10.5005/jp-journals-10039-1099

RESEARCH ARTICLE

Computerized Tomographic Morphometric Analysis of Subaxial Cervical Spine Pedicles in a South Indian Population for guiding Pedicular Mass Fixation

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ABSTRACT

Introduction: Our hospital Sri RL Jalappa Hospital is located on the national highway in South India. We receive many patients with history of trauma following road traffic accidents and fall from height. Most of the patients have sustained injuries to head and spine including cervical spine. The general population also presents with neck pain of various etiologies (e.g., cervical myelopathy).

Aim: To assess the morphometry of the subaxial cervical spine pedicles through computerized tomography and to determine the frequency of neurovascular injuries in patients who undergo pedicular mass fixation in cervical spine.

Materials and methods: This study was a hospital-based prospective intervention study centered at RL Jalappa Hospital and Research Centre attached to Sri Devaraj Urs Medical College, Kolar, from November 2013 to July 2015 in which data of 200 patients who underwent computerized tomographic scans of the cervical spine and neck for various pathologies were collected and assessed.

Results: The mean values of pedicle lengths and widths were found to be progressively increasing for both males and females from C3 to C6 vertebrae level and then slightly decreasing at C7 level. Also, it can be seen that the mean values for females are smaller than those for males, for both left and right side. We found that transverse and sagittal plane angulations were significantly dependent on spinal level. Transverse angulation was approximately 45° at C3 through C5 and decreased caudally to approximately 33°at C7 for both sexes.

Conclusion: Through this study we found that there is less significance in the demographic profile. There was a progressive increase in the lengths, widths, and height of the pedicles from C3 to C7 vertebra pedicle transverse angle. Though the literature describes the use of 3.5 mm cervical pedicular screws, Indian population will require a smaller size.

Keywords: Cervical spine pedicles, Computerized tomography, Morphometric analysis, Pedicular mass fixation.

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How to cite this article: Asadhi N, Gudi N, Sakalecha AK, Shanthappa A, Seenappa H. Computerized Tomographic Morphometric Analysis of Subaxial Cervical Spine Pedicles in a South Indian Population for guiding Pedicular Mass Fixation. J Spinal Surg 2016;3(3):96-102.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Our hospital Sri RL Jalappa Hospital is located on the national highway in South India. We receive many patients with history of trauma following road traffic accidents and fall from height. Most of the patients have sustained injuries to head and spine including cervical spine. The general population also presents with neck pain of various etiologies (e.g., cervical myelopathy). The age group of the trauma victims is at the peak earning phase of life. Cervical spine injuries with or without neurological deficits can be devastating to the individual and the family.

Subaxial cervical spine instability can be caused by various conditions, such as trauma, neoplasm, infection, or posterior cervical decompression procedures. In many conditions, the cervical spine stabilization is needed to maintain spinal alignment. Although other surgical techniques, such as clamp and hook plating, lateral mass screw fixation, or interspinous wiring have been shown effective in stabilizing the cervical spinal column, from the mechanical perspective, the cervical transpedicular screw (CPS) fixation provides a stronger construction than the others and less likely to fail.

Therefore, a quantitative understanding of cervical pedicle morphology at different spinal levels would minimize the risk and improve the successful surgical outcome. Several studies have already been documented regarding the external dimensions and angular parameters of the pedicles. To the best of our knowledge, there are only a few studies documenting the internal architecture of the cervical pedicle, especially the narrowest part of the cervical pedicle or isthmus, which is the crucial part to determine the trajectories and size of the pedicle screw.

In light of all facts, we have planned to assess the morphometry of the subaxial cervical spine pedicles through computed tomography (CT) and to determine

the frequency of neurovascular injuries in patients who undergo pedicular mass fixation.

MATERIALS AND METHODS

This study was a hospital-based prospective intervention study centered in the Department of Orthopaedics and Radiodiagnosis at RL Jalappa Hospital and Research Centre attached to Sri Devaraj Urs Medical College, Kolar, from November 2013 to July 2015 in which data of 200 patients who underwent CT scans of the cervical spine and neck for various pathologies were collected and assessed. Computed tomography scans were performed with the patient supine and the neck at a neutral position. The age group above 18 years and subjects with cervical spine fractures, cervical spine pain indicating CT requirement, viz., cervical myelopathy, were included.

