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ORIGINAL ARTICLE

Gunshot energy transfer profile in ballistic gelatine, determined with computed tomography using the total crack length method

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Abstract By measuring the total crack lengths (TCL) along a gunshot wound channel simulated in ordnance gelatine, one can calculate the energy transferred by a projectile to the surrounding tissue along its course. Visual quantitative TCL analysis of cut slices in ordnance gelatine blocks is unreliable due to the poor visibility of cracks and the likely introduction of secondary cracks resulting from slicing. Furthermore, gelatine TCL patterns are difficult to preserve because of the deterioration of the internal structures of gelatine with age and the tendency of gelatine to decompose. By contrast, using computed tomography (CT) software for TCL analysis in gelatine, cracks on 1-cm thick slices can be easily detected, measured and preserved. In this, experiment CT TCL analyses were applied to gunshots fired into gelatine blocks by three different ammunition types (9-mm Luger full metal jacket, .44 Remington Magnum semi-jacketed hollow point and 7.62×51 RWS Cone-Point). The resulting TCL curves reflected the three projectiles' capacity to transfer energy to the surrounding tissue very accurately and showed clearly the typical energy transfer differences. We believe that CT is a useful tool in evaluating gunshot wound profiles using the TCL method and is indeed superior to conventional methods applying physical slicing of the gelatine.

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Introduction

By virtue of having similar densities as muscle (1.06 g/cm^3) and their availability, glycerin soap and ordnance gelatin have proven to be useful in such experiments.

Glycerin soap has several advantages. Apart from easy storage and handling, glycerin soap keeps its shape after deformation by passage of a projectile, thus permitting an assessment of not only the permanent but also of the temporary cavity; however, due to the opacity of glycerin soap, the wound channel is not visible from the outside. Several authors [1, 2] showed that computed tomography (CT) scanning on glycerin soap blocks delivers an accurate and three-dimensional image of the wound channel without having to open the block or creating a mould.

Fackler et al. [3] showed as early as 1985 the usefulness of ordnance gelatine as a soft-tissue stimulant when studying a projectile's wound profile. Due to its large degree of translucency, the projectile passage can be documented with high-speed cameras and evaluated; however, gelatine has several drawbacks. Apart from being decomposition-prone and therefore resulting in a brief storage life, it is rather elastic and tears easily. This feature not only makes cutting uniformly thin slices extremely difficult, but also results in lacking temporary cavity as opposed to glycerine soap. The assessment of energy transfer to the tissue along a projectile course is, therefore, not possible by measuring the amount of displaced material. Several groups have studied the damage to gelatine with CT in a qualitative fashion [4–6]; however, these studies do not show how much energy was transferred to the tissue.

By measuring the total crack lengths (TCL) along a projectile course through gelatine as described in the literature [7, 8], one can calculate the amount of energy transferred to the tissue with the formula

$$\Sigma \mathrm{r}_{\mathrm{i}} = c \times (E)_{\mathrm{i}}$$

[9]. The Σr_i refers to the sum of the length of all the cracks of a section of the projectile's passage, c is a constant to be defined and $(E)_i$ is the amount of energy transferred to the surrounding tissue of such a passage section.

Measuring these gelatine cracks poses several problems. Firstly, due to the poor contrast of the cracks in the gelatine, their detection may prove difficult. Schyma [10] overcame this problem by adding acryl paint to the front side of the block, which was sucked into the temporary cavity and led to a clear staining of the cracks.

Secondly, the cutting of ordnance gelatine into thin slices, a task necessary if a high degree of accuracy in determining the energy transfer with the TCL method is required, may prove difficult. Very thin slices may tear or break, thus rendering a tear length assessment unreliable. For these reasons, we studied the possibility of the TCL method with CT in a non-destructive fashion with CT.

Method and materials

Two ballistic gelatine blocks (40×25×25 cm) were used. A 9-mm Luger, full metal jacketed (9-mm Luger FMJ; weight, 8 g; initial velocity, 350 m/s) and a .44 Remington Magnum semi-jacketed hollow point (44 Rem. Mag. SJHP; weight, 15.6 g; initial velocity 450 m/s) round were fired from a distance of 5 m at one gelatine block, and one 7.62×51 RWS Cone-Point (7.62 RWS Cone-Point; weight, 9.5 g; initial velocity, 830 m/s) round (Fig. 1) was fired from 5 m at the second gelatine block.

