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ORIGINAL ARTICLE

The relationship between laminoplasty opening angle and increased sagittal canal diameter and the prediction of spinal canal expansion following double-door cervical laminoplasty

Zhen-fang Gu · Ai-li Zhang · Yong Shen · Wen-yuan Ding · Feng Li · Xian-ze Sun

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Abstract

Purpose To clarify the relationship between laminoplasty opening angle (LOA) and the increase in sagittal canal diameter (SCD) in double-door cervical laminoplasty (DDCL) and to predict the increase in SCD using the resulting formula.

Methods We analyzed 20 patients with multilevel cervical spondylotic myelopathy who underwent DDCL between September 2010 and January 2013. The pre- and post-operative parameters of the cervical spinal canal were measured by computed tomography. We deduced a formula describing the relationship between LOA and the increase in SCD and used it to predict the increase in SCD of these patients as LOA increased.

Results When the C3–C7 LOA was 25°–45°, the magnitude of the increase in SCD was notable (increases of 3.08–5.6 mm compared with the pre-operative SCD). When the C3–C7 LOA was more than 45°, the magnitude of the increase in SCD was relatively smaller; the increase in C3–C7 SCD with a 55° LOA was merely 0.4 mm more than with a 45° LOA. When LOA was 30° at C3–C6 or 40° at C7, the increase in SCD was more than 4 mm. When the C3–C6 LOA was 40°, SCD increased by more than 5 mm.

Conclusions The formula accurately showed the relationship between LOA and the increase in SCD in DDCL. Based on the LOA, increases in SCD following C3–C7 laminoplasty can be accurately predicted using this formula. This enables DDCL based on accurate individual LOAs, which prevents inadequate or excessive opening.

Keywords Cervical spine · Laminoplasty opening angle · Spinal canal · Sagittal diameter · Cross-sectional area

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Introduction

Double-door cervical laminoplasty (DDCL) has become a widely accepted treatment for patients with multilevel cervical compression myelopathy resulting from cervical spondylotic myelopathy (CSM), ossification of the posterior longitudinal ligament, and cervical stenotic myelopathy. The short- and long-term results have been satisfactory. It is also considered to be a relatively safe procedure with a low complication risk [1–9].

In a DDCL, the spinous processes and laminae are centrally split with a burr or a threadwire saw (T-saw), and lateral hinges are created at the medial borders of the facet joints. The laminae are opened to both sides, and spacers are inserted to hold the laminae apart [10, 11]. DDCL preserves the lamina and the activity and stability of the cervical spine. The procedure expands the diameter and volume of the spinal canal by placing the bilateral laminae in a more posterior position, which alleviates posterior spinal cord compression. Because the spinal cord shifts backward, anterior compression is indirectly relieved, which enhances blood circulation of spinal cord. In this procedure, the laminoplasty opening angle (LOA) largely determines the magnitude of resulting canal expansion.

However, the precise relationship between the LOA and the increase in sagittal canal diameter (SCD) following laminoplasty remains less well understood.

The purpose of this study was to clarify this relationship using a formula deduced from trigonometry.

Materials and methods

Patient data

We included 20 patients (12 men and 8 women) with multilevel CSM who underwent DDCL (C3–C7 in 9 patients and C3–C6 in 11 patients) at The Third Hospital of Hebei Medical University between September 2010 and January 2013. The average age of the patients at surgery was 58.6 years (range 38–75 years). The median duration of symptoms before the operation was 6.1 months (range 5–92 months). In all patients, a clear history of functional loss and physical findings consistent with CSM were present; they had all received conservative treatment for more than 3 months, which was found to be ineffective. All patients had a cervical lordosis angle greater than 10°, and magnetic resonance imaging confirmed cervical disk herniation or spinal canal stenosis at three or more intervertebral levels with spinal cord compression. This study was approved by the Investigational Review Board at The Third Hospital of Hebei Medical University, and informed consent was obtained from each patient.

Formula deduction

The pre- and post-operative morphologic changes in the cervical spinal canal were studied, and the formula describing the relationship between LOA and the increase in SCD was deduced using trigonometry (refer to Fig. 1). Points E and F represent the most medial points of the bilateral hinge gutters, horizontally connected by line EF. Line OA represents a sagittal line through the midpoint (O) of the posterior surface of the vertebral body, with point A representing the split points before surgery. Points C and G represent the split points after surgery, with the line CG connecting these points. Lines CE and GF are oblique lines connecting the medial points of the lateral gutters and the split points after surgery. Line OA intersects the inner edge of the lamina at point A before surgery and line CG at point M after surgery. Vertical lines made through points A and C intersect the line EF at points B and D, respectively.

