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Is Delayed Surgery After Unsuccessful Conservative Treatment Beneficial for Spinal Cord Injury Following Whiplash? A Retrospective Study in Elderly Patients

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Background: The aim of this study was to investigate the clinical outcomes of early and delayed surgery in cervical spinal cord injury following whiplash in elderly patients.

Material/Methods: Our retrospective review identified elderly patients (≥65 years old) with spinal cord injury following whiplash injury from 2006 to 2015. The neck disability index (NDI), modify Japanese Orthopedics Association (mJOA) score, and visual analogue scale (VAS) score were used to evaluate clinical outcomes preoperatively and during follow-up. The angular range of motion (ROM) for C2–C7 was measured by dynamic flexion and extension lateral cervical radiographs at each observation follow-up time point. Treatment-related complication data were collected, and the complication rates analyzed.

Results: Forty-six elderly patients (age range 65–82 years) with spinal cord injury following whiplash injury were enrolled in this study. Twenty-four patients underwent early surgery and twenty-two patients (age range 65–78 years) received delayed surgery after conservative treatment failure. During the follow-up period, both groups had significant post-operative improvement in NDI, mJOA, and VAS scores ($p<0.05$), although the early surgery group had better outcomes than the delayed surgery after unsuccessful conservative treatment group ($p<0.05$). However, on average, no significant differences in sagittal C2–C7 ROM between the two groups were found during follow-up. Comparison of the two groups showed the incidences of pneumonia and deep vein thrombosis were significantly higher in the delayed surgery group ($p<0.05$).

Conclusions: This study indicated that delayed surgery after unsuccessful conservative treatment provided excellent clinical results for elderly patients; however, timely surgical intervention is necessary for neurological symptom deterioration.

MeSH Keywords: Retrospective Studies • Spinal Cord Compression • Whiplash Injuries

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Background

Whiplash injury is associated with an acceleration-deceleration mechanism of force or energy change that causes significant neck movement [1]. Many patients with whiplash injury will recover within weeks or months, and many studies have reported that the outcome of nonsurgical treatment has good results in terms of pain relief and patient satisfaction [2,3].

With respect to elderly patients, the incidence of whiplash injury is increasing and may provoke irreversible damage to the spinal column and spinal cord as elderly patients frequently experience osteoarthritic degeneration of the cervical spine [4]. Thus, early decompression surgery is usually recommended for elderly patients with a neurological deficit after cervical spinal cord injury [5]. However, in elderly patients with mild or slowly progressive cervical spinal cord injury following whiplash, the superiority of early surgical treatment over conservative treatment has not been established. Therefore, it would seem that conservative treatment would be a better choice for them because of lower complications and costs [6,7]. In clinical practice, however, the results of conservative treatment vary between individuals, even using the same therapeutic method. Many elderly patients with whiplash-injury induced spinal cord injury choose surgical intervention only after an unsuccessful conservative treatment, yet, little is known about the efficacy of delayed surgery.

Studies have shown that immediate spinal cord decompression can significantly improve neurologic outcomes [8]. However, there are no published studies that have examined the effects of delayed surgery for cervical spinal cord injury following whiplash injury. Thus, the present retrospective study was designed to compare the relative effectiveness of early versus delayed surgery in elderly patients with respect to clinical outcomes.

Material and Methods

Patients with clinically and radiographically confirmed whiplash-injury induced cervical spinal cord injury from June 2006 to September 2015 were enrolled in this retrospective cohort study. The key inclusion criteria were: age of 65 years or older; objective whiplash injury with a history of present illness; musculoskeletal sign(s) and neurological sign(s); objective cervical spinal cord injury on magnetic resonance imaging; no prior treatment for cervical disorders; and no cervical column fracture or dislocation. Exclusion criteria were: a history of cervical spondylopathy or upper limbs neurological syndrome; known or suspected serious physical pathology, including spinal tumor, cervical spine fracture, or dislocation; and previous cervical spine surgery.

