

Is Early Surgical Intervention Effective for Traumatic Severe Cervical Spinal Cord Injury?

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Abstract

Background: It is unclear whether early surgery for traumatic severe cervical spinal cord injury (CSCI) improves neurological outcomes and reduces complications. This study aimed to determine whether surgery within 24 h improves the neurological prognosis of and reduces the complications associated with surgery for traumatic severe CSCI.

Methods: The data of 42 patients with traumatic severe CSCI with American Spinal Injury Association (ASIA) Impairment Scale (AIS) grades of A–B who underwent surgery between December 2007 and May 2018 were retrospectively reviewed. The participants were divided into early surgery (< 24 h) and late surgery (> 24 h) groups. With inverse probability of treatment weighting (IPTW) using a propensity score adjusted for confounding factors, we compared the AIS grade before and 1 month after surgical treatment as the primary outcome. The secondary outcome was the intensive care unit length of stay (ICU-LOS) and occurrence of respiratory complications and cardiac arrest.

Results: In the early surgery group (n = 32, 76%), the average time to surgery was 10.25 h (4–23 h). The IPTW analysis indicated significant differences in neurological improvement according to the AIS grade at 1 month after surgery (odds ratio [OR]: 17.1 95% confidence interval [CI]: 1.9–156.7, $p = 0.012$), ICU-LOS > 7 days (OR: 0.14 95% CI: 0.02–0.90, $p = 0.04$), respiratory complications (OR: 0.08 95% CI: 0.01–0.73, $p = 0.03$), and cardiac arrest (OR: 0.13 95% CI: 0.02–0.85, $p = 0.03$).

Conclusion: Early surgery (within 24 h) for traumatic severe CSCI may be effective in improving the neurological prognosis and preventing a long ICU-LOS and postoperative complications.

Background

The optimal timing of surgery for traumatic cervical spinal cord injury (CSCI), particularly severe traumatic CSCI, is controversial. Patients with traumatic severe CSCI have difficulty expelling sputum due to respiratory muscle paralysis and remain in the supine position for cervical spine protection, which prevents worsening of paralysis from cervical spine instability 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 [1]. It has also been reported that the greater the severity of CSCI, the higher the frequency of respiratory complications [2]. Moreover, in patients with severe CSCI, the development of respiratory complications affects survival prognosis, making management during hospitalization difficult. To address these issues, early surgery for decompression of the spinal cord and stabilization of the spinal column might prevent the spread of secondary damage due to CSCI [2–4]. This may improve neurological outcomes, allow early mobilization, and reduce complications.

Although several previous reports of traumatic CSCI have compared the outcome of early and late surgeries, there is no consensus regarding the definition of early surgery. Vaccaro et al. analysed data from cases of CSCI with American Spinal Injury Association (ASIA) Impairment Scale (AIS) grades A–D

and found no significant differences in AIS grade improvements in patients who underwent early (< 72 h) and late (> 72 h) surgical treatment [5]. In addition, Yang et al. reported that the neurological prognosis was poorer and mortality rate was higher in the early surgery group (within 72 h) than those in the late surgery group (after 72 h) among patients with CSCI with Frankel grades A–E [6]. Further, Lubeisuki et al. reported that surgical intervention within 36 h resulted in a significantly reduced intensive care unit (ICU) length of stay (LOS), number of ventilator days, and hospital LOS in patients with spinal cord injury (SCI) with Injury Severity Scale (ISS) scores ≥ 16 [7]. Fehlings et al. indicated that, among patients with CSCI with AIS grades A–D, there was a significant improvement in the AIS grade with surgical intervention within 24 h, but no significant differences in the rate of complications were noted [8]. Thus, various time points of early surgical intervention have been reported as optimum for achieving a satisfactory neurological prognosis and averting complications; however, few studies have focused on cases of severe CSCI.

Hence, 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.

Methods

Patients and data collection

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

This study was performed at our Department of Emergency and Critical Care Medicine. We included traumatic severe CSCI patients with AIS grades A–B who underwent surgery between December 2007 and May 2018. We excluded patients with severe head injury with an Abbreviated Injury Scale score ≥ 4 and those who died within 24 h after hospital admission before surgery. Participants were divided into an “early” surgery group that underwent surgery within 24 h and a “late” surgery group that 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 neurological level of injury (NLI) at 1 month after surgical treatment, and the secondary outcomes were the ICU-LOS, occurrence of respiratory complications and cardiac arrest during hospitalization.

