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ORIGINAL ARTICLE

Transpedicular Screw Fixation of the Lumbar Spine: an anatomical perspective

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ABSTRACT

Background Transpedicular screw fixation of the lumbar spine is a popular procedure to attain stability in degenerative conditions, deformity and fracture. An inappropriate size and positioning of the screw however may result in postoperative neurological and vascular complications in up to 42% of cases emphasizing need for precise morphometric data.
Aim: This study aimed at providing morphometric features of lumbar vertebral pedicles germane to transpedicular screw fixation in Punjab.
Study design: Cross-sectional population study
Methods: Lumbar spine measurements of height and transverse diameter of pedicles along with sagittal and transverse angles were recorded from CT scans of 33 adult males and 28 females using ImageJ1.47v radiological image processor. Distance along pedicular and sagittal axes reaching anterior cortex of vertebra (screw length) was also measured.
Results: Vertical and transverse diameters of the pedicle were significantly larger in the male. Gradual increase from L1 to L5 in the sagittal and transverse angles was observed in both sexes. Both angles were comparatively larger in the females; transvers angle being much wider than the males. Depth (screw length) of anterior cortex along pediclular axis except at level L3 and parallel to sagittal axis was not significantly different in the two groups.
Conclusion: The study has provided useful gender specific data which will be of interest to the researcher and may be useful for the operating surgeon in his preoperative assessment and deliberations of lumbar transpedicular screw fixation.
Keywords: Lumbar spine, transpedicular screw fixation, morphometry, lumbar pedicle, lumbar vertebrae, Multan

INTRODUCTION

Due to their ability to provide strength and stability and favorable results in alleviating clinical symptoms transpedicular screw fixations have become increasingly popular for fractures, degenerative pathology and deformity of lumbar spine. Ever since Galibert et al[1] in 1987 percutaneous transpedicular vertebroplaty and kyphoplasty have been developed for osteoporotic fractures and deformity of the spine[2]. However inappropriate positioning and failure of the screw up to 11% with postoperative neurological and vascular complications up to 42% have been reported [3,4]. Precise morphometric data on diameters of the pedicles, angle of projection and available trajectory length therefore is vital for safe application of transpedicular screw fixation.

Although several studies [3,5,6,7,8] have described the various features of vertebral pedicles in their countries the geometrical design and its characteristics vary in different population groups depending upon their genetic makeup, geographic locations and socioeconomic conditions [9]. Such information not being available in our area we decided to study in Punjab the morphometric features of lumbar vertebral pedicles to provide baseline data germane to transpedicular screw fixation.

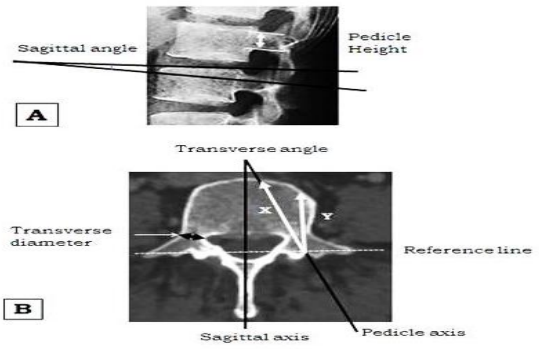
MATERIAL AND METHODS

After review and approval by the institutional ethical committee for medical research this prospective cross sectional population study was carried out during the period April 2020 to January 2021 at Services Hospital, Lahore and its affiliated teaching hospital. Individual subject consent was taken to be included in the study.
After a thorough history only normal healthy adult male and female subjects from Multan Division were selected. This included 33 males (mean age: 51.7 $\pm$ 9.3 years and mean weight: 77$\pm$12.4 kg) and 28 females (mean age: 47.3$\pm$8.5 years and mean weight: 59 $\pm$ 8.6 kg).

The scheme of various measurements is shown in Figure 1. Measurements were recorded on CT scans using ImageJ1.47v radiological image processor. Sagittal angle was measured between a line drawn along the superior border of the vertebra and sagittal axis of the pedicle in a lateral view and transverse angle between the two axes in a transverse section. The height and transverse diameter of the pedicle were recorded. A reference line at the level of transverse processes was drawn and distance along the pedicular axis to the anterior cortex of vertebral body from this line was measured. Similarly the depth of anterior cortex parallel to sagittal axis was recorded. These measurements represented the screw track and length of the screw.

All measurements were taken by one investigator and independently verified by another colleague. The results were separately tabulated for male and female groups and means and SD drawn. Student's t-test was used for comparison and significance was considered at 95% confidence limit.

