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The Comparative Study of Delayed Versus Early Surgical Decompression for Traumatic Spinal Cord Injury-Experience from Northern Pakistan

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[1]Conceptualization, data collection, manuscript drafting, and overall study coordination.
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ABSTRACT

Objective: To compare the outcomes of early versus delayed surgical decompression in patients with traumatic spinal cord injury (SCI) at a tertiary care hospital.

Methodology: This randomized controlled trial conducted from August to December 2025 at Fauji Foundation Hospital, Rawalpindi. A total of 88 patients with traumatic SCI (AIS grades A–C) were enrolled and allocated to early (within 24 hours; n=44) or delayed (>24 hours; n=44) decompression groups according to the time of presentation after injury. Neurological outcome was assessed three months postoperatively using the American Spinal Injury Association (ASIA) Impairment Scale (AIS). Improvement of at least two AIS grades from baseline was considered a good neurological outcome. Outcomes were compared using the chi-square test, with $p<0.05$ considered statistically significant.

Results: Overall, 24 of 88 patients (27.3%) achieved a good neurological outcome. Good recovery was observed in 15/44 (34.1%) patients in the early decompression group compared with 9/44 (20.5%) patients in the delayed decompression group. Although neurological recovery was more frequent following early decompression, the difference was not statistically significant ($p=0.151$).

Conclusion: Early surgical decompression was associated with a higher proportion of favorable neurological recovery than delayed decompression; however, the difference was not statistically significant. A consistent trend toward better neurological outcomes was observed with early decompression across the stratified analyses.

Keywords: decompression, delayed, early, injury, outcome, spinal cord.

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Introduction

Acute traumatic spinal cord injury (SCI) constitutes a severe neurological condition, resulting in significant and frequently irreversible impairment.[1] Spinal Cord Injury (SCI) is relatively widespread, affecting 900 to 1,200 individuals per million worldwide, with considerable geographical disparities caused by road traffic accidents, falls, violence, and sports-related injuries.[2,3]

A traumatic spinal cord injury may involve several types of impairments, including motor impairments, sensory deficits, and autonomic impairment such as problems with bladder and bowel control.[4-5] Although many studies have been conducted in regard to neuroprotective therapies and regenerative therapies, very few therapeutic options have been found for acute SCI patients. The current management strategies involve blood pressure optimization, careful administration of methylprednisolone, and surgical decompression of the spinal cord. Early surgical decompression strategy is meant to relieve mechanical compression, increase spinal cord perfusion, improve oxygenation to the vulnerable neural tissue, and mitigate the secondary injury process cascade.[5-6] Despite the consistent findings of experiments, which have shown better neurological results for prompt decompression, clinical trials show inconsistent results. Although some clinical trials show

benefits of early surgical intervention in terms of neurological results, there are others that cannot prove any difference. However, early decompression is becoming recognized as a viable and safe technique in select individuals.[7] Numerous definitions of early surgery exist, ranging from surgical intervention carried out after 24 hours of the traumatic event being experienced. Even though there is a growing interest in this concept, the actual efficacy of performing decompression during this time frame is yet to be determined .[4-7]

Owing to divergent interpretations, some facilities emphasize early decompression, whereas others employ a more conservative strategy, postponing operation for days or even weeks in specific instances.[8] It has been shown that surgery during an early period has resulted in neurological recovery in some people, particularly those that are classified as having ASIA grade B to C. Some researchers have even indicated that decompression surgery carried out early on may yield better neurological outcomes independent of the location of the injury. Early surgery may be used to reduce health care costs because it would reduce the amount of time the person is hospitalized, and cost of surgery. The exact time for carrying out decompression is yet to be established due to lack of further studies on the matter.[9]

Rehabilitation from traumatic spinal cord injury through neurologic recovery is enhanced through surgical decompression during the first 24-36 hours post injury. In many studies on the subject matter, early decompression refers to decompression surgeries done within 24 hours post injury, while anything done after this time frame is termed as delayed decompression.[10] Some studies have shown that even shorter times like eight hours post injury may yield better neurological results. There are contradicting results in some studies where there was no benefit gained from early decompression in terms of neurological improvements.[11] Real-life situations pose difficulties for the timely surgical management of injuries due to various reasons, including delayed transport and lack of facilities to carry out the surgery.[10-12]

Although international evidence regarding the timing of surgical decompression continues to evolve, limited data are available from developing healthcare settings, including Pakistan, where delayed presentation and resource limitations may influence neurological outcomes. Therefore, local evidence is required to guide clinical decision-making and optimize management strategies for patients with acute traumatic SCI.

