CASE REPORT

Hugh E. Berryman,[1] *Ph.D. and Wendy M. Gunther,*[1] *M.D.*

Keyhole Defect Production in Tubular Bone

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ABSTRACT: Fracture characteristics, reported primarily for the cranium, are valuable indicators of bullet direction. A bullet striking the vault tangentially produces an irregular opening, termed a "keyhole defect," with the circular portion of the defect being the initial point of impact. Identifying this feature in tubular bone (long bone) can also demonstrate bullet direction and the position of the bone at the time of the shooting. This case study involving a tangential shot (i.e., a keyhole fracture) to the humerus demonstrates some of the same fracture mechanics seen in the cranium.

KEYWORDS: forensic science, bone trauma, gunshot trauma, fracture mechanics, keyhole fracture, tubular bone, forensic anthropology

Determining bullet direction and body position often represent critical medico-legal elements during trial. Medical investigators normally determine direction by examining clothing, gross soft tissue, bone morphology, or radiographs. A gunshot entrance wound to the cranial vault is typically characterized by internal beveling, and an exit wound shows external beveling (1). A circular, internally beveled defect with radiating fractures is consistent with a bullet that strikes the vault perpendicularly, and a circular, externally beveled defect is consistent with an exit.

In cases where the bony entrance or exit wounds are absent because of debridement, scavengers, or other taphonomic activities, bone fracture morphology may be used to establish bullet direction (2). This morphology is important, because gunshot entrance wounds may appear atypical by exhibiting external beveling (3,4). An atypical entrance defect produced by a bullet entering the bone surface tangentially was termed a "keyhole defect" by Spitz (5) and was later described by Dixon (6).

This paper presents a case study involving a tangential shot to the humerus and a resulting keyhole fracture. Some of the same fracture characteristics in keyhole fractures to the cranium are also present in tubular bone, thereby indicating that the same fracture mechanics exist. Identifying these characteristics not only provides a means to estimate bullet direction, but may also indicate the position of the tubular bone at the time of the shooting. Directional and positional information can be used to confirm or reject statements made to law enforcement by parties involved.

[1] Department of Pathology, Regional Forensic Center, University of Tennessee, Memphis, 1060 Madison Avenue, Memphis, Tennessee.

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Case Study

The victim—a 20-year-old African American male—and the assailant became involved in an argument while traveling in an automobile. The driver lost control of the vehicle, which jumped a curb and knocked down a number of posts of a carport. The assailant removed a 9-mm Ruger rifle from the trunk of his car and opened fire on the victim who had left the vehicle after the accident. The victim was shot twice as he was fleeing the scene.

At autopsy, two bullets were discovered within the victim's clothing, and his body exhibited six gunshot wounds resulting from two bullet paths. Each bullet path was determined to be fatal (Fig. 1). One bullet entered the postero-lateral aspect of the left shoulder and arm, exited close to the axilla on the medial side of the arm, and reentered the body in the left 5th intercostal space. This bullet perforated the lungs and heart and exited the body via the right 6th intercostal space. The other bullet entered the left posterior side of the chest in the 6th intercostal space. It perforated the lungs and heart and exited the chest at the junction of the 6th rib and sternal border.

The left humerus and the sternal ends of left ribs 4, 5, and 6 were taken at autopsy. These bones were processed to remove soft tissue and oil and reconstructed. Only the humerus is relevant to this report.

The humerus exhibited a gunshot wound located in the proximal one-third of the shaft on the medial and slightly posterior surface of the bone (Figs. 2 and 3). The bullet entrance defect measured 1.09 cm (0.43 in.) in diameter, was circular in shape, and had seven radiating fractures in association. On its anterior margin, the defect exhibited external beveling that measured 2.11 cm (0.83 in.) in diameter. The crescent-shaped defect on the anterior-medial shaft measured 3.35 cm (1.32 in.) by 0.76 cm (0.30 in.) and represented unrecovered bone fragments that were blown out by the exiting bullet. The anterior margin of the entrance defect exhibited bullet wipe and crushing of cortical bone (Fig. 2).

