



Feasibility of Sub-Axial Cervical Lamina Screws, Including C7, in the Indian Population: A Study on 50 Patients Using Computed Tomography-Based Morphometry Measurements

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Study Design: Observational study of computed tomography (CT) data.

Purpose: We performed a CT-based radiographic analysis of sub-axial cervical lamina in the Indian population to assess the feasibility of laminar screws.

Overview of Literature: Morphometric studies have been performed for populations of various ethnic groups, but none exist for Indian populations.

Methods: Cervical spine CT scans of 50 adults with a minimum slice thickness of <2 mm (0.5–2 mm) were obtained from the database of a single center in northern India. Measurements (e.g., length, thickness, and height) were taken in millimeters along the axial, coronal, and sagittal planes. Three measurements were made to assess laminar anatomy, namely, the translaminar/screw length, laminar thickness, and sagittal laminar height.

Results: The final sample comprised 500 laminae in 50 patients, resulting in 1,500 measurements. The mean translaminar lengths of the C3, C4, C5, C6, and C7 laminae were 19.48 mm, 19.60 mm, 19.61 mm, 20.49 mm, and 22.85 mm, respectively. The mean thicknesses of these cervical laminae were 3.12 mm, 2.62 mm, 2.56 mm, 3.47 mm, and 5.20 mm, respectively. The mean sagittal heights of these laminae were 9.38 mm, 9.80 mm, 10.12 mm, 11.31 mm, and 13.84 mm, respectively. Except for the C7 vertebrae, all other levels had a success rate of <10% in the Indian population using the criteria of a laminar height of at least 9 mm and thickness of 4.5 mm. Limited success was achieved at the C5, C6, and C3 levels.

Conclusions: To the best of our knowledge, the present study is the only series on the feasibility of laminar screws in the sub-axial cervical spine in the Indian population. We found that Indian patients have smaller anatomical dimensions and thus, are not suitable for laminar screws in the sub-axial cervical spine, barring C7, which is contrary to findings for populations in western and south Asian countries.

Keywords: Indian; Cervical; Morphometry; Translaminar; Screws

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Introduction

Posterior instrumentation of the cervical spine and fusion with or without decompression is extensively used for the treatment of several cervical spine pathologies [1]. It may be used alone or in combination with the standard anterior cervical approach to provide immediate stabilization along with adequate decompression, allowing for early mobility [2]. The workhorse of posterior cervical instrumentation is lateral mass screw fixation, which is technically easy to place. However, due to anatomical variations, it may not be the ideal choice in several conditions, particularly at lower levels where because of size and anatomical considerations, the placement becomes technically difficult. In such cases, there is a higher pull-out rate along with lower pullout strength into the bone [3,4], with a slight possibility of injury to the vertebral artery in foramen transversarium. To address these issues, cervical pedicle screws were popularized by Abumi et al. [5-7]. Unfortunately, placing a cervical pedicle screw in the sub-axial spine is a much more technically demanding procedure than lateral mass fixation, and it may place both the vertebral artery and spinal cord at risk because of their close proximity to the screw. The rate of radiological malposition is also reported to be higher [8,9].

In view of the above limitations, recent reports on cervical laminar screws have highlighted their simplicity and safety relative to pedicle screws [10-12]. Sub-axial cervical spine morphometry reports have noted wide anatomical variability in the dimensions of the sub-axial lamina, both in pediatric and adult populations [13-15]. Biomechanically, it is better than the lateral mass as the stress around the pedicle body complex and range of movement anticipated for the construct are smaller [16]. To date, there

have been only few computed tomography (CT)-based analyses of the morphometry and feasibility of sub-axial cervical spine laminar screws [14,17,18]. However, to the best of our knowledge, none of these analyses were conducted in an Indian population.

The primary aim of this study was to conduct a CT-based radiographic analysis of the sub-axial cervical lamina in an Indian population to assess the feasibility of laminar screws and to identify ethnic differences in morphometry because knowledge on ethnic variations may allow limited use of this technique in this population.