Patients with more than one pedicle fracture in the same level cervical spine and an evidence or history of previous cervical spine surgery, infections, neoplasms, trauma, or congenital spinal anomalies were excluded from the study.

The information from these evaluations provided indirect assessments of spinal stability. Stability of the spine has been defined by White and Panjabi.

METHODOLOGY AND PROCEDURE

The cervical CT scans were performed by using a CT scanner (Siemens 16 slice CT machine). Axial CT images were obtained with 1 mm slice thickness.

Eight important anatomic dimensions have been identified, which are significant from the viewpoint of spinal surgery:

PL – L = Pedicle length (Left) (Fig. 1)
PL – R = Pedicle length (Right)
PDW – L = Pedicle width (Left) (Fig. 2)
PDW – R = Pedicle width (Right)
PDH – L = Pedicle height (Left) (Fig. 3)
PDH – R = Pedicle height (Right)
PTA – L = Pedicle transverse angle (Left) (Fig. 1)
PTA – R = Pedicle transverse angle (Right)

These parameters have been measured (for each of five cervical vertebrae, C3 to C7) from the CT scan data of the patients, by using MIMICS software. Degenerative problem is very rare at C1 and C2 level and it is prevalent at the lower cervical spine, i.e., from C3 to C7 level.

Statistical Analysis

The data obtained were analyzed using Statistical Package for the Social Sciences (SPSS) software version 20.0 for Windows (SPSS, Chicago, IL). All the results were expressed as mean ± standard deviation (SD) and frequency (%); $p < 0.05$ was considered as significant.

RESULTS

- In demographic profile, out of 200 patients, 105 were males and 95 were females.

