Neurological Outcome of Early versus Late Surgery Following Cervical Spinal Cord Injury

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Citation

Kafle P, Chaudhary PK, Thapa J, Sharma MR. Neurological Outcome of Early versus Late Surgery Following Cervical Spinal Cord Injury. *Kathmandu Univ Med J.* 2022;77(1):74-81.

ABSTRACT

Background

There are numerous retrospective studies and a few prospective studies to determine the neurologic outcome after early versus late surgical treatment for cervical spinal cord injury.

Objective

To compare the neurological outcome between early (within 72 hours after injury) and delayed (≥ 72 hours after injury) surgery in patients with cervical spinal injury.

Method

This is a retrospective analysis of the neurological outcome of early versus late surgery following cervical spinal cord trauma. Patients meeting appropriate inclusion criteria were divided into an early or a late surgical treatment group. The neurologic outcomes and other complications were recorded up to six months of follow-up.

Result

Overall, there was a significant difference in neurological status at presentation and at follow-up ($p < 0.001$). However, there was no statistically significant difference between the early versus late surgery groups (p-value 0.261) in terms of neurological outcome. Complications were found to be higher among those undergoing posterior surgical approach (OR = 23.75; 95% CI 2.65, 212.98) than those with anterior or combined approach (p=0.005). However, multivariate analysis of these variables failed to show any statistically significant difference between the two groups.

Conclusion

The timing of surgery does not alter the neurological outcomes and the development of complications significantly. The American Spinal Cord Injury Association (ASIA) status at the time of presentation is found to be the single most important factor correlating with the neurological outcome.

KEY WORDS

American spinal cord injury association, Cervical spine, Spinal decompression, Spinal injury, Road traffic accident

INTRODUCTION

The global incidence of spinal cord injury (SCI) varies from 8 to 246 cases per million inhabitants per year. The global prevalence varied from 236.0 to 1,298.0 per million inhabitants.[1] In addition to regional differences regarding the prevalence rates of SCI across the globe, there has been a trend towards increasing prevalence rates over the last decades.[1] The cervical spine remains the most common level for SCI representing 55% of all spinal traumas and about 2.4% of blunt trauma victims.[2,3] Cervical spinal cord injury (CSCI) is a major cause of disability worldwide accounting for 43%.[4-6] These injuries are usually caused by high energy mechanisms such as road traffic accidents (RTAs), falls from heights, or extreme sports. In a large population-based study, the yearly reported incidence of CSCI was found to be up to 64/100,000 population with two peaks (one in the second and third decades of the male population and another in elderly females).[7]

Older age (> 65 years) and male sex are risk factors for an increased rate of sustaining SCI in American Spinal Cord Injury Association core A and the increased rate of major complications.[8] In these populations, the outcome is also poor with mortality reaching up to 20%.[9] Causes of SCI are different in different parts of the world depending upon age and socioeconomic status. In the rural population, fall from height is the commonest cause but overall RTAs are the leading cause of CSCIs. Road traffic and high fall accidents are typical etiology in young patients. In the elderly patients with osteoporosis, even the low fall is risk factor.[10] The most common site of injury is atlantoaxial region. The most commonly injured levels in the subaxial cervical is C6 and C7.[9] Surgical intervention is the treatment of choice in patients with neurological deficits. It can be done in two ways either anterior approach or posterior. Surgery effectively prevents further neurological deterioration. It also optimize the injured cord for the further recovery. This also helps in early mobilization with subsequent lesser risk of pneumonia and decubitus ulcer, and early return to daily activities as compared to the conservative treatment.[11,12] Conservative treatment in the form of prolonged immobilization often leads to posttraumatic instability and chronic pain.[13] Hence the conservative treatment is not recommended in an otherwise healthy patient.

