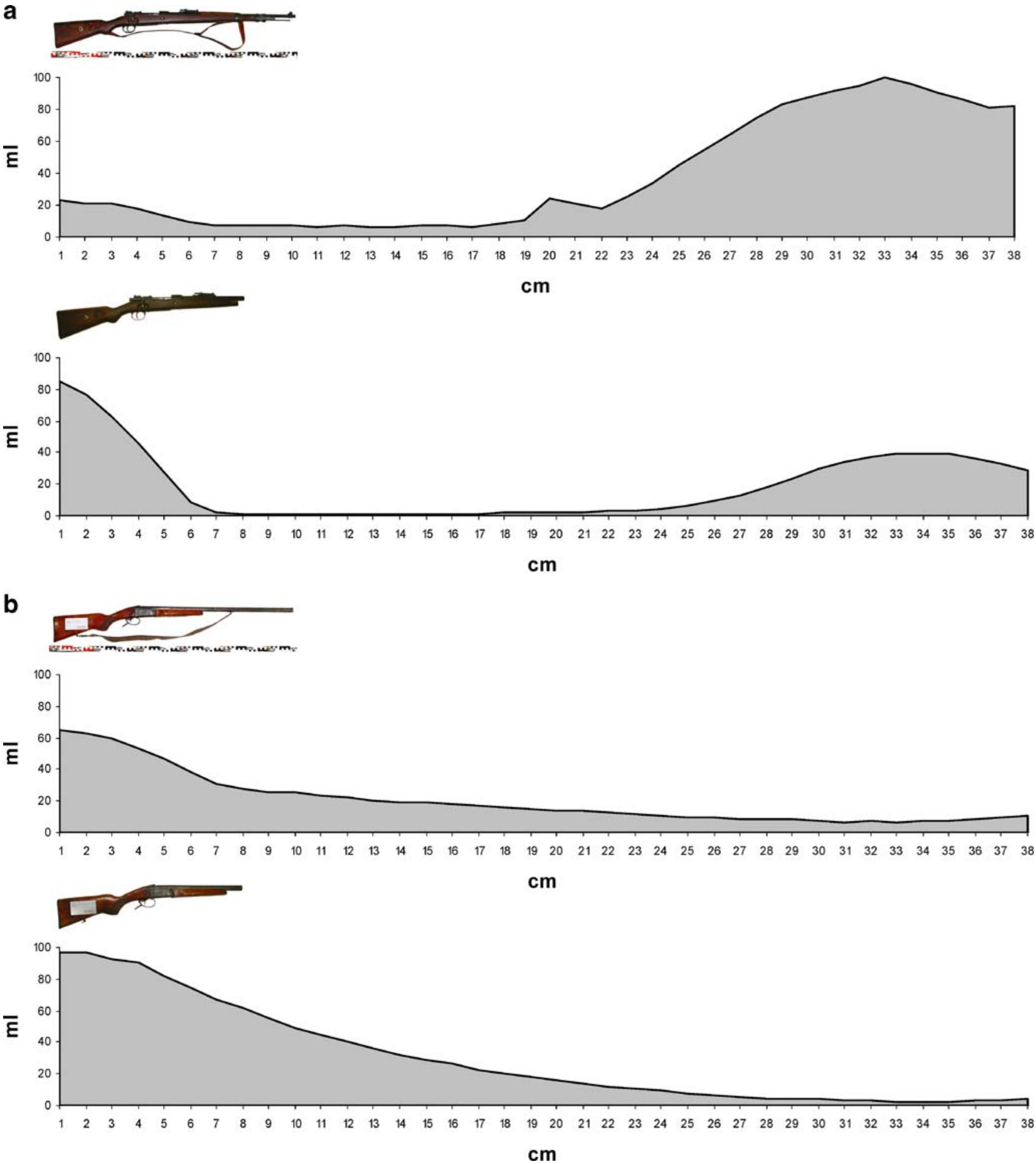

Fig. 3 **a** Diagram of the bullet track volumes after test shots from the caliber 7.92×57 repeating rifle (*above*, before shortening the barrel; *below*, after shortening the barrel); *x*-axis, bullet track in cm; *y*-axis, cavity volume in ml. **b** Diagram of the bullet track volumes after test shots from the caliber 12/70 single-barreled shotgun (*above*, before shortening the barrel; *below*, after shortening the barrel); *x*-axis, bullet track in cm; *y*-axis, cavity volume in ml

Volumetric method

Defined volume contours were manually traced on each 0.75-mm axial slice, and the whole volume was quantified automatically by adding up these slice volumes (manufacturer's CT computer software, Siemens).

