CT-Guided Pedicle Morphometry of Lumbar Vertebrae

A Comprehensive Exploration Through CT-Guided Pedicle Morphometry of Lumbar Vertebrae in Pakistani Population

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ABSTRACT

Objective: The aim of this study was to determine the dimensions of right & left pedicles of lumbar vertebrae of males and females by CT scan to reduce the risk of postoperative neurological complications while applying transpedicular screws.

Study Design: CT scan based Retrospective Cross Sectional Observational Study.

Place and Duration of Study: This study was conducted at the Radiology Department of M. Islam Teaching Hospital, Gujranwala, Pakistan, between December 2022 and November 2023.

Methods: This study was conducted on 47 patients (22 males & 25 females aged 18 to 70 years). Morphometric data of pedicles of lumbar vertebra was analyzed using CT Scan. Pedicle width (PW), pedicle height (PH), pedicle length (PL) and transverse pedicle angle (TPA) were studied.

Results: Pedicle width, in males, was minimum at right side of L1 while it was maximum at left side of L5. The mean pedicle height in males was 13.36 mm and in females was 11.76 mm. Pedicle length decreased in both males & females from L1 to L5. The greatest value of transverse pedicle angle was found to be 42.4º at right side of L5 in females. Value of transverse pedicle angle increased gradually from L1 to L5 in both males and females.

Conclusion: A detailed anatomical knowledge of lumbar spine is essential for designing implants and instrumentation and to reduce postop complications.

Key Words: Transpedicular screw, pedicle dimensions, lumbar vertebrae, CT scan

INTRODUCTION

The structural analysis of pedicle of vertebra is required for safe application of transpedicular screws[1,2]. The pedicle bone is strongest part of the vertebra so transpedicular screw fixation is increasingly used world-wide as it is stable and provides 3-dimensional fixation[3].

Posterior spine fixation has been used successfully to correct deformity and treat patients who have scoliosis, traumatic injury, vertebral collapse secondary to infection and various spinal tumors[4]. For transpedicular screws, the reported malpositioning percentage based on post operative CT assessment is 11% and 42% for

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other complications like vascular, neurological and visceral[5].

Structural measurement of lumbar vertebrae of a specific topographical area will be quite helpful in accurate implant selection for spinal surgeries, crafting of best implant, interpretation of pathoanatomy of spine, accurate diagnosis of disease and treatment for the population under study[6]. Our study was carried out to measure the parameters of lumbar vertebral pedicles keeping in view the growing interest in lumbar spine instrumentation and for superior comprehension of vertebral structure in Pakistani population. It also aims to understand the morphometric lumbar vertebra pedicle differences in males and females. Most lumbar vertebral studies have been carried out on European populations while similar data in other populations is inadequate[7].

METHODS

This retrospective cross sectional observational study was conducted between December 2022 and November 2023 in the department of Radiology, M. Islam Teaching Hospital, Gujranwala in the Central Punjab of Pakistan.

Sampling Technique and Sample Size: A total of 47 patients' data was included in the study who met the inclusion criteria after evaluating 90 patients record from CT scans of Radiology department; 22 of them were males and 25 were females.

Inclusion Criteria: Adults between the ages of 18 to 70 years, without bone disease and lumbar spinal deformities or fractures, were included in the present study. Both males and females were considered separately.

Exclusion Criteria: Patients excluded were: below 18 & more than 70 years of age, having growth disorders, systemic bone & renal diseases, congenital and acquired spinal deformities, tumors, and TB of spine.

Data Collection: Using Aquilion 16 slice CT scan Toshiba (version 3.2, Japan), 235 lumbar vertebrae were studied after taking ethical clearance from Institutional Ethical Committee. Slice thickness of CT scan machine was 1 mm, and bone window was used to take the measurements. Single observer took all the measurements to prevent the interobserver bias.

CT Scan Measurements: Axial image of spine was selected for measurement of pedicle width, length and angle. The pedicle height was measured using sagittal view of the spine.

Measurement tools of the software of CT scan machine were used to record the width, height, length, and transverse angle of pedicle of lumbar vertebrae.

