Cervical alignment following laminoplasty for cervical spondylotic myelopathy

Ravi Sharma¹, Sachin A. Borkar¹, Manoj Phalak¹, S. Leve Joseph², Shashank S. Kale¹

Departments of ¹Neurosurgery and ²Neuroradiology, All India Institute of Medical Sciences, New Delhi, India.

E-mail: Ravi Sharma - aiims.ravisharma@gmail.com; *Sachin A. Borkar - sachin.aiims@gmail.com; Manoj Phalak - manojphalak@gmail.com; S. Leve Joseph - leve_s@yahoo.com; Shashank S. Kale - skale67@gmail.com

INTRODUCTION

Cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal ligament (OPLL) may both be safely managed with laminoplasty.¹ However, laminoplasty, like laminectomy, also causes destruction of the posterior musculoligamentous complex and, therefore, can result in the loss of cervical lordosis (LOCL) or the development of postoperative kyphosis.¹ In recent literature, the T1 slope has emerged as an important predictor of LOCL/kyphosis following laminoplasty.¹,² Here, we evaluated the role of the T1 slope in predicting clinical outcomes and LOCL following laminoplasty in patients of CSM/OPLL.

ABSTRACT

Background: Laminoplasty can result in the loss of cervical lordosis (LOCL) or the development of kyphosis after surgery. Here, we evaluated the clinical and radiological parameters involved in predicting the postoperative LOCL following laminoplasty in patients with cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal ligament (OPLL).

Methods: For 50 patients with CSM and 35 with OPLL undergoing laminoplasty, preoperative and 1-year postoperative X-rays were obtained to determine the incidence and risk factors contributing to postoperative LOCL. The patients were divided into two groups depending on whether the preoperative T1 slope was above or below the median preoperative T1S (26°); Group A – high T1 slope group (n = 40) and Group B – low T1 slope group (n = 45).

Results: Following laminoplasty, Group A patients had significantly higher preoperative lordosis (C2-C7 Cobb's angle) (P = 0.001) and significantly higher LOCL (P = 0.02) versus Group B patients with low T1 slopes. The preoperative T1 slope was also found to be significantly correlated with the preoperative C2-C7 Cobb's angles (R = 0.619, P = 0.001), LOCL (R = 0.487, P = 0.001), and preoperative C2-C7 sagittal vertical axis (R = 0.480, P = 0.001). Utilizing multivariate analysis and a generalized linear model, the preoperative T1 slope significantly impacted the Oswestry disability index (ODI) index (P = 0.002) and frequency of LOCL (P = 0.001) following laminoplasty.

Conclusion: The preoperative T1 slope is a significant predictor of the LOCL and change in ODI following laminoplasty for CSM/OPLL utilizing a cutoff value of 29.5°.

Keywords: C2-C7 Cobb's angle, C2-C7 lordosis, C2-C7 sagittal vertical axis, C2-C3 disc angle, Cervical laminoplasty, Loss of cervical lordosis, T1 slope, Kyphosis

This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial-Share Alike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

©2019 Published by Scientific Scholar on behalf of Surgical Neurology International
MATERIALS AND METHODS

Clinical data

This study was conducted from 2013 to 2018 and included 50 patients with CSM and 35 with OPLL. All the patients underwent clinical, X-ray (flexion/extension), and noncontrast computed tomography evaluations of the cervical spine for CSM/OPLL preoperatively. Males comprised 90% of the study population and averaged 58.2 ± 11.2 years of age. Patients were symptomatic for an average of 22 ± 16 months and were followed an average of 31 ± 15 months (range of 12–60 months). Patients were followed for a minimum of 1 postoperative year. All underwent 2-4-level hinge door laminoplasty using titanium miniplates to keep hinged side open. The radiological parameters were measured using Centricity Enterprise PACS WV 3.0 software [Figure 1].

Postoperative follow-up

Postoperatively, patients were followed for a minimum period of 1 year and included clinical assessments based on a modified Japanese Orthopedic Association (mJOA) score and Oswestry disability index (ODI). Cervical X-rays were utilized to divide patients into two groups depending on whether the preoperative T1 slope was above or below the median preoperative T1S (26°); Group A: high T1 slope group and Group B: low T1 slope group [Table 1]. Preoperative and postoperative Cobb's angles were compared.

