

Civilian gunshot wounds of the spine: A literature review

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Abstract

The incidence of gun-related violence continues to rise, although accurate statistics are difficult to obtain. Up to 17% of spinal cord injuries are gunshot related. The recent literature pertains to the management of high velocity/energy gunshot wounds as encountered in war scenarios such as Iraq, Afghanistan, etc.

The treatment of civilian gunshot wound injuries to the spine has not been clearly stipulated, and many treatment modalities are adopted from the treatment of war injuries, which is a completely different scenario.

Aim: To evaluate the available literature pertaining to civilian gunshot wound injuries of the spine and the treatment thereof with regard to the indication for bullet removal, antibiotic prophylaxis, lead poisoning, the use of imaging modalities and fracture stability.

Conclusion: Although the literature is often conflicting and published case series are outdated, there is consensus that not all bullets or fragments need to be removed; the majority of fractures are stable; MRI is a safe imaging modality; lead poisoning is extremely rare; and extended antibiotics prophylaxis is not needed.

The indications for bullet removal is deteriorating neurology, intra-canal bullets between T12 and L4 with incomplete neurology, sepsis and lead poisoning should it occur.

Key words: gunshot, spinal injury, neurology, spinal column, lead

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Introduction

Gunshot wounds continue to be one of the most common causes of injuries in South Africa. This is due to the large circulation of illegal firearms, and firearms stolen or lost from the South African Police Service and the South African National Defence Force. It has been reported that the SAPS have 'lost' 20 429 weapons since April 2004.¹

There has been a dramatic rise in the incidence of gunshot injuries, as reported by Saadia.² In 1988 there was 988 gunshot wound injuries reported at Chris Hani Baragwanath Hospital, and this rose to 3 152 cases per year by 1998.² Groote Schuur Hospital reported between 70 and 120 gunshot injuries per month in 2005.³ Prince Mshyeni Hospital reported 78 abdominal gunshot wounds between January 2005 and June 2005.⁴

In the United States, gunshot injuries to the spine account for 13–17% of all spinal cord injuries.

Anecdotal evidence suggests that this trend has

continued, but accurate modern-day statistics are difficult to obtain. Gunshot wounds to the spinal column with associated neurological injury account for a large proportion of these injuries, leading to increased morbidity and mortality, as well as the need for allocation of extensive resources. Dunn and Le Roux reported an average hospital stay of 30 days for patients with spinal gunshot wounds.³ Carrillo *et al.* reported an average length of stay of 58–85 days when in-patient rehabilitation was included, with an average cost of \$87 750–\$142 710.⁵

Demographics of spinal gunshot injuries follow a similar pattern internationally, with most patients being males between the ages of 15 and 34 years.^{3,6-9} Most of these are also complete spinal cord injuries.^{3,10,11}

The vast majority of these injuries do not occur in isolation. Dunn *et al.* reported in their series of 49 patients that there were 55 associated injuries including haemopneumothoraces, intra-abdominal injuries, vascular injuries, etc.³

Treatment of gunshot injuries of the spinal column is controversial. The majority of studies published regarding civilian gunshot wounds are from the 1980s and 1990s.¹²⁻²⁴ Recent literature is mostly restricted to military gunshot injuries, which is more of the high velocity /energy type of injuries.²⁵⁻³³

History of treatment

When Lord Nelson sustained a spinal cord injury from a gunshot at the Battle of Trafalgar his personal surgeon told him, 'My Lord, unhappily for our country, nothing can be done for you'. Nelson died a few hours later.³⁴

The treatment of spinal cord injury and gunshot wounds has improved markedly in the last century, although much of the literature pertains to military or high energy gunshot wounds.

The principles of treatment for military gunshot wounds of the spine entail debridement of all contaminated tissue along the tract and removal of bony and bullet fragments from the spinal canal, closure of dural defects to prevent fistulas and surgical decompression of the spinal cord.^{35,36}

Civilian or low energy gunshot wounds are a completely different entity, and the same treatment rationale cannot be used. However, many still believe in the treatment principles as stipulated above.