The distance between points C and D and points M and B is equal; the increase in post-surgical SCD (represented by symbol d in the formula below) was defined as the difference between the lengths of lines MB and AB, a

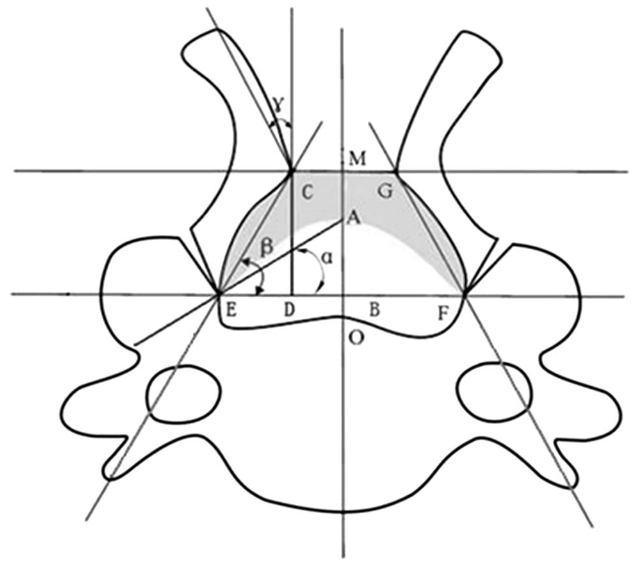

Fig. 1 Radiologic parameters used in the study. α indicates pre-operative lamina angle, β indicates the angle of the opened lamina, γ indicates laminoplasty opening angle. *MA* indicates the increase in sagittal diameter after double-door cervical laminoplasty (DDCL), *CG* indicates laminoplasty opening size, *OA* indicates pre-operative sagittal diameter, *OM* indicates post-operative sagittal diameter

value equivalent to the difference between lines OM (post-surgical diameter) and OA (pre-surgical diameter). The lengths of lines AE and CE in triangles AEB and CED are equal; this distance is represented by symbol s in the formula below. The length of line AB is represented by symbol h.

The angle of the opened lamina (β) and the lamina angle (α) was defined as the angles between lines CE and EF or lines AE and EF, respectively. Laminoplasty opening size was defined as the distance between the split points (points C and G) at the opened lamina (Fig. 1). The LOA (γ) was defined as the difference between the angle of the opened lamina (β) and the lamina angle (α), representing the angle between the central axis of the spinous processes after surgery and the sagittal plane of the spinal vertebra.

The formulas $\sin\alpha = h/s$ and $\sin\beta = (h + d)/s$ were arrived at using trigonometric functions in triangles AEB and CED. From these formulas follow the equation $\sin\beta/\sin\alpha = (h + d)/h$. Finally, the formula $d = h \times (\sin\beta/\sin\alpha - 1) = h \times [\sin(\alpha + \gamma)/\sin\alpha - 1]$ was mathematically deduced. The values of h and α can be measured before surgery, therefore the relationship between the angle of the opened lamina (β) or the LOA (γ) and the increase in SCD (d) can be determined.

The formula for computing laminoplasty opening size was $CG = 2 \times CM = 2 \times DB = 2 \times (EO - ED) = 2 \times (EF/2 - (h + d)/\tan\beta) = EF - 2 \times (h + d)/\tan\beta$. The increase in canal area was defined as the difference between the area of the trapezoid CEFG [(CG + EF) ×

$(h + d)/2]$ after surgery and the area of the triangle AEF ($EF \times h/2$) before surgery.

Parametric measurements

A computerized tomography (CT) scanner (GE Sytec 2000i) was used to perform pre-operative and 1-week post-operative CT scans on all 20 patients from C1 through C7. A 3-mm slice thickness was used, with a window level of +300 Hounsfield units and a window width of 1,200 Hounsfield units. Axial CT cuts made at each pedicle level from C3 to C7 were used for measurement. The pre- and post-surgical SCD, distances from points A to B and from points E to F, angle of the opened lamina (β), and the lamina angle (α) were measured using software (picture archiving and communication system, PACS) with an accuracy within 0.01 mm or 0.01°. Data measurements were independently performed by the first and second authors three times with 200 % magnification to ensure accuracy, and the mean value was used for analysis. Intraobserver errors were less than 5 %.

