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Gunshot Injuries to the Thoracolumbar Spine

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Gunshot wounds to the spine are a common cause of spinal cord injury. The thoracolumbar area is the second most commonly injured region of the spine by gunshot wounds and is the focus of this article. In this article, the authors discuss the fundamentals of ballistics and tissue injury, involved in both low- and high-velocity gunshot wounds to the thoracolumbar spine. A discussion of the diagnostic and therapeutic tools involved in the management of these injuries is undertaken. Furthermore, the approach to the patient with a thoracolumbar gunshot wound is presented. Management must start with maintenance of airway, breathing, and circulation, and proceed with physical examination, laboratory, diagnostic imaging, and medical and surgical interventions. Tetanus prophylaxis and antibiotic administration for 7-14 days are imperative. Surgical debridement and surgical stabilization are rarely necessary in low-velocity, low-energy civilian gunshot wounds. Indications for surgery include wartime gunshot wounds, progression of neurologic deficit, persistent cerebrospinal fluid fistula, cauda equina syndrome with mass effect from bullet or bone fragments, and intracanalicular bullets between T12 and L4.
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Gunshot wounds to the spine are the second most common cause of spinal cord injury (SCI) after vehicular trauma, accounting for 13%-17% of all cases of SCI.[1] Furthermore, while the incidence of SCI caused by vehicular trauma is decreasing, the incidence of SCI secondary to gunshot wounds continues to increase.[2] Penetrating injuries, including gunshot wounds, account for an even larger proportion of SCIs when we compare urban areas to rural areas. Spinal gunshot wounds occur most frequently in young males aged between 15 and 34 years, and in urban environments, they are more common in minority populations.[3-5] In a review of gunshot injuries resulting in SCI in the Los Angeles area, 47% of the victims were black, 45% were Hispanic, and 4% were other minorities.[6]

Gunshot wounds to the thoracic area are the most common followed by the thoracolumbar area and then the cervical spine. Of these gunshot wounds, the majority do not result in SCI. SCIs resulting from gunshot wounds are more likely to cause complete sensorimotor paralysis compared with SCIs from blunt trauma.[2] In most cases of SCI caused by gunshot injuries, the bullet has passed through the spinal canal, and in a third of these cases, there are bullet fragments retained within the canal.[6] Unlike other forms of penetrating trauma, gunshot wounds to the spine can also cause SCI without cord penetration through concussive blast injury.[7] Of victims of gunshot wounds resulting in SCI, approximately 50% result in tetraplegia and 50% in paraplegia.[8] Like spinal cord injuries in general, incomplete neurological injuries from gunshot wounds have much better prognoses.[9]

Ballistics

The energy of a bullet is proportional to its mass (m) and velocity (v), as described by the formula for kinetic energy: $KE = ½ mv^2$. According to this formula, the kinetic energy of a bullet is proportional to the square of its velocity. Thus, by convention, muzzle velocities of <1000-2000 feet per second are characterized as low energy, whereas speeds >2000-3000 feet per second are considered high energy.[10] Low-velocity, low-energy firearms include pistols and other handguns, while high-velocity, high-energy firearms include military assault rifles.[10] Shotguns are low-velocity, high-energy firearms due to the combined mass of the pellets.[9] Most civilian gunshot wounds are caused by low-energy firearms, though there has been increased use of military style high-energy firearms among civilians.[10] The concept of temporary cavitation becomes important in ballistics as muzzle velocities exceed 1000 feet per second. In temporary cavitation, the

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bullet accelerates tissue in front of and to the sides of the tract yielding a temporary cavity, which can be as much as 30 times the diameter of the bullet. The temporary cavity collapses resulting in a necrotic region.[7] Close-range gunshots lose less energy during transit, and therefore transfer more energy to the victim. Differentiation between high- and low-energy injuries is worthwhile because the treatments are distinct.[10]