Gunshot ballistics

Traditionally gunshot wounds have been classified as either low (<2 000 ft/sec) or high velocity (>2 000 ft/sec). Recent trends have tried to classify gunshot injuries as either high or low energy.³⁷

A shotgun is classified as a low velocity weapon, but extreme amounts of energy transfer occur resulting in extensive soft tissue damage.

The energy of the bullet is influenced both by the mass of the bullet, as well as the speed at which it travels. This is reflected in the formula $KE = 0.5mv^2$ where KE is the kinetic energy, m the mass of the projectile and v the velocity. Other factors that play a role are stability of the bullet, entry profile, path travelled through the body and the tissues encountered.

A 9 mm bullet of 115 grain weight has 401 ft/pound muzzle energy when it leaves the barrel. This is significantly less than an M16 5.56 mm round with 1 297 ft/pound muzzle energy. A 12-gauge shotgun firing a slug has 2 604 ft/pound muzzle energy, although the velocity is only 1 180 ft/sec, classifying it as a low velocity weapon (Figure 1).

The transfer of energy is another important factor to consider, and this is where bullet design and entry profile play a key role. Full metal jacket rounds are designed to maintain the maximum amount of energy, and very little energy is transferred to the soft tissue, unless the bullet strikes bone. If the bullet strikes tissue with a yaw it will tumble and cause greater energy transfer and tissue damage.

Hollow point ammunition is designed to fragment and transfer as much possible energy to the soft tissue, causing maximal soft tissue damage and transfer of energy.

Traditionally bullet design consisted of a lead core and a copper jacket, although newer designs of an 'environmentally friendly' bullet consist of a copper only design.

Clinical evaluation

It is important to note that gunshot spinal injuries rarely occur in isolation. There is a high incidence of associated injuries, with figures ranging from 79–280%^{3,5,38} (Figure 2). Up to 65% of these injuries require surgical intervention, and the vast majority are abdominal injuries (31%).^{5,38}

It is therefore of utmost importance to evaluate these patients along with other specialities according to ATLS principles, and not to see the spinal gunshot injury as an isolated entity.

Imaging

Entry and exit wounds should be covered with a sterile dressing, and radiopaque markers applied over the dressing, such as an ECG sticker. This will enable identification of the tract of the bullet, and will indicate the imaging modalities needed to diagnose suspected associated injuries.



Figure 1. A 10 mm, 9 mm, 22 LR, 5.56 mm and AK47 round

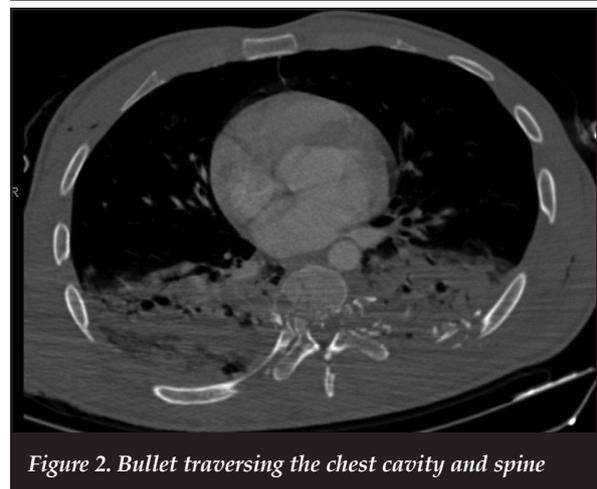


Figure 2. Bullet traversing the chest cavity and spine

With regard to the spine it is important to obtain orthogonal views of the area affected. Standard imaging modalities should be supplemented with CT scan if visualisation of the affected structures is poor.

CT scan of the affected spinal area is often necessary to ascertain whether the injury pattern is stable or not (Figure 3).

Magnetic resonance imaging of the spinal column with retained bullet fragments remains a controversial subject. Shrapnel migration and the heating of residual fragments are the main concern. Previous studies have confirmed the safety of MRI scanning in patients with retained non-ferrous bullet fragments in 1.5 Tesla magnets.³⁹⁻⁴²

Dedini *et al.* showed that MR imaging of the spine with retained bullet fragments is safe, even up to 7 Tesla.⁴³ Fragment migration was not a concern.

