

ORIGINAL RESEARCH ARTICLE

MORPHOMETRIC STUDY OF LUMBAR VERTEBRAL PEDICLES

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ABSTRACT

Background: Pedicle screw instrumentation has revolutionized spine surgery on account of its superiority over other stabilization systems. It is safe when properly placed and versatile for a range of procedure from fracture fixation to complex deformity correction. Sound anatomical knowledge of the pedicle may also be helpful during surgical approach to lumbar foramina disc herniation and epidural steroid injection as well as in the diagnosis of some lumbar degenerative diseases and chronic back pain. In this study we aimed to provide locoregional data on lumbar pedicle morphometry of Nepalese population.

Methods: A descriptive observational study was conducted on 50 dry adult human lumbar vertebrae of unknown sex at Chitwan Medical College from August 2020 to December 2020. Pedicular width, height and the interpedicular distance were measured. All the data were numerically coded in excel and analysis was done in Statistical Package for Social Sciences (SPSS) version 20.

Results: The mean width of the pedicles of left side gradually increased as we moved down the vertebrae and measured 7.43 ± 0.84 mm in L1 and 12.18 ± 1.71 mm in L5 vertebrae. The mean width of the pedicles on the right side, however, showed an increasing trend with a lower value at L3 level and was measured as 7.91 ± 1.17 mm. The mean height of the pedicles alternatively decreased and increased down the vertebrae for both the sides. The mean interpedicular distance gradually increased craniocaudally and was found to be 20.35 ± 0.95 for L1 and 25.97 ± 3.58 mm for L5 vertebrae.

Conclusions: This study confirmed the measurement of lumbar pedicles' dimensions and provides its regional data on Nepalese population. These data may be critical for clinicians working near the vicinity of the lumbar pedicles.

INTRODUCTION

Lumbar vertebra bridges axial skeleton with the appendicular skeleton and help support the weight of the upper body and permit movement. Short but strong paired pedicles arise posterolaterally from each vertebral body near its upper border. ¹ Spine and orthopedic surgeons take advantage of the robust nature and unique anatomy of lumbar pedicles for transpedicular screw fixation. Lumbar canal stenosis as suggested by decreased interpedicular distance is one of the important cause of low backache. Transpedicular approaches are also being increasingly used in many surgeries such as bone biopsy, bone grafting, vertebroplasty and kyphoplasty as well for the access of the spinal canal by anesthesiologist for lumbar epidural anesthesia. ²

The variability in width, height, orientation and interpedicular distance makes pedicle screw insertion very challenging. ³ For a successful surgery and appropriate implant design, sufficient knowledge of lumbar vertebral pedicle morphometry and anatomical data is critical in order to avoid inadvertent penetration of the pedicle wall. ⁴ The anatomy of the lumbar pedicle has been extensively studied previously using cadavers,

dry bones and different imaging techniques; however, wide regional variations has been noted. ^{2,5,6}

The aim of this anatomical study was to quantify pedicle dimensions on dry adult lumbar vertebra by using direct caliper measurement.

METHODS

A descriptive observational study was conducted on dry adult human lumbar vertebrae after getting approval from institutional review committee (CMC-IRC/077/078-020) of Chitwan Medical College. The study period was from August 2020 to December 2020.

All the lumbar vertebrae collected at the Department of Anatomy, Chitwan Medical College comprised the sample frame in our study. Samples were selected using simple random sampling technique. Sample size was calculated to be 50 using the formula $n = Z^2 \times \sigma^2 / d^2$, where, n = sample size, Z = 1.96 for 95% confidence level, $\sigma = 1.48$ from population standard deviation taken from Choubisa et al² and d = margin of error as 0.41.

Fifty clean and dried lumbar vertebrae, ten from each segment were included in the study. Deformed vertebra and vertebra with broken fragments were excluded from the study. The vertebra were serially numbered from one to fifty using blue marker pen. The instruments needed for the study were 150 mm digital vernier caliper product of china accurate up-to 0.01mm, marking pen etc.

The following parameters were observed by the measurement:

Width of the pedicle (Horizontal) in mm: The width was taken as the distance between the medial and lateral surfaces of the pedicle.

Height of the pedicle (Vertical) in mm: The height was taken as the distance between the superior and inferior margins of the pedicle.

Interpedicular distance in mm: The measurement was done at the medial surfaces of right and left pedicle of the same vertebra.

The measurement of the Pedicle width, height and interpedicular distance were done as shown in the Figures 1, 2 and 3 respectively.



