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ORIGINAL ARTICLE - SPINE TRAUMA

Early decompressive surgery in patients with traumatic spinal cord injury improves neurological outcome

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Abstract

Background The role and timing of a decompressive surgical intervention in patients with traumatic spinal cord injury (SCI) remain controversial. Given the impact of SCI on the individual and society, decompressive surgery to reduce the extent of tissue destruction and improving neurological outcome after initial spinal cord trauma are needed.

Objective To evaluate any possible correlation between the time of a decompressive procedure after traumatic SCI and end-neurologic outcome for traumatic SCI patients.

Methods A retrospective cohort study on patients with traumatic SCI in Western Denmark from 2010 to 2017. Data on date and time of injury and time of surgery and data on neurologic status at admission and one-year post-trauma were found in the Electronic Patients Journal (EPJ) and in paper journals. Patients were divided into 4 groups (< 6 h, < 12 h, < 24 h, and > 24 h) based on the time between injury and surgery. Further, patients were separated into two groups depending on whether they did or did not achieve neurological improvement one-year post-trauma. We used Fisher's exact test to compare the abovementioned groups to examine an eventual correlation between time from injury to operation and change in neurological outcome one-year post-trauma.

Results Patients undergoing surgery < 24 h after trauma obtained a significantly better neurological outcome as compared with patients who underwent surgery > 24 h after trauma ($p < 0.001$). This result did not change for subgroups of incomplete SCI patients ($p = 0.002$). However, complete SCI patients operated < 24 h as compared with > 24 h did not obtain better outcome ($p = 0.14$). We did not find a statistically significant correlation when time from trauma to surgery was reduced further to < 6 or < 12 h post-trauma. Furthermore, stratification on patients undergoing surgery before and after 24 h was made regarding gender, completeness, and years of age. The groups did not differ concerning gender and SCI completeness, but significant difference in age was found (44 and 58 years of age, respectively, $p < 0.001$). The chance of improved outcome was significantly higher for patients < 50 years of age (42% versus 24%, $p = 0.05$). Patients under the age of 50 seemed to benefit from early intervention (50% improvement versus 23%); however, difference was not statistically significant ($p = 0.08$). In patients aged above 50, the trend was similar, but significant correlation was found (40% versus 16%, $p = 0.05$).

Conclusion The present study reports a beneficial effect of early decompression surgery, especially for incomplete SCI patients; however, surgical decision-making is complex, and all cases of acute spinal cord injury should be cautiously interpreted and handled on an individual basis.

Keywords Traumatic spinal cord injury · Decompressive surgery · Early versus late

This article is part of the Topical Collection on *Spine trauma*

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Introduction

Resulting recovery after traumatic spinal cord injury (SCI) varies with the severity of the injury, and lowered odds of recovery are inversely correlated with increasing completeness of injury. A majority of improvements for the individual take place within a three-month time frame; afterwards, the window of opportunity for recovery is closing [6]. Consequences of acquired SCI are profound and perceived as catastrophic life events in a majority of individuals and their significant others. The combined motor and sensory neurological deficit in addition to the neurogenic bladder, bowel, and sexual dysfunction exerts a vast impact on quality of life [8, 10] and is closely correlated with completeness of SCI [9].

The role and the timing of a decompressive surgical intervention remain controversial [6]. Given the impact of SCI on the individual and society, procedures to reduce the extent of tissue destruction and improving the neurological outcome after initial spinal cord trauma are urgently needed. Current concepts of the pathophysiology of acute SCI indicate the existence of both primary and secondary mechanisms is playing a role for the resulting neurological damage [20].

The primary injury, usually due to rapid spinal cord compression and contusion, is supposed to induce neurogenic shock and to cause sympathetic denervation with resulting bradycardia, peripheral vasodilation, and hypotension. Hypotension leads to lowered perfusion pressure in the spinal cord and thus raises the risk of secondary injury to the spinal cord due to resulting ischemia [17, 18]. One way to reduce damage to the spinal cord is through decompression at the traumatized part of the cord and structures in its vicinity.

