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Correlations of the Laminectomy Width and C5 Palsy After Open-Door Cervical Laminoplasty

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ABSTRACT

AIM: To examine the risk factors for postoperative C5 palsy, particularly an association between the laminectomy width and C5 palsy after open-door cervical laminoplasty (CLP).

MATERIAL and METHODS: This single-center study analyzed data from 132 adult patients who underwent open-door CLP for degenerative diseases. C5 palsy developed in 8 (6.1%) patients, although seven of them made a full recovery. The demographic and radiographic findings of the C5 palsy group were compared with those of the non-C5 palsy group.

RESULTS: The laminectomy width did not correlate with the incidence of C5 palsy (C5 palsy group, 19.39 ± 1.86 mm; non-C5 palsy group, 20.77 ± 2.61 mm, $p > 0.05$). The preoperative T2-high lesion in the spinal cord on magnetic resonance imaging was present in 62.5% of the patients in the C5 palsy group, whereas it was positive in 20.3% in the non-C5 palsy group ($p = 0.021$). The mean C4/5 foraminal minimal distances on the open side were 2.42 and 3.58 mm in the C5 and non-C5 palsy groups, respectively ($p = 0.001$). These variables might be risk factors for C5 palsy.

CONCLUSION: The laminectomy width was not associated with the incidence of C5 palsy. The risk factors for C5 palsy were the preoperative T2-high lesion in the spinal cord and C4/5 foraminal stenosis on the open side after open-door CLP.

KEYWORDS: Laminoplasty, Foraminal stenosis, Laminectomy width, C5 palsy

INTRODUCTION

After open-door cervical laminoplasty (CLP), C5 palsy developed in 4.3% of the patients (1). The pathophysiology remains inconclusive regardless of the proposed hypotheses about C5 palsy (2,14). C5 palsy was supposed to be caused mainly by segmental spinal cord disorder and nerve root injury (3). However, the best procedure for C5 palsy prevention has not been established (6). In particular, few studies have reported about the association between the laminectomy width (LW) and C5 palsy (11-13,16,20). Preexisting C4/5 foraminal stenosis (FS), ossification of the posterior longitudinal ligament (OPLL), surgical procedures (laminectomy), posterior spinal cord shift, and male sex have all been mentioned as risk factors for C5 palsy (2,4). Herein, we retrospectively examined the risk factors of C5 palsy after open-door CLP.

MATERIAL and METHODS

Shin Yurigaoka General Hospital Institutional Review Board approved this study (No. 20221128-8).

Study Design and Patient Selection

In a single institution, 195 adult patients who underwent open-door CLP for cervical radiculopathy or myelopathy caused by spondylosis, developmental spinal canal stenosis, and OPLL between January 2015 and October 2021 were retrospectively reviewed. The exclusion criteria were as follows: 1) double-door CLP was performed; 2) C5 laminoplasty was not performed; 3) demyelinating diseases, trauma, hematoma, reoperation, and post-infection cases were present; 4) preexisting C5 palsy or intraoperative direct C5 root injury were present; and 5) C4/5 foraminotomy was performed simultaneously. Finally, the

