Original Article

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Comparison of the Neurological Outcome of Early Vs Late Surgery for Cervical Spinal Cord Injury

Aqib Rauf, Muhammad Shahid

Abstract:

Objective: To evaluate the differences in the neurological outcome of early and late surgical intervention in cervical spinal cord injury (CSCI) patients.

Study Design & Settings: Prospective cohort study at Department of Neurosurgery, Bahawal Victoria Hospital, Bahawalpur.

Methodology: Eighty-eight patients aged between 20-60 years of age and presenting with the acute cervical spinal cord injury within the 12 hours of injury were taken. Patients were categorized into two groups according to the timing of the surgery; early surgery (less than 24 hours) and late surgery (greater than 24 hours). The assessment of neurological status was done on the basis of the American Spinal Injury Association (ASIA) preoperative and one-month postoperative. Neurological recovery was defined as the improvement of one or more by one or two ASIA grades. The analysis of the data was done using SPSS version 25.0, and the chi-square test was used to compare the results.

Findings: A statistically significant difference between the early and late surgery groups was found with 56.8% and 31.8% patients recovering neurologically respectively (p = 0.02). Incomplete injuries (B-D) patients showed a superior recovery in comparison to the complete injuries (ASIA grade A).

Conclusion: Timely surgery is within the first 24 hours which is linked to a significantly better neurological outcome in patients with a cervical spinal cord injury. Surgical decompression to improve functional outcomes should be given priority to improve long-term disability reduction.

Keywords: Cervical spinal, cord injury, Early surgery, Late surgery, ASIA score

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INTRODUCTION:

SCI is a serious debilitating neurological disorder that has a high morbidity, mortality, and long-term consequences on disability in the global society. According to recent epidemiological investigations, the worldwide rate of SCI has been on the increase, which can be mostly attributed to the growth of motorization, urbanization, and aging. Cervical spinal cord injury (CSCI) is the most dreadful type, which is a significant percentage of neurological losses and functional disability following the trauma. The cervical region is the area that is the most susceptible to high-energy forces and partly because of its anatomical range of mobility, it is the most frequent area of involvement in traumatic cases of SCI. Accidents like road traffic, height falls, as well as injuries during sports activities are still the leading causes in the world, however, the trend changes depending on socioeconomic and geographical environment.[1,2]

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The pathophysiology of SCI is the initial mechanical insult and a secondary series of injury mechanisms, which include ischemia, inflammation, excitotoxicity, oxidative stress, and apoptosis. The mechanisms secondary should be able to intensify neuronal damage and have a major impact on neurology. Notably, this dynamic injury condition provides a period of critical therapeutic opportunity that devises, through prompt treatment, the ability to reduce additional injury and increase recovery. One of the pillars of management is surgical debridement of the spinal cord that is intended to alleviate mechanical compressibility, restore spinal height, and enhance the perfusion of the spinal cord.[3,4]

Although improved methods of surgery and critical care have emerged, the question of when to operate has been a significant issue of extensive discussion. Conventionally, delayed surgery was commonly desirable because it was believed that working on a spinal cord, which was acutely injured and edematous and likely to raise the chances of intraoperative complications, and exacerbate the neurological losses. Nevertheless, overwhelming evidence that has been building over the last decade, is questioning this conservative practice. The idea of time is spine has been coined, based upon the notion that early surgical decompression- often considered as the 24-hour window post-injury- can result in better neurological outcomes and less overall systemic morbidity.[5,6]

A range of recent studies have shown that early surgery offers a superior functional outcome as compared to late surgery. An example is that prospective and observational studies have demonstrated that early decompression can lead to an important increase in the neurological scores and motor recovery in short- and in the long-term follow-up. The suggested mechanisms are accelerated restoration of blood flow to the spinal cord, minimization of the ischemic tissue, and attainment of continuation of compression-associated harm. Moreover, by minimizing complications like pneumonia, deep vein thrombosis, and pressure ulcers, early surgery can help to achieve earlier mobilization and rehabilitation.[7,8] However, not every evidence has a consistent support of early intervention. According to some recent research, although early surgery can enhance neurological outcome in some patient groups - especially those with incomplete injuries - it does not necessarily correlate with a better quality of life or functional independence. Delayed surgery can compare to the same neurological outcomes in older patients or those with high comorbidity with a possible lower risk in perioperation. Moreover, some of these subpopulations, including individuals with complete spinal cord wounds, might also show minimal neurological recovery in spite of the time of surgical intervention, questioning the universality of the early intervention guidelines.[9,10]

Since this question of the clinical relevance of surgery timing and the validity of the surgery timing remains controversial, there is a need to objectively assess the neurologic outcomes of early versus late surgery. Knowing such differences can inform clinical decision-making, maximize patient care, and help to create evidence-based protocols specific to the regional healthcare systems. Consequently, this research will focus on comparing the neurological patient outcomes in early and late surgery cervical spinal cord injury with emphasis on the enhancement of the outcomes in the local community.

