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Morphometric analysis of Lumbar Pedicle in our population based on computed tomography

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***Abstract*---**Background: The use of pedicle screw fixation for management of various spinal disorders has become popular worldwide in recent years. Pedicle screw fixations has implications in spinal fusion by transpedicular screw insertion to achieve stability in various spinal disorders such as, fractures, scoliosis, spondylosis thesis, tumours and iatrogenic or degenerative spinal instability. It is essential for the spine surgeon to have a comprehensive knowledge of the spinal morphometric dimensions since misplacement of the pedicle screw carries significant risk for the patient. It is challenging to perform pedicle screw fixation technically due to complex anatomy. Objective: To assess the lumbar pedicle morphometry in south Indian population based on CT scans. Materials and Methods: The present prospective observational study was carried out by the department of

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Orthopedics at JSS Medical College, Mysore from November 2018 to September 2020. A total of 100 patients who underwent Computed tomography of lumbar spine and Computed tomography abdomen and pelvis in JSS Hospital, Mysuru during the study period were included in the study. Results: The mean transverse pedicle Isthmus width was the least at L1 level (6.64mm) and highest at L s level (15.66mm). There was significant difference between male and female Vertebral Diameters. The Mean transverse Pedicle angle was maximum at L5 level (3331). Conclusion**:** There is Significant Difference in the morphometric parameters existed between the gender and even between individual of the same gender. It is suggested that pre-operative CT scans of the patients must be evaluated to choose the approximately sized implant and avoid neurovascular complication.

***Keywords*---**Morphometry, Lumbar vertebra, Lumbar Pedicle, CT Scan.

Introduction

The use of pedicle screw fixation for management of various spinal disorders has become popular worldwide in recent years. Pedicle screw fixations has implications in spinal fusion by transpedicular screw insertion to achieve stability in various spinal disorders such as, fractures, scoliosis, spondylolis thesis, tumors and iatrogenic or degenerative spinal instability.[1]

It is essential for the spine surgeon to have a comprehensive knowledge of the spinal morphometric dimensions since misplacement of the pedicle screw carries significant risk for the patient. It is challenging to perform pedicle screw fixation technically due to complex anatomy.[2]

In recent years with increasing popularity of minimal invasive procedures the operating surgeon may have lesser visual reference to the vertebral anatomy and hence a through knowledge of pedicles and variations between individuals is important during spine surgery. The development of reliable and stable implants for stabilization has evolved over many years beginning from Harrington rod system, inter-spinous wiring, spinous process plates, springs, compression rods, laminar wiring and recently pedicle screws.[3]

The advantages of surgical treatment with pedicle screw and rod fixation system in spine injuries are shorter hospital stay, fewer complications of prolonged immobilization, complete rehabilitation and reduced morbidity and mortality. Pedicle screws compared to the other fixation systems like hooks and wires has lesser soft tissue damage and better synostosis rates hence considered as excellent choice of implant for surgical management of various spine pathologies.[4] Pedicle screw insertion includes the introduction of screws at various entry points described in literature such as roy-camille, magerl and Weinstein, crossing the pedicle to reach the vertebral body to provide adequate stability and fixation of the affected spinal level.

All the forces exerted over the posterior elements of spine are channelled through the pedicles and are transmitted to the body. A screw placed through the pedicle from posteriorly into the body of vertebrae engages all three columns of the spine and thus it prevents motion in all three planes as described by Dennis in spinal instability.[4,5]

Pedicles serves as channel for various other procedures performed within vertebral body other than transpedicular screw fixation such as biopsy in cases of primary metastasis and vertebroplasty.[6] Inappropriate sized pedicle screw insertion can lead to various complications due to anterior cortical breach, wall expansion. Incorrect methods and size can cause damage to spinal cord, nerve roots, vascular structures or viscera and can even result in insecure fixation.[5] Many authors using different methods have attempted to measure various dimensions of lumbar pedicle and evaluation of variation among different race, age, sex, height and weight to assist orthopaedic spine surgeon and thus help surgeons while performing spine surgery.