The patients who met the inclusion criteria were further divided into two groups based on their treatment method: the early surgery group and the delayed surgery group (surgery after unsuccessful conservative treatment). Approval for this study was obtained from the authors' institutional review board. All patients were informed about the purpose of their inclusion in the study and provided written, informed consent that was signed at least 24 hours preoperatively.

Early surgery group

The patients in the early surgery group underwent surgery between 24 hours and 48 hours after injury. The surgical method for decompression of the spinal cord was from an anterior or posterior approach, depending on the patient's condition. All patients followed a standardized post-operative rehabilitation program, and post-operative radiological follow-up with the surgeon.

Delayed surgery group

In the hospital, each patient received continuous cervical traction and brief immobilization by a soft cervical collar. Neurotropic and analgesic drugs were used to help heal their nerves and alleviate pain. Nearly two weeks after admission, patients were discharged, regardless of the outcome of conservative treatment. Patients were asked to continue cervical immobilization and medications after discharge, and refrain from some potentially dangerous activities relate to neck hyper-extension or hyper-flexion. Patients were followed regularly every month and advised to go to the hospital immediately if their symptoms deteriorated. When patients suffered worsening neurological symptoms that resulted in a mJOA score less than 12, or a patient had a reduction of more than 2 points, surgery was advised and performed. Preoperative examinations were performed by the attending surgeon; the operation and the post-operative treatment were the same in the early surgery group and the delayed surgery group. Radiological follow-up and curative effects were analyzed retrospectively by the surgeon.

Outcome measures and follow-up

Preoperatively, a patient's baseline status was assessed by clinical and radiological evaluations.

Clinical evaluation was based on the neck disability index (NDI) [9], the modify Japanese Orthopedics Association (mJOA) score [10], and the neck pain visual analogue scale (VAS) score [11]. The NDI score ranges from 0 (best) to 100% (worst), and was used to evaluate the patient's neck conditions by self-reported. The mJOA instruments are investigator-administered spinal cord injury indices measuring the severity of functional

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Table 1. Sociodemographic data between the two groups before treatment.

Characteristic	Early surgery (n=24)	Delayed surgery (n=22)	P
Mean age at surgery, y	67.2±4.6	69.3±4.2	0.11
Mean body mass index	24.9±2.8	24.7±3.3	0.83
Male sex, n	11	12	0.55
Current smoker, n	9	7	0.68
The mean time from the injury to treatment, hrs	31.5±7.9	34.2±6.7	0.22
Mean NDI score	35.1±3.3	34.2±3.5	0.37
Mean mJOA score	10.3±2.9	10.8±2.4	0.53
Mean VAS score	7.8±1.1	7.9±1.1	0.76
Mean ROM, deg	33.4±5.1	35.2±5.9	0.27
Cervical compresive level			0.62
C4/5, n	9	10	
C5/6, n	5	4	
C6/7, n	10	8	
Surgical approach			0.86
Anteriorly, n	18	17	
Posteriorly, n	6	5	

NDI – Neck Disability Index; VAS – visual analogue scale; mJOA – modify Japanese orthopedic association; ROM – range of motion.

and neurological impairment and has four parts: upper extremity motor dysfunction, lower extremity motor dysfunction, sensory disturbance, and sphincter dysfunction. It evaluates the severity of the whiplash injury by allocating points according to the degree of dysfunction in each of the four areas. The total score is a sum of the scores in the four areas and the range is from 0 (worst) to 17 (best). For neck pain intensity we used a horizontal VAS score of 0 (no pain) to 10 (worst pain imaginable).

Radiological evaluation was based on the angular range of motion (ROM) of C2–C7. Dynamic flexion and extension lateral radiographs were taken and measured the difference in Cobb angles between full flexion and extension. A positive value was used to express kyphosis, whereas a negative value was used to express the lordosis angle.

Other measures collected were sociodemographic data taken from a baseline questionnaire. The follow-up time points were 3, 6, 12, and 24 months after the surgery that removed spinal cord compression. Follow-up evaluations were performed by an independent investigator who was not involved in the treatment of the patients. In addition, participating investigators retrospectively evaluated the entire list of complications during follow-up and during all unplanned visits. All post-operative complication data were collected by the independent doctor who had expertise in the surgical treatment of cervical spine disorders.

