

Keyhole Lesions in Gunshot Wounds of the Skull and Direction of Fire

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ABSTRACT: Five cases of gunshot wounds with keyhole lesions of the skull are presented. The corresponding skin wounds are described, and elements of wound configuration are evaluated to determine the direction of fire. A proposed mechanism for the formation of such injuries is outlined.

KEYWORDS: pathology and biology, wound ballistics, ballistics, direction of fire

The features of wound configuration that commonly result when a projectile passes through bone have been described previously [1-5]. Typically, when a bullet penetrates a relatively flat bone, bevelling or coning of the bone at the surface away from the weapon can be observed at the entrance and exit sites. For the skull, the bevelling is on the inner table at the entrance and on the outer table at the exit, although in thin areas such as the temple bevelling may not occur. The same configuration can be seen in the sternum, iliac crest, scapula, and rib. These observations permit determination of the direction of fire when the overlying skin is lost through decomposition, surgical intervention, or animal or fire damage. The same principle is used by criminalists to determine the direction in which a bullet passes through glass.

However, when a projectile strikes the bone surface tangentially, the appearance is markedly different. The defect has been called a "keyhole" in the only reference [2] found to describe the entity. In a caption to a photograph depicting the inner and outer surfaces of such a defect, Spitz and Fisher [2] noted that the "entrance" and "exit" portions exhibited bevelling of the inner and outer skull tables, respectively. The terms "entrance" and "exit" imply that the projectile only grazes the bone and exits intact or as a fragment. This sequence of events is the usual case, but in the present series a keyhole defect was also seen in a situation where virtually the entire bullet entered the skull (Case 3), the total defect therefore representing an entrance wound. The arrangement of the bevelling, nevertheless, indicated a tangential shot and the direction of fire.

Adelson [1] depicts a keyhole defect in an exit wound with no description of the corresponding entrance or of the tangential nature of the shot. It is difficult in this case to evaluate the wound characteristics. External bevelling of entrance wounds in bone has been described by Coe [6], apparently from shots fired perpendicular to the surface of the bone. The present study does not consider this type of wound.

This paper presents five cases, one involving shotgun injury and four related to handguns,

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each with an entrance keyhole defect of bone. No exit keyhole defects were seen in any of the cases in the present study. The bony lesions are correlated with the corresponding skin injuries and evaluated in terms of the configuration of the bony defect. A mechanism for formation of the lesion is also discussed.

Case Material

Case 1

A 26-year-old black male looked out of a window through which a rock had been thrown and was struck on the right side of the head by a blast of #6 shot fired at a range of 30.5 cm (1 ft) from a 12-gauge shotgun.

Autopsy revealed a tangential or grazing entrance wound of the right side of the head (Fig. 1), measuring 10.2 cm (4 in.) in length and varying in width from 2.5 cm (1 in.) anteriorly to 5 cm (2 in.) posteriorly. The scalp had been shaved, so the presence of smoke or powder could not be determined. Along the margin of the graze wound trough and protruding into it (Fig. 2) were skin tags having one lacerated edge and one abraded edge [7]. Since the lacerated margin of a tag is located toward the weapon, the direction of fire in this case was from anterior to posterior (right to left in Fig. 1). An incomplete circular abrasion of entrance is located at the anterior end of the graze wound trough.

The underlying bony defect of the skull is shown in Fig. 3, oriented in the same fashion as the skin wound. It measured 6.4 cm (2½ in.) in length and 2.5 cm (1 in.) at its point of greatest width. The circular or ovoid portion of the keyhole, showing bevelling of the inner table (not visible in the photograph), is located at the anterior end and is the point of initial impact or "entrance." At the triangular portion of the defect, or the "exit," bevelling of the



FIG. 1—Grazing entrance of the scalp measuring 10.2 by 5 cm. The configuration of the skin tags (T) along the wound indicates that the direction of fire (large arrow) is from right to left (photo as reference). L = lacerated edge of skin tag; A = abraded edge of tag, C = circular abrasion of entrance (Case 78-01-023).

