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Anatomical and Computed Tomographical Study of Lumbar Pedicles

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Abstract

Introduction: Altogether there are 5 lumbar vertebrae, L1 to L4 being typical and L5 being atypical. Lumbar vertebrae have strong and large pedicles. They transmit weight and also help in determining the size and shape of pedicle implants.

Materials and Methods: 75 Human dry adult lumbar vertebra (37 typical, 38 atypical) were collected from department of Anatomy Sri Venkateeshwara Medical College Hospital and Research Centre, Ariyur, Puducherry, and 75 CT scan films (31 typical, 44 atypical) from radiology department of same research centre. Right and left side of the pedicle width, height and length were measured using vernier digital calipers in mm for human adult dry lumbar vertebrae and ortho-view orthopedic digital imaging software were used for CT scan films.

Results: In the dry bone observations, the mean length of pedicle from typical to atypical vertebrae was found to be increased, the mean height of pedicle from typical to atypical was found to be decreased and the mean width/thickness of pedicle was found to be increased from typical to atypical vertebrae. In the computed tomography scans, similar observation were noted in the mean length, height and width/thickness of pedicle from typical to atypical vertebrae.

Conclusions: Typical to atypical lumbar vertebrae parameters are varying. With no much differences on right and left side of the pedicle. The comprehensive knowledge of morphological and morphometric features are of utmost important for the surgeons in the pedicle screw fixation procedures.

Keywords: Lumbar pedicle, transpedicular screws, Tomography Scan

Introduction

Vertebral column is a series of vertebrae, present on the dorsal aspect of human body extending from the base of skull to the coccyx. It is also called as spine, comprising of cervical, thoracic, lumbar, sacral and coccygeal vertebrae along with intervertebral discs. Each lumbar vertebra consists of body, pedicles, laminae and articular facets. Altogether there are 5 lumbar vertebrae, L1 to L4 being typical and L5 being atypical. Entire vertebral column forms curves i.e thoracic and sacral curves which are termed 'primary curves,' because they are present in the fetus. The cervical and lumbar curves are termed 'compensatory or secondary curves' and are developed after birth. The cervical curve forms when the infant can hold up its head around at three or four months and to sit upright at nine months. The lumbar curve forms later from twelve to eighteen months, when the child begins to walk [1]. Since it is the mobile part of the vertebral column, the lumbar region is frequently involved during accidents, degenerative conditions, congenital defects, and

neoplastic metastases Thus it may require instrumentation for its activity to be regained. Surgical intervention in this region requires a thorough knowledge of the anatomy to identify a suitable site for instrumentation aimed at spinal fixation. The fixation of lumbar spine is needed for various conditions such as fracture in lumbar spine, resection of tumors in vertebral bodies, gross spondylolisthesis, osteoporosis, infections, secondary metastatic conditions, and also congenital malformations like kyphosis, scoliosis. All these conditions need to be stabilized by spine fixation through transpedicular screws instrumentation which means the insertion of screws through the pedicle i.e. from the posterior aspect into the vertebral body on the anterior aspect. The screws enable various devices like plates, rods or wires to be applied to the spine for the purpose of stabilization or immobilization or fixation purposes [2, 3]. In the year 1986, Zindrick *et al* reported the success of the technique depends upon the ability of the screw to maintain within the vertebral body. This is determined by the factors like choice of screw, size of the pedicle and the quality of the bone of the pedicle. The choice of screw for the procedure is determined by the minimum horizontal diameter of the pedicle. Reported complications are dural tears, leakage of cerebrospinal fluid and injuries to the nerve roots with neurological deficits. These serious complications can be explained by the factors - loosening of the screw, and penetration or fracture of the cortical bone shell of the pedicle. Penetration of the cortex or fracture of the pedicle may result from the use of relatively oversized screws [4]. Hence the comprehensive knowledge of the morphometric data on the horizontal and vertical diameters of the pedicles are of useful in preoperative designing of pedicle screws and safe instrumentation techniques.

MATERIALS AND METHODS

The study was conducted on 75 Human adult dry lumbar vertebrae. The bone specimens were collected from Department of anatomy, Sri Venkateeshwara Medical College Hospital and Research Centre, Ariyur, Puducherry. Using a vernier caliper, we measured length, height and width/thickness of the pedicles on both the sides of the typical and atypical lumbar vertebrae (L1-L5). Height was measured as a maximum diameter in sagittal plane at its midpoint. The pedicle length (PL) was measured from the junction of the transverse process and superior articular process to the point where the pedicle meets the vertebral body [8]. Width/thickness was measured as a maximum diameter between medial and lateral surfaces of pedicle at its midpoint.

