Depth Analysis of Pressure and Temporary Cavity Expansion during Ballistic Impact from Handguns and Rifles

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Summary

Ballistic experimentation of handguns and rifles was conducted into gelatin to biomechanically evaluate quantifiable metrics including energy transfer and temporary cavity. Characterizing combinations of firearms and bullets may provide emergency physicians insight into the magnitude and location of potential injury.

Introduction

In the United States, approximately 40,000 firearm-related deaths occur every year [1], and an indirect way to reduce death in civilian shootings is informing trauma clinicians with biomechanical quantification of projectile damage and potential tissue response [2]. Previous experimental ballistic studies have independently analyzed pressure and expansion of the temporary cavity in ballistic gelatin over time [3], but there has been limited attention to analyzing the relationship of pressure and cavity over gelatin *depth* based on bullet type, which may be beneficial in informing clinical care.

Methods

Eleven firearms and bullets used in community violence including handguns, sub-machine guns, and automatic rifles were selected to compare potential tissue damage metrics. A 20% synthetic ballistic gelatin at 20°C (Clear Ballistics, Greenville, SC) was used to simulate soft tissue response with less temperature dependence and simpler formation than ordnance gelatin. The synthetic gelatin model was recently shown to be biofidelic to porcine leg muscle [4]. A calibrated small synthetic gelatin block (25x15x15 cm) or larger block (25x25x25 cm) was used depending on muzzle-velocity [5]. High speed video (50,000 fps) and two pressure transducers (300,000 fps) measured bullet motion and gelatin pressure, respectively. Maximum cavity diameter, depth of maximum cavity, and bullet velocity, and kinetic energy were calculated using video analysis software (Tracker, Aptos, CA).

Results and Discussion

Bullets fired from rifles generated substantially greater energy transfer, maximum pressure, and maximum cavity diameter than bullets from the handguns (Table 1). Observed fragmentation of a 5.56 NATO bullet substantially increased maximum pressure. Maximum temporary cavity diameter and energy transferred to the gelatin expressed a power relationship (R^2=0.94), where increased energy transfer corresponded to greater maximum cavity diameters. Furthermore, bullet mass influenced the *depth* of the maximum temporary cavity, which expressed an exponential relationship (R^2=0.81). Bullets with greater mass produced a maximum cavity at shallower depths into the gelatin, as observed with depths of 3.5 – 6 cm for 40 and 45 caliber bullets and depths of 14.5 – 21 cm for 25 caliber and 5.56 NATO rounds.

Emergency physicians currently implement GSW exploration methodologies independent of the firearm and bullet combination [6], but knowledge of the diameter and depth of the maximum temporary cavity diameter may provide surgical insight into the area of maximum potential injury. Future studies may expand the combinations of firearms and bullets to establish a lethality index with various gelatin boundary conditions for age-specific differences in severity.

Conclusions

Validated synthetic gelatin was used to simulate bullet biomechanics of eleven firearm and bullet combinations over gelatin *depth*. Bullets from rifles produced substantially greater injury metrics, and bullet mass influenced *depth* of maximum temporary cavity. Quantifying the magnitude and *depth* of injury may aid surgeons in clinical decision making.

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References

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Table 1: Ranges of impact and cavity metrics between rounds from handguns and rifles (*frag represents a trial with bullet fragmentation).

Firearm	Caliber	Velocity (m/s)	Energy Transfer (J)	Max Temporary Cavity (cm)	Maximum Pressure (kPa)
Handguns	0.25 – 0.45 in	200 – 280	57 – 235	2.3 – 7.2	53 – 746
Rifles	5.56 mm	875 – 1050	1300 – 1600	17 – 18.4	610 – 1356 (*frag: 2190)