Discussion

The irregular morphology produced by a tangential bullet trajectory may be confusing. The wound itself exhibits characteristics of both gunshot entrance and exit wound trauma. In fact, a cursory examination of soft tissue around a tangential wound my be misinterpreted as an exit wound. According to Dixon (6), ". . . a keyhole defect indicates a tangential trajectory, with the circular or oval 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." Berryman

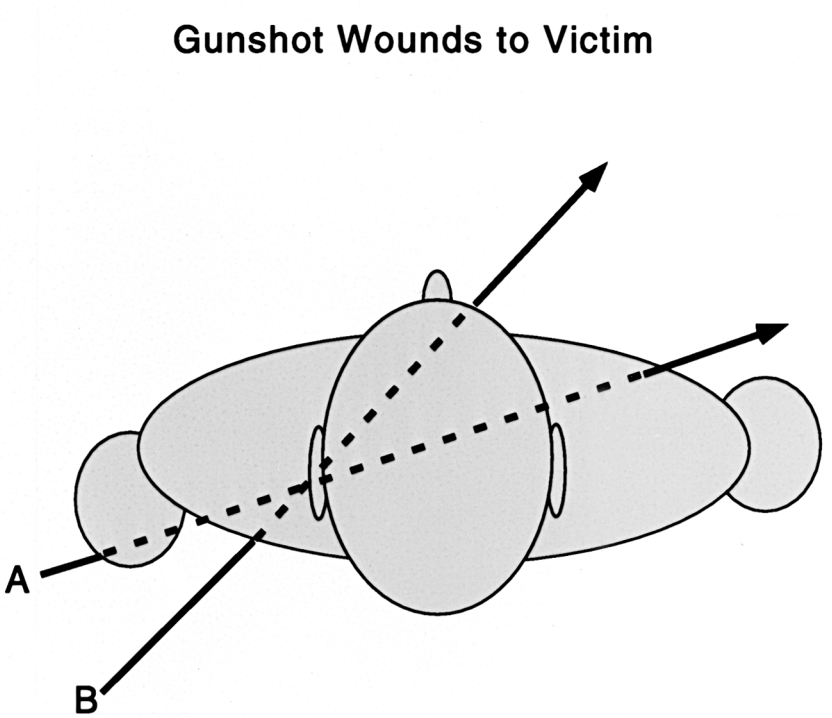

FIG. 1—*(A) The bullet entered the postero-lateral aspect of the left shoulder and arm, exited close to the axilla on the medial side of the arm, reentered the body in the left 5th intercostal space, perforated the lungs and heart, and exited via the right 6th intercostal space. (B) The second bullet entered the left posterior side of the chest in the 6th intercostal space, perforated the lung and heart, and exited the chest at the junction of the 6th rib and sternal border.*

