



A systematic review on ricochet gunshot injuries



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ABSTRACT

Ricocheted bullets may still retain sufficient kinetic energy to cause gunshot injuries. Accordingly, this paper reviews the literature surrounding gunshot injuries caused by ricocheted bullets. In doing so, it discusses the characteristics of ricochet entrance wounds and wound tracks, noting several important considerations for assessment of a possible ricochet incident. The shapes of ricochet entrance wounds vary, ranging from round holes to elliptical, large and irregular shapes. Pseudo-stippling or pseudo-gunpowder tattooing, pseudo-soot blackening and tumbling abrasions seen on the skin surrounding the bullet hole are particularly associated with ricochet incidents. Ricocheted bullets have a reduced capability for tissue penetration. Most of the resulting wound tracks are short, of large diameter and irregular—all artefacts of the instability of a bullet that has ricocheted. A ricocheted hollow-point bullet, in particular, may over-penetrate the tissue when the bullet nose is deformed or fails to enter the body in a nose-forward orientation. Similarly, internal ricochet may occur when a bullet strikes hard tissue. Postmortem computed tomographic imaging is useful for localising a bullet and its fragments in the body and characterising the wound track. Ricochet cannot be ruled out in normal-appearing entrance wounds unless that finding is supported by other evidence, including the geometrical constraints of the shooting scene and the absence of ricochet marks and a ricocheted bullet.

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Contents

1. Introduction	46
2. Materials and methods	46
3. Ricochet gunshot injuries	46
3.1. Entrance wound	46
3.1.1. Morphology	46
3.1.2. Pseudo-stippling	46
3.1.3. Bullet wipe	47
3.1.4. Tumbling abrasions	47
3.1.5. Pseudo-soot blackening	47
3.2. Wound track	47
3.3. Internal ricochet	48
4. Other considerations in ricochet incident evaluation	48
4.1. Crime scene	48
4.2. Ricocheted projectile	48
5. Conclusions	49
References	49

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1. Introduction

Projectile ricochet is defined as “the continued flight of a rebounded projectile and/or major projectile fragments after a low-angle impact with a surface or object” [1]. Ricocheted bullets may still be able to cause injuries even after having suffered some loss in velocity. Unintentional injuries and deaths resulting from ricocheted bullets have been reported occasionally, and sometimes the manner of death in such incidents is controversial [2–4]. The *Handbook of Forensic Pathology*, published by the College of American Pathologists (2003) [5], stated that “death of one who is struck by a ricochet from a firearm fired legally may be classified as accident”. However, if death caused by a ricocheted bullet that the discharge was a volitional act or there was an evident intention to threaten or harm somebody with a gun can be judged as voluntarily killing. Even so, humanitarian issues arise from these undesired firearm injuries [2,6–9].

The interpretation of ricochet gunshot injuries can pose a challenge for many forensic pathologists. Any factors, whether bullet entry location or direction or the underlying bony structures, that cause the entrance wound to have an atypical appearance thereby complicate interpretation of the injury. To establish the facticity of a ricochet shooting incident, knowledge about the process of bullet ricochet and a ricocheted bullet’s attendant wounding effect is very important. Gonzales (1934) [10], who examined rectangular gunshot entrance wounds caused by ricochet, was among the first to study ricochet gunshot injuries. Since 1960s, however, research on ricochet gunshot injuries has been conducted by many forensic practitioners and scientists, including Donoghue, Haag, Haag, DiMaio, Hawley, Schyma and Placidi, Gunsentsov, and Hlavaty [1,2,11–17].

This paper reviews the literature surrounding ricochet gunshot injuries with an eye to helping forensic pathologists better understand this issue while serving as a useful reference for interpretation of ricochet gunshot wounds. It discusses the characteristics of entrance wounds and wound tracks such as are caused by ricocheted bullets, examining several factors worthy of consideration during the investigation of a possible ricochet incident.

2. Materials and methods

PubMed, Scopus, SpringerLink, ScienceDirect, AFTE, and university library databases were used as resources for a literature search that centred on the keywords “ricochet gunshot injuries”, “post-mortem imaging” AND “gunshot injuries”, “trace evidence analysis” AND “ricocheted bullet”, and “bullet ricochet”. These searches returned 1502 English-language articles published from January 1900 to January 2017 (in forensic discipline). After excluding overlapping results and numerous other unrelated articles (e.g., articles discussing ricochets caused by nail guns), 112 publications remained for review.

