Original article:

Lower Thoracic and Lumbar Pedicle Morphometry using Computerized Tomography Scan

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Abstract:

Introduction: Pedicle fixation has become a common surgical practice now-a-days. Proper understanding of the anatomy of the vertebral pedicles is a prerequisite for the spinal surgeons. Knowledge of pedicle morphometry would reduce the risk of post operative complications. Aaccurate placement of well-fitted pedicle screw and non-interference with the adjoining neural structures is the key of successful surgery. **Methods:** Various parameters viz. length, breath, height, transverse angle and sagittal angle of the pedicle along with interpeduncular distance were measured in computerized tomography scan in all the 64 study subjects.

Observations & Results: Male subjects showed higher length, breath, height, transverse angle, sagittal angle and interpeduncular distance for all vertebral segments than their female counterpart. Steady raise in the measurements have been observed in length, breath and height of both the sexes from D9 to D12 vertebrae. Same parameters showed a gradual raise following a dip from D12 to L1 vertebrae. Wider transverse angles have been noted at D9 level. Transverse angles at D10 were narrowest, with progressive widening caudally. Sagittal angles became marginally more caudal wards from D10. No obvious left right asymmetry has been recorded. Interpeduncular distance in both the sexes showed gradual raise from D9 to D12 vertebrae. With a dip at L1 from D12, a steady increase of the interpeduncular distance has been recorded in successive lumbar vertebrae.

Conclusion: Outcome of the present study showed notable transition at thoraco-lumber junction. Detailed morphometric data generated from this study would be of immense help as a guide for pedicular surgery.

Key words: Vertebra, Pedicle, Interpeduncular distance

Introduction:

Pedicle screw fixation was first described by Boucher[1]. The use of pedicle screw fixation in patients requiring spinal surgery has expanded over the last three decades. In 1985, Roy-Camille pioneered the pedicle screw plating system for the lumbar spine. Since then pedicle screw fixation has become an increasingly popular technique of instrumentation to treat spinal disorders by providing stable fixation and correcting spinal deformities[2, 3]. The pedicle screws were initially used only in the lumbar spine. As the surgeons became more comfortable with the complex anatomy required for accurate screw placement, the technique for pedicle instrumentation gradually evolved to include their use in the thoracic levels. Anatomical knowledge of pedicle morphometry and its adjacent structures specially the neural structures will be beneficial for accurate screw placement thereby will decrease the risk of post-operative complications[4]. Many authors have described the morphometric aspects of the thoracic and lumbar spine. The details of the pedicle

sizes and its various dimensions by means of varied techniques namely plain radiograph, direct specimen measurement, CT scan, and quantitative 3-dimensional anatomic technique have been reported by these workers. Pedicle screw designing based on pedicle morphology was the most important indication of these studies[5,6,7]. Current work has attempted to study the various parameters of the pedicle to enrich our understanding about the trajectory of inserting pedicle screws at thoraco-lumbar junction, to prevent violation as it endangers the nerve root and occasionally the Dura mater.

Aims & objectives:

1. To measure and evaluate various radiological parameters of the pedicles of ninth thoracic to the fifth lumbar (D9 – L5) vertebrae by means of Computed Tomography (CT) scans, that has a bearing on the type and dimensions of screw that is required for trans-pedicular screw fixation in Indian population.
2. To accumulate data as regards the Eastern Indian population, as data for this region is not sufficiently available.
3. To compare the results obtained in this study with that of other similar studies, done both in other countries as well as in other parts of India to highlight differences (if any) that exist between these findings and to assess how it would affect the technique of screw placement in the respective study groups.
4. To compare the above parameters in male and female subjects to ascertain if any sexual dimorphism present so that placement of pedicle screws in the two sexes might differ.

Materials and methods:

All the patients who had attended 'Suraksha', a Public Private Partnership imaging centre of NRS Medical College and Hospital, Kolkata, West Bengal, India for some abdomino-pelvic ailments during the study period of six months were chosen for the study. Total 64 subjects were studied of which 40 were males and 24 were females. Persons who has attained 21 years and having normal spinal architecture without any obvious fracture and deformity of the vertebrae were chosen. Persons with congenital and / or degenerative diseases of the spinal column were excluded from the study.