Statistical analysis

Univariate analysis was performed using Chi-square test/Fischer's exact test, Student’s t-test, and Pearson’s product moment correlation coefficient. A generalized linear model was used for multivariate analysis and receiver operator characteristics curve was generated to identify the best cutoff for T1S to predict LOCL. The data were analyzed using IBM SPSS Statistics package version 20.

RESULTS

Comparison of clinical and radiological parameters according to preoperative T1S

The patients in Group A also have a significantly higher preoperative lordosis (C2-C7 Cobb's angle) and preoperative

![Figure 1: Lateral X-ray of cervical spine showing measured radiological parameters. C2–7 Cobb angle is defined as the angle between lines extended parallel to the inferior endplate of C-2 and C-7 on the standing lateral radiograph of the cervical spine. Cervical sagittal vertical alignment was defined as the perpendicular distance between a plumb line dropped from the center of C-2 (or dens) and the posterosuperior aspect of C7 (C2–7 sagittal vertical axis). T1 slope is measured as the angle between the horizontal plane and the superior endplate of T1 vertebra. C2-C3 disc angle is measured as the angle between the line drawn parallel to the C2-C3 disc space and the line drawn parallel to the floor on standing X-ray.](image)

| Patient characteristic | Total (n=85) | Low T1S group (n=45) | High T1S group (n=40) | P value |
|------------------------|-------------|----------------------|-----------------------|---------|
| Age (in years)         | 58.2±11     | 59±11                | 58±10                 | 0.666   |
| Gender (M/F)           | M-76 (89.4%)| M-40 (88.9%)         | M-36 (90%)            | 0.678   |
|                        | F-9 (10.6%) | F-5 (11.1%)          | F-4 (10%)             |         |
| Duration of symptoms (in months) | 22±16 | 20±13                | 23±19                 | 0.439   |
| CSM/OPLL               | CSM-50 (58.2%) | CSM-27(60%)       | CSM-23(57.5%)         | 0.815   |
|                        | OPLL-35 (41.2%) | OPLL-18(40%)       | OPLL-17 (42.5%)       |         |
| Total number of levels | 2-01 (1.2%) | 2-01 (2.2%)         | 2-0 (0 %)             | 0.601   |
|                        | 3-16 (18.8%) | 3-09 (20%)         | 3-07 (17.5%)          |         |
|                        | 4-68 (80%)  | 4-35 (77.7%)        | 4-33 (82.5%)          |         |
| Highest level (C3/C4)  | C3-74 (87%)  | C3-39 (87%)        | C3-35 (87.5%)         | 0.416   |
|                        | C4-11 (13%)  | C4-06 (13%)        | C4-05 (12.5%)         |         |
| Follow-up duration (in months) | 31±15 | 30±14.2               | 31±16.2              | 0.77    |

CSM: Cervical spondylotic myelopathy; OPLL: Ossification of the posterior longitudinal ligament
C2-C7 sagittal vertical axis (SVA) versus Group B ($P = 0.001$ for both). Group A also showed significantly higher LOCL following laminoplasty versus Group B ($P = 0.02$). Further, the incidence of LOCL of more than $5^\circ$ in Group A patients was 45% ($P = 0.006$) significantly higher than Group B (17%) [Table 2]. mJOA score improvement following laminoplasty did not show statistically significant differences between the two groups, whereas ODI scores showed significant improvement in patients with a low T1 slope (Group B) versus high T1 slope (Group A) ($P = 0.02$).

**Correlation of preoperative T1S with other radiological parameters**

Using Pearson’s correlation, the preoperative T1 slope was found to be significantly correlated with the preoperative C2-C7 Cobb’s angle ($R = 0.619$, $P = 0.001$), LOCL ($R = 0.487$, $P = 0.001$), and preoperative C2-C7 SVA ($R = 0.480$, $P = 0.001$) [Figure 2a-c]. However, the correlations with C2-C3 disc angle did not reach statistical significance ($P = 0.06$) [Figure 2d].