Validation of the formula describing the relationship between the angle of the opened lamina and the increase in sagittal diameter

A validation study was undertaken to assess the accuracy of the formula relating LOA to the increase in SCD. The values of h, β, and α were measured, and the predicted increase in each patient's SCD at C3–C7 was computed using the formula $d = h \times (\sin\beta/\sin\alpha - 1)$. The actual SCD increase was obtained by measuring the pre- and post-operative C3–C7 SCD for each patient. Correlation between the data obtained by clinical measurement and the data predicted by the formula was assessed by calculating Pearson's correlation coefficient. The differences between the data obtained by clinical measurement and the data predicted by the formula were evaluated with the paired t test.

Based on pre- and post-operative computed tomography scans of 20 patients who had undergone laminoplasty surgery, DDCLs with the opening angles of 25°, 30°, 35°, 40°, 45°, 50°, and 55° were then simulated to determine the increase in sagittal diameter, increase in canal area, and the laminoplasty opening size at the various opening angles using the previously described equations.

Statistical analysis

All statistical analyses were performed using Statistical Analysis System software (version 9.13, SAS Institute Inc., USA). Data are expressed as mean ± standard deviation (SD) at a significance level of $P < 0.05$.

Results

Data for C3–C7 parameters (Table 1)

1. Pre-operative lamina angle (α): The largest pre-operative lamina angles (α) were seen at C3 (32.48 ± 1.53) and C7 (33.44 ± 1.27). C5 and C6 had α values of 30.36 ± 1.63 and 29.16 ± 1.69, respectively; C4 had the smallest α value at 28.08 ± 1.66.

2. Distance between points E and F: The largest E to F distances were seen at C3, C4, C5, and C6 (values of 20.46 ± 1.05, 20.40 ± 0.99, 19.85 ± 0.68, and 19.67 ± 0.40, respectively). The smallest distance was at C7 (17.07 ± 0.83).

3. The distance between points A and B (h value): The largest distance from A to B was at C3 (6.53 ± 0.68); smaller distances were seen at C4, C5, C6, and C7 (5.46 ± 0.60, 5.83 ± 0.54, 5.50 ± 0.46, 5.65 ± 0.52, respectively).

Table 1 Parameters used in the study: pre-operative lamina angle (α), the angle of the opened lamina (β), LOA (γ), distance between points E and F, distance between points A and B, pre-operative SCD, post-operative SCD

	C3	C4	C5	C6	C7
Pre-operative lamina angle (α)	32.48 ± 1.53	28.08 ± 1.66	30.36 ± 1.63	29.16 ± 1.69	33.44 ± 1.27
Angle of the opened lamina (β)	75.25 ± 8.90	68.51 ± 8.14	73.73 ± 8.68	69.78 ± 7.73	75.32 ± 8.59
LOA (γ)	42.77 ± 7.40	40.43 ± 6.57	43.37 ± 7.06	40.62 ± 6.08	41.88 ± 7.40
Distance of point E, F (mm)	20.46 ± 1.05	20.40 ± 0.99	19.85 ± 0.68	19.67 ± 0.40	17.07 ± 0.83
Distance of point A, B (mm)	6.53 ± 0.68	5.46 ± 0.60	5.83 ± 0.54	5.50 ± 0.46	5.65 ± 0.52
Pre-operative SCD (mm)	11.17 ± 1.16	10.73 ± 1.18	10.76 ± 1.00	11.71 ± 0.98	12.00 ± 1.11
Post-operative SCD (mm)	16.27 ± 1.67	15.96 ± 1.74	15.88 ± 1.38	16.71 ± 1.37	16.17 ± 1.54

Pre-operative lamina angle (α) = (left angle α + right angle α)/2. Angle of the opened lamina (β) = (left angle β + right angle β)/2

LOA laminoplasty opening angle, *SCD* sagittal canal diameter

Table 2 Comparison of the data obtained by pre- and post-operative CT scans with the values predicted by the formula using the paired *t* test and the Pearson correlation analysis

