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ORIGINAL RESEARCH

Is early surgical intervention effective for traumatic severe cervical spinal cord injury? A retrospective study secondary publication

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Abstract

Although early surgery is known to be effective for the treatment of traumatic cervical spinal cord injury (CSCI), whether it is equally effective in severe CSCI cases remains undetermined. This study aimed to determine whether surgery within 24 h improves the neurological prognosis and reduces the complications associated with surgery for traumatic severe CSCI. The data of 42 patients with traumatic severe CSCI with American Spinal Injury Association Impairment Scale (AIS) grades A–B who underwent surgery between December 2007 and May 2018 were retrospectively reviewed. The participants were classified into early surgery (<24 h) and late surgery (>24 h) groups. Using the inverse probability of treatment weighting with propensity score adjustment for confounding factors, the AIS grades before and 1 month following surgical treatment, which were considered the primary outcomes, were compared. The secondary outcomes were the intensive care unit length of stay (ICU-LOS) and occurrence of respiratory complications and cardiac arrest. In the early surgery group (n = 32, 76%), the average time to surgery was 10.25 h (4–23 h). The inverse probability of treatment weighting analysis indicated significant differences in the neurological improvement according to the AIS grade at 1 month following surgery (odds ratio [OR]: 17.1, 95% confidence interval [Cl]: 1.9–156.7, $p = 0.012$), the ICU-LOS >7 days (OR: 0.14, 95% Cl: 0.02–0.90, $p = 0.04$), and the occurrence of respiratory complications (OR: 0.08, 95% Cl: 0.01–0.73, $p = 0.03$) and cardiac arrest (OR: 0.13, 95% Cl: 0.02–0.85, $p = 0.03$). Early surgery (within 24 h) for traumatic severe CSCI may improve the neurological prognosis and prevent a long ICU-LOS and postoperative complications.

Keywords

Cervical vertebrae; Spinal cord injury; Early surgery; Early intervention; American Spinal Injury Association Impairment Scale; Retrospective studies

1. Introduction

The optimal timing and effectiveness of surgery for traumatic cervical spinal cord injury (CSCI), particularly severe cases, is controversial. Traumatic CSCI causes neurological sequelae with lifelong disability. The primary goal of surgery is to restore neurological damage and avoid secondary damage [1–3]. Another major problem for patients with CSCI is the issue of respiratory complications. Patients with traumatic CSCI experience difficulty expelling sputum owing to respiratory muscle paralysis. Besides, patients remain in the supine position for cervical spine protection, which prevents worsening of paralysis from cervical spine instabilities, such as fractures and dislocation. Furthermore, patients experience parasympathetic dominance due to neurogenic shock, and mucus secretion in the airways is enhanced; these factors can lead to respiratory complications and asphyxiation in patients with CSCI [4]. The secondary goal of surgery is to decompress and stabilize the spine, permitting postoperative mobilization and reducing the morbidity of complications.

Several previous reports on traumatic CSCI have compared the results of early and late surgeries; however, the definitions of early surgery and the severity of CSCI remain controversial. Vaccaro *et al.* [5] analysed data from cases of CSCI with American Spinal Injury Association (ASIA) Impairment Scale (AIS) grades A–D, and observed no significant differences in the AIS grade improvements between patients who underwent early surgery (<72 h) and those who underwent late (>72 h) surgical treatment. Moreover, Yang *et al.* [6] reported that the