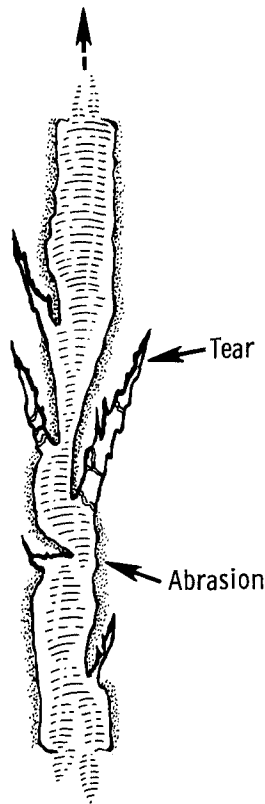


FIG. 2—Schematic diagram of graze wound demonstrating skin tags along margin of wound trough. Note that the lacerated margin of each tag is on the side toward the weapon; the arrow at the top of the drawing indicates the direction of fire.

outer table can be seen. This corroborates that the direction of fire was from anterior to posterior (right to left in Fig. 3), as was indicated by the configuration of the skin wound.

The right frontal and parietal lobes of the brain were extensively lacerated. Multiple lead pellets consistent with #6 shot were recovered from the wound track; some pellets exited the head.

Case 2

During an apparent altercation, a 30-year-old Hispanic male was shot once in the head with a .44- or .45-caliber weapon of unknown type. The range of fire is unknown.

A tangential or grazing entrance wound was present on the right parieto-occipital scalp (Fig. 4), measuring 7.6 cm (3 in.) in superior to inferior dimension and 5 cm (2 in.) in medial to lateral dimension. No smoke or powder was observed on the skin or hair. As in Case 1, skin tags and an incomplete circular abrasion at the entrance were used to determine that the direction of fire was from superior to inferior (right to left in Fig. 4).

The underlying keyhole defect of the right parietal bone is shown in Fig. 5. It measured 5 cm (2 in.) from superior to inferior dimension and 2.5 cm (1 in.) at its greatest width. The photo of the bony defect is oriented similarly to that of the skin wound. The rounded portion of the defect, which exhibited internal bevelling, was the point of initial contact of the projectile and

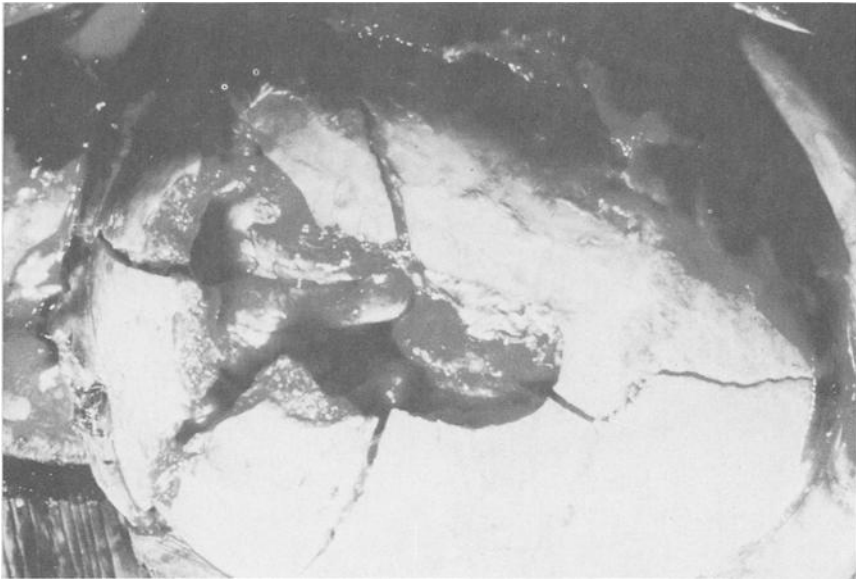


FIG. 3—Keyhole defect of skull measuring 6.4 by 2.5 cm. The direction of fire is from right to left, photo as reference (Case 78-01-023).

