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Original Article

Cervical alignment following laminoplasty for cervical spondylotic myelopathy

Ravi Sharma[1], Sachin A. Borkar[1], Manoj Phalak[1], S. Leve Joseph[2], Shashank S. Kale[1]

Departments of [1]Neurosurgery and [2]Neuroradiology, 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

***Corresponding author:**
Sachin A. Borkar,
Associate Professor,
Department of Neurosurgery,
All India Institute of
Medical Sciences, CNC, 720,
New Delhi - 110 029, India.

sachin.aiims@gmail.com

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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

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.[1,3-6] Here, we evaluated the role of the T1 slope in predicting clinical outcomes and LOCL following laminoplasty in patients of CSM/OPLL.

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

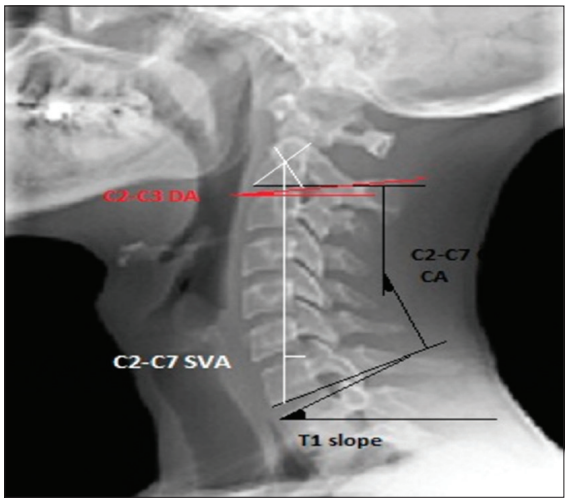

Figure 1: Lateral X-ray of cervical spine showing measured radiological parameters. C2–7 Cobb angle is defined as the angle between lines extended parallel to the inferior endplate of C-2 and C-7 on the standing lateral radiograph of the cervical spine. Cervical sagittal vertical alignment was defined 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.

Table 1: Patient characteristics of the total study population and the two subgroups.

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° 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].

