

## Original Article

# Analysis of correlative risk factors for C5 palsy after anterior cervical decompression and fusion

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**Abstract:** Background: It has been reported that C5 palsy is a potential complication of both anterior and posterior cervical spine surgery, although several mechanisms of C5 palsy following posterior cervical surgery have been proposed, few reports about correlative risk factors have been elaborated on C5 palsy after anterior cervical decompression and fusion (ACDF). Objective: The purpose of this study was to investigate the correlative risk factors of C5 palsy after anterior cervical decompression and fusion. Methods: This is a retrospective study. A total of 161 patients (108 males and 53 females) who underwent ACDF between 2007 and 2012 were included in this study. C5 palsy is characterized by deltoid and/or biceps brachii weakness. The patients were divided into two groups: one that had experienced C5 palsy (group A) and the other one had not (group B). In both groups, the age, gender, duration of disease, diagnosis, No. of surgical levels, cervical curvature correction, occupying rate of spinal canal at C4/5, diameter of the C4/5 foramen, intervertebral height variation, decompression width and preoperative high-signal intensity zone (HIZ) of spinal cord in T2-weighted MRI at C4/5 were measured and evaluated. The risk factors of C5 palsy were detected with logistic regression analysis. Results: There were no significant differences in age, gender, duration of disease, diagnosis, No. of surgical levels, rate of spinal canal at C4/5 and HIZ of spinal cord in T2-weighted MRI at C4/5. Cervical curvature correction, diameter of the C4/5 foramen, intervertebral height variation and decompression width had significant differences between the two groups ( $P < 0.05$ ). Logistic regression analysis revealed that cervical curvature, diameter of the C4/5 foramen, intervertebral height and decompression width were the pivotal risk factors for the incidence of C5 palsy. Conclusion: For patients with ACDF, greater cervical curvature correction, narrow diameter of the C4/5 foramen, improper intervertebral height variation and larger decompression width were the correlative risk factors for C5 palsy after ACDF.

**Keywords:** Cervical spine, anterior cervical surgery, decompression, C5 palsy, risk factor

## Introduction

Anterior or posterior cervical decompression surgery has been advocated for the treatment of cervical degenerative diseases [1, 2]. Although these two surgical procedures have been confirmed to yield generally good outcomes, C5 palsy is a potential complication not only after posterior cervical surgery [3], but also after anterior decompression surgery [4]. Postoperative C5 palsy is defined as deterioration in muscle strength of the deltoid and/or biceps brachii by at least one grade on manual motor testing (MMT) [5]. The prevalence of C5 palsy is low, but affected patients who have persistent muscle weakness, brachialgia, or numbness are dissatisfied with their surgery. The related

studies of C5 palsy after posterior procedure has been studied intensively [6, 7], whereas the number of studies about C5 palsy after anterior cervical decompression surgery is relatively small. Thus, the incidence, risk factors and characteristic of C5 palsy after ACDF have not yet been fully elucidated. The aim of the present study was to clarify the correlative risk factors of C5 palsy after anterior cervical decompression and fusion.

## Materials and methods

### Patient population

A total of 189 consecutive patients who underwent ACDF including the C4-C5 disc level between March 2007 and December 2012 at

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**Table 1.** Demographic summary in 161 patients

	No. patients
Sex	
Male	108
Female	53
Age (year)	37-75 (61.80±9.25)
Duration of disease (month)	2-23 (11.10±3.03)
Follow-up period (year)	2-6 (3.70±1.32)
Diagnosis	
CSM	69
CSME	56
OPLL	36
Levels of surgery	
One level	19
Two level	82
Three level	60
Preoperative JOA score (points)	12.30±2.90

CSM, cervical spondylotic myelopathy; CSME, cervical spondylotic radiculomyelopathy; OPLL, ossification of posterior longitudinal ligament; JOA, Japanese Orthopaedic Association.

our hospital were studied retrospectively. Exclusion criteria were as follows: (1) preoperative deterioration of deltoid muscle at grade 3 or less in the MMT, (2) tumor, (3) trauma, (4) infection, (5) cervical vertebral fracture, (6) history of cervical surgery, (7) severe systemic disease or osteoporosis, (8) lack of adequate follow-up data. Finally, 161 patients (108 males and 53 females) were included in this study.

