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Original Research Article

Lumbar Canal Diameter Evaluation by CT MorphometryStudy of Indian Population

Saurabh Goyal[1], Tapendra Tiwari [2], Sunil Kast[3], Rinkey Baisoya[4]

[1,2,3]Assistant Professor, Department of Radio-diagnosis, Pacific Institute of Medical Sciences, Umarda, Udaipur

[4]Resident Doctor, Department of Radio-diagnosis, Pacific Institute of Medical Sciences, Umarda, Udaipur

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Corresponding author: Dr. Saurabh Goyal
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Abstract

Background: To document dimensions of the lumbar vertebrae and bony canal in an Indian population and to compare with other studies from the subcontinent as well as from other parts of world.

Methods: An observational study was conducted on the basis of a review of thin-cut (3 mm) computed tomographic images of lumbar vertebrae. A total of 302 patients were studied, and various dimensions were analyzed.

Results: In general, the vertebral and bony spinal canal dimensions were found to be greater in male patients. Comparison of populations revealed statistically significant differences in the spinal canal between an Indian population and others.

Conclusions: The dimensions of the lumbar vertebrae and bony canal thus obtained shall provide a baseline normative data for evaluation of patients presenting with low backache and lumbar canal stenosis in an Indian population.

Keywords: Lumbar Canal Stenosis, Lumbar Morphometry, Lumbar Vertebrae, Spinal Canal, Bony Canal, Indian Population.

Introduction

The vertebral column has a complex anatomy and has long been an area of research. Lumbar spondylosis is a problem of adults but is now being increasingly seen in youth, probably due to lifestyle changes. Radiological evaluation forms an important part in evaluation and management of lumbar spondylosis. Multiple factors play a role in spondylosis, but if it is associated with spinal canal stenosis, its management differs. Lumbar canal stenosis is a condition in which the anteroposterior (AP) and lateral dimensions of the bony spinal canal are less than normal for corresponding age and sex. The most common manifestation of lumbar canal stenosis is low backache. Therefore, the dimensions of lumbar vertebrae are very important in clinical diagnosis of lumbar spinal stenosis and lower backache (LBA).

Kirkaldy-Willis et al [1] classified lumbar spinal canal stenosis into developmental, degenerative, and other types. Verbiest [2] showed that the developmental stenosis is due to the properties of the neural arch, pedicles, laminae, and articular processes in which the interpedicular distances are normal, whereas lateral sagittal diameters are shortened due to thickened laminae and articular processes.

The combined stenosis shows overall narrowing of the spinal canal or segmental narrowing, protrusion of a disc or any combination of these, associated with more neurological symptoms as compared to other degenerative and developmental types. Numerous studies have been conducted to determine morphometry of lumbar vertebrae in a western population using fresh cadaver or osteologic collections. [3–5] They had adequate sample sizes but lacked demographic data including race, age and sex. [6] Computed tomographic (CT) images have been used more recently to study lumbar vertebrae. [7,8] The recent use of CT for the measurements of the different vertebral dimensions such as canal diameter and vertebral dimension has led to better evaluation of vertebral morphometry as compared with x-ray and cadaveric studies. [9]

In this study, we conducted morphometric analysis of the lumbar vertebrae in a relatively large number of patients by using CT scans. The morphometric data thus compiled may provide a baseline of body and canal dimensions that could guide clinical experts in their practice.

Materials and Methods

This observational study was conducted in a tertiary care institute in Udaipur Rajasthan. A total of 302 patients over a period of 1 year undergoing diagnostic CT scans for abdominal or genitourinary complaints or patients attending the radiology department for a radiological investigation of regions other than the vertebral column pathology or gross spinal pathology during the study period were included in the study. Of 302 patients studied, 174 (57.6%) were men and 128 (42.4%) were women.

Exclusion criteria included all individuals with age <20 years or age >40 years, with gross spinal pathology and neurological deficit due to spinal condition, major chronic systemic disease such as chronic liver diseases and chronic kidney diseases, clinically labeled as dwarfism, movement artifact, or metallic artifact.

