Observational Study

Medicine

OPEN

Impact of spinal injury on mortality in patients with major trauma

A propensity-matched cohort study

Han-Dong Lee, MD[a], KyoungWon Jung, MD, PhD[b], ByungHee Kang, MD[b], Nam-Su Chung, MD[a], Chang-Hoon Jeon, MD, PhD[a], Hee-Woong Chung, MD[a,*]

Abstract

Major trauma is defined as a significant injury or injury that has the potential to be life-threatening and is quantitatively identified as an injury severity score (ISS) >15. Spinal injuries are common in patients with major trauma; however, because spinal injury is not independently included in the ISS calculation, the impact of spinal injury on mortality in patients with major trauma has not been fully elucidated. The purpose of this study is to identify the association between spinal injury and mortality in patients with major trauma. From January 1, 2016, to December 31, 2020, retrospective analysis was conducted on 2893 major trauma adult patients admitted to a level 1 trauma center. There were 781 patients in the spinal injury group and 2112 patients in the group without spinal injury. After matching the 2 groups 1:1, we compared injury mechanism, mortality, cause of death, intensive care unit length of stay (ICU LOS), and duration of ventilator use between spinal injury group and matched cohorts. Falls and traffic accidents were the most common injury mechanisms in the spinal injury group and the matched cohort, respectively. The mortality was significantly lower in the spinal injury group compared with the matched cohort (4.0% vs 7.9%, P = .001), and the ICU LOS was longer than the matched cohort (8.8 ± 17.4 days vs 7.2 ± 11.7 days, P = .028). In the spinal injury group, multiple organ failure (MOF) was the most common cause of death (41.9%), while that in the matched cohort was central nervous system (CNS) damage (61.3%). In patients with major trauma, spinal injury may act as a shock absorber for internal organs, which is thought to lower the mortality rate.

Abbreviations: AIS = abbreviated injury scale, CNS = central nervous system, ICU LOS = intensive care unit length of stay, ISS = injury severity score, MOF = multiple organ failure, RTS = revised trauma score, SCI = spinal cord injury.

Keywords: injury severity score (ISS), major trauma, shock absorber, spinal injury

1. Introduction

Spinal injuries are not usually life-threatening.[1] However, in patients with multiple trauma, they often occur with other concomitant injuries, which may significantly impact prognosis.[2–4] Although spinal injuries commonly occur in the multiple trauma patient population,[5] only a few epidemiologic studies on traumatic spinal injuries have been conducted.[6–8] Additionally, most studies have focused on the types of vertebral fractures, recovery of neurological deficits, and the timing of surgery, and there is limited literature on the effects of spinal injuries on mortality in patients with trauma.

Major trauma is defined as significant injury or injuries that have the potential to become life-threatening or life-changing,[9] which is quantitatively identified as an Injury Severity Score (ISS) >15.[10] The ISS was proposed by Baker et al[11] in 1974 as the first multiple injury scoring system. Since the ISS is related to patient mortality, it is considered the gold standard for trauma severity scoring.[12,13] To calculate the ISS, the 9 Abbreviated Injury Scale (AIS) body regions are grouped into 6: the head or neck, face, chest, abdominal or pelvic contents, extremities or pelvic girdle, and external.[14] The ISS is calculated as the sum of the squares of the highest AIS scores for the 3 most severely injured body regions, and ranges from 0 to 75.[11]

Evaluating the impact of spinal injury on mortality in patients with major trauma is difficult because spinal injury is not independently included in the ISS calculation. When calculating the ISS, cervical, thoracic, and lumbar injuries are included in the head or neck, chest, and abdominal regions, respectively. Therefore, spinal injuries can be masked by other injuries involved in the area. The aim of this study was to elucidate the effect of spinal injury on mortality in patients with major trauma.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

[a] Department of Orthopaedic Surgery, Ajou University School of Medicine, Suwon, Republic of Korea, [b] Division of Trauma Surgery, Department of Surgery, Ajou University School of Medicine, Suwon, South Korea.

