

Review Article

Gunshot wound causing complete spinal cord injury without mechanical violation of spinal axis: Case report with review of literature

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Journal of Craniovertebral Junction and Spine 2015, 6:39

Abstract

Penetrating spine injury (PSI) forms the third most common cause of spine injury, only next to road traffic accidents and fall. Gunshot wound (GSW) forms the major bulk of PSI. Due to easy availability of firearms and antisocial behavior, GSW which were predominant in military population is now increasingly seen in civilized society. Here, we present a detail case review of unique case of civilian GSW indirectly causing complete spinal cord injury due to shock wave generated by the bullet, along with its systematic management.

Key words: Gunshot wound of spine, missile, shock wave, spinal cord injury

INTRODUCTION

The majority of Spinal cord injury (SCI) are the result of motor vehicle accidents and falls; however, penetrating spine injury (PSI) (primarily gunshot wounds [GSWs]) accounts for 13-17% of injuries.^[1-4] This makes the PSI is 3rd most common cause of spinal injuries, only next to road traffic accidents and fall from height.^[5]

GSW to the spine, which was earlier common in the military population is now being increasingly noted in civilized society due to easy availability of firearms of low-velocity either licensed or illegal combined with an increased rate of violence in the society.^[4] Since most of these injuries are due to act of violence, it is not surprising that they tend to occur in areas with high crime rate. Assaults and arguments represent the main motivation for gunshots among civilians, whereas accidental firearm injuries are rare.

According to the National Spinal Cord Injury Database, the mean age of penetrating SCI is 29.7 years, with a 4:1 male predominance.^[1,2] GSW varies in significance, from trivial injury to life-threatening conditions, which can occur in both military and civilian surroundings.^[6] The wound thus created depends on the type of weapon, ballistic properties of the bullet, and the distance from where it has been fired. Controversies in the management of GSW to spine existed right from the beginning and persist even today. The civilian experience with these injuries has generated less optimism than previous military reports.^[7-9]

The case presented here discuss about the medical challenges and proper step-wise management of a patient who sustained low-velocity gunshot injury fired from a short range.

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How to cite this article: Patil R, Jaiswal G, Gupta TK. Gunshot wound causing complete spinal cord injury without mechanical violation of spinal axis: Case report with review of literature. J Craniovert Jun Spine 2015;6:149-57.

Access this article online	
Quick Response Code:	Website: www.jcvjs.com
	DOI: 10.4103/0974-8237.167855

HISTORICAL ASPECT

First description on traumatic spine injury was given in 1700 BC in ancient Egyptian document of Imhotep.^[10] Later on Galen (130-200 BC) showed that longitudinal spinal cord lesions do not cause serious functional damage while transverse lesions were associated with paraplegia related to the level of the lesion.^[11] Ambrose Pare (1557) gave the first description of penetrating SCI caused by firearms.^[12]

CASE

A 38-year-old male farmer was accidentally shot by rifle pistol firearm weapon in the dorsal region of back with no exit wound. Bullet was fire from close range (distance of 6-8 meters). Patient was vitally stable on admission with Glasgow coma scale score of 15/15, paraplegia (power in both L.L Grade = 0) with complete loss of all type of sensation below D10 level. There was an entry wound in left posterior axillary line at the level of 10th rib. Patient underwent immediate contrast-enhanced computed tomography (CT) thorax and abdomen, which showed Grade III spleen laceration with left and right lung contusion and foreign bodies in lateral wall of right chest in intramuscular compartment at the level of 8th rib with right sided hemopneumothorax and hemoperitonium with no obvious bony injury [Figures 1, 2 and 5]. Patient underwent immediate exploration of thorax and abdomen with splenectomy with repair of gastric perforation with jejunostomy with right sided implantable cardioverter-defibrillators placed with removal of bullet from chest. After stabilization of general condition magnetic resonance imaging (MRI) spine was done, which showed abnormal signal in the intra-medullary compartment of the cord at D11-L1 level s/o cord contusion/cord edema [Figures 3 and 4]. Patient was manage conservatively for cord contusion and was then discharge. On follow-up after 12 months patients power in both Lower limb is Grade 0.