Morphometric data of the pedicles prior to surgery is important for intraoperative planning and in designing instruments. Utilization of computed tomography (CT) to identify various dimensions of lumbar pedicle such as transverse pedicle width, sagittal pedicle diameter and screw path length in each patient at each vertebral level of fusion is ideal.[6] Transverse pedicle angle (TPA) is formed between the mid-sagittal plane of vertebral body and the plane bisecting the pedicle. TPA is an important angulation in axial plane for optimal placement of pedicle screw. [7]

Transpedicular screw fixation is considered as gold standard for lumbar spine stabilization for various spine pathology. Accurate pedicle screw placement is important to achieve adequate stability and fixation while avoiding complications. However, the methods commonly used for preoperative planning in spine surgery are not optimal.

There are no morphometric studies in our population measuring the morphometry of lumbar spine to guide pedicle screw fixation. Variation of lumbar morphometry in any sub group population should guide us to accurately use implants. This knowledge of surgically relevant dimensions of lumbar pedicle is important for safe pedicle screw insertion among our population. Hence, the aim of this study is to assess the lumbar pedicle morphometry in our population.

Objective

To assess the lumbar pedicle morphometry in south Indian population based on CT scans.

Materials and Methods

The present prospective observational study was carried out by the department of Orthopedics at JSS Medical College, Mysore from November 2018 to September 2020. A total of 100 patients who underwent Computed tomography of lumbar spine and Computed tomography abdomen and pelvis in JSS Hospital, Mysuru during the study period were included in the study.

Inclusion criteria:
a) Patients in the age group 18-80 years.
b) All normal vertebrae on CT scan.

Exclusion criteria:
a) Patients with congenital spine deformities.
b) Patient with history of previous infections and neoplasm.
c) Patient with an evidence or history of previous lumbar spine surgery.
d) Patient with more than one pedicle fracture in the same level of lumbar spine.

CT Protocol

The CT scans were performed with patient in supine position on Brilliance 64 (Phillips Healthcare, Buckinghamshire, United Kingdom) machine with X-ray source voltage of 80 to 120 kVP. Reconstruction of axial, sagittal and coronal sections were taken to measure various lumbar pedicle parameters for each of five lumbar vertebrae as described by Olsewski et al.

Image processing

The images obtained from CT were digitalised and saved on Picture Archiving Communication System (PACS) for recording and saving radiographic images and this allows access to all networked station. PACS also provides image enhancement and tools for rotation and magnification as well as measuring tool for measuring distance between any two selected points. When the mouse button is released at the second reference point, distance between the two points is automatically displayed at the information box, in the plane of the slice selected.

Each CT scan images were reformatted using Radi Ant software with synchronized axial, coronal, and sagittal displays. The image contrast levels were standardized to enable clear soft tissue and bone demarcation at the vertebral pedicles.

The relevant vertebral body was identified by counting the rib levels above downwards and confirmed by counting upwards from the sacrum. For the pedicle to be measured, the local axial viewing plane was adjusted to be parallel to the superior and inferior endplates of the vertebrae in question and aligned with the pedicle axis. The local sagittal viewing plane was then adjusted such that it was in line with the pedicle axis and perpendicular to the local axial plane.

Axial reconstruction was obtained with 3 mm thick slices. Axial images at the level of pedicle were obtained to correctly determine the true pedicle isthmus width at the narrowest point, transverse pedicle angle (TPA) and screw path length (screw trajectory). Sagittal reconstruction along the plane of longitudinal pedicle axis was obtained to measure pedicle height and sagittal pedicle angle. All the paired lumbar vertebrae pedicle parameters were measured for right and left pedicles using Philips 16 slice CT scanner.