The present study was conducted to compare neurological outcomes between early and delayed surgical decompression among patients with acute traumatic SCI admitted to a tertiary care hospital in Pakistan. The findings aim to contribute regional evidence regarding the optimal timing of decompression and assist clinicians in developing evidence-based strategies to improve neurological outcomes in this patient population.

Methodology

After obtaining approval from the Institutional Review Board (IRB) of Fauji Foundation Hospital (letter number: 999/RC/FFH/RWP), this comparative study was conducted from August 2025 to December 2025 at the Department of Neurosurgery, Fauji Foundation Hospital, Rawalpindi. A total of 88 patients (44 in each group) were enrolled through non-probability consecutive sampling after obtaining written informed consent from patients or their caregivers.

The sample size was calculated using the WHO sample size calculator with a 10% level of significance and 80% power based on findings reported by Xue et al., who observed good neurological outcomes in 9.43% of patients undergoing early decompression and 1.07% in the delayed decompression group.[13]

Patients of both genders aged 18–60 years presenting with traumatic SCI involving the cervical or thoracic spine and classified as ASIA Impairment Scale (AIS) grades A to C were included. SCI diagnosis was confirmed through CT or MRI demonstrating vertebral fractures, ligamentous instability, and/or spinal cord compression.[14]

Patients with penetrating spinal injuries (gunshot or stab wounds), malignancy, cerebrospinal fluid infection, ASA grade >2, clinical or subclinical polyneuropathy, pathological fractures, cognitive impairment, or previous history of spinal column injury or SCI were excluded.

Baseline clinical history, neurological examination, and AIS grading were recorded at enrollment. Patients were categorized into early and delayed decompression groups according to the time of hospital presentation after injury. Patients presenting within 24 hours were assigned to the early decompression group, whereas those presenting after 24 hours were included in the delayed decompression group.[15]

Surgical decompression was performed by consultant neurosurgeons with at least three years of teaching experience. A standard posterior midline approach with laminectomy and spinal cord decompression was performed, with removal of compressive elements when required. Spinal stabilization was performed when indicated. Standard postoperative care was provided to all patients. Neurological outcomes were assessed three months after surgery using the ASIA Impairment Scale. Patients demonstrating improvement of at least two AIS grades from baseline were classified as having a good neurological outcome.

Data were analyzed using SPSS version 25. Quantitative variables were presented as mean ± standard deviation, while qualitative variables were presented as frequencies and percentages. Outcomes between early and delayed decompression groups were compared using the chi-square test. Stratification analysis was performed for potential effect modifiers. A p-value <0.05 was considered statistically significant.

Results

Analysis of the gathered data showed that the mean age of the study population was 39.28±12.3 years and the mean BMI was 26.40±5.38 kg/m². The study population consisted of 44 (50%) male and 44 (50%) female patients. The delayed decompression group included 25 (56.8%) females and 19 (43.2%) males, whereas the early decompression group included 19 (43.2%) females and 25 (56.8%) males. Patients were categorized according to BMI, with normal BMI observed in 36 (40.9%) patients, overweight in 27 (30.7%), and obesity in 25 (28.4%). Falls were the most common etiology of trauma, observed in 29.5% of all patients, followed by physical assault (25%), RTA (22.7%), and sports injuries (22.7%). The baseline demographic and clinical characteristics of both groups are presented in Table I.

At three months follow-up, 24 (27.3%) patients achieved good neurological outcomes based on improvement of at least two AIS grades. Among these, 15 (34.1%) patients belonged to the early decompression group, while 9 (20.5%) patients belonged to the delayed decompression group. (Figure 1)

Although a higher proportion of patients in the early decompression group achieved good neurological recovery compared with the delayed group, the difference was not statistically significant (34.1% vs. 20.5%; p = 0.151). Stratification analysis was performed to evaluate

Table I: Frequency distribution of various qualitative variables in both study arms . (n=88)

