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Civilian Gun Shot Wounds Associated With Spinal Injuries

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Abstract

Study Design: Retrospective

Objective: To evaluate functional outcomes and characteristics associated with gunshot wound (GSW) to the spine.

Methods: Patients with GSW to the spine managed at a Level 1 Trauma Center from January 2003 to December 2017 were enrolled. Patient demographics, diagnoses, level of injury, American Spinal Injury Association (ASIA) score, ambulatory status at follow-up, bowel and bladder function, clinical improvement, and mortality were evaluated. Clinical improvement was defined as a progression in ambulatory status category at latest follow up.

Results: 51 patients with GSW of the spine were identified. 48 (94.1%) were male and 3 (5.9%) were female, with a mean age of 27 years-old (range 15-56). 38 (74.5%) were Caucasian, 7 (13.7%) were African American, 1 (2.0%) Asian-American, and 5 (9.8%) were Other/Unknown. 46 (90.2%) patients had GSW related spinal fractures and 44 (86.3%) had neurological deficits. Among patients with neurologic deficits, 5 (9.8%) had Cauda Equina Syndrome, 1 (2%) had Brown-Sequard Syndrome, and 38 (74.5%) spinal cord injuries: ASIA A 26 (68.4%); ASIA B 3 (7.9%); ASIA C 7 (18.4%); ASIA D 2 (5.3%). At mean follow-up time of 4.2 years (SD 3.9), 27 (52.9%) patients were wheelchair bound, 11 (21.6%) were ambulating with assistance, and 13 (25.5%) had normal ambulation. ASIA grade (A or B) was significantly, $P < 0.00001$, associated with being wheelchair bound and having neurogenic bowel or bladder at follow-up.

Conclusions: Most spinal GSW patients (70.6%) did not have any clinical improvement in ambulatory status and most injuries were ASIA A.

Keywords

GSW, gunshot wound, spine trauma, spine fracture, spinal cord injury, outcomes

Introduction

Gunshot wounds (GSW) to the spine are associated with significant morbidity and mortality. Spinal cord injuries (SCI) as a result of these traumatic events are associated with high lifelong healthcare expenses and a significant decrease in quality of life.[1] GSW associated spinal cord injuries are responsible for approximately 13%-21% of all traumatic spinal injuries.[2-6] Most of the injuries are in the younger populations (2nd to 3rd decades of life).[6] The rate of civilian gunshot injuries are increasing but the rate of spinal cord injury secondary to civilian GSW has reportedly decreased recently compared to prior decades.

Damage to the spinal cord is due to 1) direct damage from the bullet 2) the concussive effect of bullet impaction, and 3) temporary cavitations.[6] Factors such as projectile velocity, path, size, and distance between firearm and target affect the severity of spinal GSW.[7,8] There is also a distinction between injury patterns in military versus civilian populations. Military assault rifles are high energy weapons with muzzle velocities greater than 2000 feet/second and cause significant indirect injuries due to shock or cavitation wave effects.[5] In contrast, most civilian spinal GSW is secondary to low-energy (<2,000 ft/second) firearms that primarily cause direct injury to tissue. While the use of high velocity military style firearms has

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increased in the civilian populations, low energy weapons are still the most commons source of civilian GSW.

Management of spinal GSW is determined by neurologic function, spinal instability, and injuries to other systems.[5] In patients with incomplete spinal cord injury or nerve root level injury, surgical options to restore neurological function can be considered. Surgical options include laminectomy with or without stabilization in the lumbar spine. In the thoracic spine instrumentation and decompression is an option. In patients with a large bullet fragment in the spinal canal, an effort can be made to remove the bullet with the goal of neural decompression.[9-11] It should be noted that fragment removal from spinal segments cranial to T12 is less likely than T12 to caudal to restore function, most likely due to the more significant cord lesions at the cervical and thoracic levels. Nonsurgical management includes bracing for stability.[6]

The objectives of this study are to evaluate the demographics, prevalence, management, neurological deficits and outcomes of spinal gunshot wounds.