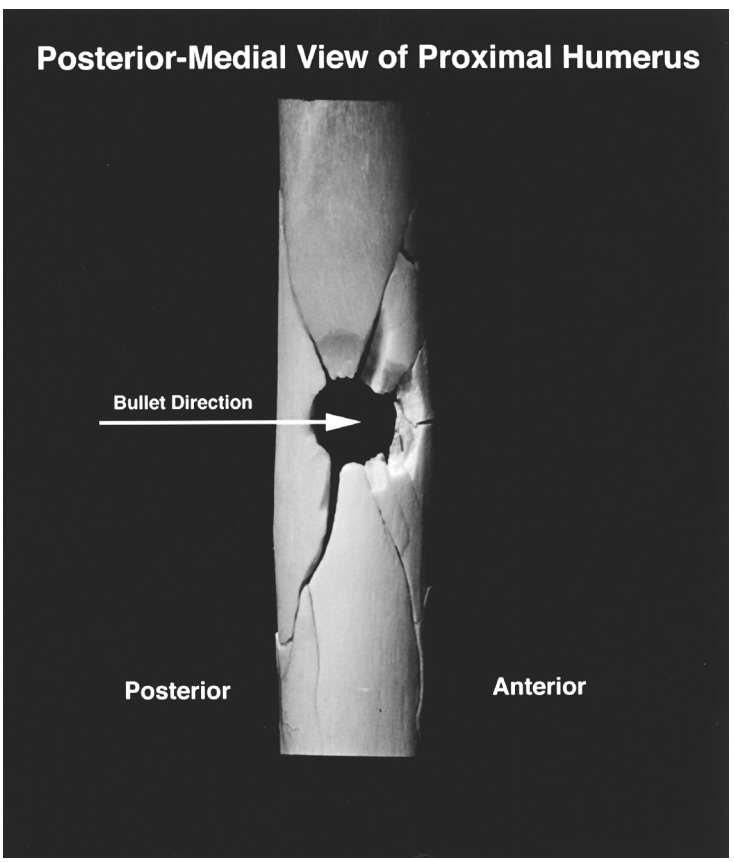

FIG. 2—*Photograph of gunshot wound to the proximal left humerus indicating bullet direction.*