The maximum temperature increase of the retained fragments was 1.7 °C, compared to background heating of tissue of 1.5 °C. This was not statistically significant.

Stainless steel is only found in pellets and certain military ammunition, and should not be of concern in civilian gunshot injuries, unless the projectile originates from a pellet gun or shotgun.

Lead toxicity

Debate over lead and copper toxicity continues, but lead toxicity is more common when bullets are bathed in synovial fluid. There are but a few case reports on lead toxicity with bullets or fragments in the spinal canal surrounded by cerebrospinal fluid, or from bullets in the disc space⁴⁴⁻⁴⁹ (Figure 4).

Given the prevalence of gunshot wound injuries of the spine and the low incidence of lead toxicity of bullet fragments in contact with cerebrospinal fluid, lead toxicity should not be a concern or a reason for removal of the bullet.

Lead poisoning can present with hypertension, abdominal cramping, constipation, joint and muscle pain, headache and mood disorders. The treatment of lead poisoning is to first remove the source, and to treat the patient with chelation therapy that binds and excretes the lead.

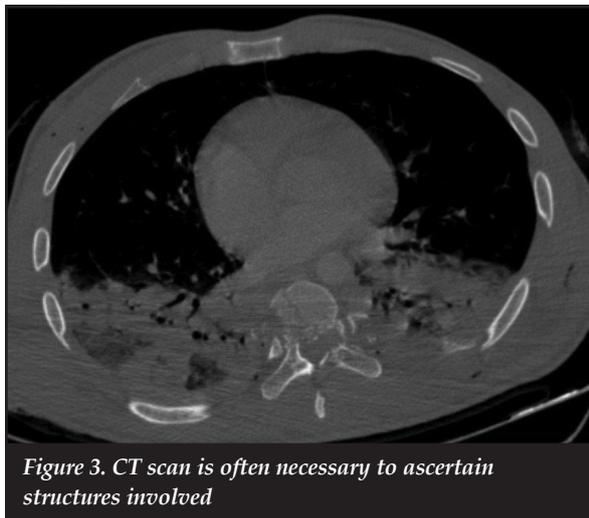


Figure 3. CT scan is often necessary to ascertain structures involved



Figure 4. Bullet in the intervertebral disc

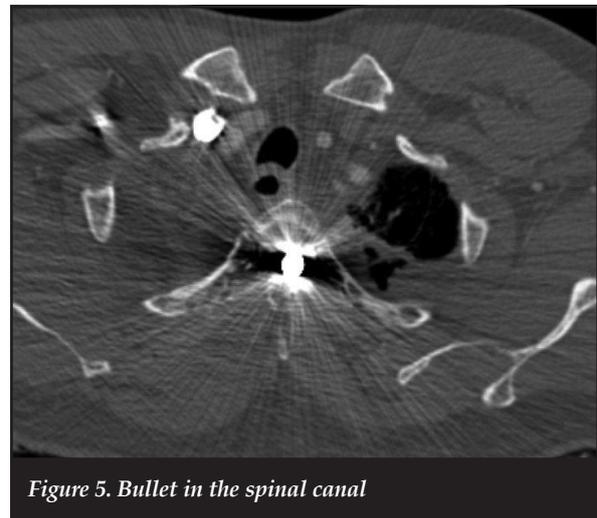


Figure 5. Bullet in the spinal canal

In-vivo experiments have demonstrated necrotic effect of copper fragments on neural tissue. Tindel *et al.* in a rabbit model demonstrated spinal cord necrosis around implanted bullet fragments beneath the dura; however, extra-dural bullet fragments did not result in any neural necrosis.⁴⁶

These results could be extrapolated to human neural tissue, but it is often difficult to ascertain the nature of the fragment material, and the complications of intra-dural bullet removal can result in further neurological deterioration and complications (Figure 5).