Figure 1. Measurement of the pedicle width (PW)

Table 1: Width of pedicle (PW) in mm

Lumbar Vertebra	Right side (Mean ± SD)	Maximum	Minimum	Left side (Mean ± SD)	Maximum	Minimum
L1	7.32±0.83	8.41	6.07	7.43±0.84	8.7	5.94
L2	8.13±1.37	11.28	6.65	7.90±1.64	11.2	5.38
L3	7.91±1.17	9.01	5.78	8.46±1.19	9.86	6.49
L4	11.30±1.55	13.5	8.77	10.79±1.72	14.18	7.86
L5	12.28±1.45	13.8	9.81	12.18±1.71	15.04	9.38

Table 2: Height of pedicle (PH) in mm

Lumbar Vertebra	Right side (Mean ± SD)	Maximum	Minimum	Left Side (Mean ± SD)	Maximum	Minimum
L1	14.76±1.40	18.2	13.29	14.12±1.36	17.47	12.9
L2	13.62±1.24	15.32	10.82	13.53±0.83	14.85	12.32
L3	14.58±1.16	15.89	12.47	14.11±1.23	15.93	11.68
L4	12.83±0.59	13.72	11.9	12.48±0.54	13.44	11.52
L5	13.24±2.16	16.64	10.06	13.37±1.60	16.93	11.19



Figure 2. Measurement of the pedicle height (PH)



Figure 3. Measurement of the interpedicular distance (IPD)

All the data were numerically coded in excel and analysis was done in Statistical Package for Social Sciences (SPSS) version 20. The mean and standard deviation of width and height of pedicle as well as interpedicular distance were calculated and tabulated.

RESULTS

The study evaluated pedicle morphometry of 50 lumbar vertebrae (L1–L5) of unknown sex. The results of the width and height of both sides are shown below in Tables 1 and 2, while the interpedicular distance are presented in Table 3.

Table 3: Interpedicular Distance (IPD) in mm

Lumbar vertebra	Mean (Mean ± SD)	Maximum	Minimum
L1	20.35±0.95	21.23	19.43
L2	21.43±1.16	22.37	20.84
L3	21.77±1.72	23.17	20.32
L4	23.41±1.61	24.39	22.32
L5	25.97±3.58	28.34	25.09

The largest pedicle width (PW) was seen on both sides at L5 with a mean of 12.28 ± 1.45 mm on the right side and 12.18 ± 1.71 mm on the left side. The smallest pedicle width was seen at L3 level on the right side and L2 level on the left side. Of the 50 evaluated vertebrae, only 5 vertebrae had width less than 5 mm. Pedicles having width less than 5, 6 or 7 mm may pose difficulty while

inserting screws; their frequency are tabulated in the Table 4. As shown in Table 4, 40% and 30% of L3 vertebrae on the right and left side respectively had sub 8 mm pedicle width; 30% right sided and 20% left sided lumbar vertebrae had PW less than 7 mm. While no L5 or right sided L4 vertebral pedicles had sub 8 mm width, only 10% of left sided pedicles were less than 8 mm wide.

Table 4: Number of vertebrae with pedicle width less than 6, 7 and 8 mm

Levels	Right (number)			Left (number)		
	5-6 mm	6-7 mm	7-8 mm	5-6 mm	6-7 mm	7-8 mm
L1	0	3	4	1	1	5
L2	0	2	3	1	1	2
L3	1	2	1	0	2	1
L4	0	0	0	0	0	1
L5	0	0	0	0	0	0

There was an increase of PW from cephalic to caudal vertebral level on the left side as shown in Figure 4. On the right side, however, a small notch was noted at the L2-L3 level as shown in Figure 5. It was found that the width of the pedicles on the right and left side are significantly different from each other (p value < 0.00001).

± 1.60 mm for the left side and 14.76 ± 1.40, 13.62 ± 1.24, 14.58 ± 1.16, 12.83 ± 0.59 and 13.24 ± 2.16 mm for the right side respectively. This ‘staircase like’ descent of the mean PH seemed more symmetric on the right side as compared to the left side as shown in Figure 6 and 7. Significant difference between the pedicle heights was noted between the two sides (p value = 0.047).