Statistical analysis

Continuous variables were compared using the Mann–Whitney *U* test, and categorical variables were compared using Fisher’s exact test. To evaluate the efficacy of early surgical intervention, we performed logistic regression analysis with inverse probability of treatment weighting (IPTW), using a propensity

score [9, 10] (PS) adjusted for age, sex, ISS score, GCS score, and neurogenic shock at admission. Odds ratios (ORs) together with their 95% confidence intervals (CIs) were estimated in these models. All data were analysed using SPSS 22.0 software (The International Business Machines Corporation, Armonk, New York). All p values of < 0.05 were considered statistically significant.

Results

Participants

We applied our inclusion and exclusion criteria 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 years), and 34 (81%) were male. 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 as AIS grade A. The NLI was C4 in 15 cases (36%), C5 in 14 cases (33%), C6 in 8 cases (19%), and C7 in 5 cases (12%). Of all injuries, 30 (71%) were caused by falls (Table 1).

Table 1
Demographic data

	(< 24 h)	(> 24 h)	
	Early surgery group	Late surgery group	
	n = 32	n = 10	<i>p</i> value
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
Etiology			
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

Outcomes

There was no significant difference between the early and late surgery groups regarding patient information at admission, but 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 those in the late surgery group. Steroids were not administered to any patient in either group (Table 1). For the ten patients who underwent late surgery,

most of the delays were at the discretion of the operating surgeon and were typically due to the need to accommodate a surgeon's absence or a lack of an available operating room.

In the univariate analysis, there was no significant difference between the groups in the rate of neurological improvement at 1 month after surgery, as assessed by one, two, and one or more AIS grades ($p = 1, 0.17, \text{ and } 0.13$, respectively) and by one, two, three, and one or more NLI levels ($p = 0.47, 0.31, 1, \text{ and } 0.15$, respectively) (Table 2). However, the ICU-LOS was significantly shorter in the early surgery group than that 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 hospitalization (Table 2).

Table 2
Results of univariate analysis of the effect of early versus late surgery

	(< 24 h)		(\geq 24 h)		
	Early surgery group		Late surgery group		
	n = 32		n = 10		<i>p</i> value
Improvement in					
AIS by one or more grades	12	37.5%	1	10%	0.13
AIS by one grade	5	15.6%	1	10%	1
AIS by two grades	7	21.9%	0	0%	0.17
NLI by one or more grades	19	59.4%	3	30%	0.15
NLI by one grade	11	34.4%	2	20%	0.47
NLI by two grades	6	18.8%	0	0%	0.31
NLI 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

The PSs of all 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 at 1 month after surgery (OR: 17.1 95% CI: 1.9–156.7, $p = 0.012$), an 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 hospitalization (Table 3).

Table 3
Results of the effect of early versus late surgery with inverse probability of treatment weighting adjustment using the inverse number of propensity scores

	OR	95% CI	<i>p</i> value
Improvement of one or more AIS 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

Discussion

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

Improvement in neurological outcomes

In a large multicentre prospective cohort study, Fehlings et al. reported a significant neurological improvement after surgical intervention within 24 h in 313 patients with CSCI with AIS grades A–D [8]. Dvorak et al. also reported that surgical intervention within 24 h resulted in a significant improvement in neurological prognosis and a significantly reduced hospital stay in 888 patients with traumatic CSCI with AIS grades A–D [11]. In the present study, univariate analysis revealed no significant difference in neurological improvement defined as an improvement of one or more AIS grades, but IPTW using a PS revealed a significant difference. This discrepancy may be due to the low number of patients in the late surgery group. However, univariate analysis revealed a tendency for early surgery to improve the neurological outcomes by one or more AIS grades ($p = 0.13$). Thus, early surgical intervention within 24 h may improve the neurological outcome in patients with traumatic severe CSCI, which is consistent with previous reports [8, 11].

