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Case Report

Gunshot wound trajectory analysis using forensic animation to establish relative positions of shooter and victim

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ABSTRACT

Forensic pathologists who autopsy the victims of gun violence are often called upon to answer questions in both criminal and civil proceedings about the relative position of the shooter and the victim. In this case report of an officer-involved shooting incident, the statement of the police officer appeared to be in direct contradiction to the statements of other eyewitnesses, the evidence at the scene, and the final resting position of the decedent's body. Trajectory analysis of two gunshot wound pathways (only one of which was instantaneously incapacitating) was performed to assess the veracity of the officer's statement and forensic animation was used to create a court exhibit. A discussion of the current peer-reviewed literature is included.

1. Introduction

Forensic pathologists who perform autopsies in gunshot cases may be asked to determine the bullet trajectories in the body in order to elucidate the circumstances of a homicide and answer questions about range of fire, the order of shots fired, and the relative positions of the shooter and victim at the scene. However, there are few peer-reviewed articles or case reports detailing how trajectory analysis is performed in complex cases with conflicting testimony. The following case report documents an instance when the testimony of a police officer who shot a suspect was at odds with the evidence at the scene and the trajectory findings upon autopsy. In cases with conflicting evidence and testimony, it is necessary for the forensic pathologist to objectively analyze the pattern of injury in order to testify if the witnesses' testimonies are consistent with the scene, evidence, and autopsy findings.

2. Case report

A 911 call made by a neighbor reported a man brandishing a handgun outside a bar at 1:42 AM. A police officer arrived at the scene and saw the man waving the gun around. The officer exited his patrol car, drew his weapon, and verbally commanded the man to drop his gun. The man began running away from the officer and the officer ran in pursuit, maintaining a distance of between 5 to 15 ft. between himself and the suspect. According to the police officer's statement, while running, the suspect tripped or fell near a pine tree. He then began to raise himself up and turn toward the officer raising his right arm as if holding a weapon (Fig. 1). The officer feared that the man was going to shoot at him and the officer fired two shots at the man, while the suspect was in this position. The officer stated that he transitioned from running to a stationary position prior to shooting and was stationary when he fired upon the suspect, who was approximately 15–45 ft. away. He fired two rounds from his department issued Glock 22 .40 caliber handgun.

Two witnesses were present at the shooting, one approximately 160 ft. east and the other approximately 70 ft. south of the scene. The witness 160 ft. east saw the pursuit and heard multiple gunshots fired in quick succession. He stated that the suspect was swinging his arms while running and appeared to throw something during the pursuit. This witness testified that the suspect was upright and running when the first shot occurred. The witness 70 ft. south of the shooting location initially stated he saw the decedent move behind the tree, but did not see the victim's body position during the shooting. However, this witness later testified that the victim was facing away from the officer at the time of the shooting and the witness never saw a gun in the