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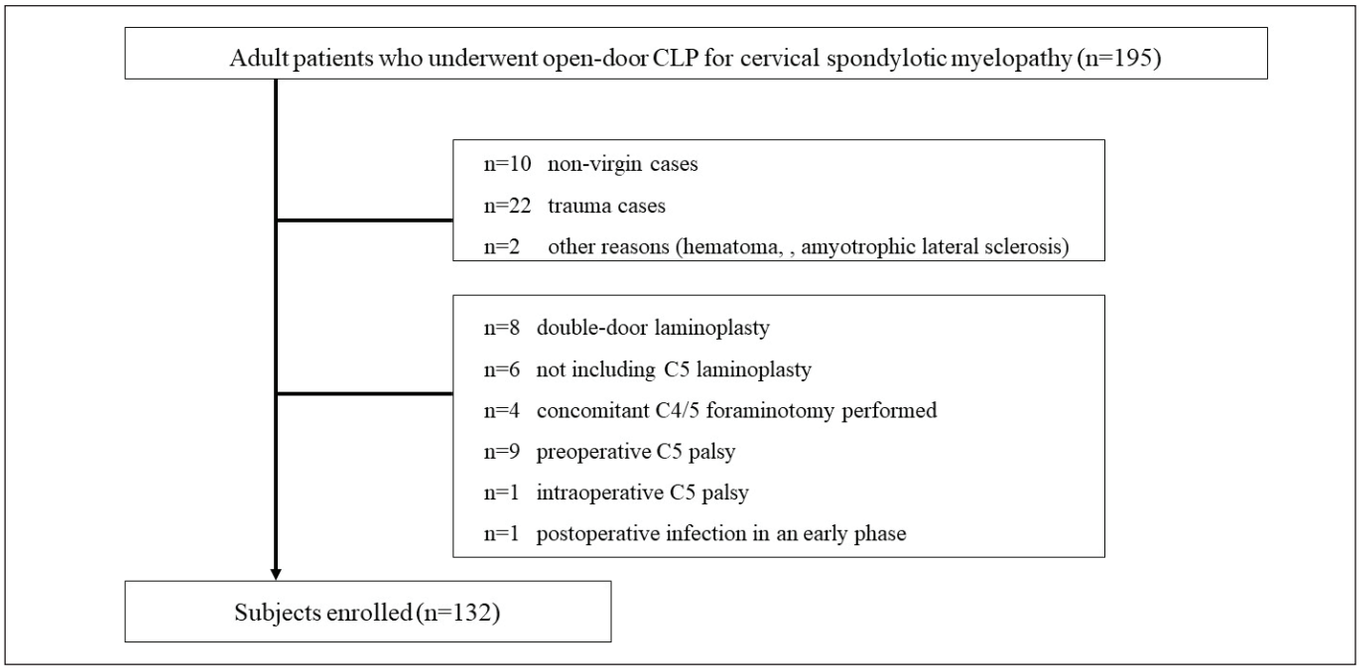

Figure 1: The study's inclusion criteria.

study included 132 patients including 99 men and 33 women (Figure 1). These patients were between 25–86 (mean 69.3) years old. Each patient underwent CLP from C3 to C7 levels.

Terms Definition

C5 palsy was defined as new postoperative paresis (manual muscle test [MMT] ≤ grade 3 of 5 points) of the deltoid muscle. The day of surgery was defined as day 0. "T2-high lesion" was judged as positive when the signal change in the spinal cord was present between the C3 and C5 in the spinal cord on the preoperative T2-weighted magnetic resonance imaging (MRI).

Surgical Procedure

Several surgeons certified by the Neurospinal Society of Japan performed the procedures. After traditional open-door CLP, bilateral laminae were exposed, and the gutter was made just medial to the lateral mass on the open side. The open side was normally the left side, unless the symptoms were more severe on the right side. Appropriate-sized titanium spacers ((Basket 1 or Basket 2; 8, 10, or 12 mm length; Ammtec Co., Tokyo, Japan; Figures 2A, B), filled with the artificial bone consisting of hydroxyapatite and atelocollagen (ReFit; HOYA Technosurgical, Tokyo, Japan), were inserted between the elevated laminae and the lateral masses and fixed with miniscrews. All patients wore a soft cervical collar for one week postoperatively.

Data Collection

Radiographic measures were taken from computed tomography (CT) images used with the picture archiving and communication system (ShadeQuest/Serv; FUJIFILM Medical Solutions Corporation, Tokyo, Japan). Then, 3-mm transverse slices parallel to the endplates were utilized to obtain preoperative and postoperative CT images. On the next day after CLP, X-ray or CT images were examined. The C2–7 angle refers to the angle between the C2 and C7 lower endplates of the vertebral body. We referred difference between the pre- and postoperative C2–7 angles as the "C2–7 angle difference." The anteroposterior diameter of the C4/5 foramen at its narrowest portion is measured to assess the "foraminal minimum distance (FMD) on the open side" (Figure 2C, a1, a2). The "C5 facet distance" is the distance between the medial lines of both facets (Figure 2C). "C5 LW" is measured as the LW of each inner cortex (spinal canal side) after open-door CLP. "C5 open angle" present as the angle between the line linked with the center of the bilateral vertebral foramen and the line with the inner cortical edges of the elevated laminae (Figure 2D).

