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MORPHOMETRIC ANALYSIS OF THE LUMBAR PEDICLES IN INDIAN POPULATION: DECIPHERING THE SAFE ZONE

Radiology

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ABSTRACT

Aims: Lumbar pedicle screw fixation is a commonly used technique for various spine pathologies. Screw size and path determination requires accurate morphometric analysis of lumbar pedicles. Since, gender and racial variations in vertebral morphometry is known, we performed this study to evaluate pedicle width and height in Indian population.

Methods: We retrospectively analyzed pedicle width (PW) and pedicle height (PH) of normal lumbar vertebral pedicles in the CT scans of 100 subjects. The results were analysed at different vertebral levels and in both genders.

Results: We found that the mean pedicle width of lumbar pedicles increased from L1 to L5 vertebral levels, maximum mean PW being 15.04 ± 0.71 mm (13-16.4 mm) in males and 14.52 ± 0.97 mm (12-16 mm) in females at L5. The mean height of lumbar pedicles was maximum at L2 [15.42 ± 0.70 mm (14-16.8 mm)] and L1 levels [15.39 ± 1.04 mm (13.2-17mm)] in males and females respectively, with decrease in the pedicle height from L3 to L5 vertebral levels.

Conclusion: Morphometric analysis of lumbar pedicles assumes importance prior to all interventions in lumbar spine since there is significant racial and gender variation in its anatomical parameters.

KEYWORDS

Lumbar vertebra, morphometric analysis, pedicle

INTRODUCTION:

Transpedicular screw fixation is frequently performed as a part of various interventions done to address different pathologies of lumbar spine, like fractures, tumor resections, spondylolisthesis etc. [1-3]. The selection of size of screws and the screw path depends on various morphological features of the lumbar pedicles in the individual. Inappropriate size of screw may lead to instrumentation failure and various complications [4-6]. Since gender and racial variations in skeletal morphometry is known, we conducted this study to evaluate the various morphometric parameters of lumbar vertebra in Indian population.

METHODS AND MATERIALS:

A retrospective evaluation of CT scans of 100 subjects performed in our department over a period of 6 months (January 2017 to June 2017) was done, which showed no radiologically detectable abnormalities in the lumbar vertebrae. Subjects showing any congenital or acquired abnormality of the lumbar spine were excluded from the study. All CT examinations were carried out on a Philips Brilliance 64 –Slice MDCT scanner V.2.6, (Philips Healthcare, Netherlands).

Morphometric analysis of all lumbar pedicles, from L1 to L5 was done in the patients included in the study. The radiological parameters which were evaluated are as follows:

- **Pedicle width**: was measured as the narrowest pedicle dimension in transverse plane (Figure 1)
- **Pedicle height:** was measured as the narrowest pedicle dimension in oblique sagittal plane , along the pedicle axis (Figure 2)

The distribution characteristics were calculated for each of the above mentioned parameters. The means of each of these parameters were compared in males and female using Student's t test.

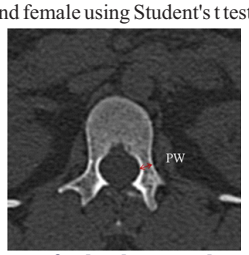


Figure 1: Axial image of a lumbar vertebra demonstrating the measurement (red double arrow) of pedicle width (PW)

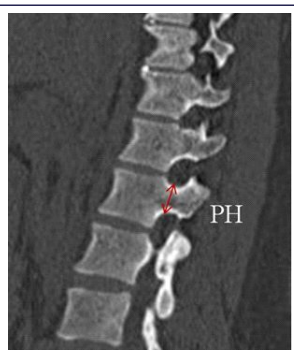


Figure 2: Oblique sagittal image of a lumbar vertebra demonstrating the measurement (red double arrow) of pedicle height (PH)

RESULTS:

100 CT scans were retrospectively evaluated over a period of 6 months from January 2017 to June 2017, in subjects with mean age of 38 ± 1.3 years (18-65 years). 49 (49%) CT scans evaluated in the study were that of males with mean age of 35 ± 1.33 years (18-65 years) and 51 (51%) were that of females with mean age of 41.3 ± 1.2 years (20-63 years).

The morphological features of lumbar vertebral pedicles analyzed in our study with the results are mentioned in Table 1.