Variable	Category	Delayed n (%)	Early n (%)	Total n (%)
Gender	Female	25 (56.8)	19 (43.2)	44 (50.0)
	Male	19 (43.2)	25 (56.8)	44 (50.0)
Age Group (years)	<40 Years	23 (52.3)	21 (47.7)	44 (50.0)
	40–60	21 (47.7)	23 (52.3)	44 (50.0)
BMI Category	Normal	21 (47.7)	15 (34.1)	36 (40.9)
	Overweight	11 (25.0)	16 (36.4)	27 (30.7)
	Obese	12 (27.3)	13 (29.5)	25 (28.4)
Residential Status	Rural	23 (52.3)	21 (47.7)	44 (50.0)
	Urban	21 (47.7)	23 (52.3)	44 (50.0)
Financial Status	<50K	18 (40.9)	16 (36.4)	34 (38.6)
	50–200K	11 (25.0)	16 (36.4)	27 (30.7)
	>200K	15 (34.1)	12 (27.3)	27 (30.7)
Etiology of Trauma	Fall	15 (34.1)	11 (25.0)	26 (29.5)
	Physical Assault	8 (18.2)	14 (31.8)	22 (25.0)
	RTA	12 (27.3)	8 (18.2)	20 (22.7)
	Sports Injury	9 (20.5)	11 (25.0)	20 (22.7)
Baseline AIS	A	16 (36.4)	19 (43.2)	35 (39.8)
	B	18 (40.9)	18 (43.2)	36 (40.9)
	C	10 (22.7)	07 (13.6)	17 (19.3)
Postoperative AIS	A	12 (27.3)	11 (25.0)	23 (26.1)
	B	13 (29.5)	12 (27.3)	25 (28.4)
	C	16 (36.4)	11 (25.0)	27 (30.7)
	D	01 (2.3)	04 (9.1)	05 (5.7)
	E	02 (4.5)	06 (13.6)	08 (9.1)
Duration of Trauma (Hrs)	<12	9 (20.5)	9 (20.5)	18 (20.5)
	12–24	17 (38.6)	18 (40.9)	35 (39.8)
	>24	18 (40.9)	17 (38.6)	35 (39.8)

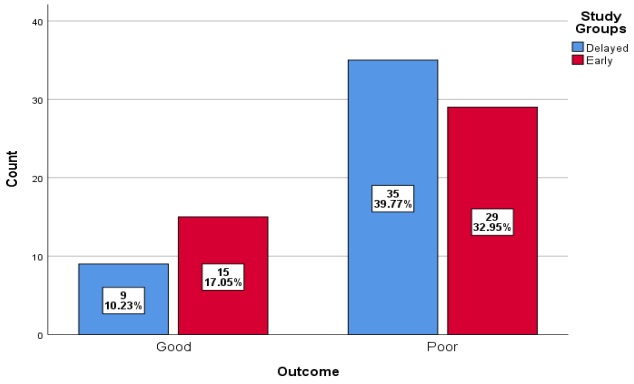


Figure 1. Comparison of outcomes among both study groups

the effect of potential confounding variables, including gender, age, BMI, residential status, financial status, and injury etiology. A higher proportion of good outcomes was observed in the early decompression group across most categories; however, none of the differences reached statistical significance. (Table II)

Table II: Stratification analysis of study outcome for various effect modifiers

Variable	Category	Good Outcome Delayed n (%)	Good Outcome Early n (%)	p-value
Gender	Female	6 (24.0)	7 (36.8)	0.355
	Male	3 (15.8)	8 (32.0)	0.219
Age Group	18–39 yrs	5 (21.7)	7 (33.3)	0.388
	40–60 yrs	4 (19.0)	8 (34.8)	0.242
BMI	Normal	4 (19.0)	5 (33.3)	0.329
	Obese	2 (16.7)	5 (38.5)	0.225
	Overweight	3 (27.3)	5 (31.3)	0.824
Residential Status	Rural	7 (30.4)	8 (38.1)	0.592
	Urban	2 (9.5)	7 (30.4)	0.086
Financial Status	<50K	5 (27.8)	7 (43.8)	0.331
	50–200K	3 (27.3)	4 (25.0)	0.895
	>200K	1 (6.7)	4 (33.3)	0.076
Etiology	Fall	4 (26.7)	1 (9.1)	0.261
	Physical Assault	0 (0.0)	5 (35.7)	0.054
	RTA	3 (25.0)	3 (37.5)	0.550
	Sports Injury	2 (22.2)	6 (54.5)	0.142

The relatively low overall rate of favorable neurological recovery may be attributed to the severity of baseline neurological impairment, as 80.7% of patients presented with AIS grade A or B injuries. Additionally, delayed presentation, injury heterogeneity, and limited sample size may have influenced the observed outcomes.