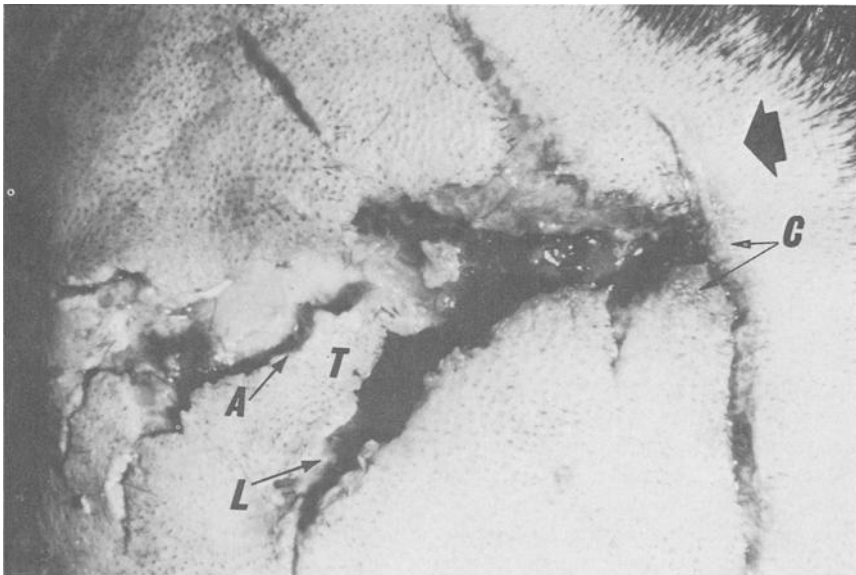


FIG. 4—Grazing entrance of the scalp measuring 7.6 by 5 cm. The configuration of the skin tags (T) indicates that the direction of fire (large arrow) is from right to left (photo as reference). L = lacerated edge of skin tag; A = abraded edge of tag; C = circular abrasion of entrance (Case 80-11-880).



FIG. 5—Keyhole defect of skull measuring 5 by 2.5 cm. The direction of fire is from right to left, photo as reference (Case 80-11-880).

was directly beneath the incomplete circular skin abrasion of entrance. The triangular, externally bevelled portion of the defect was located away from the point of entrance. Thus, the direction of fire was from superior to inferior (right to left in Fig. 5), as was suggested by the appearance of the skin wound.

The wound in the brain extended from the right parieto-occipital lobe into the left occipital lobe as two tracks from which were recovered a markedly deformed and incomplete lead projectile and a separated copper jacket. Both are consistent with a .44- or 45-caliber fully copper-jacketed lead round. A total of 100.3 grains out of a probable 225 to 230 grains was recovered, indicating that a large portion of the projectile exited from the scalp.

Case 3

During a robbery, a 24-year-old black male was shot once in the head with a .32-caliber semiautomatic weapon of unknown type; the range of fire is unknown.

A circular entrance wound was present on the right frontal scalp (Fig. 6), measuring 0.6 cm ($\frac{1}{4}$ in.) in diameter and surrounded by a margin of abrasion 0.3 cm ($\frac{1}{8}$ in.) wide. There was no smoke or powder on the skin and no exit wound.

The underlying defect of the right frontal bone is shown in Fig. 7. The photo of the bony defect is oriented similarly to that of the skin wound, which overlay the circular portion of the keyhole lesion. The defect measured 3.2 cm ($1\frac{1}{4}$ in.) in length and 2.5 cm (1 in.) across the triangular portion. The circular portion measured 1.3 by 0.6 cm ($\frac{1}{2}$ by $\frac{1}{4}$ in.) and exhibited bevelling of the inner table only.

