Original Article

Novel Morphometric Measurement Angles for Guiding Pedicular Screw and Cortical Screw Insertion in the Lumbar Spine

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Background: Placement of lumbar pedicle screw fixation shows good results due to the strength and accuracy of pedicle screws. Placement of lumbar pedicle screws via free-hand technique relies on clear exposure and identification of lumbar morphology. The purpose of this study was to investigate the reliability and accuracy of angles between the lumbar pedicles and posterior bony landmarks.

Objective: To establish new morphometric angles, and to evaluate the correlation of these angles between the pedicles and the posterior elements of the lumbar spine.

Materials and Methods: An institutional radiographic database was retrospectively searched for patients who underwent lumbar computed tomography scanning during 2007 to 2010. The transverse pedicle angle (TPA) and 3 novel angles were measured, including the transverse process-pedicle angle (TPPA), pars interarticularis-pedicle angle (PPA), and lamina-pedicle angle (LPA). Two observers independently measured all angles two times one month apart.

Results: Forty-nine patients (22 men, 27 women) were included. Mean age was 51.82±17.63 years. Mean TPA, TPPA, PPA, and LPA measurement was 17.2±7.23, 66.59±13.34, 105.74±6.43, and 67.12±7.29 degrees, respectively. There were no significant relationships with gender or laterality for any angles except PPA. Weight and body mass index correlated significantly with all angles (p<0.05), but height correlated only with TPA and TPPA. TPA and PPA gradually increased in magnitude from L1 to L5. However, TPPA was smallest at the L3 level. Intraobserver intraclass correlation coefficients (ICC) ranged from 0.90 to 0.97, and interobserver ICCs ranged from 0.88 to 0.97, which indicated strong reliability for both measures.

Conclusion: Three novel angle measurements describing the anatomic relationship of the lumbar pedicles to the posterior elements had strong measurement reliability and may help surgeons more accurately place pedicle screws, especially during revision cases in which the spinous process was previously removed. These novel measures also show screw placement for the newer cortical bone trajectory being used for lumbar fixation.

Keywords: Lumbar spine, CT scan, Spine, Pedicle screws, Anatomic landmarks

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Pedicle screw fixation is commonly used in modern lumbar spinal fusion procedures. Placement of pedicle screws via free-hand technique relies on clear exposure and identification of the posterior vertebral landmarks, including the spinous process, pars interarticularis, transverse processes, and adjacent facet joints.

Since the spinous process is the most prominent bony landmark, previous vertebral morphometric studies defined the angle between the spinous process and the pedicles as the transverse pedicle angle (TPA). Abuzayed, et al reported that the average lumbar TPA gradually increased from 13.1 degrees at L1 to 33.3 degrees at L5[(1)]. Zindrick, et al studied this measurement in a Caucasian population and similarly found that the average lumbar TPA increased from 10.9 degrees at L1 to 29.8 degrees at L5[(2)]. Other studies showed differences in pedicular morphometric values between Asian and Caucasian populations[(3-7)]. Thus, differences in measurements among studies may be influenced by the ethnicity of enrolled patients.

No previous lumbar morphometric studies have described the angles between the pedicle and other posterior bony landmarks, including the lamina, transverse process, and pars interarticularis. Accordingly, the present study aimed

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to evaluate the angles between the lumbar pedicles and other posterior bony landmarks by using computed tomography (CT) imaging. The authors hypothesized that these anatomic measurements would be consistent among patients, and that they could be measured with strong reproducibility. These angles may enhance our understanding of lumbar osteology, and may improve the safety and reliability of lumbar pedicle screw placement.

Materials and Methods

After obtaining approval from the Siriraj Institutional Review Board (SIRB) (COA No. 115/2557), the authors retrospectively reviewed our center's radiologic database for patients aged older than 18 years who underwent a lumbar CT scan at the Department of Radiology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand during 2007 to 2010. Patients with spinal trauma, infection, congenital deformity, and/or tumor were excluded. CT scan images of the lumbar spine were reconstructed to our reference sagittal view so that a true lateral view without tilting of the superior and inferior endplates was established. The standard axial view was defined as the line parallel with the superior endplate of the vertebral body, and located in the middle of the pedicle at each lumbar vertebra. To define the pars interarticularis, the authors selected the sagittal plane that showed both the superior and inferior articular processes, and we based our measurements on the dorsal aspect of the pars (Figure 1). In the axial plane, the authors measured 3 angles between the pedicle, lamina, transverse process, and spinous process. The transverse pedicle angle (TPA) was the angle subtended by the longitudinal axis of the pedicle and a line parallel to the spinous process in the axial projection. The lamina-pedicle angle (LPA) was the angle defined by the pedicle line and a line parallel to the dorsal surface of the lamina in the axial view. The transverse process-pedicle angle (TPPA) was the angle between the pedicle and a line parallel with the posterior surface of the transverse process. The pars interarticularis pedicle angle (PPA) was defined as the angle between the pedicle line and a line parallel with the posterior surface of the pars interarticularis in the sagittal plane. Examples of all angles are shown in Figure 2. Two observers independently measured all angles two times one month apart for intraobserver and interobserver reliability assessment. Bilateral measurements were taken at each lumbar level for every patient.

