Small-Caliber Gunshot Wound With Fragment Lodged in Thoracic Foramen in a Patient With Partial Brown-Sequard Syndrome

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Unfortunately, our society is marked by continued violence, including a high rate of gunshot injuries. Gunshot wounds to the spine account for 13% to 17% of all gunshot wounds.[1] Gunshot injuries to the spine occur mostly in the thoracic spine but inflict the most devastation and functional impairment when they involve the cervical spine.[2,3] Spinal cord gunshot wounds most often occur in minorities between ages 15 and 34. Spinal cord damage after gunshot wounds is more likely than blunt trauma to result in complete injury.[3-5]

Case Report

A man in his mid-20s sustained a low-caliber gunshot wound to the chest. Initially seen at an outside emergency department, he was noted to be diaphoretic and tachycardic, but otherwise his vital signs were stable. On initial evaluation, he was combative and significantly weaker in the left lower extremity than in the right. Further examination revealed the gunshot entrance wound to be within the left axilla. No exit wound was found. Subsequent workup revealed a left hemopneumothorax. Spine x-rays showed the missile projectile lodged within the thoracic spine (Figures 1A, 1B). A computed tomography (CT) scan localized the missile projectile within the T10–T11 neuroforamen (Figure 2). A left chest tube was placed. A diagnostic peritoneal lavage was negative. The spinal cord steroid protocol was instituted before the patient was transferred to our institution.

Upon arrival at our institution, the patient was intubated secondary to pulmonary difficulties. He was given tetanus booster and intravenous broad-spectrum antibiotics (these antibiotics covered gram-positive, gram-negative, and anaerobic flora). The steroid drip was discontinued at 24 hours. Sedation was weaned and neurologic function assessed. Examination findings were consistent with a Brown-Sequard incomplete spinal cord hemisection. Upper extremity examination demonstrated full strength, sensation, and range of motion with symmetrical reflexes. Lower extremity examination revealed globally decreased strength in all muscle groups (4/5 motor strength) on the right, whereas examination of the left revealed the presence of only muscle contractions (1/5 motor strength) in all groups. Sensation examination was normal in the left lower extremity but diminished to light touch over the dorsal and plantar aspects and the first web space of the right foot. There was no response to deep pressure or pain on any aspect of the right foot. Rectal examination revealed normal tone and an intact bulbocavernous reflex. There were symmetric brisk reflexes in both the upper and lower extremities, an equivocal Babinski sign bilaterally, 2 beats of clonus, and good peripheral pulses.

The patient was medically stable for extubation on hospital day 2. The rest of his hospital course was complicated by a persistent pneumothorax, pleural effusion, and subsequent pneumonia, which eventually resolved with antibiotics and prolonged thorocostomy tube drainage. Neurologically, the patient demonstrated spontane-

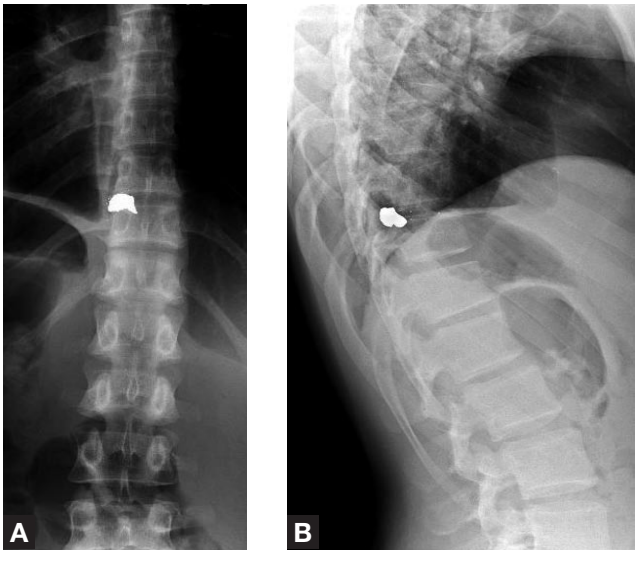

Figure 1. Anteroposterior (A) and lateral (B) x-rays show missile fragment lodged in T10–T11 foramen.

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Am J Orthop. 2008;37(3):E55-E58.