The wound track in the brain began in the right frontal lobe and extended into the left temporoparietal lobe. A partially deformed but nearly complete, fully copper-jacketed lead projectile was recovered from the left lateral ventricle. Its appearance was consistent with

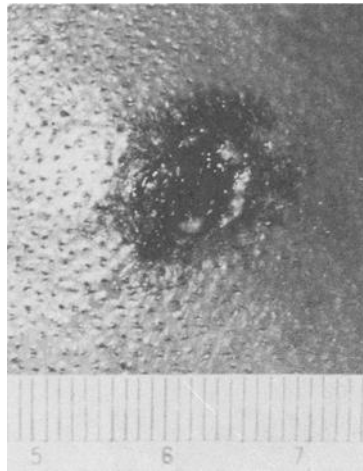


FIG. 6—Entrance defect of right frontal scalp measuring 0.6 cm in diameter (Case 80-11-925).

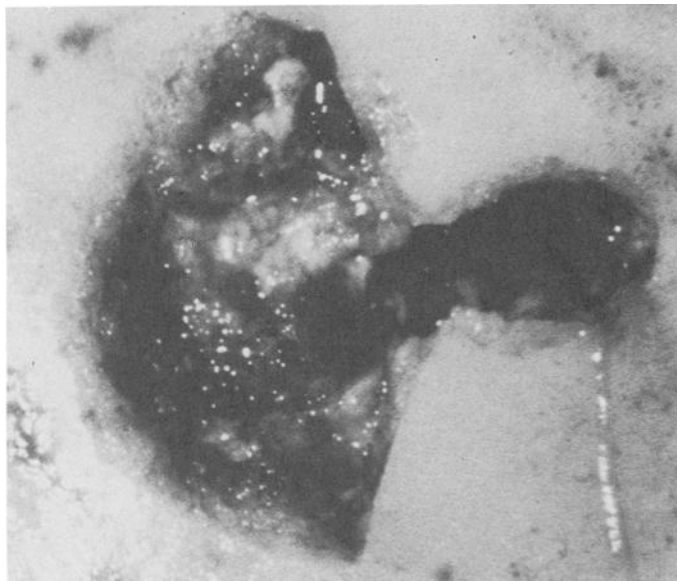


FIG. 7—Keyhole defect of skull measuring 3.2 by 2.5 cm. The direction of fire is from right to left, photo as reference (Case 80-11-925).

that of a .32-caliber projectile, and it weighed 70.9 grains compared to the probable weight of 71 grains for an intact bullet.

Case 4

During a bank robbery, a 30-year-old white male bystander was shot repeatedly with a 38-caliber handgun.

A gunshot wound of the left frontoparietal scalp is shown in Fig. 8. The entrance defect was V-shaped and was located anteriorly. It measured 2.5 cm (1 in.) in length and 0.6 cm ($\frac{1}{4}$ in.) in width. There was an incomplete circular abrasion of entrance anteriorly measuring 0.6 cm ($\frac{1}{4}$ in.) in diameter. The exit wound was located 1.3 cm ($\frac{1}{2}$ in.) from the posterior end of the defect and measured 1.9 by 1.3 cm ($\frac{3}{4}$ by $\frac{1}{2}$ in.).

There was an underlying keyhole lesion of the left frontal and parietal bones; the external and internal appearances are shown in Figs. 9 and 10, respectively. Both are oriented similarly to the skin wounds, so the entrance overlies the portion of the keyhole defect on the



FIG. 8—Entrance and exit defects of superficial tangential gunshot wound with direction of fire from right to left (photo as reference). Note circular abrasion of entrance on extreme right. The entrance is 2.5 by 0.6 cm, and the exit is 1.9 by 1.3 cm; the separation between the two is 1.3 cm (Case 80-12-973).