Materials and Methods

After obtaining the appropriate ethical approval, 50 adult cervical spine CT scans with minimum slice thickness of <2 mm (0.5–2 mm) were obtained from the database of a single center in New Delhi, northern India. The raw volumetric axial images were taken, and CT reconstruction in the sagittal and coronal planes was performed using software (Radiant version 3.2.2; <http://www.radiantcms.org/>). Patients with incomplete cervical region scans were excluded. Cases with a demonstrable lesion in the sub-axial cervical spine in the form of a fracture, tumor, infection, inflammatory disease, or congenital malformation were also excluded.

Measurements (e.g., length, thickness, and height) were taken in millimeters along the axial, coronal, and sagittal planes. Three measurements were made to assess laminar anatomy, namely, the translaminar/screw length, laminar thickness, and sagittal laminar height.

The translaminar/screw length was measured using a technique that involves measurements of the axial plane

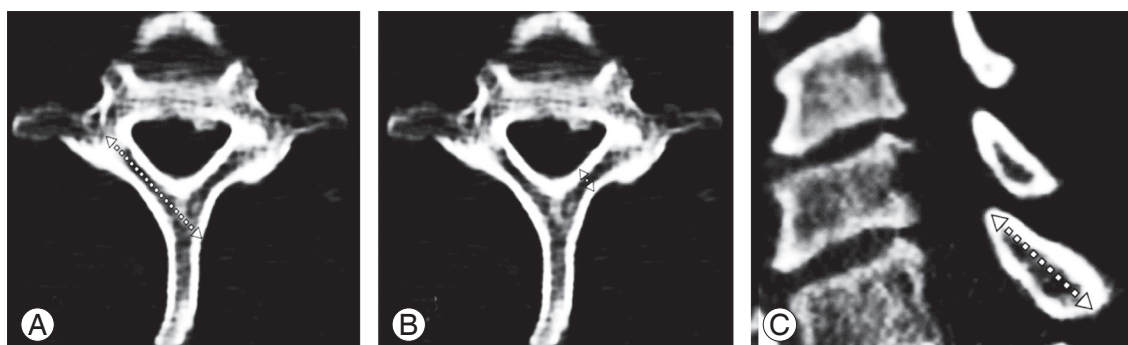


Fig. 1. Computed tomography images with representative measurement of translaminar length (A), translaminar thickness (B), and sagittal height (C).

from the junction of the lateral mass and lamina to the contralateral outer cortex of the spinous process (Fig. 1A). The next measurement was the thickness of the lamina taken at the isthmus or narrowest part of the lamina, spanning from the ventromedial to the dorsolateral sides of the central portion bilaterally from C3 to C7 (Fig. 1B). Lastly, the sagittal measurement or lamina height was measured bilaterally along the parasagittal plane from C3 through C7, which was defined as the most rostral point of the lamina, terminating at the most caudal portion of the lamina of the same vertebrae on the sagittal plane (Fig. 1C). The three measurements were performed after the two authors agreed on the image based on the above criteria using PACS software (Radiant) to achieve consistent observations.

Descriptive statistics, including the mean, standard deviation, and range, were calculated. Differences in measurements of the right and left lamina dimensions, along with sex variation, were assessed using Student *t*-tests. The literature was then reviewed along with the resulting data to identify variations and their amenability to instrumentation.

Results

1. Patient demographic data

Fifty (25 males, 25 females) cervical spine CT scans were evaluated in this study. The mean age of male patients was 54±12.1 years (range, 31–75 years) and the mean age of female patients was 49.2±15.2 years (range, 22–80 years). Age did not significantly differ between sexes ($p=0.45$).