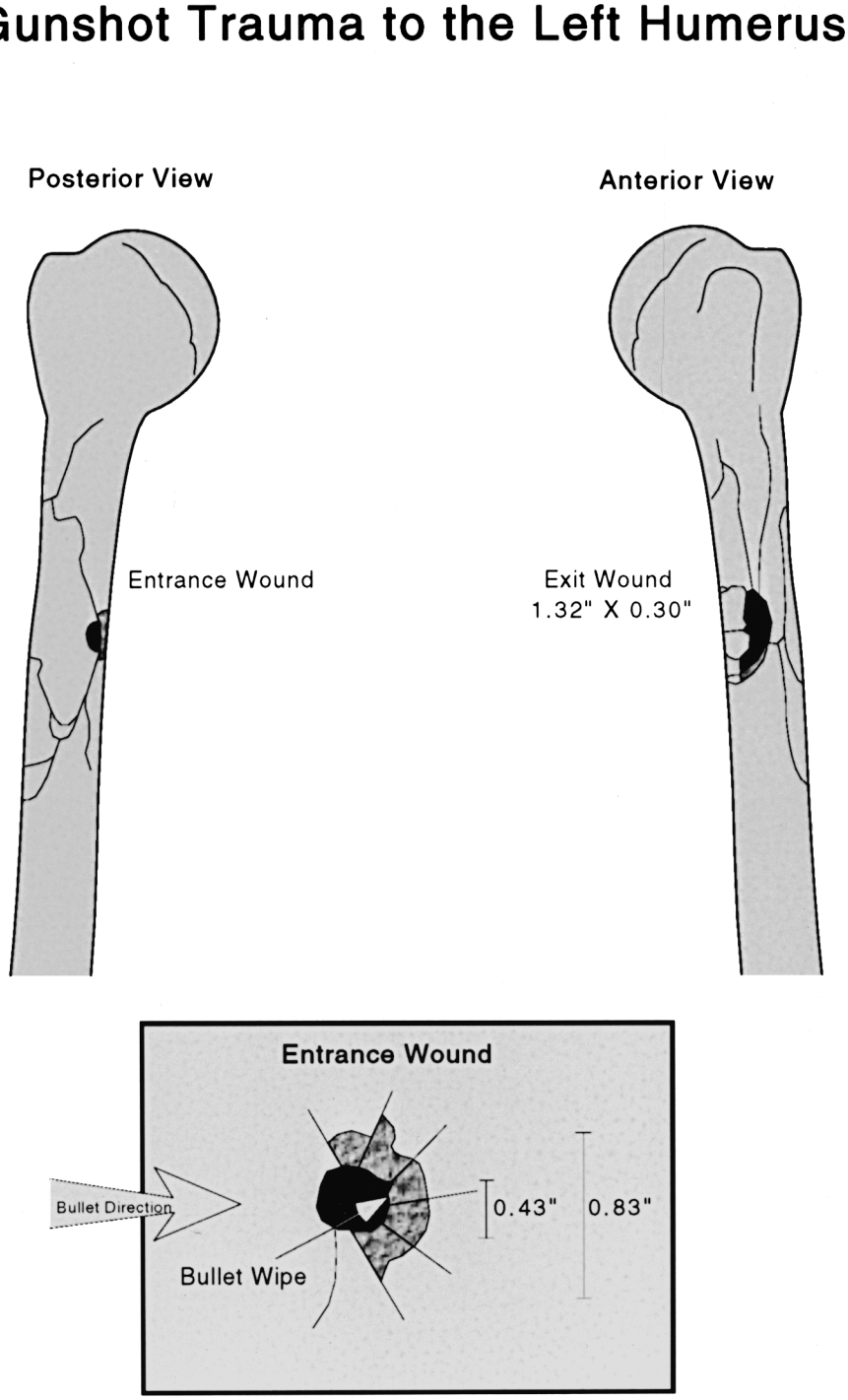

FIG. 3—*Illustration of the fracture pattern to the proximal left humerus, showing the posterior and anterior views and the entrance wound*

and Symes (7) described the fracture mechanics of this type of wound defect (Fig. 4). The bullet, entering the bone, produces a circular or oval defect. One or more radiating fractures diverge from this initial impact site, with the major fractures oriented in the direction the bullet is traveling. These radiating fractures define a triangularly shaped plate of bone that is elevated upward and outward as the bullet passes below it. This action results in hinge fractures that develop perpendicularly to the radiating fractures as the triangular plate of bone is levered out. Finally, the bone plate is ejected, leaving a keyhole-shaped defect that is beveled internally and externally along the site of last attachment.

The keyhole defect in the humerus (Fig. 5) exhibited a variation of the same defining characteristics present on the flat bones of the cranium. There was a circular entrance wound defect with five divergent radiating fractures oriented in the direction that the bullet was traveling. Only two fractures radiated in the direction opposite to bullet travel. The external flaking along the anterior portion of the circular defect was produced by the near parallel alignment of

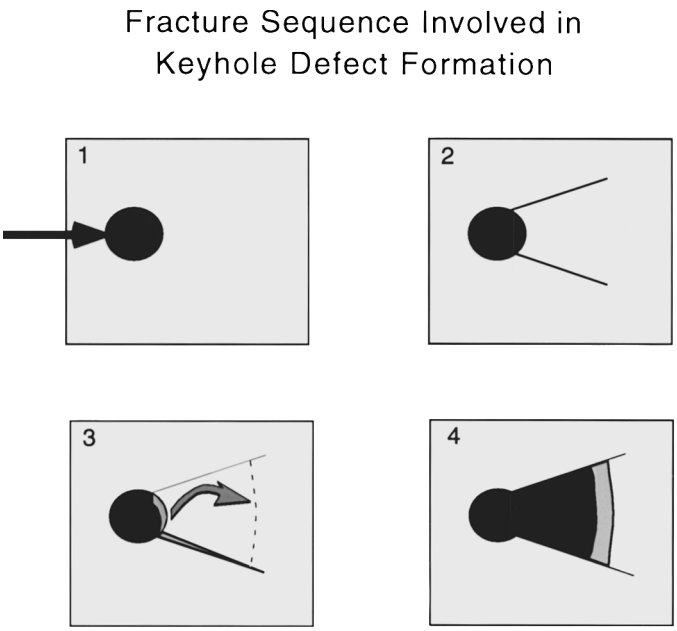

FIG. 4—*Keyhole formation. (1) A circular defect is produced upon entry. (2) Major fractures radiate in the direction of bullet travel. (3) A wedge-shaped piece of bone, defined by two radiating fractures and a concentric or hinge fracture, is levered upward as the bullet passes underneath. (4) The wedge-shaped piece of bone is dislodged, leaving an external bevel along the concentric or hinge fracture.*

the bullet with the bone surface. As the bullet entered the bone, the triangular plates of bone were levered up and out. The hinge fractures were aligned perpendicular to the radiating fractures and exhibited some external beveling along their margin. The entrance wound, radiating fractures, and hinge fracture define the keyhole defect (Fig. 6).

