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Spine and spinal cord injuries in Syria war: treatment and outcome

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STUDY DESIGN: This was a retrospective, comparative 6-year study.
OBJECTIVES: This study aimed to retrospectively analyze patients who were treated at Kilis State Hospital for spine and spinal cord injuries during the Syrian civil war and to compare the treatment results with the literature.
SETTING: Kilis State Hospital, Kilis, Turkey.
METHODS: In our study, 84 patients who were treated for spine and spinal cord injuries between December 2011 and May 2017 were examined. Patient age, sex, injury type, injury region, neurological status, time from injury to treatment, treatment methods, surgical methods applied, and complications were evaluated.
RESULTS: Of the patients, 72 were male, and 12 were female. The mean age of the patients was 23.2 ± 7.3 years. Fifty-two patients were treated surgically. Surgical treatment was applied to 44 patients with neurological deficits. At least 1-grade neurological improvement was observed in 77.3% ($n = 34$) of patients with neurological deficits who underwent surgical treatment. Surgical treatment was performed on 18 (34.6%) patients in the first 24 h, 27 (51.9%) patients within 24–72 h, and 7 patients (13.5%) between 72 h and 5 days. Neurological improvement was observed in all patients with neurological deficits who underwent surgical treatment in the first 24 h.
CONCLUSIONS: Early surgery (in the first 24 h) had a positive effect on the neurological recovery of the patients in our study. Thus, patients with spine and spinal cord injuries rendered a surgical-treatment decision should be operated on in a timely manner, particularly within the first 24 h.

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INTRODUCTION

The Syrian war, which started in 2011, represents one of the most devastating crises of the 21st century, resulting in over 470,000 deaths as of February 2016 and the displacement of 12.2 million Syrians (5.6 million refugees, 6.6 million internally displaced people) [1–3].

Spinal gunshot wounds are common in developing countries and war zones of the world [4]. Such injuries are mostly seen among young age groups and can lead to consequences ranging from stroke to death [5, 6]. Firearm injuries of the spinal cord constitute 17–31% of all spinal cord injuries [5, 7]. Traumatic spinal injury are a health problem that has started to take place frequently in neurosurgical practice due to reasons such as the rise in civil wars and terrorist acts and the increase in individual armament [5, 7]. In a study conducted on military injuries in the Iraq War in 2007, it was found that spinal injuries accounted for 7.4% of all war injuries [8].

According to de Barros Filho TE et al., penetrating injuries to the spine have recently increased in incidence to cause 13–17% of all spinal injuries [9]. Although thoracic injuries are the most common types of trauma from gunshots, cervical spine injuries may be the most destructive. The main prognostic factor considered for recovery is the initial neurological status [9, 10].

Since the beginning of this century, significant progress has been made in the management and treatment of gunshot wounds caused by wars. However, in studies on spine and spinal cord injuries caused by wars in the in the literature, no consensus has been found in terms of treatment selection and patient management [11–13]. Today, improvised explosives are frequently used in current armed conflicts [14] and often cause both penetrating and high-energy blunt injuries [15].

Kilis is a border province in southeastern Turkey, 10 km from Syria. In our study, we aimed to retrospectively analyze patients who were treated at Kilis State Hospital, located on the border of Syria, due to spine and spinal cord injuries (penetrating or blunt) sustained during the Syrian civil war and to compare the treatment results with the literature.

METHODS

Our study had a retrospective design. In this investigation, 84 patients who were treated for spine and spinal cord injuries at the Neurosurgery Clinic of Kilis State Hospital on the Syrian border between December 2011 and May 2017 were examined. Patients with spinal column and spinal cord injuries were included in our study, whereas patients with missing clinical and radiological data were not.

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Age, sex, injury types (penetrating, blunt), injury regions (cervical, thoracic, lumbar), radiological images, neurological status, time from injury to treatment, accompanying additional organ injuries, hospitalization times, treatment methods (surgical or non-operative and medical), surgical methods and complications were evaluated.

We used the American Spinal Injury Association (ASIA) score for the assessment of neurological status. To this end, patients were divided into the following five subsets depending on the neurological status: (A) complete cord injury; (B) intact sensory function but impaired motor function; (C) more than half of key muscles below the injury level with a power strength less than 3; (D) more than half of key muscles below the injury level with a power strength more than 3; and (E) normal motor and sensory function. The standard workup included radiographs and computed tomographic scans; these images were reviewed to classify fracture types and canal compromise (defined as percent canal occlusion on the axial slice with the greatest occlusion). Surgical indications were a progressive neurological deficit in the presence of an identified compressive lesion, persistent cerebrospinal fluid (CSF) leakage, infection, and spinal instability. Vertebral fractures were classified using Denis's 3-column model. We also determined the instability criteria by Denis's 3-column model [16].