Discussion

Despite increasing evidence supporting early surgical decompression for traumatic spinal cord injury (TSCI), the optimal timing of surgery remains controversial. Previous studies have reported variable results, with some demonstrating significant neurological improvement after early decompression, while others have failed to show a statistically significant difference compared with delayed intervention.[16]

The current study involved a comparison of neurological results in early versus delayed surgical decompression among patients with acute TSCI in a tertiary healthcare institution. In our sample, 24 (27.3%) patients had good neurological results, which were characterized by an improvement in at least two AIS grades within three months. Even though good results were more common in the early decompression group than in the delayed decompression group (34.1% vs. 20.5%), this difference was not statistically significant ($p = 0.151$).[17] Similar findings were reported by Badhiwala et al., where early decompression showed a greater improvement in lower extremity motor score in unadjusted analysis (mean difference 4.3; 95% CI −0.3 to 8.8), but after adjustment for baseline LEMS, AIS grade, and propensity score, the difference decreased to 2.2 (95% CI −1.5 to 5.9) and remained non-significant. These findings suggest that baseline injury severity and other patient factors may influence the observed effect of surgical timing.[17-18]

The absence of a statistically significant difference between early and delayed decompression in our study may be influenced by several clinical and methodological factors. Baseline injury severity, particularly initial AIS grade, plays a major role in neurological recovery. In our cohort, most patients presented with severe injuries (AIS A and B), limiting the potential for improvement despite early surgery. Similar findings were reported in previous studies where, despite greater baseline neurological impairment in the early group (n=126) compared with the late group (n=100), no significant differences were observed in one-year WHOQOL-BREF outcomes, including physical (65.2 vs. 65.6, p=0.868) and psychological domains (68.0 vs. 68.6, p=0.806).[19] These findings suggest that baseline injury characteristics may influence outcomes and partly explain the lack of significant differences between groups. Furthermore, the relatively small sample size and limited number of patients achieving good recovery in our study may have reduced statistical power.[19-20]

In addition, variations in baseline parameters like time of presentation to the hospital, cause of injury, timing of surgery, postoperative rehabilitation, and supportive care can affect the recovery of neurologic deficits independent of the timing of decompression. Variation in these baseline factors among studies may explain why some large multicenter studies have shown significant advantages of early surgery, while smaller single-center studies, such as our study, have demonstrated a trend towards improvement without reaching statistical

significance. Hence, the results may be considered as an indication of a possible advantage of early decompression despite the recovery being dependent on many factors other than just the timing of surgery.[21]

Our results do not show any statistical significance; however, this does not necessarily mean that early decompression is ineffective; on the contrary, our findings demonstrate the intricacies involved in neurological recovery after TSCI. Further multicenter research with more subjects, adjusting for initial injury severity, use of uniform rehabilitation program, and follow-up is necessary to establish the impact of surgical timing. [22]

The results are consistent with the existing literature supporting the trend towards early decompression with no differences in neurologic improvement. In a meta-analysis, early surgery was associated with a decreased length of hospital stay (MD = −2.31 days; 95% CI: −4.18 to −0.43; p = 0.02) and lower incidence of postoperative complications (OR = 0.70; 95% CI: 0.55–0.89; p = 0.003); however, the early decompression group demonstrated no significant improvement in ASIA scores outcomes.[21] In ultra-early surgery patients operated within 8 hours after injury, significant improvement in ASIA outcomes (OR = 2.64; 95% CI: 1.29 -- 5.40; p = 0.008) was found. The failure to achieve statistical significance may be explained by the small number of participants in the trial, good recoveries, and severe injuries – 80.7% of our patients had AIS A or B injuries.[23-24]

Prior research has found greater advantages from early decompression. According to the STASCIS trial results, patients who underwent surgical treatment within 24 hours had significantly greater chances of having at least a two-grade AIS improvement than those operated on later. On the contrary, the trend was similar in our study, but no statistically significant results were found. The divergence of results in our study and STASCIS can be associated with various factors, such as population, number of participants, severity of injuries, medical resources, and rehabilitation facilities. STASCIS was conducted on a larger multicenter population, which gave additional statistical significance.[25]