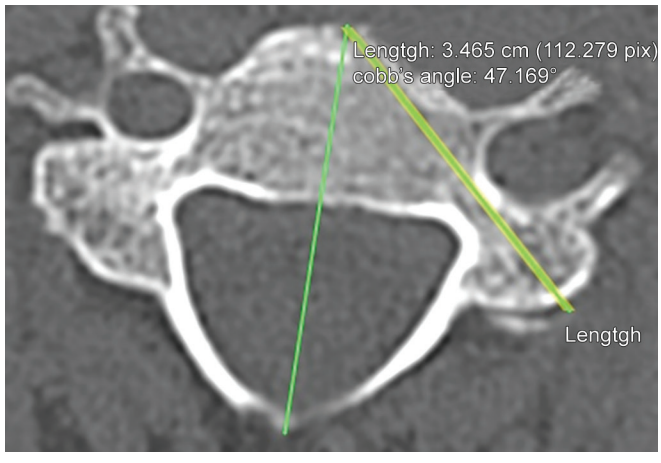

Fig. 1: Pedicular length and transverse angulation

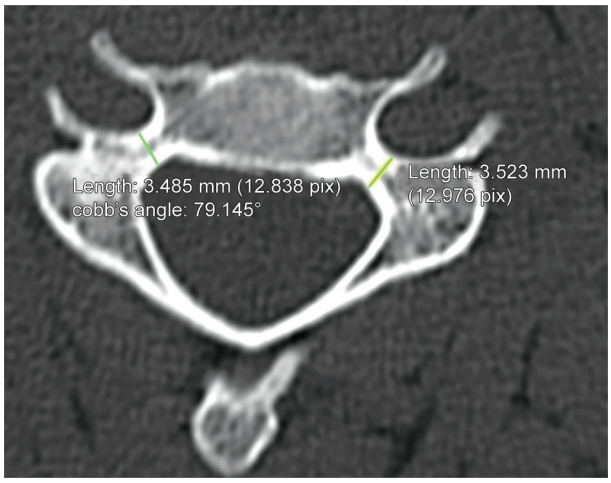

Fig. 2: Pedicular width

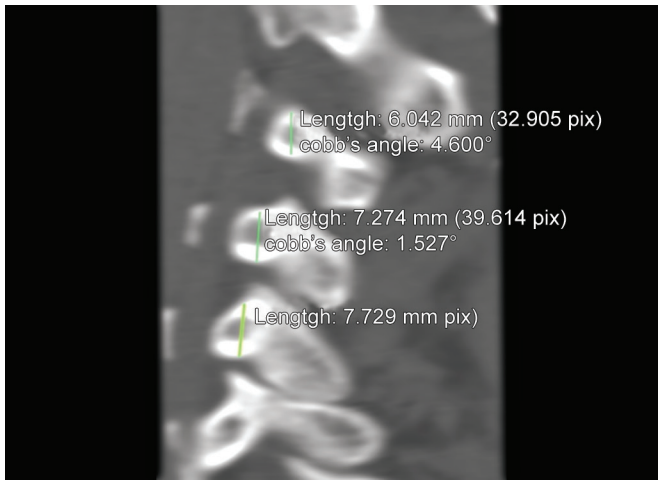

Fig. 3: Pedicular height

- The age variation between male and female patients was not statistically significant, p = 0.101.
- As shown in Table 1, the mean values of pedicle lengths have been found to be progressively increasing for both males and females from C3 to C6 vertebrae level and then slightly decreasing at C7 level. Also, it can be seen that the mean values for females are smaller than those for males, for both left and right sides.
- Table 2 shows the variation of mean values of pedicle widths through vertebrae levels from C3 to C7. The same progressively increasing trend is noticed here too, which continues up to C7. Like pedicle length values, in this case pedicle widths also are found to be smaller for women than for men, at all vertebrae levels, but the difference between left side and right side is very little for both men and women.
- The variation of mean values of pedicle height is shown in Table 3. A little fluctuating nature is observed for women, though the values are smaller than those for men. For this parameter, very little difference is observed between left side values and right side values for men. But, for women, some appreciable difference is noted.
- The variation in case of PTA among the gender has been demonstrated in this present study (Table 4). Males had wide angle than females, but not in significant amount. However, we found that the PTA variation among C3 to C7 demonstrated the same pattern among the left and right pedicles as they had wide angle in the upper subaxial cervical spine, C3 to C5, and became slightly narrow in the lower cervical region at C6 and C7.

DISCUSSION

Subaxial cervical spine instability can be caused by various conditions, such as trauma, neoplasm, infection, or posterior cervical decompression procedures. In many conditions, the cervical spine stabilization is needed to maintain spinal alignment.[1] Although other surgical techniques, such as clamp and hook plating, lateral mass screw fixation, or interspinous wiring have been shown effective in stabilizing the cervical spinal column, from the mechanical perspective, the CPS fixation provides a stronger construction than the others and is less likely to fail.[2]

To date, CPS is one of the most advanced procedures for treatment of cervical instability, and many recent studies have demonstrated the excellent efficacy of its application in cervical spine surgery.[3,4] Moreover, the advanced intraoperative imaging techniques, such as the navigation-guided spine surgery or three-dimensional image-based navigation systems, can provide a greater accuracy and safety during CPS insertion, which results

Table 1: Pedicle length (mm) of studied patients

		Left		*Right*	
		Mean ± SD	*Range*	*Mean ± SD*	*Range*
C3	Male	4.85 ± 0.4	2.75–5.98	5.34 ± 0.3	3.76–6.86
	Female	3.61 ± 0.5	2.12–5.16	4.48 ± 0.4	2.24–5.68
C4	Male	4.96 ± 0.7	2.82–5.97	5.39 ± 0.2	3.55–6.44
	Female	3.72 ± 0.6	2.32–5.62	4.36 ± 0.3	2.76–5.89
C5	Male	5.16 ± 0.3	3.22–6.86	5.54 ± 0.3	3.66–6.46
	Female	4.14 ± 0.4	2.44–5.86	4.76 ± 0.3	2.56–5.87
C6	Male	5.37 ± 0.5	3.42–6.82	5.76 ± 0.5	3.86–6.84
	Female	4.18 ± 0.3	2.36–5.63	4.78 ± 0.4	2.63–5.46
C7	Male	5.29 ± 0.3	3.44–6.98	5.49 ± 0.3	3.87–6.98
	Female	4.68 ± 0.4	2.56–6.26	4.69 ± 0.4	2.88–5.64