Figure 1: Scheme of measurements. **A**: Pedicle height (Vertical diameter) and sagittal angle. **B**: Sagittal and pedicular axes, a reference line at the level of transverse processes, transverse diameter of pedicle at isthmus. Transverse angle between the sagittal and pedicular axes X: Depth of anterior cortex along pediclular axis Y: Depth of anterior cortex parallel to sagittal axis.



RESULTS

Various measurements and their statistical comparisons are given in Table 1, 2 and 3. In an overall comparison the vertical and transverse diameters of the pedicle were significantly larger in the male. A gradual increase in the sagittal and transverse angles and more pronounced in lower lumber spine was observed in both sexes. Both these angles were comparatively larger in the females; transvers angle being much wider than the males. The depth (screw length) of anterior cortex along pediclular axis except at level L3 was not significantly different in the two groups; comparison of depth of anterior cortex parallel to sagittal axis was also insignificant.

Table 1: Mean±SD values of vertical and transverse diameters of lumbar vertebral pedicles in male and female subjects and *p-values* of their comparison.

Level	Side	**Vertical diameter of pedicle** (Pedicle height) (mm)			**Transverse Diameter of pedicle** (Pedicle width)(mm)		
		Male (n=33)	**Female** (n=28)	***p-value*** Overall male vs female	**Male** (n=33)	**Female** (n=28)	***p-value*** Overall male vs female
L1	Right	16.2±1.8	13.1±1.4		7.4±1.4	5.8±1.6	
	Left	16.5±2.2	12.9±1.9		7.2±1.7	6.2±1.4	
	Overall	16.3±1.6	13.0±2.1	< 0.0001**	7.1±1.5	5.9±1.7	0.0048**
L2	Right	17.4±2.3	14.2±1.7		8.1±1.4	6.9±0.9	0.0048**
	Left	17.9±1.7	14.6±1.5		7.9±0.8	6.6±1.3	
	Overall	17.5±2.1	14.4±2.0	< 0.0001**	7.8±1.2	6.7±1.7	0.0045**
L3	Right	17.6±2.0	14.5±1.6		9.3±1.3	7.8±1.6	
	Left	17.4±1.9	14.9±1.8		9.9±1.7	8.3±0.8	
	Overall	17.5±1.7	14.7±1.9	< 0.0001**	9.2±1.3	8.1±1.5	0.0032**
L4	Right	17.3±1.8	14.7±2.3		13.4±1.4	11.4±1.8	
	Left	17.6±2.1	15.2±2.4		13.8±1.9	10.9±2.3	
	Overall	17.5±2.3	14.9±2.7	< 0.0001**	13.5±2.1	12.2±1.9	0.0146*
L5	Right	18.5±1.9	15.2±1.9		17.7±1.8	13.3±1.9	
	Left	19.1±2.3	15.8±2.8		17.9±2.2	12.8±2.4	
	Overall	18.8±1.8	15.5±2.1	< 0.0001**	17.8±2.4	13.0±2.6	< 0.0001**

**Significant **Highly significant*

Table 2: Degrees of Sagittal and Transverse angles of lumbar vertebral pedicles in male and female subjects and *p-values* of their comparison.

Level	Side	**TRANSVERSE ANGLE (º)**			**SAGITTAL ANGLE (º)**		
		Male (n=33)	**Female** (n=28)	***p-value*** Overall male vs female	**Male** (n=33)	**Female** (n=28)	***p-value*** Overall male vs female
L1	*Right*	11.8±1.2	12.6±1.7		3.9±1.2	4.9±0.9	
	Left	12.1±0.9	11.9±1.3		4.2±0.9	4.1±0.7	
	Overall	11.9±1.4	12.3±0.9	0.1986	4.1±0.7	4.6±0.8	0.0117*
L2	*Right*	13.1±2.2	14.8±2.1		4.9±0.6	4.8±0.6	
	Left	13.6±2.4	15.2±2.4		4.3±0.8	5.3±0.8	
	Overall	13.3±1.9	14.1±2.2	0.1328	4.7±0.6	5.1±0.5	0.0069**
L3	*Right*	14.9±3.1	16.2±2.7		4.7±0.5	5.2±0.7	
	Left	15.2±2.9	16.7±2.6		5.1±0.8	6.3±0.6	
	Overall	15.0±3.0	16.3±2.4	0.0700	4.9±1.0	5.8±0.9	0.0005**
L4	*Right*	17.7±2.8	19.1±3.2		5.3±0.9	6.0±1.2	
	Left	17.1±3.1	20.1±3.4		4.6±0.4	5.3±0.7	
	Overall	17.4±2.7	19.7±2.9	0.0022*	4.8±0.6	5.7±0.9	< 0.0001**
L5	*Right*	22.3±3.3	24.5±2,8		4.9±0.7	5.9±0.8	
	Left	21.8±2.9	25.2±3.2		5.5±0.9	6.7±0.5	
	Overall	21.2±3.2	24.7±3.1	< 0.0001**	5.1±0.6	6.2±0.7	< 0.0001**

**Significant **Highly significant*

Table 3: Mean± SD values of depth (screw length) of anterior cortex along pediclular axis and parallel to the sagittal axis in male and female subjects and *p-values* of their comparison. X and Y refer to Figure 1.