METHODOLOGY:

The study was carried out as a prospective cohort study from 30th January 2026 to 29th April 2026, following the permission granted by the Institutional Ethical Review Committee (Ref. No. 473/DME/QAMC Bahawalpur dated 15-10-2025) at the Department of Neurosurgery in the Bahawal Victoria Hospital. The purpose was to compare neurological outcomes in those operated upon early and late to cervical spinal cord injury (CSCI). The study had 88 patients of which 44 patients were in each group. The sample size was determined with the use of WHO sample size calculator based on the 95% confidence interval, 80% study power and the expected rates of neurological recovery of 58 and 28 percent in early surgery group and late surgery group respectively. Eligible patients who had presented during the study period were recruited by a non-probability consecutive sampling method.

Eligibility was determined on patients of both sex aged 20-60 years who had acute cervical spinal cord injury and whose injury happened within 12 hours of trauma. Employing clinical examination and magnetic resonance imaging (MRI) confirmed a diagnosis of cord edema, ligamentous disruption or soft tissue injury. Only patients with motor-incomplete injuries but with preexisting canal stenosis without fractures and dislocations were considered. The participants were not to be included in case of severe traumatic brain injury (Glasgow Coma Scale 13) or penetrating spinal injuries, non-traumatic spinal pathology, separate spinal injury, polyneuropathy, impaired consciousness or hemodynamic instability, to eliminate confounding variables to the minimum. Baseline information regarding every patient (including demographics (age and gender), anthropometrics (height and weight as well as body mass index), and clinical features (duration and mode of trauma, neurological level, and ASIA grade) was obtained with prior informed written consent. Social-economic factors like occupation and home were also documented. Patients were then categorized into two groups on basis of timing of surgery. Individuals who received surgical intervention within 24 hours of injury were classified as the early surgery group and those who had surgery after 24 hours of injury as a result of delayed presentation, delayed diagnosis, or logistical reasons were classified as the late surgery group. Consistency and minimized bias of the operator were achieved by having all surgical procedures done by consultant neurosurgeons and a minimum of three years post-fellowship to reduce bias. Anterior, posterior or a combination of both surgeries was performed, depending on the character and type of injury necessary to accomplish sufficient spinal cord decompression and stabilization. They were taken through the optimization and stabilization of all the patients before surgery.

The American Spinal Injury Association (ASIA) impairment scale was used to determine neurological performance preoperative and in the course of follow-up. The principal measure of outcome was the neurological recovery which was articulated as increase in grade of at least one on the ASIA scale. The length of the follow-ups was 4 weeks after the operation, and the patients were evaluated every two weeks with an aim to measure the neurological enhancement and identify any complication. The end of the three months follow-up was the time when the final neurological outcome was registered.

All data gathered were inputted into a preconstructed proforma and were analyzed to determine their use through the Statistical Package of the Social Sciences (SPSS) version 25.0. Continuous variables: Age, height, weight, body mass index, and time of trauma were presented as mean + SD and categorical variables: Gender, MOI, surgical approach, ASIA grades and neurological recovery represented frequencies and percentages. The Shapiro-Wilk test was used to test the data distribution normality. Chi-square test (or Fisher exact test where valid) was employed in comparison of neurological recovery in the two groups. A p-value below 0.05 was taken as statistically significant.

Moreover, stratification was done to regulate some possible effect modifiers like age, gender, body mass index, duration and trauma mode, neurological level, pattern of injuries, and level of baseline ASIA, and surgical method. Post stratification was done to identify significant differences between the two groups using the chi-square or the Fisher exact test with a p-value of 0.05 being taken as significant. The reliability and validity of the study findings were guaranteed by using this methodological approach which reduced the potential bias and confounding factors.