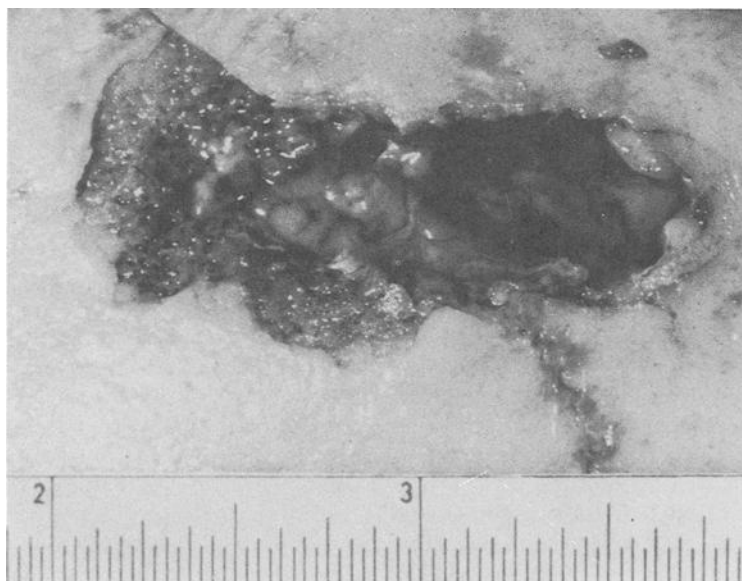


FIG. 9—External appearance of keyhole defect of skull measuring 4.4 by 1.9 cm. The direction of fire is from right to left, photo as reference (Case 80-12-973).

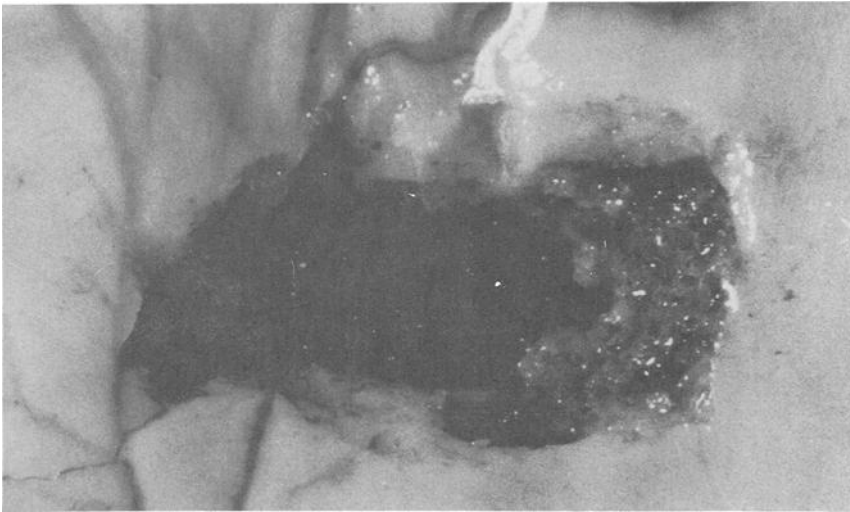


FIG. 10—Internal appearance of the keyhole defect in Fig. 9. The direction of fire is from right to left, photo as reference (Case #80-12-973).

right of each photograph. The defect measured 4.4 by 1.9 cm ($1\frac{3}{4}$ by $\frac{3}{4}$ in.) and had its ovoid portion located anteriorly. Note that the bevelling of the internal surface is reversed relative to that of the external surface. The presence of lead scrapings on the dislodged triangular fragment of bone (not shown in the photograph) indicated that the impact point was on the anterior and internal surface of the fragment.

The wound track divided in the left frontoparietal region of the brain, with one track exiting through the skin exit wound and the other extending posteriorly into the left occipital lobe. Multiple lead fragments were recovered from the lobe. These were consistent with a .38-caliber lead projectile and weighed a total 90 grains compared to approximately 158 grains for an intact bullet.

Case 5

In an apparently drug-related homicide, an 18-year-old black male was shot repeatedly at close range with a .357- or .38-caliber handgun.

One of the entrance wounds and its corresponding exit wound, both of which were located on top of the head in the right parietal region, are shown in Fig. 11. The entrance was located near the midline and measured 0.5 cm ($\frac{3}{16}$ in.) in diameter; no smoke or powder was noted around this wound. Located 3.8 cm ($1\frac{1}{2}$ in.) to the right of the entrance was a slit-like exit wound measuring 0.6 cm ($\frac{1}{4}$ in.) in length.