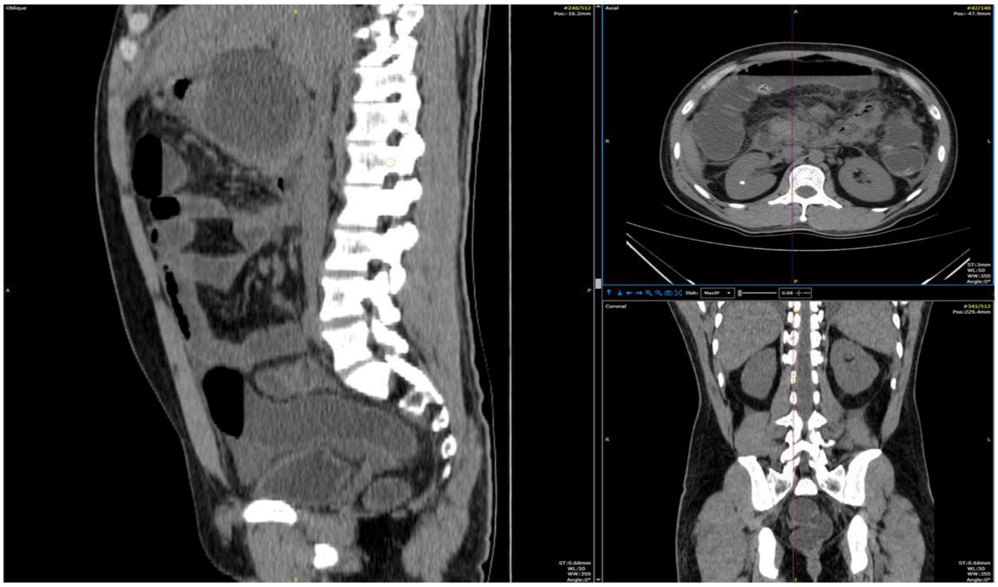

Fig 1: showing axial, sagittal and coronal reconstruction of pedicle

From the obtained images, the following measurements were made between L1-L5 vertebral levels. In 100 cases, measurements of transverse pedicle diameter transverse pedicle angle, screw path length, sagittal pedicle height and angle were measured for a total of 1000 lumbar pedicles

The following reference lines were drawn at each vertebrae level:

(a) A horizontal line drawn across the 2 transverse processes (intertransverse line)

(b) A line drawn from the spinous process perpendicular to the intertransverse line (anteroposterior mid-sagittal line)

(c) A line drawn through the mid-axis of the pedicle (longitudinal pedicle axis)

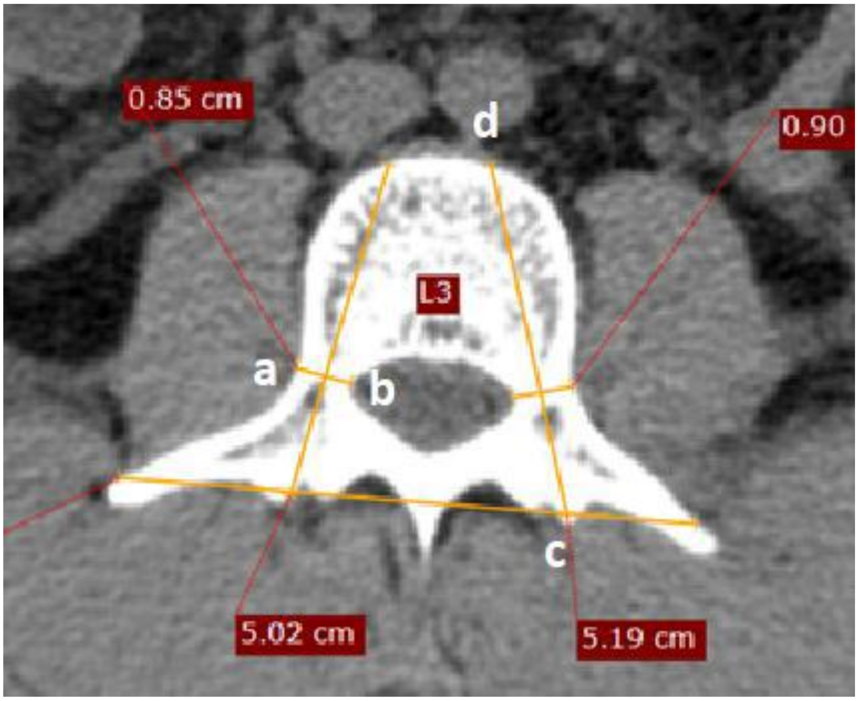

Fig 2. Measurement of transverse pedicle width(a to b), screw path length (c to d)

