



# Civilian Missile and Non-missile Penetrating Spinal Injuries: Experience of A Metropolitan Hospital in Turkey

## Sivil Toplumda Ateşli Silah ve Kesici Alet Yaralanmasına Bağlı Gelişen Penetran Spinal Yaralanmalar: Türkiye’de Bir Metropol Hastanesi Deneyimi

<sup>1</sup> Ebru Doruk<sup>1</sup>, <sup>2</sup> Feyza Karagöz Güzey<sup>1</sup>, <sup>3</sup> İlker Güleç<sup>1</sup>, <sup>4</sup> Burak Eren<sup>1</sup>, <sup>5</sup> Azmi Tufan<sup>2</sup>,  
<sup>6</sup> Nuri Serdar Baş<sup>3</sup>, <sup>7</sup> Cihan İşler<sup>4</sup>, <sup>8</sup> Özgür Yusuf Aktaş<sup>5</sup>

<sup>1</sup>University of Health Sciences Turkey, İstanbul Bağcılar Training and Research Hospital, Department of Neurosurgery, İstanbul, Turkey

<sup>2</sup>Kadıköy Florance Nightingale Hospital, Clinic of Neurosurgery, İstanbul, Turkey

<sup>3</sup>University of Health Sciences Turkey, Kanuni Sultan Süleyman Training and Research Hospital, Department of Neurosurgery, İstanbul, Turkey

<sup>4</sup>İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, Department of Neurosurgery, İstanbul, Turkey

<sup>5</sup>Manisa Merkez Efendi State Hospital, Clinic of Neurosurgery, Manisa, Turkey

### Abstract

**Objective:** In the civilian population missile and non-missile spinal penetrating injuries and literature on this subject are rare. Injuries were thought to be simpler due to differences in weapons from military. For this reason, we shared our clinical experiences in a center where crime events such as stabbing and shooting are relatively common.

**Method:** The patients with penetrating spinal injury treated between January 2011 and December 2019 were retrospectively evaluated. Patients were divided into 2 groups according to the type of the injury as missile (MPSI) and non-missile (NMPSI).

**Results:** Total 23 patients, aged between 1-53 years were evaluated. Two patients were female, 15 had missile and 8 had non-missile injuries. There were 14 thoracic, 4 cervical, 4 lumbar, 1 sacral involvement. Six (40%) of MPSI patients had serious deficits-5 paraplegia due to thoracic lesions, 1 incomplete cauda equine lesion due to lumbar migrating missile and all of these patients were operated for dura repair or removal of migrating missile. 9 patients with MPSI were neurologically normal although 3 of them had vertebral fractures. Four (50%) NMPSI patients had serious deficits, and 2 of them required operations for cerebrospinal fluid fistula. After 11.6±9.9 month follow-up, 7 patients with complete deficits which cause by missile or non-missile injuries did not improve. No problem

### Öz

**Amaç:** Sivil popülasyonda ateşli silah ve kesici aletlerle oluşan penetran spinal yaralanmaları ve bu konuyla ilgili literatür bilgileri nadirdir. Askeri silahlardan farklılıklar nedeniyle yaralanmaların daha basit olduğu düşünülür. Bu nedenle, bıçaklama ve ateş etme gibi suç olaylarının nispeten yaygın olduğu bir merkezdeki klinik deneyimlerimizi paylaştık.

**Yöntem:** Ocak 2011 ile Aralık 2019 arasında tedavi edilen delici omurga yaralanması olan hastalar geriye dönük olarak değerlendirildi. Hastalar, yaralanma türüne göre ateşli silah (MPSI) ve kesici alet (NMPSI) olmak üzere 2 gruba ayrıldı.

