Tod W. Burke,[1] *Ph.D. and Walter F. Rowe,*[2] *Ph.D.*

Bullet Ricochet: A Comprehensive Review

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ABSTRACT: The urban environment provides many surfaces from which bullets or shotgun pellets may ricochet. Factors that determine whether a ricochet will occur include the nature of the target surface, the angle of incidence, the shape of the projectile, and its velocity. Investigators of shooting incidents in which ricochets may have played a role must pay attention to the nature of the wounds suffered by the shooting victims, the deformation of the bullets or shotgun pellets, the presence of trace evidence on the bullets or shotgun pellets, ricochet marks on surfaces at the scene and the probable geometry of ricochet.

KEYWORDS: forensic science, ballistics, bullet ricochet, criminalistics, wound ballistics

In the urban environment there are numerous surfaces from which bullets or shotgun pellets may ricochet, including streets, sidewalks, floors and walls of buildings, even automobile windshields. Over many decades research has been conducted on the behavior of ricocheting bullets and shotgun pellets [*1–20*]. Of particular interest to researchers are the circumstances under which ricochet will occur, the various factors that influence the angle of ricochet and the predictability of the postricochet trajectory of the projectile. Understanding the results of this research requires familiarity with the geometry of projectile ricochet, as shown in Fig. 1. The *angle of incidence* is the angle between the bullet trajectory prior to ricochet and the surface from which the ricochet occurs; the *angle of ricochet* is the angle between the bullet trajectory after ricochet and the surface from which the bullet ricocheted. The results of this research on the ricochet of bullets and shotgun pellets are summarized as follows:

1. Surfaces have a critical angle of incidence below which projectiles will ricochet [*1,4,16,20*]. For angles of incidence above this value the projectiles will either disintegrate or perforate the surface [*16*]. The critical angle of incidence for bullets striking soft ground is approximately 7° [*4*]; experiments with projectiles ranging from solid brass spheres to 9 mm full metal jacket bullets have shown that the critical angle of incidence for water is between 6 and 7° [*1,14,20*]. The critical angle of incidence for ricochet may depend on the nature of the bullet as well and its velocity: in one series of experiments, 9 mm semi-jacketed hollow point bullets having a nominal muzzle velocity of 1165 ft/s perforated gypsum wall board at an angle of incidence of 5°, while .38 caliber lead semi-wadcutter

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[1]Assistant Professor, Justice/Public Policy Department, North Carolina Wesleyan College, Rocky Mount, NC.

[2]Professor, Department of Forensic Sciences, The George Washington University, Washington, DC.

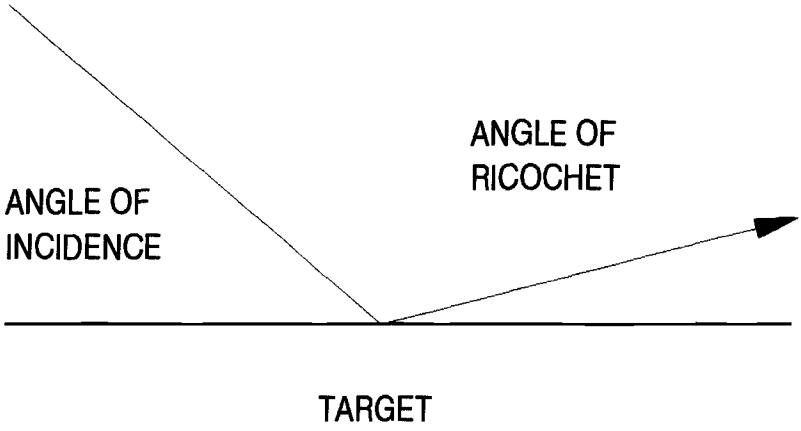

FIG. 1—*Geometry of ricochet.*

bullets with a nominal muzzle velocity of 755 ft/s ricocheted at the same angle of incidence [*19*].

2. The shape of the bullet and its makeup determine whether it will ricochet in a given situation. Round-nosed bullets are more likely to ricochet than flat-nosed bullets; full metal jacket bullets are more likely to ricochet than lead or lead alloy bullets [*21*].

