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Original Article

Computed tomographic analysis of cervical spine pedicles in the adult Indian population

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Received : 18 December 2020
Accepted : 02 February 2021
Published : 23 February 2021

DOI
10.25259/SNI_926_2020

Quick Response Code:

ABSTRACT

Background: Cervical pedicle screw insertion is a technically demanding procedure that carries the risk of catastrophic damage to surrounding neurovascular structures. Here, we analyzed computed tomography (CT)-based three-dimensional cervical spine pedicle geometry to determine the level and sex-specific morphologic differences in the adult Indian population.

Methods: The CT scans of 200 patients (2400 pedicles) without significant cervical spine pathology were collected. The mean pedicle width (PW), pedicle height (PH), pedicle axial length (PAL), and pedicle transverse angle (PTA) from C2 to C7 were measured.

Results: The smallest mean PW was at C3 in both males (4.85 ± 0.73 mm) and females (4.31 ± 0.43 mm); 7.08% of all pedicles were found to have mean PW of <4 mm. The smallest mean PH was at C5 in both males (6.25 ± 0.67mm) and females (5.54 ± 0.52 mm). The smallest mean PAL was at C2 in both males (27.46 ± 1.69mm) and females (25.90 ± 1.88 mm). The mean PW, PH, and PAL were significantly greater in males than females at all levels ($P < 0.05$). The smallest mean PTA was at C3 in males (41.79 ± 2.53°) and at C7 in females (42.40 ± 2.27°).

Conclusion: In the adult Indian population, the PW, PH and PAL were smaller than in the typical western population. Females had even smaller PW, PH and PAL as compared to males. We recommend that a small inventory of 3.5mm screws between 20mm to 30mm length be used in most cases where cervical pedicle screws are being used in the Indian population. However, individual vertebrae should be screened preoperatively with CT scans to exclude gross anatomical variations, especially in females and at the C3 and C4 levels.

Keywords: Cervical spine, Pedicle screw fixation, Pedicles morphometry

INTRODUCTION

Cervical spine fixation is needed in various conditions affecting spine, but there is considerable variability in cervical spine pedicle dimensions at each level.[1,2] Here, we have provided a three-dimensional (3D) computed tomography (CT)-based understanding of cervical pedicle morphology at different spinal levels to minimize the risk of neurovascular injury and improve outcomes for instrumented cervical pedicle screw fixations.

MATERIALS AND METHODS

With Institutional Review Board approval, we performed this prospective, observational, and single center study (2015–2017). Utilizing 3D-CT scans (using C2-C7 with 0.6mm cuts), we measured 2400 cervical spine pedicles from 200 patients. The study included 148 males and 52 females averaging 31.32 years of age (range 18-45 years). There were multiple exclusion criteria [Table 1].

3D-CT images (read by one Orthopedician and one Radiologist) were utilized to measure pedicle width (PW), pedicle height (PH), pedicle axial length (PAL), and pedicle transverse angle (PTA) [Figures 1-4 and Table 2].[7-10]

Statistical analysis

Descriptive statistics (mean, standard deviation) were determined. Intra-class Correlation Coefficient (ICC) was calculated to find inter-observer agreement and to analyze intra-observer agreement paired *t*-test (95% confidence level) was performed. To identify difference between males and females, right and left side, an independent sample *t*-test and paired *t*-test, respectively, with 95% confidence level were performed.

RESULTS

In our observations, we found that there was no significant difference between two measurements that were taken by same observer and also inter-observer agreement was very good for measurement of PW (ICC 0.95), PH (ICC 0.91), PAL (ICC 0.94), and PTA (ICC 0.92), at all cervical vertebral levels.

Table 1: Inclusion and exclusion criteria of the study.

Inclusion criteria	Exclusion criteria
• Age 18 to 45 years of either sex • All patients in whom cervical spine CT scan was required as a part of workup	• Congenital and developmental abnormality of cervical spine • History of infection, tumor, and trauma to cervical spine • History of previous cervical spine surgery

Table 2: Overall mean of PW, PH, PAL, and PTA of cervical spine pedicles from C2-C7 vertebral level.