The right parietal bone contained a keyhole defect, shown in Fig. 12 oriented in a fashion similar to that presented in Fig. 11. The defect measured 3.8 by 1.3 cm ($1\frac{1}{2}$ by $\frac{1}{2}$ in.) and demonstrated internal bevelling of the ovoid portion, corresponding to the skin entrance wound, and external bevelling of the lateral triangular portion. Lead particles were noted on the edge of the defect. Fragments of lead and pieces of the copper jacket were recovered beneath the right parietal scalp; a large fragment of lead was also recovered from a track in the right parietal lobe of the brain. Since another projectile recovered in this case was a .38-caliber bullet, it was assumed that the fragments of lead and copper from this wound,

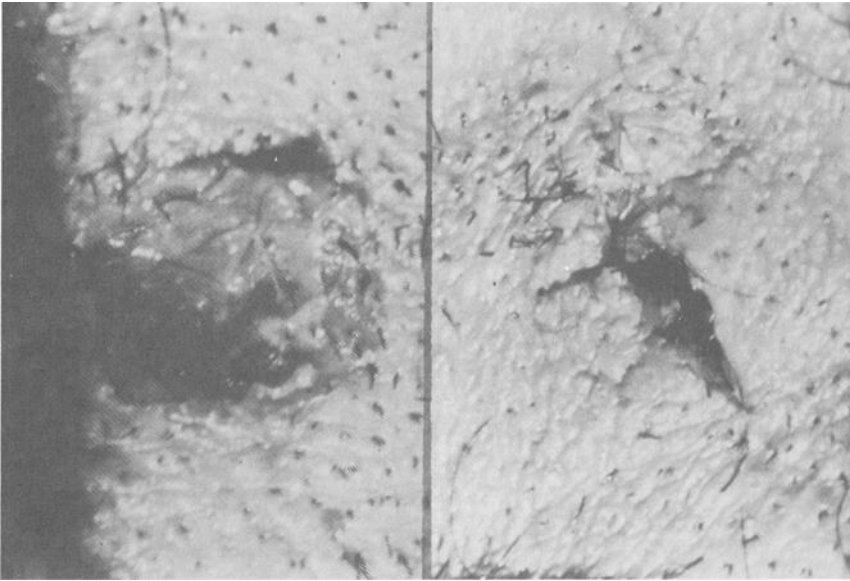


FIG. 11—Gunshot wound of right parietal scalp. The entrance on the left of the photo is 0.5 cm in diameter, and the exit on the right is 0.6 cm at its greatest length (Case 81-07-569).