CT scan images were also obtained for the lumber vertebrae with the support of department of Radiology Sri Venkateeshwara Medical College Hospital and Research Centre, Ariyur, Puducherry. The transverse section of CT scan on which both left and right pedicle appeared largest were considered as the mid pedicle cut and was used at each vertebral level to record the morphometric data for both the right and left pedicles. The average of the two values was taken as the mean value. Ortho-View Orthopedic Digital Imaging software was used for all the measurements. Height was measured in the sagittal plane at the middle of the pedicle width and was defined as the distance between its upper and lower cortices/borders. Pedicle length was measured starting from the origin of the pedicle at the vertebral body until the beginning of the superior articular facet on both sides. Transverse pedicle width/thickness was measured as distance between its medial and lateral cortices (cortex to cortex) width of pedicle along the line perpendicular to the pedicle longitudinal axis at the narrowest part of the pedicle.

Statistical Analysis

Atypical and Typical height (h), width (w) and Length (L) of lumbar pedicle were measured. Mean, Standard deviation, Range for 95% confidence level and correlation coefficient between the left and right side lumbar and p-value for two tailed test were computed using SPSS -22 version and difference were found to significant between left and right Lumbar for height, width and length and $P < 0.01$.

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RESULTS

Table 1: Pedicle length of typical and atypical lumbar vertebrae.

S.No	Pedicle Length of Lumbar Vertebrae (mm)	Right Bone	Left Bone	Right CT Scan	Left CT Scan
1	Typical	18.40±2.07	17.08±1.90	16.59±1.59	15.89±1.54
2	Range	14.26-22.54	13.28-20.88	13.387-19.77	12.81-18.98
3	Atypical	23.11±2.17	23.19±1.40	23.00±1.48	22.45±1.29
4	Range	18.78-27.45	20.39-25.99	20.03-25.97	19.88-25.02

The observation of mean length of typical and atypical lumbar vertebrae was shown in the table 1. In dry bones, the mean length of right and left pedicle in typical lumbar vertebrae was 18.40 mm and 17.08 mm respectively. The mean length of right and left pedicle in atypical lumbar vertebrae was 23.11 mm and 23.19 mm respectively. In computed tomography, the mean length of right and left pedicle in typical lumbar vertebrae was 16.58 mm and 15.89 mm respectively. The mean length of right and left pedicle in atypical lumbar vertebrae was 23.00 mm and 22.45 mm respectively. From both the observations the mean length of pedicle increased from typical to atypical vertebrae.

Table 2: Pedicle height of typical and atypical lumbar vertebrae.

S.No	Pedicle Height of Lumbar Vertebrae (mm)	Right Bone	Left Bone	Right CT Scan	Left CT Scan
1	Typical	14.89±2.03	14.01±1.45	14.98±2.33	14.69±1.95
2	Range	10.83-18.95	11.11-16.91	10.33-19.64	10.78-18.60
3	Atypical	12.57±1.45	12.02±1.67	10.83±1.84	10.92±1.78
4	Range	9.66-15.48	8.67-15.36	7.15-14.51	7.36-14.47

The observation of mean height of typical and atypical lumbar vertebrae was shown in the table 2. In dry bones, the mean height of right and left pedicle in typical lumbar vertebrae was 14.89 mm and 14.01 mm respectively. The mean height of right and left pedicle in atypical lumbar vertebrae was 12.57 mm and 12.02 mm respectively. In computed tomography, the mean height of right and left pedicle in typical lumbar vertebrae was 14.96 mm and 14.69 mm respectively. The mean height of right and left pedicle in atypical lumbar vertebrae was 10.83 mm and 10.92 mm respectively. From both the observations the mean height of pedicle decreased from typical to atypical vertebrae.

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Table 3: Pedicle width of typical and atypical lumbar vertebrae.

S.No	Pedicle Width of Lumbar Vertebrae (mm)	Right Bone	Left Bone	Right CT Scan	Left CT Scan
1	Typical	12.23±1.61	10.77±1.67	10.20±1.14	9.98±0.98
2	Range	9.02-15.44	7.43-14.12	7.92-12.49	8.42-11.54
3	Atypical	15.68±1.73	14.70±1.29	10.56±0.80	10.17±0.88
4	Range	12.22-19.15	12.11-17.29	8.96-12.15	8.41-11.95

The observation of mean width of typical and atypical lumbar vertebrae was shown in the table 3. In dry bones, the mean width of right and left pedicle in typical lumbar vertebrae was 12.23 mm and 10.77 mm respectively. The mean width of right and left pedicle in atypical lumbar vertebrae was 15.68 mm and 14.70 mm respectively. In computed tomography, the mean width of right and left pedicle in typical lumbar vertebrae was 10.20 mm and 9.98 mm respectively. The mean width of right and left pedicle in atypical lumbar vertebrae was 10.56 mm and 10.17 mm respectively. From both the observations the mean width/thickness of pedicle increased from typical to atypical vertebrae.