Vertebral level	PW	PH	PAL	PTA
C2	5.80±0.87	8.10±0.85	27.0±1.88	44.82±3.19
C3	4.71±0.70	6.22±0.75	29.26±1.78	42.08±2.46
C4	4.79±0.69	6.47±0.70	29.09±2.12	43.62±2.95
C5	5.03±0.71	6.06±0.71	30.33±1.85	44.61±3.80
C6	5.18±0.70	6.17±0.71	31.67±1.90	44.38±2.65
C7	6.14±0.80	6.64±0.80	32.22±2.21	42.30±2.44

Values are mean±SD in mm except PTA (in degree). PW: Pedicle width, PH: Pedicle height, PAL: Pedicle axial length, PTA: Pedicle transverse angle

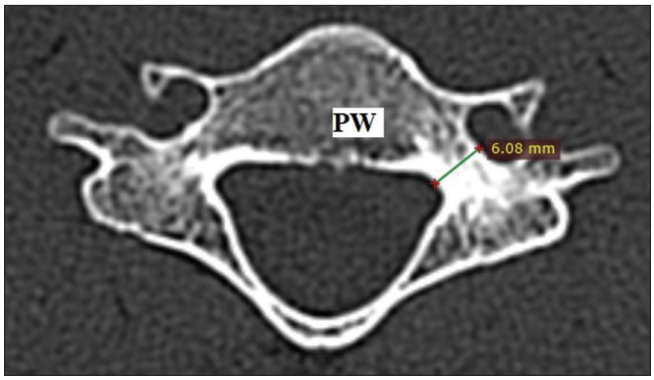

Figure 1: Pedicle width (PW) was defined as the narrowest part of pedicle in the axial cut section between medial border of transverse foramen and medial border of pedicle on either side. Measurement was done in mid-pedicle axial CT section of cervical vertebra.

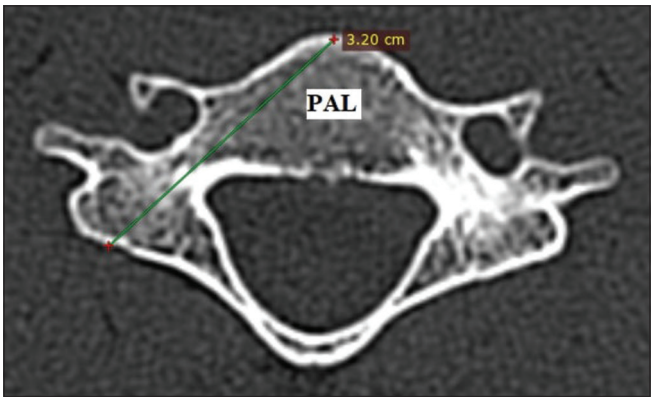

Figure 2: Pedicle axial length was defined as the distance from anterior vertebral body wall to posterior margin of lateral mass along the long axis of pedicle. Measurement was done in mid-pedicle axial CT section of cervical vertebra.

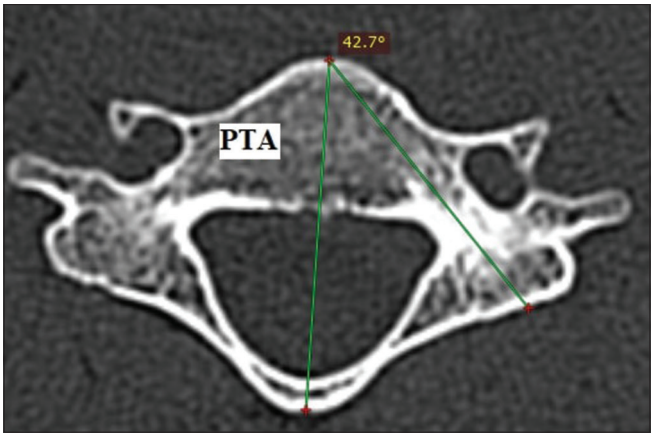

Figure 3: Pedicle transverse angle was defined as the angle formed between mid-sagittal line and pedicle axis. Measurement was done in mid-pedicle axial CT section of cervical vertebra.