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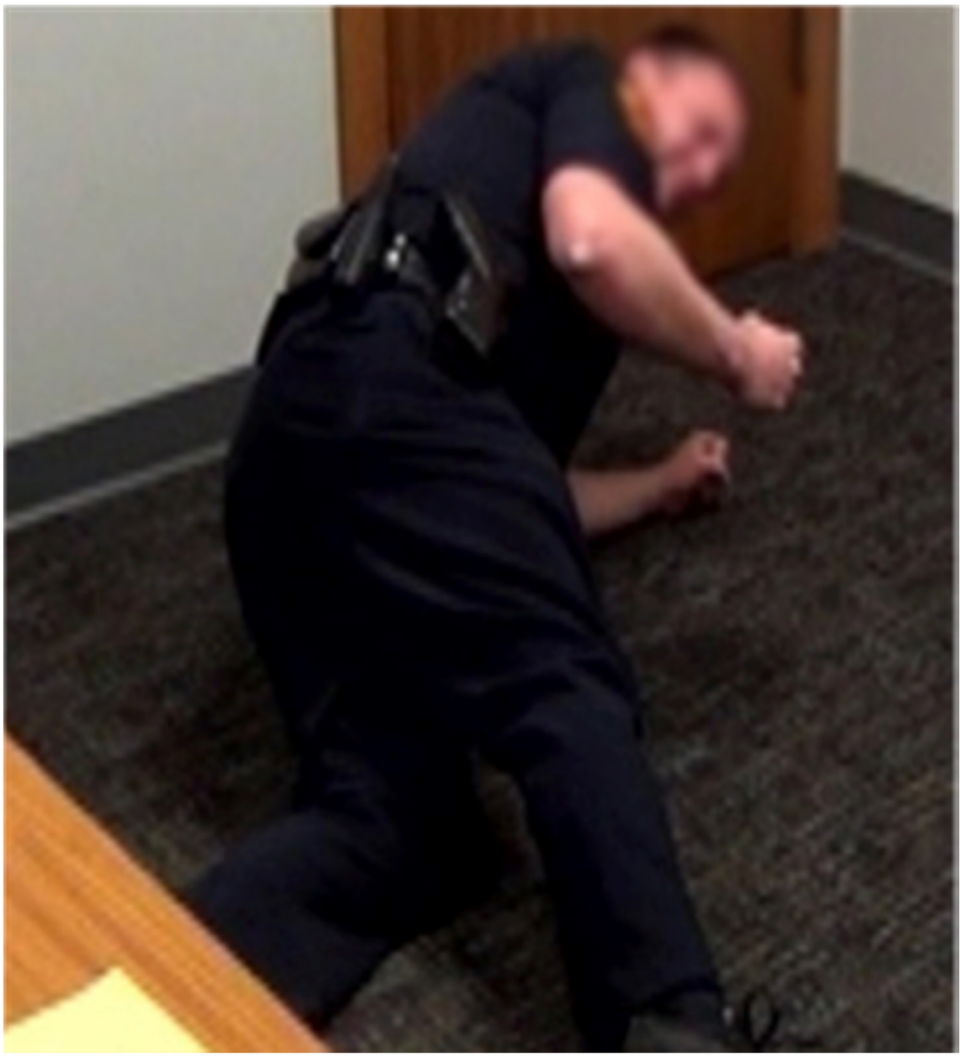

Fig. 1. In his videotaped deposition the officer demonstrates the position of the victim prior to being shot.

victim's hand. Two cartridge casings matching the officer's weapon were found 39 ft. and 44 ft. from the victim's point of rest. The distance between where the foot pursuit began and the deceased suspect's point of rest was measured at approximately 315 ft. Witnesses estimated that from the beginning of the pursuit to when the shots were fired, approximately 15–20 s elapsed. The 911 call from the neighbor recorded the two shots approximately 0.30 s apart. A gun was found in a front yard on the other side of the fence, approximately mid-way between the start of the foot pursuit and the final resting position of the victim.

Scene photos documented the location of the casings, the gun, and the position of the suspect's body at the scene. The decedent was face down against the grass with his left leg externally rotated and extended and his right leg flexed at a 90° angle at the knee, with his right foot resting up against an adjacent tree. His left hand was palm-up, down by the hip, a few inches from a baseball cap, which was in front of his body at the waist. His right hand was not visible in the facedown position, and was below his body (Fig. 2). First responders and witnesses testified that his body had not been moved from its final resting position after the shots were fired. An officer, however, said he had slightly rolled the decedent away from the tree towards the street to determine that he was dead and then rolled him back to his original position.