Earlier studies evaluated the effect of early versus delayed decompressive surgery. Most studies reported a positive correlation between early decompression and improved neurologic outcome [6, 13, 17]. Findings suggest that early surgery reduces the amount of neural tissue damage and improves long-term clinical outcome as compared with conservative treatment or delayed decompressive surgery [6, 13, 17]. Early decompression was in most studies defined as a surgical procedure undertaken earlier than 48 or 72 h [13, 16].

Yet, one of the major concerns for clinicians in traumatic SCI treatment is timing of decompressive surgery. The aim of our study was in a retrospective study to assess correlations between the timing of decompressive surgery and end-neurologic outcome for patients with complete and incomplete traumatic SCI. We hypothesized that early decompression is correlated with outcome and of importance in both complete and incomplete SCI patients.

Methods

A cohort study based on data from a retrospective file review was outlined. Patients were identified using the Western Denmark Spinal Cord Injury Database. The database contains data on every patient who received rehabilitation after traumatic SCI at the Spinal Cord Injury Centre of Western Denmark (SCIWDKB, population-based data). We included all patients with traumatic SCI from 2010 to 2017. Data on the time from injury to decompressive operation were assembled from patient files. Further, we obtained data on neurological outcome at admission to the hospital and one year after the time of injury from the SCIWDKB, from patient files.

Neurological outcome was evaluated by the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) score [1]: type A: complete SCI (No sensory or motor function is preserved in the sacral segments S4–S5), type B: motor complete injury, type C: motor function preserved in more than half of key muscles below the SCI level graded less than 3 (grade 3: active movement, full range of motion against gravity), type D: motor function preserved in half of key muscles with motor function better or equal to 3, and type E: normal function in a patient with prior SCI deficits.

Decision rules for surgery

The arguments for early versus late surgery were generally dependent on the overall status of the patient regarding other traumas requiring a more acute intervention. Further, younger patients or older patients with a high-performance status before the trauma with SCI as the primary medical problem without other injures requiring a more acute intervention were operated early. Late surgery was generally performed in patients with other traumatic problems requiring a more acute intervention. Further, patients where conservative treatment was considered did generally have a delayed surgery. Complete versus incomplete status of the SCI was in the medical charts not an indication that affects the decision about early versus late surgery.

Data and statistical analyses

Data collection and management

Data on date and the exact time and date of injury as well as the exact time of surgery were found in patient files. Patients were separated into four groups: < 6 h, < 12 h, < 24 h, and > 24 h, based on the time between injury and surgery. Further, patients were separated into two groups depending on whether they did or did not improve in the ISNCSCI score one-year post-trauma.

For subgroup analysis, patients were divided into complete (ISNCSCI score A) and incomplete (ISNCSCI scores B–D) traumatic SCI groups at admission. Analysis was based on three groups: all included SCI patients, incomplete SCI patients, and complete SCI patients depending on their ISNCSCI score at admission.

Statistical analyses

In order to evaluate a potential correlation between time from injury to surgery and neurological outcome, we used Fisher's exact test to compare time of surgery (early, < 24 h post-trauma, or late > 24 h post-trauma) with neurological outcome (improved or not improved). All confidence intervals were determined using the exact Clopper-Pearson method. A significance level of 0.05 was applied. We compared the proportion of men and complete SCI between the patients operated < 24 h post-trauma and > 24 h post-trauma using chi-square tests and age using a two-sided *t* test. To further evaluate any potential effect of age, we stratified analyses by dichotomizing age (50 years of age). *p* values were calculated using Fisher's exact test when at least one of the groups had less than 5 patients or the chi-square test when all groups had more than 5 patients.

