Original Article

The Use of Preoperative and Intraoperative Pavlov Ratio to Predict the Risk of Postoperative C5 Palsy after Expansive Open-Door Laminoplasty for Cervical Myelopathy

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Abstract

Background: No standard preoperative preventive measure has been established to decrease the occurrence of C5 palsy after expansive open-door laminoplasty. The aim of this study is to establish a reliable measured parameter in predicting the risk of the postoperative C5 palsy. **Materials and Methods:** A total of 276 patients receiving posterior open-door laminoplasty for cervical spinal stenotic myelopathy were studied. The patients were divided into two groups according to the preoperative Pavlov ratio (Group A: Pavlov ratio <0.65 and Group B: Pavlov ratio ≥0.65). Correlations between the occurrence of postoperative C5 palsy and Pavlov ratio were analyzed, and Group A was further tested. The surgical procedures, clinical symptoms, and Pavlov ratio were described. **Results:** The patients with Pavlov ratio <0.65 had a higher risk of developing postoperative C5 palsy ($P < 0.05$, odds ratio [OR] = 2.91). No significant difference was found in gender, age, etiology, type of operation, and pre- and postoperative Japanese Orthopaedic Association scores between patients with and without postoperative C5 palsy. The cutoff (1.01) of receiver operating characteristic curve of the postoperative Pavlov ratio of the Group A was calculated. The postoperative Pavlov ratio ≥1.01 of the patients in Group A was a significant risk factor of the development of postoperative C5 palsy ($P < 0.01$, OR = 10.83). **Conclusions:** The preoperative Pavlov ratio <0.65 at the C5 level was more likely to develop the postoperative C5 palsy. When the preoperative Pavlov ratio is <0.65, the postoperative Pavlov ratio ≥1.01 at the C5 level is a reliable predictor for the development of postoperative C5 palsy. Pavlov ratio may be one of the reasons for postoperative C5 palsy.

Keywords: *Expansive open-door laminoplasty, laminoplasty, palsy, Pavlov ratio*

Introduction

Expansive open-door laminoplasty for cervical spinal stenotic myelopathy was first devised by Hirabayashi *et al.* in 1977.[1] This technique is considered as a simple, safe, and effective way to treat multisegmental cervical spondylotic myelopathy, ossification of the posterior longitudinal ligament, and developmental cervical spinal canal stenosis.[2]

Complications after cervical laminoplasty including axial pain, segmental instability, and C5 palsy have been reported.[3-5] C5 palsy after cervical laminoplasty is defined as paresis of deltoid muscle and/or the biceps brachii muscle without any deterioration of myelopathy symptoms. Patients with C5 palsy suffer sensory deficits, constant pain in shoulder region–C5 dermatome area, muscle weakness, and motor weakness.[6-8] The incidence of C5 palsy following cervical expansive open-door laminoplasty has been reported to be 4.6% on an average.[6] Nassr *et al.* reported that the incident of C5 palsy after cervical spine decompression was 6.7%.[9] Chang *et al.* investigated that patients undergoing combined anterior-posterior decompression surgery had the highest incidence of C5 palsy.[10]

Pavlov ratio is defined as the sagittal diameter of the spinal canal to that of the vertebral body.[11,12] A retrospective study was conducted by Sieh to analyze the risk of postoperative upper limb palsy. The Pavlov ratio <0.65 was simple and reliable preoperative predictor for the development of cervical nerve root palsy.[13]

However, there is no reliable measured radiological parameter in predicting the occurrence risk of postoperative C5 palsy.

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This retrospective study analyzed the preoperative and postoperative Pavlov ratio of C5 level and aimed to describe the feature of Pavlov ratio and identify the preoperative and postoperative predictor for the development of C5 palsy.