There is some controversy regarding the optimal timing of surgery. In the past, many authors suggested a delayed surgical treatment to reduce postoperative complications for fear of further worsening the deficit by operation on the recently injured oedematous cord.[9,14] The time limit for early and late surgery varies in literature. Some literature suggest < 24 hours as early surgery, where as some suggest < 72 hour as early.[15,16]

After the timing of surgery, the next decision that needs to be made is the surgical approach (anterior, posterior, or combined) to decompress the spinal cord and stabilize the spine. In recent years, the anterior approach is gaining popularity.[17] It is less traumatic, can directly decompress the cord, achieves better fusion rates, and there is no need for adjacent segment fusion as in the posterior approach.[18] The disadvantages of the posterior approach are the high rates of infection, the occurrence of possible late deformity, and the inability to address the disrupted disk.[19] The posterior approach is reserved for cases of cervical fracture dislocations with locked facets and in cases with severe instability where anterior procedure alone may not be sufficient.[20]

Only a few studies have compared the outcome between patients who underwent early versus late surgery from south Asia.[21] This study aimed to describe the demographic and clinical characteristics of patients with CSCI and analyze if there was any difference in neurological outcomes in these two groups of patients.

METHODS

This is a retrospective analysis of prospectively collected data of traumatic cervical spine injury cases managed surgically at Nobel Medical College and Teaching Hospital (NMCTH), Biratnagar, Nepal from November 2017 to September 2020. Data collection was started after obtaining approval from the Institutional Review Committee of the NMCTH. Variables analyzed included demographic and clinical characteristics, admission neurological status, surgical approaches, need for postoperative ventilation, duration of hospital stay, complications, and mortality, and neurological status in 6 months.

All patients aged 18 years and above, with either neurological deficits or mechanical instability, operated for traumatic cervical spine were included. The patients with penetrating injury, documented pre-existing neurological disorders, impaired level of consciousness, and other associated life-threatening conditions were excluded from the study.

Information was collected on baseline characteristics of the study population, mechanism of injury, American Spinal Injury Association (ASIA) neurology status at presentation, in-hospital post-operative complications, and ASIA neurology status at discharge and in follow-up in 6 months. Preoperative cervical spine radio-imaging mainly X-ray ,CT-Scan and MRI along with the surgical procedure performed was recorded for each patient from the picture archiving and communication system (PACS) and the hospital medical record section. The CT angiography of neck vessels was done only when indicated. The patients were divided into two groups based on the timing of surgery: Group A) early surgery (within 72 hours of injury) and, Group B) delayed surgery after 72 hours of injury. The cut-off time for the early and delayed surgery group in the present study is different from some earlier studies. It is because most of the patients

presented after 24 hours of the event in our center and the time required for logistic arrangement before surgery. The timeline has been classified in our study as per the study by Mirza et al.[22,23] Those patient who consent for surgery were intervend before 72 hours but delayed were because of delayed consent for surgery. During the waiting period patietns were on supportive management. In the present study methyl prednisolone was not considered as a part of treatment. Cases with subluatation requiring preoperative reduction were kept on cervical traction. All the patient of cervical spine injury were kept on cervical collar by default.

Association between the groups was assessed by using the chi-square test and Fischer's exact test, while collinearity was assessed using Kendal's tau for the ordinal variables. Univariate and multivariate analyses of factors were carried out using logistic regression models. All statistical analyses were done using Statistical Statistical Package For The Social Sciences (SPSS) software (version 20; SPSS Inc., Chicago, IL, USA) and the p-value of less than 0.05 was considered statistically significant.

RESULTS

During the study period, a total of 66 cervical spine injury cases were operated. Of them, only 28 cases met the inclusion criteria and were included in the present study. They were divided into two groups based on the time of intervention as early (< 72 hours) and late (≥ 72 hours).

Baseline Characteristics of the Study Population

Age

The mean age of the study population was 42.4±14.85 ranging from 20 to 75 years. In the early surgery group, 57.1% were > 40 years whereas it was 42.9% in the late surgery group (table 1).

Sex

In the present study, there was a male preponderance comprising 85.7%of cases (table 1).