A summary of demographic data, including preoperative diagnoses for the entire patients is presented in **Table 1**. According to the presence or absence of C5 palsy after surgery, the patients were divided into two groups: one that had experienced C5 palsy (group A) and the other one had not (group B). 8 of the entire population had postoperative C5 palsy. The C5 palsy incidence in this study was 5.2%, which is consistent with the previous literature [8, 9].

### *Surgical procedures*

The operation was performed in back position after induction of general anesthesia with a right anterior approach. One level fusion surgery was performed by anterior cervical discectomy and fusion, two levels fusion surgery were performed by anterior cervical corpectomy and fusion, and three levels surgery were conducted by discectomy combined with corpectomy.

An intervertebral cage with autograft bone implanted for the discectomy segment. An titanium mesh with autograft bone implanted for the corpectomy segment. The patients wore cervical collars for 2 to 3 months postoperatively. No cervical instrument such as a halo vest was used in the postoperative patients.

### *Clinical assessment*

We evaluated the age, gender, duration of disease, diagnosis, No. of surgical levels between the two groups. The preoperative Japanese Orthopaedic Association (JOA) score was compared between the two groups used to evaluate the severity of myelopathy [10].

### *Radiological assessment*

Radiological analysis was performed on patients with both preoperative and postoperative imaging on lateral cervical radiograph, computed tomography (CT) and magnetic resonance imaging (MRI). Six radiological parameters were measured. All measurements were collected by one independent radiologist who was blinded to the patients' information. Changes in cervical curvature and intervertebral height were measured on lateral cervical radiograph (**Figures 1, 2**). Occupying rate of spinal canal at C4/5, diameter of the C4/5 foramen and decompression width were calculated on CT axial images (**Figure 3A-C**). Preoperative HIZ in T2-weighted MRI at C4/5 was also evaluated (**Figure 3D**).

### *Risk factor analysis*

Patient characteristics (include the age, gender, duration of disease, diagnosis, No. of surgical levels) and the results of their radiological assessment were considered to analyze risk factors.

### *Statistical analysis*

Data were presented as mean ± standard deviation (SD) or frequency (percentage). Statistical analyses were performed using the SPSS 17.0 statistical software program (SPSS, Inc., Chicago, IL, USA). An independent samples *t* test and Pearson  $\chi^2$  test were used to compare the C5 palsy and non-C5 palsy groups. Multivariate logistic regression analysis was used for correlative risk factor analysis. The parameter significance was evaluated using univariate analy-



**Figure 1.** Preoperative cervical curvature = $\beta$  (A), postoperative cervical curvature = $\beta'$  (B), cervical curvature variation = $\beta-\beta'$ .

sis. Factors with  $P < 0.20$  in the univariate analysis were then included in the multivariate analysis. All statistical tests were two-sided and  $P < 0.05$  were considered statistically significant.