A CT scan was performed using 64-slice and 128- slice multi-detector CT. Unenhanced CT was performed from the level of diaphragm to pubic symphysis with the area to be covered from D12 to S1. Sections 3-mm thick with reconstruction up to 1 mm were analyzed. The images were reconstructed in true axial, coronal, and sagittal planes. The scans were reformatted with bone windows in axial, sagittal, and coronal planes.Data were processed and analyzed with SPSS, version 17 (SPSS Inc, Chicago, IL), with P value of >0.05 set to be significant.

An unpaired t test was used to compare the different dimensions of the lumbar spine of Indian patients with those of other populations, and an independent t test was used to compare male and female populations.

Observations: In our study, we measured different parameters of each vertebra from D12 to S1. For simplicity, we divided these parameters broadly into 2 groups:

Vertebral dimensions include upper and lower vertebral width, upper and lower vertebral depth, and intervertebral disc height.

Canal dimensions includes spinal canal AP diameter, lateral recess diameter, intervertebral foramen diameter, and interfacet distance.

We measured the different dimensions of vertebrae and compared between men and women by applying an independent t test. We also compared our study with other studies.

The diameters of the spinal canal were found to change both transversely and anteroposteriorly from D12 to S1. The AP diameters of the spinal canal gradually decreased from D12 to L4, followed by an increase at L5 and then a decrease from L5 to S1 both in men and women; thus, it was observed that the shape of the spinal canal was changing cranio-caudally from circular to oval. The maximum spinal canal depth (SCD) was noted at the D12 level (in men, SCD 16.19 mm; in women, SCD 16.33 mm) and minimum spinal canal depth was noted at the S1 level (in men, SCD 11.00 mm; in women, SCD 11.19 mm). There was not much difference in SCDs between the vertebrae of men and women (P>0.05), but values of the AP diameter of the spinal cord were greater in women than in men.

The right and left lateral recess diameter (LRD) gradually decreased from D12 to S1 in both men and women. The maximum LRD was noted at D12 (in men, right LRD 11.45 mm, left LRD 11.60 mm; in women, right LRD 9.46 mm, left LRD 9.67 mm). The minimum LRD was noted at S1 (in men, right LRD 7.50 mm, left LRD 7.61 mm; in women, right LRD 7.45 mm, left LRD 5.80 mm). The LRD was significantly more in men from the D12 to L5 vertebrae (P<.05). There was a significant difference between right and left diameters at all levels (P<0.05).

The right and left intervertebral foramen diameter (IVFD) constantly decreased from D12 to S1 in both men and women, as depicted in Table 1. The maximum IVFD was noted at D12 (in men, right IVFD 10.62 mm, left IVFD 10.50 mm; in women, right IVFD 10.43 mm, left IVFD 10.46 mm). The minimum IVFD was noted at S1 (in men, right IVFD 5.77 mm, left IVFD 5.57 mm; in women, right IVFD 1/4 5.80 mm left IVFD 1/4 5.75 mm). There was no significant difference between men and women at all levels. A significant difference between right and left was seen only at the S1 level (P , .05).

Interface distance (IFD) increased gradually from D12 to S1 in both men and women. The minimum IFD was noted at D12 (in men, IFD ¼15.12 mm; in women, IFD ¼ 14.33 mm). The maximum IFD was noted at S1 (in men, IFD ¼ 27.91 mm; in women, IFD ¼ 26.89 mm).

Table 1: Vertebral dimensions (Mean 6 SD).

Level	n	UV Width (mm)	UV Depth (mm)	LV Width (mm)	LV Depth (mm)	IVD Height (mm)
D12						
M	174	36.99 6 2.89	27.09 6 2.59	39.30 6 3.16	27.886 2.53	6.456 1.27
F	128	34.62 6 2.82	25.10 6 2.46	36.73 6 2.99	25.826 2.73	6.356 1.27
L1						
M	174	0.15 6 3.09	28.61 6 2.61	42.26 6 4.50	29.496 2.90	7.336 1.48
F	128	36.95 6 3.14	26.53 6 2.22	39.85 6 3.13	27.316 3.24	7.306 1.37
L2						
M	174	42.55 6 4.08	30.37 6 3.26	44.35 6 3.27	30.606 2.60	8.666 1.68
F	128	39.49 6 2.97	28.30 6 2.36	42.07 6 5.53	29.006 2.39	8.456 1.41
L3						
M	174	44.34 6 3.17	31.37 6 2.78	46.66 6 3.38	31.256 2.39	9.766 1.80
F	128	41.54 6 3.47	29.77 6 2.87	43.98 6 3.44	29.586 2.28	10.1766.87
M	174	46.42 6 3.98	31.56 6 2.27	46.86 6 3.85	32.156 3.04	10.606 1.76
F	128	43.59 6 3.58	30.12 6 2.22	44.92 6 3.32	30.006 3.29	10.2361.65
L5						

