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Research Article

Pedicle Morphology of Lower Thoracic and Lumbar Spine (T10-L5) by Computed Tomography-A Cross-Sectional Study

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Abstract

Introduction: Vertebral pedicle assessment is important in choosing appropriate pedicle screw for spinal fixation. Differences have been reported in morphology of vertebral pedicles in the literature between various ethnic groups. So, main objectives of this study is to record surgically relevant parameters using Computed Tomography Scan.

Methods: This prospective cross sectional study was performed from September 2016 to August 2017 on 110 patients (>18 years) referred for Computed Tomography scan to Department of Radiology, Tribhuvan University Teaching Hospital, Kathmandu, Nepal. Ethical approval was taken from Institutional Review Board, Institute of Medicine, Maharajgunj, Kathmandu, Nepal with reference number 368 (6-11-E)/074. The scans of lower thoracic and lumbar spine of patient, free from spinal disorders were reviewed for the morphology of vertebral pedicle. We analyzed 880 vertebrae. Parameters evaluated were chord length, depth along midline axis, transverse pedicle isthmus width and transverse pedicle angle. Data was collected in predesigned proforma in Microsoft Excel spread sheet and analysis were done using software, SPSS (Statistical Package for Social Science) version 16.

Results: Mean transverse pedicle isthmus width was least at T10 vertebral level (6.21 mm) while the largest was seen at L5 vertebral level (14.04 mm). The chord length was more than the depth along midline axis at all levels except at T11 and T12. The mean transverse pedicle angle faced laterally at T11 and T12 vertebral level.

Conclusion: It is sensible to ask for pre-operative Computed Tomography scans in order to choose appropriate screw size to prevent intra-operative and post-operative complications.

Keywords: *CT; Lower Thoracic; Lumbar Spine; Vertebral Pedicle*

Introduction

After the evolution of spinal fixation systems over the years, the use of transpedicular fixation devices have increased in preference to rods, hooks and wires. They offer rigid segmented fixation for various disorders of spine, including scoliosis, spondylolisthesis, fractures, tumors, iatrogenic or degenerative stability after decompression and arthrodesis. Neurologic, vascular and visceral injuries are the complications associated with misplaced pedicle screws [1]. As reported in various studies, vertebral pedicle is subject to ethnic variations [2-6]. Hence, the ethnic specific data on pedicle morphometry is required to avoid any misplacement and inappropriate size of implants as it may result in injuries despite the best effort of spine surgeons [2]. Previous literature in our country dates back to 2014, done by Marasini., *et al*. [3] using X-Rays as the modality, considering the advantage of cost efficacy with an added benefit of good sample size. However,

the accuracy of CT (Computed Tomography) measurements of pedicle diameter, pedicle axis and screw path length has established CT scan as the best means of evaluating pedicle radiologic morphology.[4] No CT based study has been done in the Nepalese population. So, main objectives of this study is to find out the pedicle morphology in lower thoracic and lumbar spine (T10-L5) by computed tomography.

Methods

This was a prospective, cross sectional, observational study done from September 2016 to August 2017 on 110 patients. The patients who were referred to Department of Radiology and Imaging of Tribhuvan University Teaching Hospital (TUTH) by clinicians from TUTH or other hospitals/clinics for various abdominal conditions obtaining CT abdomen were selected in the study according to the inclusion and exclusion criteria. CT scan was performed using 128 slice MDCT (Multidetector Computed Tomography) Siemens of Department of Radiodiagnosis and Imaging. The CT images of the patients meeting inclusion criteria were evaluated. Sampling technique used was non probability sampling. Patients (> 18yrs) visiting the Department of Radiology and Imaging of the Tribhuvan University Teaching Hospital for CT Abdomen were included in the study. Those with congenital spinal abnormalities causing abnormal anatomy, the individual vertebrae with the concerned pathology, i.e. infective, neoplastic, traumatic were excluded from the study.