	C3	C4	C5	C6	C7
SCD increase obtained by formula (mm)	5.10 ± 0.51	5.23 ± 0.59	5.12 ± 0.40	5.00 ± 0.40	4.17 ± 0.45
SCD increase obtained by measuring (mm)	5.06 ± 0.45	5.32 ± 0.65	5.18 ± 0.42	5.06 ± 0.44	4.26 ± 0.46
t value	1.04	1.47	1.39	1.31	1.49
P value	0.3097	0.1570	0.1813	0.2044	0.1750
r value	0.9452	0.9012	0.9036	0.9009	0.9224
P value	<0.0001	<0.0001	<0.0001	<0.0001	0.0004

SCD sagittal canal diameter

Table 3 Increases in sagittal canal diameter at C3–C7 for laminoplasty opening angles of 25°–55°

LOA (°)	SCD increase of C3 (mm)	SCD increase of C4 (mm)	SCD increase of C5 (mm)	SCD increase of C6 (mm)	SCD increase of C7 (mm)
25°	3.71 ± 0.16	3.80 ± 0.16	3.65 ± 0.10	3.64 ± 0.06	3.08 ± 0.13
30°	4.24 ± 0.18	4.37 ± 0.18	4.18 ± 0.12	4.18 ± 0.06	3.51 ± 0.14
35°	4.69 ± 0.19	4.86 ± 0.19	4.64 ± 0.13	4.65 ± 0.07	3.87 ± 0.15
40°	5.05 ± 0.20	5.28 ± 0.20	5.02 ± 0.13	5.04 ± 0.08	4.16 ± 0.15
45°	5.32 ± 0.20	5.61 ± 0.21	5.31 ± 0.14	5.34 ± 0.09	4.38 ± 0.15
50°	5.50 ± 0.19	5.86 ± 0.21	5.52 ± 0.15	5.57 ± 0.10	4.52 ± 0.15
55°	5.60 ± 0.19	6.03 ± 0.21	5.65 ± 0.15	5.71 ± 0.12	4.58 ± 0.14

LOA laminoplasty opening angle, *SCD* sagittal canal diameter

Table 4 Laminoplasty opening sizes at C3–C7 for laminoplasty opening angles of 25°–55°

LOA (°)	Laminoplasty opening size of C3 (mm)	Laminoplasty opening size of C4 (mm)	Laminoplasty opening size of C5 (mm)	Laminoplasty opening size of C6 (mm)	Laminoplasty opening size of C7 (mm)
25°	7.44 ± 0.67	6.53 ± 0.59	6.79 ± 0.51	6.49 ± 0.42	6.38 ± 0.52
30°	9.27 ± 0.81	8.19 ± 0.72	8.49 ± 0.62	8.13 ± 0.50	7.94 ± 0.63
35°	11.20 ± 0.96	9.95 ± 0.85	10.28 ± 0.72	9.86 ± 0.59	9.57 ± 0.74
40°	13.19 ± 1.11	11.79 ± 0.98	12.14 ± 0.83	11.67 ± 0.67	11.26 ± 0.86
45°	15.23 ± 1.25	13.70 ± 1.12	14.06 ± 0.93	13.54 ± 0.74	12.99 ± 0.97
50°	17.32 ± 1.40	15.65 ± 1.25	16.02 ± 1.04	15.45 ± 0.82	14.76 ± 1.09
55°	19.43 ± 1.54	17.64 ± 1.37	18.01 ± 1.14	17.40 ± 0.89	16.54 ± 1.20

LOA laminoplasty opening angle

4. Pre-operative SCD (AO): Smaller pre-operative SCDs (AO) were seen at C4 and C5 (10.73 ± 1.18 and 10.76 ± 1.00, respectively). Larger pre-operative SCDs (AO) were seen at C3, C6, and C7 (11.17 ± 1.16, 11.71 ± 0.98, 12.00 ± 1.11, respectively).

Differences and correlation between the data obtained by clinical measurement and the data predicted by the formula (Table 2)

Comparison of the data obtained by clinical measurement and predicted by the formula showed no significant difference ($P > 0.05$) and also showed a very high degree of correlation ($P < 0.001$). These findings support the validity of the formula.

Increases in sagittal diameter (Table 3; Fig. 2)

Increases in the SCD became progressively larger in proportion to C3–C7 LOAs of 25°–55°. Increases in SCD differed throughout the cervical region; when the C3–C7 LOA was equivalent, the greatest increase in the sagittal diameter was at C4, and the smallest increase was at C7.