**Bulgular:** Yaşları 1-53 arasında değişen toplam 23 hasta değerlendirildi. İki hasta kadındı, 15’inde ateşli silah ve 8’inde kesici alet yaralanması vardı. On dört torasik, 4 servikal, 4 lomber, 1 sakral tutulum vardı. MPSI hastalarının altısında (%40) ciddi defisitler vardı - torasik lezyonlar nedeniyle 5 parapleji, lomber göç eden mermi nedeniyle 1 inkomplet kauda ekina lezyonu ve bu hastaların tümü dura onarımı veya yer değiştiren merminin çıkarılması için ameliyat edildi. MPSI olan 9 hasta nörolojik olarak normaldi, ancak 3’ünde omur kırığı vardı. Dört (%50) NMPSI hastasında ciddi defisitler vardı ve 2’si beyin omurilik sıvısı fistülü için ameliyat gerektirdi. 11,6±9,9 aylık takipten sonra, ateşli silah veya kesici alet yaralanmalarının neden olduğu tam defisitli 7 hasta iyileşmedi.



**Address for Correspondence:** Ebru Doruk, University of Health Sciences Turkey, İstanbul Bağcılar Training and Research Hospital, Department of Neurosurgery, İstanbul, Turkey

**E-mail:** dr\_ebrudogan@hotmail.com **ORCID:** orcid.org/0000-0002-4438-0223

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## Abstract

occurred in the follow-up of 13 MPSI and NMPSI patients without deficit, and 3 patients with incomplete spinal cord injury were neurologically improved.

**Conclusion:** Civilian missile injuries are usually low velocity lesions and have benign course if they do not initially affect spinal cord even they cause fracture of vertebrae. However, non-missile injuries affecting the spinal canal are usually serious because they frequently cause to section the spinal cord. In both cases, we recommend the removal of the foreign object to prevent late complications, infections and toxic effects.

**Keywords:** Civilian injuries, gunshot wounds, penetrating spinal injuries, stab wounds, spine injury

## Öz

Defisiti olmayan 13 MPSI ve NMPSI hastasının takibinde sorun yaşanmadı ve inkomplet omurilik yaralanması olan 3 hasta nörolojik olarak iyileşti.

**Sonuç:** Sivil ateşli silah yaralanmaları genellikle düşük hızlı lezyonlardır ve omurda kırığa neden olsalar bile başlangıçta omuriliği etkilemedikleri takdirde iyi huylu bir seyir izlerler. Bununla birlikte, omurilik kanalını etkileyen kesici alet yaralanmaları genellikle ciddidir çünkü sıklıkla omuriliğin kesilmesine neden olurlar. Her iki durumda da, geç komplikasyonları, enfeksiyonu ve toksik etkileri önlemek için yabancı cismin çıkarılmasını öneriyoruz.

**Anahtar kelimeler:** Ateşli silah yaralanmaları, kesici alet yaralanmaları, omurga yaralanması, penetran spinal yaralanmalar, sivil yaralanmalar

## Introduction

Spinal cord injury (SCI) affects a relatively small proportion of the population compared to other disabling conditions, accounting for only 2.6% of all trauma cases in the United States (1). However, SCI remains a significant medical concern due to the current inability to repair the central nervous system and restore function. Penetrating spinal injury (PSI) is the third leading cause of SCI, following motor vehicle accidents and falls. PSI can be categorized into missile (MPSI) and non-missile (NMPSI) injuries, with the former often caused by gunshot wounds and the latter by stab wounds. These injuries are most prevalent in war zones and areas with high rates of violent crime (2-4).

With the increasing prevalence of firearms in metropolitan areas, missile wounds to the spinal cord are becoming more common than stab wounds. While MPSI may appear more severe due to its high-energy characteristics, isolated MPSI is relatively rare, with its incidence varying across cultures and developmental levels of countries and regions. NMPSI, though often asymptomatic due to the spinal cord's bony protection, can result in irreversible and catastrophic consequences if compromised (1,5,6). Additionally, MPSI is often associated with other systemic injuries, leading to a significantly higher mortality rate compared to NMPSI (1,5,7).

This article aims to share our experiences with PSI in a civilian population to provide insights into the management of this type of injury.

## Materials and Methods

This study was approved by the Local Ethics Committee of İstanbul Medipol University Hospital (registration no: 585, date: 07/06/2021).