The data we obtained were analyzed using the SPSS (version 20, IBM Inc., Armonk, USA) program. Quantitative data are presented as the mean and standard deviation, while qualitative data are presented as percentages. The chi-square/Fisher test was used for comparisons between categorical variables. Data with a p value less than 0.05 were considered significant.

RESULTS

We recruited eighty-four patients with spine and spinal cord injuries. Seventy-two of the patients were male, and 12 were female (Table 1). Of the patients, 68 were adults and 16 were children. The mean age of the patients was 23.2 ± 7.3 years (range 4 to 72 years). The mean hospital stay was 16.2 ± 6.2 days. The mean follow-up period of the patients was 7.4 ± 1.2 months. Seven (8.3%) patients who participated in our study died. Three of these patients died from cardiac arrest; another 2 of them, due to pneumonia; and the remaining 2 patients, due to pulmonary embolism. While most of the patients were injured in the thoracic region ($n = 40$, 47.6%), the number of patients injured in the cervical ($n = 22$, 26.2%) and lumbar regions ($n = 22$, 26.2%) was equal. This difference in injury sites was statistically significant ($p < 0.05$) (Table 1). When the injured anatomical regions of the patients with vertebral fractures were examined, it was observed that corpus fractures were the most common ($n = 36$, 42.9%). When the patients were evaluated according to Denis's 3-column classification, it was observed that the most common number of columns (47.6%) involved was 2. Canal stenosis was present in 44 patients (52.4%) and averaged 45.2% occlusion on axial computed tomographic scans. Abdominal injuries (17.9%) were the most common additional system injuries (Table 1). When the injury types of the patients were examined, 56 (66.6%) had penetrating injuries, and 28 (33.3%) had blunt injuries.

Penetrating injuries were caused by bullet injuries ($n = 14$), bullet fragment injuries ($n = 18$), and improvised explosive injuries ($n = 24$). On the other hand, mine injuries ($n = 4$), bomb injuries ($n = 6$), and missile injuries ($n = 8$) led to blunt injuries. In addition, all of the falls from a height ($n = 6$) and vehicle accidents ($n = 4$) following an explosion caused blunt injuries.

Thirty-two (38.1%) patients were followed up with non-operative treatment without surgical treatment. Ten (31.25%) of these patients were followed with a neck brace; 4 (12.5%), with a thoracolumbosacral orthosis; and 2 (6.25%), with halo vests. Stabilization surgery was performed in 4 (12.5%) patients who were treated conservatively due to the development of instability in their follow-up. Fifty-two patients (61.9%) were treated surgically (Fig. 1, Fig. 2). Decompression was applied to 32 patients due to neurological deficits and cord injury. All decompressions were instrumented and fused. Only instrumentation and fusion were applied to 14 patients due to instability. Surgical treatment (irrigation/debridement) was administered to 6 patients due to the presence of infective tissue in the injury area and BOS fistula. Specific antibiotic regimens were administered to all patients, taking into account additional injury sites. In addition, methylprednisolone treatment was started in the early period in all patients with neurological deficits.

Table 1. Demographics and injury pattern.

	Mean	SD
Age (year)	23.2	7.3
	N	**%**
Sex		
Male	72	85.7
Female	12	14.3
Injury level		
Cervical	22	26.2
Thoracic	40	47.6
Lumbar	22	26.2
Sacral	-	-
Column fracture involvement		
1 Column	28	33.3
2 Columns	40	47.6
3 Columns	16	19.1
Fracture anatomy		
Vertebral body	36	42.9
Transverse process	19	22.6
Pedicle	22	26.2
Facet/pars	12	14.3
Lamina	12	14.3
Spinous process	16	19.1
Lateral mass	8	9.6
Nonspinal injuries		
Craniofacial/neck	8	9.6
Cardiothoracic	12	14.3
Abdominal	15	17.9
Extremity	10	11.9

Sixty-two patients had neurological deficits before treatment (ASIA scores A-D) (Table 2). Complete spinal cord injury (ASIA A) was the most common degree of impairment (16 patients, 19%) (Table 2).

