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ORIGINAL ARTICLE

Spinal Canal Measurements at the Level of Lower Three Lumbar Vertebrae by 128-Slice CT Scanner in Bangladeshi Population

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ABSTRACT

Background & objective : The knowledge of normal diameter of lumbar spinal canal is very important for diagnosing lumbar spinal canal stenosis and also for performing spinal surgeries at the lumbar level by Neurosurgeons and Orthopedicians. However, it varies widely among ethnic groups and between sexes in the same ethnic group. The present study was conducted to describe the morphometry of lumbar vertebrae at the level of L3-L5.

Methods: This descriptive cross-sectional study was conducted on 302 patients (aged 20-60 years) at Ibrahim Cardiac Hospital & Research Institute between July 2019 to December, 2020 who underwent diagnostic CT scans for abdominal or genitourinary complaints without any known vertebral column pathology or complaints of low back pain or other abnormalities attributable to lumbar spine. Patients having sciatic pain with or without pain in the back, having past history of back surgery and patients with osteophytes or developmental anomalies, trauma or vertebral fracture and known case of lordosis, scoliosis or kyphosis or other abnormalities in lumbar vertebrae were also excluded. A CT scan was performed using 128-slice multi-detector CT with unenhanced CT images from the level of diaphragm to pubic symphysis so that the area from D12 to S1 vertebra be covered (field of view). Sections 3-mm thick with reconstruction up to 1 mm were analyzed and different parameters of the spinal canal and vertebral body were measured in sagittal and transverse sections. The images were reconstructed in true axial, coronal, and sagittal planes. The canal-body ratio (CBR) was determined by dividing the sagittal diameter of the spinal canal by the sagittal diameter of the vertebral body.

Result: The findings of the present study demonstrate that nearly two-thirds (65.5%) of the subjects were early middle-aged or middle-aged with mean age of the subjects being 43 years. A male predominance was observed in the series with male to female ratio being 4:1. The study revealed that all the dimensions of the canal and the body in transverse and sagittal sections were observed to increase from level L3 to L5, while the canal body ratio was decreased slightly from L3-L5. The males have significantly wider vertebral body at all levels (L3-L5) of lumbar vertebrae compared to their female counterparts. Vertebral body diameter in sagittal section at L3 was significantly greater in males than those in females; however, they were not different between sexes at L4 and L5 levels. Canal-body ratio (CBR) was fairly comparable between males and females at L3 and L4, but it was greater in males than that in females at L5. No significant difference was observed between L3 & L4 and L4 & L5 in the same individuals in terms of CBR.

Conclusion: The study concluded that there are significant variations in some of the lumbar spinal canal dimensions and vertebral body measurements (including CBR) from L3-L5 between males and females. Although there was no significant difference between L3 and L4 in the same individuals in terms of CBR, there was reasonable difference between L4 and L5 lumbar vertebrae. The findings are of much significance in the investigation of vertebral column pathology in the context of our population.

Key words: Spinal Canal, anteroposterior dimension of canal, vertebral body, lower three lumbar vertebrae, 128-Slice CT Scanner etc.

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INTRODUCTION:

The vertebral column has a complex anatomy and has long been a subject of research interest. The spinal canal is formed by the vertebral body anteriorly, the pedicles laterally, the laminae posterolaterally, and the base of the spinous process posteriorly forming a protective ring for the neural tube. A bony tunnel, the neural foramen, can be seen bilaterally at the inferolateral aspect of each vertebra, which is formed by the vertebral pedicle superiorly, the pedicle of the following vertebral body inferiorly, the facets posteriorly, and the disco-vertebral junction anteriorly. Spinal canal stenosis (defined as the narrowing of central spinal canal) 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. Back pain is the commonest manifestation of lumbar canal stenosis which usually results from lumbar spondylosis. Lumber lordosis is a problem of adults, but is now being increasingly seen in youth, probably due to lifestyle changes. Multiple factors play a role in spondylosis, but if it is associated with spinal canal stenosis, its management differs. Radiological evaluation forms an important part in the evaluation and management of lumbar spondylosis. But it requires clear understanding of the normal dimensions of lumbar vertebrae for particular age & sex.[1]