Informed consents were obtained from all the members of the study group. Computerized Tomography scan of the defined area (D9 – L5 vertebrae region) were done. Three mm cut sections or "slices" were taken in the transverse plane. This provided four of the parameters to be studied, viz. length of the pedicle, breadth of the pedicle, transverse angle of the pedicle and the interpedicular distance. CT scan images were reformatted in the sagittal plane using the DICOM software that helped to obtain the remaining two parameters, viz. height of the pedicle and the sagittal angle of the pedicle. The distances and angles were measured by lines drawn on the CT scan images using option provided in the DICOM software and the values were directly noted from the monitor screen.

Following radiological parameters of the pedicles of D9 – L5 vertebrae were obtained for computation.

1. Length of the pedicle was measured along the long axis of the pedicle from the posterior border of the vertebral body anteriorly to the posterior border of the articular facet posteriorly (Fig 1).

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2. Breadth of the pedicle was measured as the transverse diameter of the pedicle perpendicular to the long axis of the pedicle, at the level of least value for the width (i.e., at the level of isthmus) (Fig 2).
3. Vertical height of the pedicle was calculated in the reformatted sagittal image at the narrowest dimension in the sagittal plane (Fig 3).
4. Transverse angle of the pedicle was measured as the angle formed by the long axis of pedicle with that of the median transverse plane (Fig 4).
5. Sagittal angle of the pedicle was measured as the angle between the long axis of the pedicle and the horizontal plane (Fig 3).
6. Interpedicular distance was measured as the distance between the posterior most points of the two pedicles (Fig 5).

The author performed all measurements singly for consistency. Measurements were taken thrice and the average of the three was taken. All measurements were rounded to two decimal places.

Results:

A total of sixty four (64) subjects were selected for this study. Of them, 40 were males and 24 females. Following the predetermined methods six radiological parameters obtained in each of the study subjects. Average of each data set presented in Table1 to Table6. All the data obtained, presented in sex and side specific distribution to observe if there is any sexual dimorphism or side specific variation.

Table 1: Mean Length of Pedicles (mm) of D9 – L5 Vertebrae

Vertebrae	Male	Female	Right	Left	Overall
D9	7.81	6.82	7.53	7.54	7.51 ± 1.31
D10	8.42	6.84	7.81	7.75	7.84 ± 1.16
D11	9.01	7.62	8.45	8.34	8.56 ± 1.44
D12	9.28	8.13	8.69	8.59	8.79 ± 1.47
L1	8.19	8.08	8.11	8.19	8.15 ± 1.23
L2	8.49	8.22	8.35	8.47	8.46 ± 1.49
L3	9.11	8.37	8.94	8.83	8.85 ± 1.32
L4	9.71	9.46	9.69	9.69	9.67 ± 1.22
L5	10.63	9.84	10.47	10.41	10.41 ± 1.63

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Table 2: Mean Breadth of Pedicles (mm) of D9 – L5 Vertebrae

Vertebrae	Male	Female	Right	Left	Total
D9	5.43	4.40	5.01	5.03	5.04 ± 0.91
D10	6.51	5.41	6.13	6.14	6.11 ± 1.11
D11	7.11	6.08	6.75	6.75	6.74 ± 1.43
D12	7.52	6.34	7.07	7.08	7.06 ± 1.52
L1	6.11	5.03	5.82	5.85	5.82 ± 1.21
L2	6.80	6.17	6.59	6.60	6.58 ± 1.45
L3	8.90	7.38	8.33	8.37	8.36 ± 1.75
L4	10.79	9.18	10.24	10.23	10.2 ± 2.35
L5	13.52	11.61	12.81	12.83	12.86 ± 2.24

Table 3: Mean Height of Pedicles (mm) of D9 – L5 Vertebrae

Vertebrae	Male	Female	Right	Left	Overall
D9	10.71	9.24	10.21	10.21	10.21± 1.55
D10	11.32	10.51	11.04	11.05	11.02 ± 0.59
D11	12.70	10.82	12.12	12.06	12.01 ± 0.43
D12	13.75	12.18	13.13	13.17	13.17 ± 0.67
L1	12.94	11.06	12.22	12.22	12.22 ± 1.11
L2	14.72	12.93	14.04	14.02	14.08 ± 1.15
L3	13.51	12.36	13.04	13.08	13.08 ± 0.83
L4	15.01	12.88	14.29	14.21	14.19 ± 0.64
L5	15.75	13.91	15.11	15.11	15.12 ± 0.19

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Table 4: Mean Transverse angle of Pedicles (degree) of D9 – L5 Vertebrae