Table 2: Nature of variation of pedicle width

		Left		*Right*	
		Mean ± SD	*Range*	*Mean ± SD*	*Range*
C3	Male	5.12 ± 0.5	3.16–7.18	4.82 ± 0.3	3.04–7.72
	Female	4.14 ± 0.3	2.24–6.68	4.23 ± 0.4	2.67–6.88
C4	Male	5.18 ± 0.4	3.14–7.62	4.88 ± 0.6	3.44–7.84
	Female	4.17 ± 0.5	2.62–6.71	4.27 ± 0.8	2.12–6.56
C5	Male	5.35 ± 0.6	3.46–7.36	5.15 ± 0.4	3.53–8.46
	Female	4.48 ± 0.5	2.84–6.68	4.45 ± 0.5	2.23–7.51
C6	Male	5.52 ± 0.4	3.54–8.63	5.62 ± 0.7	3.63–7.68
	Female	4.56 ± 0.5	2.38–6.94	4.56 ± 0.6	2.32–7.32
C7	Male	5.91 ± 0.6	4.76–8.63	5.83 ± 0.5	3.48–8.24
	Female	5.28 ± 0.5	3.86–7.85	5.38 ± 0.4	4.23–8.16

Table 3: Nature of variation of pedicle height

		Left		*Right*	
		Mean ± SD	*Range*	*Mean ± SD*	*Range*
C3	Male	6.81 ± 0.5	4.76–8.23	6.46 ± 0.4	4.23–8.56
	Female	6.44 ± 0.3	4.36–8.18	6.18 ± 0.5	4.06–8.28
C4	Male	6.92 ± 0.5	4.76–9.26	6.72 ± 0.4	4.27–8.48
	Female	5.93 ± 0.4	4.12–8.24	5.26 ± 0.7	4.12–8.27
C5	Male	7.07 ± 0.3	5.04–9.56	6.81 ± 0.5	4.67–8.69
	Female	6.72 ± 0.4	4.56–8.85	5.54 ± 0.3	4.15–8.42
C6	Male	6.84 ± 0.4	4.82–9.24	6.81 ± 0.5	4.67–8.96
	Female	5.76 ± 0.3	3.98–8.16	5.48 ± 0.6	4.05–8.66
C7	Male	6.94 ± 0.2	4.56–8.36	6.92 ± 0.7	4.77–8.96
	Female	5.89 ± 0.4	4.43–8.42	5.86 ± 0.4	4.21–8.43

Table 4: Pedicle transverse angle (degree) of studied patients

		Left		*Right*	
		Mean ± SD	*Range*	*Mean ± SD*	*Range*
C3	Male	46.54 ± 3.61	38.67–56.62	46.13 ± 3.65	37.13–55.72
	Female	46.37 ± 3.16	41.85–53.91	46.17 ± 3.35	42.97–55.15
C4	Male	49.74 ± 3.82	40.12–59.11	49.92 ± 4.0	39.78–60.73
	Female	48.05 ± 3.16	43.31–55.98	48.26 ± 4.36	43.68–57.85
C5	Male	49.13 ± 4.09	36.8–60.28	49.48 ± 4.29	37.82–63.05
	Female	48.03 ± 3.78	43.77–57.67	48.54 ± 3.37	43.73–54.4
C6	Male	46.02 ± 4.21	37.4–57.1	46.27 ± 4.34	34.64–57.93
	Female	46.34 ± 3.17	41.97–53.5	45.16 ± 3.96	33.44–52.71
C7	Male	39.36 ± 4.81	29.7–50.24	38.86 ± 4.84	28.93–51.0
	Female	39.42 ± 4.36	32.23–46.23	38.41 ± 4.97	31.6–49.05

in the popularity of CPS fixation among cervical spine surgeons.[5,6]