early surgery group (within 72 h) had a poorer neurological prognosis and higher mortality rate than the late surgery group (after 72 h) among patients with CSCI with Frankel grades A–E. On the other hand, Lubeisuki *et al*. [7] reported that surgical intervention within 36 h resulted in a significantly reduced intensive care unit (ICU) length of stay (LOS), the number of ventilator days, and the hospital LOS in patients with spinal cord injury (SCI) with Injury Severity Scale (ISS) scores ≥16. Bourassa *et al*. [1] compared patients with AIS grades A–D traumatic SCI who underwent surgery within 24 h and 24–72 h, and after 72 h following injury, and found that the shorter the time from injury to surgery, the lower the rate of pneumonia. Fehlings *et al*. [8] demonstrated that in patients with CSCI with AIS grades A–D, there was a significant improvement in the AIS grade with surgical intervention within 24 h; however, no significant differences in the rate of complications were noted. Recently, Badhiwala *et al*. [9] reported that among patients with acute spinal cord injury, those who underwent surgical decompression within 24 h of injury experienced improved AIS grade and less severe disability in the first postoperative year compared to those who underwent surgery later. Thus, although the results of early surgical intervention at various time points have been reported, few studies have focused on cases of severe CSCI for either outcome.

Thus, in the present study, we aimed to determine whether early surgical intervention within 24 h improves the neurological prognosis and reduces the rate of complications in patients with severe CSCI.

2. Methods

2.1 Patients and data collection

The study was approved by the Ethics Committee of Nara Medical University Hospital, and the requirement of informed consent was waived for all the patients enrolled in this study (approval number: 1027). This study has been reported according to the STROBE guidelines.

This study was performed at our Department of Emergency and Critical Care Medicine. We included patients with traumatic severe CSCI with AIS grade A to B as consecutive patients with traumatic spinal cord injury who underwent surgery between December 2007 and May 2018. Patients with severe head injury with an Abbreviated Injury Scale Score ≥4 and those who died within 24 h following hospital admission before the surgery were excluded. Participants were classified into an "early" surgery group comprising those who underwent surgery within 24 h and a "late" surgery group comprising those who underwent surgery after 24 h, which were retrospectively compared.

The collected patient information included age, sex, body mass index (BMI), ISS score, Glasgow Coma Scale (GCS) score, neurogenic shock status at admission, details of steroid administration, and presence of fracture and/or dislocation of the cervical spine. The primary outcomes were the AIS grade and the neurological level of injury (NLI) at 1 month following surgical treatment, whereas the secondary outcomes were the ICU-LOS and occurrence of respiratory complications and cardiac arrest during hospitalisation.

2.2 Statistical analysis

Continuous variables were compared using the Mann–Whitney *U* test, and categorical variables were compared using the Fisher's exact test. To evaluate the efficacy of early surgical intervention, logistic regression analysis with inverse probability of treatment weighting (IPTW) was performed using a propensity score [10] (PS) adjusted for age, sex, ISS score, GCS score, and neurogenic shock at admission. Odds ratios (ORs) with 95% confidence intervals (CIs) were estimated in these models. All data were analysed using the SPSS 22.0 software (The International Business Machines Corporation, Armonk, New York). All p values of <0.05 were considered statistically significant.

3. Results

3.1 Participants

The inclusion and exclusion criteria were applied to a total of 254 patients who underwent spinal surgery for traumatic SCI at our centre, and 42 patients were included in the final analysis (Fig. 1). Their average age was 66 years (19–85 y), and 34 participants (81%) were males. The early and late surgery groups comprised 32 (76%) and 10 (24%) patients with an average time to surgery from injury of 10.25 h (4–23 h) and 161.5 h (31–336 h), respectively. Thirty-five (83%) patients were classified to have AIS grade A. The NLI was C4, C5, C6, and C7 in 15 (36%), 14 (33%), 8 (19%), and 5 (12%) cases, respectively. Overall, 71% (30 cases) of the injuries were caused by falls (Table 1).