Statistical methods

The study sample data were analyzed using the SPSS 18.0 software (SPSS, Inc., Chicago, IL, USA). We used mean ± standard deviation (SD) for continuous variables, and frequencies for categorical variables. One-way analysis of variance (ANOVA) and the Pearson chi-square test were used to calculate the baseline descriptive statistics and compare the characteristics among the two groups. The Wilcoxon test, the Fisher's exact test and Welch t-test were used to compare continuous data among the groups. Nonparametric Mann-Whitney U tests were used to evaluate the association of post-operative scores (NDI, mJOA, and VAS), utilizing paired samples *t*-test to compare patient outcomes at four follow-up timepoints: 3 months, 6 months, 12 months, and 24 months after surgery with patient preoperative status. All analyses were conducted using two-sided tests and the statistical significance was set at $p<0.05$.

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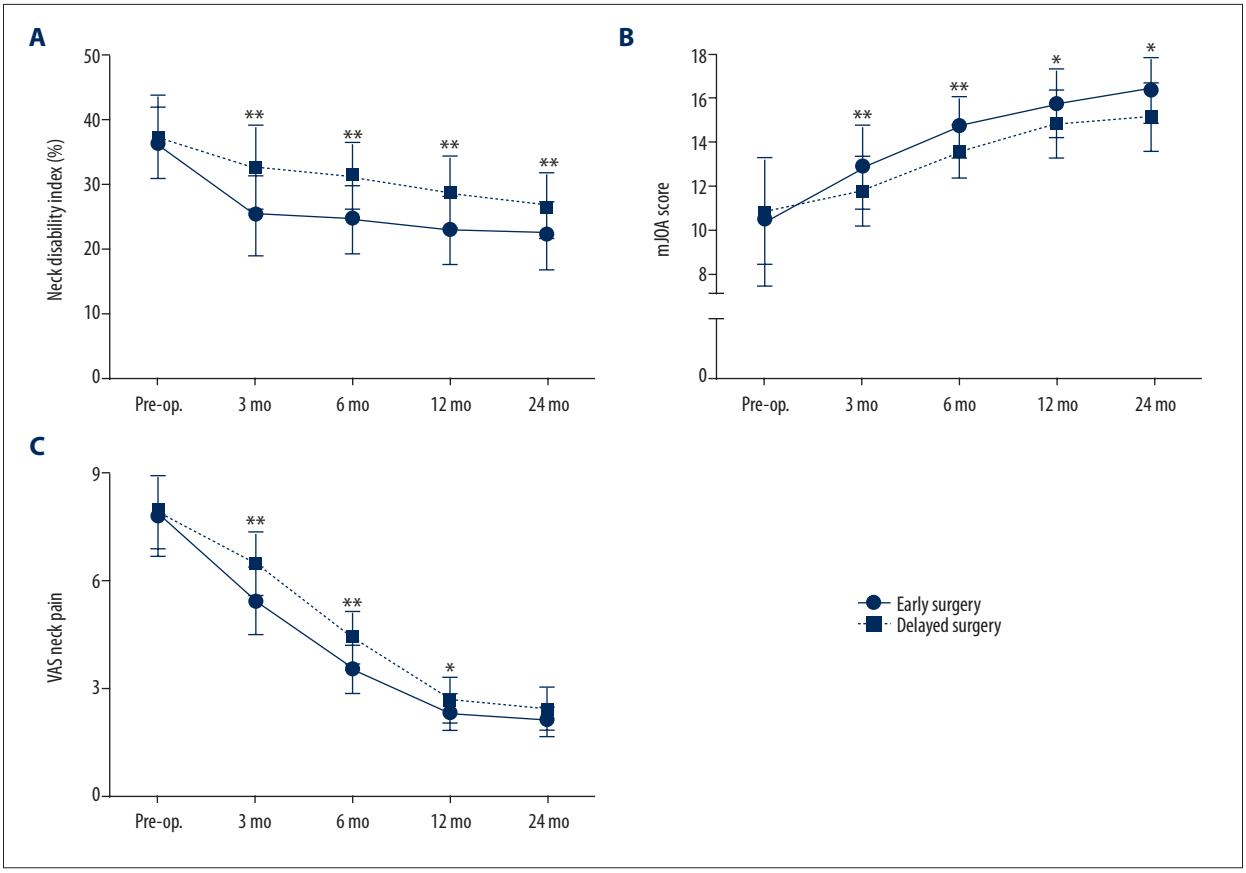