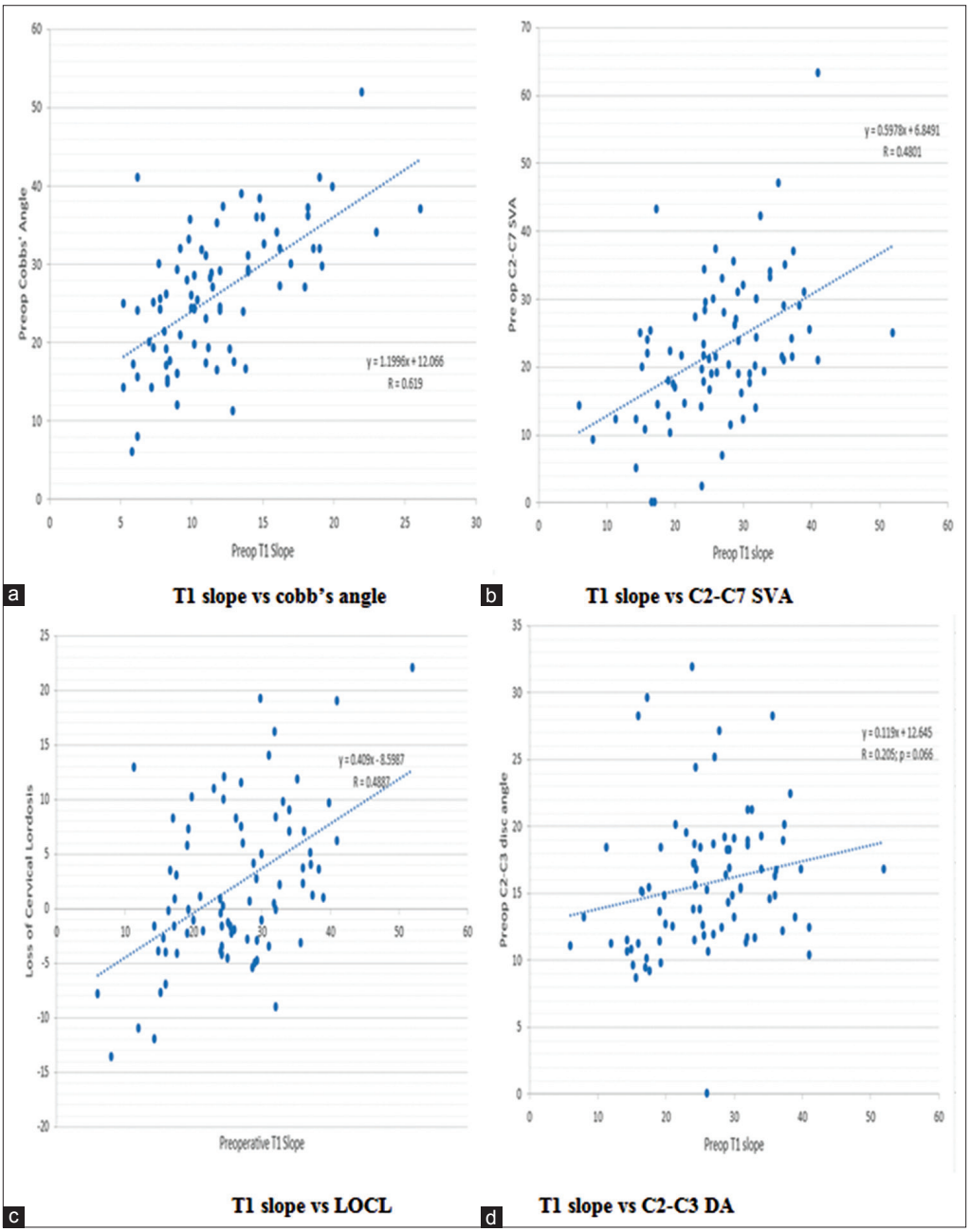

Figure 2: (a-d) Graphs showing correlation between T1 slope and other parameters.

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±4.37	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	
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

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].

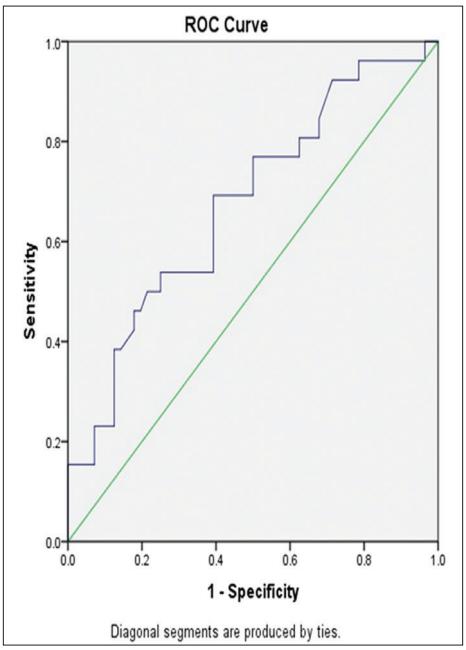

Figure 3: Receiver operating characteristic curve to establish a cutoff of T1 slope to predict loss of cervical lordosis.

DISCUSSION

In recent literature, T1 slope emerged as an important predictor for LOCL following laminoplasty.[1,3-6] Most studies[1,3-6] 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*.[3] 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 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)[5]	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)[3]	51	CSM-21 OPLL-31	C2-C7 CA, C2-C7 ROM, T1S,	Not tested	Not tested	Preoperative T1 slope (*P*=0.001)
Kim *et al*. (2016)[4]	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)[2]	76	CSM	C2-C7 CA, C2-C7 SVA, T1S, thoracic kyphosis (TK),	Not related with preoperative T1S	Not related with T1S	Not related with preoperative T1S
Zhang *et al*. (2017)[6]	41	CSM	C2-C7 CA, C2-C7 SVA, T1S, C2-C7 ROM, CVLL	Not tested	Not tested	Preoperative T1S (*P*=0.003), C2-C7 SVA (*P*=0.001), CVLL (*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

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.

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Conflicts of interest

There are no conflicts of interest.

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