Table 1. Comparison of baseline characteristics of patients among early and delayed intervention groups

Characteristics	Age Categories	Time of intervention		Total	p-value
		Early Group A (n=21)	Delayed Group B (n=7)	Total (n=28)	
Age group	< 40 Years	9 (42.9%)	4 (57.1%)	13 (46.4%)	0.670*
	> 40 years	12 (57.1%)	3 (42.9%)	15 (53.6%)	
Sex	Male	19 (90.5%)	5 (71.4%)	24 (85.7%)	0.253*
	Female	2 (9.5%)	2 (28.6%)	4 (14.3%)	

Etiology of Injury

The most common cause of injury (60.7%) was RTA followed by fall injury (28.8%). Other causes include being hit by a falling object, physical assault, and electric injury. While comparing the cause of injury in both the groups, the RTA was the cause in 61.9% in group A and 57.1% in group B.

Associated Injuries

Nine patients (32.1%) had associated injuries. The craniofacial injury was seen in five patients followed by musculoskeletal in two patients and chest and abdominal injuries in one patient each.

Levels of Injury

Cervical spine subluxation at the level of C5-C6 was the commonest injury level in the present study followed by the C6-C7 level (fig. 1).

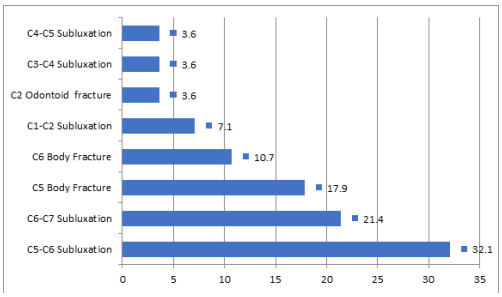

Figure 1. Bar diagram showing the level of injuries among the patients in the study:

Admission ASIA Grade

In the present study, there were more cases of ASIA-D neurology status (42.9%). Those cases with ASIA-E neurology, had no mechanical instability. So, they were managed conservatively.

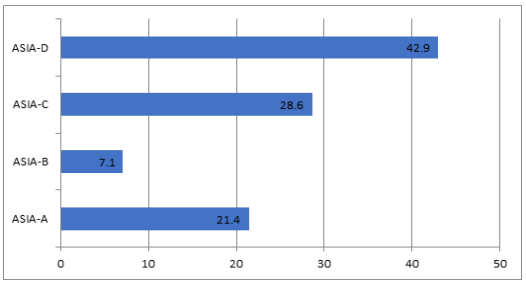

Figure 2. Bar Diagram Showing the ASIA neurology status at Presentation

Radiological Findings

In the group A, majority of patients had either cord contusion or diffuse cord edeme (85.7%). In the group B, all patient had cord contusion or diffuse cord edema on MRI. The representative CT and MRI scans are shown in figure 3.

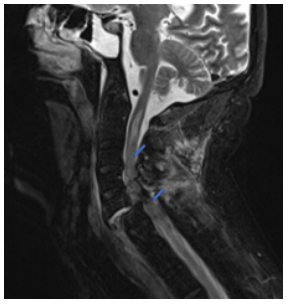

Figure 3. MRI of 35 years male with traumatic C5-C6 subluxation showing holocord contusion both proximally and distally (arrow).

Surgical Approaches

Twenty-one out of 28(75.0%) cases underwent an anterior or a combined approach. Fifteen out of 21(71.4%) cases underwent anterior approach in group A. Another patient from group A underwent a combined approach (360o). The remaining 6(28.6%) out of 21 in group A underwent a posterior approach. Simillarly, 7(14.3%) in group B also underwent posterior approach.

In the anterior approach, the anterior cervical discectomy and fusion (ACDF) was the commonest procedure performed (39.3%, n=11) followed by corpectomy and fusion of the respective level (28.6%, n=8) and one case (3.6%) had undergone odontoid screw fixation. In the posterior approach, sublaminar and interspinous wiring was the commonest procedure performed (four out of seven). Other procedures are detailed in table 2.

Table 2. Surgical procedures in patienst with cervical spine injuries

Procedure	Number(%)
ACDF*	11(39.3)
Corpectomy and Fusion	8(28.6)
Posterior C1-C2 Fusion	2(7.1)
Odontoid screw fixation	1(3.6)
Sublaminar/Interspinous wiring	4(14.3)
Posterior Pedicle/Lateral mass screw	1(3.6)
360 procedure	1(3.6)

*ACDF: AnteriorDisecetomy and Fusion

In the case of a combined approach where there was a locked facet, the initial posterior reduction was followed by anterior cervical discectomy and fusion (ACDF) and then finally posterior lateral mass screw fixation.