PW

The smallest mean PW was at C3 and largest mean PW was at C7 in both males and females while the mean PW for males was statistically significantly greater than females at all level from C2 to C7. Furthermore, noted that the mean PW for right side was greater than left side at all level from C2 to C7 (statistically significant at C3- C6) [Table 3]. About 7.08% of all pedicles were found to have mean PW of <4 mm [Table 4].

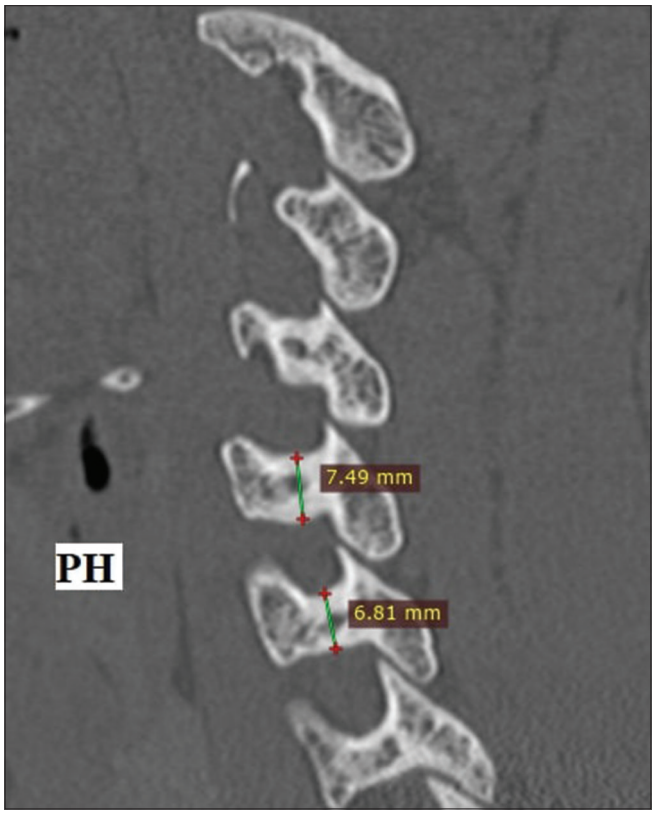

Figure 4: Pedicle height was defined as the narrowest part of pedicle in sagittal plane between upper and lower pedicle surface on either side. Measurement was done in sagittal CT section of cervical vertebra.

PH

The smallest mean PH was at C5 and largest at C2 in both males and females. At all levels PH was greater than PW. The mean PH for males was statistically significantly greater than females at all level from C2 to C7 [Table 5].

PAL

The smallest mean PAL was at C2 in both males (27.46 ± 1.69 mm) and females (25.90 ± 1.88 mm), while the largest mean PAL was at C7 in males (32.94 ± 1.87 mm) and C6 in females (30.35 ± 1.66 mm) [Table 6].

PTA

The smallest mean PTA was at C3 in males (41.79 ± 2.53°) and at C7 in females (42.40 ± 2.27°), while the largest mean PTA was at C2 in males (44.74 ± 3.15°) and at C5 in females (45.29 ± 2.75°) [Table 7].

DISCUSSION

Cervical pedicle screw fixation is technically demanding procedure as it has risk of injury to the surrounding neurovascular structures. Munusamy *et al*.[5] found significant sex and ethnic variability in cervical pedicle sizes and recommended that preoperative CT scans and image-guided screw placement be utilized to ensure safety and accuracy for cervical pedicle screw placement. Here, we determined that the mean PW was smallest at C3 and largest at C7 in adult Indian male and female patients, this is similar to findings in previous studies [Tables 8 and 9].[2,4,5,8,9]

We also found that PW progressively increased for both males and females from C3 to C7, a finding also echoed to prior Indian studies.[3,6] In our study, the mean PH of males was greater than females at all levels from C2 to C7 which is similar to previous reports [Tables 8 and 9].[2,4,5,8,9] Further, we also noted that in

Table 3: The mean pedicle width in males and females, also at right and left side from C2 to C7 vertebral level.