A retrospective analysis was conducted on all patients with PSI admitted to our neurosurgery clinic in a tertiary training hospital, between January 2011 and December 2019. Patients were categorized into two groups based on the type of injury: MPSI and NMPSI. Data collected included demographic information, cause of injury, injury location, neurological deficits, radiological findings, treatment modalities, and outcomes at the last outpatient examination.

Neurological status was classified into three groups: Normal (no neurological findings), incomplete neurological deficits, and complete neurological deficits (total motor and sensory function loss below the injury level). Cases with incomplete paresis were included in the group.

## Statistical Analysis

Data were analyzed using IBM SPSS Statistics (IBM Corp., version 28). Descriptive statistics (frequencies, percentages, means, and standard deviations) summarized patient demographics. We used independent samples t-tests to compare mean ages between MPSI and NMPSI groups. Chi-square tests and Fisher's exact test compared the frequency of neurological deficits and vertebral fractures between groups. A p-value <0.05 was considered statistically significant.

## Results

### Demographic Data

A total of 23 patients with suspected MPSI or NMPSI were admitted or referred to our clinic during the study period. The female-to-male ratio was 2/21 (91.3% male), with ages ranging from 1 to 53 years (mean 21.0±10.2). Fifteen patients had MPSI, and eight had NMPSI. The mean age for MPSI patients was 23.6±10.4 years, and for NMPSI patients,

it was  $18.6 \pm 9.5$  years. One MPSI patient and one NMPSI patient were female. No correlation was found between injury type and age ( $p=0.230$ ) or sex ( $p=0.675$ ).

Seven of the eight NMPSI cases (87.5%) were caused by knife injuries. One 9-year-old female patient with NMPSI presented after her back hit an iron fence.

### Injury Levels

There were 14 thoracic, 4 cervical, 4 lumbar, and 1 sacral injuries. The injured levels for MPSI and NMPSI patients are detailed in Table 1.

### Neurological Findings

Thirteen patients (9 with MPSI and 4 with NMPSI,) were neurologically normal, 3 had severe incomplete neurological findings, and 7 had total function loss below the injury level (Table 1). Among the MPSI patients, six had serious deficits-five with paraplegia due to thoracic lesions and one with an incomplete cauda equina lesion from a lumbar migrating missile. One of these patients, a 26-year-old male, presented with a gunshot wound that entered 15 cm lateral, from the L1 level and lodged in the spinal canal at the L5 level. On examination, he showed 3/5 weakness in both lower extremities and reported hypoesthesia between T10 and L3, loss of anal sphincter tone, and inability to feel his urine (Figure 1). Four of the eight NMPSI patients had significant neurological deficits: Two with paraplegia from complete lesions at the T5 level, one with quadriplegia from a C5 lesion, and one with right lower extremity paresis from a T8 lesion. Imaging of one of these patients is shown in Figure 2. No significant difference was observed in the frequency of neurological deficits between the two groups.

Injury locations and neurological status were compared between MPSI and NMPSI, in Table 1. No significant correlation was found between injury location and neurological status in MPSI patients ( $p=0.113$ ). However, in

NMPSI cases, neurological deficits were significantly more common in thoracic injuries compared to other locations ( $p<0.001$ ).

### Bony Involvement

Six of the 15 MPSI patients had no vertebral fractures and were neurologically normal. Three patients had vertebral fractures, but were also neurologically normal. Vertebral fractures were present in 6 MPSI patients with neurological findings. The presence of neurological findings was



**Figure 1.** Twenty-seven-year-old male patient with missile injury. Missile penetration site was on 15 cm lateral of left side of L1 spinous process' level. Small bone pieces were seen in left side of spinal canal at L1 level (a) and midline of spinal canal at L3 level (b) and the missile was seen in the spinal canal at S1 level (c and d)