Ethical approval was taken from Institutional Review Board, Institute of Medicine, Maharajgunj, Kathmandu, Nepal with reference number 368 (6-11-E)/074. No extra cost was taken from the participants. The participation of respondents were voluntary. They could withdraw from the study at any time if they want. The identity of the respondents and their response were kept confidential and data would be used for research purpose only. Informed written consent was taken from patients meeting the inclusion criteria. MDCT with or without contrast of patients, who were referred to radiology department for CT abdomen, were evaluated. All patients were scanned in 128 slice MDCT (Siemens Somatom Definition AS+) according to their respective predefined protocols. Patients were scanned in supine position in cranio-caudal direction from dome of diaphragm to symphysis pubis using 120 kVp and 200 mAs with modulation pitch of 0.85. Slice collimation of 0.6 x 128 mm was used. Mid pedicle section was obtained under bone window. The various measurements i.e. Depth along pedicle axis (Chord length), depth along midline axis, transverse pedicle isthmus width and transverse pedicle angle were done in the CT workstation using the SyngoVia software.

Data was collected in predesigned proforma in Microsoft Excel spread sheet and further analysis were done using software, SPSS (Statistical Package for Social Science) version 16. The mean with their standard deviations were calculated.

Results

Hundred and ten patients, who underwent CT scan, were evaluated for different parameters from 10th thoracic vertebra to 5th lumbar vertebra. The age ranged from 18 to 72 years with mean age being 47.9 years. Highest number of patients were seen in the age group of 50 to 60 (26.3%) and the lowest in 70+ age group (0.01%) (Figure 1). Nearly 60% of the patients in the study were males (males: female ratio = 1.5).

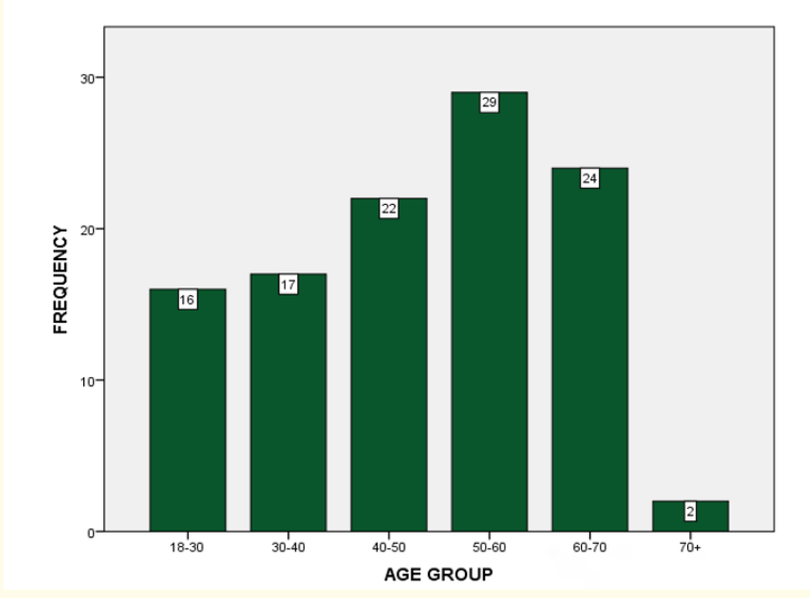

Figure 1: *Age distribution of patients.*

Mean measurements of parameters at various vertebral levels

The largest mean chord length was seen at L2 vertebral level measuring approximately 49.23 mm ± 2.69 SD while the smallest measures approximately 35.5 mm ± 4.45 SD at T11 vertebral level. Maximum variability was observed at T12 vertebral level whereas least at L1 vertebral level.

The largest mean depth along midline axis was seen at L2 vertebral level measuring approximately 42.6 mm ± 3.16 SD while the smallest measures approximately 37.1 mm ± 2.29 SD, at T11 vertebral level. Maximum variability was observed at L3 vertebral level whereas the least at T10 vertebral level (Table 1).

The largest transverse pedicle isthmus width was seen at L5 vertebral level measuring approximately 14.04 mm ± 2.16 SD while the smallest measures approximately 6.23 mm ± 0.72 SD at T10 vertebral level. Maximum variability was observed at L5 vertebral level whereas the least at T12 vertebral level (Table 1).

The largest mean transverse pedicle angle was seen at L5 vertebral level measuring approximately 24.80 ºrees ± 2.57 SD while the smallest measures approximately 3.43 ºrees ± 2.33 SD at T10 vertebral level. Maximum variability was observed at L5 vertebral level whereas the least at L2 vertebral level (Table 1).