There have been several recent reports of surgery for CSCI performed earlier than 24 h after injury [12–14]. Jug et al. reported that the prognosis associated with surgery within 8 h after injury was good [12], but the severity of the injuries varied. For severe cases, such as AIS grades A and B, as in our study, early surgery performed < 24 h after injury may be effective. These factors should be considered in a further study.

Improvement in respiratory and cardiac outcomes and ICU-LOS

Regarding complications, McKinley et al. indicated that, compared to early surgical intervention, surgical intervention after 72 h increased the prevalence of respiratory complications such as pneumonia and atelectasis in patients with traumatic SCI in a multicentre retrospective case series [15]. In a single-centre retrospective cohort study, Bourassa et al. compared traumatic SCI patients who underwent surgery within 24 h, within 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 [2]. Although these studies did not clarify why early surgery reduced the rate of complications, it has been suggested that the duration that patients are in the supine position might be related to the occurrence of complications. We permitted sitting immediately after the operation because, as indicated in previous reports [2], early mobilization of patients with severe CSCI may reduce the risk of respiratory complications. Guest et al. found that in patients with central SCI, early surgery within 24 h after injury resulted in shorter ICU and hospital stays than surgery after 24 h [16]. Mac-Thiong et al. also revealed that patients with traumatic SCI in the early surgery group (within 24 h) had a significantly shorter hospital stay than that of patients in the late surgery group (after 24 h) [17]. According to the results of this study, not only ICU-LOS but also respiratory complications and cardiac arrest risk were all reduced in patients who underwent early surgical intervention (within 24 h) compared to those who underwent late surgical intervention (after 24 h); this is consistent with the results of past studies [2, 7, 8]. Additionally, as with neurological prognosis, a cut-off for the timing of “early” surgery in terms of complications and the length of ICU stay and hospital stay is controversial. In a single-centre prospective, randomized controlled study, Cengiz et al. compared thoracolumbar SCI patients who underwent surgery within 8 h (early group) and at 3–15 days (late group) after 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 [18]. For severe cases, such as AIS grades A and B, the prevention of complications and reduction of the ICU-LOS are paramount; thus, the efficacy of early surgery at < 24 h after injury should be considered.

Limitations

There are several limitations to this study. This was a retrospective study that was not randomized 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, we did not evaluate the possibility of conservative natural recovery of paralysis. Neurological evaluation was only performed for 1 month after surgery because our centre is tertiary, and the patients were transferred to another hospital for rehabilitation 1 month after the operation. To address these limitations, it will be necessary to involve a greater number of patients, extend the observation period, and perform validation studies in the future.

The results of this study are highly beneficial to patients with severe CSCI, as surgical intervention within 24 h after injury improved neurological outcome and reduced the rate of complications. Surgery within

24 h after injury may be difficult to achieve in some facilities for various reasons; however, in others, the surgeon and the other operating staff can be ready for surgery within 24 h, allowing sufficient time to prepare, including ordering and sterilizing implants. It is also enough time to inform the family of the required course of action and acquire the necessary consent to proceed with treatment. Given these practicalities, we believe the present findings can immediately contribute to clinical practice.

Conclusions

We retrospectively compared postoperative outcomes in patients who underwent surgery for severe traumatic CSCI within 24 h or after 24 h of the injury. Early surgery within 24 h in patients with severe traumatic CSCI was effective in improving the neurological prognosis and preventing a lengthy ICU stay, respiratory complications, and cardiac arrest.

List Of Abbreviations

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

Declarations

Ethics approval and consent to participate

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

Consent for publication

Not applicable.

Availability of data and materials

The support to this study is available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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None.

Authors' contributions

Koji Yamamoto 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. Akinori Okuda was responsible for designing the protocol, screening potentially eligible studies, and extracting and analysing data, and interpreting results. Naoki Maegawa, Hironobu Konishi, Hideki Shigematsu, Kenji Kawamura and Yasuhito Tanaka contributed to writing the report, extracting and analysing data, interpreting results, and providing feedback regarding the report. Keita Miyazaki, Yusuke Tada, Yohei Kogeichi, Keisuke Takano, Hideki Asai, Yasuyuki Kawai, Yasuyuki Urisono and Hidetada Fukushima contributed to data extraction and provided feedback regarding the report.