**Table 1. Injury levels of the cases**

Localization and clinic	Cervical	Thoracic	Lumbar	Sacral	Total
Missile injuries	2 (8.7%)	10 (43.5%)	2 (8.7%)	1 (4.3%)	15 (65.2%)
Normal	2	5	1	1	9 (39.1%)
Incomplete	0	0	1	0	1 (4.3%)
Complete	0	5	0	0	5 (21.8%)
Non-missile injuries	2 (8.7%)	4 (17.4%)	2 (8.7%)	0	8 (34.8%)
Normal	1	1	2	0	4 (17.4%)
Incomplete	1	1	0	0	2 (8.7%)
Complete	0	2	0	0	2 (8.7%)
Total	4 (17.4%)	14 (60.9%)	4 (17.4%)	1 (4.3%)	23 (100%)

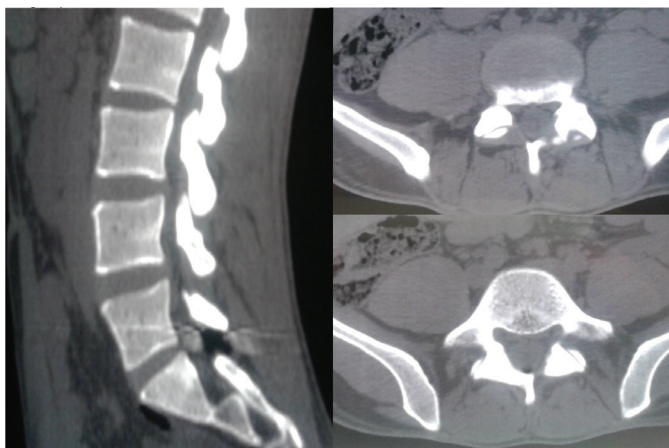
significantly higher in patients with vertebral fractures compared to those without vertebral fractures ( $p<0.001$ ). No vertebral fractures were observed in NMPSI patients.

### Treatment

Five of the nine MPSI patients without deficits underwent surgery for missile removal. The remaining six MPSI patients with serious neurological deficits (five with paraplegia from complete spinal cord transection at thoracic levels and one with an incomplete cauda lesion from a lumbar migrating missile) underwent surgery for dural repair or removal of the migrating missile causing the neurological deficit. The patient with the incomplete lumbar deficit secondary to lumbar MPSI underwent unilateral hemilaminectomy for decompression, intradural bullet removal, and duraplasty (Figure 3).



**Figure 2.** Imaging of the patient with complete dissection of spine in T5 level due to stab wound



**Figure 3.** Postoperative computed tomography images of 27-year-old patient who had a missile removed from his spinal cord. The patient underwent unilateral hemilaminectomy for decompression, foreign body removal and duraplasty

Two NMPSI patients with a complete lesion at T5 and an incomplete lesion at T8 underwent surgery for cerebrospinal fluid (CSF) fistulas. The 9-year-old female NMPSI patient underwent surgery for foreign body removal and dural repair. Surgery was not required for the other NMPSI patients.

### Follow-up and Outcome

The mean follow-up time was  $4\pm1.5$  months (range: 1 month to 1 year). The 13 patients without any neurological deficits remained unchanged during follow-up. Three patients with incomplete SCI showed neurological improvement. One of these patients with the lumbar MPSI, demonstrated neurological improvement after 2 months. His lower extremity strength improved, and he experienced minimal recovery of anal sphincter tone, although bladder sensation remained unchanged. Two NMPSI patients with incomplete lesions also improved after 2 to 6 months. However, no improvement was observed in the 7 patients with complete deficits during follow-up.

### Discussion

We analyzed penetrating spinal injuries in a civilian population, categorizing them into missile (gunshot wounds) and non-missile (stab wounds with knives or other sharp objects) injuries.

The most common causes of SCI are motor vehicle accidents and falls from height, with penetrating wounds being the third leading cause. Penetrating SCIs constitute less than 15% of all SCIs. The National Spinal Cord Injury Database (NSCID) estimates approximately 3500 new cases of penetrating SCI in the USA each year (1-3). PSIs can be broadly classified into two groups: missile (MPSI) and non-missile (NMPSI) injuries (2,3,8,9).