Fracture stability

Most fracture classification systems for spinal column trauma describe the direction of the indirect force applied to the bony and ligamentous structures of the spinal column. Gunshot wounds to the spinal structures are a directional and direct force, and hence classification systems cannot describe and help with the identification of unstable fractures. Even three-column injuries can still be stable in the low energy gunshot scenario.

The vast majority of gunshot injuries to the spinal column are stable injuries, with the ligaments and bony structures left intact, except for the areas that the bullet traversed.³⁸

Any degree of angulation or listhesis should be further evaluated for instability with flexion and extension radiographs.

If the bullet traversed both pedicles in the coronal plane, there is a risk of instability, and dynamic investigations should be performed. However, in the vast majority of cases, instability occurs secondary to decompression surgery.¹⁵

Neurological injury

Neurological injury is common, and the majority of injuries occur at the thoracic level (Figure 6) with 25–59% resulting in complete spinal cord injuries.^{5,11,38} There is a high risk of complete injury with thoracic gunshot wounds when compared to gunshot wounds to the other areas of the spinal column.

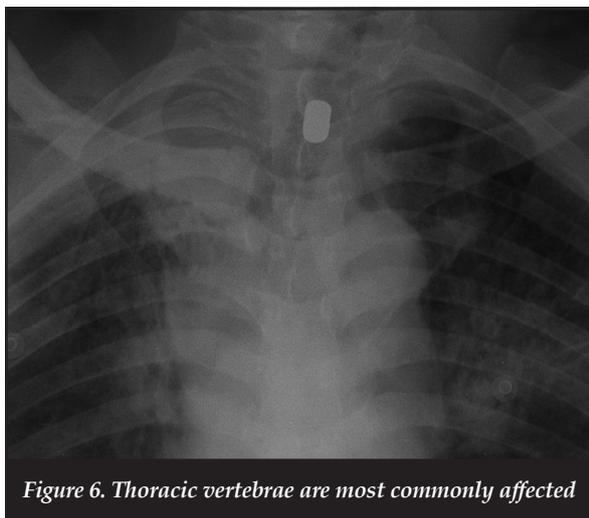


Figure 6. Thoracic vertebrae are most commonly affected

The administration of steroids for patients with neurological deficit has also been studied, and no benefit was found.^{50,51} Administration of methylprednisolone had a high incidence of pancreatitis, while dexamethasone had the highest GIT complication rate.⁵¹

Heiden *et al.* reported that the outcome and potential for recovery depended on the initial injury, and that surgical intervention did not alter neurological outcome, in either complete or incomplete patients.¹³ This still holds true today, except for patients with incomplete neurology with retained bullet fragments between T12 and L4 in the region of the cauda equina.

Removal of spinal column bullet fragments

Various studies have been performed to assess the impact of removal of bullet fragments in the spinal column and the improvement of neurology.^{13,17,18,24,38,52-56}

The available evidence clearly shows that improvement in neurological status may occur only after removal of retained bullet fragments between the levels of T12 and L4 in patients with incomplete neurological deficit.⁵² This study by Waters *et al.* showed no improvement in neurological status at any other level, regardless of it being a complete or an incomplete injury. They also reported a high complication rate associated with surgical removal of the retained fragments.

Stauffer *et al.* also found no benefit with regard to neurological improvement when bullet fragments were removed in their study.¹⁵ In contrast to Waters *et al.* they found no benefit when bullet fragments were removed from the lumbar spine. Complications from surgery were also high in Stauffer's study, ranging from sepsis and CSF leaks post-operatively to late instability. Robertson and Simpson also found no benefit from removing bullet fragments, but again reported a high complication rate from surgery.³⁷ Their study reported four wound infections, six spinal fistulae and six cases of late spinal instability.

From the literature, the only indications for removal of retained bullet fragments would be: progressive neurological deterioration, sepsis, lead poisoning and retained fragments between T12 and L4 with incomplete neurological injury.

