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Lumbar Morphometry: A Study of Lumbar Vertebrae from a Pakistani Population Using Computed Tomography Scans

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Study Design: A cross-sectional study.
Purpose: To describe the characteristics of lumbar vertebrae of Pakistani patients reporting at a tertiary care hospital and compare with studies from other populations.
Overview of Literature: Several studies have been conducted to determine morphometry of lumbar vertebrae. Most of the studies involve Caucasian populations, still data on other populations still sparse. This is the first study describing lumbar morphometry of a Pakistani population.
Methods: An observational study was conducted based on a review of thin-cut (3 mm) computed topographic images of lumbar vertebrae. Two-hundred and twenty vertebrae from forty-nine patients were studied, and various dimensions were analyzed.
Results: Generally, the size of the vertebrae, vertebral canals and recesses were found to be greater in male patients. The difference was statistically significant for transverse and anteroposterior diameters of the vertebral bodies and sagittal diameter of pedicles on the left side ($p<0.05$). Comparison of populations revealed statistically significant differences in pedicle dimensions between Pakistani population and others.
Conclusions: This study provides anatomical knowledge of the lumbar region in a sample population of Pakistan. There were significant differences in various dimensions of lumbar vertebrae between female and male patients. This would prove to be critical for performing a safe operation.

Keywords: Lumbar vertebra; Vertebral dimensions; Pakistan; Pakistani population

Introduction

Knowledge of lumbar morphometry is vital not only for the understanding of biomechanics of lumbar spine but also for various interventions aimed at its stabilization and correction of deformities. Accurate anatomical descriptions of the shape and orientation of lumbar vertebrae are necessary for the development and use of implantable devices and spinal instrumentation [1]. It is also important to distinguish differences in morphometry of vertebrae in men and women and to understand changes in the elderly [1], as incorrect placement of instruments and devices may have serious complications [2].

Several studies have been conducted to determine morphometry of lumbar vertebrae [3,4]. Most of the cases are on Caucasian populations, and data on other populations

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is relatively sparse [2]. These studies have been carried out using fresh cadaver [5,6] or osteologic collections [1,4]. Computed tomographic (CT) images have been employed more recently to study lumbar vertebrae [7,8]. Gender differences in dimensions of lumbar vertebrae have been reported in various populations. However, no data is available from Pakistani population.

This study was conduced to describe the characteristics of lumbar vertebrae of Pakistani patients, reporting at a tertiary care hospital where patients from all across the country are referred. We studied the vertebrae using thin-cut CT scan images and compared the differences between male and female patients. Furthermore, this study aimed to compare the differences in vertebral dimensions between Pakistani and other populations.

Materials and Methods

This was an observational study based on a review of CT images of lumbar vertebrae done at Aga Khan University Hospital (AKUH, Karachi, Pakistan). The patients had undergone CT lumbar spine for various reasons, including trauma, chronic backache, suspected tumors and spondylolisthesis, during the period of July 2010 to December 2010 at AKUH. Patients older than 60 years of age or younger than 18 years as well as expatriates were excluded from the study. Initially, 104 Pakistani national patients were enrolled in the study. Finally, 49 patients met the inclusion criteria, of which 33 patients were male and 16 were female. They included patients from all across Pakistan. Mean age for males was 36.70±12.06 years, and mean age of female group was 38.44±12.66 years. Individual vertebrae with congenital anomalies (for example, hemi-vertebrae), fractures, metastasis and other pathologies were also excluded; and 220 vertebrae were studied.

Thin-cut CT images (3 mm) were analyzed by two technical teams independently, using various tools available on the Picture Archiving and Communication System in AKUH. All measurements were recorded in mm. The planes and points of reference used for measuring various dimensions are shown in Fig. 1.

Data was processed and analyzed on SPSS ver. 17 (SPSS Inc., Chicago, IL, USA), with *p*-value of 0.05 set to be significant. Male and female groups were compared for differences in various dimensions of lumbar vertebrae. Paired sample *t*-test was used to compare means of different dimensions of two groups. One sample *t*-test was used to compare the pedicle dimensions of the Pakistani population vs. other populations.