3. Low velocity projectiles are more likely to ricochet than high velocity projectiles [*21*]. The velocity of the projectile also probably has an effect on the angle of ricochet. Haag [*12*] has studied ricochets of lead airgun pellets from smooth concrete. The pellets had a wide range of impact velocities (from 325 feet per s to 550 feet per s); pellets with different velocities showed small, but statistically significant, differences in their ricochet angles. The angles of ricochet for the higher velocities were smaller than those obtained with the lowest velocity; at high angles of incidence (around 60°) the angles of ricochet tended to converge to a common value.

4. Angles of ricochet are typically (although not invariably) low [*1–6,8,11–15,17–20*]. The low angle of ricochet is a result of the loss of energy caused by the distortion or fragmentation of the projectile on impact and by the loss of the energy expended in indenting the target surface. In general, the more rigid the target the lower the angle of ricochet.[3] Flexible target surfaces bend under impact and when rebounding return some of their stored energy to the ricocheting projectile. High angles of ricochet may be seen if the projectile has a high angle of incidence; however, high angles of incidence tend to cause fragmentation of the projectile.

5. The angle of ricochet increases with increasing angle of incidence, with the angle of ricochet being generally lower than the angle of incidence [*2,3,6,8,10,12,15,17,18*]. This is illustrated by Fig. 2, which shows the results of a study in which different types of pistol bullets were fired at a concrete surface at various angles of incidence. Occa-

[3]This conclusion is based on the present authors' re-examination of the data of Jauhari [*6*], Haag [*12*], and Burke et al. [*18*]. Jauhari fired .22 cal. long rifle, .38 cal. full metal jacket and .45 cal. full metal jacket rounds at 1/16" and 1/8" steel, brass and aluminum plates. When ricochets from the same type of metal plate were considered, the ricochet angles for the rebounding projectiles were lower for the thicker (and hence more rigid) plates. When ricochets from plates of the same thickness were considered, the ricochet angles were lowest for the steel plate, which has by far the highest modulus of elasticity. Haag and Burke et al. obtained even lower angles of ricochet from stone and concrete surfaces, respectively. The targets in these studies were very thick (ranging from 1 to 1½ inches in the case of the stone surfaces to a foot or more in the case of the concrete surfaces) and consequently much more rigid than Jauhari's metal plates.

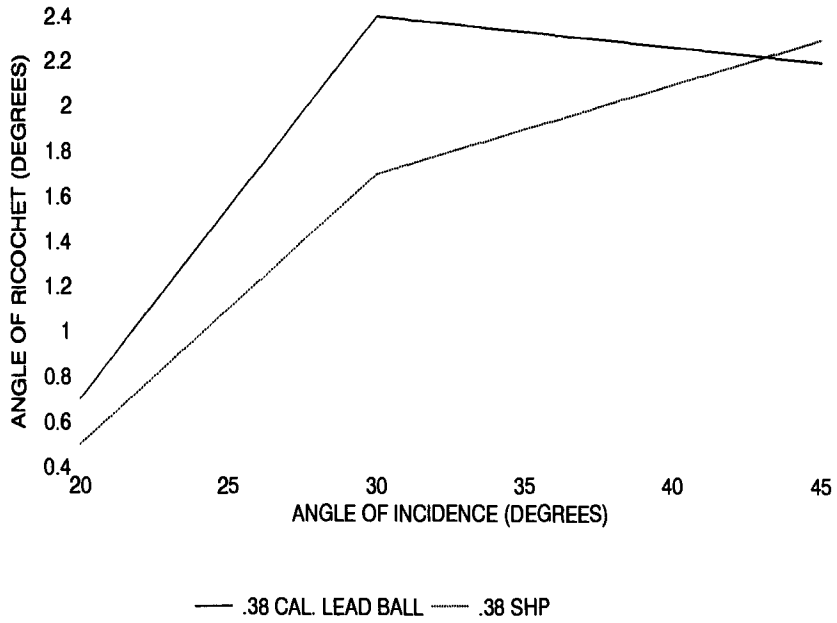

FIG. 2—*Angle of ricochet versus angle of incidence. Solid line = .38 caliber lead ball; dashed line = .38 caliber semi-jacketed hollow point.*