Vertebrae	Male	Female	Right	Left	Total
D9	17.12	12.22	16.07	11.19	14.51 ± 1.99
D10	10.01	8.79	10.51	9.58	9.55 ± 2.68
D11	11.12	9.13	10.83	9.87	10.77 ± 2.53
D12	11.57	10.18	11.00	10.11	11.04 ± 2.45
L1	12.64	10.41	12.09	10.86	11.16 ± 2.00
L2	13.26	11.71	12.92	12.16	13.06 ± 1.65
L3	17.98	15.09	17.68	15.69	16.59 ± 2.52
L4	20.54	20.58	20.78	21.83	20.81 ± 3.23
L5	27.30	23.40	27.07	26.95	26.98 ± 1.61

Table 5: Mean Sagittal angles of Pedicles (degree) of D9 – L5 Vertebrae

Vertebrae	Male	Female	Right	Left	Total
D9	2.83	2.80	2.85	2.75	2.8 ± 1.32
D10	2.80	2.67	2.75	2.73	2.75 ± 1.26
D11	2.92	3.25	3.14	3.05	3.09 ± 1.26
D12	3.94	3.80	3.88	3.93	3.9 ± 1.32
L1	4.27	4.50	4.33	4.35	4.34 ± 1.45
L2	5.62	5.53	5.55	5.60	5.58 ± 1.69
L3	5.59	5.38	5.49	5.47	5.45 ± 1.59
L4	12.56	12.83	12.63	12.65	12.64 ± 3.52
L5	32.70	32.57	32.48	32.85	32.67 ± 8.48

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Table 6: Mean Inter-peduncular distance (mm) of D9 – L5 Vertebrae

Vertebrae	Male	Female	Total
D9	24.55	22.37	23.82 ± 4.11
D10	27.81	26.25	27.41 ± 4.62
D11	30.61	26.43	29.05 ± 5.43
D12	31.56	28.48	30.39 ± 6.73
L1	30.71	27.81	29.65 ± 4.81
L2	33.60	29.77	32.15 ± 5.53
L3	37.21	32.93	35.72 ± 5.80
L4	44.15	37.13	41.52 ± 4.48
L5	52.05	46.15	49.86 ± 7.81

Table 7: Ethnic variation of Breadth (mm) of Lower Dorsal Vertebral Pedicles

Vertebrae	Lien SB [12] (Taiwan)	Singh R [9] (Haryana)	Kretzer RM [8] (USA)	Current study (West Bengal)
D9	5.3	5.33	5.5	5.04
D10	5.8	6.10	6.3	6.11
D11	7.4	7.36	7.8	6.74
D12	7.7	7.94	8.3	7.06

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Table 8: Ethnic variation of Breadth (mm) of Lumber Vertebral Pedicles

Vertebrae	Lien et al. [12] (Taiwan)	Urrutia et al. [10] (Mexico)	Current study (West Bengal)
L1	6.4	7.81	5.82
L2	7.4	8.26	6.58
L3	9.3	9.57	8.36
L4	11.6	10.79	10.20
L5	17.5	14.36	12.86

Table 9: Ethnic variation of Height (mm) of Dorso-lumber Vertebral Pedicles

	Amonoo-Koufi HS[4] (Saudi Arabia)		Singh et al. [9] (Haryana)		Current study (West Bengal)	
Vertebrae	**M**	**F**	**M**	**F**	**M**	**F**
D9			13.03	11.88	10.71	9.24
D10			14.39	13.53	11.32	10.51
D11			15.55	15.31	12.70	10.82
D12			15.53	15.36	13.75	12.18
L1	19.4	16.3			12.94	11.06
L2	18.9	15.3			14.72	12.93
L3	19.3	15.9			13.51	12.36
L4	19.9	16.1			15.01	12.88
L5	20.7	17.5			15.75	13.91

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Table 10: Ethnic variation of Transverse Angle (degree) of Dorso-lumber Vertebral Pedicles

	Lien et al. [12] (Taiwan)		**Current study (West Bengal)**			
Vertebra	**R**	**L**	**M**	**F**	**R**	**L**
D9	14.1	10.9	17.12	12.22	16.07	11.19
D10	9.6	8.4	10.01	8.79	10.51	9.58
D11	7.9	8.1	11.12	9.13	10.83	9.87
D12	8.4	7.4	11.57	10.18	11.00	10.11
L1	8.6	8.3	12.64	10.41	12.09	10.86
L2	13.2	11.5	13.26	11.71	12.92	12.16
L3	16.4	14.1	17.98	15.09	17.68	15.69
L4	18.1	19.7	20.54	20.58	20.78	21.83
L5	23.4	25.3	27.30	23.40	27.07	26.95