Following a complete autopsy, the cause of death was determined by the autopsy pathologist to be multiple gunshot wounds and the manner was certified by the coroner as a homicide. Two gunshot wounds were identified: one to the head and one to the right lower leg. The gunshot to the head entered in the inferior right occipital scalp and exited at the left forehead. The entrance wound at the back of the head was a roughly oval defect with an eccentric pink abrasion collar. A small piece of black cloth, consistent with the black jacket of the decedent, was present in the abrasion. There was no soot or stippling surrounding the entrance wound and powder was not noted on his jacket or the hood of the sweatshirt. The wound path continued through the right occipital bone, right occipital brain, right cerebellar hemisphere, midbrain, left frontal lobe, exiting at the left forehead. The exit wound at the left frontal bone had an associated comminuted fracture involving the left anterior cranial fossa. Radiating from this fracture was an 8 cm linear, nondisplaced fracture extending to the left middle cranial fossa and a 20 cm fracture extending through the ethmoid bone, the sella turcica, and the right posterior cranial fossa. The ethmoid bone and the sella turcica had a 5×2 cm comminuted fracture. Diffuse subarachnoid hemorrhage covered the cerebrum and cerebellum. The brain stem was completely transected at the pontomedullary junction and was partially transected at the junction of the midbrain and pons. The right cerebellar hemisphere was markedly lacerated. The direction of the fire was back to front, right to left and upward.

Fig. 2. Scene photo documenting the position of the decedent after he was shot. He had reportedly not been moved from his final resting position.

A gunshot wound of the outer right lower leg was located 2-1/2 in. below the knee and 1-3/4 in. right of midline of the leg. It fractured the right tibia and lodged in the patella. The direction of travel was back to front, right to left and upward. There was no soot or stippling surrounding the entrance wound and gunpowder particles were not grossly visible on the clothing.

Black dirt was noted on the decedent's face during the initial external examination. Additional injuries noted at the autopsy included abrasions on the bridge of the nose, right cheek, left nipple, right elbow, left forearm, back left hand and left knee. There was also a contusion of the right knee. These were all consistent with a terminal, prone collapse. Radiographs revealed bullet fragments in the wound track in the head, a fracture of the right tibia, and a retained projectile in the patella.

3. Methods

3.1. 3D ballistic trajectory model

The measurements and descriptions of the wounds in the autopsy report were used to create a 3D model using the software 3DStudio MAX run on a 24-core DELL XEON PC with 64 GB of RAM running the Windows 7 operating system. The autopsy report, photographs, and radiography of the knee provided the basis for the victim's height and the specific location of each entry, exit and the bullet lodgment location. The model of the decedent was based on a height of 63 in. at death. Entry and exit or point of lodgment locations were connected by a straight line to create the wound path and then extended in order to align each of them with the location and general height of the shooting officer's weapon.

The total station measurements derived by the police department crime scene unit depicted the dimensions of the overall scene including roadways, adjacent buildings, fences, areas of grass, sidewalk and the location of all the physical evidence, along with the decedent's model were used to create a 3D working model of the entire scene. The officer holding his weapon, using his known height and body position, and placed at the location he testified he was in when he fired, was inserted into the 3D model.

In order to derive the relative body posture at the time each gunshot wound occurred, the 3D model of the victim's body was articulated, rotating the torso, head and right leg until the initial end of the trajectory aligned with the 3D location of the officer. This process was repeated for both the head wound and the wound to the lower right leg and the timing of each gunshot was considered.

3.2. Nighttime visibility study

In order to accurately replicate the lighting and visibility conditions of the night, extensive scene investigation of the shooting location was performed to document the lighting and environmental conditions, the ambient light at the scene, the point of view of the eyewitnesses and the clothing, location, and the orientation of the decedent. The physical evidence found at the scene including the decedent's gun and the officer's bullet casings were reintroduced and an exemplar individual similar to the decedent in size and dress was directed to assume the stated position of the decedent by the officer. The celestial and environmental conditions at the time of the shooting were replicated in order to accurately examine the scene. Photos were taken using a Canon V60 camera. Photos were taken from the officer's perspective of the decedent's final resting location both with a flashlight and without a flashlight to determine visibility.