* Correspondence: Hee-Woong Chung, Department of Orthopaedic Surgery, Ajou University School of Medicine, 164 World Cup-ro, Yeongtong-gu, Suwon, Geyounggi-do, 16499, South Korea (e-mail: 110511@aumc.ac.kr).

How to cite this article: Lee H-D, Jung K, Kang B, Chung N-S, Jeon C-H, Chung H-W. Impact of spinal injury on mortality in patients with major trauma: A propensity-matched cohort study. Medicine 2023;102:25(e34090).

Received: 23 February 2023 / Received in final form: 15 May 2023 / Accepted: 2 June 2023

http://dx.doi.org/10.1097/MD.0000000000034090

2. Materials and methods

2.1. Study design and population

This study involved retrospective registry-based analysis. From January 1, 2016, to December 31, 2020, a total of 13,278 patients visited a level 1 trauma center. Of these, 2893 adult patients had major trauma, excluding those with incomplete data or minor spinal injury (Fig. 1). There were 781 patients (23.0%) in the spinal injury group and 2112 patients (73.0%) in the group without spinal injury. Major trauma was defined as an ISS >15.[15] Pediatric patients were excluded because the injury mechanisms and mortality rates were different from those of adults; moreover, the incidence of spinal injuries was low.[16] Spinal injury was defined as a spine fracture, dislocation, or subluxation, with or without neurologic deficit based on the definition of major injury in the Denis classification.[17] Minor spinal injuries represented by fractures of transverse processes, articular processes, pars interarticularis, and spinous processes were excluded.

Demographics (sex and age) and details of the injury (ISS, revised trauma score [RTS], mechanisms of injury, accompanying injuries) were reviewed from medical records. RTS is a physiological score that evaluates patients with trauma as proposed by Champion et al.[18] RTS is calculated using the Glasgow Coma Scale, systolic blood pressure, and respiratory rate, and has a range from 0 to 7.8408. The lower the score, the higher is the interpreted severity. Accompanying injuries were defined as an AIS ≥ 3 in each body region. The Ethics Committee of the hospital reviewed and approved our study (AJIRB-MED-MDB-21-586).

2.2. Propensity score matching and outcomes

Propensity score matching was performed to reduce the bias in the degree of injury between the groups with and without spinal injury so that they had similar levels of severity. Seven hundred eighty-one patients with spinal injuries were matched with those without spinal injury for ISS, RTS, and accompanying injuries. One-to-one matching was performed using a caliper width equal to 0.2 of the logit standard deviation of the propensity score.[19] Our main outcomes were the mechanisms of injury, mortality rate, cause of death, intensive care unit length of stay (ICU LOS), and duration of ventilator use. Additionally, within the spinal injury group, the mechanisms of injury and mortality according to the spinal injury location (cervical, thoracic, lumbar, multiple location) were compared. Finally, for the survivors of the spinal injury group, we investigated the kyphotic progression at the injured vertebrae. The kyphotic progression was defined as a more than 10-degree increase in sagittal index between the immediately postoperative radiographs and the radiographs at the time of discharge. In the case of conservative treatment, the radiographs at the time of hospitalization and discharge were compared.