Vertebral Levels	Chord Length (mm)		Depth along Midline Axis (mm)		Transverse Pedicle Isthmus Width (mm)		Transverse Pedicle Angle (º)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
T10	42.289	3.0119	38.982	1.9715	6.237	0.7259	3.439	2.3350
T11	35.590	4.4543	37.141	2.2982	6.550	0.6991	-10.206	2.1303
T12	35.657	5.5968	37.878	2.4832	7.164	0.6492	-10.276	2.2402
L1	47.331	2.4478	41.116	2.6250	7.021	0.6635	11.355	2.0467
L2	49.232	2.6903	42.601	3.1662	7.272	0.7750	12.322	1.7575
L3	47.934	3.3956	40.924	3.3677	9.266	1.7026	15.382	2.3351
L4	47.292	3.3551	40.863	3.1544	12.115	1.6001	19.381	2.4663
L5	48.315	2.6217	40.035	3.0673	14.040	2.1641	24.805	2.5792

Table 1: *Parameters at various vertebral levels.*

Parameters according to sex at various vertebral levels

Vertebral Levels	Sex	Chord Length	
		Mean (mm)	SD (mm)
T10	Male	43.5273	3.08268
	Female	40.6636	2.05801
T11	Male	36.9182	4.75219
	Female	33.4136	3.03840
T12	Male	37.2152	6.08080
	Female	33.2750	3.68404
L1	Male	48.0818	2.58314
	Female	46.2795	1.89142
L2	Male	49.9697	2.98736
	Female	48.0455	1.65957
L3	Male	48.7788	3.71672
	Female	46.7727	2.21909
L4	Male	48.0894	3.29153
	Female	46.4568	2.87470
L5	Male	48.8591	2.81507
	Female	47.4977	2.42540

Table 2: *Chord length according to sex at various vertebral levels.*

Depth along midline axis

Vertebral Levels	Sex	Depth Along Midline Axis	
		Mean (mm)	SD (mm)
T10	Male	39.4924	1.93409
	Female	38.0818	2.16841
T11	Male	37.6712	2.18285
	Female	36.1045	2.48755
T12	Male	38.3848	2.91950
	Female	36.8841	1.75247
L1	Male	41.7258	2.95064
	Female	40.1227	1.79364
L2	Male	43.6348	3.27581
	Female	40.7818	2.72203
L3	Male	41.7136	3.94087
	Female	39.8932	1.51387
L4	Male	41.9924	3.04845
	Female	39.4773	2.39591
L5	Male	40.9091	3.09410
	Female	38.9886	2.54789

Table 3: *Depth along midline axis according to sex at various vertebral levels.*

Transverse pedicle isthmus width

Vertebral Levels	Sex	Transverse Pedicle Isthmus Width	
		Mean (mm)	SD (mm)
T10	Male	6.2561	0.79210
	Female	6.2090	0.62131
T11	Male	6.6455	0.71794
	Female	6.3750	0.75302
T12	Male	7.1955	0.73095
	Female	6.9864	0.58333
L1	Male	7.1667	0.72734
	Female	6.9545	0.58088
L2	Male	7.3091	0.83348
	Female	7.1045	0.51487
L3	Male	9.6242	1.75631
	Female	8.9818	1.62485
L4	Male	12.5303	1.54790
	Female	11.5818	1.47873
L5	Male	14.6591	2.31530
	Female	13.2386	1.51338

Table 4: *Transverse pedicle isthmus width according to sex at various vertebral levels.*