Interior ballistics

If muzzle velocities are known for the same cartridge with two different barrel lengths, the pressure curve of the propellant gases and the speed curve of the bullet in the barrel can be calculated, provided there is a normal cartridge configuration (admissible maximum pressure is not exceeded, propellant burns completely in the barrel before the projectile exits). This calculation is based on the thermodynamic model of interior ballistics for which computer programs are available.

The results of this calculation (see example in Fig. 1 for the Mauser repeating rifle) indicate the muzzle velocity and the pressure inside the barrel for any barrel length.

However, the interior ballistic calculation using the thermodynamic model is based on the assumption that the pressure distribution inside the barrel is uniform. But, as the propellant gases move with the same velocity as the projectile at the bullet floor, whereas, at the base plate of the case, they are at rest, pressure decreases along the barrel according to Bernoulli's law: For a non-viscous, incompressible fluid in a steady flow, the sum of the pressure, potential, and kinetic energies per unit volume is constant at any point (fundamental law of fluid mechanics). Consequently, the actual muzzle gas pressure is lower than the pressure indicated for the muzzle exit in the model calculation. The reduction can be roughly calculated with the help of Bernoulli's equation.

Results

Test shots

All four contact shots passed completely through the soap blocks (Figs. 2 and 3a,b).

In the shortened repeating rifle, the cavity volume in the first 5 cm of the simulant was 297.01 ml and, thus, significantly larger than that observed with the original barrel length (96.72 ml). From 6 cm onward, the volume relation was inverse so that, for the remaining bullet track, the volume values were 1,359.21 ml for the test shot with the original barrel and 429.34 ml for the shot fired after shortening the barrel (Fig. 3a).

Comparable results were obtained with the test shots using shotgun slug ammunition. Up to a distance of 21 cm along the bullet path, the cavity volume was larger with the shortened barrel (1,064.43 ml) than with the non-manipulated shotgun (633.18 ml). For the remaining bullet track, the volumes were 151.24 ml for the original barrel and 90.78 ml for the sawed-off barrel (Fig. 3b).

Interior ballistic calculations

The interior ballistic calculations resulted in the data indicated in Table 2. After shortening the barrel, the gas pressure at the muzzle was 2.8-times higher in the rifle and 2.5-times higher in the shotgun.

Discussion

The assessment of gunshot injuries is often a great challenge in medicolegal practice. Gunshot findings can be atypical, unspecific, or ambiguous.

If the barrel of a long gun is shortened, bullet velocity decreases. In pellet shots, the distance-dependent shotgun pellet pattern may change [5–8]. The present study shows that, in contact shots, shortening of the barrel brings about an increased release of energy in the initial section of the bullet track. Based on the results of interior ballistic calculations, this effect is attributable to an elevated gas pressure at the muzzle, affecting the initial section of the bullet track in contact or near-contact shots.

For blank-firing hand guns, it has been repeatedly demonstrated [9, 10] that the muzzle gas pressure may possess a relevant potential. Analogous to our investigation results, Rothschild differentiated between short-barreled blank-firing hand guns with a higher energy density (of

Table 2 Data of interior ballistic calculations

	Cartridge	Barrel length (cm)	Measured v_o (m/s)	Calculated v_o (m/s)	Calculated value of the gas pressure at the muzzle (bar)	Corrected value of the gas pressure at the muzzle (bar)	Proportion of burned propellant (%)
Rifle	7.92×57	60	745	745	614	335	95
		30	604	605	1280	949	86
Shotgun	12/70	72	430	431	39	31	100
		36	400	390	91	79	100

the gas jet) at the muzzle and less dangerous weapons with long barrel mock-ups (barrel length > 120 mm in pistols and >135 mm in revolvers) [11].

The results of our test shots give an explanation for the atypical gunshot entrance wound described in our case of a suicidal gunshot to the chest from a shortened carbine [4]. Consequently, the stellate entrance wound, the oversized powder cavity with extensive undermining of the subcutis, and the destruction of the corresponding parts of the thoracic skeleton are due to the elevated muzzle gas pressure. The shortened barrel may, thus, cause an injury pattern vaguely resembling pellet shots from a short distance [12] or hits of shotgun slugs [13]. A stellate entrance as described in our case is usually not seen in contact wounds of the trunk [14].

Computed tomography has repeatedly been used in studies of wound ballistics (e.g., [15–17]). By applying it to the determination of cavity volumes in simulants, as described in this paper, sectional measurements can be performed, allowing exact conclusions as to the energy released along the bullet path. A special advantage of this method is that volumes can be determined without manipulating the soap block (e.g., by cutting it open).

The results once more underline the usefulness of an interdisciplinary approach to experimental wound ballistics, as was also emphasized recently in some other publications [17–19].

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