Results

One hundred ninety-two patients were identified (Table 1). Forty-three patients were excluded due to either missing information on time of injury, trauma origin in a foreign country, cause of SCI other than trauma, or if the patient was tubed and sedated before neurological status could be obtained. Further, 20 patients were treated conservatively and excluded. One hundred twenty-six patients were enrolled.

Baseline characteristics

Early surgery (< 24 h post-trauma): 66 patients were operated before 24 h post-trauma. Of these, 24 patients (36%) were ISNCSCI B-D pre-operatively. Of these, 16 patients (67%) improved in the INSCSCI score post-operatively. Forty-two patients (64%) with INSCSCI A pre-operatively were operated before 24 h post-trauma. Of these, 20 patients (31%) improved in the INSCSCI score post-operatively.

Late surgery (> 24 h post-trauma): 62 patients were operated more than 24 h post-trauma. Of these, 31 patients (50%) were ISNCSCI B–D pre-operatively. Three of these patients (10%) improved in the INSCSCI score post-operatively. Likewise, in the complete group, 31 patients (50%) were operated more than 24 h post-trauma. Of these, 9 patients (29%) improved in INSCSCI score postoperatively.

Results of statistical analyses

Of all traumatic SCI patients, 67 had surgery performed less than 24 h post-trauma. Of these, 31 (46%) patients obtained neurological improvement. Sixty-two patients were operated more than 24 h after trauma. Of these only, 11 (17%) gained neurological improvement. The difference between the two groups was statistically significant ($p < 0.001$) (Fig. 1a.)

In a subgroup analysis, patients with incomplete and complete SCI were evaluated. Incomplete SCI had a similar significant correlation between time of trauma and time of surgery. Twenty-four incomplete patients were operated < 24 h of whom 12 patients (50%) improved. In comparison, 3 of 31 (10%) incomplete patients operated > 24 h after trauma showed improvement ($p = 0.002$) (Fig. 1b). Despite a trend towards improvement in patients with early surgery, the proportion of

Table 1 Patient demographics

Patients demographics			
Gender (male/female)	101/28 (78.2%/21.8%)		
Age at trauma (years of age; mean (min–max))	59.2 (20–80)		
ISNCSCI score	At admission	One year post-trauma	
ISNCSCI A	70 (54%)	47 (36%)	
ISNCSCI B	19 (15%)	6 (5%)	
ISNCSCI C	8 (6%)	22 (17%)	
ISNCSCI D	32 (25%)	54 (41%)	
ISNCSCI E	0 (0%)	0 (0%)	
	All patients	Incomplete patients	Complete patients
Improved (ISNCSCI)	42 (33%)	15 (27%)	27 (36%)
Not improved (ISNCSCI)	87 (67%)	40 (73%)	47 (64%)

ISNSCI the International Standards for the Neurological Classification of Spinal Cord Injury