However, CPS insertion is a technically demanding procedure, as it carries a risk of catastrophic damage to the surrounding neurovascular structures.[7] The small size of cervical pedicles and variability in the pedicle morphometry demand a careful assessment of the entry point and the angle of placement of the screws. High percentage of pedicle wall violations has been observed in experimental model[8] and even in clinical studies despite the use of intraoperative image guide navigation.[5,6]

Therefore, a quantitative understanding of cervical pedicle morphology at different spinal levels would minimize the risk and improve the successful surgical outcome. Several studies have already been documented regarding the external dimensions and angular parameters of the pedicles.[9] To our best knowledge, there are only a few studies documenting the internal architecture of the cervical pedicle, especially the narrowest part of the cervical pedicle or isthmus,[10] which is the crucial part to determine the trajectories and size of the pedicle screw.

A prospective intervention study was carried out at the Department of Orthopaedics and Radio-diagnosis, Sri RL Jalappa Hospital with the objective to assess the morphometry of the subaxial cervical spine pedicles through CT and to determine the frequency of neurovascular injuries in patients who undergo pedicular mass fixation.

Demographic Data

Demographic data of the present study, i.e., age comparison between male and female patients and gender distribution, were not statistically significant ($p > 0.05$). Few studies were similar to our findings as reported by Chanplakorn et al,[11] Rao et al,[12] Banerjee et al,[13] and Chen et al.[14] Pedicle morphometry has previously been evaluated in cadaver spines or patients who underwent surgical intervention with use of physical measurement devices[9,15-17] or medical imaging modalities.[18-21] Sample populations included older specimens or patients,[9,17,19,20] limited sample size,[9,16,18] or unidentified age and sex.[9,15,18,20] Despite these differences in measurement technique and study population, our results are consistent with previous data.

Morphometry of the Subaxial Cervical Spine Pedicles through CT

As shown in Table 5, the mean values of pedicle lengths have been found to be progressively increasing for both males and females from C3 to C6 vertebrae level and then slightly decreasing at C7 level. Also, it can be seen that the mean values for females are smaller than those for males, for both left and right sides.

Table 2 shows the variation of mean values of pedicle widths through vertebrae levels from C3 to C7. The same progressively increasing trend is noticed here too, which continues up to C7. Like pedicle length values, in this case pedicle widths also are found to be smaller for women than for men, at all vertebrae levels, but the difference between left side and right side is very little for both men and women.

The variation of mean values of pedicle height is shown in Table 3. A little fluctuating nature is observed for women though the values are smaller than those for men. For this parameter, very little difference is observed between left side values and right side values for men. But, for women, some appreciable difference is noted.

Tables 5 to 7 show the comparative measures of mean pedicle length, width, and height of Indian males and females with those already reported previous studies – all of which dealt with European and American people as reported in the tables. From these tables, it can be seen that the pedicle dimensions of Indian people are smaller at almost all vertebra levels as compared with Caucasians. Since pedicle dimensions are important for transpedicular screw fixation and similar surgeries, this smaller size of

Table 5: Comparison of present and previous measurements of pedicle length of cervical vertebrae

		Pedicle length (mean, in mm)				
Authors (years)		*C3 level*	*C4 level*	*C5 level*	*C6 level*	*C7 level*
Bozbuga et al[15] (2004)		5.3	5.4	5.4	5.8	NA
Kayalioglu et al[22] (2007)		6.15	6.14	5.51	5.67	NA
Liu et al[23] (2010)		NA	NA	NA	NA	NA
Banerjee et al[13] (2012)	Left side	4.89	4.87	5.09	5.42	6.19
	Right side	4.71	4.76	4.98	5.34	6.03
Present study	Left side	4.23	4.34	4.65	4.7	5.07
	Right side	4.91	4.87	5.15	5.27	5.09

NA: Not applicable

Table 6: Comparison of present and previous measurements of pedicle height of cervical vertebrae