3. Ricochet gunshot injuries

Ricocheted projectiles may retain sufficient energy to cause severe or even fatal injury even after having been decelerated, deformed or fragmented [6,9,12]. The extent and nature of such injuries depend on the physical characteristics of both the projectile and the tissues it encounters—for the former, constitution, shape, mass, velocity, and orientation; for the latter, tissue density, strength, elasticity, and anatomic relationships [18–22]. The overall extent of tissue destruction caused by a penetrating projectile is determined by missile–tissue interaction [23,24].

3.1. Entrance wound

3.1.1. Morphology

Most commonly, ricochet entrance wounds are described as being atypical: large, irregular, elliptical or keyhole or D-shaped, having ragged edges and wide, eccentric, abraded margins. Some have a large stellate appearance [6,13,15,16,25–27]. Ricocheted bullets, being destabilised, yaw and tumble in their postimpact flight. They may strike the body in any orientation, causing entrance wounds whose appearances range from typical round to large and irregular [1,15,27–30]. When Haag (2007) [12] used six cardstock witness panels (at spacings of 15 cm) to explore bullets’ post-ricochet behaviour, one of the tested bullets produced a round hole in the third witness panel but fully yawed on striking the fifth witness panel.

In a case reported by Spitz (1969) [3], a ricochet entrance wound produced by a 9 mm Luger initially went unrecognised because it resembled a close-range entrance wound—this despite the lack of gunpowder and soot deposits around the bullet hole. Even though the accused denied having fired at the victim—but rather claimed to have fired in a different direction—he was convicted of murder. Suspicion of ricochet later arose in response to questions remarking on the absence of gunpowder and soot deposit in the surrounding skin of the bullet hole. When evidence from test firings finally explained the appearance of this gunshot injury by supporting the conclusion that it had been caused by a ricochet rather than a close-range shot, the trial was reopened and the case dismissed. Ricochet thus cannot be ruled out even in cases featuring a round entrance wound.

Gusentsov (2014) [17] further examined the influence of angle of incidence on the morphology of ricochet entrance wounds, performing test shootings at incident angles of 10°, 20°, 30°, 40°, and 50°. Among four groups tested, 44% of entrance wounds were nearly round, 24% were polygonal, 21% resembled English letters (e.g., C, F, G, L), and 11% resembled a slit. Ricocheted bullets tended to create nearly round entrance wounds at low incident angles, but variance in appearance of entrance wounds increased with angle of incidence.

At an incident angle of 10°, Hlavaty et al. (2016) [11] investigated the roles of bullet calibres, bullet types, and impact surfaces on the morphology of ricochet gunshot injuries. The most commonly used handgun calibres—0.22 Long Rifle, 9 × 19 Parabellum, 0.40 Smith & Wesson, and 0.45 Automatic Colt Pistol (ACP) handgun ammunition and 5.56 mm and 7.62 mm rifle ammunition—were selected for the study. Four types of ammunition were used—solid, total metal jacket (TMJ), hollow-point (HP), and full metal jacket (FMJ)—against five targets surfaces: concrete, clay brick, asphalt, aluminium sign, and flat paint-coated drywall (in all experimental cases, ricochet did not occur in bullets encountering drywall at a 10° angle of incidence and above). All examined entrance injuries had at least one atypical characteristic, whether size/shape irregularity, pseudo-stippling, exit wound mimicking, or lack of abraded margins, and no remarkable difference distinguished among wounds from different calibres or bullet types. By contrast, all direct-fire entrance injuries displayed a typical round appearance exhibiting marginal abrasions and having a diameter smaller than that of the bullet producing it. Among the five impact surfaces tested, asphalt ricochets were found to produce the greatest variety of entrance wound appearances—likely owing to the heterogeneous composition of asphalt.

3.1.2. Pseudo-stippling

When the victim is close to the impact site, transference of intermediate surface materials and fragmented projectiles may cause satellite injuries around the bullet hole, manifest as numerous punctate abrasions to the skin [2,6,12,15,16,27,31]. These

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