Is early surgical intervention effective for traumatic severe cervical spinal cord injury?

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Research Article

Keywords: Traumatic severe cervical spinal cord injury, early surgery, American Spinal Injury Association Impairment Scale

Posted Date: May 25th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-142432/v2

Abstract

Background

This study aimed to determine whether surgery within 24 h improves the neurological prognosis and reduces the complications associated with surgery for traumatic severe cervical spinal cord injury (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. Using inverse probability of treatment weighting (IPTW) with propensity score adjustment for confounding factors, the AIS grade before and 1 month following surgical treatment as the primary outcome were compared. 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 following 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, $p = 0.03$).

Conclusions

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 thus, 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 the survival prognosis, complicating the management during hospitalization. To address these issues, early surgery for decompression of the spinal cord and stabilisation of the spinal column could prevent secondary damage due to CSCI [2–4]. This may improve neurological outcomes, allow early mobilisation, and reduce complications.

Although several previous reports of traumatic CSCI have compared the outcome of early and late surgeries, no consensus on the definition of early surgery exists. 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 the AIS grade improvements in patients who underwent early (< 72 h) and late (> 72 h) surgical treatment [5]. Moreover, Yang et al. reported that the neurological prognosis was poorer and the 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]. Furthermore, 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. demonstrated that inpatients 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 [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.

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.

Methods

Patients and data collection

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). The study followed 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 grades A–B 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 surgery were excluded. 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 following 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 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 [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 the SPSS 22.0 software (The International Business Machines Corporation, Armonk, New York). All p values of < 0.05 were considered statistically significant.

Results

Participants

The inclusion and exclusion criteria was 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 (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, C5, C6, and C7 in 15 (36%), 14 (33%), 8 (19%), and 5 (12%) cases, respectively. Of all the injuries, 30 (71%) were caused by falls (Table 1).

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 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 commonly 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 following surgery, as assessed 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 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 hospitalisation (Table 2).

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 following 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).

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 following 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; however, 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 following injury [12–14]. Jug et al. reported that the prognosis associated with surgery within 8 h following injury was good [12]; however, 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 following injury may be effective. However, these factors should be considered in further studies.

Improvement in respiratory and cardiac outcomes and ICU-LOS

Considering the complications, McKinley et al. demonstrated 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 patients with traumatic SCI 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 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 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 following injury resulted in shorter ICU and hospital stays than surgery following 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]. Based on the results of this study, not only the ICU-LOS but also the respiratory complications and risk of cardiac arrest were 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 previous studies [2, 7, 8]. However, 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, randomised controlled study, Cengiz et al. 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 [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 following injury should be considered.

Limitations

There are several limitations to this study. This was a retrospective study that was not 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 of paralysis was not evaluated. Neurological evaluation was only performed for 1 month following the surgery since our centre is tertiary, and the patients were transferred to another hospital for rehabilitation after 1 month following the operation. To address these limitations, future validation studies with greater number of patients and longer observation periodare warranted.

The results of this study are highly beneficial to patients with severe CSCI since surgical interventions within 24 h following injury improved the neurological outcome 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 sterilizing implants. It is also 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 the present findings could contribute to prompt clinical practice.

Conclusions

We retrospectively compared the postoperative outcomes in patients who underwent surgery for severe traumatic CSCI within 24 h or following 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.

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

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 pertaining to 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 Author(s) declares that there is no conflict of interest

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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.

Acknowledgements

We would like to thank Editage (www.editage.jp) for English language editing.

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Tables

Table 1: Demographic data

	(<24 h) Early surgery group n=32	(>24 h) Late surgery group n=10	*p* 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

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

	(<24 h) Early surgery group n=32		(≥24 h) Late surgery group n=10		*p* 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

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	*p* 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

Figures

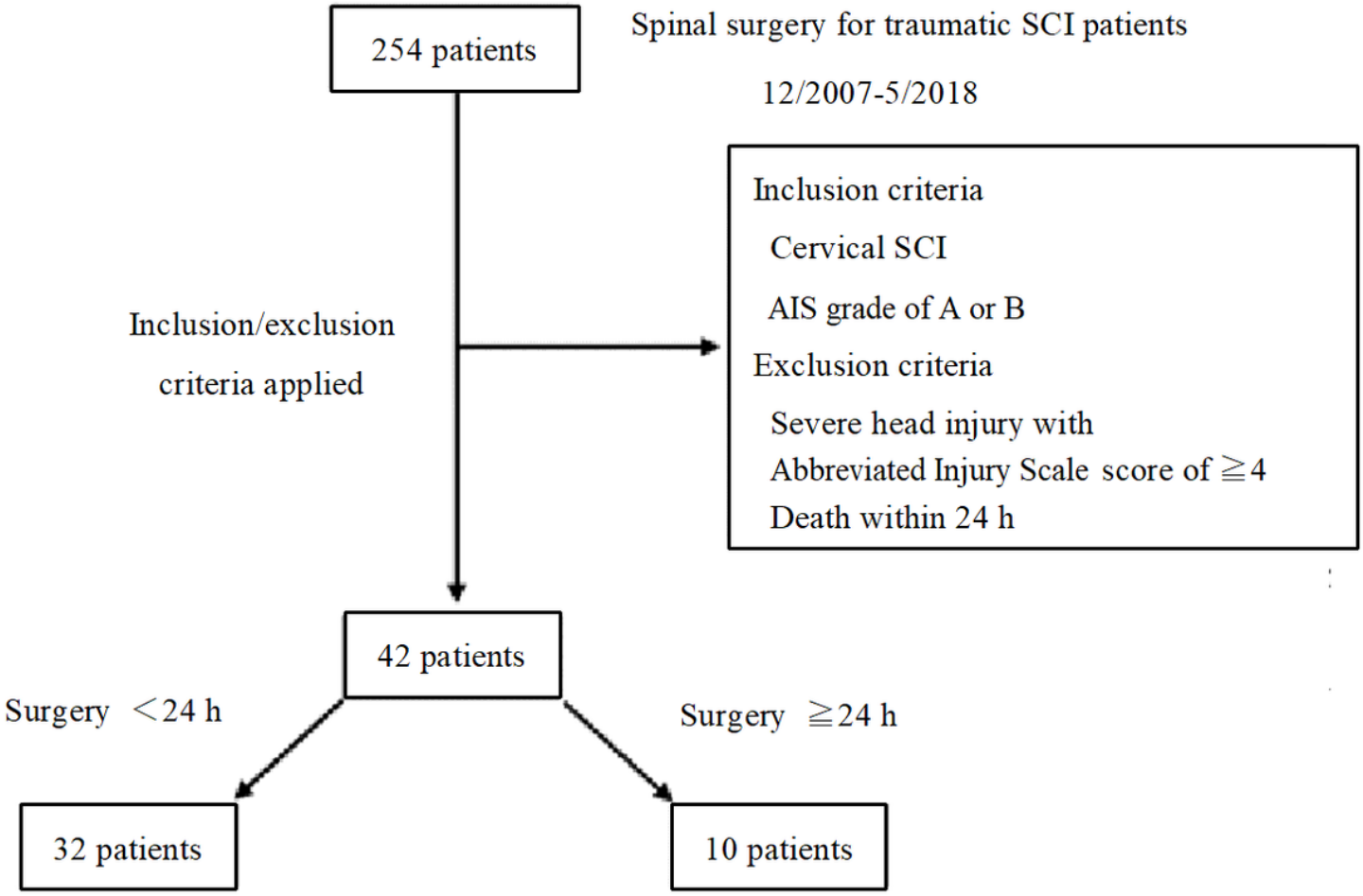

Figure 1

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