While there are cultural variations, MPSI is generally more common than NMPSI. According to the NSCID, approximately 95% of PSIs in the USA are caused by gunshot wounds (3). Burney et al. (1) reported that stab wounds cause only 1% of all SCI cases in the USA. In contrast, Peacock et al. (10) found that NMPSI accounted for 25% of all SCI cases in South Africa.

These findings suggest that penetrating SCI, particularly stab wounds, may be more prevalent among less educated individuals in areas with lower socioeconomic status and in developing countries. In our study, 34.8% of PSI cases were caused by stab wounds. Our clinic is situated in an area with a lower socioeconomic level than other parts

of Istanbul, which may explain the higher incidence of NMPSI, compared to other studies.

Knives are the most common weapons used in NMPSI, accounting for 84% of cases (11). In our study, 87.5% of NMPSI cases were caused by knives. Almost all NMPSI incidents occurred when victims were stabbed from behind.

According to the NSCID, approximately 80% of patients affected by MSCI and NMSCI are male, with a mean age of 29.7 years (3). Our study similarly found that 91.3% of patients were male, with a mean age of 21.0 years, consistent with the literature.

Previous studies on PSI have reported the thoracic spine as the most commonly affected level, accounting for approximately 50-60% of cases (2,3,8,9,12). Specifically, around 50% of MPSI and 60% of NMPSI involve the thoracic spine (1,10,13). Our results align with these findings, with 60.9% of all cases, 66.7% of MPSI cases, and 50% of NMPSI cases affecting the thoracic spine.

In penetrating trauma, SCI can range from normal appearance to complete anatomic destruction. MPSI is associated with a high incidence of neurological damage, caused by multiple mechanisms, primarily, the blast effect and direct mass effect of the missile. Military weapons cause more extensive damage due to the blast and secondary effects of high-velocity missiles. However, in civilian missile injuries, the prognosis is generally better due to the limited blast effect from lower-velocity and smaller-mass missiles (4,12-14). In these patients, the primary causes of damage are missile penetration into the spinal canal and spinal damage from bone fragments due to vertebral fractures (12,13). Our study supports this, as among patients without vertebral fractures, none exhibited any fractures exhibited any clinical findings.

Most studies on the management of spinal gunshot injuries are based on military experiences, and managing MPSI in these studies remains complex, and challenging. However, civilian gunshot wounds to the spine are typically low-velocity injuries, and the incidence of spinal cord involvement is lower than in military injuries. Consequently, conservative management is often sufficient for civilian injuries (8,15). Surgical indications for MPSI include removal of foreign bodies penetrating or compressing the spinal cord, progressive neurological deficits after admission, CSF fistula, or spinal instability. Additionally, late complications such as infections and pain syndromes may necessitate surgery.

In our study, 11 MPSI patients required surgery for exploration or bullet removal. Five of these patients were neurologically normal, and no complications arose during their follow-up. Five of the 11 patients had paraplegia due to complete spinal cord transection and showed no improvement. One patient with an incomplete deficit who underwent surgery on the day of admission for migrating bullet removal showed neurological improvement. In incomplete SCI, some case reports suggest that emergent foreign body removal can improve neurological status. Additionally, removal can prevent future toxic effects from the bullet. Some case reports also indicate that late surgical removal of a foreign body can improve neurological status, whereas others show improvement without surgical removal (7,8,14,15). Many authors suggest that exploration should not be attempted in the early period if there is no CSF leak or neurological deficit (2,9). Nevertheless, the improvement seen in our patient suggests that early surgical removal of a foreign body may have the potential to improve prognosis. However, the improvement seen in our patient with a lumbar injury highlights the potential for favorable outcomes with early surgical intervention. This patient presented with weakness and sensory deficits in the lower extremities, along with abnormal anal sphincter tone and neurogenic bladder. The bullet lodged in the spinal canal and became displaced, continuing to pose a risk of further neurological deterioration. Given the patient's young age and potential for recovery, the decision was made to perform early surgical removal of the bullet and duraplasty. The subsequent improvement in motor function and anal sphincter tone supports our belief that early surgical intervention may provide a significant advantage and should be strongly considered in selected cases of incomplete SCI in which a foreign body is trapped, compressing neural structures.