Figure 1. (**A**) Neck disability index (score percent range, 0–100) in both groups pre-operatively and at follow-ups. (**B**) Modify Japanese Orthopedics Association (mJOA) score, (mJOA, range 0–17) in both groups pre-operatively and at follow-ups. (**C**) Neck pain intensity (VAS, range 0–10 cm) in both groups pre-operatively and at follow-ups. Nonparametric Mann-Whitney U tests evaluate the difference between early surgery and delayed surgery after physiotherapy. ** $p<0.01$. Pre-op. – pre-operatively.

Results

A total of 46 patients met the eligibility criteria and received treatment for cervical spinal cord injury following an acceleration-deceleration accident. Patients were classified according to the type of treatment: 24 patients (52.2%) had early surgical treatment, while 22 patients (47.8%) had delayed surgery. Demographics were similar between groups. The mean patient age in the early surgery group was 67.2 years (range 65–82 years); the mean patient age in the delayed surgery group was 69.3 years (range 65–78 years). All patients had suffered one level cervical compression after whiplash injury. In the early surgery group, there were 9 patients with C4/5 spinal cord compression, 5 patients with C5/6 spinal cord compression, and 10 patients with C6/7 spinal cord compression. In the delayed surgery group, 10 patients had C4/5 spinal cord compression, 4 patients had C5/6 spinal cord compression, and 8 patients had C6/7 spinal cord compression. There were no statistically significant differences between groups in the spinal cord compressive level. Patient demographic data and the parameters at baseline are presented in Table 1. By the end of September 2017, three patients from the early surgery group and two patients from the delayed surgery group were lost to follow-up. Mean follow-up was 22 months in the early surgery group and 22.9 months in the delayed surgery group.

Functional and disability-related outcomes

The comparison of results among patients is presented in Figure 1. Overall, the NDI score, mJOA score, and VAS score improved significantly from baseline to two years post-operative ($p<0.05$). During the post-operative study period, the early surgical group showed better results in NDI scores (Figure 1A), mJOA scores (Figure 1B), and pain intensity VAS scores (Figure 1C) than the delayed surgery group. Furthermore, significant NDI score and VAS score reductions, compared with preoperative scores, were seen in both groups at 3, 6, 12, and 24 months follow-up ($p<0.001$) (Table 2). Pairwise comparisons of the improvement in mJOA scores, between preoperative status and each follow-up, found a larger improvement for the early surgical group at three months (mean: 2.53, 95% CI: 0.67–4.39; $p<0.001$). Significant mJOA score improvement compared with

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Table 2. Neck Disability Index, Pain Intensity (VAS) Reduction and mJOA Score icreased at different follow-ups compared with preoperation in the early surgery group.

	3 months			6 months			12 months			24 months		
	Mean	95% CI	P	Mean	95% CI	P	Mean	95% CI	P	Mean	95% CI	P
NDI reduction, score % 0–100	11.21	4.45–17.97	<0.001#	11.65	4.06–19.24	<0.001#	13.62	5.09–22.15	<0.001*	14.25	4.67–23.83	<0.001*
Neck pain reduction, VAS score	2.33	1.19–3.47	<0.001#	3.87	1.50–6.24	<0.001#	4.27	1.66–6.88	<0.001#	5.29	2.21–8.37	<0.001*
mJOA increased score	2.53	0.67–4.39	<0.001*	4.36	1.38–7.34	<0.001*	5.41	1.53–9.29	<0.001#	6.18	2.20–10.16	<0.001#

The values are given as within group mean change (95% CI). Figures and P values display paired differences within groups.
* Significance was calculated with paired samples test; # Significance was calculated with Wilcoxon matched-samples rank sum test, NDI – indicates Neck Disability Index; VAS – visual anlogue scale; CI – confidence interval.