Laminoplasty opening size (Table 4; Fig. 3)

Laminoplasty opening size increased steadily relative to C3–C7 LOAs of 25°–55°. Laminoplasty opening size differed throughout the cervical region; when the C3–C7 LOA was equivalent, the largest laminoplasty opening size was at C3 and the smallest was at C7.

Increases in canal area (Table 5; Fig. 4)

The canal area increased relative to C3–C7 LOAs of 25°–55°. The magnitude of the increase differed throughout the cervical region for equivalent LOAs. The greatest increase in the canal area was at C3, and the smallest increase was at C7.

Discussion

Results of inadequate and excessive opening of the canal

In DDCL, inadequate increases of SCD or canal volume will not relieve the spinal cord compression and may lead to undesirable results after laminoplasty. However, excessive opening of the lamina may cause the cord to migrate and extend posteriorly to an excessive degree, which can lead to the occurrence of post-operative C5 nerve root palsy [12]. Tsuzuki et al. [13] stated that the exertion of traction forces by the posteriorly expanded dura on the extradural portions of the anterior and posterior roots might play a major role in the occurrence of post-operative paralysis of the arms after posterior spinal cord decompression. Uematsu et al. [14] reported that the incidence of radiculopathy was significantly increased among patients with a large angle (≥60°) of the lamina after expansion or when the expansion was excessive. Hatta et al. [15] reported that the magnitude of post-operative posterior spinal cord shift is related to the occurrence of post-operative C5 nerve root palsy. Other authors have also expressed the idea that excessive opening of the lamina may lead to post-operative C5 nerve root palsy [16, 17]. Wang et al. [18] pointed out that excessive opening also creates a wider epidural space and leads to the formation of more epidural scar tissues than normally expected.

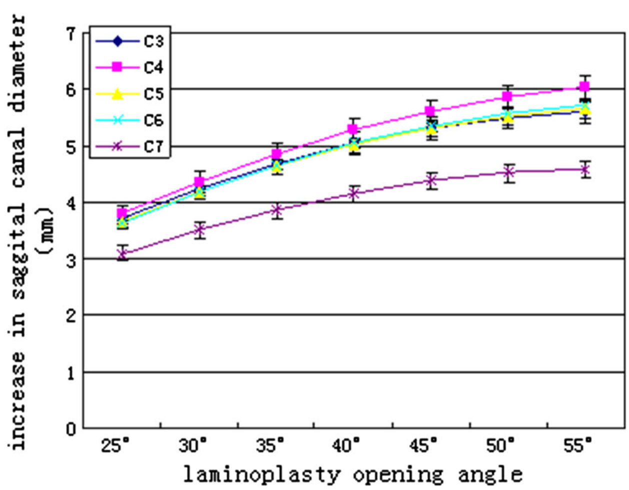

Fig. 2 Increases in sagittal canal diameter at C3–C7 for laminoplasty opening angles of 25°–55°

Optimal increase in the sagittal diameter in DDCL

What is the optimal extent that the spinal canal must be widened to obtain good results? Some authors have previously investigated this question. Itoh and Tsuji [19] noted that a 4.1-mm enlargement of the spinal canal was ideal and that this could be achieved by opening the separated lamina by 8 mm. Other authors [20, 21] have stated that the optimal increase in the sagittal diameter of the stenotic canal by laminoplasty is >4–5 mm.

Clinical relevance of the formula

Using the formula $\sin\beta/\sin\alpha = (h+d)/h$ for stenotic canal enlargements of >4–5 mm in the SCD, the β value (angle of the opened lamina) can be obtained since α and h can be measured. The distance between points E and F was measured, therefore the distance between points C and G (laminoplasty opening size) could be obtained on the basis of the formula $\mathrm{CG} = \mathrm{EF}-2\times(h+d)/\tan\beta$, which determined the degree of lamina opening during the operation. This enables individualized DDCL based on an accurate LOA or laminoplasty opening size, preventing

Table 5 Increases in canal area at C3–C7 for laminoplasty opening angles of 25°–55°