Likewise, better neurological outcomes in patients who were treated using early decompression, with a significantly larger number of patients having at least two AIS grades improvement at 12 weeks than those who underwent late surgery. Despite the fact that our study demonstrated a greater recovery in the early treatment group, the difference was less significant and insignificant.[26] The differences might be associated with the varying characteristics of the patients' injury, presentation time and initial neurological state.[25-26] Many of our patients had very serious injuries and had a late admission to the hospital.[25-26]

Most meta-analyses have also shown evidence to suggest that early decompression could help in achieving neurological benefits. Badhiwala et al. found that patients who had surgery done in less than 24 hours showed better sensorimotor recovery, whereas various other systematic reviews have indicated that early decompression could offer some neurological benefit without the occurrence of any surgical complications. Several studies have also highlighted inconclusive evidence, especially in conditions when there is delay in presentation, absence of emergency facilities, and limited rehabilitation facilities. These results correspond with our findings wherein we got a trend favoring early decompression but it did not prove significant.[27]

Our results show an overall low percentage of neurologically favorable recovery among patients. A number of variables could explain this result. Firstly, most of the subjects had a very severe level of neurological injury, most of which were graded A or B. It has been seen that there is a higher chance of neurological recovery in incomplete injuries (C and D) than in complete injuries. Secondly, delayed presentation might have made secondary injuries like ischemia, inflammation, and apoptosis occur before decompression was done.[28]

In this study, 79.5% of the subjects came after 12 hours of trauma; thus, reducing the possibility of any neurophysiological benefit associated with early surgical procedure. Thirdly, variation in causative agents of injury such as falls, road traffic accidents (RTAs), physical assaults, and sport-related injuries could have led to the variability in injury severity. [29]

In the subgroup analysis performed in our study, there was a definite tendency towards better neurological results in favor of the early decompression group for several parameters, namely age, gender, BMI, living conditions, financial conditions, and cause of trauma. But none of these differences reached the level of statistical significance. So these results should be taken into consideration with caution. Younger patients have had somewhat higher rates of recovery which is in line with

the existing literature stating the possibility of higher neuroplasticity, lower presence of co-morbidities, and increased opportunities for rehabilitation in case of young age.[30]

The current study is an important source of local information on the time of surgery in patients with acute spinal cord injury in a tertiary center in Pakistan. Advantages of the current study include standardized neurological examination by the use of AIS scoring system, equal distribution of patients in both the groups and investigation of multiple effect modifiers. The conclusions need to be taken in consideration of certain weaknesses of the study like one center, small sample size, lack of any functional assessment tool such as SCIM and adjustment for factors like ICU care and polytrauma.

On the whole, this study findings have shown that early decompression is associated with better chances for neurological recovery than delayed surgery, but the difference is not statistically significant. We can conclude that there is a need to evaluate SCI patients in time and take appropriate actions, although we should not forget that neurological recovery depends on many other aspects as well.

LIMITATIONS: Despite the various strengths, some limitations are required to be recognised. The sample size was small so statistical power was limited. Being a single center study, the generalizability is limited. No long-term functional outcomes and rehabilitation metrics were assessed. Heterogeneity of spinal injuries and delayed presentations may have been a contributing factor to neurological recovery. Additionally, unmeasured variables like ICU care, physiotherapy intensity and associated polytrauma were not controlled.

Conclusion

Early surgical decompression in traumatic spinal cord injury showed a higher percentage of good neurological outcome as compared to delayed intervention; however, the difference was not statistically significant. Early surgery was linked to favorable trends across most of the demographic and clinical categories, based on stratification analysis; patients living in low-income were, in particular, related to a statistically significant benefit. The results indicate that early decompression can be useful in clinical situations, particularly in resource-scarce situations. However, it is important to note that the severity of the damage at baseline and time of presentation can have a major effect on neurological recovery. The effect of the timing of spinal surgery on neurological and functional outcome after traumatic spinal cord damage should be better known because of larger multicenter studies with long-term follow-up.