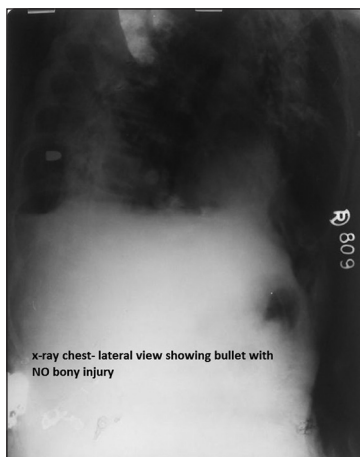


Figure 1: X-ray chest lateral view showing the bullet with no bony injuries

DISCUSSION

In the past decade, there has been steady increase in the incidence of penetrating spine injuries in civilians. Most are gunshot injuries; stabbing and other penetrating injuries are comparatively less common. Most common site of injury is thoracic cord 48-64% followed by cervical cord 19-37% then the lumbar spine 10-29%.^[1,13,18] Approximately, 40% of patients are shot in the back, while 19% are shot anteriorly.^[14]

PATHOPHYSIOLOGY OF GUNSHOT WOUND TO SPINE

Although there have been plenty of literature regarding GSW to the spine, a thorough review of unique mechanical and biological factors that affect the final outcome has been lacking. A thorough conceptual understanding of the pathogenesis of GSW to the spine is important to guide decision-making in such cases.^[15,16] The pathophysiology of GSW is complex. The key factor, which determines the amount of damage caused to the tissue depends on the amount of energy delivered to the affected tissues.^[16]

The kinetic energy of an object depends on its mass and velocity ($E = 1/2 mv^2$).

Missile injury causes damage to spinal cord and nerve roots by:

1. Direct injury.
2. Concussive injury secondary to shock wave.
3. Temporary cavitations.

Missile injuries are of two types:

1. Low-velocity injury.
2. High-velocity injury.

Because of contrasting mode of injury, low-velocity missile produces injury by direct contact and vertebral fractures while high-velocity missile can produce massive necrosis leading to paralysis merely by dissipation of enormous energy throughout the soft tissue and without any naked eye evidence of viscous or cord injury.^[15-17] Civilian GSW is much more different from military GSW due to the difference in weapons used.^[19] Civilian gunshot injuries are almost always accompanied with fracture of vertebrae causing direct injury by bullet or due to fracture vertebral bone segments. Military weapons causes' SCI secondary to shock wave and cavitations generated by high speed bullet.^[16] Of patients suffering from missile injuries as reported in the literature, 49-83% had complete injuries, 12-43% had incomplete injuries and 17-20% had cauda equina injuries.^[14,18-20] Civilian GSW causing cord contusion without vertebral fracture or direct injuries are rare. Bullet travelling in high speed in paravertebral plane causes cord contusion mostly due to shock wave generated by its trajectory. The other possible cause of such an injury is secondary to excessive ligament laxity leading to hypermobilization of cord, which is mostly seen in children's. These patients mostly present with clinical features of incomplete or complete cord injury. These patients