A representative case of C6-7 subluxation and zero profile cage placement is shown in figure 4.

Figure 4. a) X-ray of cervical spine lateral view showing C6-C7 Subluxation, b) MRI sagittal view showing spinal cord contusion at the subluxated level, c) Intraoperative picture showing titanium d) Zeroprofile cage placement after preoperative reduction and discectom

Outcome

The outcome characteristics in the present study were complications, the requirement of ventilator supports in the postoperative period for a duration other than the planned extubation in the post-operative period, duration of hospital stay, and postoperative neurological status in six months. One patient who developed fulminant pneumonia died in the postoperative period. The respiratory complication was the most common complication observed in the present study which was five out of eight. Other complications observed were surgical site infection in one, hardware failure in one, and one mortality.

Six patients out of 21(28.6%) required postoperative ventilation in group A whereas two patients out of seven(28.6%) in group B required postoperative ventilatory support.

The average duration of hospital stay in group A was 15.7 (± 5.6) whereas that for group B was 17.3(± 9.6).

Neurological Status in 6 Months

Following the surgery, there was no improvement seen in patients with ASIA-A status. However, 50% of patients in ASIA- B status cases improved to better grades. Similarly, in ASIA-C grade, 37.5% population improved to a better grade, 50% remained in the same and 12.5% deteriorated to a poor grade. Patients in different status of neurology at presentation and on follow up is shown in figure 5.

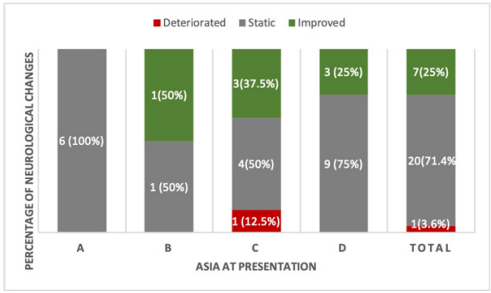

Figure 5. ASIA Neurological status at presentation and in 6 months

Co-relation between Different Variables and Neurological Status on Follow up

There was a significant difference in neurological status at presentation and at follow up which was co-related using Kendall's tau-b test (0.850) which was statistically significant (p-value < 0.001). It showed that those cases with good ASIA neurological status at presentation had better recovery. But when the neurological outcome was compared in two groups depending upon the time of intervention, there was no statistically significant difference between the two groups (p-value 0.261).

Comparison between Timing of Surgery and Postoperative Complications

Overall complications occurred in eight patients (28.6%). Among the early group, the complications were noted in six

(28.7%) patients, while in the delayed group it was seen in one (14.3%). However, the differences were not statistically significant.

Factors Associated with Complications

The presence of complications was compared with different characteristics to identify the associated factors. The variables such as age, sex, etiology, associated injuries, ASIA neurology status at presentation, surgical approach were compared with complications (table 3).

Table 3. Association of complications with different factors

Characteristics	Categories	Complications		Total	p-value
Age group	< 40 years	11 (84.6%)	2 (15.4%)	13 (100%)	0.396*
	≥ 40 years	10 (66.7%)	5 (33.3%)	15 (100%)	
Sex	Male	18 (75.0%)	6 (25.0%)	24 (100%)	1.000*
	Female	3 (75.0%)	1 (25.0%)	4 (100%)	
Cause as RTA		11 (64.7%)	6 (35.3%)	17 (100%)	0.191*
Significant associated injuries		7 (77.8%)	2 (22.2%)	9 (100%)	1.000*
ASIA Neurology at Presentation	A	1 (16.7%)	5 (83.3%)	6 (100%)	0.003*
	B	2 (100%)	0 (0.0%)	2 (100%)	
	C	7 (87.5%)	1 (12.5%)	8 (100%)	
	D	11 (91.7%)	1 (8.3%)	12 (100%)	
Surgical Approach	Anterior	18 (90.0%)	2 (10.0%)	20 (100%)	0.004*
	Posterior	2 (28.6%)	5 (71.4%)	7 (100%)	
	Combined	1 (100%)	0 (0.0%)	1 (100%)	