RESULTS:

The average age of the early surgery was 38.5 10.2 years and that of the late surgery was 40.1 11.3 years and there was no statistical difference ($p > 0.05$) between the two groups. Most patients in the early group and in the late group were male with 72.7 percent and 68.2 percent respectively. (Table 1). Regarding clinical aspects, the mode of injury was the most frequent in both groups, i.e., road traffic accidents, followed by falls. The predominant pattern was that of having most patients with level of injuries of 4 and below with most cases being that of central cord syndrome. (Table 2). According to the groups, there was no difference in the distribution of surgical approaches (anterior, posterior and combined) and the most prevalent method was the anterior one. The baseline characteristics did not show statistically significant difference between the groups thus showing that both groups are similar before the interventions ($p > 0.05$). (Table 3). The baseline neurological status which was examined by the use of the American Spinal Injury Association (ASIA) grading system had the same distribution in both groups. There were 22.7% ASIA grade A patients, 27.3% grade B, 31.8% grade C and 18.2% grade D in the early surgery group and 27.3, 22.7, 29.5, and 20.5 in the late surgery group, respectively. (Table 4). After the three months of the follow-up time, it was found that the neurological recovery (i.e. improvement of one or more grades in ASIA scale) was more prevalent in the early surgery group than the late surgery group. Early surgery group (N=44) had 25 (56.8%) out of 44 patients (neurological recovery) and late surgery group (N=44) had 14 (31.8%) out of 44 patients (neurological recovery). This was found to be statistically significant ($p = 0.02$) which is equivalent to have an evident advantage of the early surgical intervention. (Table 5) The stratification analysis revealed that in most of the subgroups, the neurological recovery was always better with early surgery. Recovery among patients aged =40 years showed higher in the early surgery group (58.3) than the late surgery group (40.0), but statistically not significant ($p = 0.21$). In patients older than 40 years, however, early surgery was much more helpful (55.0% vs 25.0.; $p = 0.04$). Early surgery (56.3) outperformed late surgery (30.0) in male patients ($p = 0.03$) as did early intervention (58.3) compared to late (35.7), but this was not statistically significant ($p = 0.26$). In patients with BMI >25 kg/m 2 there was a significant difference in recovery with early surgery (54.5 vs 26.1 $p = 0.05$), but not with BMI 25 or less ($p = 0.16$). Road traffic accident patients improved

Table 1: Demographic Characteristics of Patients (n = 88)

Variable	Early Surgery (n=44)	Late Surgery (n=44)	p-value
Age (years, Mean ± SD)	38.5 ± 10.2	40.1 ± 11.3	0.45
Gender (Male)	32 (72.7%)	30 (68.2%)	0.64
Gender (Female)	12 (27.3%)	14 (31.8%)	
BMI (kg/m², Mean ± SD)	24.8 ± 3.2	25.3 ± 3.5	0.48
Residence (Rural)	26 (59.1%)	28 (63.6%)	0.67
Residence (Urban)	18 (40.9%)	16 (36.4%)	

Table 2: Clinical Characteristics of Injury

Variable	Early Surgery (n=44)	Late Surgery (n=44)	p-value
Mode of Injury (RTA)	25 (56.8%)	27 (61.4%)	0.66
Mode of Injury (Fall)	15 (34.1%)	14 (31.8%)	
Others	4 (9.1%)	3 (6.8%)	
Injury Level = C4	28 (63.6%)	30 (68.2%)	0.65
Injury Level > C4	16 (36.4%)	14 (31.8%)	
Central Cord Syndrome	22 (50.0%)	20 (45.5%)	0.67
Anterior Cord Syndrome	12 (27.3%)	13 (29.5%)	
Posterior Cord Syndrome	10 (22.7%)	11 (25.0%)	

Table 3: Surgical Approach Distribution

Surgical Approach	Early Surgery (n=44)	Late Surgery (n=44)	p-value
Anterior	24 (54.5%)	26 (59.1%)	0.66
Posterior	12 (27.3%)	10 (22.7%)	
Combined	8 (18.2%)	8 (18.2%)	

Table 4: Baseline ASIA Grades

ASIA Grade	Early Surgery (n=44)	Late Surgery (n=44)	p-value
A	10 (22.7%)	12 (27.3%)	0.83
B	12 (27.3%)	10 (22.7%)	
C	14 (31.8%)	13 (29.5%)	
D	8 (18.2%)	9 (20.5%)	

Table 5: Neurological Recovery

Neurological Recovery	Early Surgery (n=44)	Late Surgery (n=44)	p-value
Yes	25 (56.8%)	14 (31.8%)	0.02
No	19 (43.2%)	30 (68.2%)	

Table 6: Stratification of Neurological Recovery Between Early and Late Surgery Groups