## Results

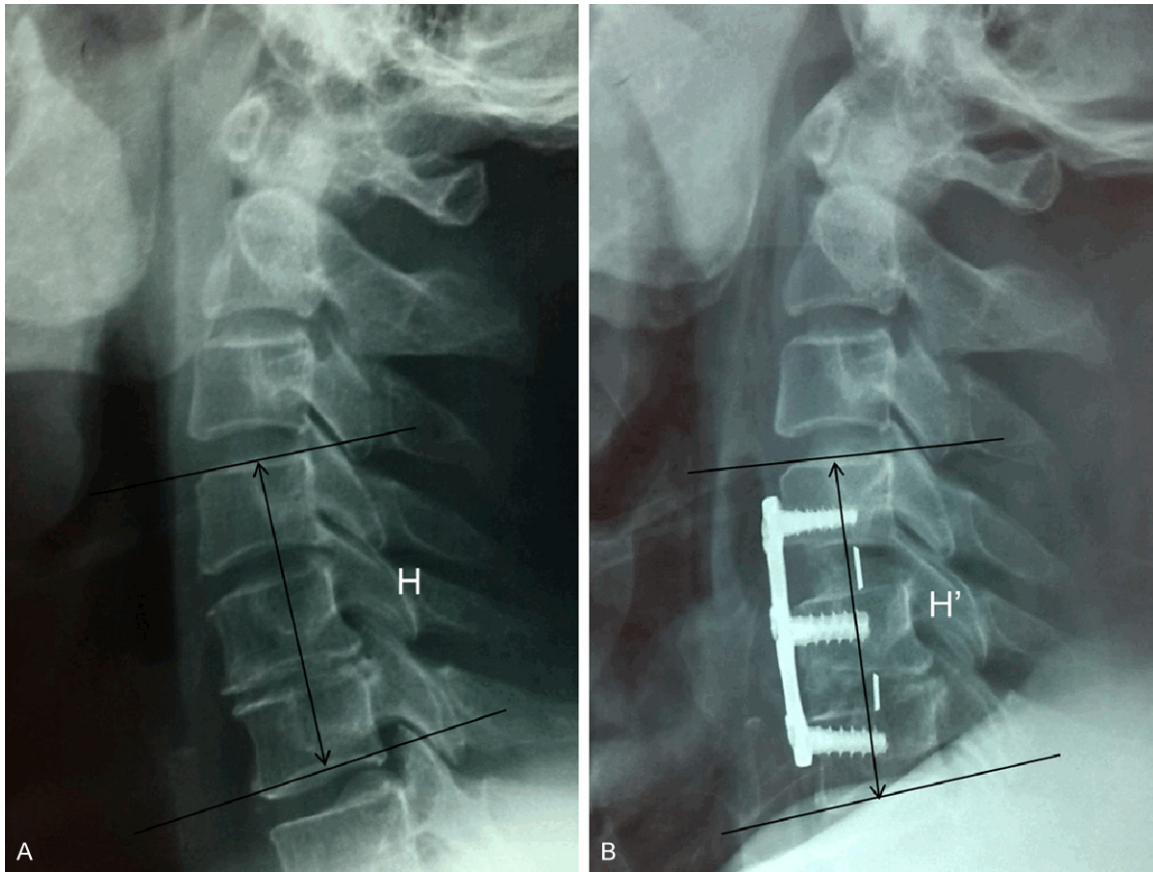
### *Demographic data of 8 patients with C5 palsy*

C5 palsy developed in 8 patients (5.2%) after the surgery, of whom 6 were men and 2 were women. The average age at operation was 58.88 years (range, 37-74), and the average follow-up period was 3.7 years (range, 2-6). The occurrence of C5 palsy was within 10 days after surgery in all patients. The status of the 8 patients were summarized in **Table 2**. The preoperative diagnoses for the 8 cases included 3 CSM cases, 3 OPLL cases, and 2 CSME cases.

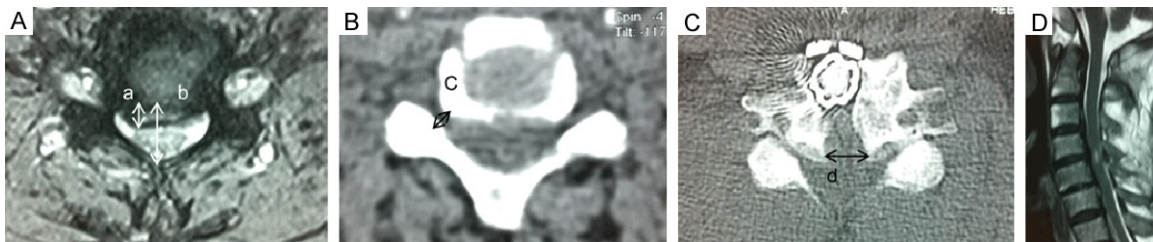
C5 palsy was found in 1 patient who underwent 1 level fusion, 4 patients with 2 levels fusion, and 3 patients with 3 levels fusion. The mean MMT score at the onset of C5 palsy was 2.4 (range, 1-3) for the muscle weakness. No further surgery was performed for the 10 cases. When C5 palsy occurred, the patients were treated with active and passive shoulder range of motion exercises, rest and drug administration to prevent contracture of the patient's muscles. 5 patients showed full recovery from their C5 palsy. However, the recovery was incomplete in other 3 patients.