Materials and Methods

This study was approved by our Institutional Review Board and is a retrospective evaluation of patients with gunshot wounds to the spine managed at a Level 1 Trauma Center from January 2003 to December 2017. Patients were identified using an administrative billing database. All patients diagnosed with a new penetrating gunshot wound to the spine were included in this study. The patients were managed by orthopedic spine surgeons and neurosurgeons. Chronic spinal injuries or new spinal injury developments from old gunshot wounds were excluded from the study, as were those with incomplete medical records. In addition, patients who had spinal damage not directly attributable to the bullet were removed from the study.

Demographic and clinical data were analyzed including: age, sex, race/ethnicity, diagnoses, level of injury, American Spinal Injury Association (ASIA) grade if applicable, management, complications, ambulatory status at follow-up, bowel and bladder function, and mortality. All patient outcomes were followed using electronic medical records up to January 1, 2019. Clinical improvement was defined as a progression in ambulatory status category (wheelchair bound, able to walk with assistance, or able to ambulate without any aid) at follow up.

For statistical analysis, we used the Chi-square test, Fisher's exact test, and logistic regression analyses to determine correlations between categorical or continuous variables. Significance was set at $P < 0.05$.

Results

Demographics and Prevalence

52 unique patients were identified and 51 met our inclusion criteria. One was removed from the study after retrospective review determined that the spinal involvement (disc herniation) was incidental rather and not related to a gunshot injury. Of the 51 patients, 48 (94.1%) were males and 3 (5.9%) were females (Table 1). The mean age at admission was 27 years old (range 15-56). Patients were predominantly Caucasian (38, 74.5%), followed by 7 (13.7%) African Americans, 3 (5.9%) Other, 2 (3.9%) Unknown, and 1 (2%) Asian-American. The mean age at admission was 27 years-old (range 15-56).

Table 1. Demographics.

	N (%) of all patients (N = 51)
Gender	
Male	48 (94.1)
Female	3 (5.9)
Race	
African-American	7 (13.7)
Caucasian	38 (74.5)
Asian	1 (2.0)
Other	3 (5.9)
Unknown	2 (3.9)
Age	
Mean age at initial injury	27 (range 15-56)

Table 2. Diagnoses and Severity of Injury.

	N (%) of all patients (N = 51)
Diagnoses	
Fractures	46 (90.2)
Bullet Fragment in Canal	14 (27.5)
Bullet Through Cord	1 (2.0)
Spinal Cord Infarct	2 (3.9)
Cauda Equina Syndrome	5 (9.8)
Brown Sequard Syndrome	1 (2.0)
Spinal Cord Injury	38 (74.5)
ASIA A	26
ASIA B	3
ASIA C	7
ASIA D	2
Neurological Deficits	
Yes	44 (86.3)
No	7 (13.7)
Highest level of Injury	
Cervical	8 (15.7)
Lumbar	20 (39.2)
Thoracic	23 (45.1)

Diagnoses and Management

The majority of injuries were at the thoracic level (n = 23, 45.1%), followed by lumbar (n = 20, 39.2%) and cervical (n = 8, 15.7%). 46 (90.2%) patients had spinal fractures as a result of gunshot injury (Table 2). 44 (86.3%) patients had neurological deficits. Of those with neurological deficits, there were 5 (9.8%) Cauda Equina Syndromes, 1 (2.0%) Brown-Sequard Syndrome, and 38 (74.5%) spinal cord injury with ASIA grade as follows: ASIA A 26 (68.4%), ASIA B 3 (7.9%), ASIA C 7 (18.4%), and ASIA D 2 (5.3%). 14 (27.5%) had bullet fragments within the spinal canal, and one (2%) patient was noted to have the bullet completely travel through the canal from

posterior to anterior. These 15 cases with bullet fragments in the spinal canal were all ASIA A injuries. 2 (3.9%) patients in this study had hemorrhagic spinal cord infarct, with one ASIA A and one ASIA C.