sionally, the angle of ricochet has been found to be greater than the angle of incidence; in such cases, however, the angle of incidence was usually very low and the surface from which the projectile ricocheted was easily cratered (soil, for example) [*2,12,14,19,20*]. However, Haag [*12*] has presented data on the ricochet of .30 cal. M1 carbine rounds from stone surfaces; in this instance one of the shots fired at an angle of incidence of 30° rebounded with an angle of ricochet of 30.5°.

6. Although attempts have been made to produce a mathematical model of bullet ricochet [*9,10*], the trajectory of the bullet after ricochet will in general be impossible to predict in any detail. At any particular angle of incidence the angle of ricochet can vary over a range of several degrees [*15,17,18,19*] and the ricocheting projectile may be deviated from the original plane of flight [*20*].

7. Bullets may tumble after ricochet [*6,7,19*]. This is a result of the change in orientation of the axis of a spinning projectile produced by the collision with the surface. Such tumbling is not unique to ricochets; generally, spinning bullets will tumble after striking virtually any intermediate target. Figure 3 shows the hole made in gypsum wallboard by a tumbling ricochet.

8. When shotgum pellets ricochet from a surface, the pellets will spread out parallel to the surface [*5,15,17*]. The spread increases with the angle of incidence and with the angle of ricochet [*15,17*].

Injuries Resulting from Ricochets

Although both bullets and shotgun pellets lose energy as the result of striking a surface, they retain sufficient energy after ricochet to inflict serious, even fatal injuries, as has been demonstrated on many occasions. In one incident [*5*] a police officer confronted two burglary suspects emerging from a liquor store. One of the suspects appeared to be armed. When the officer fell prone and called on the suspects to halt, the armed suspect

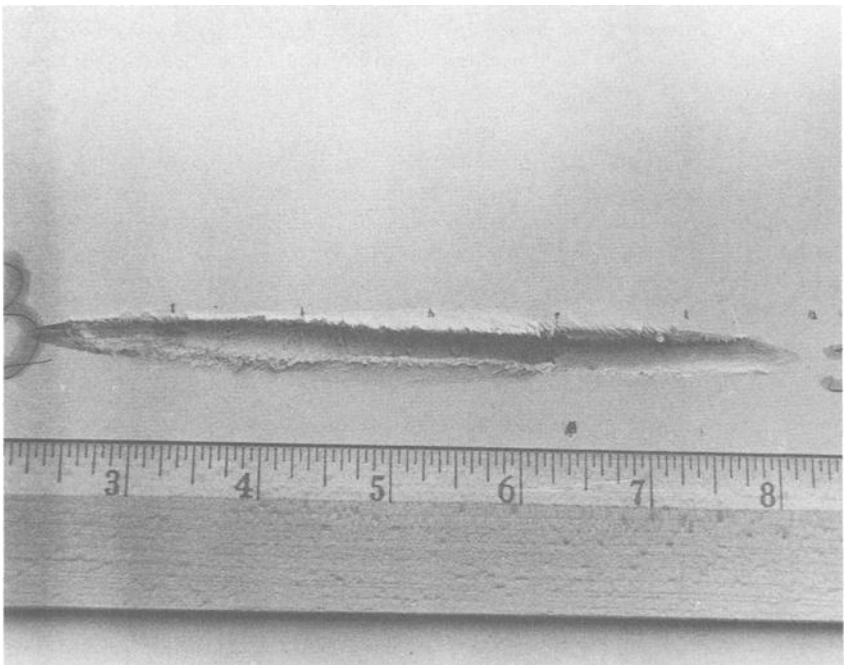

FIG. 3—*Hole made in gypsum wallboard by tumbling ricochet.*

fired at the officer, the bullet striking the concrete road surface six feet in front of the officer and ricocheting to strike him in the forehead. In another shooting incident [*22*], two men were target shooting a .30-06 rifle. One of the rounds struck a piece of building stone left over from the construction of a stone wall. It traveled a distance of more than 1400 yards (over three-quarters of a mile), penetrating a window screen and a window shade before lodging in the abdomen of the victim. It is also important to keep in mind that because ricocheting bullets may be grossly distorted by impact as well as tumbling, they may inflict wounds that involve more tissue destruction than those caused by non-ricocheting bullets.