4. Discussion

An analysis of the peer-reviewed literature reveals a lack of recent articles examining the survival time and physical activity following gunshot wounds even though a careful determination of these can be crucial in reconstructing a crime. It is necessary to interpret the injuries of the deceased in order to determine the probable sequence of events, particularly in cases with conflicting evidence and testimony. If the deceased had multiple gunshot

wounds and only one was instantaneously incapacitating, this might help determine the order of the shots and the likely position of the victim at the time of the fatal shot in relation to his point of rest. Karger analyzed incapacitation or lack thereof in gunshot wounds to the head, but little else has been noted in the literature [1]. Most analyses of activity and survival time are limited to a few case reports that examine wounds to the abdomen and chest, which do not immediately incapacitate an individual [1,2]. Surprisingly, considerable physical activity is possible even in those individuals that are fatally shot [3,4]. Even following complete destruction of the heart, the central nervous system has enough oxygen to supply at least several seconds of movement [1]. Rapid incapacitation can be caused by massive tissue destruction or severe hemorrhage, but this still takes between 30 s to min, allowing enough time for some mobility following the shooting [5–7]. The only way to achieve instantaneous incapacitation is to sever or disrupt the central nervous system, generally the brain stem [1]. Most other gunshot wounds, even if ultimately fatal, do not rapidly incapacitate and allow for some physical activity [8].

In this case, the victim died of a perforating gunshot wound of the head. He had another gunshot wound of the right lower leg and knee but this wound would not have been immediately life threatening and would have likely been survivable. The gunshot wound to the head was inflicted at a distant range and the trajectory was back to front, right to left and upward. Because the gunshot wound to the head went through the brainstem, it would have immediately incapacitated the victim in the position he was in when he was shot [5]. If he was running when he was shot through the head, as the independent eye witnesses testified, he would have instantaneously lost all muscle tone and fallen forward with his running momentum indicating that at the time of the head shot his hands were down by his waist and his legs were in a running position with the right leg flexed at the knee, accounting for his final resting position (Fig. 2).