Surgical treatment was applied to 44 (71%) of these patients, and non-operative treatment was administered to 18 (29%). At least 1-grade neurological improvement was observed in 77.3% ($n = 34$) of the patients with neurological deficits who underwent surgical treatment and 50% ($n = 9$) of the patients with neurological deficits who received non-operative and medical treatment. This difference was statistically significant ($p < 0.05$). Of the 43 patients who recovered, 33 had a 1-grade neurological improvement, 5 had a 2-grade neurological improvement, and 5 had a 3-grade neurological improvement. All patients with 2- and 3-grade improvement underwent surgical treatment. There was no significant difference between injury sites and neurological recovery ($p > 0.05$).

Forty-four (78.6%) patients with penetrating injuries had neurological deficits, and 29 (65.9%) of these patients had at least 1-grade neurological improvement after treatment. Eighteen (64.3%) patients with blunt injuries had neurological deficits, and 14 (77.8%) of these patients had at least 1-grade of neurological

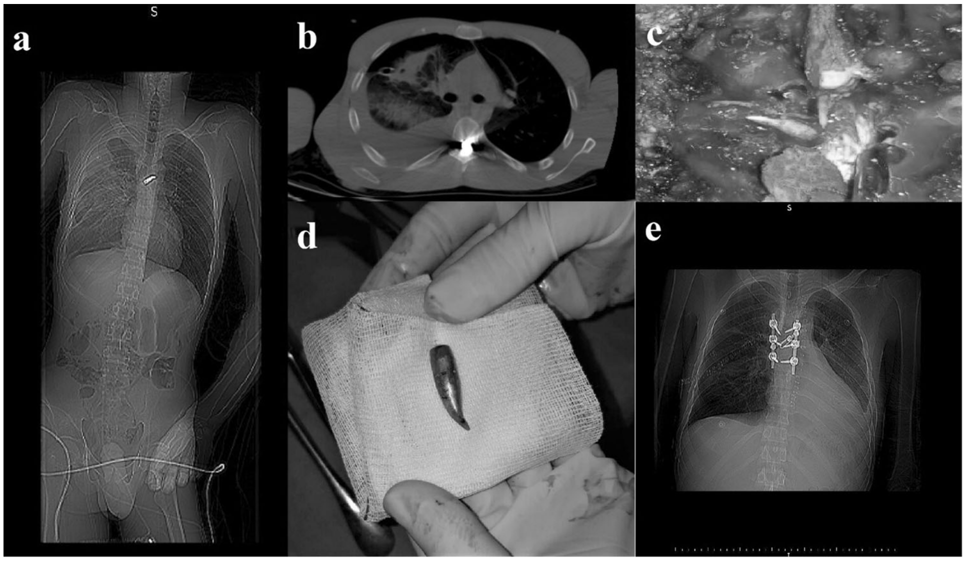

Fig. 1 A 26-year-old male patient with a civilian spinal gunshot wound at T4–T5, resulting in an initial American Spinal Injury Association (ASIA) B neurological injury. Anterior-posterior (**a**) radiographs and axial (**b**) computed tomographic scans demonstrated a large retained ballistic fragment within the spinal canal. T4 total laminectomy and T5 partial laminectomy were performed in this patient with spinal cord injury. **c** The bullet was removed from the spinal canal. **d** Transpedicular screws were placed in T3, T4 and T5. **e** At 4 months after injury, the patient had an ASIA C neurologic exam, no instability, and no clinical signs of metal toxicity.