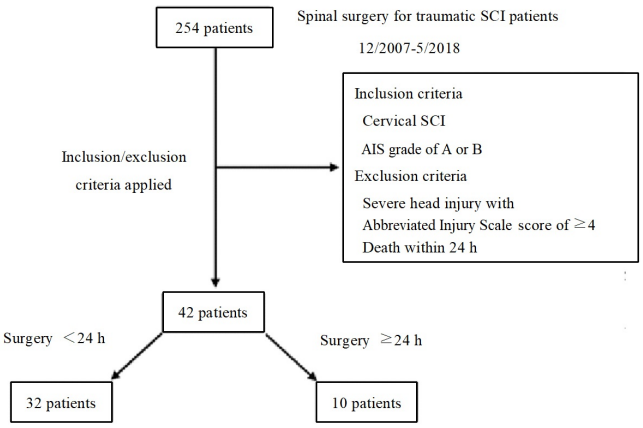

FIGURE 1. Flowchart depicting the process of patient inclusion/exclusion in the present study. AIS, American Spinal Injury Association (ASIA) Impairment Scale; SCI, spinal cord injury.

3.2 Outcomes

There was no significant difference between the early and late surgery groups based on the patient information at admission; however, the ISS score (25 vs. 29, $p = 0.08$) was lower and the GCS score (14 vs. 12, $p = 0.07$) was higher in the early surgery group than in the late surgery group. Steroids were not administered to any patient in either group (Table 1). All

TABLE 1. Patients' demographic data.

	(<24 h)	(>24 h)	*p*-value
	Early surgery group	Late surgery group	
	n = 32	n = 10	
Age	70.5 (61–75.3)	67.5 (60–74.3)	1
Male sex (%)	26 (81.3)	8 (80)	0.64
Body mass index (kg/m^2)	24.0 (21.2–25.7)	23.7 (21.7–25.2)	0.78
Glasgow Coma Scale score	15 (14–15)	14 (9.5–15)	0.07
Injury severity score	26 (25–26)	26 (25.3–28.3)	0.08
Neurological shock (%)	11.0 (34.4)	3.0 (30)	1
Fracture/dislocation (%)	26.0 (81.3)	8.0 (80)	1
Steroid administration (%)	0.0 (0)	0.0 (0)	1
Aetiology			
Fall (%)	23 (72)	7 (70)	1
Slip (%)	3 (9.4)	1 (10)	1
Road traffic accident (%)	3 (9.4)	0 (0)	1
Other (%)	3 (9.4)	2 (20)	1
AIS grade A (%)	27 (84)	8 (80)	1
Neurological level of injury			
C4 (%)	12 (38)	3 (30)	1
C5 (%)	9 (28)	5 (50)	1
C6 (%)	7 (22)	1 (10)	1
C7 (%)	4 (13)	1 (10)	1

AIS, American Spinal Injury Association (ASIA) Impairment Scale.

10 cases of delayed surgery were due to transfer of patients from other hospitals, the absence of the doctor in charge of the surgery, or unavailability of an operating room. None of the patients were unable to undergo surgery within 24 hours due to their life-threatening general condition.

In the univariate analysis, there was no significant difference between the groups in the rate of neurological improvement at 1 month following surgery, assessed as an improvement by one, two, and one or more AIS grades (p = 1, 0.17, and 0.13, respectively) and by one, two, three, and one or more NLI levels (p = 0.47, 0.31, 1, and 0.15, respectively) (Table 2). However, the ICU-LOS was significantly shorter in the early surgery group than in the late surgery group (7.4 vs. 21.4 days, p = 0.0001), and there were significant differences in the occurrence of postoperative respiratory complications (37.5% in early surgery vs. 90% in late surgery, p = 0.009) and cardiac arrest (9.4% in early surgery vs. 40% in late surgery, p = 0.04) during hospitalisation between the study groups (Table 2).

The PSs of all the patients were generated using age, sex, ISS scores, GCS scores, and neurogenic shock at admission, and an IPTW analysis using the inverse number of PSs was performed. There were significant differences between the groups in neurological improvement, as indicated by improvements of one or more AIS grades 1 month following surgery (OR: 17.1, 95% CI: 1.9–156.7, p = 0.012), the ICU-LOS >7 days (OR: 0.14, 95% CI: 0.02–0.90, p = 0.04), the occurrence of respiratory complications (OR: 0.08, 95% CI: 0.01–0.73, p = 0.03), and the occurrence of cardiac arrest (OR: 0.13, 95% CI: 0.02–0.85, p = 0.03) during hospitalisation (Table 3).