Materials and Methods

A retrospective study of 276 patients undergoing posterior laminoplasty for cervical spinal stenotic myelopathy from 2010 to 2015 in our Hospital was conducted. Patients were excluded if they had an infection, spondylolisthesis (>2.00 mm), an acute trauma, or preoperative C5 deficit without a new postoperative symptom of C5 palsy. The patients with newly developed postoperative deterioration of motor function in standard manual muscle testing and/or new sensory disturbance and dysesthesia with dermatomal distribution (deltoid and biceps brachii muscle) were included in the study. The patients were divided into two groups according to the preoperative Pavlov ratio (Group A: Pavlov ratio <0.65 and Group B: Pavlov ratio ≥0.65). Sixty-seven patients presented with preoperative Pavlov ratio <0.65 in Group A and 209 patients presented with preoperative Pavlov ratio ≥0.65 in Group B.

The surgical procedures of expansive open-door laminoplasty

The surgical procedures used in this study have been described in previous studies[14,15] and are detailed as follows with some modification. A posterior midline longitudinal approach was made from the caudal edge of C2 to the cranial edge of T1. The paraspinal muscles were separated from the spinous processes. On the hinge side, the outer cortex was removed using high-speed spherical cutting burr to make a trough. The hinge side was decided by the side of symptoms or the side of stenosis. On the open side, the outer cortex and cancellous bone were removed using a high-speed spherical cutting burr. Moreover, the remaining inner cortex was removed using a 1 mm laminal forceps. The spinous processes were cut short. The facet joint was protected from violation. The ligament flavum between the C2 and C3 vertebrae and C7 and T1 vertebrae was removed. Then, the laminae from C3 to C7 were opened by a scalp clip applier. Moreover, the underlying ligament flavum on the open side was divided. Each lamina was fixed with a 4-hole miniplate and with two miniscrews at each site at the C2 to C7 levels that prevented the door from being closed. The patients were taught to perform neck extension exercises while protected by the collar.

The clinical symptoms of C5 palsy and Japanese Orthopedic Association score

C5 palsy after cervical laminoplasty is defined as paresis of deltoid muscle and/or the biceps brachii muscle without any deterioration of myelopathy symptoms. Japanese Orthopaedic Association (JOA) score[16] was applied to evaluate the severity of clinical symptoms. Preoperative and postoperative JOA scores and the recovery rates were calculated by the first author.

Recovery rate (%) = (postoperative score − preoperative score)/(17 − preoperative score) × 100%.

Pavlov ratio

Radiologic parameters included the sagittal diameter of the spinal canal (preoperative: A, postoperative: C) and the sagittal diameter of the vertebral body (B) [Figure 1].[11,12] The sagittal diameter of the spinal canal and the vertebral body were measured by Carestream's Vue PACS. The Pavlov ratios of patients at C5 level and the average Pavlov ratios were calculated. The spinal canal/vertebral body ratio was determined with the formula A (C)/B as Pavlov ratio.

Statistical analysis

The differences in demographic characteristics and radiologic parameters before and after operation were tested by *t*-test and χ^2 tests as appropriate. Continuous data such as age, JOA scores, and Pavlov ratio were compared between the two groups by *t*-test. Categorical data were assessed with the Chi-square test. Univariate analyses were performed to estimate the odds ratios. Statistical significance was defined by $P < 0.05$. All statistical analyses were performed using SPSS version 19.0 (SPSS Inc, Chicago, USA).

Results

In Group A, 67 patients presented with preoperative Pavlov ratio <0.65 and postoperative C5 palsy occurred in 19 cases with newly developed symptoms of C5 palsy, so the incident rate was 28.36% [Table 1]. In Group B, 209 patients presented with preoperative Pavlov ratio ≥0.65 and postoperative C5 palsy occurred in 25 cases, so the incident rate was 11.96%. The comparison analysis showed that the incident rate of postoperative C5 palsy in Group A

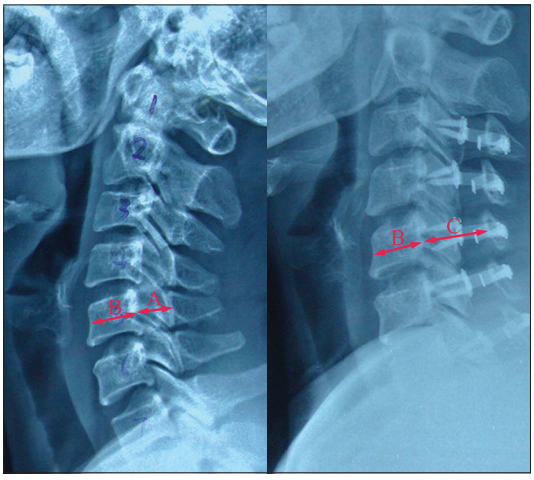

Figure 1: Measurements of the sagittal diameter of the spinal canal (preoperation: A; postoperation: C) from the posterior point of the corresponding spinal laminar line. The measurement of the sagittal diameter of the vertebral body (B) at the midpoint, from the anterior surface to the posterior surface