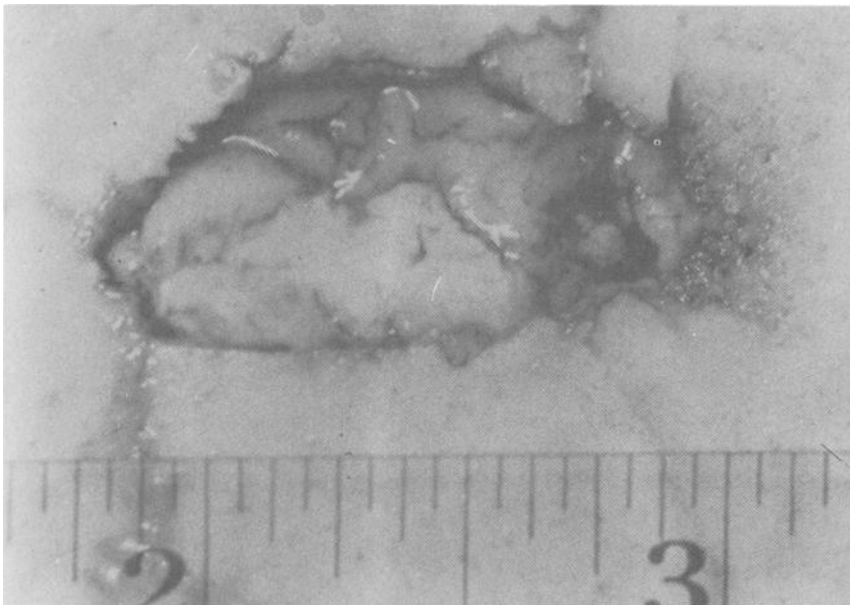


FIG. 12—Keyhole defect of right parietal bone measuring 3.8 by 1.3 cm. Note large ovoid portion of the defect on the left of the photo and the small triangular part on the right. The direction of fire is from left to right, photo as reference (Case 81-07-569).

which weighed 29.5 grains, came from a .357- or .38-caliber copper-jacketed hollow-point bullet with a probable weight of 125 grains.²

Discussion

These cases all demonstrate keyhole lesions of the skull. Common to the lesions are a circular or ovoid component with internal beveling and a triangular portion with external beveling. These features are diagrammed in Fig. 13.

In Cases 1 and 2, the skull lesions were associated with grazing skin wounds that, on the basis of a previous study [7], have specific characteristics indicating the direction of fire. These observations indicate that the circular portion of the keyhole lesion is, in fact, the point of initial impact or entrance and the triangular portion is the exit. Cases 4 and 5 have associated skin entrance-exit complexes that verify the interpretation of direction of fire from the morphology of the keyhole lesion.

In Case 3, the skin wound appearance cannot be used to determine the direction of fire, whereas the underlying keyhole lesion is unequivocal. The skin wound has the configuration of a typical distant-fire entrance wound, but the defect of the skull connotes a tangential shot, thereby revealing the direction of fire. Thus, in cases where the skin is altered by decomposition, fire damage, or surgical intervention, the bony defect is a reliable indicator of direction of fire.

The cases presented indicate that keyhole lesions may be produced by handgun ammunition of a variety of calibers as well as by shotgun ammunition.

In postulating a mechanism to explain the formation of keyhole lesions, one must consider the tangential nature of the projectile trajectory. Such a projectile exerts vertical as well as horizontal force vectors. The vertical component results in the internally bevelled ovoid portion of the defect, the formation of an internal wound track, and the presence within the track of a bullet fragment or, rarely, of an intact projectile. The horizontal component causes the formation of the externally bevelled triangular portion of the defect, fragmentation of the projectile, and the exit of the fragment and perhaps pieces of bone. In a typical situation, the projectile is fragmented and partially exits from the body, as in Cases 2, 4, and 5, or, as in Case 1, a portion of a shotgun load is lost externally. Rarely, as in Case 3, can a keyhole lesion be caused by a projectile that does not split as a result of the transmission of

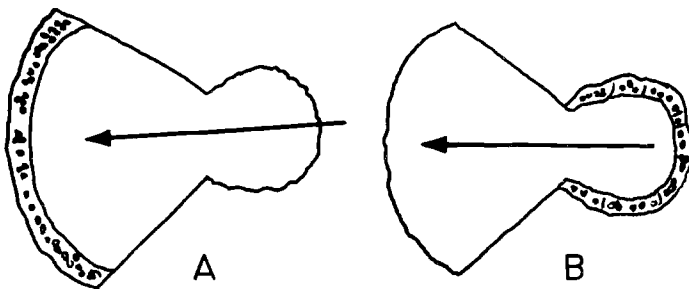


FIG. 13—Schematic diagrams of a keyhole lesion of skull. The arrows indicate the direction of fire. Diagram A represents an external view of the lesion, while Diagram B is an internal view.

²Since the preparation of this paper there has been another case with an entrance wound in the right occipital scalp and an underlying typical keyhole lesion. The unusual feature of this case was that the bullet that caused the keyhole was recovered intact but distorted *outside* the skull beneath the scalp. There was brain injury due to bony fragments from the keyhole defect.