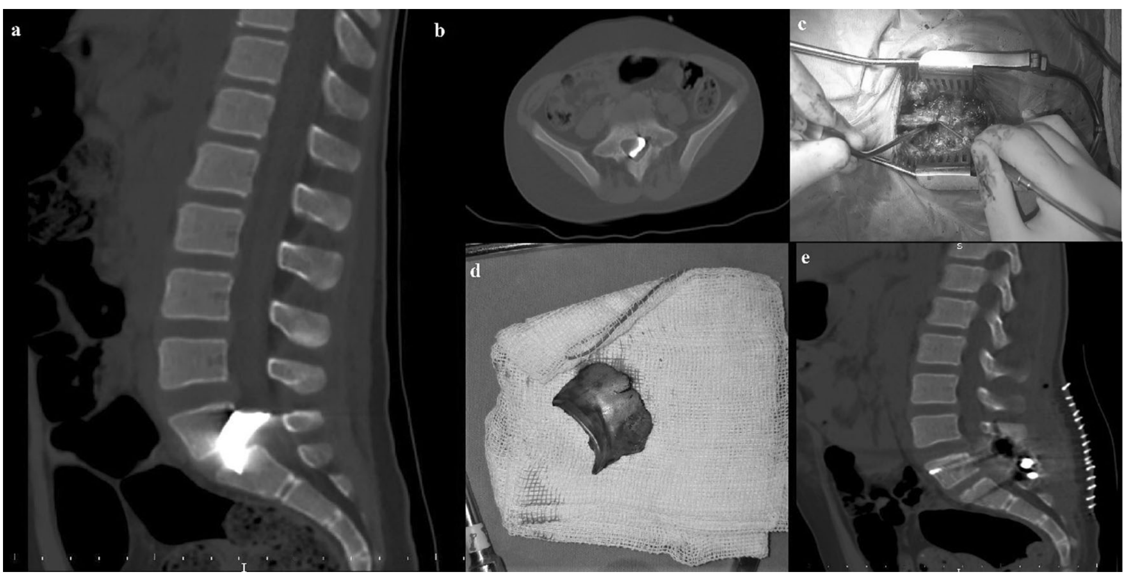

Fig. 2 A 22-year-old female patient with a civilian spinal gunshot wound at L5–S1, resulting in an initial American Spinal Injury Association (ASIA) B neurological injury. Sagittal (**a**) and axial (**b**) computed tomographic scans demonstrated a large fragment of shrapnel within the spinal canal. L5 total laminectomy was performed in this patient with spinal cord injury. **c** The shrapnel was removed from the spinal canal. **d** Transpedicular screws were placed in L5 and S1. **e** At 5.5 months after injury, the patient had an ASIA D neurologic exam, no instability, and no clinical signs of metal toxicity.

improvement after treatment. There was no statistically significant difference in recovery between injury types ($p > 0.05$).

The time from the injury to the treatment of the patients who underwent surgical treatment was evaluated. Surgical treatment was performed on 18 (34.6%) patients in the first 24 h, on 27 (51.9%) patients within 24–72 h, and on 7 patients (13.5%) between 72 h and 5 days. Delays in patient transport time mostly result from mandatory waiting at the border for security reasons. Neurological improvement was observed in all patients with neurological deficits who underwent surgical treatment in the first 24 h. This result was found to be statistically significant ($p < 0.001$) (Table 3).

The mean age of patients who recovered was 21.4 years, while the mean age of patients who did not improve was 28.7 years. Although younger patients had better recovery, this difference was not statistically significant ($p > 0.05$). Neurological improvement was not found to be associated with sex, age, injury level, number of columns involved, concomitant injury or presence of complications.

Complications developed after treatment in 11 patients (13.1%). The most common complication was neuropathic pain ($n = 5$). The complication rate in the patients who underwent surgical treatment was 13.5% ($n = 7$), while the complication rate in the non-operative and medical treatment groups was 12.5% ($n = 4$).

Table 2. Distribution of the level of injury according to the AIS on admission.

	Complete		Incomplete					
Spinal level	A	%	B	C	D	E	*n* (incomplete total)	%
Cervical	6	27.3	3	3	3	7	16	72.7
Thoracic	6	15	10	7	11	6	34	85
Lumbosacral	4	18.2	3	3	3	9	18	81.8
Total	16	19	16	13	17	22	68	81

Table 3. Timing of conservative and surgical treatment.

		0–24 h	24–72 h	72 h – 5 day	*p*
Surgery	No change	-	11	7	
	Improved	18 (100%)	16 (59.3%)	−(0%)	$p < 0.001$
Non-Operative	No change	5	7	3	
	Improved	2 (28.6%)	2 (22.3%)	1 (25%)	$p > 0.05$

Although the complication rate was higher in patients who underwent surgical treatment, this difference was not statistically significant ($p > 0.05$).

DISCUSSION

In published studies on combat-related spine and spinal cord injuries, non-operative and medical treatment have been emphasized. It has been stated that surgical treatment is not neurologically beneficial enough and causes serious complications, and the number of patients who have undergone surgical treatment has been reported at low rates [11–13]. Many studies have been conducted on firearm injuries in the Syrian civil war [17, 18]. However, there is no study in the literature examining spine and spinal cord injuries in detail. We believe that our study will make a serious contribution to the literature, as it examines spine and spinal cord injuries in the Syrian civil war and the high rate of such patients who underwent surgical treatment.

In published studies on spine and spinal cord injuries, it was determined that patients in the second and third decades of life were most frequently affected [11, 19]. The mean age of the patients in our study was consistent with published reports. In the literature, combat-related spine and spinal cord injuries were found to be more common in males (91–94%) [9, 20]. In our study, the number of male patients was high, which was consistent with the literature. Moreover, published studies have emphasized that the hospitalization period of spine and spinal cord injury patients who undergo surgical treatment is long [11, 20]. The hospital stay in our study was 16.2 ± 6.2 days, which was consistent with the literature [11, 20].