was significantly higher than the control group (χ^2 = 10.18, P < 0.01, odds ratio [OR] = 2.91) [Table 1]. Patients with preoperative Pavlov ratio <0.65 were more likely to develop postoperative C5 palsy after expansive open-door laminoplasty.

In Group A, the cutoff of receiver operating characteristic (ROC) curve of the postoperative Pavlov ratio of the 67 patients was 1.01, the sensitivity was 0.68, and the specificity was 0.83 [Figure 2]. According to the cutoff of ROC curve of the postoperative Pavlov ratio, the patients were divided into two groups (postoperative Pavlov ratio ≥1.01 and postoperative Pavlov ratio <1.01). There were no significant differences in gender, age, etiology, type of operation, and pre- and postoperative JOA scores between two groups (P < 0.01) [Table 2]. The postoperative Pavlov ratio of 21 patients with preoperative Pavlov ratio <0.65 was ≥1.01 after the expansive open-door laminoplasty, and 13 of them developed postoperative C5 palsy, and the incidence was 61.90% [Table 3]. Between the two groups, the patients with postoperative Pavlov ratio ≥1.01 had a significant higher incidence of C5 palsy than those with postoperative Pavlov ratio <1.01 (χ^2 = 16.94, P < 0.01, OR = 10.83) [Table 3]. When the preoperative ratios of the patients were <0.65, the patients with postoperative Pavlov ratio ≥1.01 were more likely to develop postoperative C5 palsy.

In Group A, 19 patients presented with preoperative Pavlov ratio <0.65 and developed postoperative C5 palsy. The mean Pavlov ratio of patients before surgery was 0.63 in C5 level (standard deviation = 0.03), and the postoperative mean Pavlov ratio at the same level was 1.02 (standard deviation = 0.07) [Table 4]. In Group A, 48 patients presented with preoperative Pavlov ratio <0.65 and did not develop postoperative C5 palsy. The mean preoperative Pavlov ratio of patients without postoperative C5 palsy was 0.64 (standard deviation = 0.03), and the mean postoperative Pavlov ratio was 0.80 (standard deviation = 0.04) (C5 level) [Table 4]. In Group A, according to the analysis of preoperative and postoperative Pavlov ratio of the patients with and without C5 palsy, the postoperative statistical data between the two groups had statistical significance (t = 2.18, P = 0.03), while the preoperative statistical data had no statistical significance (t = −1.73, P = 0.09) [Table 4].

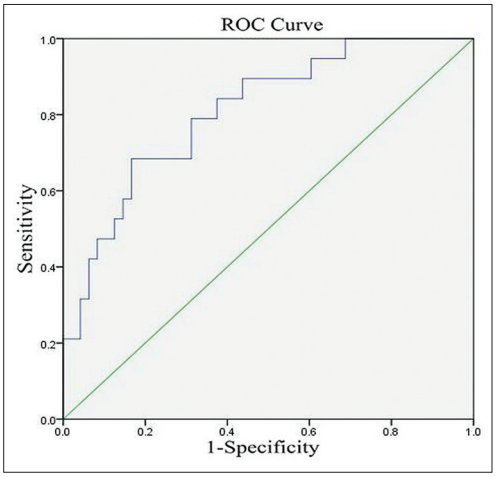

Figure 2: The receiver operating characteristic curve of the postoperative Pavlov ratio of Group A. The cutoff was 1.01, the sensitivity was 0.68, and the specificity was 0.83