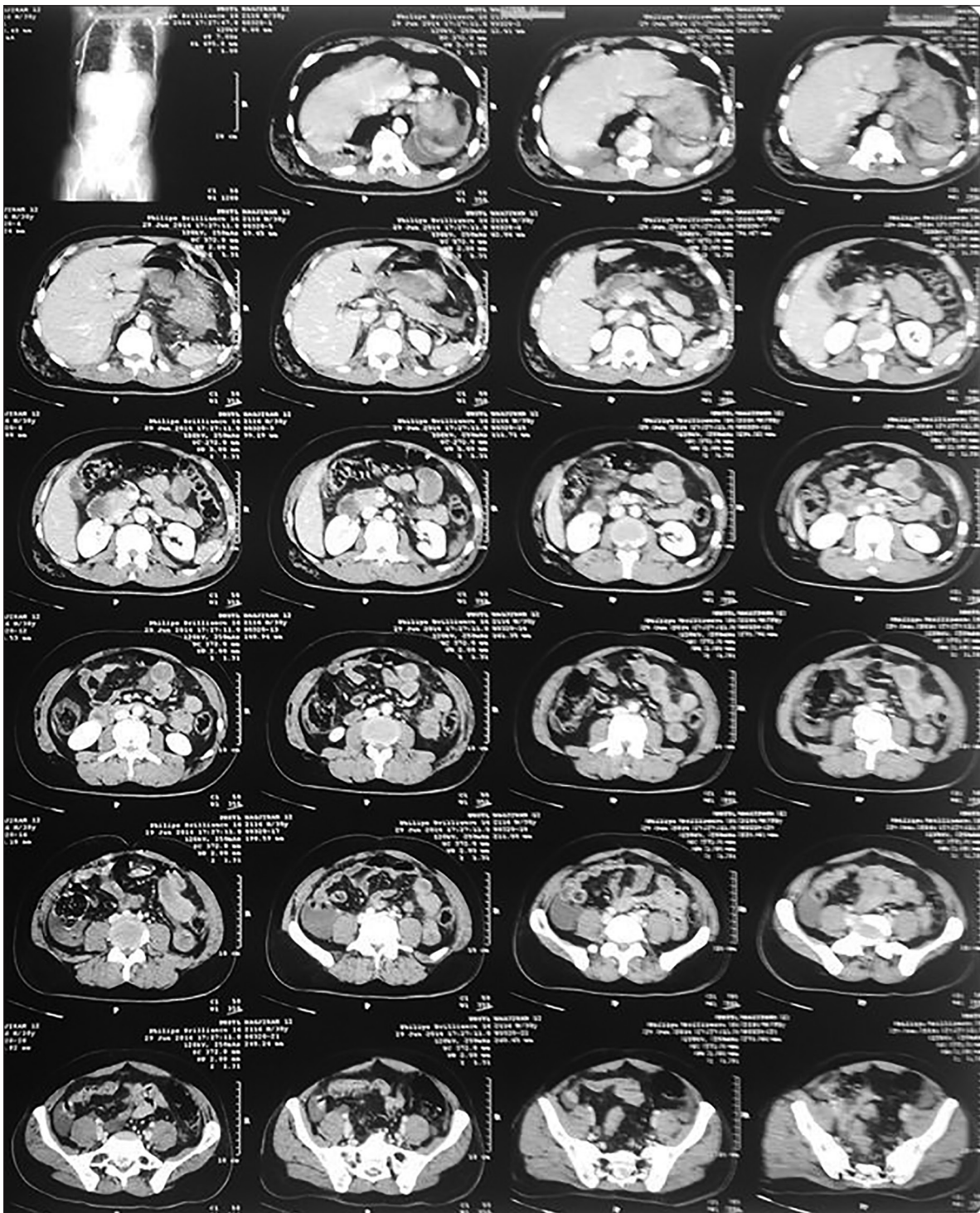


Figure 2: Computed tomography scan of the thorax and abdomen

are to be managed conservatively unless and until there is any other serious organ injury.

BALLISTIC

Ballistics is defined as the scientific study of projectile motion. A basic understanding of firearms and ballistics is needed to appreciate the wounding capacity of GSWs. Ballistic study is

further classified into three categories:

1. Internal ballistic,
2. External ballistic,
3. Terminal ballistics.

Internal ballistics is concerned with the projectile within the firearm. External ballistics is concerned with the projectile in the air. Terminal ballistics is concerned with what happens



Figure 3: Magnetic resonance imaging dorso-lumbar spine (sagittal view) showing cord contusion at D11-L1 vertebral level

when the projectile hits its target. Wound ballistics is a subset of terminal ballistics and is the most important aspect of ballistics that physicians need to understand.^[21,22]

Firearm exists with different size, muzzle velocities, and general uses. There is a major difference between military and civilian population GSW of spines, as firearms used in these two population groups are categorized according to energy and velocity.^[23]

Low-energy projectiles fired from pistols, revolvers, handgun, rifle travel at 1000-2000 feet per second (f.p.s.); are commonly seen in civilian use. Projectiles traveling at 2000-3000 f.p.s. are high-energy bullets fired from rifles and military weapons.^[24] Gunshot accidents in the civil population, therefore, involve low-energy firearms, and the tissue damage occurs mainly because of the impact from the projectile mass.^[25] The projectile velocity determines the wounding potential of the weapon,^[26] however, the energy is not the only factor contributing to tissue damage. The physical properties of the bullets, such as design and fragmentation, path of projectile, yaw of the bullet, size of projectile, distance from which it is fired, also determine lesion characteristics.^[27,28] Caseless ammunition tends to spread and produce a large, circumferential harm. Bullet comes in three different size:

1. Large caliber (0.45 caliber),
2. Medium caliber (0.32-0.38 caliber),
3. Small caliber (0.22-0.25 caliber).

In civilian GSW firearm firing small and medium caliber bullets are indeed the most common;^[24] however, the incidence of high-energy GSW in the civil population has increased.^[29] However, because of the difference between high- and low-energy weapons, treatment protocols designed in war situations should not be extrapolated to the normal routine in peaceful regions.^[9,30,31]

EVALUATION OF PENETRATING SPINE INJURY

The initial management of patient with PSI should follow the fundamentals of trauma resuscitation (ATLS protocol). Once

systemic stabilization is achieved, detail history including the mechanism of injury, weapon use and the distance from which the shot was fired, number of shots should be noted. A complete neurological examination should be done, determining the level and character of injury. Accurate classification as complete or incomplete SCI should be done using American Spinal Injury Association-SCI score. Mortality in patients suffering from GSW increases with the severity of neurological deficit.^[32]

The wound should be classified as entry and exit wound. The wound should be inspected for cerebrospinal fluid (CSF) leak, bullet, and other foreign bodies. The temptation to remove a foreign body from the wound in the emergency room should be avoided, as these foreign bodies may act as tamponade to vessels and prevent hemorrhage. Such removal should be done in the operation room.

CERVICAL SPINE GUNSHOT INJURIES

Injuries in the cervical spine are frequently associated with airway lesions and vascular lesions that may require emergency intubation or tracheostomy with or without neck exploration.^[33,34] Cervical GSWs most likely result in complete rather than the incomplete neurological deficit.^[25]

THORACIC SPINE GUNSHOT INJURIES

The thorax is the region most frequently affected by GSW.^[25,30,35-37] Solid organ, hollow visceral organs are at risk. Abdominal lesions and hemopneumothorax are the most prevalent (24% and 20%, respectively) associated injury^[25] and that transfixing lesions are the most common.^[30,38] The incidence of lesions to vital organs is 20%.^[39]

DIAGNOSTIC IMAGING

Routine multiplane X-rays of spine should be obtained in emergency room. Note should be made about the fracture spine, bullet fragments in spinal canal and neural foramina. In today's times, however CT and MRI form the mainstay of the investigation.

CT is an important adjuvant in the assessment of PSI. Precise identification of fracture, location of bone and disc fragments, location of foreign body, hematoma can be done, especially when the ferromagnetic properties of the bullet are not known.^[40] CT also helps in identifying the stability of spine.^[41] CT scan is also important tool in emergency situation to assess the whole body quickly.^[40] CT angiogram helps to rule out vascular injury. CT myelography can be quite helpful in selected cases with persistent CSF fistula.

MRI although a preferred modality of investigation in all spinal trauma, it is not so in PSI (with retained foreign body). Low-velocity bullets having copper jackets are nonferromagnetic and hence MRI may be performed.^[42] However, in an emergent setting it may be difficult to know the exact composition of the bullet.