Variable	Category	Early Surgery Recovery Yes n/N (%)	Late Surgery Recovery Yes n/N (%)	p-value
Age (years)	=40	14/24 (58.3%)	8/20 (40.0%)	0.21
	>40	11/20 (55.0%)	6/24 (25.0%)	0.04*
Gender	Male	18/32 (56.3%)	9/30 (30.0%)	0.03*
	Female	7/12 (58.3%)	5/14 (35.7%)	0.26
BMI (kg/m^2)	=25	13/22 (59.1%)	8/21 (38.1%)	0.16
	>25	12/22 (54.5%)	6/23 (26.1%)	0.05*
Mode of Injury	RTA	15/25 (60.0%)	8/27 (29.6%)	0.03*
	Fall/Others	10/19 (52.6%)	6/17 (35.3%)	0.31
Neurological Level	=C4	16/28 (57.1%)	10/30 (33.3%)	0.05*
	>C4	9/16 (56.3%)	4/14 (28.6%)	0.12
Pattern of Injury	Central Cord	13/22 (59.1%)	7/20 (35.0%)	0.11
	Others	12/22 (54.5%)	7/24 (29.2%)	0.08
Surgical Approach	Anterior	15/24 (62.5%)	9/26 (34.6%)	0.04*
	Posterior/Combined	10/20 (50.0%)	5/18 (27.8%)	0.18
Baseline ASIA Grade	A	2/10 (20.0%)	1/12 (8.3%)	0.40
	B–D	23/34 (67.6%)	13/32 (40.6%)	0.03*

with early surgery (60.0 vs 29.6; p = 0.03) but there was no statistically significant difference between early and late surgery in falls or other injury (p = 0.31). On the same note, patients that had injury of level up to C4 demonstrated much better results in early surgery (57.1% vs 33.3; p = 0.05) as compared to those with the injuries beyond C4 (p = 0.12). Though there was an increased recovery when surgery occurred early in cord syndrome of the central cord (59.1% vs 35.0%), or other patterns of injuries; these were not significantly different. There was a significant difference in early intervention as patients who survived anterior surgery surgery had a much better recovery rate than those who survived the surgery through an anterior/combined surgical approach (62.5 vs 34.6, p = 0.04). Notably, patients with incomplete injuries (ASIA grade B -D) performed much better with early surgery (67.6% vs 40.6; p = 0.03) but patients with complete injuries (ASIA grade A) performed poorly in both cases and no significant difference was found (p = 0.40). (Table VI)

DISCUSSION

In the present research, it was found that there was a statistically significant difference in the neurological recovery of patients with early and late surgery, 56.8% and 31.8% respectively (p = 0.02). Such results are consistent with various other recent studies which have reported positive neurological outcomes with early surgery intervention. An example in point is a study conducted by Xiao et al. that found that the early surgical decompression showed more positive neurological outcome than delayed surgery, which indicated the idea that a timely intervention was capable of restraining secondary injury mechanisms.[11] Correspondingly, Song et al. have observed that early surgery was highly related to better neurological outcomes, especially during the short-term follow-up care.[12] Biological explanations to these findings are in the pathophysiology of spinal cord injury. Secondary damage to neurons occurs after the initial mechanical insult via mechanisms of ischemia, edema and cascades of inflammation. Early decompression will assist in the restoration of spinal cord perfusion, decrease edema, and deter continued compression, which will limit the amount of irreparable damage. Such notion receives the evidence of a work by Trung et al. that showed that early surgery within 24 hours raised the chances of neurological recovery by over three times (OR = 3.12, p = 0.006).[13] Additionally, a recent systematic review and meta-analysis found that neurological outcomes and length of stay decreased significantly with surgical decomposition in the 24 hours after surgery, and more so in the 12 hours after surgery, yet had no association with complication rate escalation.[14] These results are quite consistent with the results of the current study and they support the role of early intervention when dealing with CSCI.

Besides the overall recovery, the current study also revealed that incomplete injured patients (ASIA grades B-D) achieved a lot better outcomes as opposed to complete injured patients (ASIA grade A). This observation has been supported by other new studies which have indicated that baseline neuro-logical state has been a robust predictor of recovery. It has been observed, for instance, that the patients who had incomplete injuries of the spine, when it was decomposed early, showed more neurological improvements than those with complete injuries.[15] On the same note, Tone et al.