The mean width of lumbar pedicles in males from L1 to L5 vertebral bodies were 7.95 ± 0.68 mm (6.1- 9.4 mm), 8.68 ± 0.75 mm (6.4-10.3 mm), 10.11 ± 0.99 mm (8-12.8 mm), 12.94 ± 0.81 mm (11.6-15 mm) and 15.04 ± 0.71 mm (13-16.4 mm) respectively. The mean width of lumbar pedicles in females from L1 to L5 vertebral bodies were 7.81 ± 0.94 mm (5.4-9.6 mm), 8.25 ± 0.91 mm (6.4 - 10.1 mm), 9.42 ± 0.93 mm (7.5-12.1 mm), 11.35 ± 1.11 mm (8.6-13.2 mm) and 14.52 ± 0.97 mm (12-16 mm) respectively.

The mean height of lumbar pedicles in males from L1 to L5 vertebral bodies were 14.65 ± 0.77 mm (13.0-16.4 mm), 15.42 ± 0.70 mm (14-16.8 mm), 15.04 ± 0.73 mm (13.5-16.4 mm), 14.51 ± 0.82 mm (13-16 mm) and 13.86 ± 0.75 mm (12-15.0 mm) respectively. The mean height of lumbar pedicles in females from L1 to L5 vertebral bodies

were 15.39 ± 1.04 mm (13.2-17mm), 14.8 ± 0.97 mm (13-16.4 mm), 15.05 ± 0.99 mm (13-16.7 mm), 14.45 ± 0.95 mm (12.8-16 mm) and 13.86 ± 0.91 mm (12-15.40 mm) respectively.

The difference between mean widths of lumbar pedicle between males and females was significant from L2 to L5 vertebral bodies ($p < 0.05$), however it was not significant at L1 vertebral level. The difference between mean heights of lumbar pedicle between males and females was significant at L1 and L2 vertebral level ($p < 0.05$), however it was not significant from L3-L5 vertebral level.

Table 1: Results

	Parameter	Characteristics	Male (n-49)	Female (n-51)	't' value	p value
1	Age (years)		35 ± 1.33 (18-65)	41.3 ± 1.2 (20-63)	2.49	0.01
2.	Pedicle Width (mm)	L1	7.95±0.68 (6.1-9.4)	7.81±0.94 (5.4-9.6)	0.79	0.43
		L2	8.68 ± 0.75 (6.4-10.3)	8.25 ± 0.91 (6.4-10.1)	2.57	0.01
		L3	10.11±0.99 (8-12.8)	9.42 ± 0.93 (7.5-12.1)	3.5	0.0006
		L4	12.94 ±0.81 (11.6-15)	11.35 ± 1.11 (8.6-13.2)	7.57	0.00001
		L5	15.04 ± 0.71 (13-16.4)	14.52 ± 0.97 (12-16)	2.99	0.003
3.	Pedicle height (mm)	L1	14.65 ± 0.77 (13.0-16.4)	15.39 ± 1.04 (13.2-17)	3.99	0.0001
		L2	15.42 ± 0.70 (14-16.8)	14.8 ± 0.97 (13-16.4)	3.6	0.0004
		L3	15.04 ± 0.73 (13.5-16.4)	15.05 ± 0.99 (13-16.7)	0.03	0.97
		L4	14.51 ± 0.82 (13-16)	14.45 ± 0.95 (12.8-16)	0.32	0.74
		L5	13.86 ± 0.75 (12-15.0)	13.86 ± 0.91 (12-15.40)	0.01	0.99

DISCUSSION:

Lumbar trans-pedicular screw fixation is a commonly performed procedure for fracture fixation, post-tumor resections, spondylolisthesis etc. Precise pre-operative anatomical evaluation of lumbar pedicles is imperative to decide the size of the screws and its path of insertion, to prevent surgical failure or complications. The most devastating complication related to pedicle screw insertion is neurological injury secondary to misplaced screw. Since gender and racial variations in lumbar pedicle morphometry is known [4, 7-10], we conducted this study to evaluate the various morphometric parameters of lumbar pedicles in Indian population by means of CT evaluation.