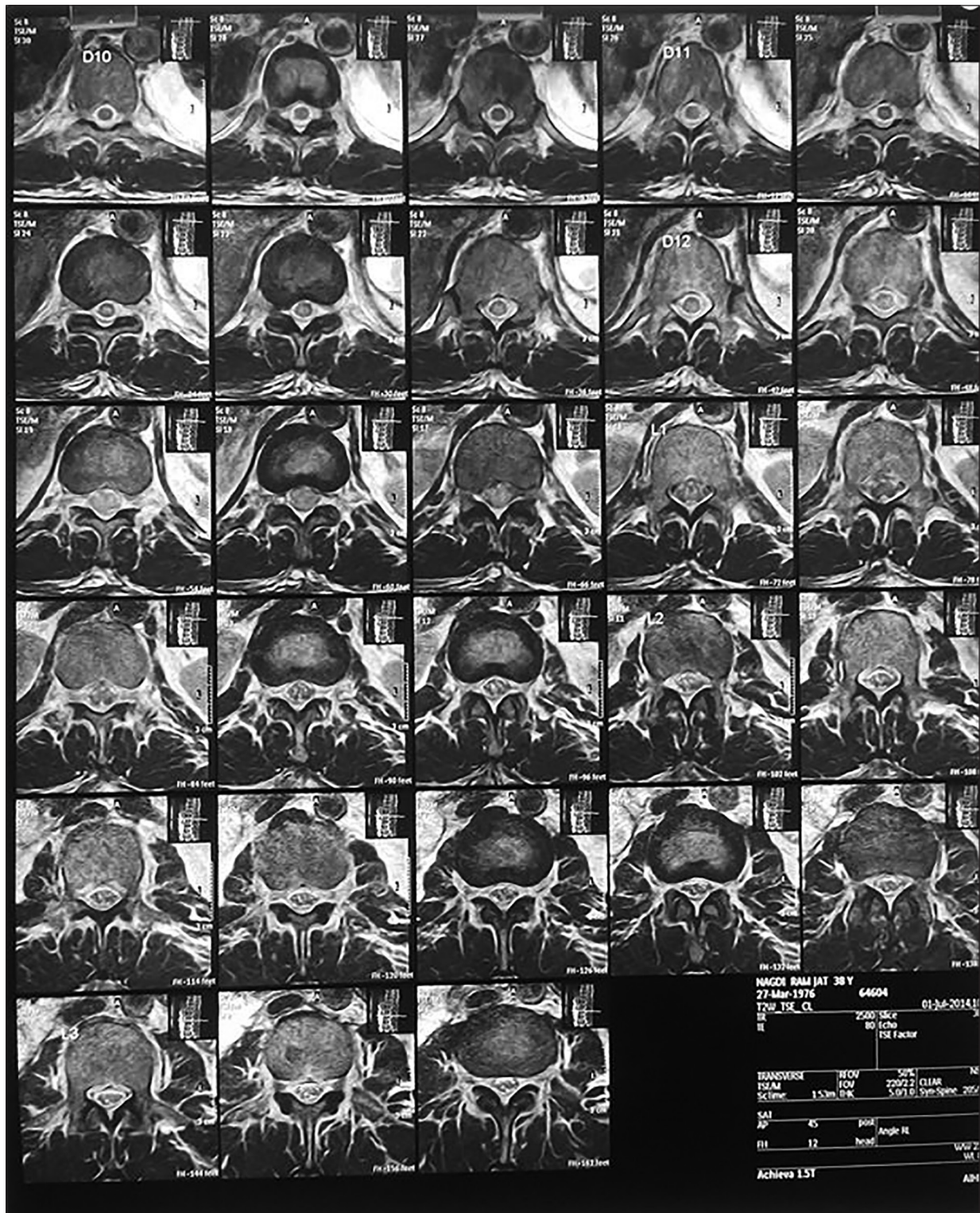


Figure 4: Magnetic resonance imaging dorso-lumbar spine coronal view showing cord contusion at D11-L1 vertebral level

TREATMENT OF PENETRATING SPINE INJURY

Much of the contemporary literature regarding penetrating spinal wound (GSW) presents analyses of neurosurgical and orthopedic military experiences. The early literature concerning

spinal missile injury reported poor outcome in world war I, which improved in world war II and thereafter.^[10,43,44] This was possible because of advance trauma support, proper understanding of Pathophysiology and biomechanics of the GSW, use of antibiotic and early surgery with advancement of micro-neurosurgical techniques.^[4] A proper concept of



Figure 5: Topogram image of computed tomography scan Thorax and abdomen showing bullet in right lateral chest wall

GSW spine pathophysiology, types, prognostic factors and management strategies should be in minds of neurosurgeons when dealing with such types of cases.