Table 4: Correlation coefficient between right side and left side of dry bones and CT scans in typical and atypical lumbar vertebrae.

Morphometric Parameters	Typical Lumbar Vertebrae		Atypical Lumbar Vertebrae	
	Bone – right and left	CT scan - right and left	Bone – right and left	CT scan - right and left
	Correlation coefficient	Correlation coefficient	Correlation coefficient	Correlation coefficient
Length	0.889	0.660	0.906	0.927
Height	0.604	0.945	0.590	0.906
Width	0.682	0.633	0.777	0.807

The Correlation coefficient between right side and left side of dry bones and CT scans in typical and atypical lumbar vertebrae was shown on table 4. The diameter of right pedicle and left side pedicle was measured and compared separately in all parameters in both dry bones and CT scan films. There is a positive correlation between right and left side in both dry bones and CT scans with p-value 0.00001, which is highly significant.

DISCUSSION

The lumbar vertebrae which are the five in number vertebrae situated between the rib cage and the pelvis. They form the largest segments of the vertebral column, characterized by the absence of the foramen transversarium in the transverse process found in the cervical region and by the absence of facets on the sides of the body found in the thoracic region. The lumbar vertebrae help in supporting the weight of the body and permit movements. Lumbar vertebral pedicles are short, strong thick dorsal projections coming from the superior part of the body at the junction of its lateral and dorsal surface. Pedicles form the concavity by the curved superior and inferior border [5]. Vertebral pedicle forms an important part in weight transmission from the neural arch to the anterior part of the vertebral column [6]. The lumbar pedicles suffer from fractures commonly in older age group population due to osteoporosis, which requires open surgical or percutaneous Pedicle

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screw fixation to stabilize the vertebrae. Lumbar vertebral pedicles are widely used for various other surgical procedures such as vertebroplasties, biopsies related with vertebral bodies, and kyphoplasties [7]. Pedicle screw fixing on lumbar part of vertebral column is a popular technique for instrumentation to treat spinal disorders as it provides a stable fixation and corrects the spinal deformities. This pedicle screw system, often referred to as the bilateral pedicle screw system, has become the gold standard technique for spinal fusion [8].

In the year 1948, King was the first person to attempt to stabilize a lumbar spine by internal fixation through transfacet screw placement using short screws [9]. In the year 1959, Boucher successfully initiated passing long screws through the lamina and pedicle into the vertebral body below for spinal fusion, with internal splinting by screw fixation, thus temporarily stabilizing L4 to L5 and L5 to Sl [10]. In the year 1984, Magerl developed adjustable external spinal skeletal fixation for stabilizing the lower thoracic and lumbar spine in patients with acute spinal trauma, in which screws were firmly anchored through the pedicle into the vertebral bodies [11]. With the help of screws, it enables several devices such as rods, plates or wires to be applied to the spine for immobilization or fixation. The success rate of the spinal fixation or stabilization depends upon the ability of the screw to maintain within the vertebral body. This is determined by factors like the accuracy of choice of screw size, size of the pedicle and the quality of the bone of the pedicle. Loosening of the screw and penetration or fracture of the cortical bone shell of the pedicle are common causes of device failure that can lead to serious complications. Penetration of the cortex or fracture of the pedicle may result from the use of relatively oversized screws. Some of the complications that have been reported include dural tears, leakage of cerebrospinal fluid and injuries to the nerve roots with neurological deficits [4, 12].

Thus, for safer pedicle screw placement techniques it is important to understand pedicle dimensions and angulations and also for the development of techniques and devices for spinal instrumentation. In pedicle screw insertion, the screw is passed through the posterior aspect of the pedicle into the body of the vertebra anteriorly. Since the success of this technique depends upon the ability of the screw to obtain strength within the vertebral body, the choice of the screw to be used is determined by the minimum diameter of the pedicle. Variations and differences in the dimensions of the lumbar vertebral pedicles at various levels have clinical inferences for neurosurgeons to carry out safe surgical procedures in this site [3]. In the present study on dry bones in typical vertebrae, mean height of pedicle was 14.88 mm on right side and 14.01 mm on left side. As compared to the study done by Tiwari *et al*, whose results were 13.442 mm on right side and 13.068 mm, our results were slightly higher [2]. Arora *et al*. reported slightly higher values of 16.42 mm in males and 15.6 mm in females [13].