Both blocks then underwent CT scanning with a GE Lightspeed QX/i unit (General Electric Medical Systems, Milwaukee, WI) with 2.5 mm slice thickness. Using a Leonardo workstation (syngo CT software, Siemens Medical Solutions, D-91301 Forchheim, Germany), two- and three-dimensional reconstructions were calculated.

The gelatine block CT data was analysed on two-dimensional images and the TCL determined as described previously [6, 7] (Fig. 2). Cracks due to projectile fragments were not included. This procedure was repeated every four slices, therefore, resulting in wound crack measurements in precise 1-cm steps.

Radiation streak artefacts could be largely eliminated or at least relevantly reduced with proper reconstruction windowing.

Fig. 1 Used ammunition. **a** A 9-mm Luger full metal jacket. **b** A .44 Remington Magnum semi-jacketed hollow point. **c** A 7.62×51 RWS Cone-Point

Results

The CT measurement of the TCL of the different ammunition types clearly showed the typical energy transfer differences. The 9-mm Luger FMJ delivered a minimal amount of energy to the gelatine with the maximum between 28 and 33 cm from the entrance (Fig. 3). By contrast, the steep rise in TCL seen in the semi-jacketed projectile wound profiles after only a few centimetres of penetration depth [maxima at 8 cm of the 44 Rem. Mag. SJHP (Fig. 4] and 11–17 cm of the 7.62×51 RWS Cone-Point (Fig. 5), respectively reflect the high energy transfer typical for these ammunition types, espe-

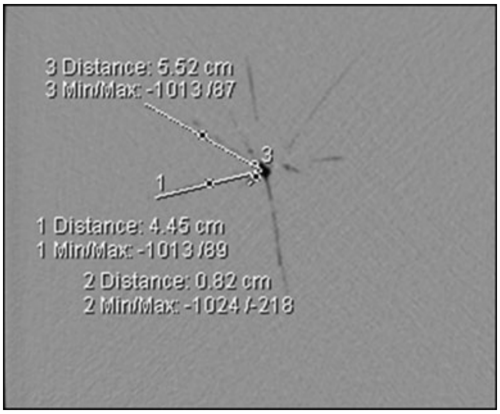

Fig. 2 Screenshot of a two-dimensional reconstruction of a 2.5-mm thick slice of gelatine upon which a 7.62×51 RWS Cone-Point was fired. Note the clearly visible cracks in the gelatine which can the be measured using the CT software

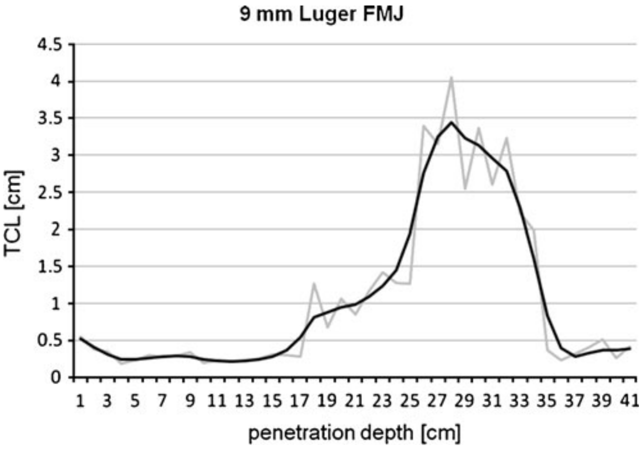

Fig. 3 TCL curve of the 9-mm Luger FMJ projectile (*grey line* actual lengths; *black line* smoothed)

cially when comparing the smoothed TCL profiles (Fig. 6) (smoothing according to Rutishauser [11]).

Discussion

The CT measurement of the TCL reflects the energy transfer of different projectiles within a wound profile very graphically and allows for the calculation of the transferred energy to the surrounding tissue, i.e. gelatine, thus permitting conclusions as to the temporary cavity and the damage inflicted to living victims in the same way as the visual TCL analysis.