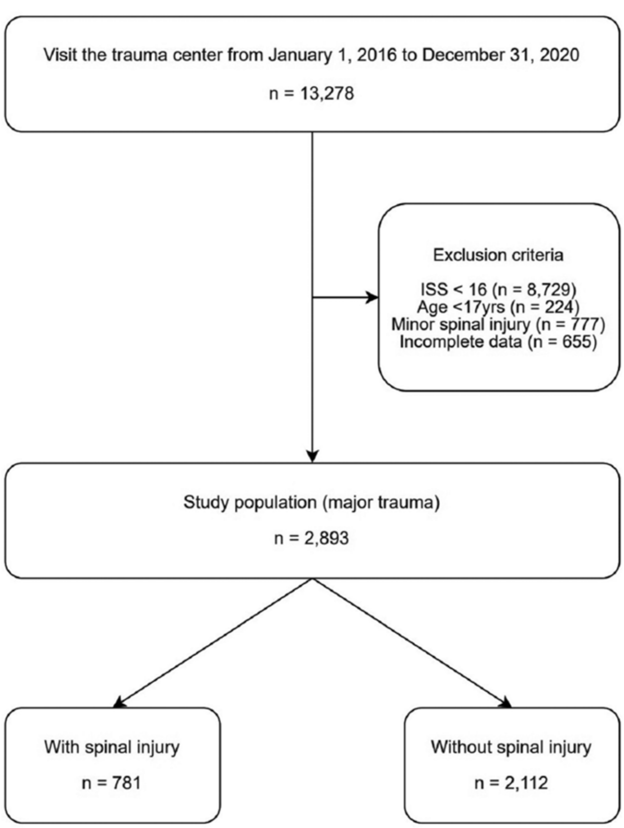

Figure 1. Patient selection criteria. ISS indicates injury severity score. ISS = injury severity score.

2.3. Statistical analysis

Descriptive statistics are presented as frequencies (percentages) for categorical variables, and as mean ± standard deviation (ranges) for continuous variables. Continuous variables were compared between the groups using the independent 2 sample *t* test; categorical variables were compared using the Chi-Squared test and Fisher exact test. Statistical analysis was performed using Statistical Package for the Social Sciences for Windows (ver. 20.0; IBM Corp., Armonk, NY). In all analyses, $P < .05$ was considered to indicate statistical significance.

3. Results

3.1. Baseline characteristics

The study population comprised 2236 men and 657 women with a mean age of 53.0 ± 17.7 years (range, 17–97). The mean ISS was 23.9 ± 8.3 (range, 16–75), whereas the mean RTS was 7.281 ± 1.069 (range, 0–7.8408). The most common mechanism of injury was traffic accident (52.0%), followed by falls (35.7%). Among the accompanying injuries, injuries to the chest region (63.2%) were the most common, followed by those to the head or neck region (45.1%) and the extremities (29.0%). The mortality rate for the entire study population was 7.7%. Before matching, there were significant differences in sex, age, ISS, RTS, mechanisms of injury, and type of accompanying injury between the groups with and without spinal injury.

3.2. Comparison of mortality and cause of death between propensity-score-matched groups

After matching, the spinal injury group and the matched cohort showed similar characteristics with respect to age, ISS, and RTS (Table 1); however, they showed a difference in the mechanisms of injury. The most common mechanism of injury in the spinal injury group was falling (51.2%) and that in the matched cohort was traffic accident (58.8%). The spinal injury group had a significantly lower mortality rate than the matched cohort (4.0% vs 7.9%, $P = .001$). The cause of death also differed between the 2 groups. In the spinal injury group, multiple organ failure (MOF) (41.9%) was the most common cause, followed by central nervous system (CNS) damage (32.3%). As for the matched cohort, CNS damage (61.3%) was the most common cause, followed by bleeding (24.2%). Furthermore, the ICU LOS was significantly longer in the spinal injury group (8.8 ± 17.4 days vs 7.2 ± 11.7 days, $P = .028$); however, the duration of ventilator use did not differ significantly between the 2 groups (4.0 ± 11.2 days vs 3.5 ± 9.0 days, $P = .428$).

Table 1

Comparison of demographics ant outcomes for spinal injury group and matched cohort.