References

1. Lu Y, Shang Z, Zhang W, Pang M, Hu X, Dai Y, et al. Global incidence and characteristics of spinal cord injury since 2000–2021: a systematic review and meta-analysis. BMC Med. 2024;22(1):285-8. https://doi.org/10.1186/s12916-024-03514-9.
2. Afridi EAK, Naeem S, Ihsan A, Maqbool S, Shehzadi A. Incidence of acute complications associated with spinal cord injury (SCI): a study of the Ayub Teaching Hospital, Abbottabad. Pak J Neurol Surg. 2023;27(2):162-8. https://doi.org/10.36552/pjns.v27i2.853.
3. Kim M, Jeong W, Jang S, Park JH, Bae Y, Lee SW. Spinal cord injury epidemiology and causes: a worldwide analysis with 2050 projections. Healthcare (Basel). 2025;13(20):2552. https://doi.org/10.3390/healthcare13202552.
4. Wilson JR, Forgione N, Fehlings MG. Emerging therapies for acute traumatic spinal cord injury. CMAJ. 2013;185(6):485-92. https://doi.org/10.1503/cmaj.121206.
5. Ahuja CS, Wilson JR, Nori S, Kotter M, Druschel C, Curt A, et al. Traumatic spinal cord injury. Nat Rev Dis Primers. 2017;3:17018. https://doi.org/10.1038/nrdp.2017.18.
6. Tator CH, Fehlings MG. Review of the secondary injury theory of acute spinal cord trauma with emphasis on vascular mechanisms. J Neurosurg. 1991;75(1):15-26. https://doi.org/10.3171/jns.1991.75.1.0015.
7. 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. Int J Surg. 2021;91:106098. https://doi.org/10.1016/j.ijsu.2021.106098.
8. Sarfraz M, Shiren H, Shafee I, Firdous S, Ali KL. Assessment of functional independence in different levels of traumatic spinal cord injury (SCI) patients of Pakistani population: a cross-sectional survey. Pak BioMed J. 2022;5(3):106-9. https://doi.org/10.54393/pbmj.v5i3.351.
9. Yousefifard M, Hashemi B, Forouzanfar MM, Khatamian Oskooi R, Madani Neishaboori A, Jalili Khoshnoud R. Ultra-early spinal decompression surgery can improve neurological outcome of complete cervical spinal cord injury: a systematic review and meta-analysis. Arch Acad Emerg Med. 2022;10(1):e11 https://doi.org/10.22037/aaem.v10i1.1471.
10. Tanaka C, Tagami T, Kaneko J, et al. Early versus late surgery after cervical spinal cord injury: a Japanese nationwide trauma database study. J Orthop Surg Res. 2019;14:302. https://doi.org/10.1186/s13018-019-1341-4.
11. Lee DY, Park YJ, Kim HJ, Ahn HS, Hwang SC, Kim DH. Early surgical decompression within 8 hours for traumatic spinal cord injury: is it beneficial? A meta-analysis. Acta Orthop Traumatol Turc. 2018;52(2):101-8. https://doi.org/10.1016/j.aott.2017.12.001.