Table 3. Neck Disability Index, Pain Intensity (VAS) Reduction and mJOA Score increased at different follow-ups compared with preoperation in the delayed surgery group.

	3 months			6 months			12 months			24 months		
	Mean	95% CI	P	Mean	95% CI	P	Mean	95% CI	P	Mean	95% CI	P
NDI reduction, score% 0–100	4.61	2.18–7.04	<0.001*	5.78	1.78–9.78	<0.001*	8.93	2.25–15.61	<0.001*	10.25	4.15–16.35	<0.001#
Neck pain reduction, VAS score of 0–10 cm	1.46	0.42–2.50	<0.001*	3.50	1.07–5.93	<0.001*	5.23	1.53–8.93	<0.001*	5.48	1.62–9.34	<0.001*
mJOA increased score	0.91	–2.96–4.77	<0.001#	2.70	0.50–4.90	<0.001*	3.97	0.95–6.99	<0.001#	4.29	0.68–7.90	<0.001#

The values are given as within group mean change (95% CI). Figures and P values display paired differences within groups.
* Significance was calculated with paired samples test; # Significance was calculated with Wilcoxon matched-samples rank sum test.
NDI – indicates Neck Disability Index; VAS – visual anlogue scale; CI – confidence interval.

preoperative status was also seen in both groups ($p<0.001$) (Table 2). Nevertheless, patients who underwent surgical intervention after failed conservative treatment had a smaller improvement in mJOA and NDI scores relative to the early surgery group (Table 3).

Radiographic outcomes

In both groups, sagittal C2–C7 ROM was restricted after 3, 6, 12, and 24 months post-operatively compared with preoperative ROM ($p<0.05$). In the early surgical group, the maintained C2–C7 ROM averaged 27.9° at 12 months and 27.6° at 24 months after surgery. With respect to the delayed surgery group, the maintained C2–C7 ROM averaged 28.1° at 12 months and 28.9° at 24 months after surgical intervention. However, no significant differences were found in sagittal C2–C7 ROM between the early surgery and delayed surgery groups at all post-operative time points ($p>0.05$) (Table 4.).

Postoperative complications

The complications data related to the two groups are presented in Table 5. Ten patients (45.5%) from the delayed surgery group suffered from post-operative complications; there were two types of complications in three patients. In the delayed surgery group, the most common complication was pneumonia, which accounted for 22.3% of complications. In the early surgery group, one patient suffered worsening of myelopathy complications after treatment. Compared to the early surgery group, the delayed surgery group exhibited a higher risk of pneumonia and deep vein thrombosis post-operatively ($p<0.05$).

Discussion

This retrospective study represents a large comprehensive evaluation of surgical outcomes in elderly patients who suffered cervical spinal cord injury syndrome secondary to acute whiplash

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Table 4. The ROM of C2–C7 at the different follow-ups compared with baseline.

Group	Mean preoperative ROM, deg	Mean postoperative ROM, deg			
		3 month	6 month	12 month	24 month
Early sugery	33.4±5.1	22.6±4.8*	26.3±5.4*	27.9±3.2*	27.6±3.5*
Delayed surgery	35.2±5.9	23.1±5.7*	27.3±3.8*	28.1±4.7*	28.9±3.9*

deg – degree; ROM – range of motion. Paired t-test was used to examine the difference between pre- and postoperative time point.
* P<0.05.

Table 5. Postoperative complications occurred during follow-up.

Complications	Early surgery	Delayed surgery	P
Deep vein thrombosis, n (%)	0 (0)	4 (18.1)	0.03
Neurological deteriorarion, n (%)	0 (0)	1 (4.5)	0.29
Numbness and tingling, n (%)	0 (0)	1 (4.5)	0.29
Pneumonia	0 (0)	5 (22.3)	0.01
Worsening of myelopathy, n (%)	1 (4.1)	2 (9.1)	0.50

injuries. Our results demonstrated that elderly patients with failed conservative treatment can be benefited from delayed surgical decompression. On the other hand, our findings also highlight the critical role of timing in determining the benefits of early surgical intervention in cervical spinal cord injury, which was consistent with results from a previous clinical study [12].