The mean width of pedicle was 12.23 mm on right side and was 10.77 mm on left side. As compared to the study done by Tiwari *et al*. whose results were 9.482 mm on right side and 9.557 mm on left side, our results were slightly higher [2]. In the present study on dry bones in atypical vertebrae (L5), mean height of pedicle was 12.57 mm on right side and on left side 12.02 mm. Tiwari *et al*, reported mean height of pedicle was 14.56 mm on right side and left side [14]. Lokesh *et al*,. reports mean height was 13.55 mm on right side and 13.43 mm on left side [15]. Our study results were similar to that of Rudraprasad *et al*., with a mean height of 12.59 mm [16]. The mean width of pedicle was 15.68 mm on right side and 14.70 mm on left side. Tiwari *et al*., reports mean width of the pedicle was 17.385 mm on right side and 17.705 mm on left side, with minimum value of 15 mm on both sides [14]. Nithya *et al*., reports mean width as 12.89 mm [17]. A Attar *et al*. reports 17.2 mm [18], and Rudraprasad reports 11.3 mm [16], Jaskaran Singh *et al*., reports 16.93 mm [19]. Compared to these findings, our findings is similar to that of Tiwari *et al*.

In the present study on CT scans in typical vertebrae, mean height of pedicle was 10.83 mm on right side and on left side 10.92 mm, which was much lower than the studies done by Scoles [20] Mithra [21] and Ridhi Karan *et al*. [22]. The mean width was 10.20 mm on right side and 9.98 mm on left side. Our study results are similar to the previous studies of Mithra *et al*., ranging from 7.05 – 11.6 mm [21], Ridhi Karan *et al*. ranging from 7.2 – 10.5 mm [22].

In the present study on CT scans in atypical vertebrae, mean height of pedicle was 10.83 mm on

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right side and on left side 10.92 mm, which was much lower than the previous studies done by Ridhi Karan *et al*., which records 14.5 mm [22]. The mean width of pedicle was 10.56 mm on right side and 10.17 mm on left side, which was much lower than reported by Ridhi Karan *et al*., it measures 12.7 mm on both sides[22] and Gurinder Singh *et al*., reported mean pedicle width was 12.8 mm [23].

In the present study, all the values of right and left side pedicles of typical and atypical vertebrae were compared and showed the positive correlation with p value < 0.00001 which is considered significant. P value of <0.05 was taken as significant. The mean length and width of the pedicles went on increasing towards the caudal part of vertebral column and mean height of pedicle decreased towards the caudal part of vertebral column. Regarding the length of lumbar pedicle done in the present study, mean length of pedicle – right was 18.40 mm, left – 17.08 mm of typical lumbar vertebrae. Atypical bone - Mean length of pedicle – right was 23.11 mm, left – 23.19 mm, measured on dry bones. Studied on CT scans; Typical bones - Mean length of pedicle – right was 16.58 mm, left – 15.89 mm. Atypical bone - Mean length of pedicle – right was 23.00 mm, left – 22.45 mm. Navkirat *et al*., conducted a study on 952 human cadaveric specimens without spondylolysis and 120 specimens with spondylolysis [24]. He reports, in spondylolytic specimens, pedicles start to elongate after the age of 40 years. The pedicle lengths increase progressively from 5.6 mm at 40 years to 6.7 mm at 80 years with a 1% to 3% increment every decade. The pedicle lengths showed little variation in specimens from healthy subjects. In the normal skeletal specimens, there was little variation in pedicle length with progressive age, with length being constant at 4.4 mm until the sixth decade and then declining to 4.1 mm in the specimens older than 80 years.

CONCLUSION

The comprehensive knowledge of morphological and morphometric features is of utmost important for the surgeons in the pedicle screw fixation procedures. Pedicle screw fixation is a preferred method for the spine stabilization techniques. Pedicle diameter is used as a reference for surgeons while choosing the size of pedicle screw. Few studies have stated reported that pedicle screw of larger diameter increased axial pullout force and enhanced spinal stability, but it may have higher chances of breaking through the pedicle medial wall and further damage nerve root. Selecting the proper screw size varies according to the different races or geographical areas because of the population specific measurements of lumbar pedicles. Hence it is recommended for the surgeons to have sound knowledge of pedicle features and patients should be analyzed pre-operatively by CT scan to make sure of the appropriate diameter of pedicles for accurate pedicle screw placement. Therefore, morphometric data concerning pedicles is useful in preoperative planning and also in designing pedicle screws and other implantable devices.

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