Original Article

Radiological Anatomy of the Lumbar Canal: A MRI study

Mohammed Awais Ahmed[1], Aditya M[2], Anitha T[3], Sailaja TK[4]

[1,2] Asst. Professor
[3] Professor & HOD
Department of Anatomy
Chalmeda Anand Rao
Institute of Medical Sciences
Karimnagar-505001
Telangana, India.
[4] Assoc. Professor
Department of Anatomy
Mamata Academy of
Medical Sciences,
Bachupally,
Hyderabad - 500090
Telangana, India.

CORRESPONDENCE:

Dr. Aditya M
MD (Anatomy)
Assistant Professor
Department of Anatomy
Chalmeda Anand Rao
Institute of Medical Sciences
Karimnagar-505001
Telangana, India.
Email: aditya.moota@gmail.com

ABSTRACT

Aim and Objectives:

1. To examine the morphometric dimensions of the lumbar spinal canal in relation to gender in symptomatic Telangana state population and to relate the acquired data with other populations.
2. To determine whether mid-sagittal and transverse diameters vary with gender or not.

Materials and Methods: The mid-sagittal and transverse diameters of the lumbar spinal canal (L1-L5) from 80 symptomatic adults were recorded using Magnetic Resonance Imaging (MRI) at the Radiology department of Chalmeda Anand Rao Institute of Medical Sciences, Karimnagar, Telangana. Individuals with former lumbar spine surgery, vertebral trauma, tumours and infections or congenital anomalies were excluded from the study.

Results: The mean transverse diameter of the lumbar canal was significantly larger in males. There was no statistical gender difference observed for the average mid-sagittal diameter. The smallest average mid-sagittal diameter for both the genders was observed at L3 level which was responsible for hour-glass shape of the canal.

Conclusion: The present study gave us an idea regarding the anatomical dimensions of the human lumbar canal of clinically symptomatic patients in relation to basic parameters like gender and race. Also since transverse diameter was the largest dimension of spinal canal, it indicates that mid-sagittal diameter is clinically the most significant dimension of spinal canal and valuable in diagnosis of lumbar spinal stenosis.

Keywords: Lumbar spinal stenosis, lumbar spinal canal, mid-sagittal diameter, transverse diameter

INTRODUCTION

Low backache has various causes, but lumbar spinal stenosis (LSS) as a causative factor is of great interest, especially in the extent to which the cauda equina may be compressed within the lumbar spinal canal by constriction or narrowing of the bony ring of the canal, in contrast to impingement by soft tissues.

Stenosis due to decreased mid-sagittal diameter has been reported in the cervical spine as well as in the lumbar spine. It has also been suggested that reduced inter-pedicular distance is one of the cause of primary narrowing of the spinal canal.[1] Shobeiri et al reported the prevalence of LSS as 37% among patients with sciatica and 11% among patients with low back pain (LBP) (p value < 0.001).[2] According to the North American Spinal Society (NASS), around 20% of the adult population suffers from this pathology (5% central stenosis and 15% lateral stenosis).

It was necessary to concentrate this study on the

measurements of diameters of the lumbar spinal canal, since it was found that previous researchers, who gave parameters of lumbar spinal canal depended on the measurements given by Ullrich et al who found that the normal adult sagittal diameter of the lumbar spinal canal ranges from 14-15 mm as measured by CT scan.[3] Others depended on the measurements given by Hincket al., Eisenstein and Amonoo-Kuofi, who measured the lumbar canal diameters on plain radiographs or osteological specimens from cadavers.[4-7]

There are many studies about the measurement of spinal canal diameters in North Indian populations using different imaging modalities. To our knowledge, there is sparse information on lumbar spinal canal diameters in symptomatic subjects of Telangana State population.

There is need for establishing mean values of various parameters of the lumbar canal for the Indian population, which is difficult because of the heterogeneity of the Indians. Magnetic Resonance (MR) image interpretation is becoming necessary knowledge for all physicians. This is because of the importance and accuracy of this type of examination.

MRI has become investigation of choice as it is non-invasive, with no radiation risks and gives overview of spine along with its soft-tissue components. In this study, with MRI as the imaging modality and defined planes of measurement of the lumbar canal dimensions, it was tried to determine the mean values of lumbar canal diameters in a symptomatic population of Telangana state.