### *Comparison of patient characteristics between group A and group B*

**Table 3** summarized patient characteristics in group A and group B. There were no significant differences between the two groups in terms of



**Figure 2.** Preoperative intervertebral height =H (A), postoperative intervertebral height =H' (B), Intervertebral height variation =H'-H.



**Figure 3.** Occupying rate of spinal canal at C4/5= $a/b \times 100\%$  (A), anterior-posterior diameter of the C4/5 foramen at the narrowest portion =c (arrows) (B), vertebral trough width =d (C), preoperative HIZ in T2 weighted MRI at C4/5 (arrow) (D).

age, gender, duration of disease, diagnosis, No. of surgical levels or preoperative JOA score ( $P > 0.05$ ).

*Comparison of radiological results*

The radiological findings between the two groups are summarized in **Table 4**. In group A, radiological measurements showed that the preoperative cervical curvature increased from 6.24°C to 17.65°C postoperatively, and in

group B it increased from 10.45°C to 17.89°C. There was a significant difference in cervical curvature correction between the two groups (11.25 vs. 7.35,  $P = 0.001$ ). The anteroposterior diameter of the C4/5 foramen was 2.35 mm in group A and 3.20 mm in group B, and there was a significant difference in the diameter of the C4/5 foramen ( $P = 0.001$ ). The values of decompression width were 16.05 and 13.92 respectively. These differences were statistically sig-

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**Table 2.** Characteristics of 8 patients with postoperative C5 palsy

Cases	Age	Sex	Diagnosis	Fusion levels	Time from surgery to paralysis (d)	Pre-MTT	Final-MTT
1	53	M	CSM	3	0	5	5
2	57	M	CSM	2	2	5	5
3	72	M	OPLL	2	3	5	4
4	63	M	CSME	1	5	5	5
5	37	M	OPLL	2	10	5	4
6	56	M	OPLL	3	1	5	4
7	59	F	CSM	2	0	5	5
8	74	F	CSME	3	2	5	5

M, male; F, female; CSM, cervical spondylotic myelopathy; CSME, cervical spondylotic radiculomyelopathy; OPLL, ossification of posterior longitudinal ligament; MTT, manual motor testing.

**Table 3.** Comparison of patient characteristics with and without postoperative C5 palsy

Variables	Group A	Group B	P Value
No. of cases	8	153	
Age (year)	58.88±11.61	61.95±9.13	0.36
Sex			
Male	6	102	0.92
Female	2	51	
Diagnosis			
CSM	3	66	0.95
OPLL	3	53	
CSME	2	34	
Duration of disease (month)	9.27±2.30	11.20±3.04	0.08
No. of surgical levels	2.25±0.70	2.23±0.89	0.94
Preoperative JOA score	11.16±2.60	12.36±2.91	0.26

P<0.05 were considered statistically significant.

nificant (P=0.008). The intervertebral height variation between the two groups was significant difference (P=0.04). However, occupying rate of spinal canal at C4/5 and preoperative HIZ in T2-weighted MRI at C4/5 were non-significantly different in the two groups.

### *Postoperative C5 palsy risk factor analysis*

To identify correlative risk factors that influence C5 palsy after ACDF, we performed a logistic regression. Multivariate logistic regression analyses revealed cervical curvature correction, diameter of the C4/5 foramen, intervertebral height variation and decompression width to be significant risk factors for developing postoperative C5 palsy (cervical curvature correction: RR 0.15 [95% CI 0.02-0.97], P=0.047; diameter of the C4/5 foramen: RR 0.03

[95% CI 0.001-0.76], P=0.034; intervertebral height variation: RR 0.03 [95% CI 0.001-0.57], P=0.037; and decompression width: RR 0.04 [95% CI 0.001-0.81], P=0.02). Whereas age, gender, duration of disease, diagnosis, No. of surgical levels, rate of spinal canal at C4/5 and HIZ of spinal cord in T2-weighted MRI at C4/5 did not significantly affect the incidence of postoperative C5 palsy (Table 5).