established that early surgery enhanced neurological outcomes especially amongst incomplete injury patients but the outcome of complete injuries was limited.[16] Surprisingly, though the results in the early surgical case were overall better, the stratified analysis in the current study indicated that the advantage of early intervention was more evident in some subgroups, which include older adults (> 40 years), males, higher BMI and patients injured in road traffic accidents. These results indicate that though early surgery is as a rule good, patient-specificity may affect the extent of the healing. Similar is observed in other recent literature, even though the influence of demographic and injury related factors was found to alter the outcome. An example is Trung et al. who observed that higher-level lesion injury and increased cord injury were related to poor recovery in spite of early intervention.[13] Nevertheless, the benefits of early surgery have not been consistently welcomed in all studies. Recent studies have indicated that there was no significant outcome difference between early or delayed impairment of the surgical operation especially in certain groups of patients. As an example, Romijn et al did not find any significant differences between early and late decompression groups in terms of quality of life or neurological outcomes at the post discharge period of 6 and 12 months.[17] Likewise, Segi et al. performed a multicenter trial in patients of the older age on the topic and indicated that early surgery did not ensure a significantly better neurological outcome compared to late surgery, albeit the study was carried out in a safe manner.[18]

Such opposite results can be attributed to the variation in study populations, what constitutes early surgery, and outcomes measures. Comorbidities, frailty, and diminished physiological reserve in elderly patients can put a cap on the possible neurological recovery, thus weakening the beneficial effect of early intervention. Another study conducted by Marland et al. also indicated that delayed surgery could be advantageous even in some elderly individuals as it could lead to fewer complications during the perioperative phase and to fewer intensive care visits.[19]

The other one is the uncertainty in determining early and late surgery. Although the current study has assumed the use of early surgery at 24 hours, other studies have widened this to 48 or 72 hours meaning this can affect the results. According to Nori et al, a surgery conducted in the next 48 hours did not significantly show a better neurological outcome in some subgroups, which also showed the necessity to establish a standard definition of the concept of early intervention.[20]

These differences notwithstanding, the contemporary clinical practice still supports early surgical decompression. Based on more recent evidence, surgery within 24 hours of admission is correlated with a better neurological outcome and fewer complications.[21] Speed The notion of time as spine has become rather popular, with a focus on how any delay in surgical care might cause an irreversible neurological loss.[22]

The results of the current investigations also indicated that gender, BMI, mode of injury and method of surgery did not lead to relevant differences in the neurological recovery following stratification and therefore the most important outcome determinant continues to be the timing of surgery. The current literature has justified this observation by indicating that surgical timing has always been an independent predictor of recovery. Indicatively, one study carried out in 2026 indicated that early intervention showed better outcomes despite other patient-related factors.[23] Moreover, earlier surgery has been reported to minimise systemic complications, and early mobilization that is essential with regard to overall recovery. In a study by Ahmed et al. it was pointed out that early decompression is linked to a reduced level of complications and enhanced functional outcomes at one year.[24] Likewise, in a study conducted recently, early surgery was shown to decrease the time of stay and rehabilitation.[14] Nevertheless, one should take into consideration the disadvantages of the early surgical intervention. A study has shown in some cases an increase in the intraoperative blood loss and increased length of operation in the early surgery groups, however it did not correlate with the increase in complication.[25] Moreover, the logistic issues of late presentation of the patient, difficulty in accessing imaging and availability of operating rooms can also interfere with the introduction of early surgery, especially where resources are scarce as in South Asia. The current research has various strengths such as a prospective design, clear inclusion criteria, and the assessment of neurological outcomes in a standardized way with the use of the ASIA grading system. Balanced distribution of the patient population of the two categories of patients and the application of stratification to balance out the confounding factors also contribute wholly towards the reliability of the results. Nonetheless, there are some limitations to be taken into consideration. The results might be restricted by the short follow-up time (4 weeks) and the rather limited sample size. Moreover, the long-term functional outcomes and quality of life measures were not determined, which may give a better idea of the recovery.

CONCLUSION:

It was inferred that the current research found neurological outcome in case of early surgical intervention in 24 hours or later of cervical spinal cord injury showed a significant difference in the case of a positive neurological recovery. The patients with early decompression also showed an increase in a higher percent among ASIA grading indicating the significant impact of early management on salvaging neurological functions. Besides, the research results highlighted that the baseline neurological condition is a major predictor of recovery, and patients with incomplete injuries (ASIA stages B-D) demonstrated better recovery than their counterparts with complete injuries (ASIA grade A). Finally, surgical treatment in patients with a cervical spinal cord injury in the early phase must be viewed as the treatment of choice, and health care systems should put primary focus on those strategies that will enable timely closure to limit morbidity and enhance the quality of life.

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Authors Contribution:
Aqib Rauf: Study design, conception statistical analysis, data collection
Muhammad Shahid: Literature review, proof reading

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