ROLE OF SURGERY

Role of surgery in treatment of GSW to spine is controversial. Most of the war time experience prefers surgical exploration with wound debridement laminectomy and removal of bullet. The possible explanation being, prevent infection, CSF leak, lead toxicity, pain, bullet migration. In contrast, the civilian literature favors nonsurgical management unless there is evidence of incomplete injury to the spinal cord with progressive neurological deterioration and persistent CSF fistula, migration of bullet within the spinal canal is present.^[45]

A recent study by Bumpass *et al.* found that the majority of civilian GSWs should be managed nonoperatively, regardless of neurological grade or number of spinal columns injured. Indications for surgery in his study were spinal infection and persistent CSF leaks.^[45] Yashon *et al.* also has similar experience in his study of 65 patients of civilian GSW.^[9] Heiden JS *et al.*, found that, irrespective of the type of SCI surgical management offer no added advantage in functional recovery.^[7] Stauffer *et al.* shared similar experience of Heiden *et al.*^[46] In contrast Le Roux and Dunn analyzed 49 cases of gunshot injuries and advised a conservative approach except where bullet is in the region of caudaequina.^[35] Waters and Adkins further stress that operative decompression is more beneficial for incomplete injuries between D12 and L4.^[47] Kalkan *et al.* reported a rare case in which his team has retrieved the bullet from the epidural space, however this bullet have not cause any cord contusion or vertebral fracture. Surgery in this case was done to avoid infection and lead toxicity.^[48]

The disparity between military and civilian reports however, may be due to a higher velocity missiles in military injuries, which in turn lead to a higher false incidence of improvement after uniformly applied surgical exploration.^[9,31]

Despite of lack of clear guidelines about surgical exploration general consensus exists which suggests; GSW should be managed conservatively despite of the type of cord injury, except in condition like:

1. Persistent CSF fistula
2. Progressive neurological deterioration
3. Persistent pain due to nerve root compression
4. Bullet migration
5. Spinal column instability
6. Bullet in lumbar canal causing cauda equine syndrome.

The following algorithm shows overall systematic management of GSW of spine [Figure 6].

TIMING OF SURGERY

Unless associated with other vital organ injury, requiring emergency surgical exploration all patients of GSW should be manage as elective cases [Figure 6]. Surgical exploration should be done by multi-specialty team under the radiological guidance.

ROLE OF STEROIDS

The results of National Acute SCI Study (NASCIS) II and III trials led to the widespread adoption of a high-dose methylprednisolone regimen for patients treated within 8 h of SCI, subsequent studies have called into question the validity of NASCIS conclusions. At present, time methylprednisolone therapy carries no added advantage in acute spinal injury (both PSI and non-PSI).^[49]

COMPLICATION

Infection

Spinal infection once uses to be common infection in cases of GSW to spine, especially when associated with visceral perforation. Meningitis, osteomyelitis, epidural abscess, intra-medullary abscess all have been reported in the literature.^[29,50,51] With the advent of antibiotic the rate of infection has drastically reduce. The administration of broad-spectrum antibiotics intravenously extended for 7-14 days reduces the rate of infection compared with administration for 48-72 h.^[54-56] Patient should be started on broad-spectrum antibiotic coverage, which includes Gram-positive, Gram-negative, anaerobic bacteria coverage. Minimum 7 days course of antibiotic is recommended, and if require it can be extended further.

The surgical removal of the bullet and bone debridement in the spine path are not considered necessary or effective in preventing infectious complications, and leaving the bullet lodged in the spine is not a risk factor for infection.^[52,53]

MIGRATING BULLET

Migrating bullet is popularly known as irritating bullet. The migration of intra-durally located bullet has been described in