Results

1. Dimensions of vertebral body

Significant differences were noted in various dimensions of lumbar vertebral bodies (Table 1). All the dimensions

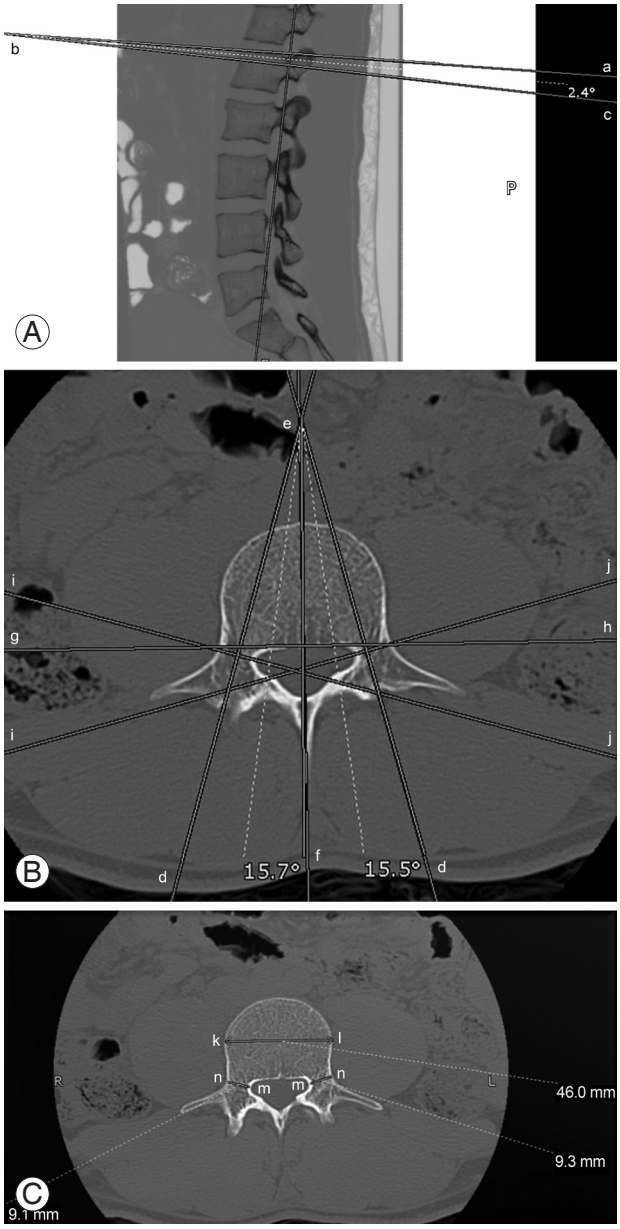

Fig. 1. **(A)** Sagittal pedicular angle (a-b-c). **(B)** Axial pedicular angle (d-e-f), Axial pedicular axis (d-e), Midsagittal plane (e-f), Posterior vertebral margin (g-h), Transverse pedicular axis (i-j). **(C)** Transverse vertebral diameter (k-l), Axial pedicular diameter (m-n).

Table 1. Gender differences in dimensions of vertebral bodies (in mm)

Dimension	L1		L2		L3		L4		L5	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Anterior height	24.5	23.9	26.65	25.61	27.30	27.05	27.46	26.92	27.60	26.72[a]
Posterior height	28.2	25.6[a]	29.23	26.69[a]	28.55	27.47[a]	27.10	26.21	24.84	23.90
Superior transverse diameter	41.7	38.4[a]	43.44	39.5[a]	45.45	40.88[a]	47.08	43.43[a]	48.95	46.24[a]
Inferior transverse diameter	42.5	38.9[a]	44.69	40.70[a]	45.39	42.35[a]	46.91	43.51[a]	47.04	44.90[a]
Anteroposterior superior diameter	30.4	27.7[a]	32.47	29.60[a]	32.85	30.00[a]	33.85	30.00[a]	33.71	31.50[a]
Anteroposterior inferior diameter	31.7	29.0[a]	32.99	29.86[a]	33.01	30.01[a]	33.85	31.77[a]	33.03	31.91

Values are presented as mean.
[a]*p*-value<0.05.