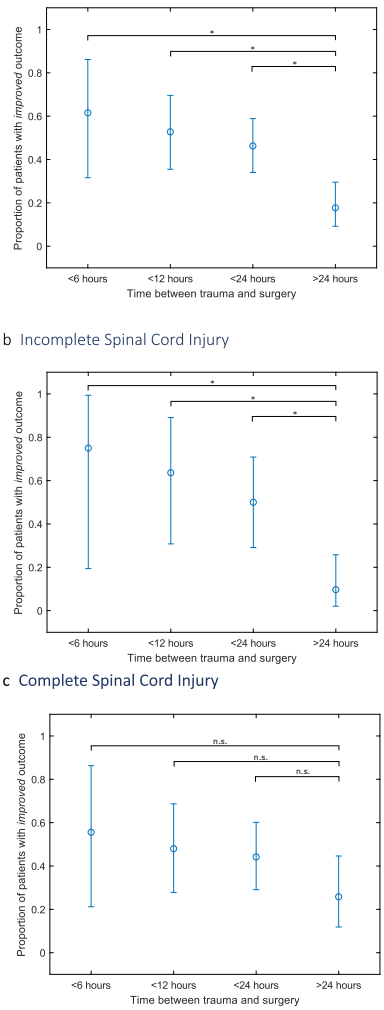

Fig. 1 Proportion of neurologically improved patients being operated after (a) < 6 h, (b) < 12 h, (c) < 24 h, and (d) ≥24 h post-trauma. **a** All patients (incomplete/complete). Thirty-one of 67 (46%) patients being operated < 24 h improved neurologically. Only 11 of 62 (17%) patients operated > 24 h improved neurologically ($p < 0.001$). **b** Incomplete spinal cord injury. Twelve of 24 (50%) incomplete patients operated < 24 h improved neurologically. Only 3 of 31 (10%) incomplete patients operated > 24 h improved ($p = 0.002$). **c** Complete spinal cord injury. Forty-three (44%) patients operated < 24 h post-trauma improved neurologically. Only 8 of 31 (25%) patients operated > 24 h improved ($p = 0.014$). n.s., not significant. * indicates significance

improved patients operated < 24 h with complete SCI was not found to be significantly higher in comparison with patients operated > 24 h post-trauma. Nineteen of 43 patients (44%) operated < 24 h after trauma improved as compared with 8 of 31 (25%) patients operated > 24 h after trauma ($p < 0.14$) (Fig. 1c).

To examine if further shortening of time between trauma and surgery had additional beneficial effect on neurological outcome, we compared the patients operated < 6 h to 6–12 h and < 12 h with patients operated 12–24 h post-trauma in all groups. All analyzed groups showed a trend towards improvement of neurological outcome with early decompression; however, none reached statistical significance. When looking at all SCI patients and comparing surgery < 6 h and 6–12 h after trauma to surgery, data did not reach statistical significance ($p = 0.20$). The same result was found for comparison of patients who underwent surgery < 12 h and 12–24 h post-trauma ($p = 0.30$). For incomplete patients, comparing < 12 compared to 12–24 h or < 6 to 12–24 ($p = 0.40$ and $p = 0.30$); for complete SCI patients trauma to surgery time < 6 compared to 12–24 h, $p = 0.40$, and < 12 compared to 12–24 h $p = 0.80$ (Fig. 1a, b, c).

For further analysis, patients undergoing surgery before and after 24 h were stratified on gender, completeness of injury, and years of age. The groups did not differ concerning gender and SCI completeness, but a statistically significant difference in age was found (44 and 58 years of age, respectively, $p < 0.001$ (Table 2)). The chance of improved outcome was significantly higher for patients < 50 years of age (42% versus 24%, $p = 0.05$). Patients under 50 years of age seemed to benefit from early intervention (50% improvement versus 23%); however, difference was not statistically significant ($p = 0.08$). In patients aged above fifty, the trend was similar, but significant (40% versus 16%, $p = 0.05$).

Discussion

This study confirms previous results indicating that early decompressive surgery improves long-term neurological outcome after traumatic SCI.

Table 2 Data stratified on surgical timing and age, gender, SCI completeness, and improvement

	Surgery < 24 h	Surgery > 24 h	*p* value
Age	44	58	< 0.001
Males (%)	76	80	0.80
Complete (%)	63	51	0.20
Improved (%)	46	18	0.002

A subgroup analysis of time from trauma to surgery did only reach statistically significant impact on incomplete SCI patients. However, data indicates a trend of improvement in the INSCSCI score for complete SCI patient group as well. Lack of significance could be due to the small sample size in subgroups.

In the literature, the commonly used timelines to define early surgical intervention after traumatic spinal injury is 24 and 72 h [5, 7]. The notion of early surgery originates from an increased understanding of secondary mechanisms of SCI deduced primarily from animals [12, 15].

Most studies find surgical intervention of SCI in humans earlier than 24 h to be associated with various positive outcomes such as reduced hospital duration, reduced intensive care unit duration, and improved neurological outcome [4, 6, 11, 13, 16]. A large multicenter prospective cohort study found odds of at least a 2-grade AIS improvement to be 2.8 times higher among those who underwent early surgery (< 24) compared with those who underwent later surgery [6]. These results are consistent with our findings.