CT scans provides a noninvasive, non-operator dependent method of direct imaging of the spinal canal without injection of intra thecal contrast and is better than MRI for bony detail as in osteophytes. CT and myelography are important in patients who, for technical reasons, cannot enter the MRI scanner (e.g., those with pacemakers or claustrophobia) or in patients whose MRI findings do not correlate with clinical symptoms.[2] Though there is a wide variation in the capacity of spinal canal in patients who are clinically and radiologically normal. It is said that those with smaller canals are more likely to have symptoms from nerve root compression.[3] By determining normal ranges of spinal canal diameter we can make early diagnosis in individuals who have lower diameters of spinal canal. These individuals are predisposed to spinal canal stenosis, which is a major cause of spinal radiculopathies.[4]

Precise anatomic classification of the site of stenosis (central canal, lateral recess and/a neural foramina) is perhaps the most practical approach and helps to determine the nature and extent of surgical treatment.[5] Numerous studies have been conducted to determine morphometry of lumbar vertebrae in a western population using fresh cadaver or osteologic collections.[5-7] Eisenstein's two large Anatomic studies of skeleton found the lower anteroposterior diameter of spinal canal in adults to be 12 mm and 13 mm. 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.[8] CT scan measurement of lumbar spine demonstrated a mean AP canal diameter between 12 mm and 14 mm with a measurement of 11.5 mm considered small.[9] On CT scan, electronic measurement of the sagittal diameter of the normal bony canal are 11.5 mm.[10] These differences in dimension of the spinal canal across studies demands necessity of study of dimension of the spinal canal in every ethnic group. Several studies over lumbar interpedicular distances from plain radiographs have been reported among various ethnic group and both sexes as in Maharashtra population[11] white Americans,[12] Nigerians,[13,14] and in Gujarathis.[15] Therefore, the present study aims to establish a normal range of measurements of lumbar vertebrae in Bangladeshi population.

METHODS:

This descriptive cross-sectional study was conducted at Ibrahim Cardiac Hospital & Research Institute (ICHRI) between July 2019 to December, 2020. A total of 302 patients (17 males and 19 females) who underwent diagnostic CT scans at ICHRI for abdominal or genitourinary complaints without any known vertebral column pathology or gross spinal pathology (low back pain or other abnormalities attributable to lumbar spine) during the study period were included in the study. As the study carries hazardous electromagnetic radiation, no scan was performed for the purpose of study alone. Patients <20 years and >60 years old were excluded because the former may be at growing stage and latter may

have age related degenerative or other problems of vertebral column. Patients having sciatic pain with or without pain in the back, having past history of back surgery and patients with osteophytes or other abnormalities in lumbar vertebrae were also excluded from the study. Patients having developmental anomalies, any trauma or vertebral fracture and known case of lordosis, scoliosis or kyphosis were also refrained from participating in the study. Exclusion was done by history taking, patients' complaint and provisional diagnosis made by clinicians as per the relevant papers brought by patients. Data were collected using a semi-structured data-sheet addressing the variables of interest.

A CT scan was performed using 128-slice multi-detector CT. Unenhanced CT was performed from the level of diaphragm to pubic symphysis with the area to be covered (field of view) from D12 to S1 vertebra. 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 and measurement was done as shown in Figure 1.

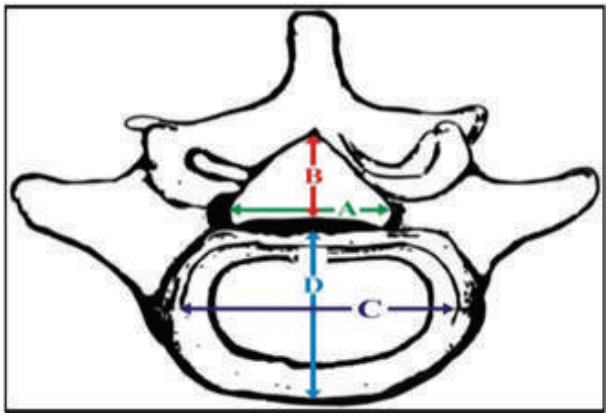

Fig. 1: Diameters of spinal canal and vertebral body in transverse section; A-Interpedicular distance; B-Anteroposterior diameter of the canal; C-Transverse diameter of the vertebral body; Anteroposterior diameter of the vertebral body (Source: Bhaumik & Bhaumik, 2016)[16]