LOA (°)	The increased amount in canal area of C3 (mm^2)	The increased amount in canal area of C4 (mm^2)	The increased amount in canal area of C5 (mm^2)	The increased amount in canal area of C6 (mm^2)	The increased amount in canal area of C7 (mm^2)
25°	76.43 ± 10.11	69.25 ± 8.56	68.57 ± 6.63	65.58 ± 4.48	54.29 ± 6.78
30°	93.76 ± 12.32	85.16 ± 10.47	84.22 ± 8.07	80.61 ± 5.44	66.57 ± 8.26
35°	111.24 ± 14.49	101.37 ± 12.36	100.09 ± 9.48	95.88 ± 8.36	78.92 ± 9.72
40°	128.55 ± 16.57	117.61 ± 14.21	115.90 ± 10.82	111.15 ± 7.23	91.11 ± 11.11
45°	145.33 ± 18.51	133.58 ± 15.95	131.34 ± 12.07	126.11 ± 8.01	102.89 ± 12.41
50°	161.19 ± 20.26	148.95 ± 17.55	146.07 ± 13.17	140.46 ± 8.68	113.99 ± 13.58
55°	175.75 ± 21.75	163.38 ± 18.96	159.74 ± 14.09	153.85 ± 9.20	124.12 ± 14.58

LOA laminoplasty opening angle

inadequate or excessive opening, reducing the incidence of complications.

Influence of increased size of the post-surgical SCD

On the basis of the formula $d = h \times (\sin\beta / \sin\alpha - 1) = h \times [\sin(\alpha + \gamma) / \sin\alpha - 1]$, the d value (post-surgical increase in SCD) was directly proportional to the values of h and $\sin\beta$ and varied inversely with $\sin\alpha$. For DDCL within the same vertebral segment, the values of h and $\sin\alpha$ were the same, and the increase in post-surgical SCD was dependent on LOA. The greater the LOA, the greater the increase in SCD.

For DDCL of the same segment in different patients or different segments in the same patient, the values of h, $\sin\alpha$, and the distance between points E and F varied. Therefore, the increase in SCD after laminoplasty differed, even when LOA was the same. The largest increase in SCD was at C4, and the smallest increase was at C7. Even when the LOA at C7 was 55°, the SCD only increased by 4.58 mm because of the smaller distance between points E and F and the greater pre-operative lamina angle.

The position of the lateral hinges is closely related to the α value, h value, and distance between points E and F. As these three values changed with the position of the lateral hinges, the SCD was affected. For same-segment DDCL with the same LOA, the closer was the position of the lateral hinges to the inside of the lamina, the lower were the α and h values, the less was the distance between points E and F, and the smaller was the increase in SCD. Most authors advocate that the lateral hinges should be positioned just at the medial border of the facet joints [7, 10–12, 14, 21, 22]. Therefore, in the current study, the lateral gutters were created at the lamina-lateral mass junction.

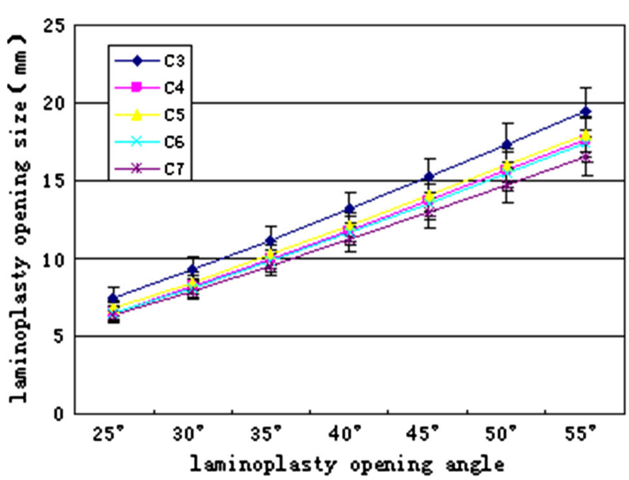

Fig. 3 The laminoplasty opening size at C3–C7 for laminoplasty opening angles of 25°–55°

Optimal LOA and laminoplasty opening size following DDCL

In this study, when the LOA at C3–C6 was 30°, the laminoplasty opening sizes at C3–6 were 9.27, 8.19, 8.49 m, 8.13 mm, respectively, and when the LOA at C7 was 40°, the laminoplasty opening size at C7 was 11.26 mm, the increase in SCD was more than 4 mm. When the C3–C6 LOA was 40°, the laminoplasty opening sizes for C3, C4, C5, and C6 were 13.19, 11.79, 12.14, and 11.67 mm, respectively, and the increase in SCD was more than 5 mm.