Statistical analysis

Statistical analysis was performed using SPSS Statistics software (SPSS, Inc., Chicago, IL, USA). Student's t-test and Chi-square test was used to compare continuous and categorical variables, respectively. Categorical data are presented as number and percentage, and continuous data are presented as mean $\pm$ standard deviation and range. Correlations between angles and demographic data were calculated using Pearson's correlation coefficient. Intraobserver and interobserver reliability was determined using intraclass correlation coefficients (ICCs). Statistical

Figure 1. Standard computed tomography view after reconstruction in the sagittal (A) and axial planes (B).

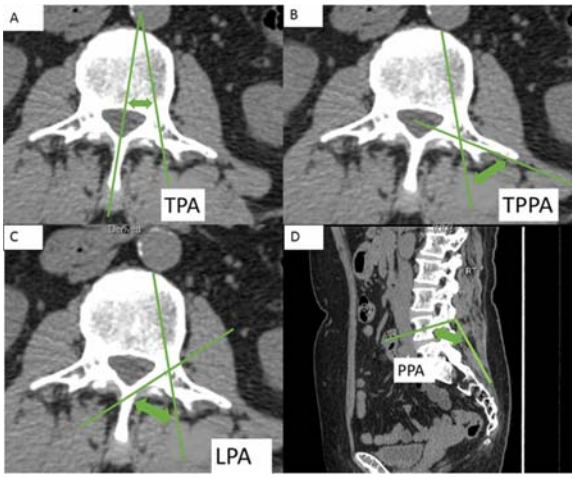

Figure 2. Measurement of the transverse pedicle angle (A), transverse process-pedicle angle (B), lamina-pedicle angle (C), and pars interarticularis-pedicle angle (D).

significance was assumed at a *p*-value less than 0.05.

Results

A total of 49 patients (22 men and 27 women) with a lumbar CT scan were studied. The mean age was 51.82$\pm$17.63 years. Mean height, weight, and BMI was 162.88$\pm$7.90 cm, 60.76$\pm$10.64 kg, and 22.95$\pm$4.08 kg/m^2, respectively.

The mean transverse pedicle angle (TPA) was 17.2$\pm$7.23 degrees. There was no statistically significance difference between genders ($p = 0.26$), or for the TPA between the right-side and left-side pedicles ($p = 0.11$). However, there was a statistically significant difference among levels ($p<0.001$). The mean TPA was found to increase gradually from L1 to L5 (Figure 3).

The mean transverse process-pedicle angle (TPPA) was 66.59$\pm$13.34 degrees. No significant differences between

sides ($p = 0.59$) or genders ($p = 0.63$) were found. TPPA also differed significantly among levels ($p = 0.005$). TPPA was smallest at the L3 level. The mean pars interarticularis-pedicle angle (PPA) was 105.74±6.43 degrees. There were no significant differences between sides ($p = 0.843$) or among levels ($p = 0.081$). The mean lamina-pedicle angle (LPA) was 67.12±7.29 degrees. There were no significant differences between sides ($p = 0.320$) or genders ($p = 0.108$). However, there was statistically significant difference between the average LPA of each level that ranged from 66.42 to 72.16 degrees ($p<0.001$). All four measured angles were significantly correlated with BMI accept TPPA (r = 0.024 p-value <0.001. Height was significantly correlated only with TPA (Table 2). Reliability of measurement was excellent for all measured angles (Table 3). The intraobserver ICC ranged from 0.903 to 0.976, and the interobserver ICC ranged from 0.880 to 0.971. TPPA had the highest reliability, and PPA had the lowest reliability in both interobserver and intraobserver reliability.

Discussion

Most previous morphometric studies of the lumbar spine reported the angle between the pedicles and the spinous processes, and they called this angle the transverse pedicular angle (TPA). It is known that differences in this angle exist between Asian and Caucasian populations[1,4,5,7]. However, few studies have systematically described the anatomic relationship of the pedicle to other posterior bony landmarks, including the lamina, transverse process, and pars interarticularis. These relationships are important in free-hand pedicle screw placement, and also show placement of cortical-trajectory screws, which is a newer technique that is gaining in popularity[8].

In the present study of a Thai population, the mean TPA was 17.2±7.23 degrees. Figure 4 compares our TPA values to those from other published studies. Our values fall squarely within the ranges previously described, and similarly demonstrate a trend for the angle to increase from

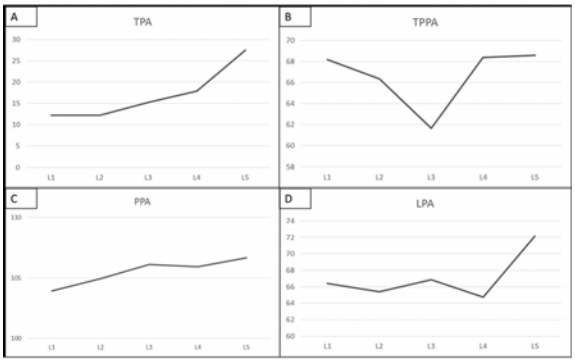

Figure 3. Progression of the average of all measured angles between L1 to L5, including transverse pedicle angle (TPA) (A), transverse process-pedicle angle (TPPA) (B), pars interarticularis angle (PPA) (C), and lamina-pedicle angle (LPA) (D).