— TPW = transverse pedicle width — the distance between both cortical walls of the pedicle in the transverse plane (Fig. 1A, distance from ‘a’ to ‘b’); and — PAL = pedicle axis length — the distance between the posterior cortex of the pedicle and vertebra corpus anterior along the pedicle axis (Fig. 1A, distance from ‘c’ to‘d’)

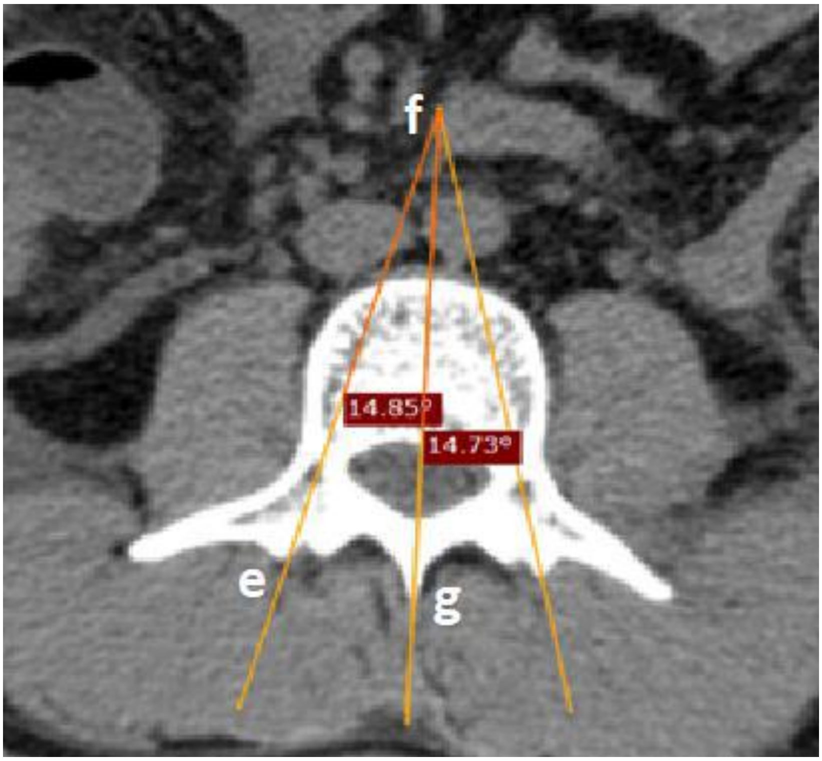

Fig 3. Measurement of transverse pedicle angle (e,f,g)

— TPA = transverse pedicle angle — the angle between the pedicle axis and midline in the transverse plane (Fig. 1C, angle between (‘e’and‘f and‘g’). The values at each lumbar level were compared in groups based on age, sex, height and weight.

Statistical Analysis

All measurements - pedicle length, width, height, transverse and sagittal pedicle angle were entered in MS-EXCEL and analyzed using SPSS software version 23.0 for windows (SPSS, Chicago) and summarized in terms of mean+/- SD and range (minimum to maximum). All the parameters were taken in millimeters and degrees. Independent t test was used, to compare these measurements between both gender and right/left. Age, sex, height and weight wise measurements was obtained and compared using ANOVA. P value of < 0.05 was considered to be significant.

Results

Out of the total 100 study subjects , 50 male patients of age ranging from 23-76 years, mean age of 47.14 ± 14.79 years and 50 female patients of age ranging from 21-80 years, mean age of 50.09 ± 17.02 years were included in the study.

Table 1
Distribution of study based on gender

		Frequency	Mean Age	Range
Gender	Male	50	47.14±14.79	23-76
	Female	50	50.09±17.02	21-80
Total		100	48.61±15.93	21-80

Table 2
Comparison of mean transverse pedicle width (TPW) between males and females along right and left pedicle at various lumbar vertebral levels

TRANSVERSE PEDICLE WIDTH (TPW)		Right (in mm)	Left (in mm)
L1	Male	6.65 ± 0.53	6.64 ± 0.51
	Female	6.36 ± 0.65	6.40 ± 0.65
L2	Male	7.31 ± 0.69	7.27 ± 0.66
	Female	6.81 ± 0.56	6.80 ± 0.55
L3	Male	8.56 ± 0.92	8.60 ± 0.88
	Female	8.32 ± 0.83	8.29 ± 0.82
L4	Male	10.37 ± 1.03	10.33 ± 1.02
	Female	9.50 ± 0.94	9.42 ± 0.94
L5	Male	13.59 ± 1.13	13.55 ± 1.12
	Female	12.69 ± 1.14	12.70 ± 1.14

Table no.2 shows variation in mean transverse pedicle width (TPW) of right and left pedicles for male and females. The variation between right and left pedicle is statistically insignificant. (P-value > 0.05).