Pedicle Width: The width in millimeters (mm) was measured, in transverse plane, at the midpoint of the pedicle from outer cortex to outer cortex where maximum dimensions were visible (figure-1).
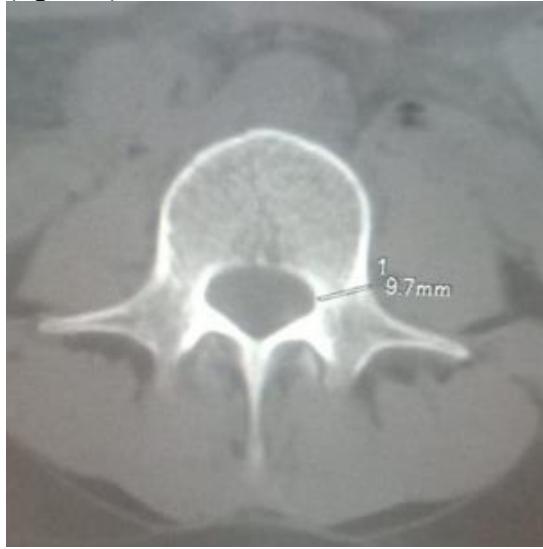

Figure No. 1: Pedicle Width (PW) Measurement in millimeters (mm)

Pedicle Height: It was measured in sagittal plane. Vertical distance between superior and inferior borders of the pedicle at its midpoint was measured in millimeters (figure-2).

Figure No. 2: Pedicle Height (PH) Measurement in millimeters (mm)

Figure No. 3: Pedicle Length (PL) Measurement in millimeters (mm)

Pedicle Length: A horizontal line was drawn touching the posterior border of the vertebral body. Another line was drawn along the longitudinal axis of lamina; the length of pedicle was calculated by drawing a third line that passes through the axis of the pedicle and touches the above-mentioned lines (figure-3).

Transverse Pedicle Angle (TPA): This was measured by drawing one line along the pedicle longitudinal axis extending anteriorly and another line is drawn along the anteroposterior midline axis of the vertebra. The TPA was measured where these two lines meet anteriorly (figure-4)

Data Analysis: Mean, standard deviation, and p-value were calculated in SPSS version 2023.

RESULTS

Gender distribution: There were 46.81% males & 53.19% females in this study.

Age distribution: Mean age of males was 45.6 while of females was 35.6.

Pedicle Width: Pedicle width measurements are shown in Table-1.

Table No. 1: Pedicle Width (PW) in millimeters (mm)

Vertebra	Side	Male				Female				Male & Female (Right & Left) (p-value)
		Mean±SD	Range		Right & Left Sides (p-value)	Mean±SD	Range		Right & Left Sides (p-value)	
			Min	Max			Min	Max		
L1	Right	6.26±0.78	4.7	7.7	0.511	5.04±1.16	2.90	7.10	0.539	<0.001
	Left	6.43±0.90	4.8	7.9		5.24±1.03	3.50	7.20		<0.001
L2	Right	6.94±0.64	5.9	7.8	0.136	5.52±1.02	4.10	7.90	0.522	<0.001
	Left	7.35±0.61	6	8.2		5.34±0.90	3.70	7.70		<0.001
L3	Right	8.58±0.98	7.2	9.9	0.184	7.28±1.39	4.60	9.80	0.932	0.001
	Left	8.17±1.03	6.4	9.9		7.31±1.24	5.30	10.00		0.014
L4	Right	9.95±1.51	6.9	12.9	0.251	8.41±1.24	5.60	10.50	0.138	0.002
	Left	9.43±1.47	6.6	12		8.7±1.57	7.30	13.10		0.049
L5	Right	13.17±1.93	11.1	16.4	0.787	11.41±1.51	8.80	13.90	0.072	0.001
	Left	13.32±1.61	11.6	18		12.27±1.80	8.60	15.60		0.042

Pedicle Height

Pedicle height measurements are shown in Table-2.