Management of these GSW are listed in Table 3. Eight (15.7%) patients underwent operative management—primarily decompression, fusion, or both (Figure 1). Of these surgeries, there were 3 (37.5) major post-operative complications (2 deep wound infections and 1 post-operative ileus requiring NG tube) as defined by Glassman et al. in 2007.[12] There was one (12.5%) case of a superficial wound infection treated medically. The overall complications rate associated with surgical management of GSW to the spine was 50%.

Clinical Outcomes

The mean follow-up time in this study was 4.2 (SD 3.9) years (Table 4). At latest follow-up, 27 (52.9%) patients were wheelchair bound, 11 (21.6%) were ambulating with assistance or aid, and 13 (25.5%) demonstrated normal ambulation without assistance. Being wheelchair bound was associated with an initial spinal cord injury level ASIA A or ASIA B, $P < 0.00001$. Thirty-one (60.8%) had neurogenic bowel or bladder at latest follow-up, and this was also associated with more severe initial SCI ($P < 0.0001$). Clinical improvement in ambulatory status was seen in 11 (21.6%) patients and was associated with less severe initial injury ($P = 0.0002$), while 36 (70.6%) did not have any improvement over time. 4 (7.8%) patients did not have an initial deficit in ambulation. At last follow-up, 47 (92.2%) were still alive, with an overall mortality rate of 7.8%.

Table 3. Management.

	N (%) of all patients (N = 51)
Management	
Operative	8 (15.7)
Non-operative	43 (84.3)
Complications from Surgery	
Major	
Deep wound infection	2 (25.0)
Post-operative ileus	1 (12.5)
Minor	
Minor infection	1 (12.5)
Overall Complications	4 (50.0)
No complications	4 (50.0)

Authors' Preferred Approach

At our level 1 Trauma center, the orthopedic spine service takes the majority of the spine trauma call (Figure 2). A GSW to the spine is typically identified on trauma pan-CT scans of the Chest, Abdomen and Pelvis and prompts a consult to the spine team on-call. If the patient presents with a GSW and associated spinal cord injury decision making on whether or not to intervene surgically depends on the patient's hemodynamic status, extent of spinal instability, level of injury and the presence of large bullet fragments near the neural elements. MRI is not routinely obtained in our center following GSW. However, several studies have demonstrated that non-nickel and non-steel based bullets are safe to undergo MRI.[13-15] Venous lead levels are routinely drawn on GSW patients in order to obtain baseline values. If spinal instability is present, bracing is offered or surgical intervention consisting of instrumentation and fusion with removal of bullet fragment if encountered. On