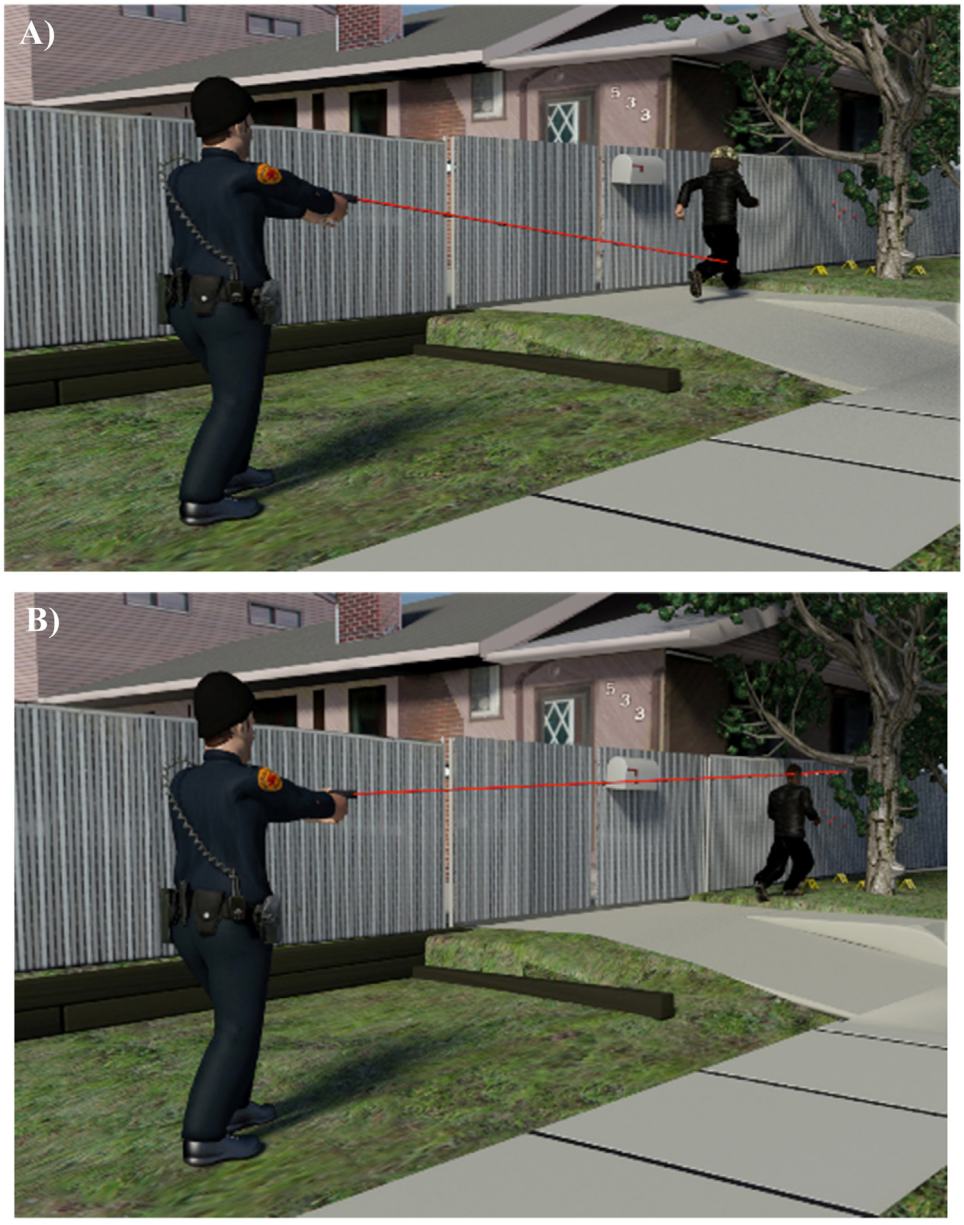

Fig. 3. 3D reconstruction of shooting incident showing likely trajectory of both gunshot wound: (A) perspective view of gunshot wound to the knee; (B) perspective view of gunshot wound to the head.

The knee shot was likely the first shot because if he was shot in the head first he would have immediately lost all muscle tone and not kept the knee flexed. The knee shot's trajectory could not have occurred with the victim already on the ground following incapacitation from the headshot. It would not have been possible to obtain this upward, back to front trajectory with the known location of the shooting officer if the victim had already collapsed from the headshot. If he was however shot first in the leg while running away, as the witnesses stated, the trajectory would match the officer's known location and the pain from the injured leg would have made it difficult for him to run; he would have most