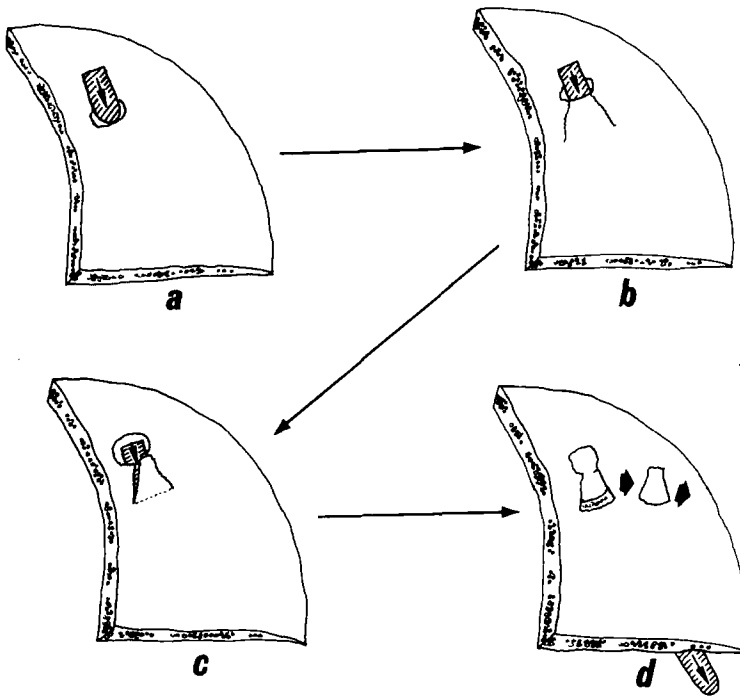


FIG. 14—Schematic representation of a proposed mechanism for the formation of a keyhole defect. A bullet enters the skull tangentially in a, forming a typical entrance defect by the vertical force vector. The horizontal vector forms the triangular portion of the defect b and c; it is at this point that the projectile is usually fragmented. The completed defect, loss of bone fragment and usually bullet fragment, and trajectory of remainder of bullet are shown in d.

its horizontal force component to the bone. A proposed mechanism for these situations is represented schematically in Fig. 14.

Conclusions

Keyhole lesions of the skull can be seen underlying graze wounds, entrance-exit wound complexes, or apparent distant-fire entrance wounds. A wide range of weapons including handguns and shotguns may cause such an injury. The presence of a keyhole defect indicates a tangential trajectory, with the circular or ovoid portion of the defect being the point of initial impact or entrance. In the usual case, the projectile is fragmented and a portion of it is lost externally, but occasionally the defect may be due to a projectile that remains virtually intact within the wound track.

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References

- [1] Adelson, L., *The Pathology of Homicide*, Charles C Thomas, Springfield, IL, 1974, pp. 196-198.
- [2] Spitz, W. U. and Fisher, R. S., *Medicolegal Investigation of Death*, 2nd edition, Charles C Thomas, Springfield, IL, 1980, pp. 254-255.
- [3] Tedeschi, C. G., Eckert, W. G., and Tedeschi, L. G., *Forensic Medicine: A Study in Trauma and Environmental Hazards*, Vol. 1 (Mechanical Trauma), W. B. Saunders, Philadelphia, 1977, p. 518.
- [4] Fatteh, A., *Medicolegal Investigation of Gunshot Wounds*, Lippincott, Philadelphia, 1976, pp. 100-102.
- [5] Gonzales, T. A., Vance, M., Helpert, M., and Umberger, C. J., *Legal Medicine: Pathology and Toxicology*, Appleton-Century-Crofts, New York, 1954, pp. 421-423.
- [6] Coe, J., "External Bevelling of Entrance Wounds by Handguns," *American Journal of Forensic Medicine and Pathology*, in press.
- [7] Dixon, D. S., "Determination of Direction of Fire from Graze Gunshot Wounds," *Journal of Forensic Sciences*, Vol. 25, No. 2, April 1980, pp. 272-279.

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