Table 1. Morphometric measurements between pedicle and posterior bony landmarks of the lumbar spine

	Mean ± SD	95% CI	p-value
TPA			
L1	12.25±2.80	11.44 to 13.05	
L2	12.25±3.07	11.37 to 13.13	
L3	15.39±3.18	14.47 to 16.30	<0.001
L4	17.95±3.75	16.87 to 19.02	
L5	27.51±5.88	25.82 to 29.20	
TPPA			
L1	68.16±9.91	65.31 to 71.00	
L2	66.36±10.62	63.31 to 69.415	
L3	61.65±11.35	8.38 to 64.91	0.005
L4	68.37±12.96	64.65 to 72.09	
L5	68.58±12.24	65.06 to 72.09	
PPA			
L1	103.92±4.26	102.70 to 105.14	
L2	104.95±4.57	103.63 to 106.26	
L3	106.10±5.92	104.40 to 107.80	0.081
L4	105.93±5.86	104.24 to 107.61	
L5	106.66±6.12	104.91 to 108.42	
LPA			
L1	66.40±5.62	64.81 to 68.04	
L2	65.39±6.64	63.48 to 67.29	
L3	66.87±5.40	65.32 to 68.42	<0.001
L4	64.74±4.32	63.50 to 65.98	
L5	72.16±7.81	69.91 to 74.40	

TPA = transverse pedicle angle, TPPA = transverse process-pedicle angle, PPA = pars interarticularis-pedicle angle, LPA = lamina-pedicle angle

Table 2. Correlations between each angle and height-BMI

Angle	Height		BMI	
	Correlations coefficient (r)	p-value	Correlations coefficient (r)	p-value
TPA	0.107	<0.001	0.60	0.028
TPPA	0.011	0.066	0.024	0.620
PPA	0.041	0.120	0.121	<0.001
LPA	0.026	0.235	0.324	<0.001

Table 3. Intraclass correlation coefficients for each angle

Angle	Intraobserver reliability	Interobserver reliability
TPA	0.966	0.961
TPPA	0.976	0.971
PPA	0.903	0.880
LPA	0.940	0.934

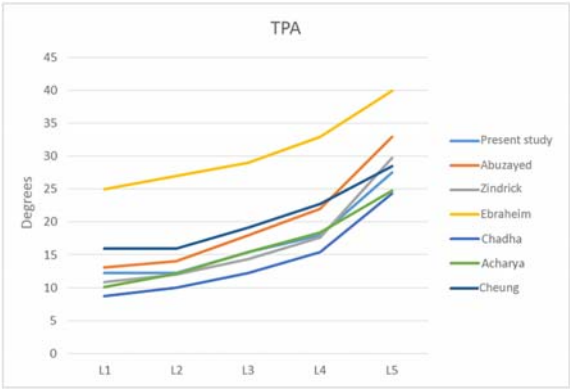

Figure 4. Mean transverse pedicle angle (TPA) values from L1 to L5 compared against other published values.

L1 to L5.

The present study proposes three novel angles, including the transverse process-pedicle angle (TPPA), the pars interarticularis-pedicle angle (PPA), and the lamina-pedicle angle (LPA). There was excellent reliability for measurement of these angles. PPA and LPA showed significant increase from L1 to L5, although TPPA was smallest at L3. In revision spine surgery, the TPA often cannot be used to guide screw placement since the spinous processes are frequently removed. These novel measurement angles can help spine surgeons more accurately place pedicle screws in these revision cases since computer navigation is not available in many hospitals.

The limitations of the present study include its retrospective design, its small sample size, and the fact that our data were collected from a single center. The authors also included patients of a single ethnicity, which may limit extrapolation of these findings to other ethnic populations.

Conclusion

Three novel angle measurements describing the anatomic relationship of the lumbar pedicles to the posterior elements had strong measurement reliability and may help surgeons more accurately place pedicle screws, especially during revision cases in which the spinous process was previously removed. These novel measures also show screw placement for the newer cortical bone trajectory being used for lumbar fixation. Future studies are needed to demonstrate that screw placement accuracy is indeed improved by using these measurement angles. Importantly, the present study defines those angles and provides an initial range of measurement values.

What is already known on this topic?

Previous studies reported the angle between the lumbar pedicle and spinous process to be the transverse pedicle angle. Differences in pedicular morphometric values between Asian and Caucasian populations were previously reported.

What this study adds?

The present study shows 3 new lumbar morphometric angles in Thai patients that use the pars interarticularis as a reference, and that had good reliability. These data will help surgeons insert pedicle or cortical screws more accurately, especially in revision cases in which the spinous process was previously removed.

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Potential conflicts of interest

The authors declare no conflicts of interest.

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