We found that the pedicle width of lumbar vertebrae increased progressively from L1 to L5 vertebral level, in both genders. The minimum and maximum mean width of lumbar pedicles in males was 7.95 ± 0.68 mm and 15.04 ± 0.71 mm respectively while that in females was 7.81± 0.94 mm and 14.52 ± 0.97 mm respectively. The difference between mean widths of lumbar pedicle between males and females was significant from L2 to L5 vertebral bodies ($p < 0.05$), however it was not significant at L1 vertebral level. Singel et al. [7] conducted a study to evaluate the width and height of lumbar pedicles in Indian population and found that the pedicle width increased from L1-L5 in both genders, minimum and maximum being at L1 and L5 vertebral level respectively [8.2 ± 6.7 mm (6-11mm) and 18.2 ± 9.7 mm (15-23mm) respectively in males and 8.5 ± 2 mm (6-11 mm) and 19.25 ± 3.25 (16-21) in females]. No significant difference was noted between the pedicle widths in males and females. Trend of the pedicle width in our patients is in concordance with their study; however we found a significant difference between pedicle widths in both genders. Also, the mean pedicle width in our study was less than that found in this study. Rajput et al. [8] also found that the transverse pedicle diameter increased progressively from L1 to L5 vertebral level, minimum and maximum transverse diameter being at 7.24 ± 2.22 mm (5 -11mm) at L1 and 12.00 ± 4.39 mm (9 – 20 mm) at L5 level respectively. Though the trend of pedicle widths in our patients is in concordance with their study; the maximum mean pedicle width (at L5) is more in our study. Amonoo-Kuofi [9] studied lumbar pedicle width and heights on radiographs of 270 males and 270 females, and found similar trend in lumbar pedicle width.

We found that the pedicle height of lumbar vertebrae was maximum at L2 and L1 vertebral level in males and females respectively. It however decreased from L3 to L5 vertebral level in both genders. The minimum and maximum mean height of lumbar pedicles in males was 13.86 ± 0.75 mm and 15.42 ± 0.70 mm respectively while that in females was 13.86 + 0.91 mm and 15.39 ± 1.04 mm respectively. The difference between mean heights of lumbar pedicle between males and females was significant at L1 and L2 vertebral level ($p < 0.05$), however it was not significant from L3-L5 vertebral level. Singel et al. [7] found that pedicle height was maximum at L2 in males and L1 in females while it decreased from L3 to L5 level which is in concordance with our study. The minimum and maximum pedicle height was 13.4 ± 6 mm (11-17 mm) and 15 ± 4.6 mm (13-17 mm) respectively in males and 13.25 ± 2.5 mm (12-15 mm) and 15.5 ± 2 mm (14-17 mm) in females respectively. No significant difference was noted between the pedicle heights in males and females. Trend of the pedicle height in our patients is in concordance with their study; however we found a significant difference between pedicle heights in both genders at L1 and L2 level. Berry et al. [10] also found a similar trend in the pedicle height, with the means of pedicle heights at various levels to be similar as found in our study. Rajput et al. [8] however found that the pedicle height decreased marginally from L1 to L3 but again increased at L4 and abruptly increased at L5. The minimum pedicle height was noted at L3 [14.17 ± 1.57 mm (12 - 16 mm)] and the maximum pedicle height was noted at L5 [19.23 ± 4.03 mm (14 - 25 mm)]. Amonoo-Kuofi et al. [9] also found that there was increase in pedicles height from L1-L5, and found that pedicle height in females was less than that in males.

Weight-bearing and mechanical factors play important roles in morphological adaptation of the pedicles [11-13]. Greater pedicle height in upper lumbar vertebrae is postulated to be due to its closer location to the thoraco-lumbar transitional junction which is a site of complex zygapophyseal joint [14]. This helps to withstand the marked compressive forces transmitted from the relatively immobile dorsal spine to the highly mobile lumbar spine. Pal et al. [15] suggested that in the thoracic spine which is concave anteriorly, the load is transmitted from the posterior to the anterior vertebral column and in the lumbar spine which is concave posteriorly, the load is transmitted from anterior vertebral column to the neural arch. This shifting of load is in accordance with the position of the line of gravity. At the L5 level, load through the pedicles has to pass in an antigravity direction. Therefore considering the above facts, the pedicles of L5 vertebrae are speculated to have maximum width. Differences in various studies may be attributed to racial or ethnic differences or to certain typical postures of the body depending upon local customs and practices.

CONCLUSION:

We conclude that the dimensions of lumbar pedicles vary according to the gender, ethnicity and level of consideration (L1-L5). Morphometric evaluation of lumbar pedicles is thus relevant and critical for accurate placement of the trans-pedicular screws and hence avoid complications. This study provides an anatomical data base which is necessary for the use of implantable devices and spinal instrumentation techniques, which will not only help surgeons, but also biomedical engineers designing pedicle screws for Indian population.

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