Studies have shown that gunshot wounds mostly affect the thoracic spine [9, 21]. Sidhu et al. reported thoracic spine injuries with a rate of 49% [22]. In our study, the most frequently injured area was the thoracic region (rate of 47.6%), which was consistent with the literature.

There are a limited number of large studies in the literature on combat-related spine and spinal cord injuries [11, 12, 23]. The most comprehensive published combat-related spine and spinal cord injuries studies, which occurred during war, were those conducted in the Afghanistan and Iraq wars [24]. Heary et al. evaluated the injury characteristics, treatment methods, and neurological recovery rates of 219 cases [23]. Heary et al. found that the rate of patients who underwent surgical treatment was 23%, but the surgical indications were not clearly stated. Nwosu et al. accepted the presence of symptomatic bullets under the skin, the presence of bullets in the spinal canal at T12 or below, the presence of neurological deficits and CSF leaks as surgical treatment indications [12]. Abbas et al., on the other hand, for patients with incomplete injuries, performed surgical treatment on those with spinal canal compression, bullets in the spinal canal, and instability [20]. In our study, we primarily applied surgical treatment in patients with neurological deficits, instability, spinal cord injury (on MRI), CSF leakage, and symptomatic subcutaneous bullets. Bumpass et al. conducted a study finding that surgical treatment did not contribute to neurological recovery, instability was prevented by non-operative and medical treatment, and surgical treatment was applied to only 6% of patients [11]. Nwosu et al. and Abbas et al. reported that there was no difference between patients who underwent surgical treatment and those who received non-operative medical treatment in terms of neurological recovery [12, 20].

Stauffer et al. evaluated 185 patients with spine and spinal cord injury between 1966 and 1973 [25]. In the study, 101 patients underwent decompression surgery. Neurological recovery was observed in 71% of patients with incomplete lesions and surgical treatment, while 77% of patients treated without surgery had neurological recovery. Wound infection or CSF leakage developed in 10% of the patients who underwent surgical treatment, while these complications did not develop in any of the patients who did not undergo surgery. In the study of Waters and Adkins, 90 patients were included in the study, and decompression was applied to 32 of them [26]. In that investigation, significant neurological improvement was found in patients with T12-L4 injury who underwent surgical treatment. In some other studies, it was concluded that decompression surgery, especially when applied to the lumbar region, is beneficial in terms of neurological recovery [27]. In our study, no significant difference in neurological recovery was found between the injury sites ($p > 0.05$).

Surgical treatment rates for spine and spinal cord injury patients vary in the literature [11, 13, 28]. In one study, it was stated that only 18% of spine and spinal cord injury patients had an indication for surgery, and many patients (75%) who underwent surgical treatment were treated without indication [12]. In some published studies, it was stated that the time from injury to surgical intervention did not have a clear effect on neurological recovery [29]. Wilson et al. conducted a prospective study and found that neurological improvement was significantly higher in patients who underwent surgical treatment in the first 24 h [30]. In a study conducted by Iqbal et al., it was stated that the first 48 h are a useful surgical time frame for patients [13]. In our study, the rate of patients with at least 1-grade neurological improvement who underwent surgical treatment was higher than that in the literature (77.3%). We operated without delay on patients for whom we had a surgical indication. Most of the patients who received surgical treatment underwent the operation within the first 24 h. Considering the surgical timing and neurologic recovery rates, there was a statistically significant positive difference in patients who underwent surgery within the first 24 h ($p < 0.001$). In our study, there was a high rate of neurological recovery in patients who underwent surgical treatment. We believe that this rate depends on the correct indication for surgery and on application of the surgical treatment in a timely manner. We consider the first 24 h to be the most critical time frame for combat-related spine and spinal cord injuries patients with an indication for surgery.

In a study of 142 cases, Simpson et al. applied surgical treatment to 31 (22%) of the patients [31]. Neurological improvement was observed in 13% of patients with complete injury who underwent surgical treatment and in 15% of patients with complete injury who did not undergo surgical treatment. Neurological improvement was observed in 40% of patients with incomplete injuries who underwent surgical treatment and in 58% of patients with incomplete injuries who did not undergo surgical treatment. Neurological recovery results in the study by Simpson et al. were correlated with those in the work of Bumpass et al. [11]. In both studies, it was emphasized that complication rates such as CSF leaks and meningitis were higher in patients who underwent surgical treatment. While the overall complication rate in our study was 13.1%, the complication rate in patients who underwent surgical treatment was 13.5%. These rates were similar to those in many of the published studies [15, 22, 25].