2. Morphometric analysis

The final study sample comprised 50 laminae in 50 patients, giving 1,500 measurements. The mean translaminar lengths of the C3, C4, C5, C6, and C7 laminae were 19.48 mm, 19.60 mm, 19.61 mm, 20.49 mm, and 22.85 mm, respectively. The mean thicknesses of these cervical laminae were 3.12 mm, 2.62 mm, 2.56 mm, 3.47 mm, and 5.20 mm, respectively. The mean sagittal heights of these laminae were 9.38 mm, 9.80 mm, 10.12 mm, 11.31 mm, and 13.84 mm, respectively (Table 1).

Measurements for individual levels for both sexes were done as depicted in Table 2. There were statistically significant differences in lamina thickness for males and fe-

Table 1. Mean morphometric (i.e., translaminar length, thickness, height, and sagittal-diagonal) measurements at each vertebral level

Level	Lamina length	Lamina thickness	Lamina sagittal height
C3	19.48±2.03	3.12±0.77	9.38±1.59
C4	19.60±2.08	2.62±0.65	9.80±1.44
C5	19.61±2.13	2.56±0.66	10.12±1.54
C6	20.49±2.41	3.47±0.88	11.31±1.82
C7	22.85±2.38	5.20±0.79	13.84±1.37

Values are presented as mean±standard deviation.

males, particularly at C7 ($p=0.0017$). In the morphometric values, no statistically significant differences were noted between the right and left sides at all levels.

3. Success rate of screw placement

As depicted in Table 3, the success rate of screw insertion was calculated using the criteria of Chern et al. [13], Shin et al. [17], and Alvin et al. [18]. Besides the C7 vertebrae, all other levels had success rates of <10% in the Indian population using the criteria of a lamina height of at least 9 mm and thickness of 4.5 mm. The C4 did not allow placement of lamina screws by the criteria, whereas limited success was noted at the C5, C6, and C3 levels.

Discussion

Lamina screws were popularized by Wright [19] for C2 as a safer alternative to pedicle screws in the C1–C2 constructs. This technique allows direct insertion under regular vision, eliminating the need for navigation or fluoroscopy, and is not limited by the positioning of vascular structures with good biomechanical stability. Encouraged by the use of C2 lamina screws, Hong et al. [14] extended their use in the sub-axial spine. Subsequently, many authors have reported the feasibility and use of this technique in a limited way, but none have done so in the context of Indian patients. Because ethnic variation has been reported for anatomical structures, such as pedicles and condyles [20–22], this study focused on the ability to apply this technique to Indian populations.

1. Morphometric Measurements

Lamina thickness, which is the most critical dimension

Table 2. The mean morphometric (i.e., translaminar length, thickness, and sagittal-height) measurements at each vertebral level for men and women

Vertebrae	Length		Thickness		Sagittal height	
	M	F	M	F	M	F
C3	19.8±1.7 (16.5–28.3)	19.1±2.20 (13.7–24.5)	3.22±0.77 (1.3–5.2)	3.02±0.75 (1.80–5.40)	9.89±1.59 (6.90–13.4)	8.8±1.42 (5.10–12.6)
C4	19.51±2.22 (9.4–23.7)	19.48±2.41 (14.8–24.9)	2.70±0.65 (1.60–4.20)	2.53±0.64 (1.30–4.40)	9.29±1.36 (7.00–12.4)	10.30±1.31 (7.2–12.9)
C5	20.23±2.19 (16.3–23.4)	18.99±1.89 (18.4–24)	2.64±0.65 (1.20–3.90)	2.46±0.66 (1.40–4.60)	10.69±1.32 (7.40–12.8)	9.63±1.57 (4.80–12.5)
C6	21.7±1.85 (17.4–25.9)	19.31±2.34 (13.6–23.6)	3.66±0.90 (1.50–5.90)	3.29±0.82 (1.90–5.40)	11.75±1.55 (7.1–14.6)	10.87±1.97 (5.50–14.5)
C7	23.59±2.53 (17.5–30.1)	22.11±1.97 (17.9–27.2)	5.43±0.70 (3.7–6.9)	4.97±0.80 (3.3–6.8)	14.10±1.20 (11.0–16.9)	13.58±1.40 (11.1–17.8)