Discussion

The researchers have focused on C5 palsy after expansive open-door laminoplasty for several decades, but pathogenesis and preventive measures of this complex complication are still controversial. Komagata *et al*. had reported that the patients undergoing bilateral partial foraminotomy showed lower incidences of C5 palsy.[17] A prospective study by Katsumi investigated that open-door laminoplasty concomitant with prophylactic C4/5 foraminotomy significantly decreased the incidence of C5 palsy.[18] The intraoperative neurophysiologic monitoring was used to detect iatrogenic injury to the C5 nerve that innervates deltoid and biceps during cervical procedures, but patients remain at risk for C5 palsy.[19,20] Retrospective review studied by Thomas determined that the combination of preoperative anteroposterior diameter, foraminal diameter, and cord-lamina angle could predict the development of postoperative C5 palsy after decompression surgery for patients with cervical spondylotic myelopathy.[7] Kurakawa *et al*. showed that a correction angle exceeding 20° of cervical posterior

Table 1: The comparison of incident rate of C5 palsy between two groups

Groups	Group A	Group B
Cases (*n*)	67	209
Cases with C5 palsy	19	25
Cases without C5 palsy	48	184
Incident rate (%)	28.36	11.96
χ^2	10.18	
P	<0.01	
OR	2.91	

OR=Odds ratio

Table 2: Demographic data of patients

Groups	Pavlov ratio ≥1.01 (21)	Pavlov ratio <1.01 (46)
Sex (male/female)	11/10	11/7
Mean age (Years)	60.1	57.6
Disease etiology (%)		
CSM	15 (71.4)	31 (67.4)
OPLL	6 (28.6)	15 (32.6)
Mean preoperative JOA score	11.36	11.18
Mean postoperative JOA score	14.47	14.12
Recovery rate (%)	55.14	50.52

CSM=Cervical spondylotic myelopathy, OPLL=Ossification of the posterior longitudinal ligament, JOA=Japanese Orthopaedic Association

instrumented surgery was critical for developing the C5 palsy (C4/5 foraminal diameter reached 4.1 mm), and there was a higher risk when the C4/5 foraminal diameter was <2.7 mm regardless of any correction.[21] A study of consecutive case series showed that cervical compressive myelopathy patients with anterolisthesis of C4 were at increased risk of severe postoperative C5 palsy after laminoplasty and reduction with posterior instrumentation.[22] Radcliff *et al*. reported that a wider laminectomy at C5 and increased preoperative spinal canal diameter were associated with increased risk of C5 palsy, and patients who experienced C5 palsy had a greater posterior spinal cord drift.[23] Otherwise, Klement suggested that laminectomy width was not associated with an increased risk of postoperative C5 palsy at any level.[24] Hence, the spinal cord drift was a significant risk of postoperative C5 palsy, and the foraminal diameter was associated with C5 palsy of cervical posterior instrumented surgery. However, there was inconsistent suggestion whether the laminectomy width was associated with the risk of postoperative C5 palsy.

Pavlov ratio was significantly lower in patients with cervical spondylotic (mean 0.72 ± 0.08), so Pavlov ratio could be used to predict the development of cervical spondylotic myelopathy.[25] Indeed, it was reported that a cervical Pavlov ratio of 0.8 could be regarded as the presence of cervical spinal stenosis.[11] Average Pavlov ratio <0.65 was regarded as a reliable predictor for the development of postoperative upper limb palsy and those patients are defined as having extremely narrow spinal canal.[13] Hence, the patients were divided into two groups according to preoperative Pavlov ratio. It was demonstrated that the patients having preoperative Pavlov ratio of <0.65 had a significantly higher risk of developing postoperative C5 palsy. Moreover, there was a higher rate of postoperative C5 palsy in patients with preoperative Pavlov ratio of <0.65 and postoperative Pavlov ratio of >1.01.

