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Original Research Article

Determining the Various Dimensions of Lumbar Vertebral Pedicles in Adults and its Clinical in Various Surgical Procedures: Morphometric Assessment

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Abstract

Aim: The aim of the present study was to measure the various dimensions in Indian adult human lumbar vertebral pedicles and to prepare data of lumbar pedicles useful in various surgical procedures.

Methods: The study was implemented on 45 dry, fully ossified normal lumbar vertebral sets from the Department of Anatomy, Nalanda Medical College, Patna, Bihar, India from Jan 2023 to November 2023. For study purpose, all vertebrae were categorized into typical (L1 to L4) and atypical (L5). Exclusion of deformed vertebrae was done.

Results: In present study, the mean length and height of pedicles in typical vertebrae (L1 to L4) ranged from 8.85 mm to 10 mm and 13.08 mm to 13.81mm respectively. The pedicle thickness of typical vertebrae was noted between 7.11 mm 11.22 mm. For L5, the mean values of PDL, PDH and PDTh were 8.80 mm, 12.79 mm and 16.10 mm respectively. It was observed that PDL increased till L3 but after that it declined at L5. There was a gradual gain in PDH from L1 to L4. However, it was reduced at L5. PDTh was enhanced from L1 to L5 but in the fifth lumbar vertebra, the thickness of pedicle suddenly increased as compared to that of fourth. The transverse angle of pedicle elevated steadily from L1 to L4 but at L5, it abruptly increased than in L4. The mean transverse angle of right and left side (22.63 degree and 21.61 degree) of pedicle at L5 was greater than L4 (16.98 degree and 15.81 degree), Pedicle axial length rose from L1 to L3 and subsequently it dropped from L4 to L5 (Table 2). However, mean sagittal angle and mean axis length of pedicle of L5 was found to be less than L4. However, there was no any significant change in sagittal angle of typical as well as atypical vertebra.

Conclusion: The present study revealed significant differences in multiple dimensions of pedicles of typical as well as atypical lumbar vertebrae. These differences bear critical implications for neurosurgeons to operate in safe environment on patients in Indian settings.

Keywords: Dimensions; Lumbar Vertebral Pedicle; Pedicle Screw Fixation

Introduction

There are a number of well researched and documented sub axial cervical spine fixation methods for different pathologies. These include but not limited to pedicle screws, lateral mass screws, interspinous wiring, laminar hooks, and plating. Among all these, pedicle screw fixation has demonstrated the best biomechanical attributes like a high pull-out strength. Among the five different human vertebra types (cervical, thoracic, lumbar, sacral, and coccygeal), the cervical spine exhibits the smallest and widest population variability in pedicle morphometry. This predisposes visceral structures contained in the cervical spine (the spinal cord, the nerve roots, and vertebral arteries) to damages during any form of instrumentation surgery [1-4]

Therefore, a thorough understanding of the osteology of the sub axial cervical spine is a prerequisite for safe surgery in this region. Studies of cervical morphometric dimensions have been done in different ethnic populations including Brazilians, Indians, Thais, Europeans, Chinese-Singaporeans, and Malaysians. Many indicated that there are interracial differences in the pedicle morphometric [5-9] In 1963, Roy-Camille first applied 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 in the treatment for degenerative diseases, trauma, deformities, and tumours of the spine. The trans-pedicular segmental

method of fixation provides rigid support that allows surgeons to limit instrumentation to one or two motion segments, thus preserving maximum motion. A thorough understanding of the anatomy and orientation of the posterior elements of the spine is essential for safe and accurate surgical procedures. The complications associated with misplaced pedicle screws include neurologic, vascular, and visceral injury. [10-12]

The seven cervical vertebrae are identified by the presence of the foramen transversarium in the transverse process through which important vessels like the vertebral artery pass, except in the seventh cervical vertebra. Altogether, the cervical vertebral column has a secondary curvature, i.e., an anterior convex curvature. The vertebral body and pedicle are stronger components of the third to seventh cervical vertebrae and are thus widely used for instrumentation. The pedicle on each side is a short cylindrical bony part that projects posterolateral from the body of the vertebra, and after joining the lamina of the vertebra, it completes the neural arch. Morphometry of the vertebral body and the pedicle plays a role in providing stability post-fixation by screws or wires. Variability in the morphometric data has been reported regarding the vertebral body and pedicle of each cervical vertebra and in different populations [13-14] The procedure of introducing a cervical screw carries a risk of neurovascular damage if the screw violates its course while traversing the pedicle [15-18]

The aim of the present study was to measure the various dimensions in Indian adult human lumbar vertebral pedicles and to prepare data of lumbar pedicles useful in various surgical procedures.