		Pedicle height (mean, in mm)				
Authors (years)		*C3 level*	*C4 level*	*C5 level*	*C6 level*	*C7 level*
Panjabi et al[9] (1991)		7.4	7.4	7.0	7.3	NA
Xu et al[24] (1999)		6.4	6.5	6.1	6.0	NA
Ugur et al[25] (2000)		6.3	6.5	6.4	6.6	NA
Panjabi et al[10] (2000)		6.7	7.1	6.3	6.2	NA
Bozbuga et al[15] (2004)		6.9	6.7	7.7	6.9	NA
Kayalioglu et al[22] (2007)		5.93	6.24	6.29	6.23	NA
Liu et al[23] (2010)		6.7	6.78	6.95	7.25	7.63
Banerjee et al[13] (2012)	Left side	6.66	6.69	6.95	6.43	6.75
	Right side	6.15	6.35	6.59	6.41	6.71
Present study	Left side	6.62	6.42	6.89	6.3	6.42
	Right side	6.32	5.99	6.17	6.14	6.39

NA: Not applicable

Table 7: Comparison of present and previous measurements of pedicle width of cervical vertebrae

		Pedicle width (mean, in mm)				
Authors (years)		*C3 level*	*C4 level*	*C5 level*	*C6 level*	*C7 level*
Panjabi et al[9] (1991)		5.6	5.4	5.6	6.0	NA
Ugur et al[25] (2000)		4.9	5.2	5.3	5.7	NA
Panjabi et al[10] (2000)		4.3	4.4	4.9	5.1	NA
Bozbuga et al[15] (2004)		4.5	4.4	4.7	4.7	NA
Kayalioglu et al[22] (2007)		4.16	4.57	5.03	5.28	NA
Reinhold et al[26] (2007)		5.7	5.6	6.2	6.7	7.9
Rao et al[12] (2008)		5.3	5.5	5.75	6.1	7.05
Liu et al[23] (2010)		5.26	5.33	5.68	5.91	6.63
Banerjee et al[13] (2012)	Left side	4.89	4.87	5.09	5.42	6.19
	Right side	4.71	4.76	4.98	5.34	6.03
Chanplakorn et al[11] (2014)	Left side	4.72	4.87	5.28	5.51	6.60
	Right side	4.81	4.85	5.28	5.50	6.54
Present study	Left side	4.63	4.67	4.91	5.04	5.59
	Right side	4.52	4.57	4.8	5.09	5.60

NA: Not applicable

pedicle in the Indian population needs to be taken into account while planning such a surgical procedure.

In CT comparison also, we note that mean transverse pedicle width in our study is less as compared with those reported in the Western population. Our measurements are in agreement with other studies in the Indian population as reported by Banerjee et al,[13] Patwardhan et al,[27] and Gupta et al.[28]

Transverse pedicle width in our study is smaller than that reported in other studies done by Reinhold et al.[26] Reinhold et al[26] in their study used 3.5 mm screws at all levels and reported high percentage of pedicle violations.

The calculated mean values, SD, and also ranges of variation of one morphological parameter, viz., PTA (for male population), are tabulated and compared with those of two previous reports as reported by Ruofu et al[29] and Liu et al.[23] Angular measurements of the transverse pedicle axis provide a quantitative description of the direction of pedicle screw insertion. In a previous study, Abumi et al[30] recommended that the transverse angulation should be medially inclined from 25° to 45°. However, in a more recent study, Sakamoto et al[31] recommended screw insertion angles of approximately 50° from C3 to C6 in order to orient the screw coaxial with the pedicle axis and to reduce the risk of vertebral artery injury. We found that transverse and sagittal plane angulations were significantly dependent on spinal level. Transverse angulation was approximately 45° at C3 through C5 and decreased caudally to approximately 33° at C7 for both sexes.