The univariable analysis of the factors affecting complications was done using binary simple logistic regression. The RTA was found 5.5 times likely to have complications than the non-RTA injury. Similarly, complications were 15 times more likely among ASIA-A or ASIA-B-status at presentation than those with ASIA- C or ASIA-D status at presentation, and it was statistically significant (p=0.009). Similarly, complications were found to be higher among those undergoing posterior surgical approach (OR = 23.75; 95% CI 2.65, 212.98) than those with anterior or combined approach (p=0.005) shown in table 4.

Three variables that were significant in univariate analysis were checked using multivariate logistic regression.

After adjusting the effects of other variables, complications were found to be 4.33 times likely in RTA injuries compared to non-RTA injuries. Similarly, those with ASIA A or B at presentation had 3.5 times likely to have complications than those with C or D presentation. And, those undergoing surgery by posterior approach were 13.10 times likely to have complications than those by anterior or combined approach. However, none of these variables could attain statistical significance. The adjusted odds ratios is plotted in figure 6.

Table 4. Univariate logistic regression of factors affecting complications

Characteristics	Beta-co-efficient	Odds Ratio	95% C.I. for Odds Ratio		p-value
			Lower	Upper	
Cause as RTA (Yes vs No)	1.696	5.455	0.556	53.523	0.145
ASIA neurology at presentation (ASIA-A/ASIA-B vs ASIA-C/ ASIA-D)	2.708	15.000	1.940	115.963	0.009
Surgical approach binary (Posterior Vs Anterior)	3.168	23.750	2.648	212.979	0.005

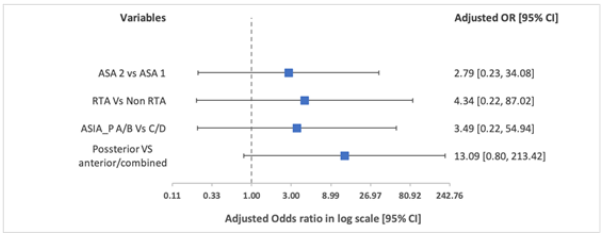

Figure 6. Adjusted Odds ratio of complications for variables obtained after multivariable analysis

DISCUSSION

The real clinical benefits of early surgery for spinal injury is difficult to assess in the absence of class I data.[24] Although the window of opportunity for surgical decompression (SD) and the best chance of neurological recovery has been shown to be 4-9 hours after injury in western literature, there exist certain factors like delayed arrival to hospital in resource-constrained environments.[25] The timing of surgical decompression is not the only determining factor for the neurological outcome. The degree of spinal cord contusion before surgery is also a significant independent predictor of neurological recovery. In the study by Jug et al. there was a tendency toward a reduced probability of neurological recovery in patients who presented with complete versus incomplete cervical traumatic SCI.[25]

The severity of primary injury plays a significant role in the pathophysiology of SCI in preclinical models.[26] Therefore, the severity of the primary injury is an important predictor of neurological recovery in patients with cervical SCI irrespective of the degree of injury or timing of surgery. Although the severity of primary injury may not be directly reflected in ASIA impairment scale (AIS) grades,

more prominent posttraumatic changes on MRI have been reported in clinical studies comparing patients with complete SCI with patients with incomplete SCI at admission.[27]

Nonetheless, till now in the cases with SCI either with neurological or mechanical instability the surgical decompression of the spinal cord and the restoration of vertebral alignment are considered as the standard treatment.[11] Timing of surgery is still a matter of debate. A multicentric prospective cohort study surgical timing in traumatic spinal cord injury study (STASCIS) concludes that decompression prior to 24 hours after SCI can be performed safely and is associated with improved neurologic outcome, defined as at least a 2-grade ASIA improvement at 6 months follow-up.[9,21]

Of the many issues, radiological evaluation with MRI prior to reduction for identification of herniated disc material is of concern. It is because, in cases with a herniated disc, the reduction procedure applying the traction can further deteriorate the neurological status. Though this is a rare phenomenon, it may have a worse outcome.[28]