Fig 1: Measuring length of pedicle

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Fig 2: Measuring breadth of pedicle

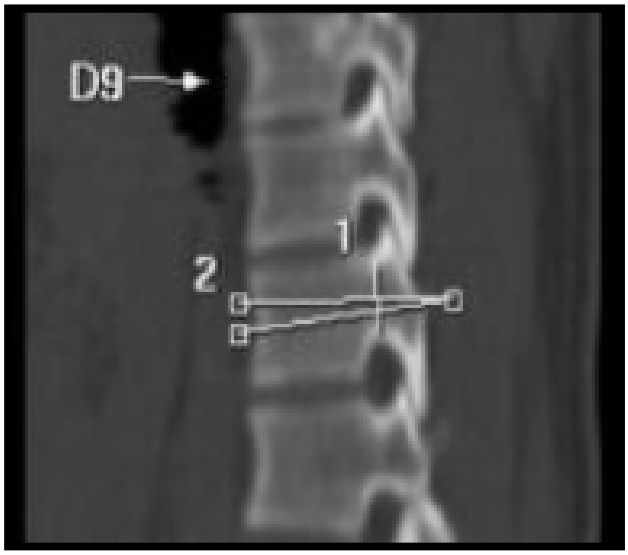

Fig 3: Measuring **(1)** Vertical height

& (2) Sagittal angle of the pedicle

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Fig 4: Measuring Transverse angle of pedicle

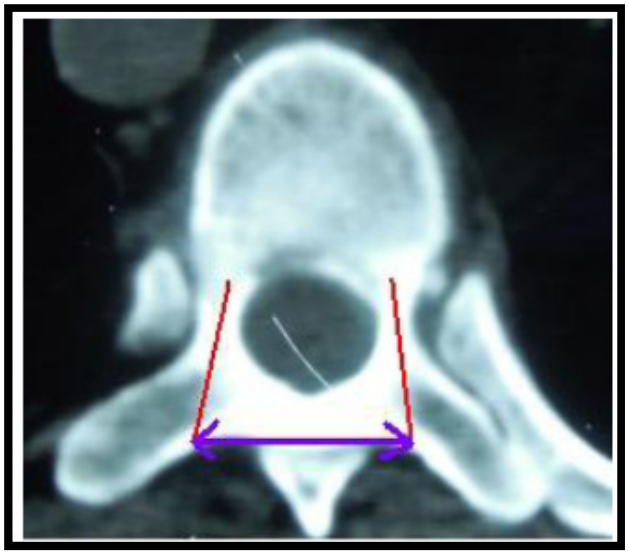

Fig 5: Measuring Interpedicular distance

Discussion:

Many authors have described the morphometric aspects of the thoracic and lumbar spines and the details of the pedicle sizes and dimensions by means of varied techniques such as direct specimen measurement, plain radiology image, CT scan etc. Most of the studies concentrated on either the thoracic region[8,9] or on the lumbar spines[5, 10, 11]. Only few authors have reported about the entire thoraco-lumbar region[12]. In the present study pedicles from D9 to L5 vertebrae considered, as this is the region where most of the pedicular screw fixations are done. Another reason for choosing the region is that, it might give us an idea about any change in the orientation or shape of the pedicles at the dorso-lumbar junction. Since the junctional areas of the

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spine are relatively more prone to the stresses borne by the vertebral column, anatomical changes from the thoracic to the lumbar spine might be elicited by this study.Comparative analyses of the observations with the prior works by other authors reveal many interesting facts. Amonoo-Koufi[4] and Singel et al[7] reported no obvious right and left variation in dimensions of the pedicles of the lumbar vertebrae. On the contrary, in the present study the results are different and hence presented separately. Current study findings corroborate with the findings of a similar study conducted at by Prakash et al[11]. However they have used dry vertebrae and plain AP view radiograph of lumber spines instead.

Length of the pedicles: In the present study, length of pedicles gradually increased from D9 to D12 vertebrae, then showed a dip from D12 to L1, and then a steady increase noticed up to L5 (Table 1). Singh et al[9] worked with thoracic vertebrae only. They reported similar results, where the lengths of the pedicles increased steadily from the mid-thoracic to the last thoracic vertebrae. Some researchers measured the length from the posterior aspect of the pedicle to the anterior aspect of the vertebral body in line with the long axis of the pedicle. Their results were not suitable to compare with this study, hence not considered.