4. Discussion

The present study revealed that compared to late surgical intervention, early surgical intervention within 24 h improved the neurological outcomes and reduced the ICU-LOS and the risk of respiratory complications and cardiac arrest in patients with traumatic severe CSCI.

4.1 Improved neurological outcomes

In a large multicentre prospective cohort study, Fehlings *et al.* [8] reported significant neurological improvement with surgical intervention within 24 h in 313 patients with AIS grade A–D traumatic CSCI. Similarly, Dvorak *et al.* [11] reported that surgical intervention within 24 h significantly improved the neurological prognosis and shortened the hospital stay in 888 patients with AIS grade A–D traumatic CSCI. Following the results of these large studies, there has recently been a consensus that early surgical intervention within 24 h may improve the neurological prognosis of patients with traumatic CSCI; however, patients in these studies had AIS grades A–D, and only a few results reported were limited to severe CSCI cases. In a meta-analysis, Wengel *et al.* [12] reported that early surgery within 24 h was associated with a better neurological outcome than late surgery in patients with complete traumatic

TABLE 2. Results of univariate analysis of the outcomes of early and late surgeries.

	(<24 h)		(≥24 h)		*p*-value
	Early surgery group		Late surgery group		
	n = 32		n = 10		
AIS improvement by one or more grades	12	(37.5%)	1	(10%)	0.13
AIS improvement by one grade	5	(15.6%)	1	(10%)	1
AIS improvement by two grades	7	(21.9%)	0	(0%)	0.17
NLI improvement by one or more grades	19	(59.4%)	3	(30%)	0.15
NLI improvement by one grade	11	(34.4%)	2	(20%)	0.47
NLI improvement by two grades	6	(18.8%)	0	(0%)	0.31
NLI improvement by three grades	2	(6.3%)	1	(10%)	1
ICU-LOS (days)	7.4375		21.4		0.0001
Respiratory complications	12	(37.5%)	9	(90%)	0.01
Cardiac arrest	3	(9.4%)	4	(40%)	0.04

AIS, American Spinal Injury Association (ASIA) Impairment Scale; NLI, neurological level of injury; ICU-LOS, intensive care unit length of stay.

TABLE 3. Results of the outcomes of early and late surgeries with inverse probability of treatment weighting adjustment using the inverse number of propensity scores.

	OR	95% CI	*p*-value
Improvement in AIS by one or more grades	17.1	1.9–156.7	0.012
Respiratory complications	0.08	0.01–0.73	0.03
Cardiac arrest	0.13	0.02–0.85	0.03
ICU-LOS >7 days	0.14	0.02–0.90	0.04

OR, odds ratio; CI, confidence interval; AIS, American Spinal Injury Association (ASIA) Impairment Scale; ICU-LOS, intensive care unit length of stay.

CSCI. Consistent with the results of a previous study, the results of our study, which focused on severe cases such as AIS grade A and B, also showed an improved neurological prognosis at 1 month. Univariate analysis revealed a tendency for early surgery to improve the neurological outcomes by one or more AIS grades (p = 0.13); however, no significant difference was observed. In contrast, IPTW using a PS revealed a significant difference, and this discrepancy may be due to the small sample size of the late surgery group. This suggests that early surgical intervention is effective even in severe cases of CSCI. There have been several recent reports of surgery for CSCI performed earlier than 24 h following injury [13–15]. Jug *et al*. [13] reported that the prognosis associated with surgery within 8 h following injury was good; however, the severity of the injuries varied. Even in severe cases, such as AIS grades A and B as in our study, surgery earlier than 24 hours after injury may be beneficial. However, these factors should be considered in further studies.