The variation in case of PTA among the gender has been demonstrated in this present study (Table 8). Males had wide angle than females but not in a significant amount. However, we found that the PTA variation among C3 to C7 demonstrated the same pattern among the left and right pedicles as they had wide angle in the upper subaxial cervical spine, C3 to C5, and became slightly narrow in the lower cervical region at C6 and C7. Our results revealed the characteristic trend, which were comparable to the previous studies as reported in Table 4.[11,13,23]

We assume that this result may be caused by measurement error representing the variation in pedicular axis drawing due to the relatively large dimension of the C7 internal pedicle height and the variation among the shape of C7 vertebral endplate, which may be distorted in a step of image reconstruction.

We identified larger pedicle sizes in men for all four linear dimensions and different angular measurements between men and women. The mean pedicle width and height were approximately 10% greater in men than in women. This finding is consistent with the results of a

Table 8: Comparison of present and previous measurements of PTA of cervical vertebrae

			Pedicle transverse angle (mean, degree)				
Authors (years)			*C3 level*	*C4 level*	*C5 level*	*C6 level*	*C7 level*
Liu et al[23] (2010)	Male		46.34	47.62	46.24	43.36	37.65
	Female		45.44	46.35	46.59	43.22	36.91
Banerjee et al[13] (2012)	Male	Left	47.56	50.77	50.16	47	40.26
		Right	47.3	50.89	50.46	47.25	39.89
	Female	Left	47.39	49.03	49.01	47.31	40.52
		Right	47.14	49.24	49.57	46.13	39.39
Chanplakorn et al[11] (2014)	Male	Left	42.02	43.48	42.86	41.35	38.27
		Right	42.21	43.56	43.05	41.54	38.62
	Female	Left	42.91	44.59	44.59	42.51	39.13
		Right	43.32	44.91	45.05	42.89	39.45
Present study	Male	Left	46.54	49.74	49.13	46.02	39.36
		Right	46.13	49.92	49.48	46.27	38.86
	Female	Left	46.37	48.05	48.03	46.34	39.42
		Right	46.17	48.26	48.54	45.16	38.41

study involving the Japanese population that demonstrated pedicle width and height to be 5.3 and 19.2% greater in men respectively.[19]

Considering these facts and findings from our study, it can be inferred that pedicle screw fixation may not be feasible in the Indian population for all or at all levels for a particular patient, especially in females. Although we did not measure the cortical thickness of pedicle wall, we noted the medial wall to be thicker than the lateral wall.

Multiple authors have reported that medial wall is thicker than the lateral wall and hence pedicle guide probe should be directed toward the medial wall for safe placement of pedicle screw.[11]

Many studies have concluded that preoperative evaluation of each level with multiplanar CT is essential if pedicle screw instrumentation is planned in cervical spine as reported by Ludwig et al,[32] Rao et al,[12] Chanplakorn et al,[11] and Reinhold et al.[26]

In our study the transverse diameter was minimum at C3 for both males and females. It increased from C3 to C7. According to the literature, 3.5 mm screw may not be suitable and could have violated most of the pedicles from C3 to C6 in our study. Hence, a smaller size screw should be considered in the Indian population.

CONCLUSION

- Demographic profile of studied patients was not significant.
- The mean values of pedicle lengths have been found to be progressively increasing for both males and females from C3 to C6 vertebrae level and then slightly decreasing at C7 level. Also, it can be seen that the mean values for females are smaller than those for males, for both left and right sides.
- Table 2 shows the variation of mean values of pedicle widths through vertebrae levels from C3 to C7. The same progressively increasing trend is noticed here too, which continues up to C7. Like pedicle length values, in this case pedicle widths also are found to be smaller for women than for men, at all vertebrae levels, but the difference between left side and right side is very little for both men and women.
- It can be seen that the pedicle dimensions of the Indian people are smaller at almost all vertebra levels.
- Regarding inclinations of pedicles or PTA, which are supposed to determine the direction of screw advancement, it is found from the present study that the angle varies from 28.93° to 63.73°, with mean value of 47.50° for Indian males, while the corresponding values are from 31.6° to 57.85° with mean value of 46.17° for Indian females.
- Hence, a smaller size screw should be considered in the Indian population.

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