A Review Paper

Gunshot Wounds to the Spine: Literature Review and Report on a Migratory Intrathecal Bullet

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Abstract

Treatment of the complex injury to the spine produced by a gunshot wound remains controversial. Treatment depends on the physician's ability to understand mechanism of injury, principles of medical management, diagnostic imaging, and surgical options. Antibiotics are an important component of treatment and should be continued for a minimum of 7 days in cases of wounds that both perforate the colon and injure the spine. Corticosteroids do not affect neurologic outcome and therefore should not be used.

Decompression and removal of intracanal bullets at T12 and below may improve motor function. In select cases of cervical injuries, removal of intracanal bullet fragments may be justified, particularly with incomplete lesions. Regardless of injury level, new-onset or progressive neurologic deterioration is an indication for urgent decompression. Optimal surgical timing remains a controversial issue, and more study is needed to develop treatment guidelines.

Intrathecal migratory missiles represent a very rare subset of the gunshot wounds to the spine, and their treatment should be individualized. In this article, we review the literature and then describe the case of a migratory intrathecal bullet in the lumbar spine of a patient who presented with cauda equina–type symptoms.

Initial Evaluation and Management

Gunshot wounds to the spine are potentially devastating injuries that account for approximately 13% to 17% of all spinal cord injuries every year.[1] Gunshot wounds are most common in the thoracic region, are more likely than blunt trauma to cause complete spinal cord damage, and have their highest incidence in young minority males.[2-4] Initial management of a patient with a gunshot wound must include following standard trauma protocols, with maintenance of airway, breathing, and circulation taking precedence. Evaluation should be guided by area of injury: Gunshot wounds to the neck may be complicated by injuries to the airway or esophagus; wounds to the thoracic region are at risk for damaging major organs, including the heart, lungs, and bowel; and sacral injuries are most often complicated by hemorrhage.[5,6]

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After the patient is stabilized, the spinal injury should be thoroughly evaluated. Important history may include information about type of weapon used, number of shots fired, and proximity of shot(s). This information provides important clues regarding extent of injury and will guide treatment decisions. The physical examination is equally important in assessing gunshot patients. A complete neurologic examination must be performed to document motor function, reflexes, and sensation at time of injury. Periodic examination, preferably by the same physician, is needed to assess any deterioration in neurologic function because it may affect treatment decisions. A rectal examination should also be performed. Entrance and exit wounds should be inspected and radiopaque markers placed over all wounds to help identify the gunshot path in radiographic studies.

Initially, 2 orthogonal plain radiographic views of the spine must be obtained to locate fragments of the bullet and detect fractures. This should be followed by computed tomography (CT), which is the study of choice, as it allows for more precise localization of the bullet fragments within the spinal canal or vertebral segments.[7] Although magnetic

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resonance imaging (MRI) is better for detecting soft-tissue damage and produces less artifact, its use remains controversial because of the potential for bullet fragments to migrate and cause additional neural injury.[7,8] However, a detailed study of morbidity associated with MRI use after gunshot wounds to the spine has not been conducted, and numerous investigators have demonstrated that MRI can be used safely in the appropriate clinical context.[7]

Role of Antibiotics and Steroids

Aggressive medical management is indicated for all spinal gunshot wound patients. Tetanus prophylaxis is required, especially if immunization status is unknown. Moreover, broad-spectrum antibiotics should be started immediately, regardless of injury location and without delaying treatment for wound culture, which has limited utility in this setting.[7,9] Recommendations regarding optimal length of antibiotic treatment vary in the literature. The decision should be based on clinical assessment of the wound, injury location, and whether a viscus was perforated. Antibiotic prophylaxis of gunshot wounds that have not perforated the viscera should continue for a minimum of 48 to 72 hours. If the injury is complicated by viscus perforation before the bullet enters the spine, however, antibiotics should be continued for 7 to 14 days, particularly with colonic wounds.[10-12]

Roffi and colleagues[11] retrospectively studied 42 patients with gunshot wounds to the spine. In each case, the bullet perforated the viscus before entering the spine. Various combinations of antibiotics were used, including cefoxitin, gentamicin, clindamycin, and penicillin, for a minimum of 6 days. There were 3 spinal infections, 2 paraspinal abscesses, and 1 case of meningitis. More recently, Kumar and colleagues[10] found, in 13 patients with spinal gunshot wounds and colonic perforation, no spinal infection after treatment with antibiotics for 7 days. Optimal antibiotic treatment for spinal cord gunshot injuries after esophageal and upper airway perforation is unclear. There is a need for controlled studies to demonstrate the effects of antibiotics in these situations. Regardless of viscus perforation, use of diverting colostomies and surgical débridement does not appear to affect the rate of spinal infection.[7]