### **Discussion**

As we all know, the technique of ACDF is the main surgical procedure for various cervical degenerative diseases due to its direct decompression. Now the anterior surgery has become more common than the posterior surgery. Postoperative C5 palsy is a serious complication of both posterior approach and anterior approach. Although it has a relatively good prognosis, it decreased the quality of people' living. An increased incidence

of C5 palsy has been reported for cervical decompression procedures. Sakaura et al. [8] have analyzed the literature on C5 palsy published from 1986 to 2002. They summarized that its average incidence after ACDF was 4.3% (range 1.6%-12.1%), and posterior decompression surgery was 4.7%. Hashimoto M et al. [4] reported that the incidence of C5 palsy after anterior surgery differed from 3.2 to 9.1%, depending on previous studies. In our study, the incidence of postoperative C5 palsy concurred with previous reports. A few scholars have investigated the incidence and mechanism of C5 palsy after posterior decompression surgery [5-7, 11, 12]. But the number of studies regarding C5 palsy after anterior cervical surgery was smaller than that for posterior surgery, and few suggestions have been made regarding correlative risk factors of C5 palsy

## Risk factor for C5 palsy

**Table 4.** Comparison of the radiological measurements between group A and group B

Measurements	Group A	Group B	P Value
Cervical curvature correction ( )	11.29±3.91	7.35±2.90	0.001*
Occupying rate of spinal canal at C4/5 (%)	38.10±5.35	34.92±5.02	0.087
Diameter of the C4/5 foramen (mm)	2.35±0.30	3.20±0.43	0.001*
Vertebral trough width (mm)	16.05±2.48	13.92±2.18	0.008*
Preoperative HIZ in T2 weighted MRI at C4/5			
Have	3	70	0.93
Not have	5	83	
Intervertebral height variation (mm)			
<3	2	102	0.04*
≥3	6	51	

\*Statistically significant.

**Table 5.** Logistic regression analysis for the risk factors of postoperative C5 palsy

Variables	Univariate		Multivariate#	
	RR (95% CI)	p Value	RR (95% CI)	p Value
Age	1.44 (0.63-3.30)	0.39		
Sex	1.50 (0.79-7.69)	0.63		
Diagnosis	0.87 (0.36-7.14)	0.77	0.27 (0.02-3.14)	0.30
Duration of disease	5.05 (0.99-25.88)	0.05		
No. of surgical levels	0.97 (0.44-2.17)	0.95		
Preoperative JOA score	3.90 (1.11-13.66)	0.03	0.86 (0.09-8.12)	0.89
Cervical curvature correction	0.26 (0.08-0.71)	0.008	0.15 (0.02-0.97)	0.047*
Occupying rate of spinal canal at C4/5	0.75 (0.28-2.06)	0.18	0.26 (0.02-3.30)	0.299
Diameter of the C4/5 foramen	0.13 (0.01-0.76)	0.02	0.03 (0.001-0.76)	0.034*
Vertebral trough width	0.16 (0.03-0.79)	0.03	0.04 (0.001-0.81)	0.037*
Preoperative HIZ in T2 Weighted MRI at C4/5	1.41 (0.32-6.09)	0.65		
Intervertebral height variation	0.17 (0.03-0.86)	0.17	0.03 (0.001-0.57)	0.02*

#The multivariate model includes variables with P<0.20 by univariate analysis. \*Statistically significant.

after ACDF. In the present study, a multivariate logistic regression analysis of its correlative risk factors has been performed, and the mechanism of C5 palsy after ACDF has been preliminarily investigated.

Numerous investigators have analyzed the cause of C5 palsy after cervical decompression surgery but none has provided definite evidence of its mechanism. There are various hypotheses regarding the etiology of postoperative C5 palsy. One is that C5 palsy was considered to result from direct C5 root injury due to the surgical procedure [13]. They proposed that surgical instruments may injure neural tissue. However, with the improvement of surgical technique for both anterior and posterior approaches, the incidence of C5 palsy has not significantly reduced [3]. Tanaka et al. [14] had not

observed abnormal events by transcranial electric motor-evoked potential monitoring during surgery, so they considered that C5 palsy is not associated with intraoperative injury and this hypothesis cannot explain the development of C5 palsy occurred several days after the surgery.