Table 3
Comparison of mean transverse pedicle angle (TPA) between males and females along right and left pedicle at various lumbar vertebral levels

TRANSVERSE PEDICLE ANGLE (TPA)		Right (in mm)	Left (in mm)
L1	Male	10.17 ±2.00	9.82 ± 1.45
	Female	9.36 ± 1.72	9.42 ± 1.47
L2	Male	10.72 ± 1.31	11.46 ± 1.16
	Female	11.12 ± 1.56	11.41 ± 1.40
L3	Male	15.00 ± 1.57	16.11 ±1.49
	Female	15.13 ± 1.63	15.17 ± 1.67
L4	Male	17.96 ± 1.53	18.04 ± 1.83
	Female	17.20 ± 2.15	17.62 ±2.02
L5	Male	27.05 ± 2.34	27.67 ± 2.80
	Female	25.59 ± 3.32	25.84 ± 4.12

Table no 3 shows variation in mean transverse pedicle angle (TPA) at different lumbar vertebrae of studied population. The variation between right and left pedicle is statistically insignificant. (P-value > 0.05).

Table 4
Comparison of mean screw path length (SPL) between males and females along right and left pedicle at various lumbar vertebral levels

SCREW PATH LENGTH (SPL)		Right (in mm)	Left (in mm)
L1	Male	41.25 ± 1.48	41.82 ± 1.49
	Female	41.03 ± 1.72	41.48 ± 1.81
L2	Male	43.34 ± 1.22	43.96 ± 1.27
	Female	42.87 ± 1.41	43.06 ± 1.55
L3	Male	45.07 ± 1.67	45.36 ± 1.67
	Female	44.59 ± 1.54	44.67 ± 1.51
L4	Male	46.80 ± 1.61	46.96 ± 1.59
	Female	46.20 ± 1.58	46.42 ± 1.91
L5	Male	48.96 ± 2.27	49.23 ± 2.21
	Female	47.87 ± 2.54	48.26 ± 2.42

Table no.4 shows variation in mean screw path length (SPL) at different lumbar vertebrae of studied population. The variation between right and left pedicle is found to be statistically insignificant. (P-value > 0.05).

Discussion

Spine surgery is one of the rapidly evolving field that has changed significantly over last three decades with advances in various operative technique. The posterior segmental transpedicular construct in preference to other stabilisation systems provides primary means of rigid internal stabilization, which is useful in various spinal disorders such as spinal instability, fractures, spondylolisthesis, scoliosis and tumours. Accurate placement of pedicle screws reduces operative and postoperative complications and increases biomechanical stability.[1]

With the advanced imaging techniques such as intraoperative fluoroscopic imaging, three-dimensional image based navigation system, computed tomography can provide greater accuracy in posterior segmental transpedicular fixation and thus reduces intra and postoperative complications. Transpedicular instrumentation is technically challenging and pedicle wall violations during instrumentation carries significant risk of damaging neurovascular structures around the pedicle. A number of techniques have been employed to reduce the potential complications during transpedicular instrumentation such as different entry points, assessing various dimensions of pedicle pre operatively by computed tomography and MRI, intra operative imaging systems, use of electro physiological monitors and probing the pedicle after tapping.

Therefore a proper understanding of various dimensions of pedicle at different lumbar vertebrae would reduce the risk and provide better surgical outcome. Several studies have documented the external dimensions and angulations at different lumbar vertebrae levels.

To the best of our knowledge there are only few studies determining the morphometry of lumbar pedicles at narrowest part or isthmus and studying on correlation of weight, height and age with mean transverse pedicle width (TPW) at various lumbar vertebrae.