Table No. 2: Pedicle Height (PH) in millimeters (mm)

Vertebra	Side	Male				Female				Male & Female (Right & Left) (p-value)
		Mean±SD	Range		Right & Left Sides (p-value)	Mean±SD	Range		Right & Left Sides (p-value)	
			Min	Max			Min	Max		
L1	Right	14.92±1.16	13.2	16.9	0.928	13.38±0.93	12.00	15.50	0.878	<0.001
	Left	14.95±1.16	13.1	17		13.34±0.91	12.00	15.40		<0.001
L2	Right	14.07±1.53	12.3	16.7	0.968	12.25±1.03	10.70	14.00	0.924	<0.001
	Left	14.05±1.49	12.1	16.7		12.22±1.03	10.70	14.00		<0.001
L3	Right	14.32±1.66	11.4	16.8	0.659	12.34±1.28	9.80	14.40	0.887	<0.001
	Left	14.1±1.59	11.4	16.9		12.39±1.29	9.70	14.50		<0.001
L4	Right	13.05±1.25	10.5	14.9	0.911	11.06±1.21	9.40	13.70	0.789	<0.001
	Left	13.01±1.17	10.5	14.8		11.16±1.20	9.30	13.80		<0.001
L5	Right	10.71±0.67	9.9	12.9	0.526	9.76±1.24	6.40	11.50	0.856	0.002
	Left	10.56±0.87	9.3	12.9		9.82±1.24	6.40	12.00		0.024

Pedicle Length

Pedicle length measurements are shown in Table-3.

Table No. 3: Pedicle Length (PL) in millimeters (mm)

Vertebra	Side	Male			Female			Comparison of Male & Female (p-value)
		Mean±SD	Range	Comparison of Right & Left Sides (p-value)	Mean±SD	Range	Comparison of Right & Left Sides (p-value)	
L1	Right	8.98±1.66	6.4 – 11.6	0.073	9.64±2.30	4.70-12.60	0.949	0.272
	Left	10.01±2.00	7.6 – 12.9		9.60±1.64	7.00-12.10		0.453
L2	Right	8.85±2.51	4.2 – 12.1	0.942	8.24±1.96	4.80-11.50	0.341	0.358
	Left	8.9±2.01	5.5 – 12.2		8.71±1.41	6.30-11.60		0.703
L3	Right	7.37±2.11	4.5 – 9.7	0.314	7.06±2.10	3.70-11.50	0.798	0.613
	Left	6.7±2.23	3.5 – 9.8		7.20±1.86	4.10-10.50		0.407
L4	Right	5.44±1.94	2.9 – 10.6	0.090	5.29±2.17	2.50-9.60	0.334	0.806
	Left	4.45±1.86	1.8 – 8		4.75±1.72	1.50-7.90		0.566

L5	Right	4.28±1.16	1.9 – 6.5	0.267	3.87±1.32	1.80-8.10	0.552	0.116
	Left	3.92±0.95	2 – 5.9		3.61±1.46	1.80-8.10		0.399

Transverse Pedicle Angle

Transverse pedicle angle measurements are shown in Table-4.

Table No. 4: Transverse Pedicle Angle (TPA) in degrees (º)