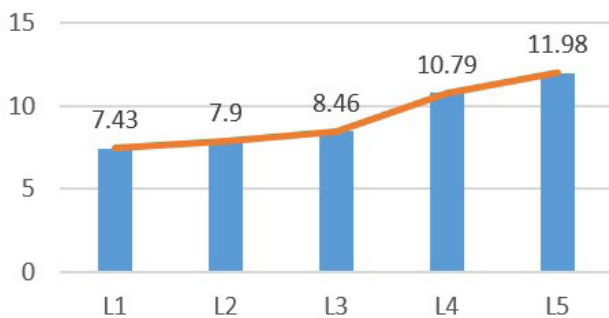


Figure 4. Pedicle width on the left side

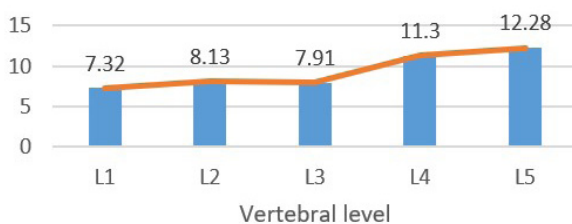


Figure 5. Pedicle width on the right side

The mean PH alternatively decreased and increased down the vertebrae for both the sides and was noted to be 14.12 ± 1.36, 13.53 ± 0.83, 14.11 ± 1.23, 12.48 ± 0.54 and 13.37

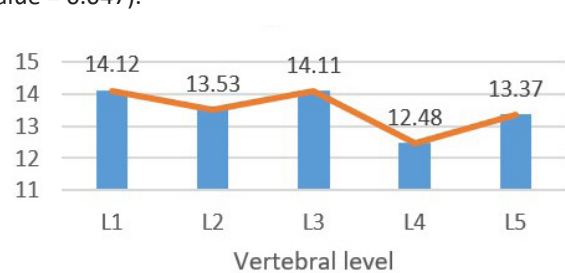


Figure 6. Pedicle height on the left side

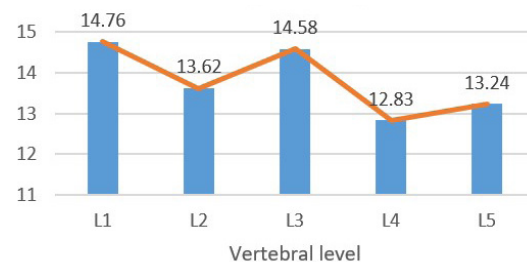


Figure 7. Pedicle height on the right side

At vertebral levels L1 to L3, PH was always greater than the PW; the gap, however, gradually decreased as we moved caudally. Although 20% of L4 vertebrae on the right side and 10% on the

left side had larger PW as compared to PH, 30% on the right and 20% on the left side had such pattern at L5 level.

The mean IPD in our study increased steadily from L1 to L5 vertebral level with a relatively steeper climb caudally as shown in Figure 8.

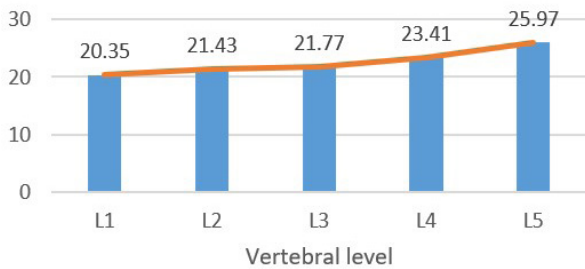


Figure 8: Mean interpedicular distance

DISCUSSION

The lumbar vertebra, being the mobile region of the vertebral column, is often involved during accidents, degenerative changes, congenital defects and metastasis. Advances in medical technology has enabled spine surgeons maneuver a screw to fix it for regaining activity.⁷ Posterior approach into the lumbar pedicle is a preferred method for a screw placement as it has been proven to be the strongest part of the vertebra even in osteoporotic bone.⁸ A mistakenly placed pedicle screw can, however, impinge nerve root, leak cerebrospinal fluid, fracture pedicle and cause screw loosening.

Screw placement in practicable position requires in-depth anatomical knowledge of the lumbar pedicles. Individual variability as well as age, gender and ethnic differences would make its accurate placement challenging.^{6,9} Although intraoperative use of modern radiological techniques such as navigation with CT, fluoroscopy or O-arm decreases the inadvertent risk of injury to the surrounding structures, it still carries some risk of a screw misplacement; tinkering the screw for intraoperative adjustment would increase the risk further.¹⁰ We used direct caliper measurements for lumbar pedicles. It has advantage over radiological methods as it provides the most accurate account of pedicle morphometry.⁸