Discussion

Pedicle screw placement has become widespread. Chord length, also known as depth along the pedicle axis or the screw path length, is an important measurement relating to the anterior cortical perforation and hence vascular injury. Current recommendation is selecting the largest fully threaded screw that can be accommodated by a pedicle [1]. In our study, chord length gradually decreased in the lower thoracic vertebral region and then increased in the lumbar vertebra with measurements being similar in the lumbar region. Studies done by Chadha., *et al*. [1] and Acharya., *et al*. [2] showed similar trend. In the current study, the chord length was found to be greatest at L2 vertebral level (mean, 49.23 mm) consistent with the findings of Mitra., *et al*. [5] (mean, 47.56 mm) and Acharya., *et al*. [2] (mean, 49.03 mm). Findings by Chadha., *et al*. [1] were similar but their longest chord length was at L5 (mean, 49.4 mm) followed by L2 (mean, 49.0 mm) vertebral level. Chord length in males was comparatively larger than females. However, in a study done by Hou., *et al*. [6] in Chinese population, significant difference between male and female was seen only at L1 vertebral level. In the Japanese population, Nojiri., *et al*. [7] found significant difference ($p < 0.01$) at all vertebral levels. Hence, chord length in males and females followed a varied trend in different population. In all vertebral levels, depth along midline axis was less than chord length of their corresponding vertebral levels, except at T10 and T11 vertebral level, this may be due to the laterally oriented pedicles, findings which are consistent with the Indian and Korean studies [1,8]. However, study done by Zindrick., *et al*. [9] showed this trend only at T12 vertebral level. Depth along midline axis in males was comparatively larger than females. Regarding the differences between genders in depth along midline axis, significant differences existed at L1 ($p = 0.002$) and L3 ($p = 0.007$) vertebral levels. Hou., *et al*. [6] found differences at L1 vertebral level.

Transverse pedicle isthmus width being the most important determinant along with chord length, shared similarity with the studies done on the Indian population [1]. Various studies [4,10] revealed the oval nature of the pedicles, evidenced by the fact that the transverse diameter being less than the sagittal diameter, hence transverse diameter being the single most important factor in selecting the appropriate screw size. Transverse pedicle isthmus width in our studies was comparable to other studies with the trend that it is lower at lower thoracic levels, with gradual increase caudally. Transverse pedicle angle is also a strong determinant of accurate screw fixation owing to the nature of the most dreaded complication, that is the medial penetration and subsequent neural injury that can occur during procedure. In our study, angles varied from negative at lower thoracic levels with gradual positive increase caudally. This negative angle is explained by the fact that the pedicles in the lower thoracic vertebrae are laterally oriented with respect to lumbar pedicles which are medially oriented. In our study mean negative angle was seen at T11 (-10.20º) and T12 (-10.27º) vertebral levels. This trend was similar to study done by Chadha., *et al*. [1], Hou., *et al*. [6] and Kim., *et al*. [8]. Acharya., *et al*. [2] however, observed mean negative angle also at T10 (-9.40º) in their study. In our study, approximately 14 of the pedicles showed a lateral angulation at T10 vertebral level but most of pedicles at T10 in our study showed medial angulation. Shallowest angle in our study was found at T12 (-10.27º) vertebral level, also seen in study by Chadha., *et al*. [1]. However their mean value was -3.0º. Study by Zindrick., *et al*. [9] showed mean negative angle only at T12 vertebral level (mean, -4.2º). At T10 vertebral level, they concluded that all the 32 pedicles were laterally oriented but at T11 vertebral level, mean being positive (1.2º), their range varied from -6.0 to 9.5º.

In lumbar vertebrae, angle gradually increased caudally, being largest at L5 vertebral level (24.80º) which was the trend seen in all the studies. At L5 vertebral level Chadha., *et al*. [1], Acharya., *et al*. [2] measured angles as 24.33º and 24.75º respectively. Mitra., *et al*. [5] observed 24.3º and 24.5º in males and females respectively. Our findings were similar to the studies done in Indian subcontinent [4]. Mitra., *et al*. [5] found statistically significant difference between their study and the studies done by Zindrick., *et al*. [9] and Olsewski., *et al*. [11] further supporting our study. At L5, Zindrick., *et al*. [9] and Olsewski., *et al*. [11] measured angles as 29.8º and 29º respectively, which were considerably higher than our study.

Conclusion

Stability and versatility make pedicle screw fixation widely used method for spinal fusion surgeries. There are significant differences in the pedicle morphometric parameters that exist between the Nepalese and Western population. However, measurements are similar to

the Indian population owing to the ethnic and part geographical similarities. Reliability, simplicity, patient specificity and non-invasiveness make CT scan an ideal modality for choosing accurate screw size so, that inadvertent complications can be prevented. Preoperative assessment using CT scan is recommended.

Conflict of Interest

None.

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