Bumpass et al. found that even patients who were conservatively followed up with 2- and 3-column damage according to the Denis classification did not develop kyphosis and instability in their follow-up and that no additional surgical intervention was required [11]. However, in our study, 12.5% of the patients who were treated conservatively and medically subsequently underwent stabilization surgery due to the development of instability in their follow-up. According to our study results, we believe that non-operative follow-up of patients with 2- and 3-column damage according to the Denis classification is not a correct approach and that stabilization should be performed.

Consistent with the literature in our study, the most common incomplete injury was found in cervical injuries (40.9%) [7, 9, 20]. Surgery was performed on 10 patients with cervical injury. Decompression + stabilization was performed in 6 patients, and stabilization + fusion was performed in 4 patients due to instability. Contrary to the low rates in the literature, at least 1-grade neurological improvement was observed in 90% of the patients with cervical region injuries who underwent surgical treatment in our study. All patients with cervical injury who were scheduled for surgical treatment underwent surgery within the first 24 h.

In many studies, it has been reported that neurologic recovery rates are low in thoracic complete injuries [9, 11]. Iqbal et al. reported that the group with the best treatment results according to the ASIA scale was the patient group with thoracic injury [13]. Surgical treatment was applied to 40 of 46 patients with incomplete injuries in our study, and 70% of these patients had at least 1-grade neurological improvement. No improvement was observed in any of the patients with thoracic injuries with complete injuries. While our surgical treatment success in patients with incomplete injuries was remarkable, the results in patients with complete injuries were consistent with the literature [9, 11].

Blair et al. evaluated combat-related spine and spinal cord injuries sustained during war; 66% of the patients had blunt injuries, and 28% had penetrating injuries [15]. In that study, surgical treatment was applied to 28% of patients with blunt injuries and 41% of patients with penetrating injuries. Neurological recovery was observed in 60% of blunt-injured soldiers who underwent surgical treatment, while 43% of patients with penetrating injuries had neurological recovery. In our study, 66.7% of the patients had penetrating injuries, while 33.3% suffered blunt injuries. The neurological recovery rates in our study were found to be high in penetrating injuries (65.9%) and blunt injuries (77.8%). There was no significant relationship between injury type and neurological recovery of the patients in our study. The increased destructive power of weapons and bombs thanks to advanced weapon technologies may have led to high rates of patients with penetrating injuries. We also think that spine and spinal cord injuries coexist due to the use of high-energy weapons and improvised explosives.

According to Apte et al. stated that lead toxicity caused by retained bullet fragments can lead to serious neurological and psychiatric disorders [32]. For this reason, it is recommended that patients with large bullet fragments should be followed closely in the first year of their clinical and blood values and that patients with a lead value above 5 ngr/dl should be intervened [32]. Ge et al. suggested that retained bullet fragments in the spinal cord, spinal canal or intervertebral disc should be removed to reduce the risk of lead poisoning [33]. In our study, in order to prevent possible lead poisoning in patients; retained bullet and shrapnel fragments in spinal cord, bullet fragments associated with CSF and large bullet and shrapnel fragments were removed. Bullet and shrapnel fragments, which have the potential to worsen the injury and the existing neurological status of the patients, were not interfered with.

Our study has several limitations, including its retrospective nature and the unequal distribution of patients between groups. Such limitations might have obscured the true outcome, attenuating the differences between management strategies. Randomized multicenter studies may therefore help formulate definitive guidelines for civilian gunshot injuries.

Our surgical treatment rate in our study was quite high compared to the literature. Due to the surgical technique applied, a high rate of instrumentation was used. Despite all these treatment methods, our complication rates were consistent with the literature. However, our neurological recovery rates were better than those of patients who underwent surgical treatment in the literature. Early surgery (performed in the first 24 h) had a positive effect on the neurological recovery of the patients in our study. In addition, we believe that early surgery (in the first 24 h) ensures early mobilization of patients and protects patients from problems that may occur due to immobility (decubitus wound, pulmonary embolism, etc.). We also believe that patients with combat-related spine and spinal cord injuries who are rendered a surgical-treatment decision should be operated on in a timely manner, particularly, within the first 24 h.

DATA AVAILABILITY

Due to the nature of this research (Syrian War), some of the participants in this study did not agree to share their data publicly, so no supporting data are available. However, authors will consider reasonable requests for access to data.