4.2 Improved respiratory and cardiac outcomes and ICU-LOS

Considering the complications, McKinley *et al*. [16] demonstrated that compared to early surgical intervention, surgical intervention following 72 h increased the prevalence of respiratory complications, such as pneumonia and atelectasis, in patients with AIS grades A–D traumatic SCI in a multicentre retrospective case series. In a single-centre retrospective cohort study, Bourassa *et al*. [1] compared patients with AIS grades A–D traumatic SCI who underwent surgery within 24 h and 24–72 h, and after 72 h after injury, and found that the shorter the time from injury to surgery, the lower the rate of pneumonia. Although these studies did not elucidate the reason for the reduced rate of complications in early surgeries, it has been suggested that the duration for which the patients are in the supine position could be related to the occurrence of complications. We permitted sitting immediately following the operation since early mobilisation of patients with severe CSCI could reduce the risk of respiratory complications, as indicated in previous reports [1]. Guest *et al*. [17] found that in patients with central SCI, early surgery within 24 h following injury resulted in shorter ICU and hospital stays than surgery after 24 h. Additionally, Mac-Thiong *et al*. [18] revealed that patients with AIS grades A–D traumatic SCI in the early surgery group (within 24 h) had a significantly shorter hospital stay than patients in the late surgery group (after 24 h). In a recent meta-analysis, Qiu *et al*. [19] reported that surgery within 24 hours of injury for acute spinal cord injury was associated with fewer complications and shorter hospital stays than surgery after that time.

The results of these studies suggest that early surgery for traumatic CSCI is effective in terms of complications and length of hospital and ICU stays; however, these studies do not consider the severity of cases, in the same manner as neurological prognosis. The severity is especially important in terms of complications and hospitalisation management, and greater severity of CSCI has been reportedly associated with a higher incidence of cardiac and respiratory complications [1, 20]. Therefore, pneumonia should be prevented by frequent sputum suctioning, repositioning, and positioning the patient sitting. In addition, patients with hypotension and bradycardia require vasopressors to stabilise their hemodynamic status and need greater nursing care than patients with mild or moderate cases of CSCI. Consequently, the more severe the CSCI, the longer the ICU-LOS. Therefore, performing early surgery for neurogenic shock recovery and repositioning and ensuring a sitting position could prevent complications and reduce ICU-LOS. Based on our results, patients who underwent early surgery (within 24 h) had a reduced risk of respiratory complications, cardiac arrest, and ICU-LOS compared to patients who underwent late surgery (after 24 h), which is consistent with the results of previous studies that included AIS grade A–D [1, 7, 8]. Prevention of complications and reduction of ICU-LOS are especially important in severe cases, such as patients with AIS grades A and B. Early surgery within 24 h after injury should be considered from these perspectives and that of neurological prognosis. In terms of complications, there are few reports of surgery earlier than 24 h. In terms of complications, there are few reports of surgery earlier than 24 h. In a single-centre prospective, randomised controlled study, Cengiz *et al*. [21] compared patients with thoracolumbar SCI who underwent surgery within 8 h (early group) and at 3–15 days (late group) following injury and found that the early surgery group had a significantly shorter overall hospital and ICU stay and fewer systemic complications, such as pneumonia, than the late surgery group. In cervical spinal cord injury, surgery earlier than 24 h may be beneficial in preventing complications, and these factors should be considered in further studies.

4.3 Limitations

There are several limitations to this study. This retrospective study was non-randomised and included a small number of patients. Moreover, although the patient background data were adjusted by the IPTW method using PSs, the influence of unknown confounding factors was not considered. In addition, the possibility of conservative natural recovery from paralysis was not evaluated. Neurological evaluation was only performed for 1 month following the surgery since our centre is tertiary, and the patients were referred to another hospital for rehabilitation after 1 month following the operation. Another limitation is that the study period was approximately 10 years. In this study, no major changes were made to the drug treatment or surgical techniques; however, postoperative management has progressed over the past 10 years, and this may have affected the results. To address these limitations, future validation studies with more patients and longer observation periods are warranted.