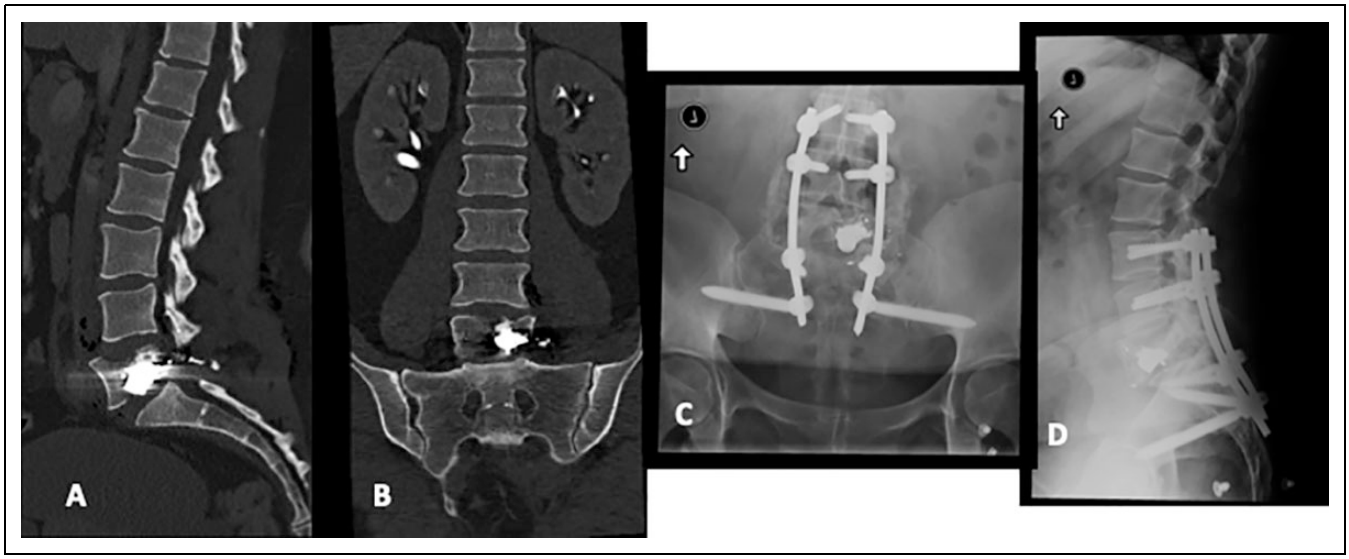

Figure 1. This is a 31-years-old female who sustained a gunshot wound to the spine. The bullet fragment was partially lodged in the L5 vertebral body with associated fracture. The patient had bilateral foot drops and neurogenic bladder and bowel. (A) Sagittal CT and (B) Coronal CT of the lumbar spine demonstrating fracture at L5 with the retained bullet fragment. The patient was treated with L3-Pelvis instrumentation, laminectomy and some removal of the bullet fragments. At 2 years post-op (C) AP and (D) Lateral radiograph of the lumbar spine demonstrate intact instrumentation and posterolateral fusion.

a case-by-case basis, if large bullet fragments are retained in the spinal canal/spinal cord or intervertebral disc an attempt to remove these fragments can be made in order to decrease the possibility of lead poisoning.[16-18]

Discussion

Recent reports on gunshot wounds to the spine focus on the injuries sustained by soldiers during the conflicts in Iraq and Afghanistan.[19-21] However, GSW injuries in the civilian populations are inherently different given most are attributed to lower velocity handguns.[22,23] This study focuses on patients managed at a Level I trauma center in the BLINDED region of New York State. The cohort was 94.1% male and 5.9% female, which is in line with existing literature.[6,24] Despite the large age range of 15 to 56 years, the mean age was 27-years-old which aligns with prior studies indicating that the majority of these injuries are sustained by younger male patients.[5,24,25] Neurological deficits were present in 86.3% of our patients, which is a higher rate than some reports but in line with others.[3,26] 74.5% had spinal cord injuries of severity as follows: 68.4% ASIA A, 7.9% ASIA B, 18.4% ASIA C, and 5.3% ASIA D. With a significant proportion of patients having ASIA A complete spinal cord injuries, this data reflects a more severely injured patient population than others have reported.[27] In line with existing literature, most injuries were at the thoracic (45.1%) level.

However, our literature deviates from others by having a significantly higher number of lumbar (39.2%) injuries versus cervical (15.7%). In other studies, there were more cervical than lumbar injuries.[5,28,24] 15.7% (8) patients underwent operative management, with an overall 50% complications rate, half of which were deep wound infections, and others included ileus and superficial infection. The operative rate is similar but our complications rate is higher than previously described.[27,29] The purpose of this study was not to evaluate the surgical indications and outcomes. Prior studies have reported that operative management is associated with a higher rate of complications.[5,30,31]

Table 4. Outcomes.