Investigation of Shooting Incidents in Which Ricochets May Have Occurred

From time to time police officers or other investigators may have to investigate shooting incidents in which ricochets have occurred. The following is a check list of evidence to which special attention should be paid:

Wounds—Wounds inflicted by ricocheting bullets may be elliptical or keyhole-shaped[4] (resulting from the bullet's tumbling and striking the person sideways) [*7*]. Wounds caused by ricocheting bullets are frequently larger and more irregular in shape than normal bullet wounds [*23,24*]. Because ricocheting bullets lose 10 to 20% of their velocity, the wounds they inflict are usually penetrating rather than perforating (that is, the bullets usually lodge within the victim's body, rather than passing straight through) [*24*]. Ricocheting

[4]Elliptical and keyhole-shaped wounds may also result if the bullet passed through another target (including another person) before striking the victim. Keyhole injuries of the skull may also result from bullets striking the head tangentially [*27*].

shotgun pellets may inflict slitlike injuries due to their being flattened by impact [*17*]. If the ricochet occurs close to the body surface, it may produce fragments of bullet or pellet that become embedded in the skin around the wound to produce pseudotattooing that might be initially confused with the powder tattooing or stippling caused by a close-range shot [*24*].

Projectiles—Bullets and shotgun pellets may be distorted or fragmented in ricocheting from a surface. For example, a lead bullet that ricochets from a surface may have one side flattened and burnished to a mirror finish [*24*]. Because ricocheting bullets frequently tumble, they may be embossed with the weave pattern of the victim's clothing on their sides or bases [*24*]. Projectiles may pick up trace evidence from the surfaces from which they ricochet. The trace evidence may aid the investigator in identifying the surface from which the bullet or pellet ricocheted. In one case, a scanning electron microscope was used to identify particles on a bullet as limestone from a stone surface from which the bullet had ricocheted [*25*]. Investigators need to be aware that forensic pathologists may inadvertently destroy such evidence in the course of an autopsy.

The Crime Scene—Ricochets generally leave traces on the surfaces from which the bullets ricochet. Metal from the bullet or pellet will usually be left on the surface and can be readily identified by laboratory tests. The surface may also be gouged or cratered by the ricocheting projectile. The precise nature of the gouging depends on the nature of the surface: soft metal [*26,27*] and wallboard [*19*] will show elongated gouges whose long dimension extends in the direction the projectile was traveling and whose narrow dimension is approximately the diameter of the bullet or pellet (Fig. 4). On the other hand, ricochet marks in soil or sand will be less well-defined [*12*].

Geometrical considerations must play a role in the reconstruction of any shooting