The parameters studied were APT (antero-posterior dimension in transverse section), MLT (medio-lateral dimension in transverse section), VBW (vertebral body width), APS (antero-posterior dimension of canal in sagittal section) and VBS (vertebral body diameter in sagittal section). The spinal canal to vertebral body ratio (CBR) was determined by dividing the sagittal diameter of the spinal canal by the sagittal diameter of the vertebral body.

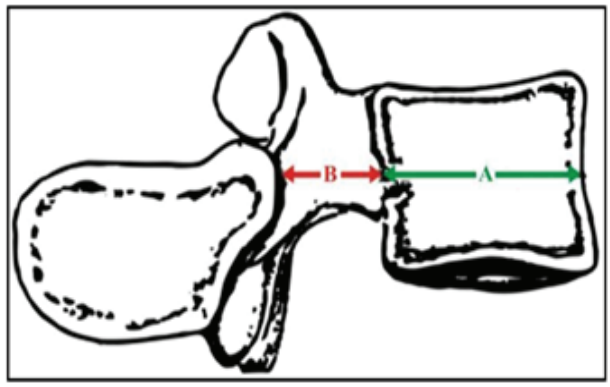

Fig. 2: Diameters of spinal canal and vertebral body in sagittal section; A- Anteroposterior diameter of the vertebral body; B-Anteroposterior diameter of spinal canal (Source: Bhaumik & Bhaumik, 2016)[16]

RESULT:

About one-third (32.7%) of the study subjects was in their 3rd decade of life another one-third (32.7%) in their 4th and 26.9% in the 5th decade of life. Very few subjects were 30 or < 30 years old. The mean age of the subjects was 42.9 ± 9.9 years and youngest and the oldest subjects were 22 and 58 years old. Majority (80.8%) of the subjects was male with male to female ratio being 4:1. Fifty percent of the subjects were overweight, 23.1% obese and 26.9% were of normal BMI (Table I). Different dimensions of the spinal canal and vertebral body at 3rd, 4th and 5th lumbar vertebrae are illustrated in Table II.

The vertebral body widths at L3, L4 and L5 were significantly wider in males compared to those in their female counterparts (40.8 vs. 33.4 mm, p<0.001; 42.8 vs. 38.9 mm, p=0.002 and 46.4 vs. 42.1 mm, p=0.032 respectively). Vertebral body diameter in sagittal section at L3 was significantly greater in males than those in females (28.6 vs. 27.2, p=0.002), although they were no different

between sexes at L4 and L5 (29.2 vs. 28.9 mm, p=0.465 and 29.1vs. 28.9, 0.633 respectively). Canal-body ratio (CBR) was almost similar between males and females at L3 and L4, but it was considerably greater in males than that in females at L5 (0.58 vs. 0.55, p=0.073) (Table III). No significant difference was observed between L3 & L4 and L4 & L5 in the same individuals in terms of CBR (p=0.683 and p=0.070 respectively) (Table IV).

Table I. Demographic characteristics of the study subjects (n = 52)

Demographic characteristics	Frequency	Percentage
Age* (years)		
≤ 30	4	7.7
31 – 40	17	32.7
41 – 50	17	32.7
>50	14	26.9
Sex		
Male	42	80.8
Female	10	19.2
BMI (kg/m^2)		
Normal BMI	14	26.9
Overweight	26	50.0
Obese	12	23.1

***Mean age** = 42.9 ± 9.9 years; **range** = 22 – 58 years.

Table II. Different dimensions of spinal canal and vertebral body at 3rd, 4th and 5th lumbar vertebrae