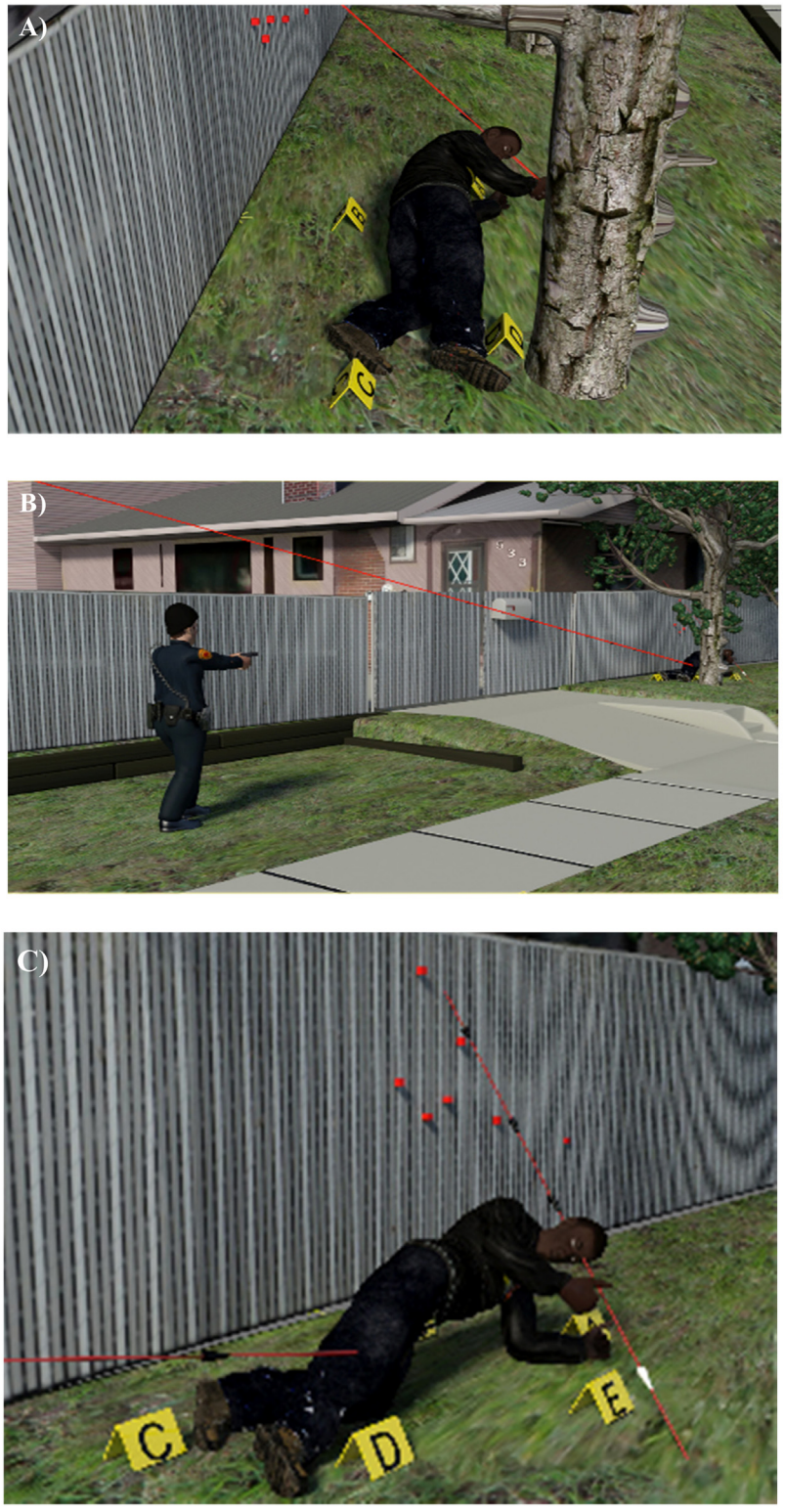

Fig. 4. (A) trajectory of gunshot wound to the knee does not align with the officer's shooting position. (B) trajectory of gunshot wound to the head does not align with the officer's shooting position. (C) Trajectory of both the leg and head wound do not align with the officer's shooting position if the victim was in the position stated by the officer shown in Fig. 1.

likely kept it flexed to avoid the pain that would have occurred with running.

Due to the back to front and upward trajectory of the second gunshot wound to the head, the victim could not have been turning toward the officer. Had he been on the ground and looking back at the officer, the trajectory through the head would have been front to back, right to left and downward, since the shooter would have been positioned behind, slightly to his right, and above him (Fig. 3). An upright, running position during the headshot also corresponds to the location of the blood spatter on the middle of the fence to the left and in front of the victim. It would have been too high for the head shot to have occurred if the victim was lifting up from ground level, as the officer stated.

The body position that the victim was allegedly in that the officer demonstrated in his interview and subsequent deposition (Fig. 1) is inconsistent with the physical findings at the autopsy and the trajectories of either gunshot wound. It is unlikely that the victim was lifting up on his arms when he was shot in the head, or his arms would not have been in the final resting position under his abdomen when he was found; they would have been at his shoulders or to his side. Furthermore, his right leg would not have been flexed against the tree.