However, the CT TCL measurement has two very great advantages. Firstly, one can reconstruct very thin slices in the range of even less than 1 mm. This feature, impossible when cutting gelatine due to its wobbly consistency and its tendency to tear, results in far more accurate wound profile measurements.

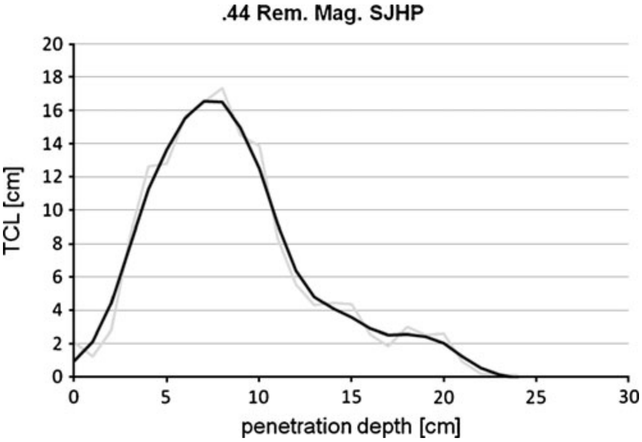

Fig. 4 TCL curve of the .44 Rem. Mag. SJHP projectile (*grey line* actual lengths; *black line* smoothed)

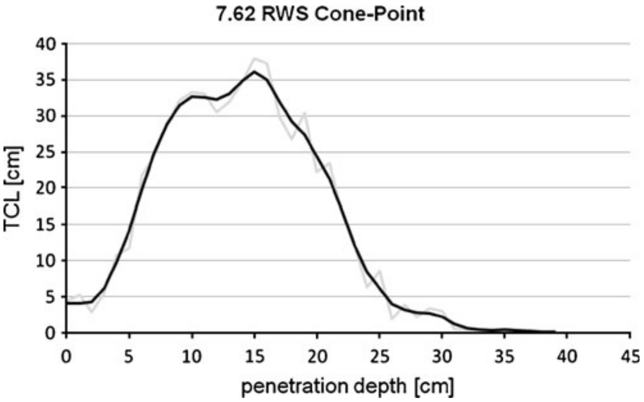

Fig. 5 TCL curve of the 7.62×51 RWS Cone-Point projectile (*grey line* actual lengths; *black line* smoothed)

Secondly, gelatine must be kept refrigerated to prevent it from decomposing; however, even if kept cool, the visibility of the cracks will be reduced with increasing storage time. With CT, the data of the gelatine blocks can be stored permanently without loss of crack visibility and examined at a later point in time if necessary.

Conclusion

Due to the fact that the digital CT data can be stored indefinitely and very thin slice thicknesses are possible with CT, we believe that CT is a useful tool when examining gunshot wound profiles with the TCL method.

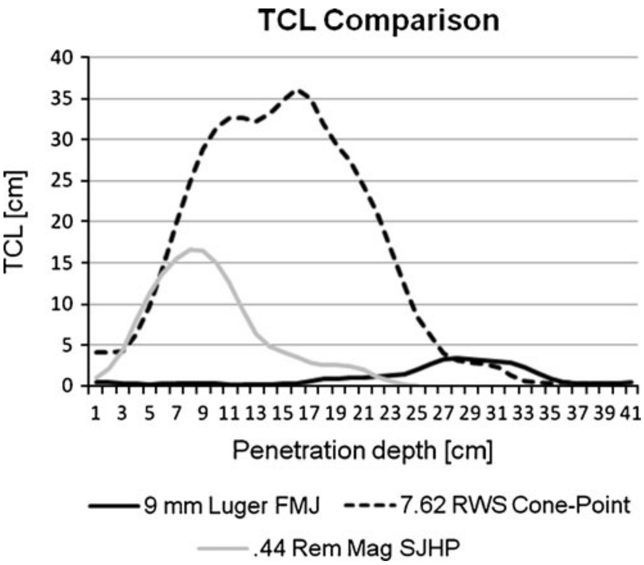

Fig. 6 Smoothed curves of the TCL of the three ammunition types, clearly depicting their different energy transfer behaviour along their passage through the gelatine

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Conflict of interest No conflict of interest.

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