Level	Side	**X** **Depth of anterior cortex along pediclular axis** (mm)			**Y** **Depth of anterior cortex parallel to sagittal axis** (mm)		
		Male (n=33)	**Female** (n=28)	***p-value*** Overall male vs female	**Male** (n=33)	**Female** (n=28)	***p-value*** Overall male vs female
L1	*Right*	46.8±3.9	47.2±5.1		40.7±5.1	39.2±5.4	
	Left	44.9±4.1	46.8±4.8		38.3±4.3	40.5±6.2	
	Overall	45.7±4.4	46.9±4.3	0.2878	39.4±4.4	40.2±5.2	0.5176
L2	*Right*	46.6±5.1	50.4±3.9		41.2±3.9	41.4±4.8	
	Left	47.9±4.8	48.8±4.7		40.5±4.6	40.8±4.7	
	Overall	47.4±3.9	49.7±5.2	0.0534	41.1±5.2	41.0±5.3	0.9411
L3	*Right*	47.6±4.7	50.6±5.4		39.6±6.1	40.3±5.7	
	Left	48.8±4.8	51.9±4.8		40.8±5,8	42.1±6.1	
	Overall	48.3±5.2	51.4±5.4	0.0263*	40.3±5.5	41.7±5.6	0.3299
L4	*Right*	52.2±4.6	52.4±6.2		42.6±4.9	42.8±5.3	
	Left	51.7±5.1	54.1±5.6		41.9±6.2	43.6±4.9	
	Overall	51.5±4.8	53.7±4.9	0.0824	42.1±5.7	43.1±5.8	0.5008
L5	*Right*	53.7±5.3	56.2±6.3		43.2±4.9	41.2±5.4	
	Left	55.8±5.6	57.8±5.8		42.7±6.1	40.9±4.9	
	Overall	54.6±4.8	57.1±6.1	0.0785	42.8±5.8	41.0±5.6	0.2247

**Significant*

Table 4: Values of pedicular diameters and transverse and sagittal angles of the current study and mean values recorded by Alam et al[13].

PARAMETERS	Level	Side	MALE		FEMALE	
			Current study	Alam et al[13]	Current study	Alam et al[13]
Vertical diameter of pedicle (Height) **(mm)**	L1	Right	16.2±1.8	13.50	13.1±1.4	12.8
		Left	16.5±2.2	13.20	12.9±1.9	12.6
	L2	Right	17.4±2.3	13.40	14.2±1.7	12.31
		Left	17.9±1.7	13.46	14.6±1.5	11.90
	L3	Right	17.6±2.0	12.03	14.5±1.6	11.71
		Left	17.4±1.9	12.38	14.9±1.8	11.36
	L4	Right	17.3±1.8	12.03	14.7±2.3	11.71
		Left	17.6±2.1	12.38	15.2±2.4	11.36
	L5	Right	18.5±1.9	11.53	15.2±1.9	10.94
		Left	19.1±2.3	10.26	15.8±2.8	10.84
Transverse diameter of pedicle (Width) **(mm)**	L1	Right	7.4±1.4	6.40	5.8±1.6	5.6
		Left	7.2±1.7	6.10	6.2±1.4	5.9
	L2	Right	8.1±1.4	7.29	6.9±0.9	6.38
		Left	7.9±0.8	7.29	6.6±1.3	6.37
	L3	Right	9.3±1.3	10.54	7.8±1.6	9.56
		Left	9.9±1.7	10.64	8.3±0.8	9.67
	L4	Right	13.4±1.4	10.54	11.4±1.8	9.56
		Left	13.8±1.9	10.64	10.9±2.3	9.67
	L5	Right	17.7±1.8	13.53	13.3±1.9	12.19
		Left	17.9±2.2	13.53	12.8±2.4	12.71
Transverse angle **(°)**	L1	Right	11.8+1.2	13.11	12.6+1.7	14.13
		Left	12.1+0.9	13.20	11.9+1.3	14.8
	L2	Right	13.1+2.2	13.86	14.8+2.1	13.94
		Left	13.6+2.4	13.91	15.2+2.4	14.40
	L3	Right	14.9+3.1	16.15	16.2+2.7	17.55
		Left	15.2+2.9	16.77	16.7+2.6	17.37
	L4	Right	17.7+2.8	16.15	19.1+3.2	17.55
		Left	17.1+3.1	16.77	20.1+3.4	17.37
	L5	Right	22.3+3.3	22.47	24.5+2,8	20.13
		Left	21.8+2.9	23.08	25.2+3.2	21.77
Sagittal angle **(°)**	L1	Right	3.9+1.2	3.70	4.9+0.9	4.4
		Left	4.2+0.9	3.80	4.1+0.7	4.0
	L2	Right	4.9+0.6	3.95	4.8+0.6	4.61
		Left	4.3+0.8	4.21	5.3+0.8	4.28
	L3	Right	4.7+0.5	4.68	5.2+0.7	4.90
		Left	5.1+0.8	4.52	6.3+0.6	4.81
	L4	Right	5.3+0.9	4.68	5.3+0.7	4.90
		Left	4.6+0.4	4.52	5.7+0.9	4.81
	L5	Right	4.9+0.7	4.06	5.9+0.8	4.21
		Left	5.5+0.9	3.84	6.7+0.5	4.79