REFERENCES

1. Syrian Centre for Policy Research. Syria: Confronting Fragmentation. Impact of Syrian Crisis Report. 2015. https://www.undp.org/syria/publications/confronting-fragmentation.
2. World Health Organization. World Health Organization Syrian Arab Republic: annual report 2017. 2017. https://www.who.int/publications/i/item/world-health-organization-syrian-arab-republic-annual-report-2017.
3. United Nations High Commissioner for Refugees (UNHCR). Situation Syria Regional Refugee Response. 2018. https://data.unhcr.org/en/situations/syria.
4. Aarabi B, Alibaii E, Taghipur M, Kamgarpur A. Comparative study of functional recovery for surgically explored and conservatively managed spinal cord missile injuries. Neurosurgery. 1996;39:1133–40. https://doi.org/10.1097/00006123-199612000-00013.

5. Joseph C. Characteristics and outcomes of gunshot-acquired spinal cord injury in South Africa. S Afr Med J. 2017;107:518–22. https://doi.org/10.7196/SAMJ.2017.v107i6.12296.
6. Rahimi-Movaghar V, Sayyah MK, Akbari H, Khorramirouz R, Rasouli MR, Moradi-Lakeh M. et al. Epidemiology of traumatic spinal cord injury in developing countries: a systematic review. Neuroepidemiology. 2013;41:65–85. https://doi.org/10.1159/000350710.
7. Trahan J, Serban D, Tender GC. Gunshot wounds to the spine in post-Katrina New Orleans. Injury. 2013;44:1601–6. https://doi.org/10.1016/j.injury.2013.06.02.
8. Schoenfeld AJ, Newcomb RL, Pallis MP, Cleveland AW, Serrano JA, Bader JO. et al. Characterization of spinal injuries sustained by American service members killed in Iraq and Afghanistan: a study of 2,089 instances of spine trauma. J Trauma Acute Care Surg. 2013;74:1112–8. https://doi.org/10.1097/TA.0b013e31828273be.
9. de Barros Filho TE, Cristante AF, Marcon RM, Ono A, Bilhar R. Gunshot injuries in the spine. Spinal Cord. 2014;52:504–10. https://doi.org/10.1038/sc.2014.56.
10. Maiti TK, Konar S, Bir SC, Bollam P, Nanda A. Historical vignette of infamous gunshot injury to spine: "An ailment not to be treated"?. World Neurosurg. 2015;84:1441–6. https://doi.org/10.1016/j.wneu.2015.03.037.
11. Bumpass DB, Buchowski JM, Park A, Gray BL, Agarwal R, Baty J. et al. An update on civilian spinal gunshot wounds: treatment, neurological recovery, and complications. Spine (Philos Pa 1976). 2015;40:450–61. https://doi.org/10.1097/BRS.0000000000000797.
12. Nwosu K, Eftekhary N, McCoy E, Bhalla A, Fukunaga D, Rolfe K. et al. Surgical management of civilian gunshot-induced spinal cord injury: is it overutilized?. Spine (Philos Pa 1976). 2017;42:E117–24. https://doi.org/10.1097/brs.0000000000001716.
13. Iqbal N, Sharif S, Hafiz M, Ullah Khan A. Gunshot spinal injury: factors determining treatment and outcome. World Neurosurg. 2018;114:e706–12. https://doi.org/10.1016/j.wneu.2018.03.062.
14. Ritenour AE, Blackbourne LH, Kelly JF, McLaughlin DF, Pearse LA, Holcomb JB. et al. Incidence of primary blast injury in US military overseas contingency operations: a retrospective study. Ann Surg. 2010;251:1140–4. https://doi.org/10.1097/SLA.0b013e3181e01270.
15. Blair JA, Possley DR, Petfield JL, Schoenfeld AJ, Lehman RA, Hsu JR. et al. Military penetrating spine injuries compared with blunt. Spine J. 2012;12:762–8. https://doi.org/10.1016/j.spinee.2011.10.009.
16. Denis F. Spinal instability as defined by the three-column spine concept in acute spinal trauma. Clin Orthop Relat Res. 1984;189:65–76.
17. Aras M, Altaş M, Yilmaz A, Serarslan Y, Yilmaz N, Yengil E. et al. Being a neighbor to Syria: a retrospective analysis of patients brought to our clinic for cranial gunshot wounds in the Syrian civil war. Clin Neurol Neurosurg. 2014;125:222–8. https://doi.org/10.1016/j.clineuro.2014.08.019.
18. El Hajj Abdallah Y, Beveridge J, Chan M, Deeb T, Mowafi H, Al-Nuaimi S. et al. Devastating neurologic injuries in the Syrian war. Neurol Clin Pr. 2019;9:9–15. https://doi.org/10.1212/CPJ.0000000000000556.