MATERIALS AND METHODS

A cross sectional study done at Chalmeda Anand Rao Institute of Medical Sciences included 80 subjects aged between 20-70 years. Among these 80 subjects, there were 36 males and 44 females.

All 80 consented individuals who were referred for lumbar MRI scan to the Department of Radiology between June 2017 to October 2018, had complaints of low back pain with or without radiculopathy.

Individuals below the age of 20 years were not included in the study. Patients with former lumbar spine surgery, vertebral trauma, tumours and infections or congenital anomalies were excluded from the study.

All study subjects underwent MRI of the lumbar spine. The MRI scan was performed on GE (General Electric) Signa HDxt 1.5 Tesla scanner with advanced technology.

The coil used was sense spine, 4 mm slice thickness, sequence included (1) T2W Fast spin echo (FSE) SAG, (2) T1W FSE SAG, (3) short tau inversion recovery (STIR) COR, (4) T1 W FSE axial, (5) T2W FSE axial (6) T2 FSE drive axial (high resolution) sequence using drive with a small field of view (FOV) to reduce cerebrospinal fluid (CSF) flow artefacts.

The images were stored in a computerized system software called INSTARAD viewer version 1.7. The sequential images were viewed and the dimensions of lumbar canal at all the levels (L1-L5) of lumbar vertebra were measured and recorded in millimeters.

Mid-sagittal (antero-posterior) diameter was measured on T2-weighted mid sagittal image as the distance from the mid point of the posterior border of the vertebral body (identified by the point of exit of the basivertebral vein)to the most anterior part of the spinous process [Figure No.1].

Transverse diameter (Interpedicular distance) was measured on T2-weighted axial image at the mid pedicular level as the distance between the inner borders of both the pedicles of vertebral bodies [Figure No.2]. Descriptive statistical analysis was done for all data including percentage, mean and standard deviation. The inferential statistics was done by student's t-test. A 'P' value < 0.05 was considered significant.

RESULTS

The mid-sagittal and the transverse diameters among 80 individuals (36 males and 44 females) were measured at all lumbar levels (L1 – L5).

In the males, it was observed that the largest mean mid-sagittal diameter was 14.28±1.16 mm at L1 and the narrowest was 12.63±1.47 mm at L3.

Likewise in the females, the largest mean mid-sagittal diameter was 14.38±1.38 mm at L1 and the narrowest was 12.12±1.35 mm seen at L3. There was no statistical gender difference of the mid-sagittal diameter of the lumbar canal. [Table No.1 & Figure No.3]

Table 1: Relationship of the Mid-sagittal diameter with Gender (Mean & SD)

Level	Mean Mid-sagittal diameter Mean±SD (mm)			
	Males	Females	'P' value	Total Population
L1	14.28 ±1.16	14.38 ±1.38	0.398	14.34
L2	13.33 ±1.24	13.51 ±1.27	0.521	13.43
L3	12.63 ±1.47	12.12 ±1.35	0.110	12.35
L4	12.88 ±1.44	12.54 ±1.17	0.262	12.7
L5	13.91 ±2.06	13.4 ±1.68	0.233	13.63