Recent Findings About Steroids. Until recently, the role of corticosteroids in the treatment of spinal gunshot wounds was undetermined. Levy and colleagues[13] retrospectively reviewed 252 cases of spinal cord gunshot injuries and concluded that use of methylprednisolone did not affect neurologic outcome in either incomplete or complete spinal injuries. Supporting this conclusion, Heary and colleagues[14] found that patients with spinal cord injuries from gunshots treated with methylprednisolone or dexamethasone showed no improvement in neurologic recovery compared with patients who did not receive steroid therapy. Given the lack of efficacy, steroids should not be included in the treatment regimen for patients with spinal cord injuries from gunshots.

Surgical Indications

The decision to perform surgery depends on 4 main variables: neurologic status, spinal stability, bullet location, and injury level. Structured algorithms that may facilitate treatment decisions for blunt and penetrating chest and abdominal trauma were described by Bishop and colleagues.[2] However, the mortality rate was not substantially higher for these gunshot patient protocols than for treatments that deviated from the algorithms.[2] There is a continued need for well-studied protocols, specific to spinal gunshot injuries, to simplify treatment decisions and improve the standard of care.

Neurologic Status. Neurologic status is best evaluated in thorough serial examinations by a single experienced observer who can accurately document findings. Patients with a progressive or new-onset neurologic deficit with a radiologically identifiable cause—including patients with bone fragments, bullet fragments, or compressive epidural hematoma—should be treated with urgent decompression regardless of other factors.[2,7] In neurologically intact patients, there are relatively few indications for surgery, as overly aggressive treatment may result in additional injury.[7] Recently, Medzon and colleagues[15] retrospectively reviewed 81 patients with cervical spine gunshot injuries and reported a low rate of fracture and instability in alert, neurologically intact patients. Decompression after complete and incomplete spinal cord injuries was studied by Stauffer and colleagues.[16] Of the 185 cases of gunshot paralysis, approximately half were treated with observation; the other half were treated with decompression. For complete injuries, there was no statistical difference between those treated surgically and those treated nonsurgically. For incomplete injuries, 77% of nonsurgically treated patients and 71% of surgically treated patients showed neural improvement. Surgically treated patients also experienced a higher rate of complications, including wound infections, spinal fistulae, and late spinal instability. It is important to note that spinal injuries from gunshot wounds are not always accompanied by neurologic impairment.[17] Recently, Klein and colleagues[17] reported a significant incidence of spinal injury in asymptomatic gunshot wound patients and recommended complete radiographic imaging to ensure that spinal injuries are not missed in this population.

Spinal Stability. Criteria for spinal stability after gunshot injuries are not well established. Previously, the 3-column theory for spinal stability popularized by Denis[18] was applied to gunshot injuries of the spine.[7] Unlike blunt trauma, however, gunshot injuries provide a directional force on the static spine and may be less likely to cause instability, even in 2- or 3-column injury.[7] Flexion and extension x-rays of the cervical spine are indicated to visualize abnormal mobility of the spine. Ideally, these studies are performed after immobilization for 2 weeks, by which point pain and muscle spasms have decreased. As already noted, MRI may also be indicated in the acute setting to identify ligamentous stability if there is no significant risk

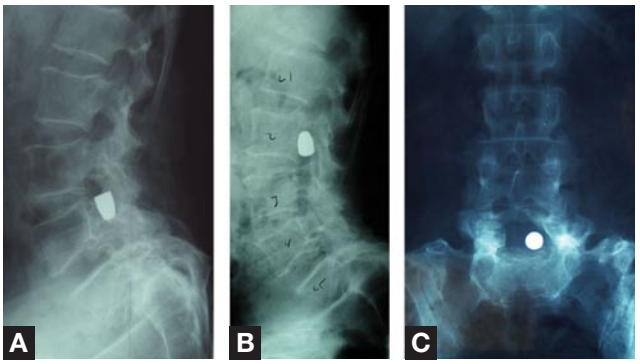

Figure 1. (A) Lateral x-ray of lumbosacral spine shows bullet lodged in spinal canal at L4. Note vertical orientation of missile and previous decompression and fusion at L4–S1 for isthmic spondylolysthesis. (B) Lateral x-ray myelogram shows even farther cephalad migration of bullet to L2. (C) Anteroposterior x-ray of lumbosacral spine. Note 90° change in bullet orientation from lateral x-ray. Bullet is now oriented horizontally, which confirms its migration.