Antibiotics and wound management

Tetanus prophylaxis should be administered in all spinal gunshot injuries if there is doubt with regard to previous tetanus immunisations. Broad spectrum antibiotics should be administered, but the duration of administration should be guided by the amount of soft tissue damage. If there is no evidence of viscus perforation, 48–72 hours should be sufficient.

Antibiotic treatment of gunshot wounds traversing the gastrointestinal tract into the spine remains a widely debated topic, with proponents for both short course therapy as well as extended administration.

Romanick *et al.* published their study in 1985 where patients with transvisceral injuries were treated with antibiotics for a period of between 2 and 14 days.⁵⁸ A total of 87.5% of their patients developed spinal or paraspinal infections. Some of these infections presented only after 11 weeks, even in those patients who had antibiotic therapy extended beyond 5 days. Romanick concluded that patients with transvisceral injuries should be monitored closely for the development of delayed sepsis, even when treated with extended periods of antibiotics.

In 1989 Roffi *et al.* published a lower rate of spinal or paraspinal infections with only three of 42 developing infection. These three patients had prophylactic antibiotics for 6, 14 and 14 days respectively. However no mention was made of resistance or adverse events.²²

Kihtir *et al.* used a short course of antibiotic prophylaxis of 48 hours along with appropriate intra-abdominal injury treatment and irrigation of the missile tract in 21 patients with transvisceral spinal gunshot injuries. They reported no spinal or paraspinal injuries.⁵⁹

Lin *et al.* treated 29 patients with only 48 hours of prophylactic antibiotics, and only two patients developed paraspinal infections in the form of psoas abscesses.⁶⁰

Kumar *et al.* reported no spinal infection in their series of 13 patients with trans-colonic injuries who were treated with 7 days of prophylactic antibiotics.⁶¹

Rabinowitz *et al.* published their retrospective review of 51 patients with trans-visceral injuries in 2012.⁶² Only one patient developed a spinal or paraspinal infection. The majority of patients in the study received 48 hours of prophylactic antibiotics in the form of a second generation cephalosporin, while some received a combination of ampicillin/sulbactam, piperacillin/tazobactam and clindamycin. Thirty-three of the 51 patients did develop non-spinal infections and required further appropriate antibiotic treatment. The patient that developed spinal sepsis did so after two weeks of piperacillin/tazobactam treatment for a bacteraemia.⁶²

In all of the abovementioned studies it was not deemed necessary to remove retained fragments. Missile tracts were not routinely irrigated in any of the studies, with no associated risk of developing spinal sepsis.

Should laparotomy be indicated for intra-abdominal injury, it is advisable to irrigate the missile tract.

Conclusion

Civilian gunshot injuries to the spinal column are increasingly common worldwide. Patients with associated spinal cord injury have a high morbidity due to associated injuries and require prolonged in-hospital treatment and rehabilitation.

Current literature is aimed at the treatment of ballistic injuries sustained in war, and few studies pertain to civilian gunshot injuries of the spinal column and their treatment. If the treatment protocol of wartime injuries is applied, it would add to the already massive cost burden associated with these patients, without much added benefit.

From the literature it is clear that most injuries are stable, and can be treated by conservative means. Lead poisoning is extremely rare, and thus not an indication for routine bullet removal.

The only indications for removal of retained bullet fragments would be: progressive neurological deterioration, sepsis, lead poisoning and retained fragments between T12 and L4 with incomplete neurological injury.

Routine irrigation and removal of the bullet fragments that traverse the abdomen is not necessary, unless the intra-abdominal injury warrants exploration.

Duration of prophylactic antibiotic treatment has also been reduced, and spinal sepsis is an uncommon occurrence. Cases of spinal sepsis occurred even in those patients that had extended periods of prophylactic antibiotics.

In conclusion the surgical management of civilian gunshot injuries to the spinal column should be reserved for selected cases only. The majority of injuries are managed conservatively, but close scrutiny should be given for associated injuries, many of which will need surgical intervention.

Compliance with Ethics Guidelines

A Botha, RN Dunn and C. Booyesen have no conflict of interest to declare, and the work is solely that of the authors.

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