	N (%) of all patients (N = 51)
Mean (SD) Follow-up Time	4.2 (3.9) years
Ambulatory Outcomes	
Wheelchair Bound	27 (52.9)
Ambulating with Assistance/Aid	11 (21.6)
Normal Ambulation	13 (25.5)
Bowel and Bladder Function	
Neurogenic Bowel or Bladder	31 (60.8)
Normal	20 (39.2)
Clinical Improvement in Ambulatory Status	
No Initial Deficit	4 (7.8)
Improvement	11 (21.6)
No Improvement	36 (70.6)
Mortality Outcome	
Alive	47 (92.2)
Deceased	4 (7.8)

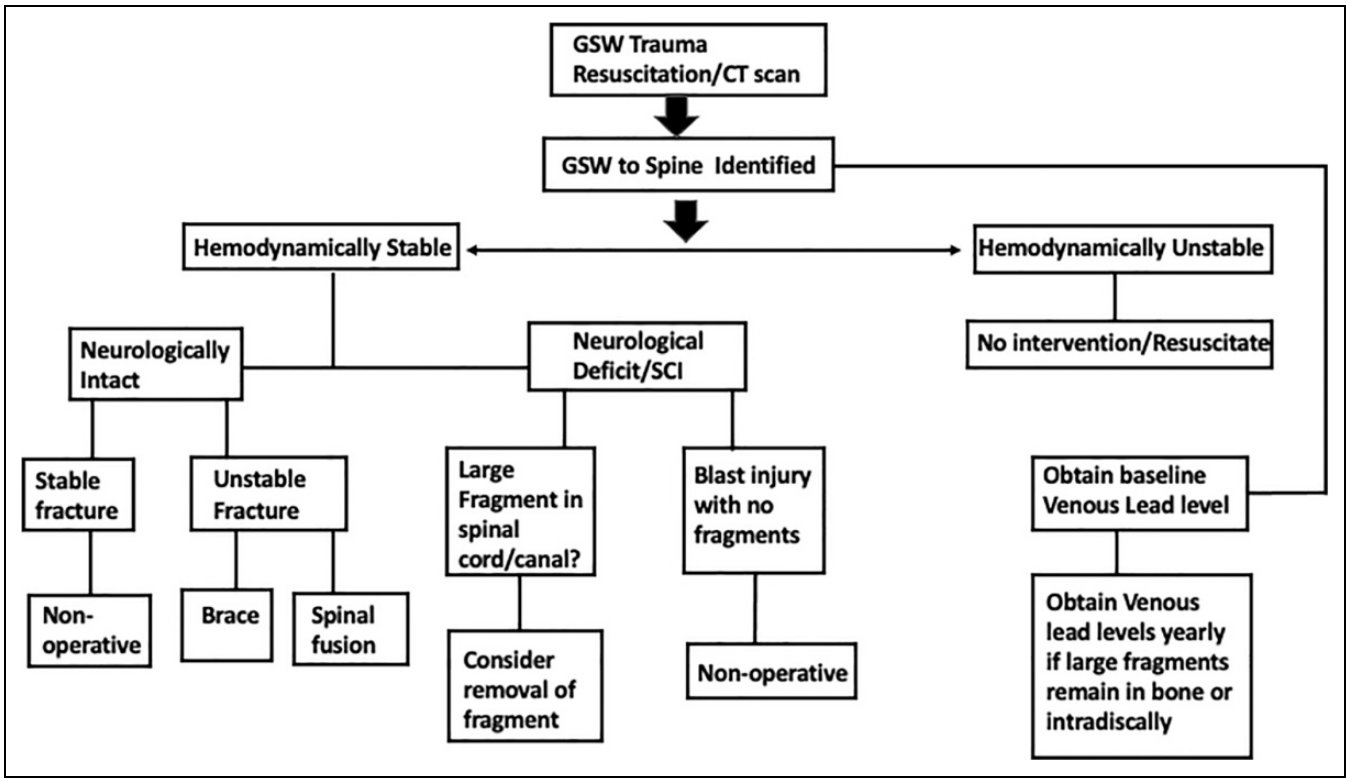

Figure 2. This chart demonstrates the authors' algorithm for the management of GSW to the spine.