Materials and methods

The study was implemented on 45 dry, fully ossified normal lumbar vertebral sets from the Department of Anatomy, Nalanda Medical College, Patna, Bihar, India from Jan 2023 to November 2023. For study purpose, all vertebrae were categorized into typical (L1 to L4) and atypical (L5). Exclusion of deformed vertebrae was done. The dimensions including length, height, thickness, axial length, transverse and sagittal angles were measured by 'Digital Vernier Caliper' with 0.01 mm precision and 'Geometrical Protractor' with marking up to 180 degrees. All observations were entered and analyzed in 'SPSS Version 25' software. Mean and Standard Deviations (SD) of each side were calculated. The statistical differences were computed by 'ANOVA' test. Pedicle parameters were recorded in millimeters and angle in degrees.

Pedicle Length - (PDL) - measurement between two points, one at the junction of pedicle and vertebral body and the second at the junction of pedicle and superior articular process.

Pedicle Height - (PDH) - maximum vertical measurement at the posterior end of pedicle.

Pedicle Thickness - (PDTh) - maximum transverse measurements of pedicle at its posterior end.

Pedicle Axis length- (PDAL) - measurement between posterior end of pedicle at the junction with superior articular process to anterior aspect of cortex of the vertebral body along the long axis of the pedicle.

Pedicle Transverse Angle: (PDTAn) - angle formed by the long axis of the pedicle with mid-sagittal line.

Pedicle Sagittal angle :(PDSAn) – angle formed by the long axis of the pedicle with the superior surface of the body.

All the dimensions were measured twice, first on right and then on left side to minimize error.

Results

Table 1: Dimensions of Pedicle of Lumbar Vertebra (L1 to L5)

Vertebrae	PDL (mm)		PDH (mm)		PDTh (mm)	
	R	L	R	L	R	L
L1	Mean	9.76	9.5189	13.6091	13.2317	7.1155
	SD	1.1125	1.7482	1.7905	1.6041	1.3729
L2	Mean	10.0055	9.6245	13.5445	13.4126	7.4836
	SD	1.201	1.227	1.2764	1.1393	1.4781
L3	Mean	9.8002	9.6143	13.8188	13.6902	8.7432
	SD	1.3363	1.2309	1.3743	1.3664	1.3275
L4	Mean	9.0004	8.8577	13.1596	13.0843	10.7489
	SD	1.1732	1.0919	1.9338	2.6481	2.1447
L5	Mean	8.8038	8.8523	12.7921	12.7549	16.1023
	SD	1.4853	1.3621	1.9089	1.9692	3.4175

In present study, the mean length and height of pedicles in typical vertebrae (L1 to L4) ranged from 8.85 mm to 10 mm and 13.08 mm to 13.81mm respectively. The pedicle thickness of typical vertebrae was noted between 7.11 mm 11.22 mm. For L5, the mean values of PDL, PDH and PDTh

were 8.80 mm, 12.79 mm and 16.10 mm respectively. It was observed that PDL increased till L3 but after that it declined at L5. There was a gradual gain in PDH from L1 to L4. However, it was reduced at L5. PDTh was enhanced from L1 to L5 but in the fifth lumbar vertebra, the thickness of pedicle suddenly increased as compared to that of fourth.