Pedicle width (PW) is the most important limitation in relation to pedicle screw fixation due to its smaller size compared to the pedicle height (PH). In our study, PW progressively increased from L1 to L5 on the left side. The width on the right side, however, increased from L1 to L2, slightly decreased at L3, and again increased at L5 which is unlike any other study. Most authors, however, have noted the width to gradually increase from L1 to L5.¹¹⁻¹⁴ Alam et al noted that, although, the pedicle diameter in their study of 49 CT images gradually increased from L1 to L5; the mean values for the L3 and L4 vertebrae were identical.¹⁵ The width of the pedicle is smallest at L1 and largest at L5 level which suggests that pedicle screw fixation is relatively unsafe at upper lumbar vertebra. The

values of the PW in our study are comparable to some studies;^{2,6,12} however, few studies have documented smaller values^{11,16} while many studies have shown higher values as compared to ours.^{8,13,17} Some authors have noted a much smaller values in some of their specimens at L1^{11,14} and a much higher value at L5 level.^{13,16,18} L2 and L5 vertebra on the left side had the lowest (5.38 mm) and highest (15.04 mm) value of pedicle width in our study. Shorter stature of Nepalese population on addition to genetic, environmental and dietary factors could have played a role in the overall smaller pedicle dimension in our population. Yu et al noticed that pedicle width at level L1 to L3 was more in African Americans as compared to Caucasians while reverse was true at levels L4 and L5.⁸ Dzierzanowski et al noted that most morphometric lumbar similarities concern the L1 and L2 vertebra bodies; whereas it varied the most in the caudal part of lumbar spine, irrespective of the race.¹⁰

Due to a smaller number of sub-8 mm PW at the lower vertebral pedicles (Table 4), it seems reasonable to use a 5 mm pedicle screw diameter for lower lumbar fixation in Nepalese population but we support the existing literature recommending pre-operative use of imaging and limiting the screw diameter to less than 80% of the measured width for its safe placement.¹⁹

Many studies have shown that PH values decreases from L1 to L5.^{4,12,15} In our study, however, we noted that PH slightly increased at L3 level, decreased at L4 and increased again at L5. These findings are in accordance to few other studies.²⁰⁻²² Some authors noted that the PH increased from L1 up-to L2 and then gradually decreased.^{2,6,16} Dzierzanowski et al observed that the PH decreased steadily on the right side; on the left side, however, it decreased up-to L4 and then increased.¹⁰ Mitra et al as well as Kim et al noted that the mean PH gradually decreased from L1 to L4 but it again increased at L4 and L5.^{11,18} Seema et al noted a minimum vertical diameter at L5 level while the maximum value was seen at L2 level in their study of 100 plain X-ray films.¹⁷ In our study, the mean PH ranged from 12.83 to 14.76 mm on the right side and from 12.48 to 14.12 mm on the left side. L1 on both sides had the highest mean P values; the largest PH value being 19.47 mm on the left side and 18.20 mm on the right side.

Interpedicular distance is a reliable index for the assessment of the size of the lumbar canal and its measurement may be a preliminary, but useful aid in the diagnosis of the lumbar canal stenosis syndrome.²³

We report a progressively increasing mean interpedicular distance from 20.35 ± 0.95 mm at L1 to 25.97 ± 3.58 mm at L5. This is in agreement with several other studies showing interpedicular distance to increase gradually from L1 to L5.^{17,23,24} Al-Rakhawy et al and Banik et al encountered a dip in IPD at L3 level while Attar et al found the mean IPD increase to halt at L2 level.^{23,25,26}

Some studies have reported much larger values of IPD at L5 level.^{5,24,25} The remarkably higher value at L5 was probably

caused by the different configuration of the vertebra, in which the pedicles were more lateroventrally implanted on the body and were fused with the transverse processes.²⁷

Mansur et al noted that the transverse diameter of the spinal canal of any lumbar vertebra is proportional to the size of the vertebral body at that level and that its ratio with the body would be more helpful for identifying spinal canal stenosis.⁵ Choubisa et al from India compared their findings with the study by Marasini et al from Nepal and noted that lumbar IPD of their population was 5 to 6 mm less while PH and PW were 1 mm more.^{2,6}

Although the difference in pedicle size between gender, age and race has been well documented in literature, we are unable to report such a finding as the present study was conducted in dry adult lumbar vertebrae of unknown sex.^{20,24,28} Further studies are warranted on lumbar morphometry on a larger population in both genders and in various ethnic groups for generalizability.

The study was carried out in preserved human lumbar vertebrae. No comparison was made with clinical or radiological data. Low sample size and specimen of unknown sex may have

introduced some inaccuracies in our measurements.

CONCLUSION

The present study noted that the mean width of the left sided pedicles gradually increased down the vertebrae whereas the right side showed an increasing trend with a lower value at L3 level. The mean pedicle height alternatively decreased and increased down the vertebrae for both the sides. IPD gradually increased as we moved down the vertebral level. Regional data from the present data forms a baseline of adult lumbar vertebral morphology and would be useful for anatomists, radiologists, surgeons and physicians. It may also be helpful for the screw and implant manufacturers. Larger study with sex and ethnic consideration can generate forensic and anthropological data of the Nepalese population.

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CONFLICT OF INTEREST: None

FINANCIAL DISCLOSURE: None

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