| Vertebra	Side	Male			Female			Comparison of Male & Female (p-value)
		Mean±SD	Range	Comparison of Right & Left Sides (p-value)	Mean±SD	Range	Comparison of Right & Left Sides (p-value)	
L1	Right	20.45±2.32	17.1 – 24.5	0.985	22.09±2.08	18.20-26	0.391	0.014
	Left	20.44±2.47	16.7 – 23.1		22.62±2.22	18.00-26		0.003
L2	Right	21.6±2.52	16.8 – 25	0.924	21.98±2.53	16.20-26	0.687	0.627
	Left	21.55±1.80	19.1 – 24		22.24±1.95	17.80-25.20		0.219
L3	Right	23.77±1.69	21.4 – 26.7	0.337	24.44±2.33	20.10-28.20	0.676	0.272
	Left	24.28±2.80	21.4 – 29.7		24.17±2.23	18.80-27.90		0.140
L4	Right	27.09±2.43	21.2 – 32.9	0.927	26.31±3.00	20.40-31.70	0.303	0.341
	Left	27.01±2.75	21.9 – 30.8		27.23±3.23	20.70-32		0.806
L5	Right	29.81±4.88	21.7 – 38.4	0.601	32.29±4.39	20.30-42.40	0.722	0.074
	Left	30.64±5.44	20 – 39		32.73±4.29	24.30-41.90		0.149
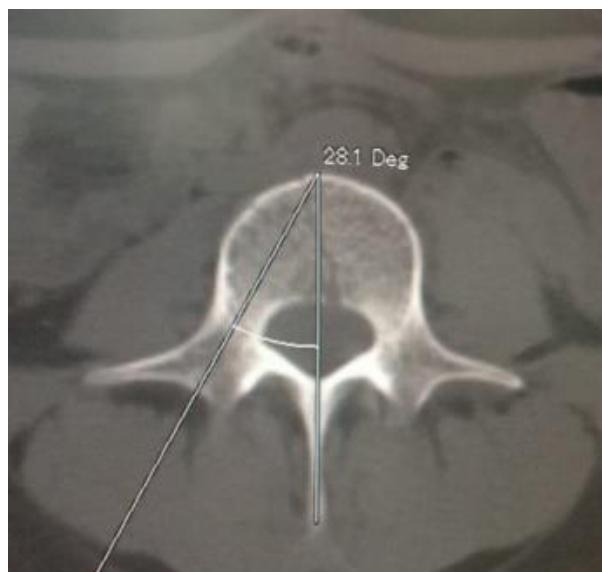
Figure No. 4: Transverse Pedicle Angle (TPA) Measurement in degrees (º)

DISCUSSION

Multiple morphometric studies have been done previously to determine the dimensions of pedicles of vertebrae by taking direct measurements of the cadaveric spines[6], the measurements of dry vertebrae[8-10] and computed tomography[7,11,12] including our current study.

The largest mean of lumbar pedicle width was seen at left side of L5 vertebra in both males (13.32±1.61) and females (12.27±1.80). The least measurement of pedicle width was at right side of L1 vertebra in both males (6.26±0.78) and females (5.04±1.16). The minimum value was noted at right side of L1 in female (2.9 mm) and maximum value was noted at right side of L5 vertebra in males (16.4 mm). Mean of pedicle width at all lumbar vertebral levels was larger in males as compared to females and the difference was statistically significant (p<0.05), except at the left side of L4 vertebra. Lumbar vertebral pedicle width increased gradually from L1 to L5 in both males and females. When we compared the mean of pedicle width of our study with different populations, the results were similar with studies carried out in Taiwan[13] and USA. However, there was variation in pedicle width between our study and the study of Singapore carried out in 2004[13] where mean pedicle width was around 6.98 mm on the right side and 7.18 mm on left while in our study it was 8.27 mm on the right and 8.40 mm on the left side. When compared with another study of Pakistan[7], the results were very nearby similar (Table-5).

Pedicle screw selection is also affected by pedicle height. In our study, height of pedicles in males is maximum at left side of L1 vertebra with a value of 14.95±1.16, and in females at right side of L1 vertebra with a value of 13.38±0.93. In our study the pedicle height was found in both males and females to decrease gradually from L1 to L5 (14.92 to 9.76) which is in contrast to Ali STM et al[8], where it has been shown to increase from L1 to L5 (13.27 to 16.15 mm). Results similar to our study have been observed in another Indian study in 2015 conducted on cadavers[15]. When we compared the mean value with other races there was not much variation in the mean values of pedicle height of our study (Right:12.68 mm and Left:12.55 mm) and others (13.68 mm), Tan et al[15] (Right: 13.03 mm and Left: 12.8 mm), Shiu-Bii Lien et al[13] (Right: 13.68 mm Left: 13.5 mm), and by Alam MM et al[7] (Right: 12.19 mm Left: 11.97 mm) as shown in Table-5.

Our study showed the results of pedicle length decreasing from L1 to L5 in both males and females

which shows a similar decreasing pattern in the mean of pedicle length of Momeni et al[2]. The value of mean in our study is 6.85 mm on right side and 6.78 mm on left side, which greatly differs from the mean pedicle length as recorded by Momeni et al[2] which is 9.04 mm on the right side and 9.2 mm on the left side.