Statistical Analysis

Statistical analysis was conducted using R version 4.1.2 software (Free Software Foundation's GNU General Public License, MA, USA). The normality of the distribution of continuous variables was assessed using the Shapiro-Wilk test. The C5 and non-C5 palsy groups were compared using an unpaired t-test (normally distributed variables) or the Wilcoxon rank-sum exact test (non-normally distributed) for continuous variables and using the Chi-squared or Fisher's exact test for categorical variables. Normally distributed variables were described as mean ± the standard deviation of the mean. Non-normally distributed variables were described as median (interquartile range; 25%, 75%). In each analysis, a p-value level of <0.05 was regarded as statistically significant.

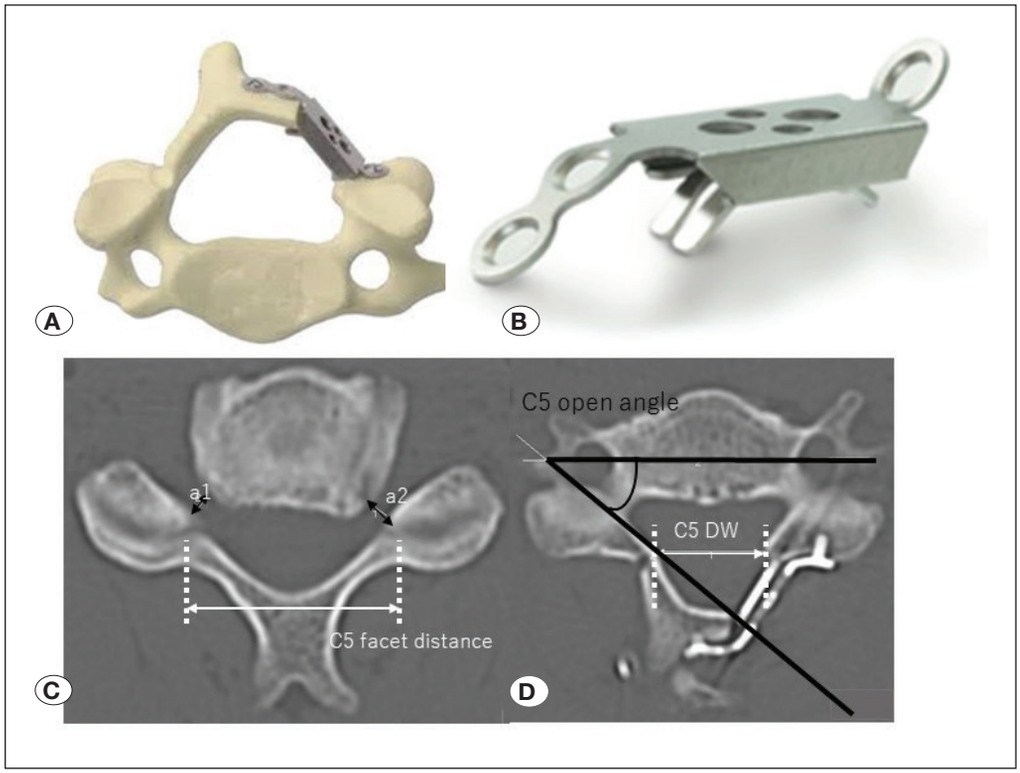

Figure 2: A, B) Basket 2 system. **C)** Preoperative and **D)** postoperative CT axial images. "foraminal minimal distance on the open side" is measured as the anteroposterior diameter of the C4/5 foramen at the narrowest portion (C; a1, a2). "C5 facet distance" is the distance between the medial lines of both facets (white dots line; D). After open-door laminotomy, "C5 LW" is calculated as the laminectomy width of each inner (spinal canal side) cortex (white dots line). The angle between the line connecting the bilateral vertebral foramen's centers and the line connecting the inner cortical edges of the raised lamina is referred to as the "C5 open angle" (D).