M	174	48.79 6 5.54	32.41 6 2.35	46.93 6 3.36	31.666 2.89	9.826 1.99
F	128	46.00 6 3.66	30.94 6 2.41	45.91 6 3.39	30.306 2.52	9.376 2.25
S1 M	174	49.08 6 4.40	31.16 6 3.19	30.78 6 3.45	22.7862.66	3.55 60.87
F	128	46.17 6 4.74	29.47 6 3.09	29.67 6 4.46	22.03 6 2.98	3.35 6 0.87

Abbreviations: LV, lower vertebral; UV, upper vertebral.

The IFD was significantly (P <0.05) larger in men from the D12 to L5 vertebrae.

Significant differences were noted between men and women in most of the dimensions of lumbar vertebral bodies.

Upper vertebral width (UVW) progressively increased from D12 to S1 in both men and women, as depicted in Table 1. The minimum UVW was noted at D12 (in men, UVW 36.99 mm; in women, UVW 34.62 mm). The maximum UVW was noted at S1 (in men, UVW 49.08 mm; in women, UVW 46.17 mm). The UVW was significantly larger in men at all levels (P<0.05).

Lower vertebral width (LVW) gradually in- creased from D12 to L5, followed by a decrease atthe S1 level in both men and women. The minimum LVW was noted at S1 (in men, LVW 30.78 mm; in women, LVW 29.67 mm).The maximum LVW was noted at L5 (in men, LVW 46.93 mm; in women, LVW 45.91 mm. The LVW was significantly larger in men at all levels (P< 0.05; Table 1).

Upper vertebral depth (UVD) progressively increased from D12 to L5, then it decreased at S1 in both men and women. The minimum UVD was noted at D12 (in men, UVD 27.09 mm; in women, UVD 25.10 mm). The maximum UVD was noted at L5 (in men, UVD 32.41 mm; in women, UVD 30.94 mm). The UVD was significantly (P < 0.05) larger in men at all levels (Table 1). Lower vertebral depth (LVD) increased from D12 to L4, followed by a decrease from L5 to S1 in men, but in women it progressively increased from D12 to L5, followed by a decrease at S1. The minimum LVD was noted at S1 (in men, LVD 22.78 mm; in women, LVD 22.03 mm). The maximum LVD was noted at L4 in men (LVD 32.15 mm) and in women at the L5 level (LVD

30.30 mm). The LVD was significantly (P <0.05) more in men at all levels (Table 1).

Intervertebral disc height (IVDH) gradually increased from D12 to L4, but decreased progressively from L5 to S1 in both men and women, as depicted in Table 1. The minimum IVDH was noted at S1 (in men, IVDH 3.55 mm; in women, IVDH 3.35 mm). The maximum IVDH was noted at L4 (in men, IVDH 10.60 mm; in women, IVDH 10.23 mm). The IVDH was significantly larger in men atall levels (P <0.05).

Discussion

Low backache is the most common complaint requiring radiological investigations in current setup. [10] Assessment of lumbar canal size is one of the most essential steps in diagnosing LBA. [11] Any pathological changes in the structures that surround the spinal canal and foramina may disturb the alignment of the spinal canal in the lumbar region, resulting in LBA. [11] The values of the AP diameter of the spinal cord were greater in women than in men. Similar results were observed in the sagittal plane that are necessary for absorbing impact and reducing stiffness. [10]

Lumbar spinal stenosis is a result of a narrowing of the bony spinal canal or intervertebral foramina, resulting in secondary compression of the spinal cord traversing centrally and spinal nerve roots traversing laterally through the intervertebral foramina. Clinically, lumbar spinal stenosis presentsas LBA, paresthesia, and bilateral lower limb pain. [12,13] The data thus presented in our study provide relevant clinical and anatomical information on lumbar vertebral and canal dimensions in a relatively large sample size.