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Authors' information (optional)

Not applicable.

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Figures

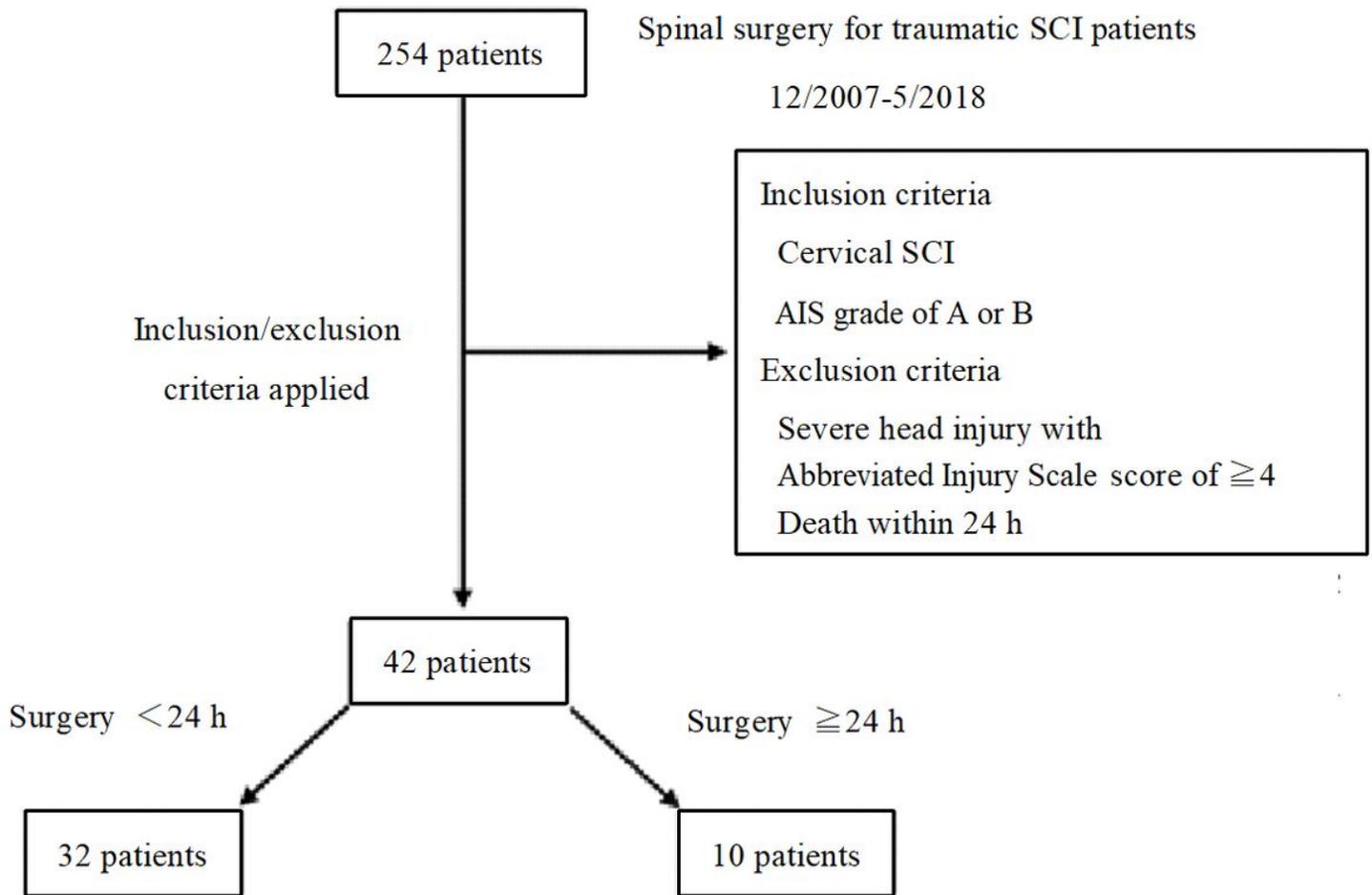


Figure 1

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