In this study, with increases in the C3–C7 LOA from 25° to 45°, the magnitude of the increase in SCD was notable, with increases of 3.08–5.6 mm compared with the pre-operative SCD. When the C3–C7 LOA was greater than 45°, the degree of increase in the SCD was relatively smaller at these larger angles. The increase in the C3–C7 SCD was merely 0.4 mm larger with a 55° LOA compared with a 45° angle.

On the basis of the formula $d = h \times (\sin\beta / \sin\alpha - 1)$, when the β value was 90°, the laminoplasty opening size was equal to the distance between points E and F, and the increase in the SCD reached the maximum value. When the β value was more than 90°, this parameter (increase in the SCD) could actually decrease. Therefore, in DDCL, the β value cannot exceed 90°, and the laminoplasty opening size could not exceed approximately 20 mm at C3–C6 or approximately 17 mm at C7.

Kohno et al. [21] showed that canal area widening by 95 mm^2 was optimal and achieved good recovery. In this study, when the C3 LOA was 30°, the C4–C6 LOA was 35°, or the C7 LOA was 40°, the cross-sectional area of the spinal canal increased by 91–101 mm^2, and the SCD increased by more than 4 mm.

When the C3–C7 LOA was more than 45°, the magnitude of the increase in the SCD was relatively smaller, but

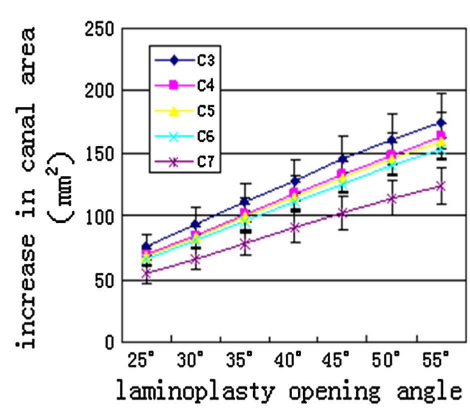

Fig. 4 Increases in canal area at C3–C7 for laminoplasty opening angles of 25°–55°

the risk of complications resulting from excessive LOA is increased at these larger angles. Therefore we conclude that, to obtain a widening of 4–5 mm in the diameter, optimal canal area widening during DDCL, the optimal LOAs are as follows: 30°–45° at C3, 35°–45° at C4–C6, and approximately 40°–45° at C7. The corresponding laminoplasty opening sizes are approximately 10–15 mm at C3, approximately 10–14 mm at C4–C6, and approximately 11–13 mm at C7. In addition, except for the case which has main compressive factor at C6/7, it does not have to expand the sagittal canal diameter at C4 and C7 to same degree because C4 is the midpoint of the arc of cervical lordosis, whereas C7 is the endpoint of that arc. In the literature, the average opening size varied from 10 to 20 mm for DDCL [11, 23–26], which is consistent with our study.

Study limitations

There are some limitations in this study. As the α value, h value, and the distance between points E and F changed with the position of the lateral hinges, the SCD was affected. Therefore, if the planned position of the lateral hinges (before surgery) did not agree with the actual surgical positioning of the lateral hinges, the increase in the post-surgical SCD would not agree with the planned increase. So the method of reducing this difference should be studied in the future.

When the spinous processes and laminae are centrally split; the surgeon, the technique and instruments used influence the quantity of bone lost. When splitting the lamina, almost no bone is sacrificed using the T-saw procedure, whereas a large amount of bone is lost using the burr. The amount of bone removed is transverse of width of the cutting laminae. In the current study, we deduced the formula in an ideal circumstance that no bone was removed when splitting the lamina. In reality, we have taken into account the removed bone when splitting the lamina, the laminoplasty opening size in surgery should equal the value calculated by the formula plus the amount of bone removed (transverse of width of the cutting laminae).

Conclusions

Our formula, as described above, accurately revealed the correlation between the LOA and the increase in SCD. For increases in SCD of 4–5 mm, the previously described equations enable the calculation of laminoplasty opening size or angle. This enables the performance of DDCL based on accurate individual laminoplasty opening angles or sizes, which prevents inadequate or excessive opening, reduces the incidence of complications.

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Conflict of interest There is no actual or potential conflict of interest in relation to this article.

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