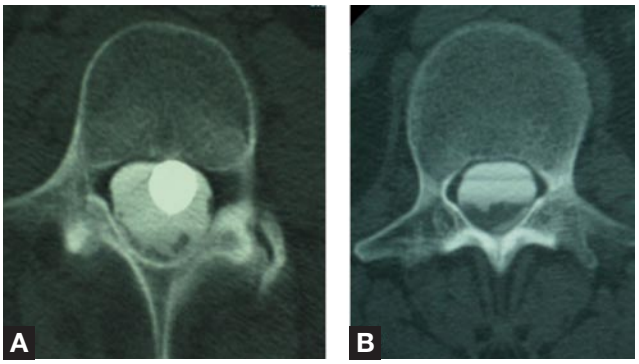

Figure 2. (A) Axial cut of computed tomography (CT) myelogram at L2 pedicle. Note intrathecal nature of missile. (B) Axial cut of CT myelogram shows layering of cerebrospinal fluid with intrathecal contrast, possible organized hematoma, and clumped rootlets consistent with arachnoiditis.

to neurologic status. If there is evidence of spinal instability, surgical intervention with instrumentation and fusion constructs may be indicated to prevent additional neurologic damage.[7]

Bullet Location and Level of Injury. Decisions regarding removal of bullets or bullet fragments depend on spinal canal proximity. Prospectively analyzing results of decompression on spinal injuries with intracanal bullets, Waters and Adkins[19] found statistically significantly improved motor function after surgical decompression of T12 to L4 lesions compared with nonsurgical treatment. However, there were no significant neurologic improvements with surgical removal and decompression at other levels of the cervical and thoracic spine. There is a paucity of evidence as to the efficacy of bullet removal in the cervical and thoracic spine. Bono and Heary[7] advocated removing intracanal fragments from cervical-level injuries, particularly with incomplete lesions, because of the potential for 1 or 2 levels of recovery. However, the authors did not believe that surgical removal is justified in thoracic-level injuries in which little functional return is sacrificed.[7]

Although gunshot wounds are most common in the thoracic spine, injuries to the cervical spine are potentially more devastating to neurologic function.[2,5] Recently, Medzon and colleagues[15] analyzed the incidence of spinal cord injury and the stability of cervical spine fractures after gunshot wounds to the head and neck. Of the 81 patients identified over a 13-year period, 19 had sustained cervical spine fractures. Approximately 84% of patients with cervical spine fractures presented with either neurologic deficits or altered mental status. Only 3 patients underwent operative stabilization and/or decompression for unstable cervical spine injuries; all 3 had associated neurologic deficits. The authors found a low incidence of unstable cervical spine fractures in patients who were alert and examinable and who showed no signs of neurologic deficit. They concluded that spinal precautions and/or a hard cervical collar should not be maintained if they are hindering emergent airway or hemodynamically stabilizing procedures, particularly in awake, neurologically intact patients.[15]

Special Indications for Surgery. A few special indications for surgery warrant further discussion. If there is evidence of cerebrospinal fluid leak, then a lumbar subarachnoid drain should be inserted. For persistent cerebrospinal fluid leaks, open surgery with laminectomy and repair of the dural injury must be considered because of the risk for meningitis.[11,12] Lead intoxication from gunshot wounds to the spine is another rare complication.[20,21] If the bullet is located near facet joints or intervertebral discs, lead intoxication is more likely to occur, as synovial fluid can elute lead from the bullet.[7] Patients who have lead intoxication confirmed by peripheral blood lead levels or bone marrow biopsy should be treated with chelating agents and then bullet removal if it can be safely accomplished.[7] Gunshot wounds to the spine have also reportedly caused disc herniation and acute neurologic compromise.[22] Treatment of these injuries is the same as for any other cause of disc herniation, with disc excision being the definitive procedure. Bullet removal is not absolutely required unless it can be done safely, without damaging surrounding structures.