	Spinal injury n = 781	Matched cohort n = 781	*P*
Sex, n (%)			**.019***
Male	567 (72.6)	607 (77.7)	
Female	214 (27.4)	174 (22.3)	
Age (yr)	53.8 ± 16.6	54.0 ± 18.1	.771
ISS	24.6 ± 9.6	24.5 ± 9.2	.823
RTS	7.465 ± 0.897	7.386 ± 1.035	.109
Mechanisms of injury, n (%)			**<.001***
Traffic accidents	328 (42.0)	458 (58.6)	
Falls	401 (51.2)	235 (30.1)	
Industrial accidents	43 (5.5)	71 (9.1)	
Others	9 (1.15)	17 (2.2)	
Accompanying injury, n (%)			
Head	214 (27.4)	280 (35.9)	**<.001***
Face	1 (0.1)	5 (0.6)	.218
Chest	525 (67.2)	568 (72.7)	**.018***
Abdomen	81 (10.4)	103 (13.2)	.084
Extremities	197 (25.2)	269 (34.4)	**<.001***
External	0 (0.0)	0 (0.0)	1
Mortality rate	4.0	7.9	**.001***
Cause of death, n (%)			**.005***
Central nervous system	10 (32.3)	38 (61.3)	
Bleeding	6 (19.4)	15 (24.2)	
Multiple organ failure	13 (41.9)	8 (12.9)	
Respiratory failure	0 (0.0)	0 (0.0)	
Others	2 (6.5)	1 (1.6)	
ICU LOS (d)	8.8 ± 17.4	7.2 ± 11.7	**.028***
Duration of ventilator use (d)	4.0 ± 11.2	3.5 ± 9.0	.428

ICU LOS = intensive care unit length of stay, ISS = injury severity score, RTS, revised trauma score.
Bold *: indicates $P < .05$.

Table 2

Comparison of mechanisms of injury, mortality rate, and cause of death by spinal injury location.

	C-spine	T-spine	L-spine	Multiple	*P*
N (%)	195 (25.0)	216 (27.7)	191 (24.4)	179 (22.9)	
Mechanisms of injury, n (%)					**.002***
Traffic accidents	95 (48.7)	107 (49.5)	70 (36.6)	56 (31.3)	
Falls	86 (44.1)	92 (42.6)	112 (58.6)	111 (62.0)	
Industrial accidents	11 (5.6)	13 (6.0)	9 (4.7)	10 (5.6)	
Others	3 (1.5)	4 (1.9)	0 (0.0)	2 (1.1)	
Death, n (%)	7 (3.6)	11 (5.1%)	7 (3.7%)	6 (3.4%)	.798
Cause of death, n (%)					.341
CNS	2 (28.6)	3 (27.3)	4 (57.1)	1 (16.7)	
Bleeding	0 (0)	4 (36.4)	1 (14.3)	1 (16.7)	
MOF	4 (57.1)	4 (36.4)	1 (14.3)	4 (66.7)	
Respiratory failure	0 (0.0)	0 (0)	0 (0)	0 (0)	
Others	1 (14.3)	0 (0)	1 (14.3)	0 (0)	

CNS = central nervous system, MOF = multiple organ failure.
Bold *: indicates $P < .05$.

Spinal injuries most commonly occurred in the thoracic spine (27.7%), followed by the cervical spine (25.0%), lumbar spine (24.4%), and spinal injury at multiple locations (22.9%). Cervical and thoracic spine injuries were mostly caused by traffic accidents, while lumbar spine and spinal injury at multiple locations were mainly caused by falling. There was no difference in mortality according to spinal injury locations (Table 2).

3.3. Kyphotic progression in survivors of the spinal injury group

Of the 750 survivors of the spinal injury group, 358 underwent surgery, and 392 underwent conservative treatment. The rate of progression of kyphosis was significantly lower in the group that underwent surgery than in the group that received conservative treatment (Table 3).

4. Discussion

The primary purpose of this study was to investigate the effect of spinal injury on outcomes in patients with major trauma. A cohort was matched with the spinal injury group through propensity score matching, and the differences between the 2 groups were analyzed. There were significant differences between the 2 groups in terms of mechanisms of injury, mortality rate, cause of death, and ICU LOS. However, there was no difference noted in the duration of ventilator use.