Table 3: The comparison analysis of postoperative Pavlov ratio and C5 palsy

Groups	Pavlov ratio ≥1.01	Pavlov ratio <1.01
Cases (*n*)	21	46
Cases with C5 palsy	13	6
Patients without C5 palsy	8	40
Incident rate (%)	61.90	13.04
χ^2	16.94	
P	<0.01	
OR	10.83	

OR=Odds ratio

When patients are fit for expansive open-door laminoplasty, preoperative measures and calculation of Pavlov ratio can be used to predict the risk of postoperative C5 palsy. After the laminoplasty, intraoperative real-time X-ray verifies the Pavlov ratio again [Figure 3]. We measured the sagittal diameter of the vertebral body (B) and the sagittal diameter of the spinal canal (C) and then calculate the Pavlov ratio in real time. If this intraoperative Pavlov ratio is >1.01, then this patient was likely to develop postoperative C5 palsy. Hence, we considered to reducing the size of hinge opening. The intraoperative sagittal diameter of the spinal canal should be limited to <1.01-fold of the sagittal diameter of the vertebral body. Those intraoperative measures could be decrease the risk of postoperative C5 palsy. However, the flexibility of adjusting the suboptimal expansive laminoplasty can be achieved only by the proficiency of the surgeon.

Postoperative C5 palsy is a common complication after expansive open-door laminoplasty. Those patients with cervical stenotic myelopathy and ossification of the posterior longitudinal ligament, especially accompanied with preoperative Pavlov ratio <0.65, should accept expansive open-door laminoplasty. The postoperative Pavlov ratio could be <1.01, and preoperative and intraoperative measurement maybe be a simple and reliable way to predict the risk of C5 palsy. Decreased pavlov ratio may be one of the reasons for postoperative C5 palsy.

Despite the fact our study presented a potential risk predictor of C5 palsy, several limitations were also present

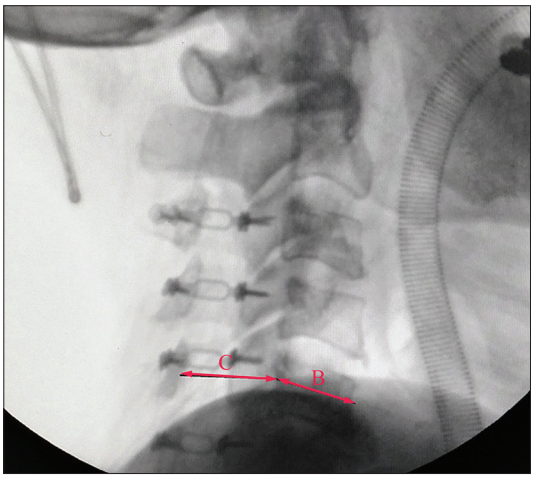

Figure 3: The intraoperative real-time X-ray. The sagittal diameter of the vertebral body (B), the sagittal diameter of the spinal canal (C)

Table 4: The characteristics between patients with and without C5 palsy (level C5)

Groups	Patients with C5 palsy (19)		Patients without C5 palsy (48)		*t*/*P* between 2 groups	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Average number	0.63	1.02	0.64	0.80	−1.73	2.18
SD	0.03	0.07	0.03	0.04	0.09	0.03

SD=Standard deviation

in our study. Small population size is the drawback of the current study, further only radiographs were used in this study to measure the Pavlov ratio. Moreover, in obese patients with short neck, the real-time lateral images distal to C5 may not be easily obtained and the value of intraoperative Pavlov ratio may be limited. Inspite of these drawbacks, our study demonstrates that by using preoperative and intraoperative measurement of Pavlov ratio one is able to control the postoperative Pavlov ratio (<1.01) of expansive open-door laminoplasty thus reducing the risk of postoperative C5 palsy. This suggested that preoperative and intraoperative radiological parameters provide some beneficial information with predicting postoperative C5 palsy.

Conclusions

Postoperative C5 palsy is a significant complication of expansive open-door laminoplasty. The patients with the preoperative Pavlov ratio <0.65 at the C5 level were more likely to develop the postoperative C5 palsy. If the patient has preoperative Pavlov ratio <0.65, and postoperative Pavlov ratio ≥1.01 it is a reliable predictor for the development of postoperative C5 palsy. Postoperative Pavlov ratio should be kept maximum as 1.01 for prevention of C5 palsy. Preoperative and intraoperative measures can be used to predict postoperative C5 palsy. The intraoperative sagittal diameter of the spinal canal should be limited to <1.01-fold of the sagittal diameter of the vertebral body to decrease the risk of postoperative C5 palsy.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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