Table I: Clinical Features of Eight Cases with Postoperative C5 Palsy

No	Age	Sex	CLP	LN	Palsy side /Open side	Onset (day)	MMT (points)	Recovery (week)	Steroid use	T2 high	C5 DW (mm)	C5 OA (degrees)	C5 FD (mm)	FS open (mm)	FS hinge (mm)
1	75	F	C4-6	C3, C7	Rt / Lt	2	3→5	8	-	+	21.13	33.37	29.27	1.68	2.31
2	71	M	C4-6	C3	Lt /Lt	3	3→5	5	-	+	20.45	45.19	25.21	1.41	1.83
3	83	M	C4-6	C3	Rt / Lt	4	3→5	1	-	-	17.9	45.86	29.13	2.24	2.77
4	80	M	C4-5	C3, C7	Lt /Lt	1	2→5	NA	-	+	18.27	31.13	29.6	3.9	1.77
5	60	M	C4-6	C3	Lt /Lt	5	3→5	15	-	-	20.05	49.61	26.17	3.21	3.1
6	53	M	C4-6	C3	Lt /Lt	1	3→5	11	+	+	18.03	43.03	28.78	2.46	1.64
7	74	M	C4-6	C3	Rt / Lt	1	2→5	3	-	-	16.99	44.82	28.47	2.7	2.49
8	68	M	C4-6	C3, C7	Lt /Lt	1	3→5	16	+	+	22.3	41.95	27.42	1.75	3.14

***CLP:** Cervical laminoplasty, **DW:** Decompression width, **FD:** Facet distance, **FS:** Foraminal stenosis, **LN:** Laminotomy, **MMT:** Manual muscle test, **NA:** Not assigned, **OA:** Open angle.*

RESULTS

Of the 132 patients, 8 (6.06%) had C5 palsy, which emerged 2.25 ± 1.48 days and developed dominantly on the open side (62.5%). Only one patient was lost to follow-up. In seven cases—except for case 4—C5 palsy resolved within 4 months. Table I contains a summary of all data.

Table II demonstrates the baseline demographic and radiographic characteristics of each group. The LW did not correlate with the incidence of C5 palsy (19.39 ± 1.86 and 20.77 ± 2.61 mm in the C5 and non-C5 palsy groups, respectively, p>0.05). The preoperative T2-high lesion in the spinal cord was present in 62.5% of the patients in the C5 palsy group, whereas it was positive in 20.3% in the non-C5 palsy group (p=0.021). In addition, the mean C4/5 FMDs on the open side were 2.42 and 3.58 mm in the C5 and non-C5 palsy groups, respectively (p=0.001). Thus, the presence of the preoperative "T2-high lesion" (p=0.021) and "FMD on the

Table II: Radiographic Variables Between Individuals with and without C5 Palsy

Variables	Non-C5 palsy group n=124	C5 palsy group n=8	p-value
Age (years)	63.0 (71, 79)	61.5 (71, 77)	0.753*
Male (%)	92 (74.2)	7 (87.5)	0.674***
LP number	3 (2, 3)	3 (3, 3)	0.541*
LN number	2 (2, 2)	2 (2, 2)	0.553*
OPLL (%)	35 (28.2)	2 (25.0)	1***
Spondylolisthesis (%)	13 (10.6)	0 (0)	0.72***
T2-high lesion (%)	25 (20.3)	5 (62.5)	0.021***
C5 LW (mm)	20.77 ± 2.61	19.39 ± 1.86	0.146**
C5 open angle (degrees)	43.03 ± 8.03	41.87 ± 6.38	0.689**
C5 facet distance (mm)	29.31 (28.43, 29.99)	28.87 (27.59, 29.53)	0.158*
C5 LW/C5 facet distance (%)	0.72 ± 0.10	0.70 ± 0.09	0.473**
Hinge fracture (%)	29 (23.4)	1 (12.5)	0.782***
FMD on the open side (mm)	3.32 (2.70, 4.14)	3.46 (2.87, 3.98)	0.001*
C2-7 angle difference (degrees)	-1.55 (-4.11, 2.46)	-1.05 (-6.42, 3.47)	0.447*

** Wilcoxon rank sum exact test, **Unpaired t-test*
**** Chi-squared test or Fisher's exact test*
Normally distributed continuous variables; Mean ± the standard deviation
Not normally distributed continuous variables; Median (IQR; 25%, 75%)
***LP:** Laminoplasty, **LN:** Laminotomy, **OPLL:** The ossification of the posterior longitudinal ligament, **LW:** Decompression width, **FMD:** Foraminal minimum distance, **IQR:** Interquartile range.*

open side" (p=0.001) may be significantly different between the two groups. No correlations were observed in the numbers of CLP or laminectomy and the presence of OPLL, spondylolisthesis, or hinge fractures. Other radiographical variables including "C5 open angle," "C5 facet distance," and "C2–7 angle difference" did not influence the incidence of C5 palsy.

In the non-C5 palsy group, all patients showed improvement with more than "fair" outcomes using the Odom criteria. No major postoperative problems or implant-related issues occurred in either group.