Vertebral level	Right	Left	*P*-value right-left difference	Male	Female	*P*-value male-female difference
C2	5.88±1.00	5.72±0.97	0.087	5.98±0.84	5.35±0.81	0.001
C3	4.88±0.75	4.53±0.78	0.001	4.85±0.73	4.31±0.43	0.001
C4	4.86±0.69	4.72±0.82	0.02	4.94±0.70	4.35±0.44	0.001
C5	5.10±0.82	4.95±0.70	0.013	5.18±0.70	4.59±0.53	0.001
C6	5.25±0.74	5.11±0.76	0.014	5.35±0.68	4.70±0.53	0.001
C7	6.20±0.85	6.08±0.87	0.061	6.33±0.74	5.60±0.72	0.001

Values are mean±SD in mm

Indian adult females, 23.07% at C3 and 15.38% at C4 had mean PW <4 mm.

Table 4: Distribution of pedicles at each vertebral level from C2-C7 that have pedicle width <3 mm, <4 mm, and <5 mm.

Vertebral level (number of pedicles)	Number of pedicles		
	<3 mm	<4 mm	<5 mm
C2 (400)	2	10	68
C3 (400)	2	70	238
C4 (400)	2	52	266
C5 (400)	0	22	218
C6 (400)	0	16	176
C7 (400)	0	0	20
Total (2400)	6	170	986

Based on our finding regarding 3D-CT confirmation of pedicle size in Indian adults, we would recommend that 3.5 mm screws be utilized from the C2 to C7 levels, although 7.08% of pedicles would likely not suitable for such 3.5/4 mm screws.

Further, since we observed, the mean PAL for Indian patients fell within a narrow range of 25.90mm to 32.94 mm from C2 to C7 which is smaller than American population (range from 28.9 mm to 34.3 mm) and similar to Chinese population (range from 27.9mm to 32.5mm), a small inventory of screw lengths ranging from 20 mm to 30 mm should be kept on hand [Tables 8 and 9].

The mean PTA in our study was within a narrow range of 41.79° to 45.29°. Therefore, a rough guideline for angle could be around 40-45° from midline.

Table 5: The mean pedicle height in males and females, also at right and left side from C2 to C7 vertebral level.

Vertebral level	Right	Left	*P*-value right-left difference	Male	Female	*P*-value male-female difference
C2	8.16±0.94	8.03±0.87	0.035	8.32±0.79	7.52±0.72	0.001
C3	6.27±0.85	6.17±0.78	0.100	6.41±0.67	5.67±0.70	0.001
C4	6.53±0.76	6.40±0.77	0.062	6.67±0.61	5.89±0.60	0.001
C5	6.15±0.75	5.98±0.80	0.005	6.25±0.67	5.54±0.52	0.001
C6	6.17±0.72	6.11±0.81	0.297	6.32±0.66	5.64±0.62	0.001
C7	6.64±0.80	6.62±0.86	0.761	6.84±0.70	6.02±0.68	0.001

Values are mean±SD in mm

Table 6: The mean pedicle axial length (PAL) in males and females, also at right and left side from C2 to C7 vertebral level.

Vertebral level	Right	Left	*P*-value right-left difference	Male	Female	*P*-value male-female difference
C2	27.09±1.90	26.90±2.09	0.200	27.46±1.69	25.90±1.88	0.001
C3	29.43±1.89	29.09±1.88	0.007	29.54±1.80	28.47±1.47	0.008
C4	29.17±1.64	29.01±1.84	0.143	29.48±1.53	28.28±2.34	0.001
C5	30.47±2.03	30.20±1.84	0.022	30.78±1.71	29.08±1.66	0.001
C6	31.93±2.10	31.41±1.99	0.001	32.17±1.76	30.35±1.66	0.001
C7	32.49±2.37	31.96±2.22	0.001	32.94±1.87	30.21±1.80	0.001

Values are mean±SD in mm

Table 7: The mean pedicle transverse angle in males and females, also at right and left side from C2 to C7 vertebral level.