Measurements of different dimensions of spinal canal and vertebral body at 3rd, 4th and 5th lumbar level	Mean ± SD (mm)	Range (mm)
L3 APT	13.6 ± 1.7	11.3 -17.5
L3 MLT	23.7 ± 3.1	18.2 -30.0
L3 VBW	39.4 ± 4.4	27.2 – 45.7
L3 APS	14.3 ± 1.4	11.0 – 16.0
L3 VBS	28.3 ± 1.2	26.2 – 30.0
L4 APT	13.8 ± 1.4	11.0 – 17.6
L4 MLT	26.2 ± 3.6	19.0 – 37.8
L4 VBW	42.1 ± 3.6	34.4 – 49.5
L4 APS	14.4 ± 1.7	11.3 – 18.0
L4 VBS	29.1 ± 1.4	27.0 – 33.4
L5 APT	14.7 ± 2.4	12.1 – 22.0
L5 MLT	29.6 ± 4.6	19.6 – 38.0
L5 VBW	45.6 ± 5.8	24.4 – 57.5
L5 APS	14.8 ± 2.1	11.2 – 19.9
L5 VBS	29.2 ± 1.2	27.0 – 31.6
CBR at L3	0.56 ± 0.05	0.34 – 0.63
CBR at L4	0.55 ± 0.06	0.34 – 0.69
CBR at L5	0.55 ± 0.07	0.35 – 0.72

Table III. Comparison of different dimensions of spinal canal and vertebral body at 3rd, 4th and 5th lumbar level

Parameters	Sex		p-value
	Male (n = 42)	Female (n = 10)	
L3 APT (mm)	13.6 ± 1.8	13.6 ± 1.3	0.999
L3 MLT (mm)	23.7 ± 3.1	23.9 ± 3.4	0.868
L3 VBW (mm)	40.8 ± 2.8	33.4 ± 5.4	< 0.001
L3 APS (mm)	14.3 ± 1.5	14.2 ± 0.90	0.787
L3 VBS (mm)	28.6 ± 1.2	27.2 ± 0.9	0.002
L4 APT (mm)	13.8 ± 1.5	13.6 ± 0.8	0.632
L4 MLT (mm)	26.4 ± 3.7	25.4 ± 3.4	0.431
L4 VBW (mm)	42.8 ± 3.5	38.9 ± 1.7	0.002
L4 APS (mm)	14.5 ± 1.7	14.0 ± 1.6	0.469
L4 VBS (mm)	29.2 ± 1.4	28.9 ±0.9	0.465
L5 APT (mm)	14.9 ± 2.2	14.0 ± 3.2	0.295
L5 MLT (mm)	29.9 ± 3.4	27.9 ± 7.9	0.226
L5 VBW (mm)	46.4 ± 6.1	42.1 ± 1.9	0.032
L5 APS (mm)	14.9 ± 2.2	14.9 ± 1.1	0.161
L5 VBS (mm)	29.1 ± 1.2	28.9 ± 1.2	0.633
CBR at L3	0.57 ± 0.05	0.58 ± 0.03	0.194
CBR at L4	0.56 ± 0.07	0.55 ± 0.05	0.613
CBR at L5	0.58 ± 0.07	0.55 ± 0.04	0.073

*Data were analyzed using **Unpaired t-Test** and were presented as **mean ± SD**.

Table IV. Comparison of CBR between L3 & L4 and L4 & L5

Parameters	Measurements		p-value
	Mean	SD	
CBR L3	0.57	0.05	0.683
CBR L4	0.57	0.07	
CBR L4	0.56	0.07	0.070
CBR L5	0.57	0.07	

*Data were analyzed using **Unpaired t-Test** and were presented as **mean ± SD**.

DISCUSSION:

The findings of the present study demonstrate that nearly two-thirds (65.5%) of the subjects were early middle-aged or middle-aged with mean age of the subjects being 43 years. A male predominance was observed in the series with male to female ratio being 4:1. About three quarters (73.1%) of the subjects were obese or overweight. The study of different dimensions of the spinal canal and vertebral body at the level of 3-5 lumbar vertebrae revealed that all the dimensions of the canal and the body in

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transverse and sagittal sections were observed to increase from level L3 to L5, while the canal body ratio was decreased slightly from L3-L5. The males have significantly wider vertebral body at all levels (L3-L5) of lumbar vertebrae compared to their female counterparts. Vertebral body diameter in sagittal section at L3 was significantly greater in males than those in females; however they were not different between sexes at L4 and L5 levels.