Timing of Surgery

If surgery is to be pursued, the important issue of procedure timing should be addressed. Controversy continues over early versus delayed surgical management, and there is no conclusive evidence for either side of the debate. Interestingly, almost all these studies fail to address the role of surgery in spinal injury after gunshot wounds. Cybulski and colleagues[23] retrospectively reviewed 88 patients with gunshot injuries at the conus or cauda equine level lesions and found no statistical difference in neurologic recovery for patients treated with decompressive laminectomy within 72 hours versus patients treated more than 72 hours after injury. Moreover, early versus delayed surgery or no surgical treatment at all may not significantly affect the overall rate of complications or length of hospital stay.[24] However, more randomized, controlled prospective studies

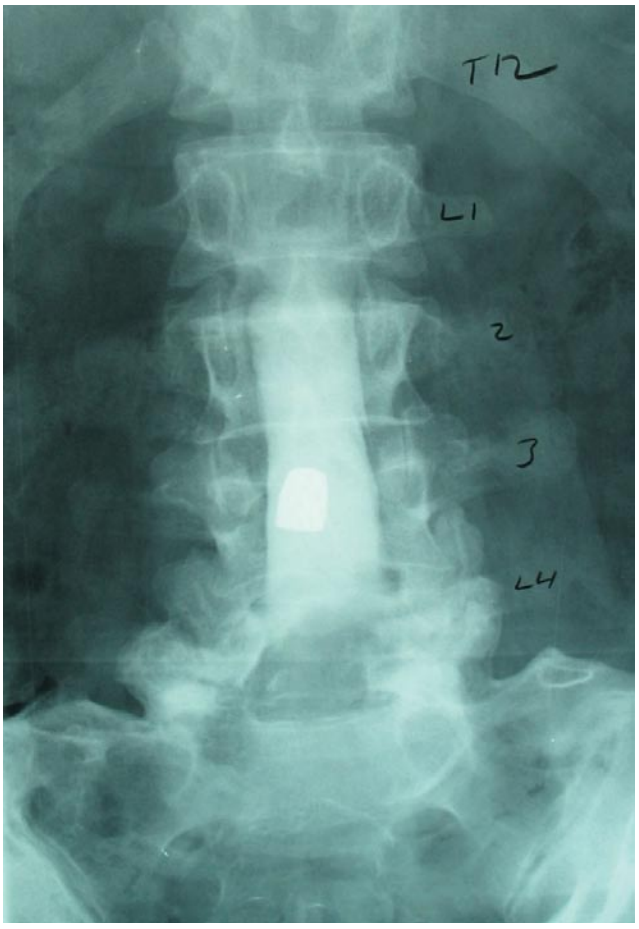

Figure 3. Anteroposterior x-ray myelogram shows missile at L3. Again note change in bullet orientation and in position from Figures 1 and 2.

specifically addressing the timing of treatment after spinal gunshot injuries must be conducted to provide evidence for optimal management.

A Caveat About High-Energy Wounds. One caveat is that the mentioned recommendations apply specifically to low-velocity, low-energy gunshot wounds. High-energy wounds caused by rifles or shotguns have different patterns of injury and wound characteristics that may increase the complexity of treatment decisions. Mirovsky and colleagues[25] recently reported a case in which a high-velocity gunshot wound caused complete paraplegia, but without evidence that the spinal canal had been violated. High-energy wounds may also cause more soft-tissue injuries, which are prone to infection. Studies performed on soldiers wounded in combat zones, where the majority of injuries are high-energy, have shown that surgical débridement is efficacious in preventing secondary complications.[26,27] It is likely that the same treatment principles apply to civilians who sustain high-energy wounds, which are becoming increasingly prevalent.

Migratory Bullets

Migration of retained missiles, which has been reported in the brain, blood vessels, and body cavities, presents an extremely challenging clinical problem. In the English-language literature, we found only one report of an intrathecal migratory missile (the patient presented with delayed radicular symptoms).[28] In the next section, we describe the case of a migratory intrathecal bullet in the lumbar spine of a patient who presented with cauda equina–type symptoms. The patient was informed that his clinical findings would be submitted for publication.