Vertebral level	Right	Left	*P*-value right-left difference	Male	Female	*P*-value male-female difference
C2	44.72±3.52	44.92±3.40	0.491	44.74±3.15	45.05±3.33	0.700
C3	42.51±2.75	41.65±2.67	0.001	41.79±2.53	42.91±2.10	0.047
C4	43.96±3.13	43.20±3.13	0.001	43.27±2.92	44.62±2.88	0.045
C5	44.79±3.22	44.42±3.25	0.075	44.37±3.17	45.29±2.75	0.193
C6	44.59±2.74	44.17±2.85	0.027	44.25±2.75	44.71±2.36	0.458
C7	42.33±2.59	42.28±2.72	0.803	42.27±2.50	42.40±2.27	0.816

Values are mean±SD in degree

Table 8: Comparison of PW, PH, PAL, and PTA in males of present and previous studies at C2-C7 vertebral level.

	C2				C3				C4			
	PW	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**
Ebraheim *et al.*[2]	ND	ND	ND	ND	4.9±0.8	6.8±0.8	ND	ND	4.7±0.7	6.9±0.8	ND	ND
Rao *et al.*[8]	ND	ND	ND	ND	5.8±0.9	6.6±0.8	34.3±2.2	47.4±3.4	6.0±0.8	6.8±0.7	33.7±2.4	47.8±3.6
Ruofu *et al.*[9]	ND	ND	ND	ND	5.4±0.6	6.5±0.5	29.6±1.0	50.2±2.4	5.3±0.6	6.4±0.5	28.9±1.1	51.3±2.5
Munusamy *et al.*[5]	ND	ND	ND	ND	5.74±0.89	7.63±0.71	ND	45.7±5.23	5.70±0.87	7.78±0.76	ND	48.4±4.69
Herrero *et al.*[4]	ND	ND	ND	ND	5.1±0.78	6.8±0.86	33.4±2.25	45.6±3.79	5.2±0.80	6.9±0.85	32.3±2.28	46.3±3.97
Present study	5.98 ±0.84	8.32 ±0.79	27.46 ±1.69	44.74 ±3.15	4.85 ±0.73	6.41 ±0.67	29.54 ±1.80	41.79 ±2.53	4.94 ±0.70	6.67±0.61	29.48 ±1.53	43.27 ±2.92

Values are mean±SD in mm except PTA (in degree). ND: Not done. PW: Pedicle width, PH: Pedicle height, PAL: Pedicle axial length, PTA: Pedicle transverse angle

(*Contd...*)

Table 8: (*Continued*).

	C5				C6				C7			
	PW	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**
Ebraheim *et al.*[2]	4.9±0.8	6.50±0.9	ND	ND	5.2±0.6	6.4±0.9	ND	ND	ND	ND	ND	ND
Rao *et al.*[8]	6.3±0.8	6.6±0.7	34.2±2.4	45.9±3.6	6.5±0.8	6.6±0.8	34.1±3.2	41.8±4.3	7.6±1.0	7.0±0.8	32.6±3.2	33.8±5.7
Ruofu *et al.*[9]	5.6±0.6	6.8±0.6	31.3±1.1	50.9±2.3	5.8±0.6	6.9±0.6	31.2±1.3	48.6±2.7	6.7±0.7	7.2±0.7	32.5±1.1	41.2±3.0
Munusamy *et al.*[5]	6.07±0.80	7.53±0.79	ND	47.9±4.20	6.42±0.82	7.51±0.70	ND	44±4.36	7.07±0.77	8.04±0.76	ND	38.2±5.17
Herrero *et al.*[4]	5.6±0.82	6.8±1.97	32.0±2.92	46.4±4.57	5.9±0.84	6.8±0.84	32.1±2.35	45.3±5.46	6.8±0.97	7.3±0.83	31.0±2.24	43.8±7.16
Present study	5.18±0.70	6.25±0.67	30.78±1.71	44.37±3.17	5.35±0.68	6.32±0.66	32.13±1.76	44.25±2.75	6.33±0.74	6.84±0.70	32.94±1.87	42.27±2.50

Values are mean±SD in mm except PTA (in degree). ND: Not done. PW: Pedicle width, PH: Pedicle height, PAL: Pedicle axial length, PTA: Pedicle transverse angle

Table 9: Comparison of PW, PH, PAL, and PTA in females of present and previous studies at C2-C7 vertebral level.