The sagittal diameter of lumbar vertebra gives the standard diameter of lumbar spinal canal. Previously many researchers have measured sagittal diameter/ anteroposterior diameter to arrive at standard diameters of lumbar spinal canal. This morphometry is of use in defining stenosis. Huzinga and colleagues measured the midsagittal diameter from the center of the anterior surface of the laminae to posterior surface of vertebral body on lumbar veterbrae obtained from Dutch cadavers.[17] In a European study, 100 patients (51 men and 49 women) presenting with low back pain or sciatica, but free from clinical diagnosis of spinal canal stenosis, were studied prospectively with CT or CT myelography. The patients were from 19 to 76 years of age with weight from 50 to 109 kg and height from 150 to 190 cm. The mean anteroposterior diameter of the spinal canal of L3, L4 and L5 were 16.5 ± 2.4, 17.0 ± 2.8 and 18.3 ± 3.1 mm respectively.[18] As these dimensions vary largely among population of different ethnic origin and between sexes in the same ethnicity. The lumbar part of vertebral canal harbors cauda equina and narrowing of the bony ring of the canal, either developmental or acquired, may lead to compression of these nerve roots and causes low back pain.[19] Though most of the back pains are not accurately localized, a vast majority may arise from a limited part of the spine.[20] As most of the complex spinal structures are inaccessible to detailed physical examination, it is of utmost need to take help of ancillary methods in examining them. The introduction of radiographs, CT scan and MRI scans provide accurate diameter of lumbar canal as well as the entire lumbar vertebra. The recent introduction of 128-Slice CT Scanner gives a vivid picture of vertebral column. The 128-slice CT scanner can be adapted to provide three-dimensional images of any body-structures including those with vertebral column, cardiac or respiratory conditions that make it difficult to get high-quality images with other types of scanners. Therefore, the different dimensions of the lumbar vertebrae used in this study seems to be reliable and valid.[21] Esptein & Lavin[21] postulated that any antero-posterior diameter of the canal less than 15 millimeters indicates narrowing of canal. A recent study from Rajasthan, India demonstrated that the minimum antero-posterior diameter for L1 vertebra to be 17.68 mm in males and 17.48 mm in females, while the maximum antero-posterior diameter of canal is 21.98 mm in males, and 19.80 mm for females for L5 vertebra.[16] In the present study, the mean APS (antero-posterior dimension of the canal in sagittal section) at all levels (L3-L5) were < 15 mm. Although none of them has any complaints of low-back pain or any known vertebral column pathology indicating that majority of the APS of the Bangladeshi population is < 15 mm. The canal-body ratio (CBR) in the present study was fairly comparable between males and females at L3 and L4, but it was greater in males at L5 (mean CBR: 0.58) than that in females at the same level (mean CBR: 0.55). Mallik and associates in a study in Nepal showed that almost all the parameters increase from L3 to L4 to L5 but the difference is more between L4 and L5 than between L3 and L4 except in vertebral body width (VBW) where it increases smoothly, however canal body ratio (CBR) remained constant at 0.6. All the parameters were larger in males than in females except antero-posterior dimension of the canal in transverse section (APT), which is larger in females.[22]

CONCLUSION:

The findings of the present study suggest that there are significant variations in the lumbar spinal canal dimensions and vertebral body measurements (including CBR) from L3-L5 between males and females. In the same individuals, although there was no significant difference between L3 and L4 in terms of CBR, there was reasonable difference between L4 and L5 lumbar vertebrae. As the study was conducted on individuals free from known vertebral column pathology or gross spinal pathology (low back pain or other abnormalities attributable to

lumbar spine), the findings carry much significance in the investigation of spinal canal stenosis in the context of our population.

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