Breadth of the pedicles: In the current study, breadth increased gradually from D9 to D12, then dropped slightly from D12 to L1, and followed by steady increase from L1 to L5 (Table 2). In a similar study conducted using thoracic vertebrae in subjects of Haryana, Singh et al[9] reported values comparable with those found in this study. Findings of the current study have been compared with that of data generated for the lower thoracic vertebrae by other researchers like Lien et al [12], Singh et al [9] and Kretzer et al [8] (Table 7). Relatively smaller lower thoracic vertebral pedicular breadth have been observed in short statured Bengal population than its Haryana and US counterpart. Breadth of the lumber vertebral pedicles found in the present study, have been compared with the findings of the workers like Lien et al [12] and Urrutia et al [10] (Table 8). Taiwanese and Mexican population possess broader lumber vertebral pedicle than people of Bengal. In the present study breadth of pedicle in either sex is also compared. Data yielded has shown that the breadth of the pedicle is more in males than in females for all the vertebrae under this study. The uniform increase of pedicle width from D9 to D12 and again from L1 to L5 bilaterally in both sexes is primarily related to the role in weight transmission.

Height of the pedicle: Some workers have measured pedicle height based on antero-posterior X-ray images as shown by the arrow in the figure 6. But a screw whose diameter is chosen based on the above height may violate the superior or inferior cortex as the girth is not uniform throughout. Hence, in the present study, height at the location of narrowest dimension in the sagittal plane has been chosen.

In the present study, it has been observed that the height of the pedicle increased from D9 to D12, then decreased slightly from D12 to L1, then increased from L1 to L2, then again decreased at L3, to increase again from L3 through to L5. Chaynes et al[13] in their cadaveric study reported that pedicular height in spine gradually increased from D1 to L5. Study by Singel et al[7] showed that vertical height of pedicles increased from L1 to L2, then decreased from L3-L5 in both sexes. Amonoo-Kuofi[4] observed that there was increase in vertical height of pedicles in both the sexes from L1-L5. A significant study conducted by Prakash et al[11], though was confined to the lumber

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region only, demonstrate closest match of the present work viz. pedicle heights increased from L1 to L2, then again decreased at L3, to increase again from L3 to L4 and markedly increased from L4 to L5. Greater vertical height values of L2 vertebra than that of L1 vertebra is due to the closer location of the first lumbar pedicle to the transitional junction of thoracolumbar spine, and is again the site of complex zygapophyseal joint[11]; the brunt of this force transmission should then be on L2 vertebra which has adapted itself resulting in increased pedicle height. This stable position makes the L2 vertebra less prone to dislocate as compared to L1 transition vertebra.

In the present study sexual dimorphism if there is any was also searched for. Few other researchers also reported sexual dimorphism in their studies. Amonoo-Koufi[4] reported shorter pedicle height in female lumbar vertebrae than their male counterpart in Saudi Arabian population. In another study Singh et al[9] showed similar findings in lower dorsal vertebrae. Data yielded in the present study have shown the values for height of the pedicle to be higher in males than in females. Heights of the pedicles as obtained by different authors are presented in Table 9. Lesser pedicle heights obtained in the present study than those found in the other population groups are probably due to different ethnicity, and relative sedentary life style leading to overall shorter stature of the people in this part of the world.

Transverse angle of the pedicle: In this study, a fall in the values of transverse angle of the pedicle has been noticed from D9 to D10. There after the transverse angles have increased steadily from D10 to all successive vertebrae till L5 vertebra (Table 4). When data of the present study compared with the findings of another similar study conducted in Taiwanese population by Lien et al[12], both results appear to be complementary to each other (Table 10).

Conclusion:

The present study describes Morphometric characteristics of the lower dorsal and lumber vertebral pedicles in a good number of subjects in detail. No significant variations have been observed from the findings of other previous workers in the field. Some differences whatever obtained might be attributed to racial or ethnic differences or may be due to certain typical postures of the body depending upon local customs and practices of the daily life. Data generated from the present study may be beneficial for those biomedical engineers engaged in designing pedicle screws for Indian recipients. Obtained data further would act as a regional guide for the spinal surgeons attempting pedicle screw fixation of the local population groups.

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