Table 2: Transverse, Sagittal Angles and Axial Length of Lumbar Vertebrae

Vertebrae	PDTAn(degree)		PDSAn (degree)		PDAL (mm)	
	R	L	R	L	R	L
L1	Mean	11.7447	11.6383	6.2979	6.2766	35.2323
	SD	0.9434	0.8451	0.5071	0.5398	2.0877
L2	Mean	13.2766	13.2766	7.1915	36.344	36.2528
	SD	0.9714	0.6801	0.6473	1.9852	2.2354
L3	Mean	14.5851	14.4362	8.234	8.234	37.5053
	SD	1.0699	0.9244	0.8899	0.8899	2.4791
L4	Mean	16.9894	15.8191	8.3404	8.4255	36.2732
	SD	1.3331	2.9256	0.9841	0.8274	2.2656
L5	Mean	22.6383	21.617	7.8936	7.7234	34.4291
	SD	1.1214	3.5297	1.1838	1.2105	2.1911

The transverse angle of pedicle elevated steadily from L1 to L4 but at L5, it abruptly increased than in L4. The mean transverse angle of right and left side (22.63 degree and 21.61 degree) of pedicle at L5 was greater than L4 (16.98 degree and 15.81 degree), Pedicle axial length rose from L1 to L3 and subsequently it dropped from L4 to L5. However, mean sagittal angle and mean axis length of pedicle of L5 was found to be less than L4. However, there was no any significant change in sagittal angle of typical as well as atypical vertebra.

Table 3: Significant Differences of Pedicle Dimensions (L1 to L5)

	F-value	p-value
Length	8.38	< 0.001
Height	2.77	0.027
Thickness	143.54	< 0.001
Transverse Angle	707.92	< 0.001
Sagittal Angle	43.87	< 0.001
Axial Length	13.26	< 0.001

Except height, for all dimensions, highly significant ($P < 0.01$) difference was observed. There was also significant correlation between length, height, thickness as well as angles of lumbar pedicle of right and left side of typical and atypical lumbar vertebrae ($p < 0.05$).

Discussion

The pedicles of lumbar spine are stronger and larger and are commonly used for screw fixation during lumbar spinal stabilization surgeries. [19] 'Spinal fixation' is often indicated in certain ailments of lumbar columns like fractures, degenerative changes, malignancy or lumbar instabilities. [20] The prevalence of low back pain and other associated signs of lumbar spinal diseases are being increased in modern world and it is estimated that around 70-90% of general population has chronic low backache and 4% of them require operation at certain time. [21]

In present study, the mean length and height of pedicles in typical vertebrae (L1 to L4) ranged from 8.85 mm to 10 mm and 13.08 mm to 13.81mm respectively. The pedicle thickness of typical vertebrae was noted between 7.11 mm 11.22 mm. For L5, the mean values of PDL, PDH and PDTh were 8.80 mm, 12.79 mm and 16.10 mm respectively. It was observed that PDL increased till L3 but after that it declined at L5. There was a gradual gain in PDH from L1 to L4. However, it was reduced at L5. PDTh was enhanced from L1 to L5 but in the fifth lumbar vertebra, the thickness of pedicle suddenly increased as compared to that of fourth. The transverse angle of pedicle elevated steadily from L1 to L4 but at L5, it abruptly increased than in L4. The mean transverse angle of right and left side (22.63 degree and 21.61 degree) of pedicle at L5 was greater than L4 (16.98 degree and 15.81 degree), Pedicle axial length rose from L1 to L3 and subsequently it dropped from L4 to L5. However, mean sagittal angle and mean axis length of pedicle of L5 was found to be less than L4. However, there was no any significant change in sagittal angle of typical as well as atypical vertebra.

Lumbar segment is the most movable part of spine and is frequently compromised during traumatic injuries, congenital anomalies, tumors, infections or degenerative defects. Hence, it may require stabilization or reconstruction to restore its activity. Any disruption in the integrity of pedicle could affect the weight conduction mechanisms and can lead to compression of neural structures. [22] Therefore, treating lumbar instability with appropriate stabilization devices is utmost important.

Except height, for all dimensions, highly significant ($P < 0.01$) difference was observed. There was also significant correlation between length, height, thickness as well as angles of lumbar pedicle of right and left side of typical and atypical lumbar vertebrae ($p < 0.05$). Direct measurement method often provides more consistent and reproducible results than imaging sources. [23] Joseph Albano et.al[24] demonstrated that the Asian population consistently had significantly smaller pedicles in the lumbar spine than in the Black or White populations.

Conclusion

The present study revealed significant differences in multiple dimensions of pedicles of typical as well as atypical lumbar vertebrae. These differences bear critical implications for neurosurgeons to operate in safe environment on patients in Indian settings.

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