Table 2. Gender differences in the dimensions of pedicles (diameter in mm; angle in degrees)

Dimension	L1		L2		L3		L4		L5	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Right transverse diameter	6.40	5.6	7.29	6.38[a]	10.54	9.56	10.54	9.56	13.53	12.19[a]
Right vertical diameter	13.5	12.8[a]	13.40	12.31[a]	12.03	11.71	12.03	11.71	11.53	10.94
Left transverse diameter	6.10	5.9	7.29	6.37[a]	10.64	9.67	10.64	9.67	13.53	12.71
Left vertical diameter	13.20	12.6	13.46	11.90[a]	12.38	11.36[a]	12.38	11.36[a]	10.26	10.84
Right sagittal angle	3.70	4.4	3.95	4.61[a]	4.68	4.90	4.68	4.90	4.06	4.21
Right axial angle	13.11	14.13[a]	13.86	13.94	16.15	17.55	16.15	17.55	22.47	20.13[a]
Left sagittal angle	3.80	4.0	4.21	4.28	4.52	4.81	4.52	4.81	3.84	4.79[a]
Left axial angle	13.20	14.8	13.91	14.40	16.77	17.37	16.77	17.37	23.08	21.77

Values are presented as mean.
[a]*p*-value<0.05.

of lumbar vertebra were greater in males than females. Anterior body height was found to be significantly greater in males in L5 vertebra ($p<0.05$). Posterior heights of L1, L2, and L3 were significantly greater in males ($p<0.05$). The superior transverse, inferior transverse and anteroposterior superior diameters were significantly greater in males at all levels ($p<0.05$). The difference in anteroposterior inferior diameter was also significant ($p<0.05$), but only for the upper four levels.

2. Pedicle dimensions

Overall, the diameters were greater in males, and angles were greater in females (Table 2). Regarding diameter, the difference was significant ($p<0.05$) for transverse diameter at L2 and L5, as well as vertical diameter at L1 and

Table 3. Gender differences in dimensions of canal (in mm)

Dimension	L1		L2		L3		L4		L5	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Mid-sagittal diameter	17.7	16.7	16.26	16.28	15.48	15.31	14.77	14.28	15.25	13.76[a]
Interpedicular distance	24.2	23.5	24.34	23.46	24.13	22.36[a]	24.48	23.81	28.43	25.96[a]
Right lateral recess height	9.7	9.5	9.30	8.833	8.56	8.17	7.82	6.74[a]	7.05	6.66
Left lateral recess height	10.1	9.5	9.65	9.067	8.562	8.10	7.77	6.85[a]	6.64	6.64

Values are presented as mean.
[a]p-value<0.05.

L2 for right pedicle. On the left side, the difference was significant (p<0.05) for transverse diameter at L2 and for vertical diameter at L2–L4. Regarding angles, the difference was significant (p<0.05) for sagittal angle at L2 and for axial angle at L1 and L5 on the right side. On the left side, the only significant difference (p<0.05) was at left L5 sagittal angle.

3. Canal diameters

Canal diameters were found to be greater in males (Table 3). There was significant statistical difference in mid-sagittal diameter at L5 vertebra (p<0.05). Interpedicular distance was found to be significantly greater in L3 and L5 (p<0.05). Right and left lateral recesses were significantly larger in males at L4 vertebra (p<0.05).

4. Lamina

Lengths and widths of lamina were greater in males, but significant differences were found only in L1 and L2 vertebrae (p<0.001 and p=0.015, respectively).

5. Comparison of pedicle dimensions in a Pakistani population vs. other populations

Transverse pedicle diameter and axial pedicle angle were compared between the Pakistani population and other populations, using data from India [2], Iran [9], USA [1] and Israel [10] (Table 4). From one-sample t-test, statistically significant differences were present in Pakistani vs. Iranian, American and Israeli populations (p<0.001). There was no statistical significant difference among populations from Pakistan and India.