12. Wutte C, Becker J, Klein B, et al. Early decompression (<8 hours) improves functional bladder outcome and mobility after traumatic thoracic spinal cord injury. World Neurosurg.2020;134. https://doi.org/10.1016/j.wneu.2019.11.015.
13. Xue F, Zhan SZ, Zhang DY, Jiang BG. Early versus delayed surgery for acute traumatic cervical/thoracic spinal cord injury in Beijing, China: the results of a prospective, multicenter nonrandomized controlled trial. Orthop Surg. 2021;13(8):2246-54. https://doi.org/10.1111/os.13120.
14. van Wessem KJP, Niemeyer MJS, Leenen LPH. Polytrauma patients with severe cervical spine injuries are different than with severe traumatic brain injury despite similar AIS scores. Sci Rep. 2022;12(1):21538. https://doi.org/10.1038/s41598-022-25809-8.
15. Haghnegahdar A, Behjat R, Saadat S, Badhiwala J, Farrokhi MR, Niakan A, et al. A randomized controlled trial of early versus late surgical decompression for thoracic and thoracolumbar spinal cord injury in 73 patients. Neurotrauma Rep. 2020;1(1):78-87. https://doi.org/10.1089/neur.2020.00027.
16. Song Y, Zhu KL, Zhou CP, Zhao J, Qian S, Guo SK, et al. Association between surgical timing and neurological recovery after traumatic spinal cord injury. Eur J Med Res. 2025;30(1):1168. https://doi.org/10.1186/s40001-025-03443-0.
17. Hosman AJF, Barbagallo G; SCI-POEM Study Group; van Middendorp JJ. Neurological recovery after early versus delayed surgical decompression for acute traumatic spinal cord injury. Bone Joint J. 2023;105-B(4):400-11. https://doi.org/10.1302/0301-620X.105B4.BJJ-2022-0947.R2.
18. 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. Lancet Neurol. 2021;20(2):117-26. https://doi.org/10.1016/S1474-4422(20)30406-3.
19. Romijn P, Kussige PGP, van Hooff ML, Evaniew N, van de Meent H, van Middendorp JJ, et al. Early versus late surgical decompression in acute traumatic spinal cord injury: does it impact the quality of life? Spinal Cord. 2026;64(2):142-50. https://doi.org/10.1038/s41393-025-01165-y.
20. Aarabi B, Akhtar-Danesh N, Chryssikos T, Shanmuganathan K, Schwartzbauer GT, Simard JM, et al. Efficacy of ultra-early (<12 h), early (12-24 h), and late (>24-138.5 h) surgery with magnetic resonance imaging-confirmed decompression in American Spinal Injury Association impairment scale grades A, B, and C cervical spinal cord injury. J Neurotrauma. 2020;37(3):448-57. https://doi.org/10.1089/neu.2019.6606.
21. Fehlings MG, Hachem LD, Tetreault LA, Skelly AC, Dettori JR, Brodt ED, et al. Timing of decompressive surgery in patients with acute spinal cord injury: systematic review update. Global Spine J. 2024;14(3 Suppl):38S-57S. https://doi.org/10.1177/21925682231197404.
22. Vasquez-Paredes G, Zavaleta-Corvera C, Caballero-Alvarado J. Early versus delayed surgical decompression in spinal cord injury: a systematic review and meta-analysis. Asian J Neurosurg. 2024;20(2):199-210. https://doi.org/10.1055/s-0044-1801373.
23. Yu C, Wang J, Wang J, Wang L, Ding Y, Ji Y. Impact of ultra-early, early and delayed decompression on neurological and clinical outcomes in spinal cord injury: a systematic review and meta-analysis. J Spinal Cord Med. 2025;48(5):763-72. https://doi.org/10.1080/10790268.2025.2483074.
24. Bourassa-Moreau É, Mac-Thiong JM, Ehrmann Feldman D, Thompson C, Parent S. Complications in acute phase hospitalization of traumatic spinal cord injury: does surgical timing matter? J Trauma Acute Care Surg. 2013;74(3):849-54. https://doi.org/10.1097/TA.0b013e31827e1381.
25. Fehlings MG, Vaccaro A, Wilson JR, Singh A, Cadotte DW, 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(2). https://doi.org/10.1371/journal.pone.0032037.
26. Trung ND, Su HX, Chinh DT, Tam NC, Khanh LN, Van Nam D. Impact of early decompression surgery and injury characteristics on neurological recovery following traumatic cervical spinal cord injury. Brain Spine. 2025;5:104326. https://doi.org/10.1016/j.bas.2025.104326.
27. 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. J Neurotrauma. 2019;36(6):835-44. https://doi.org/10.1089/neu.2018.5974.
28. Stenimahitis V, Gharios M, Fletcher-Sandersjöö A, El-Hajj VG, Singh A, Buwaider A, et al. Long-term outcome and predictors of neurological recovery in cervical spinal cord injury: a population-based cohort study. Sci Rep. 2024;14(1):20945. https://doi.org/10.1038/s41598-024-71983-2.
29. Shetty S, Ahmed R, Mukherjee A, Austin WJ, Aamir M, Rasul S, et al. Effect of early surgical intervention on neurological outcomes in acute spinal cord injury: a systematic review and meta-analysis. Cureus. 2025;17(11). https://doi.org/10.7759/cureus.97164.
30. Ali G, Sajjad W, Ali MZ, Sadbar S, Khan MN, Kamran M. Early versus delayed decompression in cauda equina syndrome: neurological and functional outcomes. J Coll Physicians Surg Pak. 2025;35(11):1402-6. https://doi.org/10.29271/jcpsp.2025.11.1402.