In stab wounds, SCI is expected to be less common due to the protection provided by the bony structures of the vertebral column. However, in our study, SCI was more common in NMPSI than in civilian MPSI. Most SCIs in NMPSIs result from hemisection of the spinal cord, leading to incomplete neurological deficits. This occurs because, during an assault, the sharp object is often guided along the gutter between the spinous and transverse processes of the vertebra. Consequently, the most common clinical presentation is Brown-Sequard syndrome. In these patients, the prognosis is better than in those with complete deficits (6,16). Conversely, when neurological deficit is complete, it generally does not improve, as it is often caused by complete transection of the spinal cord (17,18).

There is no standardized strategy for removing a foreign body through closed or open surgery in NMPSI, and the decision for surgical exploration remains controversial (8,16,17). However, early debridement and removal of the foreign body can prevent infection, relieve compression, and potentially improve neurological function (18). Furthermore, removing metallic materials, such as the case of our patient who was injured by an iron fence, allows for future magnetic resonance imaging investigations. Additionally, potential toxic effects from the foreign body are avoided.

In our study, four out of nine NMPSI patients underwent surgery because of a CSF fistula. Two of these patients with incomplete neurological deficits showed neurological improvement during follow-up, while the two with complete deficits remained unchanged, which was expected. Recovery from complete neurological deficits is not anticipated in either missile or non-missile injuries. In our study, 7 patients had complete deficits, and none showed neurological improvement. However, cauda equina lesions and incomplete spinal cord deficits may recover, as seen in 3 of our patients. These patients represent the group that requires particular attention from surgeons and prompt treatment decisions. Based on these results, the prognosis for patients with complete deficits is poor. However, incomplete neurological deficits, especially Brown-Sequard syndrome in stab wounds, often improve.

### Study Limitations

This study is limited by its retrospective design, small sample size (n=23), and single-center setting, which may affect the generalizability of the findings. The short follow-up period (mean 4 months) may not capture long-term outcomes or late complications. The heterogeneity within the MPSI and NMPSI groups and the lack of a control group and standardized treatment protocols also limit the ability to draw definitive conclusions about treatment efficacy. Future prospective studies with larger samples, longer follow-up, and standardized protocols are needed to further investigate the management of penetrating spinal injuries.

## Conclusion

Civilian missile injuries are typically low-velocity lesions and may have a benign course if they do not initially affect the spinal cord or cause vertebral fractures. Stab wounds affecting the spinal canal are less common than missile wounds but can be very serious as they often result in spinal cord transection. Surgical indications include neurological compression causing deficits, intramedullary abscess, and

open or closed CSF fistulas. In cases of gunshot injuries where the bullet remains in the body, and penetrating injuries, where a foreign body is present, surgery may be considered to prevent late complications and toxic effects related to the foreign body. Improvements in the prognosis of our patients with incomplete damage who underwent early surgery support this approach. Therefore, we recommend that the missile or foreign body be removed whenever possible.

### Ethics

**Ethics Committee Approval:** This study was approved by the Local Ethics Committee of İstanbul Medipol University Hospital (registration no: 585, date: 07/06/2021).

**Informed Consent:** Retrospective study.

### Footnotes

#### Authorship Contributions

Surgical and Medical Practices: E.D., F.K.G., İ.G., B.E., A.T., N.S.B., C.İ., Ö.Y.A., Concept: E.D., F.K.G., İ.G., B.E., A.T., N.S.B., C.İ., Ö.Y.A., Design: E.D., F.K.G., İ.G., B.E., A.T., N.S.B., C.İ., Ö.Y.A., Data Collection or Processing: E.D., F.K.G., İ.G., B.E., A.T., N.S.B., C.İ., Ö.Y.A., Analysis or Interpretation: E.D., F.K.G., Literature Search: E.D., F.K.G., Writing: E.D., F.K.G.

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