4.1. Limitations of ISS

The ISS is an anatomical index that evaluates the severity of multiple trauma and is widely used because of its high association with mortality.[12,13] However, there are some limitations to its usage. First, physiological indicators, such as blood pressure or Glasgow Coma Scale at the time of injury and individual characteristics of the patient, such as age or comorbidities, were not considered. Therefore, it is difficult to implement it in the clinical setting or to use it as a triage tool.[20] Second, the ISS only evaluates the 3 most severely damaged areas out of the 6 body regions; hence, it does not accurately reflect the severity of some injuries.[21] Moreover, even if there is bilateral damage to the extremities, it is likely underestimated because it is considered a single region injury. Finally, spinal injuries are not independently included in the ISS calculation. Cervical, thoracic, and lumbar spine injuries are calculated as head or neck, thoracic, and abdominal regions injuries, respectively.[13] Spinal injury is very common in patients with multiple trauma, and in the case of spinal cord injury (SCI), it is associated with the patient long-term prognosis.[22] Therefore, in multiple trauma patients with spinal injury, it is difficult to evaluate the prognosis or severity of cases using ISS alone.

In this study, we have shown that spinal injury is associated with mortality, so spinal injury should be included independently in the evaluation of patients with major trauma.

4.2. Mechanisms of injury

In previous epidemiologic studies on major trauma, the most common mechanism of injury was traffic accident,[8,23,24] but in epidemiological studies of spinal injuries, falling was the most common.[2,8] Similarly, even in our study, the most common mechanism of injury in the entire cohort was traffic accident, and falling was the most common in the spinal injury group. According to the spinal injury location, traffic accidents were the most common cause for cervical and thoracic spine injuries, while falls were the most common cause for lumbar and spinal injury at multiple locations. These differences could be explained by different biomechanical environments. Structurally, the cervical or thoracic spine has relatively weak muscle support and is therefore vulnerable to acceleration/deceleration forces; thus, it is highly likely to be damaged in a high-speed traffic accident. On the other hand, although the thoracolumbar junction or lumbar spine is well protected

Table 3

Kyphotic progression of survivors after spinal injuries upon discharge.

	Operation n = 358	Conservative care n = 392	P
Kyphotic progression, n (%)			**.002***
None	350 (97.8)	364 (92.9)	
Progression	8 (2.2)	28 (7.1)	

Bold *: indicates $P < .05$.

against distraction forces due to well-developed muscles, the large weight applied to each vertebral body makes it vulnerable to compression forces, and is therefore highly likely to be damaged by a fall.[2] Although the rates of traffic accidents and falls were similar for cervical and thoracic spine injuries, the rate of falls was much higher in lumbar and spinal injury at multiple locations than that of traffic accidents, which may have affected the overall injury mechanism rate in the spinal injury group.

Therefore, in the case of trauma patients due to a fall, it is necessary to focus on the evaluation of spinal injuries, especially lumbar injuries, and the possibility of damage to multiple locations of the spine should be considered.

4.3. Mortality

The causes of death differ between the 2 groups. In the spinal injury group, MOF was the highest cause of death, and in the matched cohort, CNS damage was the highest. This result could be explained by the difference in accompanying injuries. According to the major trauma outcome study,[25] mortality was closely related to serious head injury, and the mortality rate reached 40% in the presence of an AIS score ≥4. In our study, head injuries with an AIS score ≥3 were more common in the matched cohort, and this may have resulted in more deaths from CNS damage. On the other hand, in the spinal injury group, long ICU LOS, duration of ventilator use, and SCI may have acted as risk factors for the development of MOF.