Another theory concerns a tethering effect. In 1996, Tsuzuki, et al. [15] presumed that the tethering phenomenon of nerve roots might cause C5 palsy as the result of a shift of the spinal cord in association with anchoring of the nerve root at the edge of the uncovertebral joint or the superior facet after tethering. This hypothesis appears to be concerned with the anatomic features of C5, which includes the C5 root is shorter than the other segments' roots, and the C5 segment is usually at the level

where the extent of posterior shifting of the cord is thought to be greatest [16]. However, some authors pointed out that there was no correlation between the incidence of C5 palsy and the posterior shift of the cord [5, 17].

Another hypothesis is that C5 palsy might be associated with damage of the gray matter of the spinal cord. Because HIZ in the spinal cord on postoperative T2-weighted MRI was found in patients with C5 palsy [18]. Hashimoto M et al. [19] proposed that the presence of HIZ on T2-weighted MRI preoperative might be one etiology of C5 palsy. Some researchers speculated that local reperfusion injury in the spinal cord and deterioration of gray matter might be correlation with C5 palsy, by HIZ on T2-weighted MRI newly or expansively after surgery [3, 20]. However, Seichi et al. [21] found no difference of the expansion of HIZ on T2-weighted MRI in patients with or without C5 palsy. In our study, logistic regression analysis demonstrated that HIZ on T2-weighted MRI preoperative was not a risk factor of C5 palsy after ACDF.

Therefore, the mechanisms of postoperative C5 palsy were still controversial. To find the risk factors of C5 palsy with multivariate studies is particularly important. In this study, significant risk factors for the development of postoperative C5 palsy included cervical curvature correction, diameter of the C4/5 foramen, intervertebral height variation and decompression width were found by multivariate logistic regression analysis. We proposed that increased cervical curvature may be a risk factor of C5 palsy, in the present study, patients with C5 palsy tended to have greater cervical curvature correction than those of patients without C5 palsy ( $P < 0.05$ ). Tanaka N et al. [14] implied that the correction of the cervical alignment might be a cause of C5 palsy after cervical laminoplasty due to posterior shift of the spinal cord. Hojo et al. [22] found that the change in the C2-7 angle with C5 palsy was significantly larger than that without C5 palsy. This indicated that the magnitude of change in cervical curvature correlated with postoperative C5 palsy. We considered that greater correction of cervical curvature might increase the tension of C5 nerve root due to anatomic factor and result in C5 palsy after ACDF. Recently, several studies have described the relationship between C5 palsy and preoperative C4/5 foraminal stenosis. Some authors [6, 23] observed significant narrowing of the

C4/5 foramen in preoperative CT axial images between palsy group and non-palsy group. Some surgeons [6, 23, 24] noted that prophylactic C4/5 foraminal decompression can decrease the incidence of C5 palsy which supported the above opinion. Our findings revealed a significant difference in preoperative C4/5 foraminal stenosis in patients with C5 palsy and suggested that diameter of the C4/5 foramen was a risk factor for C5 palsy. Our results demonstrated that the decompression width with C5 palsy was significantly larger than that without C5 palsy (15.69 vs. 14.38 mm,  $P < 0.001$ ). This result suggested that decompression width is associated with C5 palsy. Odate et al. [25] analyzed 32 patients with postoperative C5 palsy after ACDF, they revealed that patients with C5 palsy had larger decompression width compared with non-palsy group and suggested excessive wide decompression may enhance C5 palsy development. Saunders [26] also stated that restriction of the decompression width to less than 15 mm could prevent C5 palsy after ACDF. Our results support the above hypothesis. This may result from increased root traction force caused by excessive anterior dural expansion. There had no papers investigated the relationship between C5 palsy and intervertebral height variation by now. Kawakami et al. [27] revealed that patients with improper enlargement of intervertebral height may cause axial symptom. In our study, we found that  $\geq 3$  mm intervertebral height variation may increase the incidence of C5 palsy. Excessive enlargement of intervertebral height could increase the tension of nerve root and cause root paralysis.

There are several limitations of this study. One is that our study may be limited in the sample size of C5 palsy cases, and the risk of Type 1 error is high with so few events. A larger number of patients will be required to confirm our conclusions. The other one is this is a retrospective study, although our results are statistically significant, retrospective study has inherent limitations. Hence, further studies with a prospective design are required.