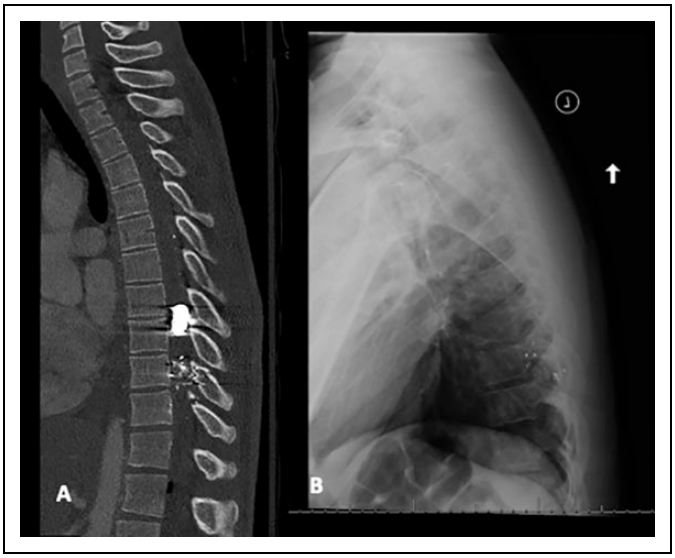

Figure 3. This is a 22-years-old male who sustained a gunshot wound with retained bullet fragment in the spinal cord at T9-T10 (A) as seen in the sagittal CT of the thoracic spine. The patient was ASIA A on presentation and underwent laminectomy with removal of the bullet fragment (B). At 1-year post-op his blood lead level remains normal.

However, in the setting of a retained bullet in the canal, there is a role to remove the bullet in order to decrease the risk of elevated lead level and plumbism overtime.[32,33] (Figure 3).

Literature on the mid to long-term clinical outcomes of patients with spinal GSW is sparse. The mean follow-up in this study was 4.2 (SD 3.9) years, longer than most studies in this realm.[2,28,34] At latest follow-up 52.9% of our patients were wheelchair bound, with 21.6% ambulating with assistance and. 60.8% had neurogenic bowel or bladder. All patients with initial ASIA A injury were wheelchair bound, and in general being wheelchair bound or having neurogenic bowel or bladder was associated with more severe initial spinal cord injury (ASIA A or B, $P < 0.00\,001$). Ambulatory status was associated with less severe (ASIA C or D) initial injuries ($P = 0.0002$). Clinical improvement was seen in 21.6% of patients and was associated with less severe initial injuries ($P = 0.0002$). This rate of clinical improvement, 31%, was lower than some studies but unsurprising given our higher rate of ASIA A injury.[35,36] The improvement seen in lower ASIA grades are consistent with literature.[27] It appears that outcomes from spinal gunshot injuries are stratified into 2 groups (ASIA A/B versus ASIA C/D) and recent studies further support this.[36]

Overall, our study of civilian spinal gunshot wounds aligns with existing literature in some areas but deviate in others. Overall demographics such as age and sex were consistent with multiple other studies, affirming that this patient population is dominated by young adult men.[6,24] With 86.3% having neurologic deficits and 68.4% of spinal cord injuries being ASIA A in severity, our data reflects a more severely injured patient population. Our lower rate of clinical improvement over time can primarily be attributed to this fact.

There are some limitations to this study. First, as this was a single center study, the demographics cannot be extrapolated to other regions of the United States or globally. Second, the retrospective nature of our study is not meant to inform providers of optimum management strategies. And given the severe nature of these injuries, patient death prior to admission may contribute to an underestimation of the scope of spinal GSW injuries in our catchment area. While ambulatory and functional outcomes were documented, long term complications were not and could be useful in future studies. There were also no standardized patient-reported outcomes because multiple providers from different specialties were involved in the care of these patients. Injuries to other organs or other portions of the musculoskeletal system were not reported. Lastly, monitoring blood lead levels for patients with retained fragments was done by the senior author but not by the remaining surgeons and cannot comment on how many patients with retained fragments developed blood lead level elevation needing treatment.

In conclusion, spinal gunshot wounds, in this singer center series, caused a high rate of neurologic deficits with severe spinal cord injuries. At latest follow more than half of all patients were still wheelchair bound and had neurogenic bowel or bladder at latest follow-up. Clinical improvement was associated with less severe neurologic injury (ASIA C or D).

Declaration of Conflicting Interests

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