Many patients with acute whiplash injuries will make full recovery through conservative treatment, but in 10% to 40% of the patients, conservative care is ineffective [13]. Despite the limitations of conservative interventions, much research has nevertheless been undertaken to determine the effect of various conservative treatment options, including neck collar immobilization, neck traction, or even pulsed electromagnetic therapy [6]. So far, however, there has been little evidence presented for their accepted used, and conservative care has been associated with worse outcomes when the cervical spinal cord is compressed [13].

Surgical treatment is generally based on the fact that tissue damage and consequent injury are relevant to the patient's symptoms. Some research has demonstrated outstanding clinical outcomes for surgical intervention of whiplash injuries, associated with clear spinal cord compression. Currently, however, the information about the results of timing of surgical intervention, especially for delayed surgery after unsuccessful conservative management, is scarce. To answer this question, we designed this study, and found that the clinical outcomes, including mJOA, VAS, and NDI scores, of elderly patients' perceived change showed a significant improvement in the delayed surgery group, even though the treatment effect in the early surgery group was more pronounced.

In this study, the timing of surgical intervention may have caused the different clinical outcomes between early and delayed surgery group. Numerous clinical studies of spinal cord injury have demonstrated that early surgical decompression might provide excellent clinical and neurologic results [5,14]. This principle is based not only on basic research that shows that early surgical intervention can alleviate primary and secondary damages, but also on clinical studies that have demonstrated that longer durations of spinal cord compression produce greater neurologic deficits. Furlan et al. reviewed preclinical research and concluded that the timing of spinal cord decompression had a great influence on the neurologic prognosis, and suggested that early surgical decompression is safe and feasible [15]. In addition, some previous studies also supported early surgery of spinal cord injury in elderly patients as it could lead to more favorable neurologic improvements [12,16]. Thus, delayed surgical intervention can solve failed conservative treatment; in addition, invalid conservative treatment can lead to persistent neurologic deficits [17].

A previous study reported that physiotherapy treatment can improve ROM during the first one to two months [18], while reports about post-operative changes in ROM are scarce in spinal cord injury secondary to whiplash injuries. Our study found that post-operative ROM was decreased in the two groups during follow-up, although it was restored largely at 12 and 24 months post-operatively. As for the intergroup differences at each follow-up timepoint, no statistical significance was found in ROM degree between the early surgery group and the delayed surgery group. Given that the ROM of patients is dependent on the number of operated cervical levels [19], we

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consider this result may be attributed to the surgical approach and cervical level fixation.

The delayed surgery group exhibited a higher ratio of post-operative complications. The ratio of post-operative complications increased significantly and reached 45.5% in the delayed surgical intervention group, while only one patient from the early surgery group suffered worsening of myelopathy post-operatively. Moreover, the most common complication of the delayed surgery group was pneumonia and deep vein thrombosis in a total of five and four patients, respectively, with no such cases in the early surgery group, and the differences were significant ($p<0.05$). Considering that post-operative complications increased in the delayed surgery group, patients in the early surgery group were able to ambulate early and spend less time in bed, which likely decreased complications [20].

Several limitations should be noted for this study. The retrospective design and potential loss of data might lack statistical power compared to randomized clinical studies. In addition, the difference in surgical approaches between the early surgery group and delayed surgery group, and the limited duration of follow-up might weaken the ability of the study to assess clinical outcomes. Consequently, future studies involving reliable and long-term follow-up are needed to further confirm the present findings.

Conclusions

In this retrospective study of elderly patients with cervical spinal cord injury following whiplash injury, it was shown that early surgery resulted in more rapid and significantly greater improvement in clinical outcomes than delayed surgery. Nevertheless, if conservative treatment fails, timely surgical decompression is likely and necessary to reverse the deterioration of spinal cord compressive symptoms in the elderly.

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