Case Illustration

A man in his early 50s presented to us 6 months after being shot and treated. He had been shot 4 times from a short distance with a low-velocity 45-caliber handgun during a robbery. One bullet was lodged in the spine. The shoulder and abdomen had also sustained gunshot wounds. The patient underwent emergent exploratory laparotomy at a nearby hospital. Initially, the spine wound was treated nonoperatively. The patient presented to us to seek a consultation regarding possible removal of the bullet. He could ambulate only with cane or crutches and complained of lost sensation in the toes on the right and of being incontinent of bowel and bladder. His Oswestry score was 60 points. On a pain diagram, he indicated pain in the left hip, right anterior knee, right lateral calf, right dorsal medial foot, midline lower back and buttock, bilateral posterior thigh, and plantar aspect of the right foot. On a 10-point scale, he rated his pain 3/10 at its best, 9/10 at its worst, and 4/10 on average. On the McGill questionnaire, he described his pain as shooting, exhausting, unbearable, and numb. He could not sit for more than 1 hour at a time. His pain was alleviated by bending forward and lying on his side.

Prior surgical history was remarkable for noninstrumented L4–S1 fusion for a high-grade isthmic spondylolysthesis (30 years earlier). Current medications included hydrocodone bitartrate and acetaminophen (Vicodin), morphine sulfate controlled-release (MS Contin), and gabapentin (Neurontin).

The physical examination was remarkable for somewhat decreased lumbar lordosis. There was 50% loss of range of motion in forward flexion and extension, which was painful. Extension with rotation to either side was painful. Flexion with rotation to either side was painless. Lateral bending to either side was painful with 50% loss of motion. Sensation was abnormal with hypoesthesia on the right in the L4, L5, and S1 dermatomes to light touch. Neither clonus nor Babinski sign could be elicited. Deep tendon reflexes were intact and symmetrical. The right extensor hallucis longus was 3/5 in strength, and the right gastrocnemius was 1/5 in strength. The rest of the motor examination was normal.

The patient's imaging studies have included plain x-rays, myelogram, and CT myelogram. The myelogram showed an intrathecal bullet, which migrated from L3 to L2 during the myelogram procedure. It also showed a solid prior fusion and decompression at L4–S1. The bullet was seen as low as L4–L5 on plain x-rays and as high as L2 during myelography, confirming migration of the mis-

sile. It also was observed spinning around its axis, changing its orientation in the spinal canal from horizontal to vertical on different views (Figures 1–3). As mentioned, the patient could alleviate his pain by bending forward and lying on his side—results that could be explained by the change in bullet position with those postures. As the bullet is a space-occupying lesion, his flexing forward (increasing the canal diameter) may also have alleviated the stenosis-type symptoms.

We consulted the army surgeon (see Acknowledgment). Bullet removal was recommended because of possible intrathecal lead toxicity and the potential for continued nerve rootlet microtrauma caused by bullet migration. However, the patient was cautioned that his traumatic cauda equina–type symptoms might not change significantly after surgery.

The surgery was performed with the patient in the prone position. Intraoperative fluoroscopy localized the bullet to L2–L3, and L2–L3 laminotomy was performed to expose the dural sac. Then a midline durotomy was performed to expose the intrathecal bullet, which was removed. The dural sac was closed and dural collagen patch with fibrin glue was applied.

The patient had immediate postoperative improvement in right leg symptoms, and the improvement was still evident at 13-month follow-up. He was back to work in his physically demanding occupation. He had complete bowel control but no bladder control and was completely dependent on self-catheterization. Residual pain was 60% in the legs and 40% in the lower back. However, the patient was still taking hydrocodone bitartrate and acetaminophen, morphine sulfate controlled-release, and gabapentin. His Oswestry score was improved (44 points).

Summary

A gunshot wound to the spine is a complex injury, and treatment remains controversial. Treatment depends on the physician's ability to understand mechanism of injury, principles of medical management, diagnostic imaging, and surgical options. Antibiotics are an important component of treatment and should be continued for a minimum of 7 days in cases of wounds that both perforate the colon and injure the spine. Corticosteroids do not affect neurologic outcome and therefore should not be used.

Decompression and removal of intracanal bullets at T12 and below may improve motor function. In select cases of cervical injuries, removal of intracanal bullet fragments may be justified, particularly with incomplete lesions. Regardless of injury level, new-onset or progressive neurologic deterioration is an indication for urgent decompression. Optimal surgical timing remains a controversial issue, and more study is needed to develop treatment guidelines. Intrathecal migratory missiles represent a very rare subset of the gunshot wounds to the spine, and their treatment should be individualized.

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