![Figure 2: (a-d) Graphs showing correlation between T1 slope and other parameters.](image-url)
Clinicoradiological outcome predictors of change in mJOA score, ODI index, and LOCL

Generalized linear model and multivariate analysis helped determine the preoperative predictors of change in mJOA, ODI, and LOCL [Table 3].

DISCUSSION

In recent literature, T1 slope emerged as an important predictor for LOCL following laminoplasty. Most studies concluded that a high preoperative T1 slope is an increased risk factor for postoperative kyphosis or LOCL following laminoplasty [Table 4]. For example, Kim et al. noted that for patients with a high T1 slope, laminoplasty cannot compensate with sufficient lordosis to avoid postoperative LOCL/malalignment. In this series, laminoplasty was only performed for patients with an adequate cervical lordosis, but those with a high T1 preoperative slope had a higher incidence of postoperative LOCL versus those with a low T1 slope before surgery.

We have attempted to create a statistical cutoff value of the preoperative T1 slope (29.5°) that can help predict LOCL following laminoplasty and a relationship between

Table 2: Comparison of clinical and radiological parameters according to preoperative T1S.

| Parameter                        | Low T1S group | High T1S group | P value |
|----------------------------------|---------------|----------------|---------|
| Preoperative mJOA                | 12.75±2.31    | 11.97±2.64     | 0.14    |
| Postoperative mJOA               | 13.46±2.08    | 12.84±2.64     | 0.11    |
| Δ mJOA                           | 0.69±0.89     | 0.86±0.79      | 0.32    |
| Preoperative ODI                 | 45.85±7.01    | 58.5±8.09      | 0.001   |
| Postoperative ODI                | 40.19±7.67    | 57.2±7.81      | 0.001   |
| Δ ODI                            | -5.7±2.94     | -1.3±3.13      | 0.02    |
| Preoperative Cobb’s angle        | 9.12±2.39     | 17.33±4.52     | 0.001   |
| Postoperative Cobb’s angle       | 8.80±1.12     | 12.9±4.16      | 0.001   |
| Δ Cobb’s angle                   | 0.32±6.5      | 4.4±7.16       | 0.01    |
| Incidence of loss of lordosis (Δ Cobb’s angle) >5° | 8/45 (17%) | 18/40 (45%) | 0.006 |
| Preoperative C2-C7 SVA           | 19.84±8.63    | 26.42±10.28    | 0.001   |
| Δ C2-C7 SVA                      | 4.24±2.63     | 4.92±3.63      | 0.617   |
| Preoperative C2-C3 disc angle    | 15.21±5.51    | 16.72±4.29     | 0.155   |
| Postoperative C2-C3 disc angle   | 15.45±3.42    | 16.43±3.47     | 0.37    |

Δ mJOA is the difference between postoperative mJOA preoperative mJOA. Δ ODI is defined as the difference between postoperative ODI and preoperative ODI; Δ Cobb’s angle is calculated as difference between preoperative and postoperative Cobb’s angle; Δ C2-C7 SVA is the difference between preoperative and postoperative C2-C7 SVA. mJOA: Modified Japanese Orthopedic Association, ODI: Oswestry disability index, SVA: Sagittal vertical axis

Table 3: Multivariate analysis using generalized linear models.

| Predictors for change in mJOA | P value |
|-------------------------------|---------|
| Duration of symptoms          | 0.037   |
| Preoperative T1 slope         | 0.638   |
| Preoperative C2-C7 SVA        | 0.977   |
| Preoperative Cobb’s angle (CA)| 0.814   |
| Predictors of LOCL            |         |
| Duration of symptoms          | 0.757   |
| Preoperative T1 slope         | 0.001   |
| Preoperative C2-C7 SVA        | 0.389   |
| Predictors of change in ODI   |         |
| Duration of symptoms          | 0.08    |
| Preoperative T1 slope         | 0.002   |
| Preoperative C2-C7 SVA        | 0.916   |

LOCL: Loss of cervical lordosis, Values in bold show the p-values of the factors significant on multivariate analysis

Figure 3: Receiver operating characteristic curve to establish a cutoff of T1 slope to predict loss of cervical lordosis.
the preoperative T1 slope and change in ODI following laminoplasty [Figure 3].