Just as identifying such defects in cranial bone can indicate bullet trajectory, their occurrence in the appendicular skeleton can indicate bullet direction, as well as the relative position of the appendage at the time of the shooting. Determining body position can provide significant collaborative information for statements made by the assailant or witness. In the case presented in this study, the orientation of the keyhole defect indicated that the bullet trajectory was mainly posterior left to anterior right and traversed perpendicularly to the long axis of the humeral shaft. Such data were consistent with the information presented in this particular case (i.e., the victim was running away from the shooter).

Conclusions

The key to the accurate interpretation of gunshot trauma, especially in complex cases, lies in the complete recovery of bone fragments at the crime scene and at autopsy and an accurate reconstruction of the bone in question. A gross examination of the reconstructed specimen may be enhanced by low-power magnification and radiology. Fractured margins should be closely examined for crushing, fragments of metal, or metal streaking indicating evidence of the bullet impact site. Tubular bone exhibiting keyhole defects is useful in determining bullet direction and more useful in determining body position.

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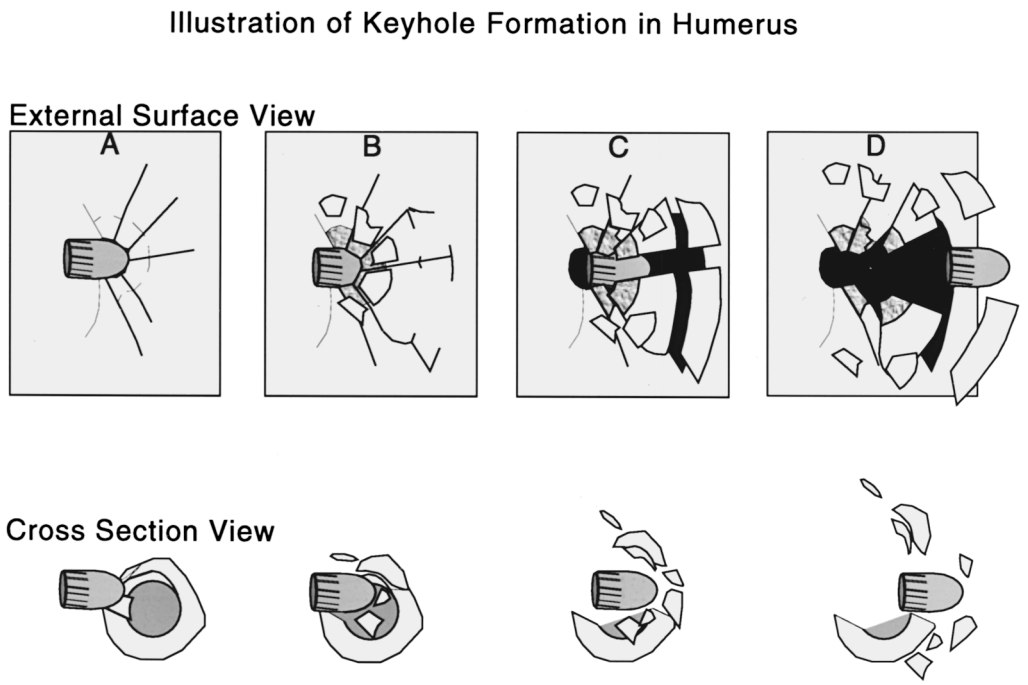

FIG. 5—*Stages in the production of the keyhole fracture in the humerus begin with (A) a circular entrance wound defect with five divergent radiating fractures oriented in the direction of bullet travel and two in opposition. (B) As the bullet enters, external flaking of cortical bone around the entrance defect occurs. (C) Triangular plates of bone, defined by the radiating fractures and the heaving fracture, are levered up and out as the bullet enters. (D) The bullet exits.*