Discussion

The goal of internal fixation for fusion is to reconstruct the compromised columns within a spinal motion segment with non-biologic materials, affording temporary immobilization and stabilization until bony fusion can develop. Fixation is successful when a construct can withstand the wear and tear of stresses and strains until fusion occurs. The systems used in thoracolumbar spine include pedicle screw fixation, which is used to treat instability. In the lumbar area, detailed anatomical knowledge is critical for performing a safe operation [11]. Other implants include vertebral body screws, cages and laminar hooks etc.

Because of the increasingly popular use of pedicle screws, emphasis of recent studies on lumbar anatomy has been on dimensions of pedicles and the differences between genders and populations. We studied all the dimensions of the lumbar vertebrae, considering various types of implants used for lumbar spine. A study done by Olsewski et al. [1] in 1990 on vertebrae of 49 cadavers by radiographic and autopsy analysis showed statistically significant differences in transverse and sagittal diameters of all five lumbar vertebrae. Our study supports the same. However, overall pedicle diameters are considerably small in our population.

This study did not find any statistically significant differences in angles of pedicles in male and female patients. However, we found significant differences in sagittal and transverse angles at some levels (Table 2). Other studies

Table 4. Population differences in the dimensions of pedicles

Study	No. of patients	Transverse pedicle diameter (cm)	Axial pedicle angle (degree)
L1			
Pakistan (our study)	49	6.1	13.4
India (Acharya et al. [2])	50	7.2	10.6
Iran (Lotfinia et al. [9])	25	9.2	16.7
USA (Olsewski et al. [1])	49	8.2	6.0
Israel (Wolf et al. [10])	55	5.0	11.8
L2			
Pakistan (our study)	49	6.6	13.8
India (Acharya et al. [2])	50	7.6	12.4
Iran (Lotfinia et al. [9])	25	9.4	17.0
USA (Olsewski et al. [1])	49	8.3	6.0
Israel (Wolf et al. [10])	55	4.3	11.0
L3			
Pakistan (our study)	49	8.1	14.9
India (Acharya et al. [2])	50	9.0	15.4
Iran (Lotfinia et al. [9])	25	11.6	20.2
USA (Olsewski et al. [1])	49	10.0	7.0
Israel (Wolf et al. [10])	55	4.7	12.8
L4			
Pakistan (our study)	49	10.2	16.6
India (Acharya et al. [2])	50	11.1	18.3
Iran (Lotfinia et al. [9])	25	14.2	20.8
USA (Olsewski et al. [1])	49	13.2	11.0
Israel (Wolf et al. [10])	55	5.3	14.7
L5			
Pakistan (our study)	49	13.0	21.6
India (Acharya et al. [2])	50	13.9	24.7
Iran (Lotfinia et al. [9])	25	17.2	23.6
USA (Olsewski et al. [1])	49	20.1	22.0
Israel (Wolf et al. [10])	55	5.8	18.5

p-value<0.05.

have found no differences with respect to the diameter [12,13] and angle [12] of the lumbar pedicle between the two sexes. We found statistically significant differences between pedicles at some levels. However, Gulek et al. [14] found a major difference. Our study also found a statistically significant difference in pedicle dimensions of the Pakistani population and populations from Israel and USA. Acharya et al. [2] has described a similar difference. There was no statistically significant difference among the Pakistani and Indian populations. However, this cannot be generalized about all Asian countries, due to statistically significant difference present between pedicle dimensions of Pakistani and Iranian populations.

This is the first effort to describe the characteristics of lumbar vertebrae in a Pakistani population. There are several limitations to the study, such as its small sample size and heterogeneity of population included. Studies on large sample size with regard to racial backgrounds are required for generalizability.

Conclusions

This study found significant differences in various dimensions of lumbar vertebrae between females and males. Moreover, there was a statistically significant difference among pedicle dimensions in a Pakistani population and other populations. These differences have critical implications for spinal surgeons to perform a safe operation on patients of South-Asian background.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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