DISCUSSION

For various disorders of the spine such as fractures, spondylolisthesis, scoliosis and degenerative instability wires, hooks and rods have been used in the past[10]. These techniques largely compromised the movement of spinal column. Transpedicular fixation instead offers rigid segmental fixation to the one or two affected sections only thus allowing maximum possible range of movements. However an inappropriate selection of the screw and its placement may result in postoperative neurological and vascular complications or even complete failure of the procedure[3,4].

Skeletal geometry in general varies in different ethnic and racial groups depending upon such variables as genetic, socioeconomic conditions and geographic location[9]. Accurate information of the various dimensions and angulation of the pedicles in a population group is important for a careful preoperative assessment to avoid postoperative complications. Although several studies [3,5-8,10-12] describing the morphology of lumbar vertebrae and their pedicles by means of plain radiographs, CT scans and direct cadaveric dissection are available such information for our region is scanty. Morphometric differences in these studies indicate that skeletal features are specific to the race or ethnicity of the population.

In literature search we found only one study from Pakistan that described pedicle dimensions and angles recorded from CT scan images of 33 male and 16 female subjects of 18 to 60 years of age by Alam et al[13] at a tertiary care hospital based at Karachi. Comparison of their mean values with our study is shown in Table 4. Despite the obvious similarities between the two studies there are differences. Vertical diameter of pedicle had much higher values in both sexes especially in males while the transverse diameter was relatively wider at L4-5 in our study. Transverse angle was relatively wider in the male in their study but wider in the females in our study especially at L4-5. Sagittal angle was wider in the females at L2-5 and in the males at L5 in our study. These features could be particular to our sample which was taken exclusively from Multan region whereas Alam et al's sample was heterogeneous from all over the country. This nevertheless is an important outcome from our study that may have critical implications and demands regional studies from other areas of the country.

The transverse and vertical diameters of pedicle are critical factors in deciding the width of the screw; length of the screw depending upon the anteroposterior available distance. Fully threaded screws that can be accommodated in the pedicle and not reaching the anterior cortex of the vertebra have been recommended[14]. The outer diameter of most commonly used screw range between 5 to 7 mm[15,16]. Our study has shown much smaller transvers diameters (4-6 mm) in both males and females. Therefore these recommendations for our population should be taken with caution because a large size screw can damage the pedicle cortex leading to vascular and neural complications. Optimum diameter of the screw that fits well within the outer and inner cortices of the pedicle would be desirable.

Posteroanterior trajectory length is also important. A short screw does not promise the desired rigidity and long screw may penetrate the anterior cortex of vertebral body leading to injury to vital structures. It has been found that insertion of a screw to 85% length can provide as much pull out strength as 100% length insertion[17,18]. For accurate placement of the screw knowledge of transverse and sagittal angles and the available trajectory length in a population group has vital importance. Our study has provided gender specific values of these angles and trajectory length in Punjab.

A limitation of the study is its small number of subjects; a study with larger sample and segmented in different age groups would be desirable. Nevertheless it has provided useful gender specific morphometric data of lumbar spine which may be of interest to the researcher and may also be useful for the operating surgeon in his preoperative assessment and deliberations of transpedicular screw fixation.

CONCLUSION

The study has provided useful gender specific data which will be of interest to the researcher and may be useful for the operating surgeon in his preoperative assessment and deliberations of transpedicular screw fixation in lumbar spine.

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