In addition to velocity, the wounding potential of a bullet depends on its composition, design, and size. Most bullets are composed of a lead core, which may be combined with other metals to achieve a desired hardness. Bullets may be jacketed with a thin layer of copper, brass, or nickel. Fully jacketed bullets exhibit little deformation with firing and are designed for accuracy to hit long-range targets.[10] The jacketing metal can have both local and systemic toxicities. Partially, or nonjacketed missiles expand on tissue impact and, like hollow-point bullets, exponentially extend the circumference of tissue damage.[10] Such designs are intended for close range targets. In cases of retained lead bullets, serum lead levels can be monitored periodically. Notwithstanding other clinical factors, significant increases in lead level and characteristic hematopoietic changes on bone marrow biopsy can be an indication for bullet removal. While cases of lead poisoning have been described with bullets lodged in the intervertebral disc, bullets rarely need to be removed from the spine to treat or prevent lead toxicity.[11] Animal experiments have demonstrated that copper can cause local necrosis of both brain and spinal cord tissue.[12,13] Fragments of lead seemed to result in less axonal damage than did copper. Furthermore, extradural fragments, regardless of composition, did not cause appreciable pathologic changes.[12,13]

Bullet caliber refers to the diameter of the bullet as measured in hundredths of an inch. Most civilian firearms use bullet calibers of 22-45. The shape of a bullet can influence its energy, as well. The more pointed a bullet, the greater its ability to overcome air resistance. Hollow-point bullets will flatten, rapidly decelerate, and explode on impact, leading to multiple fragments that deviate from the initial trajectory.[10] Yaw refers to the rotation of a projectile about its vertical axis. As bullet length increases, so does its yaw, resulting in a larger zone of destruction.[10]

Evaluation

The initial evaluation of the victim of a gunshot wound to the thoracic or lumbar spine begins with maintenance of airway, breathing, and circulation. With gunshot wounds to the thoracic spine, injuries to the heart, lungs, and great vessels must be considered. Careful chest auscultation can detect asymmetric breath sounds, indicating hemothorax or pneumothorax. Until stabilization of ventilation and hemodynamics, the evaluation of any spinal injury remains secondary. As such, routine spinal precautions should be used for all gun shot wound victims until a detailed neurological and radiological assessment is completed. The abdominal examination should focus on injuries to the viscus and/or vascular structures. Perforation of the colon is associated with high rates of spinal infection unless appropriate antibiotics are used.[14-17]

After hemodynamic stability is achieved, then focus is turned to the spinal injury. The cervical spine should be immobilized with a hard collar until radiographic clearance is confirmed. Strict log roll precautions must be enforced and the patient must be stripped of all clothing and examined thoroughly. The entrance and exit wounds should be identified and marked with radiopaque markers, after all wounds are cleaned and dressed. After this, a rigorous neurological examination should commence.

After the physical examination, 2 orthogonal plain radiographic views of the spine can help detect gunshot fractures and locate bullet fragments. Using radiopaque bullet hole markers, the bullet path can be deduced. Parameters, such as vertebral body height, interpedicular distance, and segmental kyphosis can be measured. In the awake, neurologically intact patient in whom spinal stability is in question, dynamic active flexion-extension views may be obtained. This is best delayed until 2 weeks after injury, when pain and spasms have sufficiently subsided.[10]

After plain films have determined the level of the bullet and/or fracture, computed tomography (CT) should be considered. CT images are useful in evaluating the location of the bullet and bone fragments, though their utility can sometimes be limited by metallic artifact.

The role of magnetic resonance imaging (MRI) for the evaluation of gunshot wounds to the thoracic and lumbar spine remains controversial. There is a theoretical risk of bullet migration, though multiple reports have not supported this concern.[18] The most common complaint from patients undergoing MRI scans is a sensation of heat in the area of the bullet.[10] At our institution, we routinely perform MRI on victims of civilian gunshot wound injuries with retained nonjacketed lead bullets.

Antibiosis

Tetanus prophylaxis must be considered in all instances of spinal gunshot wounds. If there is any question regarding the most recent immunization, tetanus prophylaxis should be administered in the emergency room at the time of initial evaluation.

Broad-spectrum antibiosis should be initiated for spinal gunshot wounds. For gunshot wounds without perforation of the bowel, 48-72 hours of antibiotics is adequate.[10] Perforation of the viscus, especially the colon, carries the highest rates of infection. In studies comparing spinal infection after colonic perforation vs perforation of the small intestine or stomach, colonic perforation yielded an 88% rate of spinal infection vs 0% for the others. The authors of this study found that surgical debridement may be beneficial in cases of colonic perforation.[17] Additional studies have shown that in cases of colonic perforation, the lowest infection rates have been found when parenteral antibiotics were given for 7-14 days.[14,16] Among the antibiotics chosen were cefoxitin, gentamicin, clindamycin, and penicillin. In our opinion, surgical debridement does not appear to be of benefit. Rather, a min-