We found that the mortality rate was significantly lower in the spinal injury group than in the matched cohort (4.0% vs 7.9%, $P = .001$). A previous study by Bederman et al[26] showed similar results. They assembled a cohort of 114 patients with severe polytrauma (ISS > 15) and spinal injury, and matched them to a cohort without spinal injury. The authors reported that the mortality rate in the spinal injury cohort was lower than in the matched cohort (7.8% vs 14.2%). However, there was no statistical difference in these results, probably because of the small number of patients. These results suggest that the structure of the spine acts as a shock absorber and is effective in protecting internal organs. Interestingly, ICU LOS was significantly longer in the spinal injury group. This may have been associated with a higher number of early deaths in the matched cohort.

4.4. Kyphotic progression

Among the 750 survivors of the spinal injury group, 36 (4.8%) had progression of kyphosis. In the case of surgery for spinal injuries, the progression of kyphosis was significantly lower than that of conservative treatment (2.2% vs 7.1%, $P = .002$). This result is different from previous studies. Shen et al[27] and Knight et al[28] compared the results of surgery and conservative treatment for 80 and 22 spinal fracture patients, respectively, and reported that there was no difference in the progression of kyphosis. In our series, there would have been fewer cases of progression of kyphosis because we compared the radiographs taken immediately after surgery and the radiographs taken at the time of discharge. In other words, about 5% of patients had progression of kyphosis at the time of discharge, and it can be expected that the rate will increase when the long-term follow-up.

4.5. Strengths and limitations

The strength of this study is that it describes the effect of spinal injury on mortality in patients with major trauma by controlling other variables that may affect mortality in such patients through propensity-score matching. In particular, the difference in severity was minimized by matching the ISS and RTS, unlike a previous study that matched only the ISS.[26] Nevertheless, this study has several limitations. First, this was a retrospective single center study, hence, selection bias cannot be excluded. Especially considering that our trauma center is the largest in Korea, there may have been an overrepresentation of severely injured patients. However, it is thought that the selection bias was rather small because all patients who visited the trauma center for 5 years were included and the number was large. Second, logistic regression analysis of factors related to mortality was not performed. Further studies are needed to determine how much spinal injury affects the mortality rate of major trauma patients. However, it would be meaningful that propensity score matching was performed for a large number of 781 patients and there was a statistical difference in the mortality rate. Third, we did not include SCI and neurological deficits in this study. Due to the nature of trauma patients, there was a limit to retrospective evaluation because the study population was heterogeneous and the initial medical records were insufficient. Since SCI can have a significant impact on the quality of life after injury, additional studies are required to determine prognosis prediction and treatment strategies.

5. Conclusion

This matched cohort study provides information related to differences in epidemiology and mortality of patients with major trauma, according to the presence or absence of spinal injuries at a level 1 trauma center in Korea. The group with spinal injury had a significantly lower mortality rate than the group without spinal injury. Therefore, in patients with major trauma of similar severity, spinal injury is thought to act as a shock absorber relieving impact on internal organs. In addition, it seems necessary to independently evaluate spinal injuries in the evaluation of major trauma patients.

Author contributions

Conceptualization: KyoungWon Jung, Chang-Hoon Jeon, Hee-Woong Chung.
Data curation: KyoungWon Jung.
Formal analysis: Chang-Hoon Jeon.
Investigation: ByungHee Kang.
Methodology: ByungHee Kang, Nam-Su Chung, Chang-Hoon Jeon.
Supervision: Nam-Su Chung, Hee-Woong Chung.
Writing – original draft: Han-Dong Lee.
Writing – review & editing: Hee-Woong Chung.

References

[1] Laurer H, Maier B, El Saman A, et al. Distribution of spinal and associated injuries in multiple trauma patients. Eur J Trauma Emerg Surg. 2007;33:476–81.