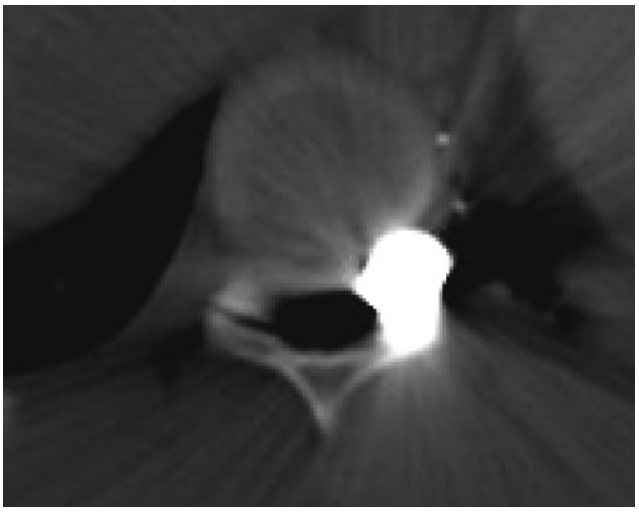

Figure 2. Computed tomography image shows fragment in T10–T11 neuroforamen.

ous improvement in strength and sensation of the lower extremities. He was allowed to mobilize with physical therapy without restrictions. Brace treatment was instituted for comfort. Total hospital stay was 21 days.

By time of discharge, the patient's right lower extremity strength had returned to normal, but sensation was still diminished to deep pain. The left lower extremity demonstrated gradual improvement in strength; the patient had 2/5 hip and knee flexors, 3/5 dorsiflexion and plantar flexion, and 4/5 strength of the extensor and flexor hallucis longus. The patient also had complete and normal sensation to pain and light touch on the left lower extremity. He was discharged home with outpatient physical therapy, an external brace for comfort, and gabapentin for residual neuropathic pain.

By the most recent clinical and radiographic follow-up (18 months), the patient had returned to baseline with full neurologic return of motor and sensory function, and he no longer required additional medications or bracing.

Discussion

The case we describe in this report provides an excellent example of gunshot injury to the spine and appropriate management. Our objective in writing this report was to review the management of gunshot wounds, to educate emergency and trauma physicians as to the proper indications for antibiotic therapy and management, and to issue the warning that steroids are not indicated for gunshot wounds to the spine.

Evaluation and Management

Energy from a gunshot projectile is directly related to both mass and square of the velocity of the bullet ($KE = \frac{1}{2}\, mv^2$). Gunshot energy is further classified into low and high energy, depending on muzzle velocity. Muzzle velocities of less than 1000 to 2000 ft/s are defined as low energy, whereas speeds of more than 2000 to 3000 ft/s are defined as high energy.[4] Low-energy firearms include pistols and handguns; high-energy, high-velocity weapons include military assault rifles.[4] It is crucial to determine what type of weapon was used and the distance between the weapon and the victim, as treatment options will differ. In addition to the amount of energy from the weapon, the path of the bullet can result in increased injury, as the zone of destruction may be larger than expected. Yaw refers to the tumbling of a bullet along its longitudinal axis. Therefore, longer bullets produce more yaw and can result in a larger zone of destruction.

Bullet Toxicity. Bullets are commonly composed of a lead core that may also contain copper, nickel, or brass. Grogan and colleagues[6] and Linden and colleagues[7] noted that these substances can have both systemic and local toxicities on tissues. Lead intoxication (plumbism) from retained bullets has seldom been reported but may be fatal if unrecognized. Bullets lodged within joint spaces or pseudocysts are more likely to develop this complication, though patients with retained missiles in other locations may also be at risk. Subtle findings, such as unexplained anemia, abdominal colic, nephropathy, or neurologic deterioration in patients with retained missiles, may suggest consideration of plumbism.[6] With any of these symptoms, bullet removal is necessary. In clinical practice, bullets that involve the spinal cord seldom need to be removed from the spine in order to treat or prevent lead toxicity.[7,8]