Although there have been various reports on the effectiveness of early surgeries for traumatic CSCI, the severity of the injury varies, and only a few studies have focused on severe cases of AIS grades A and B [12]. The results of this study are highly beneficial to patients with severe CSCI since surgical interventions within 24 h following injury improved the neurological outcomes and reduced the rate of complications. Surgery within 24 h following injury may be difficult to achieve in some facilities for various reasons; however, in others, the surgeon and the other operating staff could consider surgery within 24 h, allowing sufficient time to prepare, including ordering and sterilising implants. Similarly, it allows sufficient time to inform the family of the required course of action and acquire the necessary consent to proceed with treatment. Considering these expediencies, we believe that the present findings could contribute to prompt clinical practice.

5. Conclusions

We retrospectively compared the postoperative outcomes in patients who underwent surgery for traumatic severe CSCI of AIS grade A–B within 24 h or after 24 h following injury. Early surgery within 24 h even in patients with traumatic severe CSCI such as AIS grade A–B, effectively improved the neurological prognosis and prevented a lengthy ICU stay, respiratory complications, and cardiac arrest.

ABBREVIATIONS

CSCI, cervical spinal cord injury; ASIA, American Spinal Injury Association; AIS, ASIA Impairment Scale; ICU, intensive care unit; LOS, length of stay; ISS, Injury Severity Scale; SCI, spinal cord injury; BMI, body mass index; GCS, Glasgow Coma Scale; NLI, neurological level of injury; IPTW, inverse probability of treatment weighting; PS, propensity score; OR, odds ratio; CI, confidence interval.

AUTHOR CONTRIBUTIONS

KY was responsible for designing the protocol, conducting the search, screening potentially eligible studies, extracting and analysing data, interpreting results, creating tables, creating figures, and writing the report. AO was responsible for designing the protocol, screening potentially eligible studies, extracting and analysing data, and interpreting results. NM, HK, HS, KK, and YT contributed to writing the report, extracting and analysing data, interpreting results, and providing feedback regarding the report. KM, YT, YK, KT, HA, YK, YU, and HF contributed to data extraction and provided feedback regarding the report. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Study approval and an informed consent waiver were obtained from the Ethics Committee of Nara Medical University Hospital pertaining to all patients enrolled in this study (approval number: 1027).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

The data that support this study are available from the corresponding author on reasonable request.

FOOTNOTE

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REFERENCES

[1] Bourassa-Moreau E, Mac-Thiong J, Ehrmann Feldman D, Thompson C, Parent S. Complications in acute phase hospitalization of traumatic spinal cord injury: does surgical timing matter? Journal of Trauma and Acute Care Surgery. 2013; 74: 849–854.

[2] Croce MA, Bee TK, Pritchard E, Miller PR, Fabian TC. Does optimal timing for spine fracture fixation exist? Annals of Surgery. 2001; 233: 851–858.

[3] Kerwin AJ, Griffen MM, Tepas JJ, Schinco MA, Devin T, Frykberg ER. Best practice determination of timing of spinal fracture fixation as defined by analysis of the National Trauma Data Bank. The Journal of Trauma. 2008; 65: 824–830.

[4] Berlly M, Shem K. Respiratory Management during the first Five Days after Spinal Cord Injury. The Journal of Spinal Cord Medicine. 2007; 30: 309–318.

[5] Vaccaro AR, Daugherty RJ, Sheehan TP, Dante SJ, Cotler JM, Balderston RA, *et al*. Neurologic outcome of early versus late surgery for cervical spinal cord injury. Spine. 1997; 22: 2609–2613.

[6] Liu Y, Shi CG, Wang XW, Chen HJ, Wang C, Cao P, *et al*. Timing of surgical decompression for traumatic cervical spinal cord injury. International Orthopaedics. 2015; 39: 2457–2463.

[7] Lubelski D, Tharin S, Como JJ, Steinmetz MP, Vallier H, Moore T. Surgical timing for cervical and upper thoracic injuries in patients with polytrauma. Journal of Neurosurgery. 2017; 27: 633–637.