The dirt and abrasions on the decedent's face, chest and elbow indicate that he fell forward in a terminal collapse from a significant height. This most likely occurred with a fall from standing, running or leaning, rather than from a prone or kneeling position. Had he fallen prior to the gunshot wound of the head, the abrasions would have likely been on the palms of his hands, and not on the same dependent locations consistent with his terminal collapse. Had he stumbled onto his knees and gotten back up on all fours, there should also be dirt stains on the knees of his pants and those were noticeably absent on examination of his clothing.

Following the reconstruction, several conclusions were evident: the officer testified that he was stationary when firing the two rounds. The bullet casings were found within 5 ft. of each other, one 39 ft. and the other 44 ft. from the victim's final position indicating the officer did not move significantly once he decided to shoot. Based on the type of weapon used and the direction of the cartridge casing's ejection behind and to the right of the shooter, the officer was approximately 20–30 ft. from the victim when he fired. The nighttime visibility study indicated that given the lighting conditions at the time of the shooting the officer would have seen only a shadow of the man. The officer would not have been able to see the victim clearly enough to determine the victim's body position.

The results of the 3D analysis refute the statement by the officer that the victim had tripped and was on the ground, turning toward the officer when the officer decided to shoot. Analysis of the scene and bullet trajectory demonstrate that it would have been impossible for the officer to have affected the back to front shot to the head had the victim been turning toward him, unless the officer had been standing directly above the victim or had been on the other side of the fence (Fig. 4A and C). Further, the gunshot wound to the leg could not have occurred while the victim was in this position. The officer would have had to shoot well above his own head to account for the trajectory of the shot to the flexed right knee (Fig. 4B and C). Due to the placement of the bullet casings, the officer could not have caused these injuries if the victim was on the ground, as the officer stated. The trajectories, however, do fit with a man running with an upright posture, facing away from the officer, as asserted by an eyewitness at the scene.

The victim's handgun, which the victim carried at the beginning of the pursuit, was on the opposite side of a 6-foot tall fence from where the final chase occurred. Witness testimony asserted that the victim was seen throwing the weapon prior to the shooting, as the officer had commanded the victim to do repeatedly. Analysis of the scene and the timing determined that the gun would have been thrown by the victim 30 ft. and 2 s prior to the point at which the victim was first shot by the officer. The officer stated that he saw the gun in the victim's hand prior to tripping but the victim had thrown the handgun approximately 20 ft. prior to reaching the location the officer stated the victim tripped and well before the shooting occurred. At the time that the victim threw the gun, the officer was only 10 ft. away and should have been able to see the weapon being thrown. The victim, when shot, was unarmed and facing away from the officer.

Recent articles have examined how to determine direction and sequence of fire between multiple gunshots to the head by investigating the fracturing pattern in bone [9,10]. However, other methods of determining firing sequence in multiple gunshot wound cases are lacking in the peer-reviewed literature. As this case demonstrates, an analysis of body position and gunshot wound location in order to determine the physical activity impairment from each shot and the possible positions of the shooter and victim allow investigators to determine sequence of fire. Bullet trajectory analysis is a necessary skill of the forensic pathologist but must be considered along with all auxiliary evidence. A complex three-dimensional reconstruction of a crime scene incorporating the bullet trajectories, bullet casings, blood spatter, and witness testimony allows the forensic pathologist as well as those evaluating the crime to determine the likely true events, but also to convey that information to others in legal proceedings [11]. Although accounting for all possible scenarios is challenging, a 3D reconstruction is an important tool that can allow for several conflicting witness testimonies to be examined and the most probable events to be determined. A recent case report using 3D analysis and animation also examined bullet trajectory in order to determine the relative positions of both victim and shooter [12]. However, in that case report the single eyewitness testimony was relied upon and no litigation occurred. This more complex case with conflicting witness testimony required the use of a 3D model analysis in order to analyze the credibility of conflicting witness testimony. In this case, criminal charges were not filed against the police officer, but the civil case against the police department was settled prior to going to court.

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