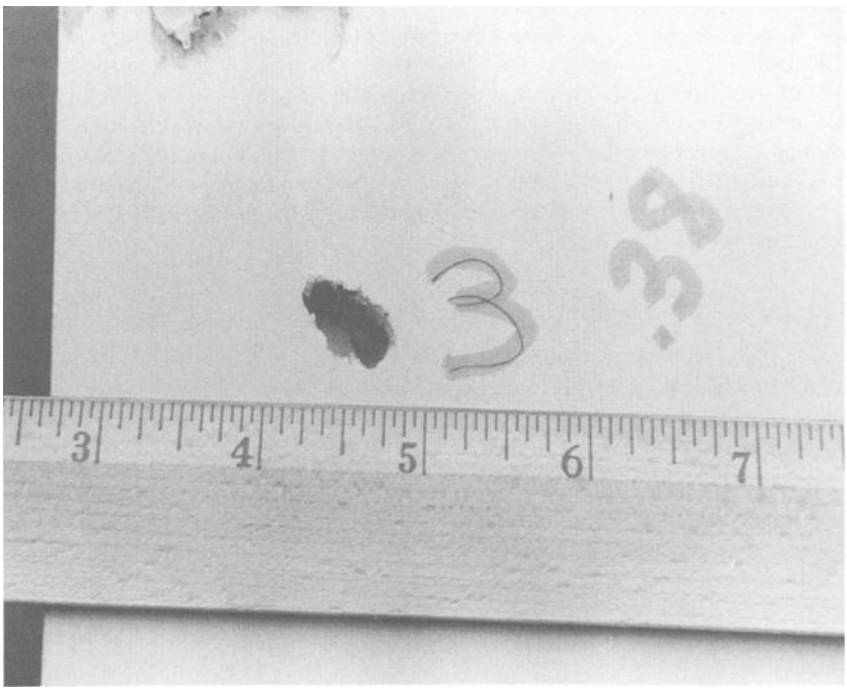

FIG. 4—*Ricochet mark made in gypsum wallboard.*

incident in which ricochets have occurred. It must be kept in mind that angles of ricochet are usually quite small (typically only a few degrees). If a reconstruction requires a large angle of ricochet, it is probably wrong. For example, consider the case in which two police officers were accused of unnecessary use of force following the shooting of a patron in a bar. According to the officers, they were forced to shoot after the clearly inebriated patron refused their directions to drop the pistol he was holding and instead pointed it in their direction. The patron later brought a civil action against the officers and their department. While acknowledging that he was armed, the patron claimed that his pistol was pointed at the floor when the officers wantonly and without cause opened fire. Unfortunately for this claim, one of the police bullets was found lodged in the barrel of the pistol. A "firearms expert" testified for the plaintiff that this bullet ricocheted off the floor and entered the pistol's barrel. Fortunately, another firearms expert was able to point out to the jury the unlikeliness of this scenario—first, the bullet had to ricochet at a high angle and then, while tumbling, enter the barrel of the pistol.

Conclusion

The urban environment provides many surfaces from which bullets or shotgun pellets may ricochet. Factors that determine whether a ricochet will occur include the nature of the target surface, the angle of incidence, the shape of the projectile and its velocity. Investigators of shooting incidents in which ricochets may have played a role must pay attention to the nature of the wounds suffered by the shooting victims, the deformation of the bullets or shotgun pellets, the presence of trace evidence on the bullets or shotgun pellets, ricochet marks on surfaces at the scene and the probable geometry of ricochet.

References

[1] C. Cranz and Becker, K., "Exterior Ballistics," in *Handbook of Ballistics*, Vol. 1, H. M. Stationary Office, London, 1921.

[2] Birkhoff, G., "Ricochet Off Land Surfaces," Ballistic Research Laboratory Report 535, Aberdeen Proving Ground, MD, 21 March 1945.

[3] Jauhari, M., "Ricochet of Cartridge, Ball, S. A., Revolver .380 Mk2 K.F. Bullet," *Journal of the Indian Academy of Forensic Sciences*, Vol. 5, 1966, pp. 29–33.

[4] Sellier, K., *Schusswaffen und Schusswirkung*, Max Schmidt-Römhild, 1969.

[5] Federal Bureau of Investigation, "Bouncing Bullets," *FBI Law Enforcement Bulletin*, Vol. 38, Oct. 1969, pp. 1–9.

[6] Jauhari, M., "Bullet Ricochet from Metal Plates," *Journal of Criminal Law, Criminology and Police Science*, Vol. 60, No. 3, Sept. 1969, pp. 387–394.

[7] Jauhari, M., "Bullet Ricochet," *Indian Police Journal*, Vol. 16, No. 3, Jan. 1970, pp. 43–47.

[8] Jauhari, M., "On the Ricochet of .22 Long Rifle K. F. Bullet," *Journal of the Indian Academy of Forensic Sciences*, Vol. 9, 1970, pp. 14–18.

[9] Jauhari, M., "Mathematical Model for Bullet Ricochet," *Journal of Criminal Law, Criminology and Police Science*, Vol. 61, No. 3, Sept. 1970, pp. 469–473.