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The Primary Survey. In evaluating a patient who recently sustained a gunshot wound, one must be primarily concerned with treating any life-threatening injuries first. As in our patient's case, management of airway, breathing, and circulation (ABC) is of primary importance. The thoracic spine is the area most commonly affected by a gunshot wound to the spine.[2,8] One must evaluate for any damage to the heart, lung, and great vessels and for any signs of hemothorax, pneumothorax, cardiac tamponade, or heart perforation. The abdomen must also be evaluated for any solid organ damage, bowel injury, or vascular injury, as these injuries have a high incidence of spinal infection if not treated with appropriate antibiotics.[7,8,10] The cervical spine must be stabilized with a hard collar until radiographic evaluation of the spine is complete. During spine evaluation, gunshot wounds that fracture the vertebrae are inherently unstable. The entire patient should be exposed to look for entrance wounds and possible exit wounds. It is also critical to determine if the bullet passed from front to back in order to assess if bacteria from

the abdomen and bowel may have been tracked to the spine. It is critical to treat these cases with appropriate antibiotics as soon as possible.

Evaluating Spinal Cord Injury. After completion of the primary survey, a specific and detailed examination of any spinal cord injury should follow. Examination should encompass motor function, sensation, reflexes, and anal sphincter tone. If possible, initial examination should be performed before the patient is intubated, sedated, or given paralytics, so that the most detailed and accurate examination findings can be obtained. If paralytics have not been used, it will be possible and necessary to test deep tendon reflexes and the bulbocavernous reflexes.

"[With MRI] ...bullet fragments may migrate under the magnetic pull and cause additional damage and injury."

Spine Imaging. When imaging the spine to assess damage and attempt to track the pathway of the bullet and its fragments, anteroposterior and lateral plain x-rays should be obtained. X-rays will help determine the bullet and fragment locations. The next step in imaging is CT. CT images allow for better localization of the bullet within the vertebral segment and can more clearly demonstrate foreign bodies in the spinal canal; however, CT images are often obscured by artifact when metallic bullet fragments are present and can limit details.[8] Use of magnetic resonance imaging (MRI) in assessing gunshot wounds to the spine is still contested. There is legitimate concern that bullet fragments may migrate under the magnetic pull and cause additional damage and injury.[8,11] The advantages of MRI over CT include markedly less artifact, better soft-tissue imaging, and coronal, sagittal, and axial visualization of neural elements.[8,12,13] In our practice, we do not routinely perform MRI unless there is clear clinical evidence of neurologic deterioration. Even in these instances, the benefits should be carefully weighed against the risks and discussed with the patient if possible.

Antibiotics. Use of antibiotics in gunshot wounds depends on injury location and risk for sepsis. Length and type of antibiotic treatment vary according to extent of soft-tissue and organ injury, site of bullet entry, path of bullet within body, and possible exit wound. Bono and Heary[9] recommended that, for gunshot wounds not complicated by viscus perforation, antibiotics should be maintained for 48 to 72 hours. In this situation, broad-spectrum antibiotics for gram-positive and gram-negative organisms should be used. Numerous studies have demonstrated that organ perforations carry a much higher risk for infection.[6,7,12,14] Bullet pathway is important to consider, particularly if the bullet penetrated the colon before entering the spinal column. Romanick and colleagues[10] realized an 88% rate of spinal infection after colonic perforation versus no infections if the bullet penetrated the stomach or small intestine. Spinal infections secondary to gunshot wounds that carry with them colonic flora include meningitis, vertebral osteomyelitis, and abscess. For patients with associated colonic perforation, it is recommended that broad-spectrum antibiotics for gram-positive, gram-negative, and anaerobic organisms be considered for 7 to 14 days after initial injury.[7,12] In addition, in all cases, if it is learned during initial evaluation that the patient has not recently received tetanus prophylaxis, it should be given immediately along with broad-spectrum antibiotics.[13]

The Importance of Serial Exams. It is critical to complete serial examinations on patients with gunshot wounds to the spine. One must establish a baseline examination, and multiple examinations must be performed and documented. Compared with blunt trauma, gunshot wounds more often result in a complete injury, which is complete loss of motor function and sensation distal to the spinal cord injury. In some instances, the gunshot wound may produce an incomplete spinal cord injury that renders a deficit distal to the spinal cord injury, but with some preservation of function.