19. Klimo P,Jr, Ragel BT, Rosner M, Gluf W, McCafferty R. et al. Can surgery improve neurological function in penetrating spinal injury? A review of the military and civilian literature and treatment recommendations for military neurosurgeons. Neurosurgical Focus. 2010;28:E4 https://doi.org/10.3171/2010.2.Focus1036.
20. Abbas A, Aziz HF, Rizvi R, Rehaman L, Javeed F, Afzal A. et al. Gunshot acquired spinal cord injury in civilians. Turk Neurosurg. 2019;29:506–12. https://doi.org/10.5137/1019-5149.JTN.24121-18.2.
21. Guzelkucuk U, Demir Y, Kesikburun S, Aras B, Yavuz F, Yasar E. et al. Spinal cord injury resulting from gunshot wounds: a comparative study with non-gunshot causes. Spinal Cord. 2016;54:737–41. https://doi.org/10.1038/sc.2016.29.
22. Sidhu GS, Ghag A, Prokuski V, Vaccaro AR, Radcliff KE. Civilian gunshot injuries of the spinal cord: a systematic review of the current literature. Clin Orthop Relat Res. 2013;471:3945–55. https://doi.org/10.1007/s11999-013-2901-2.
23. Heary RF, Vaccaro AR, Mesa JJ, Northrup BE, Albert TJ, Balderston RA. et al. Steroids and gunshot wounds to the spine. Neurosurgery. 1997;41:576–83. https://doi.org/10.1097/00006123-199709000-00013.
24. Lawless MH, Lytle EJ, McGlynn AF, Engler JA. Surgical management of penetrating spinal cord injury primarily due to shrapnel and its effect on neurological outcome: a literature review and meta-analysis. J Neurosurg: Spine SPI. 2018;28:63–71. https://doi.org/10.3171/2017.5.Spine161037.
25. Stauffer ES, Wood RW, Kelly EG. Gunshot wounds of the spine: the effects of laminectomy. J Bone Jt Surg Am. 1979;61:389–92.
26. Waters RL, Adkins RH. The effects of removal of bullet fragments retained in the spinal canal: a collaborative study by the National Spinal Cord Injury Model Systems. Spine (Philos Pa 1976). 1991;16:934–9. https://doi.org/10.1097/00007632-199108000-00012.
27. Aryan HE, Amar AP, Ozgur BM, Levy ML. Gunshot wounds to the spine in adolescents. Neurosurgery. 2005;57:748–52. https://doi.org/10.1093/neurosurgery/57.4.748.
28. Sajid MI, Ahmad B, Mahmood SD, Darbar A. Gunshot injury to spine: an institutional experience of management and complications from a developing country. Chin J Traumatol. 2020;23:324–8. https://doi.org/10.1016/j.cjtee.2020.07.005.
29. Biglari B, Child C, Yildirim TM, Swing T, Reitzel T, Moghaddam A. Does surgical treatment within 4 h after trauma have an influence on neurological remission in patients with acute spinal cord injury?. Ther Clin Risk Manag. 2016;12:1339–46. https://doi.org/10.2147/TCRM.S108856.
30. Wilson JR, Singh A, Craven C, Verrier MC, Drew B, Ahn H. et al. Early versus late surgery for traumatic spinal cord injury: the results of a prospective Canadian cohort study. Spinal Cord. 2012;50:840–3. https://doi.org/10.1038/sc.2012.59.
31. Simpson RK Jr, Venger BH, Narayan RK. Treatment of acute penetrating injuries of the spine: a retrospective analysis. J Trauma. 1989;29:42–6.
32. Apte A, Bradford K, Dente C, Smith RN. Lead toxicity from retained bullet fragments: a systematic review and meta-analysis. J Trauma Acute Care Surg. 2019;87:707–16. https://doi.org/10.1097/ta.0000000000002287.
33. Ge L, Jubril A, Mesfin A. Civilian gun shot wounds associated with spinal injuries. Global Spine J. 2022;12:1428–33. https://doi.org/10.1177/2192568221991802.

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AUTHOR CONTRIBUTIONS
IDC drafted and revised the manuscript. MCS conducted the statistical analysis and reviewed the manuscript. IDC, IK and BK participated in the study's implementation. IK and BK performed the translation work and data collection. IK and NY were responsible for the project's design and implementation, quality control, and manuscript revision.

COMPETING INTERESTS
The authors declare no competing interests.

ETHICAL APPROVAL
Ethics committee approval was received for this study from the Kutahya Dumlupınar University Non-interventional Clinical Researches Ethics Board (2017-12/7 no decree dated 15.11.2017).

ADDITIONAL INFORMATION
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