Values are presented as mean±standard deviation (range).
M, male; F, female.

for placing laminar screws, was at its maximum at C7 (>5 mm) and <3 mm at all other levels, barring C3 where the mean was 3.12 mm. This is mostly in line with reports by Xu et al. [23] and Chern et al. [13] of pediatric patients, but lower than the values reported by Alvin et al. [18] where the average thickness was >4 mm at all sub-axial cervical levels. This finding underscores the wide variation in anatomy. Males were significantly more likely than females to have a laminar thickness that allows safe placement of laminar screws at C7.

The laminar length, which determined the length of laminar screw, was smaller than previously reported values. The mean was consistently <24 mm at all levels, including C7. This is important as a 24-mm screw length was used in biomechanical and anatomical studies on laminar screws [14,24], and these may thus, not be suitable for Indian patients as none would qualify for this technique. This finding warrants further biomechanical research focused on the effect of screw length and pullout strength/biomechanical stability in the above technique.

The laminar height was >9 mm at all levels in the sub-axial spine, which should allow bilateral placement of adequately sized screws, assuming the commonly used screw dimensions of 3.5 mm. The maximum sagittal height was noted at C7, and the mean values decreased moving from the caudal to cephalad level. Our findings were similar to those by Alvin et al. [18] for mean sagittal diagonal measurements, but with consistent measurements of >10 mm at all levels.

2. Anatomical feasibility of screw placement

The reported feasibility of placing 3.5 mm laminar screws, based on anatomical measurements, varies across studies. In this study, we applied the criteria used by Chern et al. [13], Shin et al. [17], Alvin et al. [18] as outlined in Table 3. Based on these criteria, laminar screws are not feasible at C3, C4, C5, and C6; C7 was the only level where the acceptability was >80% for at least two criteria. This resonates with work by Cardoso et al. [24] that reported 100% feasibility in C7 lamina in nine patients in a series for 3.5-mm screws. The study by Shin et al. [17] reported higher feasibility of C7 laminar screws and screws at other levels compared to our study. However, they did not recommend placing laminar screws at C4 or C5, and recommended extreme caution at C3 and C6 (approximately 30%). This emphasizes the anatomical limitations of lami-

Table 3. Feasibility of laminar screw using various published criteria

Variable	Feasibility using criteria of Chern et al. [13]	Feasibility using modified criteria of Shin et al. [17]	Feasibility using criteria of Alvin et al. [18]
Criteria			
Laminar height (mm)	≥9	-	≥7
Laminar thickness (mm)	≥4.5	≥4.0	≥4.5
Screw length (mm)	-	25	≥7
Vertebral level (%)			
C3	6	0	7
C4	0	0	0
C5	1	0	1
C6	8	1	13
C7	83	12	83

nae in Indian patients and possible ethnic differences.

3. Limitations

The study investigated a limited number of patients and their CT scans to assess the morphometry of the laminae of the sub-axial cervical spine in Indian patients. The dataset mainly comprised patients from northern India and may thus, not represent the full spectrum of India's ethnic diversity. Moreover, we did not perform a computer simulation and relied on criteria published by other authors to assess the feasibility of the screws. Finally, height, weight, and body mass index were not considered in this study. Despite these shortcomings, this is the first study to assess this novel technique in an Indian population.

Conclusions

To the best of our knowledge, the present study is the only series that assessed the feasibility of laminar screws in the sub-axial cervical spine in an Indian population. We found that Indian patients, by virtue of genetic and ethnic variations, have smaller anatomical dimensions that make them unsuitable for laminar screws in the sub-axial cervical spine, barring C7, contrary to reports from western and south Asian countries. These findings suggest that standard implant dimensions need to be altered and supplemented by biomechanical studies for this technique to be successful in Indian populations, and such alterations may include a smaller diameter and length screws that are custom built for use in this technique.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Acknowledgments

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