	C2				C3				C4			
	PW	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**
Ebraheim *et al.*[2]	ND	ND	ND	ND	4.5±0.9	4.7±0.6	ND	ND	4.6±0.7	6.3±0.5	ND	ND
Rao *et al.*[8]	ND	ND	ND	ND	4.8±0.9	5.6±1.0	30.9±1.9	46.6±3.2	5.0±0.8	5.6±0.8	30.3±1.7	47.8±2.9
Ruofu *et al.*[9]	ND	ND	ND	ND	4.4±1.0	5.7±0.4	28.2±1.1	49.1±2.1	4.4±0.9	5.9±0.8	27.9±1.2	52.1±3.0
Munusamy *et al.*[5]	ND	ND	ND	ND	4.75±0.43	6.89±0.85	ND	46.7±3.81	4.77±0.38	6.97±0.78	ND	48.8±4.26
Herrero *et al.*[4]	ND	ND	ND	ND	4.3±0.65	6.3±0.81	31.4±1.76	45.1±3.54	4.5±0.59	6.3±0.77	30.4±2.01	45.7±3.31
Present study	5.35±0.81	7.52±0.72	25.90±1.88	45.05±3.33	4.31±0.43	5.67±0.70	28.47±1.47	42.91±2.10	4.35±0.44	5.89±0.60	28.28±2.34	44.62±2.88

Values are mean±SD in mm except PTA (in degree). ND: Not done, PW: Pedicle width, PH: Pedicle height, PAL: Pedicle axial length, PTA: Pedicle transverse angle

(*Contd...*)

Table 9: (*Continued*).

	C5				C6				C7			
	PW	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**	**PW**	**PH**	**PAL**	**PTA**
Ebraheim *et al.*[2]	4.9±0.7	5.9±0.7	ND	ND	5.0±0.8	5.7±0.6	ND	ND	ND	ND	ND	ND
Rao *et al.*[8]	5.2±0.8	5.6±0.7	30.9±2.1	46.9±4.2	5.7±0.8	5.6±0.8	30.6±2.6	42.5±4.5	6.5±0.9	6.0±1.0	28.9±3.5	33.0±5.6
Ruofu *et al.*[9]	5.1±0.7	6.4±0.8	30.0±1.3	48.3±2.7	5.4±0.7	6.7±0.9	30.8±1.3	46.9±2.8	6.3±0.7	6.9±0.9	31.7±1.3	40.6±3.5
Munusamy *et al.*[5]	5.18±0.43	6.82±0.81	ND	47.6±3.81	5.45±0.38	6.82±0.81	ND	44.9±5.28	6.29±0.65	7.16±0.87	ND	37.8±6.16
Herrero *et al.*[4]	4.9±0.66	6.1±0.76	29.9±1.97	46.0±3.75	5.1±0.71	6.1±0.79	29.8±2.19	44.4±3.86	6.0±0.84	6.6±0.83	29.4±2.49	41.0±4.64
Present study	4.59±0.53	5.54±0.52	29.08±1.66	45.29±2.75	4.70±0.53	5.64±0.62	30.35±1.66	44.71±2.36	5.60±0.72	6.02±0.68	30.21±1.80	42.40±2.27

Values are mean±SD in mm except PTA (in degree). ND: Not done, PW: Pedicle width, PH: Pedicle height, PAL: Pedicle axial length, PTA: Pedicle transverse angle

CONCLUSION

Having performed a 3D CT analysis of cervical pedicle morphometry (including PW, PH, PAL, and PTA) in the adult Indian population, we determined that 3.5 mm screws between 20 mm to 30 mm length would usually be sufficient in most cases requiring posterior cervical instrumented fusion.

Declaration of patient consent

Institutional Review Board permission obtained for the study.

Financial support and sponsorship

Publication of this article was made possible by the James I. and Carolyn R. Ausman Educational Foundation.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Kumar S, Saini NK, Singh D, Chadha M, Mehrotra G. Computed tomographic analysis of cervical spine pedicles in the adult Indian population. Surg Neurol Int 2021;12:68.