However, traction can be applied gradually by monitoring the neurological status of the patient. In the present study, there was one case noted to have worsened neurologically after applying cervical traction that failed to improve after surgery. Another important fact is that no surgical procedure has been shown to lessen the primary damage while it is mandatory to prevent the secondary SCI that appears within 72 hours after spinal injury.[29,30]

In the present study, there was a male preponderance comprising 85.7% of the study population and the commonest age group was 31-40 years indicating the involvement of male outdoor activities is more. There were 90.48% males in the early group whereas it was 71.73% in the late group. It was similar to the study conducted by Shrestha et al where there were 80% males and 20% female and the 44.0% of age group were between 30-49 years.[31]

In the present study, the RTA was the most common cause of spinal injury (60.17%). In the study by Shrestha et al. fall injury was the commonest cause of spinal injury (60%) which is contrary to the present study.[31] C6-7 subluxation was the most common injury level followed by C5-C6 subluxation. This finding was similar to in the study by Gupta et al. all where 37% of the study population had C6-C7 subluxation.[21]

The commonest surgical approach (with decompression and stabilization) was anterior in our study. Overall, 21 out of 28 (75%) patients underwent an anterior approach. Fifteen out of 21 (71.43%) underwent anterior approach in the early group and six out of seven (85.71%) underwent anterior approach in the delayed group. Six out of 21(28.57%) underwent a posterior approach in the early group whereas one out of 7(14.29%) underwent a posterior approach in the delayed group. Approaches of both groups were similar as observed in the study by Gupta et al. where the anterior approach was 92% and 85% in the early and late group respectively.[21] There was a significant difference in ASIA neurology status at the time of discharge ($p < 0.001$) but there was no difference between the timing of surgery and neurological outcome. It may be due to short-term follow-up and small sample size. In a study by Mauro et al. grade D improved in 78.1% of the cases while patients in grade B improved in 66.6%.[32] Where as in the our study, ASIA A and B neurology patients did not show any improvement. Three out of eight patients in ASIA C improved to ASIA E. Four remained in the same ASIA-C status and one case deteriorated to ASIA-B, of the 12 cases in ASIA-D, three cases improved to ASIA-E, nine cases remained the same ASIA-D status.

Overall, the complication rate was 25.0% .In the early group the complications were noted in 28.6% patients while that in the late group was 14.3%. Respiratory complications were the most common complication (17.8%). In a study by Mauro et al. there were 5.7% respiratory system-related complications.[32]

There was one in-hospital mortality due to ventilator-associated pneumonia (3.6%). The mortality rate compared to current literature is very less in the present study. This might be due to the higher number of ASIA D neurology cases treated. The mortality as reported in the study by Shrestha et al. is 17%.[31] In summary, the neurological outcomes of the present study are similar to findings noted in the prospective study by Vaccaro et al. where they compared patients who had early surgery (< 72 h after injury) with those who had late surgery (> 5 days after injury).[16] In their study they concluded that there is no significant neurologic benefit when cervical spinal cord decompression is performed < 72 h after the injury as opposed to waiting longer than 5 days. Hence we believe that presenting ASIA neurological status is still the best determinant of the neurological outcome of the victims. This statement, however, needs to be verified by conducting other randomized controlled trials to generate a higher level of evidence.

This is a single-center study with a small sample size which might have obscured the statistical association of factors with complications and neurological outcomes. Moreover, most of the patients presented after 24 hours of the event, so early decompression as in much current literature could not be done. So, the neurological outcomes in our study groups might have differed from other similar studies. Thus, multicentric prospective, large volume studies are recommended to gather further evidence on neurological outcomes among the cases operated in this time frame.

CONCLUSION

This study reports that the timing of surgery does not alter the neurological outcomes and the development of complications significantly. ASIA neurological status at the time of presentation correlates with the neurological outcome and thus is still the best indicator of prognosis. Though statistical significance could not be attained, complications were found to be higher among cases with raod traffic accidents having ASIA A and B neurology status.

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