**CONCLUSION**

The preoperative T1 slope is a significant predictor for the postoperative LOCL and change in ODI following laminoplasty for patients with CSM/OPLL. If the preoperative T1 slope is greater than 29°, it is a significant predictor for postoperative LOCL following laminoplasty.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Cao J, Zhang J, Yang D, Yang L, Shen Y. Multivariate analysis of factors associated with kyphotic deformity after laminoplasty in cervical spondylotic myelopathy patients without preoperative kyphotic alignment. Sci Rep 2017;7:43443.

2. Cho JH, Ha JK, Kim DG, Song KY, Kim YT, Hwang CJ, et al. Does preoperative T1 slope affect radiological and functional outcomes after cervical laminoplasty? Spine (Phila Pa 1976) 2014;39:E1575-81.

3. Kim TH, Lee SY, Kim YC, Park MS, Kim SW. T1 slope as a predictor of kyphotic alignment change after laminoplasty in patients with cervical myelopathy. Spine (Phila Pa 1976) 2013;38:E992-7.

4. Kim B, Yoon DH, Ha Y, Yi S, Shin DA, Lee CK, et al. Relationship between T1 slope and loss of lordosis after laminoplasty in patients with cervical ossification of the posterior longitudinal ligament. Spine J 2016;16:219-25.

5. Miyazaki M, Ishihara T, Notani N, Kanezaki S, Tsumura H. Relationship of T1 slope with loss of lordosis and surgical outcomes after laminoplasty for cervical ossification of the posterior longitudinal ligament. Clin Neurol Neurosurg 2018;164:19-24.

6. Zhang JT, Li JQ, Niu RJ, Liu Z, Tong T, Shen Y, et al. Predictors of cervical lordosis loss after laminoplasty in patients with cervical spondylotic myelopathy. Eur Spine J 2017;26:1205-10.

---

**Table 4: Review of literature of studies on T1 slope predicting LOCL following laminoplasty.**

| Study               | N  | Diagnosis | Parameters measured to predict LOCL | Factors affecting mJOA | Factors affecting ODI | Factors affecting LOCL |
|---------------------|----|-----------|-------------------------------------|------------------------|-----------------------|------------------------|
| Miyazaki et al. (2018) | 35 | OPLL     | C2-C7 CA, C2-C7 SVA, T1S, MRI grade, C2-C7 ROM | MRI grade (P=0.01) | Not tested | Preoperative T1 slope (P=0.03) |
| Kim et al. (2013)   | 51 | OPLL-31  | C2-C7 CA, C2-C7 ROM, T1S, MRI grade, C2-C7 ROM | Not tested | Not tested | Preoperative T1 slope (P=0.001) |
| Kim et al. (2016)   | 64 | OPLL     | C2-C7 CA, C2-C7 SVA, T1S, C2-C7 ROM, T1S-C2-C7 CA | Not tested | Not tested | Preoperative T1 slope (P=0.04), Preoperative T1S-CA (p 0.03) |
| Cho et al. (2014)   | 76 | CSM      | C2-C7 CA, C2-C7 SVA, T1S, thoracic kyphosis (TK), C2-C7 ROM, C2-C7 SV A | Not related with preoperative T1S | Not related with T1S | Not related with preoperative T1S (P=0.003), C2-C7 SVA (P=0.001), CVLL (P<0.001) |
| Zhang et al. (2017) | 41 | CSM      | C2-C7 CA, C2-C7 SVA, T1S, C2-C7 ROM, CVLL | Not tested | Not tested | Preoperative T1 slope (P=0.001) |
| Present study      | 85 | CSM-50, OPLL-35 | C2-C7 CA, C2-C7 SVA, T1S, C2-C3 DA | Duration of symptoms (P=0.03) | Preoperative T1 slope (P=0.02) | Preoperative T1 slope (P=0.001) |

MRI: Magnetic resonance imaging, LOCL: Loss of cervical lordosis, mJOA: Modified Japanese Orthopedic Association, SVA: Sagittal vertical axis