Incomplete Spinal Cord Injuries. Types of incomplete spinal cord injuries include central cord syndrome, anterior cord syndrome, posterior cord syndrome, and Brown-Sequard syndrome.[7,15]

The most common of the incomplete spinal cord injuries is *central cord syndrome*. This usually results from a hyperextension injury in a patient with preexisting spinal column narrowing. Patients present with decreased motor strength affecting the upper extremities much more than the lower extremities. Patients have a fair prognosis from this injury.

The second most common incomplete injury is *anterior cord syndrome*. This results in damage to the anterior portion of the cord, yet the posterior columns that provide proprioception and vibratory sensation are intact. These patients have more motor loss in the lower extremities than in the upper extremities, and this type of injury has a poor prognosis for recovery.

The very rare *posterior cord syndrome* results from damage to posterior columns of the spinal cord. Patients present with intact motor function, pain, and temperature sensation but have diminished or absent vibration and proprioception.

Brown-Sequard syndrome carries the best prognosis. These patients present with loss of ipsilateral motor function, loss of contralateral pain, and loss of temperature sensation, with the result being damage to the ipsilateral corticospinal tract and the spinothalamic tract. The corticospinal tract carries motor function distally to the ipsilateral muscles, and the spinothalamic tract carries pain and temperature from the contralateral sides that entered the spinal cord several levels below.

Bullet Removal. In contrast to the predominance of cervical-level injuries after blunt trauma, the majority of spinal cord injuries after gunshot wounds occur at the

thoracic level.[7] There has been much debate regarding removal of bullet fragments, and the first and most important step is to assess neurologic function. Stauffer and colleagues[16] reviewed 185 cases of gunshot paralysis and found no appreciable return of neurologic function after both surgical and nonoperative management of complete and incomplete spinal cord injuries. Several studies have found that lesions to the lumbar spinal cord and thoracolumbar junction have better neurologic recovery than lesions at more cranial levels, regardless of whether surgery has been performed.[7,16] Waters and Adkins[17] demonstrated motor improvement after surgical decompression from T12 to L4. They compared this with nonoperative treatment of spines and found the more cranial sites in the thoracic and cervical regions, surgical removal, and decompression had no significant effect on neurologic outcome. However, if there are progressive neurologic symptoms, surgical decompression is necessary and emergent to remove the bullet fragments and possibly evacuate an epidural hematoma or fracture fragments.

Steroid Use. Regarding management of patients with gunshot injuries to the spine, there has been much debate regarding use of steroids and their outcome. Numerous recent studies have shown that use of either methylprednisolone or dexamethasone regimens does not improve neurologic recovery of patients who sustained gunshot wounds to the spine with either complete or incomplete injuries compared with patients who did not receive steroids.[7,17] More important, administration of steroids is not a benign process. As with all medications, there are side effects. In the National Acute Spinal Cord Injury Study (NASCIS-II), complications of steroid use were evaluated at 24 hours, 48 hours, 72 hours, 6 weeks, and 1 year. NASCIS-II and other studies have shown that wound infections and gastrointestinal hemorrhage were increased with use of intravenous steroids.[7,18] Given these findings, we are no longer routinely initiating or continuing use of high-dose steroids for gunshot injuries to the spine and are individualizing its use to each case.

Conclusions

Gunshot wounds to the spine are increasing in incidence. It is critical to manage these injuries properly. Initial management should follow the rules of the primary survey and focus on addressing ABC management. Once the patient is medically stable, attention can turn to the secondary survey and evaluation of the neurologic injury. A thorough initial and serial neurologic examination with careful documentation is mandatory. Imaging should begin with plain x-rays and, if necessary, a CT scan. Because of the theoretical risks associated with use of MRI and the metallic projectile, routine use of MRI has not been advocated.

The few indications for surgical removal of the projectile include an inherently unstable spine and progressive neurologic deterioration. Early data suggest that recovery from gunshots to T12–L5 may be better after removal of intracanal bullets than after nonoperative treatment. Current data do not support use of high-dose steroids for the isolated gunshot wound to the spine; in the absence of worsening neurologic deficits, use of high-dose steroids should not be implemented. Use of steroids has shown no functional benefit and much higher risk for infection and gastrointestinal bleeding. Because mechanical instability is unlikely after gunshot wounds to the spine, brace treatment can be instituted for comfort but is usually not required for long-term stabilization. Finally, risk for metal toxicity has not been shown with retained fragments.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.