For a more detailed analysis, we further evaluated the correlation of timing of surgery within the first 24 h. No additional reduction of trauma to surgery time did significantly correlate with improved neurological outcome. When looking at our data, a tendency towards an improvement in neurological outcome is seen when time is reduced to 6 or 12 h post-trauma. As for the subgroup analysis, the lack of statistical significance in the group of complete SCI patients might be due to the small sample size, when dividing the group of patients into even smaller groups to do the subanalyses. Shorter time from trauma to surgery (< 6 h) has previously been tested but only in animals. In animal models made on rats, surgical decompression before 6 h from trauma offered greater neurological improvement [7]. Furthermore, a different study made on dogs showed that the shorter time from trauma to decompression of the medulla, the better chances of recovery was found. They found that decompression after only 30 min of compression provided improved electrophysiological recovery, reduced histopathological lesion, and resulting improvement in behavioral recovery when compared with a decompression after 3 h of compression [2].

Other studies suggest that patients who undergo delayed surgical decompression can obtain similar outcomes as patients who received early decompressive surgery [7, 19]. No statistically significant neurologic benefit was found when spinal cord decompression after trauma was performed less than 24–72 h after injury [7]. Their findings contrast with the findings in the present study where a decompressive surgery before 24 h had significant impact.

The abovementioned studies are prospective and therefore to a lesser extent sensitive to introduction of bias as compared with our study. Timing of surgery is complex and decision-making is not one-dimensional. Surgery within 24 h from the onset of symptoms may increase the amount of surgical procedures performed during nighttime. The duration of the surgical procedure, the expertise of the performing surgeon, and the availability of neuro-anesthesiologist and expertise staff are different in the daytime setting and during late night hours, in consideration of the risk of complication, the mortality rate, and so forth [3, 14, 21]. However, concerning SCI, a previous multicenter prospective study found lowered odds of complications in early decompression surgery in comparison with later performed decompression surgery. This may indicate that complication rates do not increase when reducing trauma to surgery time [6].

We found a statistically significant difference in age with patients aged < 50 years having improved significantly more, and a significant age difference was found between the surgical groups (Table 2). This probably underlines the complexity in surgical decision-making where several factors are taken into consideration. Our results suggest that early intervention is important for all age groups, but the study did not examine the effect of performance status and other injuries. That might explain some of the difference between the stratified groups.

Limitations

Data in the present study are retrospectively collected and thereby liable to interpretation bias. Causality between time of surgery after trauma and SCI cannot be established in this study. Severely traumatized SCI patients are often unstable which could delay surgery and induce skewness in distribution of recovery effect in the groups.

Further, selection bias between our two groups cannot be ruled out. Patients likely to improve neurologically will in most cases be operated earlier than patients expected to have a bad prognosis for improvement. This could possibly overestimate the present findings as patients most likely to improve probably have been operated earlier than patients with less favorable odds for recovery.

Conclusion

The present study indicates a beneficial effect of early decompression surgery regardless of age, especially for incomplete SCI patients; however, surgical decision-making is complex, and all cases of acute spinal cord injury should be handled on an individual basis.

Author Contributions

		1. Conceived and/or designed the work that led to the submission, acquired data, and/or played an important role in interpreting the results	2. Drafted or revised the manuscript	3. Approved the final version	4. Agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved
1	Mette Haldrup	X	X	X	X
2	Ole Søndergaard Schwartz	X	X	X	X
3	Helge Kasch	X	X	X	X
4	Mikkel Mylius Rasmussen	X	X	X	X

Compliance with ethical standards

For this type of study, formal consent is not required. This article does not contain any studies with human participants performed by any of the authors.

Conflict of interest The authors declare that they have no conflict of interest.

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