Table No. 5: Comparison of mean pedicle width (PW), pedicle height (PH), pedicle length (PL), and transverse pedicle angle (TPA) of lumbar vertebrae with other studies.

Study	Year	Country	Material for Study	PW (Pedicle Width in mm)	PH (Pedicle Height in mm)	PL (Pedicle Length in mm)	TPA {Transverse Pedicle Angle in Degrees (°)}
Ebraheim et al	1996	USA	Dry bones	9.52	13.68		28.82°
Alon Wolf et al	2001	Israel	CT scan	8.4	14.8		12.42°
Mitra SR et al	2002	India	Cadaveric	8.72	15.21		11.24°
Singel TC et al	2004	India	Dry bones	10.28	14.65		Right: 14.07° Left: 13.4°
Tan et al	2004	Singapore	Dry bones	Right: 6.98 Left: 7.18	Right: 13.03 Left: 12.8		
Shiu-Bii Lien et al	2007	Taiwan	Dry bones, cadaveric	Right: 8.68 Left: 8.68	Right: 13.68 Left: 13.5		Right: 14.07° Left: 13.4°
Momeni et al	2019	Iran	CT scan	Right:10.08 Left:10.29	Right:12.66 Left:12.66	Right:9.04 Left:9.2	
Aruna N et al	2011	India	Dry bones	9.15	14.3		
Patil & Bhuiyan	2014	India	Dry bones	Right: 8.41 Left: 8.57	Right: 13.9 Left: 13.96		Right: 11.79° Left: 11.67°
Alam MM et al	2014	Pakistan	CT scan	Right:9.15 Left:9.25	Right:12.19 Left:11.97		Right:16.5° Left:16.93°
Present Study		Pakistan	CT scan	Right: 8.27 Left: 8.40	Right: 12.68 Left: 12.55	Right:6.85 Left:6.78	Right: 24.98° Left: 25.39°

In our study it was observed that the transverse pedicle angle (TPA) increased from L1 to L5 the exception being the right TPA at L2 in both males (16.8°) and females (16.2°) which showed a smaller angle. The transverse pedicle angle on the left side ranged from 16.7° to 39° with a mean of 24.98° and on the right it ranged from 16.8° to 38.4° with a mean of 24.54° in males. In females the transverse pedicle angle on the left side ranged between 17.8° and 41.90° with a mean of 25.79° and on the right side between 16.20° and 42.40° with a mean of 25.42°. The mean TPA recorded in our study is closer to the mean TPA as shown by a researcher where it has been recorded as 28.82°. However other studies conducted on different populations (Table-5) show a significant difference in the TPA; ours being higher as compared to Alon Wolf et al[16] (12.42°), Mitra SR et al[17] (11.24°), Shiu-Bii Lien et al[13] (right: 14.07°, left: 13.4°) and Patil & Bhuiyan[9] (right: 11.79°, left: 11.67°). Our study value cannot be generally applied on the entire Pakistani population as when compared with another study conducted by Alam MM et al[7] in Sindh province of Pakistan, there was a marked difference in the value of TPA in that region which was found to be 16.5° on the right side and 16.93° on the left side which is quite less than the TPA recorded in our study.

In our study, the p value was less than 0.05 when pedicle width and height of lumbar vertebrae of males and females were compared, however, it was not significant for pedicle length and transverse pedicle angle. These results are somewhat similar to the study of Momeni et al[2] where difference of male and female value was significant for all the three parameters of pedicle width, height and length. In our study, when right and left sides of all lumbar vertebrae in males and females were compared, the p value (p>0.05) was not significant for any morphologic parameters.

CONCLUSION

Knowledge of lumbar spine anatomy is essential for both surgeons and anaesthetists. This study provides a database of morphometric characteristics of pedicle of lumbar vertebrae, thus refining our knowledge of pedicle dimensions and orientation for clinical applications and as an aid for implant designing. Racial and gender differences must be considered while using international transpedicular screw system. This study will help in developing pedicular screws for lumbar vertebrae for Pakistani population.

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