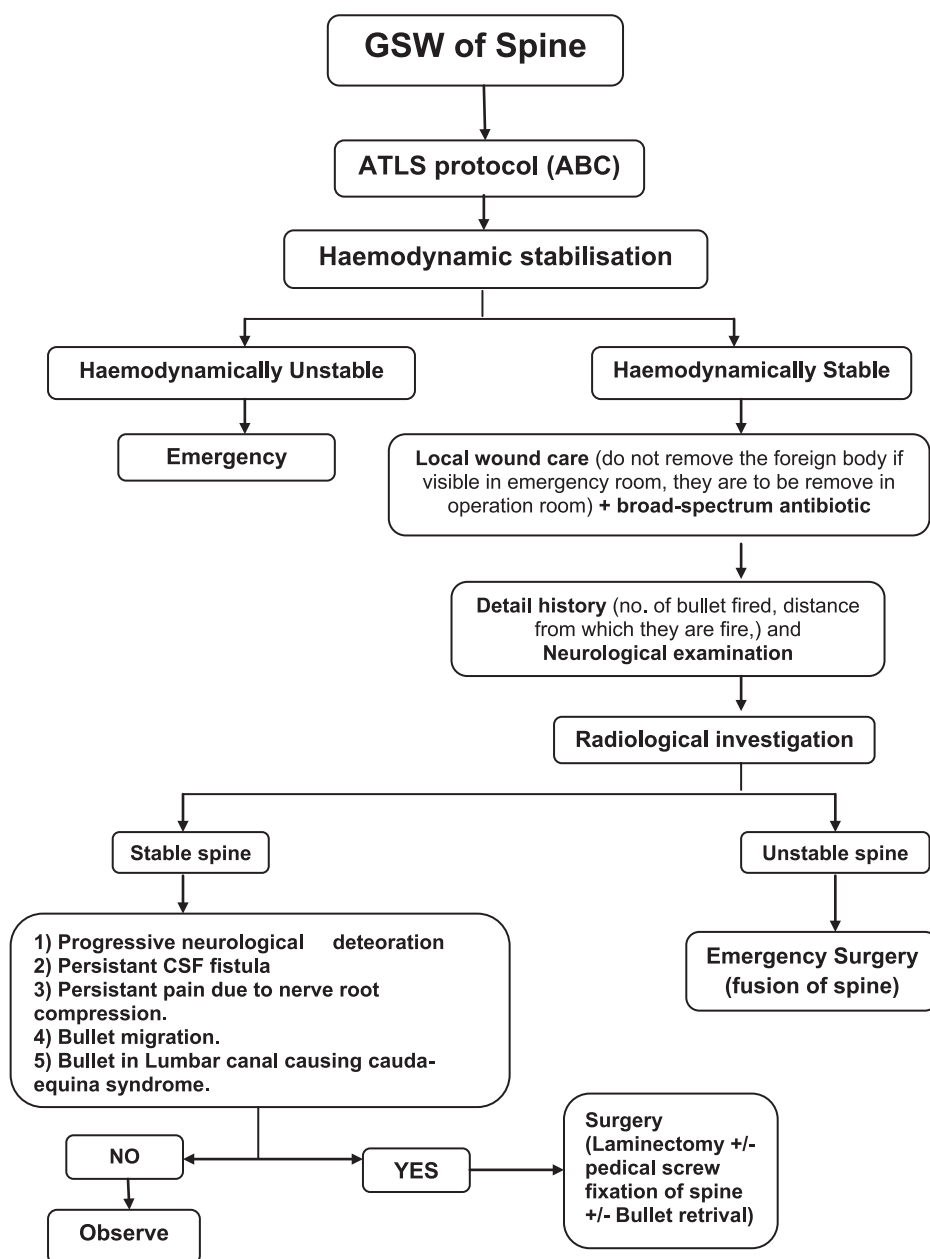


Figure 6: Systematic management of GSW of spine

literature before.^[42,57-59] This migration is towards the caudal end of the dura. Give rise to variable range of neurological symptoms ranging from paraesthesia to radicular pain to motor weakness. Removal of the bullet results in resolution of symptoms, thus making it a indication for surgery.

LEAD INTOXICATION

Retain bullet fragments rarely produces lead intoxication.^[60] Fewer than 100 cases of lead toxicity in patients with retained bullets have been reported in the medical literature.^[61] Lead intoxication is a risk if bullet fragments are located in disc space or joints. Symptoms of plumbism develop years after injury. Considerations for treatment are given to asymptomatic patients

with blood lead levels of 80-100 $\mu\text{g}/\text{dl}$ and for symptomatic patients with blood lead levels between 50 and 80 $\mu\text{g}/\text{dl}$.^[62] Treatment involves use of chelation therapy combined with removal of bullet fragments if possible.

CONCLUSION

GSW to the spine is a complex injury and are encounter increasingly by the neurosurgeon. A proper concept of GSW of spine with its pathophysiology, types, prognostic factors and management strategies should be in minds of neurosurgeons when dealing with such types of cases. SCI in absence of vertebral fracture in a civilian GSW though rare should not be overlooked. As the prognosis in GSW to spine remains poor, a

more conservative approach should be followed. Indication for surgery must be clear. Unstable spine should be stabilize with proper procedure to avoid further SCI. Surgical exploration if needed should be done by the multispecialty team.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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