Population-specific variations in dimensions of body segments exist, thus necessitating continuous data gathering of lumbar dimensions in various population groups. In addition, whereas most studies have been done on a western population using cadaveric samples, no reliable source exists for an Indian population that also uses CT data. Hence, it is necessary to have a large data set to compare with radiographic and osteologic techniques with a view to providing a reference standard for lumbar dimensions within the Indian population group.

Canal Diameters

The AP diameters of the spinal canal gradually decreased from D12 to L4 but marginally increased at L5 and then decreased from L5 to S1 in both menand women; thus, the shape of the spinal canal was changing from circular to oval.

Right and left LRD decreased from D12 to S1 in both men and women. Significant difference was found between men and women in LRD, which was significantly larger in men at the D12 to L5 vertebrae ($P > 0.05$). There was significant difference between right and left diameters at all levels ($P > 0.05$). A similar pattern was also observed by Alam et al [14] in a Pakistani population for both men and women.

Right and left IVFD constantly decreased from D12 to S1 in both men and women. The maximumIVFD was noted at D12 and the minimum IVFD was noted at S1. There was no significant difference ($P < 0.05$) between men and women at all levels. Significant difference between right and left was seen only at the S1 level ($P < 0.05$)

Interfacet distance increased gradually from D12 to S1 in both men and women. The minimum IFD was noted at D12 and the maximum IFD was noted at S1. The IFD was significantly larger in men at all levels ($P < 0.05$)

Vertebral Dimensions

Upper vertebral width increased from D12 to S1 in both men and women. Similar results were found by Singh et al [15] on a study of 20 cadavers. Alam et al [14] studied a Pakistani population and Kang et al [16] studied a Korean population using CT morphometry; in both studies, researchers observed similar trends of an increase of UVW cranio-caudally from L1 to L5.

Lower vertebral width increased from D12 to L5 but decreased at the S1 level in both men and women. Lower vertebral width was significantly larger in men at all levels ($P < 0.05$). A similar study by Singh et al [15] on 20 cadavers from a north Indian population noted that LVW increased from L1 to L2 then decreased at L3, followed by an increase from L3 to L5. This pattern was not seen in our study. Alam et al [14] conducted a study of measurement of lumbar vertebrae by CT scan on 49 patients from a Pakistani population and noted similar patterns in both men and women, as seen in our study. The values of LVW was greater in men than in women, similar to our study.

Upper vertebral depth increased from D12 to L5, then it decreased at S1 in both men and women. Upper vertebral depth was significantly larger in men at all levels ($P < 0.05$). A similar pattern also was observed by Alam et al [14] in a Pakistani population in both men and women. The values ofUVD were greater in men than in women at all levels, similar to our study .

Lower vertebral depth increased from D12 to L4, followed by a decrease from

L5 to S1 in men, but in women it progressively increased from D12 to L5, followed by decrease at S1. The minimum LVD was noted at S1 in both men and women, and the maximum LVD was noted in men and in women at L4 and L5, respectively. Lower vertebral depth was significantly larger in men than in women at all levels ($P<0.05$). Similar patterns were observed in a study on a Pakistani population by Alam et al. [14,15]

Intervertebral disc height gradually increased from D12 to L4, followed by a progressive decrease from L5 to S1 in both men and women. In both men and women, minimum and maximum IVDH were noted at the S1 and L4 levels, respectively. Intervertebral disc height was significantly larger in men at all levels ($P<0.05$)

Conclusions

In our study, we measured different parameters (vertebral and canal diameters) of vertebrae from D12 to S1 in an Indian population with the help of CT scans in a relatively large number of patients (N 302), which was more clinically relevant and accurate in contrast to cadaveric or manually measured data. We compared our study with other studies from the same subcontinent as well as from other parts of world. The present study also provided a comparison between men and women, and we found significant differences in various dimensions of lumbar vertebrae.

The AP diameters of the spinal canal gradually decreased from D12 to L4, followed by an increase at L5, and then decreased from L5 to S1 both in men and women. On comparison, similar trends were noted with other studies, but the values were lower in our research. Vertebral dimensions (vertebral width, vertebral depth) progressively increased from D12 to S1. On comparison, similar trends wereobserved in other studies.

The dimensions of the lumbar vertebrae and bony canal thus obtained will provide a baseline normative data for evaluation of patients presenting with LBA and lumbar canal stenosis in an Indianpopulation.

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