[8] Fehlings MG, Vaccaro A, Wilson JR, Singh A, W Cadotte D, Harrop JS, *et al*. Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). PLoS ONE. 2012; 7: e32037.

[9] Badhiwala JH, Wilson JR, Witiw CD, Harrop JS, Vaccaro AR, Aarabi B, *et al*. The influence of timing of surgical decompression for acute spinal cord injury: a pooled analysis of individual patient data. The Lancet Neurology. 2021; 20: 117–126.

[10] Austin PC. Variance estimation when using inverse probability of treatment weighting (IPTW) with survival analysis. Statistics in Medicine. 2016; 35: 5642–5655.

[11] Dvorak MF, Noonan VK, Fallah N, Fisher CG, Finkelstein J, Kwon BK, *et al*. The influence of time from injury to surgery on motor recovery and length of hospital stay in acute traumatic spinal cord injury: an observational Canadian cohort study. Journal of Neurotrauma. 2015; 32: 645–654.

[12] ter Wengel PV, De Witt Hamer PC, Pauptit JC, van der Gaag NA, Oner FC, Vandertop WP. Early Surgical Decompression Improves Neurological Outcome after Complete Traumatic Cervical Spinal Cord Injury: a Meta-Analysis. Journal of Neurotrauma. 2019; 36: 835–844.

[13] Jug M, Kejžar N, Vesel M, Al Mawed S, Dobravec M, Herman S, *et al*. Neurological Recovery after Traumatic Cervical Spinal Cord Injury is Superior if Surgical Decompression and Instrumented Fusion are Performed within 8 Hours versus 8 to 24 Hours after Injury: a Single Center Experience. Journal of Neurotrauma. 2015; 32: 1385–1392.

[14] Mattiassich G, Gollwitzer M, Gaderer F, Blocher M, Osti M, Lill M, *et al*. Functional Outcomes in Individuals Undergoing very Early (<5 h) and Early (5–24 h) Surgical Decompression in Traumatic Cervical Spinal Cord Injury: Analysis of Neurological Improvement from the Austrian Spinal Cord Injury Study. Journal of Neurotrauma. 2017; 34: 3362–3371.

[15] Biglari B, Child C, Yildirim TM, Swing T, Reitzel T, Moghaddam A. Does surgical treatment within 4 hours after trauma have an influence on neurological remission in patients with acute spinal cord injury? Therapeutics and Clinical Risk Management. 2016; 12: 1339–1346.

[16] McKinley W, Meade MA, Kirshblum S, Barnard B. Outcomes of early surgical management versus late or no surgical intervention after acute spinal cord injury. Archives of Physical Medicine and Rehabilitation. 2004; 85: 1818–1825.

[17] Guest J, Eleraky MA, Apostolides PJ, Dickman CA, Sonntag VKH. Traumatic central cord syndrome: results of surgical management. Journal of Neurosurgery. 2002; 97: 25–32.

[18] Mac-Thiong J, Feldman DE, Thompson C, Bourassa-Moreau E, Parent S. Does timing of surgery affect hospitalization costs and length of stay for acute care following a traumatic spinal cord injury? Journal of Neurotrauma. 2012; 29: 2816–2822.

[19] Qiu Y, Chen Y, Xie Y, Xie H, Dong J. Comparative analysis of the efficacy of early and late surgical intervention for acute spinal cord injury: a systematic review and meta-analysis based on 16 studies. International Journal of Surgery. 2021; 94: 106098.

[20] Casha S, Christie S. Systematic Review of Intensive Cardiopulmonary Management after Spinal Cord Injury. Journal of Neurotrauma. 2011; 28: 1479–1495.

[21] Cengiz EL, Kalkan E, Bayir A, Ilik K, Basefer A. Timing of thoracolomber spine stabilization in trauma patients; impact on neurological outcome and clinical course. a real prospective (rct) randomized controlled study. Archives of Orthopaedic and Trauma Surgery. 2008; 128: 959–966.

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