In conclusion, for patients with ACDF, greater cervical curvature correction, narrow diameter of the C4/5 foramen, improper intervertebral height variation and larger decompression width were the correlative risk factors for C5 palsy after ACDF. Our findings may be valuable for

surgeons considering ACDF. Surgeons should consider proper correction of cervical curvature, decompression of C4/5 foramen stenosis, <3 mm intervertebral height variation and restriction of the decompression width to reduce the incidence of C5 palsy.

### Disclosure of conflict of interest

None.

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### References

- [1] Yoo M, Kim WH, Hyun SJ, Kim KJ, Jahng TA, Kim HJ. Comparison between Two Different Cervical Interbody Fusion Cages in One Level Stand-alone ACDF: Carbon Fiber Composite Frame Cage Versus Polyetheretherketone Cage. *Korean J Spine* 2014; 11: 127-135.
- [2] Wang Q, Cai J, Tao Y, Sun Y, Li X, Zhang Z, Fang Y, Wang J. Comparison of Clinical Outcomes of Anterior Versus Posterior Surgery in Treating Multi-segmental Cervical Degeneration. *Cell Biochem Biophys* 2015; 71: 1077-82.
- [3] Hasegawa K, Homma T, Chiba Y. Upper extremity palsy following cervical decompression surgery results from a transient spinal cord lesion *Spine (Phila Pa 1976)* 2007; 32: E197-E202.
- [4] Hashimoto M, Mochizuki M, Aiba A. C5 palsy following anterior decompression and spinal fusion for cervical degenerative diseases. *Eur Spine J* 2010; 19: 1702-1710.
- [5] Shiozaki T, Otsuka H, Nakata Y, Yokoyama T, Takeuchi K, Ono A, Numasawa T, Wada K, Toh S. Spinal cord shift on magnetic resonance imaging at 24 hours after cervical laminoplasty. *Spine (Phila Pa 1976)* 2009; 34: 274-279.
- [6] Imagama S, Matsuyama Y, Yukawa Y, Kawakami N, Kamiya M, Kanemura T, Ishiguro N; Nagoya Spine Group. C5 palsy after cervical laminoplasty: a multicentre study. *J Bone Joint Surg Br* 2010; 92: 393-400.
- [7] Nassr A, Eck JC, Ponnappan RK, Zanoun RR, Donaldson WF 3rd, Kang JD. The incidence of C5 palsy after multilevel cervical decompression procedures: a review of 750 consecutive cases. *Spine (Phila Pa 1976)* 2012; 37: 174-178.
- [8] Sakaura H, Hosono N, Mukai Y, Ishii T, Yoshikawa H. C5 palsy after decompression surgery for cervical myelopathy: review of the literature. *Spine (Phila Pa 1976)* 2003; 28: 2447-2451.
- [9] Eskander MS, Balsis SM, Balinge C, Howard CM, Lewing NW, Eskander JP, Aubin ME, Lange J, Eck J, Connolly PJ, Jenis LG. The association between preoperative spinal cord rotation and postoperative C5 nerve palsy. *J Bone Joint Surg Am* 2012; 94: 1605-1609.
- [10] Masaki Y, Yamazaki M, Okawa A, Aramomi M, Hashimoto M, Koda M, Mochizuki M, Moriya H. An analysis of factors causing poor surgical outcome in patients with cervical myelopathy due to ossification of the posterior longitudinal ligament: anterior decompression with spinal fusion versus laminoplasty. *J Spinal Disord Tech* 2007; 20: 7-13.
- [11] Minoda Y, Nakamura H, Konishi S, Nagayama R, Suzuki E, Yamano Y, Takaoka K. Palsy of the C5 nerve root after midsagittal-splitting laminoplasty of the cervical spine. *Spine (Phila Pa 1976)* 2003; 28: 1123-1127.
- [12] Yanase M, Matsuyama Y, Mori K, Nakamichi Y, Yano T, Naruse T, Sakai Y, Imagama S, Ito Z, Yukawa Y, Kamiya M, Ito K, Kanemura T, Sato K, Iwata H. Intraoperative spinal cord monitoring of C5 palsy after cervical laminoplasty. *J Spinal Disord Tech* 2010; 23: 170-175.
- [13] Hirabayashi K, Toyama Y, Chiba K. Expansive laminoplasty for myelopathy in ossification of the posterior longitudinal ligament. *Clin Orthop* 1999; 359: 35-48.
- [14] Tanaka N, Nakanishi K, Fujiwara Y. Postoperative segmental C5 palsy after cervical laminoplasty may occur without intraoperative nerve injury: a prospective study with transcranial electric motor-evoked potentials. *Spine (Phila Pa 1976)* 2006; 31: 3013-3017.
- [15] Tsuzuki N, Abe R, Saiki K, Zhongshi L. Extradural tethering effect as one mechanism of radiculopathy complicating posterior decompression of the cervical spinal cord. *Spine (Phila Pa 1976)* 1996; 21: 203-211.
- [16] Nakashima H, Imagama S, Yukawa Y, Kanemura T, Kamiya M, Yanase M, Ito K, Machino M, Yoshida G, Ishikawa Y, Matsuyama Y, Hamajima N, Ishiguro N, Kato F. Multivariate analysis of C-5 palsy incidence after cervical posterior fusion with instrumentation. *J Neurosurg Spine* 2012; 17: 103-110.
- [17] Hatta Y, Shiraishi T, Hase H. Is posterior spinal cord shifting by extensive posterior decompression clinically significant for multilevel cervical spondylotic myelopathy? *Spine (Phila Pa 1976)* 2005; 30: 2414-2419.
- [18] Kaneko K, Hashiguchi A, Kato Y, Kojima T, Imajyo Y, Taguchi T. Investigation of motor dominant C5 paralysis after laminoplasty from the results of evoked spinal cord responses. *J Spinal Disord Tech* 2006; 19: 358-361.
- [19] Hashimoto M, Mochizuki M, Aiba A. C5 palsy following anterior decompression and spinal