Demographic data of present study includes comparison between males and females, right vs left pedicle and correlation of weight, height and age with mean transverse pedicle width (TPW) at various lumbar vertebrae. Age comparison between males and females and gender distribution was not statistically significant. (p-value >0.05)

Transverse pedicle width (TPW)

TPW is the most important parameter for pedicle screw insertion as it determines the size of the pedicle screw to be used during surgery. In all the previous studies to assess transverse pedicle diameter showed males had higher dimensions than female and right sided pedicle had higher values than left side. In a study by Muhammad M Alam (2014) et al using CT scans in Pakistani population males had higher dimension than that of females population.[8]

In a cadaveric study in American population also showed gradual increase in TPW from L1 to L5 vertebrae and male cadaveric specimens had higher dimensions than females. [9] Studies in Indian population also showed higher dimensions in males than females with right sided pedicles having higher values than left pedicles. [1]

The TPW dimensions obtained in present study using CT is slightly lesser than the western population and similar to those of other Indian studies, hence a slightly smaller size screws may be required for Indian population particularly in females.[10]

In an American study on cadavers including 503 specimens taking into consideration sex, body height, and weight showed consistent increase in dimensions in a linear fashion indicating males taller and heavier individuals having higher dimensions at all the lumbar vertebrae. [9]

Variation in TPW with respect to age, height and weight was also studied in present study which showed a correlation between age, height and weight at each lumbar vertebrae in male population. In female population there was correlation between TPW with age, height and weight only at L3, L4 and L5 vertebrae, whereas at L1 and L2 vertebrae there was no correlation between TPW with height and weight, but age had significant correlation with TPW values. These results shows that age weight and height should also be considered while selection of appropriate screws during transpedicular pedicle screw fixation.

Transverse pedicle angle (TPA)

TPA is the most important angle for insertion of a pedicle screw. An CT based Indian without differentiation between sex showed gradual increase in medial angulation as moved caudally ranging from L1: 8.5, L2: 9.6, L3: 11.2, L4: 13.9, L5: 30.2. [10]

An Mexican population based study using CT scan showed gradual increase in TPA from L1 to L5 with female population having higher values than male population at all the lumbar vertebrae levels. [11]

In present study TPA followed similar trend as previous studies among Indian and western population with slight variation in values. TPA gradually increased as we moved caudally from L1 to L5 with a steep increase between L4 to L5 vertebrae.

In our study the angulations were higher compared to other studies indicating pedicles are more converging than other population. TPA in Mexican population at L5 was 18.98 degrees as compared to 27.05 mm in our study. [11] Hence in axial plane a higher angulation may be required in our population for pedicle screw insertion than western population.

Screw Path Length (SPL)

Knowledge of the screw path length is important to prevent anterior cortical breach causing damage to the vital structures. Various biomechanical studies have showed no difference exist in pull out strength between 85% depth insertion and 100% depth insertion of the pedicle screws .[12]

The Turkish study using CT including a total of 240 individuals with reference to sex found that screw path length was highest at L1 measuring 56.27 mm and gradually reduced as moved caudally with L5 measuring 52.92 mm in males whereas 50.71 mm at L1 and 48.16 mm in female population. [13]

Most of the studies conducted on western population showed gradual decrease in screw path length from L1 to L5 vertebrae (15–17) whereas few studies conducted in Indian population (1,8) showed gradual increase in SPL which were comparable with the present study.

In present study SPL increased from L1 to L5 vertebrae with shortest at L1 vertebrae and longest at L5 and Males had higher values than females. The results in present study showed that L1and L2 SPL were close to each other whereas and L3, L4 and L5 SPL had steep increase.

Conclusion

Pedicle screw fixation for surgical management of various spinal disorders has become increasingly popular worldwide in recent years. Pedicle screw fixations has implications in spinal fusion by transpedicular screw insertion to achieve stability in various spinal disorders such as spondylolisthesis, fractures, scoliosis, tumours and iatrogenic or degenerative instability. The transverse pedicle angle in our study is higher compared to other studies indicating pedicles are more converging than other population, hence higher angulation is required in Indian population during pedicle screw insertion. Hence morphometric analysis will give a better anatomical reference to the operating spine surgeon in an otherwise visually challenging surgery. Thus, helping the surgeon manoeuvre through the surgery with ease.

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