DISCUSSION

In this study, the LW did not correlate with the incidence of C5 palsy. The relationship between LW and C5 palsy is still being debated. The postoperative C5 palsy rate increased with wider laminectomy (11-13), whereas no significant differences were found between the narrow and wide laminectomy groups (20). In a previous study, a bony gutter made across the most medial portion of the facet joint may cause C5 palsy because an extended procedure time could increase the risk of heat injury; therefore, all their cases involved C5 palsy that occurred on the open side (12). Studies have also debated the occurrence of C5 palsy after cervical laminectomy with fusion (9,17). A width of 19 mm in laminectomy accompanied by foraminotomy was recommended, given that the mean spinal cord transverse diameter is 13 mm (16). No other studies have reported an obvious LW cutoff. The objective of CLP is to achieve sufficient decompression of the spinal cord; thus, the gutter should be positioned as lateral to the spinal cord edges as possible (13).

In this study, one of the risk factors of C5 palsy was the preoperative T2-high lesion in the spinal cord on MRI. A theory for this is acute reperfusion of the spinal cord (1,3). T2-high lesions reflect various changes in the gray matter, such as nonspecific edema, inflammation, ischemia, gliosis, and myelomalacia (1,3). Long-standing severe impairment of the spinal cord blood flow, followed by acute reperfusion, and hyperemia may lead to further damage, and such circulation changes may affect anterior horn cells and synapses and eventually cause paralysis (1). In our cases, the ratio of patients with preoperative T2-high lesions was significantly higher in the C5 palsy group than in the non-C5 palsy group, suggesting that the T2-high lesion may reflect ischemia.

This study also clarified that C4/5 FS on the open side was another risk factor for C5 palsy. Another possible hypothesis is that preexisting FS results in postoperative root injury (4). The C5 nerve root is anatomically shorter than the other nerve roots and is located in the center of the cervical lordosis; therefore, it was thought to cause nerve root tethering by the

posterior shifting of the spinal cord (4,5,21). A diameter of the C4/5 foramen of ≤2 mm was significantly related to C5 palsy (10). Compressed nerve roots may be sensitive and vulnerable to reperfusion after ischemia (10). The preoperative cross-sectional area of the C5 nerve root on the affected side was significantly enlarged in the C5 palsy group than in the non-C5 palsy group (18). They insisted that the kink in a swollen nerve root caused by deteriorated venous perfusion and intraneural edema became more severe when the posterior shift of the spinal cord happened after CLP (18). However, prophylactic foraminotomy could not prevent it completely (7).

As shown in Table I, C5 palsy occurred in an early postoperative phase and recovered gradually in most cases. C5 palsy usually manifested within 3 days postoperatively, and more than half of patients with C5 palsy recovered within 6 months (14). The prognosis was often good in the absence of subsequent surgery, although the recovery time varied depending on the severity of motor weakness (19). Patients with a deficit with MMT of grade ≤3 of 5 points had a ≤50% chance of full recovery (15,19). In addition, compared with C3C6 CLP, C5 palsy in patients with C4–C6 CLP demonstrated fewer symptoms and quicker recovery (22). In our samples, two patients with MMT of grade ≤3 of 5 points could achieve a full recovery. C5 palsy occurred unilaterally in 93%–95% of the patients (5).

Furthermore, some arguments have been raised for C5 palsy between open-door and double-door CLP. The incidence of C5 palsy was 4.3% and 3.1% in open-door and double-door CLPs, respectively (2). Moreover, asymmetric decompression by open-door CLP might introduce imbalanced rotational movement of the spinal cord (6). However, the CLP type had less influence on biomechanical changes, posterior shift of the spinal cord, and nerve root displacement for C5 palsy development (8).

The sample size is a key limitation. Gathering more cases is challenging; thus, a more comprehensive nationwide study is desired.

CONCLUSION

The LW did not correlate with the occurrence of C5 palsy. Moreover, the presence of the preoperative T2-high lesion in the spinal cord and C4/5 FS on the open side were risk factors for C5 palsy after open-door CLP.

Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: KD, JM
Data collection: KD
Analysis and interpretation of results: KD
Draft manuscript preparation: KD
Critical revision of the article: KS, TO, ST
All authors (KD, TO, KS, ST, JM) reviewed the results and approved the final version of the manuscript.

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