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- fusion for cervical degenerative diseases. *Eur Spine J* 2010; 19: 1702-1710.
- [20] Chiba K, Toyama Y, Matsumoto M, Maruiwa H, Watanabe M, Hirabayashi K. Segmental motor paralysis after expansive open-door laminoplasty. *Spine* 2002; 27: 2108-2115.
- [21] Seichi A, Takeshita K, Kawaguchi H, Nakajima S, Akune T, Nakamura K. Postoperative expansion of intramedullary high-intensity areas on T2-weighted magnetic resonance imaging after cervical laminoplasty. *Spine (Phila Pa 1976)* 2004; 29: 1478-1482.
- [22] Hojo Y, Ito M, Abumi K, Kotani Y, Sudo H, Takahata M, Minami A. A late neurological complication following posterior correction surgery of severe cervical kyphosis. *Eur Spine J* 2011; 20: 890-898.
- [23] Katsumi K, Yamazaki A, Watanabe K, Ohashi M, Shoji H. Can prophylactic bilateral C4/C5 foraminotomy prevent postoperative C5 palsy after open-door laminoplasty?: a prospective study. *Spine (Phila Pa 1976)* 2012; 37: 748-54.
- [24] Komagata M, Nishiyama M, Endo K, Ikegami H, Tanaka S, Imakiire A. Prophylaxis of C5 palsy after cervical expansive laminoplasty by bilateral partial foraminotomy. *Spine J* 2004; 4: 650-655.
- [25] Odate S, Shikata J, Yamamura S, Soeda T. Extremely wide and asymmetric anterior decompression causes postoperative C5 palsy: an analysis of 32 patients with postoperative C5 palsy after anterior cervical decompression and fusion. *Spine (Phila Pa 1976)* 2013; 38: 2184-2189.
- [26] Saunders RL. On the pathogenesis of the radiculopathy complicating multilevel corpectomy. *Neurosurgery* 1995; 37: 408-412.
- [27] Kawakami M, Tamaki T, Yoshida M, Hayashi N, Ando M, Yamada H. Axial symptoms and cervical alignments after cervical anterior spinal fusion for patients with cervical myelopathy. *J Spinal Disord Tech* 1999; 12: 50-54.