[2] Leucht P, Fischer K, Muhr G, et al. Epidemiology of traumatic spine fractures. Injury. 2009;40:166–72.
[3] Saboe LA, Reid DC, Davis LA, et al. Spine trauma and associated injuries. J Trauma. 1991;31:43–8.
[4] Hebert JS, Burnham RS. The effect of polytrauma in persons with traumatic spine injury: a prospective database of spine fractures. Spine. 2000;25:55–60.
[5] Harris MB, Sethi RK. The initial assessment and management of the multiple-trauma patient with an associated spine injury. Spine. 2006;31:S9–15; discussion S36.
[6] Wang H, Zhang Y, Xiang Q, et al. Epidemiology of traumatic spinal fractures: experience from medical university–affiliated hospitals in Chongqing, China, 2001–2010. J Neurosurg Spine. 2012;17:459–68.
[7] Niemi-Nikkola V, Saijets N, Ylipoussu H, et al. Traumatic spinal injuries in Northern Finland. Spine. 2018;43:E45–51.
[8] den Ouden LP, Smits AJ, Stadhouder A, et al. Epidemiology of spinal fractures in a level one trauma center in the Netherlands: a 10 years review. Spine. 2019;44:732–9.
[9] Thompson L, Hill M, Lecky F, et al. Defining major trauma: a Delphi study. Scand J Trauma Resusc Emerg Med. 2021;29:63.
[10] Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma score and the injury severity score. J Trauma. 1987;27:370–8.
[11] Baker SP, o'Neill B, HaddonWJr, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14:187–96.
[12] Abajas Bustillo R, Amo Setién FJ, Ortego Mate MDC, et al. Predictive capability of the injury severity score versus the new injury severity score in the categorization of the severity of trauma patients: a cross-sectional observational study. Eur J Trauma Emerg Surg. 2020;46:903–11.
[13] Trunkey DD, Siegel J, Baker SP, et al. Panel: current status of trauma severity indices. J Trauma. 1983;23:185–201.
[14] Stevenson M, Segui-Gomez M, Lescohier I, et al. An overview of the injury severity score and the new injury severity score. Inj Prev. 2001;7:10–3.
[15] Thompson L, Hill M, Shaw G. Defining major trauma: a literature review. Br Paramed. 2019;4:22–30.
[16] Akbarnia BA. Pediatric spine fractures. Orthop Clin North Am. 1999;30:521–36, x.
[17] Denis F. Spinal instability as defined by the three-column spine concept in acute spinal trauma. Clin Orthop Relat Res. 1984;189:65–76.
[18] Champion HR, Sacco WJ, Copes WS, et al. A revision of the trauma score. J Trauma. 1989;29:623–9.
[19] Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. Multivariate Behav Res. 2011;46:399–424.
[20] MacKenzie EJ. Injury severity scales: overview and directions for future research. Am J Emerg Med. 1984;2:537–49.
[21] Copes WS, Champion HR, Sacco WJ, et al. Progress in characterizing anatomic injury. J Tauma. 1990;30:1200–7.
[22] Motiei-Langroudi R, Sadeghian H. Traumatic spinal cord injury: long-term motor, sensory, and urinary outcomes. Asian Spine J. 2017;11:412–8.
[23] Demetriades D, Murray J, Sinz B, et al. Epidemiology of major trauma and trauma deaths in Los Angeles County. J Am Coll Surg. 1998;187:373–83.
[24] Søreide K. Epidemiology of major trauma. Br J Surg. 2009;96:697–8.
[25] Champion HR, Copes WS, Sacco WJ, et al. The major trauma outcome study: establishing national norms for trauma care. J Trauma. 1990;30:1356–65.
[26] Bederman SS, Murnaghan O, Malempati H, et al. In-hospital mortality and surgical utilization in severely polytraumatized patients with and without spinal injury. J Trauma. 2011;71:E71–8.
[27] Shen WJ, Liu TJ, Shen YS. Nonoperative treatment versus posterior fixation for thoracolumbar junction burst fractures without neurologic deficit. Spine. 2001;26:1038–45.
[28] Knight RQ, Stornelli DP, Chan DP, et al. Comparison of operative versus nonoperative treatment of lumbar burst fractures. Clin Orthop Relat Res. 1993;293:112–21.