[10] Jauhari, M., "Approximate Relationship Between the Angles of Incidence and Ricochet for Practical Application in the Field of Forensic Science," *Journal of Criminal Law, Criminology and Police Science*, Vol. 62, 1970, pp. 122–125.

[11] Sellier, K., Ueber Geschossablenkung und Geschossdeformation, *Zeitschrift für Rechtsmedizin*, Vol. 69, 1971, pp. 217–251.

[12] Haag, L. C., "Bullet Ricochet: An Empirical Study and a Device for Measuring Ricochet Angle," *AFTE Journal*, Vol. 7, 1975, pp. 44–51.

[13] Sellier, K., Verletzungsmöglichkeiten von geschosen, die an Sand oder Beton abgeprallt sind, *Zeitschrift für Rechtsmedizin*, Vol. 78, 1976, pp. 149–158.

[14] Haag, L. C., "Bullet Ricochet from Water," *AFTE Journal*, Vol. 11, No. 3, July 1979, pp. 26–34.

[15] McConnell, M. P., Triplett, G. M., and Rowe, W. F., "A Study of Shotgun Pellet Ricochet," *Journal of Forensic Sciences*, Vol. 26, No. 4, Oct. 1981, pp. 699–709.

[16] Zukas, J. A., "Penetration and Perforation of Solids," in Zukas, J. A., Nicholas, T., Swift,

H. F., Greszczuk, L. B., and Curran, D. R., *Impact Dynamics*, John Wiley & Sons: New York, 1982.
[17] Hartline, P. C., Abraham, G., and Rowe, W. F., "A Study of Shotgun Ricochet from Steel Surfaces," *Journal of Forensic Sciences*, Vol. 27, No. 3, July 1982, pp. 506–512.
[18] Burke, T. W., Griffin, R., and Rowe, W. F., "Bullet Ricochet from Concrete Surfaces," *Journal of Police Science*, Vol. 16, 1988, pp. 264–267.
[19] Jordan, G. E., Bratton, D. D., Donahue, H. C. H., and Rowe, W. F., "Bullet Ricochet from Gypsum Wallboard," *Journal of Forensic Sciences*, Vol. 33, No. 6, Nov. 1988, pp. 1477–1482.
[20] Gold, R. E. and Schecter, B., "Ricochet Dynamics for the Nine Millimeter Parabellum Bullet," *Journal of Forensic Sciences* (in press).
[21] Wilbur, C. G., *Ballistic Science for the Law Enforcement Officer*, Charles C Thomas, Springfield, 1977.
[22] Hatcher, J. S., Jury, F. J., and Weller, J., *Firearms Investigation, Identification and Evidence*, The Stackpole Company, Harrisburg, PA, 1957.
[23] Spitz, W. U., "Injury by Gunfire. Part 1. Gunshot Wounds," in Spitz, W. U. and Fisher, R. S., *Medicolegal Investigation of Death*, Second Edition, Charles C Thomas, Springfield, 1980.
[24] DiMaio, V. J. M., *Gunshot Wounds: Practical Aspects of Firearms, Ballistics, and Forensic Techniques*, Elsevier Science Publishing Co., Inc., New York, 1985.
[25] DiMaio, V. J. M., Dana, S. E., Taylor, W. E., and Ondrusek, J., "Use of Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis (SEM-EDXA) in Identification of Foreign Material on Bullets," *Journal of Forensic Sciences*, Vol. 32, No. 1, Jan. 1987, pp. 38–47.
[26] Mitosinka, G. T., "Technique for Determining and Illustrating the Trajectory of Bullets," *Journal of the Forensic Science Society*, Vol. 11, 1971, pp. 55–61.
[27] Janssen, D. W. and Levine, R. T., "Bullet Ricochet from Automobile Ceilings," *Journal of Forensic Sciences*, Vol. 27, No. 1, Jan. 1982, pp. 209–212.

Address requests for reprints or additional information to
Walter F. Rowe, Ph.D.
Department of Forensic Sciences
The George Washington University
2036 H Street, NW
Washington, DC 20052