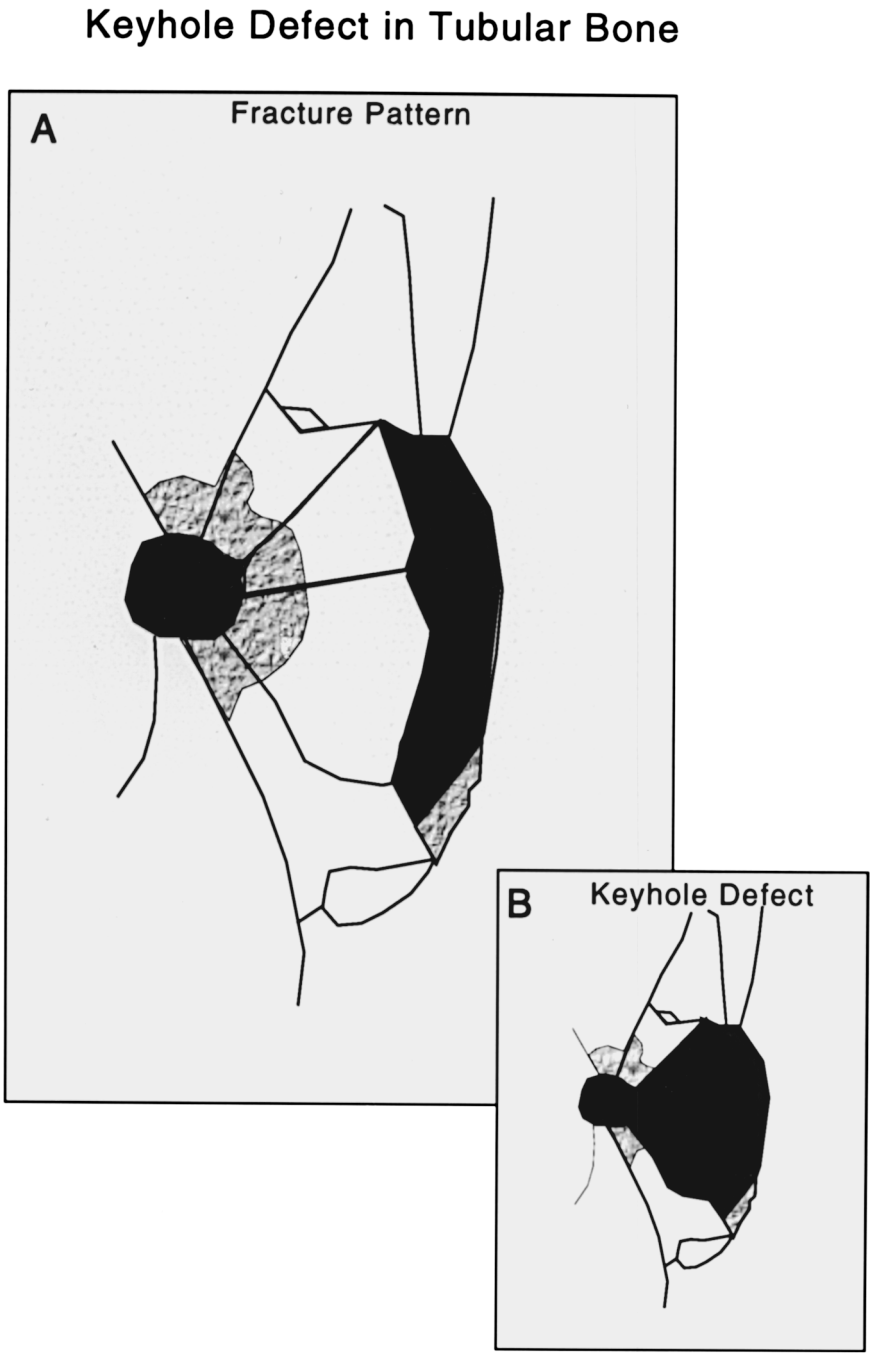

FIG. 6—*(A) Fractures associated with the gunshot wound to the humerus. (B) Bone fragments removed to reveal the keyhole-shaped defect.*

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Additional information and reprint requests:
Hugh E. Berryman, Ph.D.
Department of Pathology
Regional Forensic Center
University of Tennessee, Memphis
1060 Madison Avenue
Memphis, Tennessee 38104