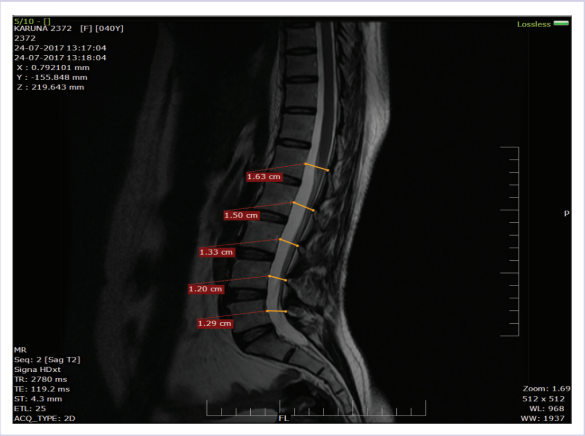

Figure 1: T_2W mid-sagital image of Lumbar spine

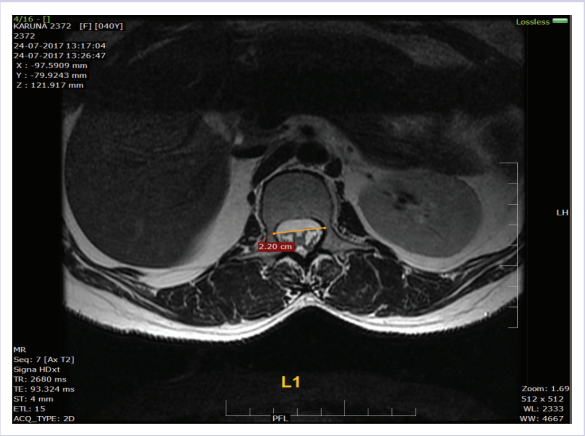

Figure 2: T_2W axial image at L_1 level

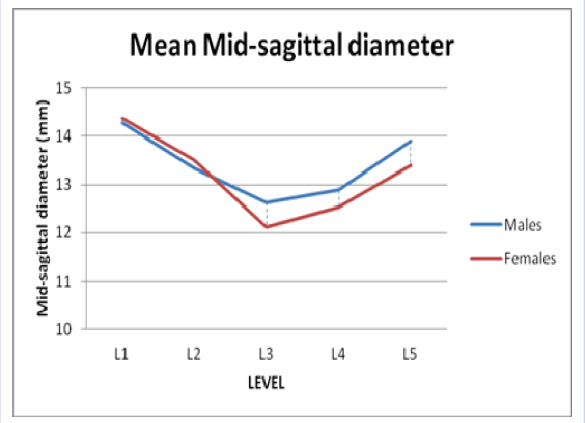

Figure 3: Relationship of the Mid-sagittal (Antero-posterior) diameter with Gender (Mean dimensions).

The largest mean transverse diameter was 27.89±2.76 mm at L5 and the narrowest was 23.32±2.00 mm at L1 in the males. Likewise in the females, the largest mean transverse diameter was 27.50±2.50 mm at L5 and the narrowest was 21.69±1.38 mm seen at L1. In both the sexes, it was observed that there was widening of the transverse diameter from the cephalic to the caudal end of the lumbar canal (L1-L5). This widening of the diameter was responsible for attributing the trefoil shape of the lumbar canal when seen in axial MR images.

At all levels (L1-L5), the transverse diameter was seen to be wider in males. A 'P' value of less than 0.05, which is a statistically significant difference was observed at L1-L4 levels between the two genders. A difference of 1-1.5 mm was observed between the mean values of the transverse diameters of both the groups from L1 to L4. But at L5, the difference was less than 0.5mm between the mean values of the transverse diameter in both sexes and therefore 'P' value was not significant. [Table No.2 & Figure No.4]

DISCUSSION

The growth of the vertebral body and spinal canal in the lumbar region are a result of various postural, mechanical and genetic factors. Hence, studies of spinal canal reveal ethnic and racial disparities, apart from age and sex related differences in size. The space within the spinal canal determines the movements of its contents without any hazard by tension and pressure. Therefore, any lessening in the normal size of the lumbar spinal canal could result in low back pain.

Verbiest while demonstrating the significance and principles of computerized axial tomography in idiopathic developmental stenosis of the bony lumbar vertebral canal stated that an antero-posterior diameter of <12 mm was regarded as relative stenosis and <10 mm was considered absolute stenosis of the lumbar spinal canal.[8] Since then many authors have worked on diagnostic importance of mid sagittal diameter [Table No.3]. [7, 9-13]

In the present study, the mean midsagittal diameter of the vertebral canal in both the genders was wider at the cephalic end than it was at the caudal end, and showed a mid-lumbar narrowing. This 'hour-glass' shape of the canal has been observed in other populations such as Nigerian population,[7] Pakistani population [13] and Iraqi population.[11]

Kapoor et al in their cadaveric study of the lumbar vertebrae of the South Indian population recorded the average mid sagittal diameter of vertebral canal ranged from 13.06 mm to 14.75 mm at L1 - L5 vertebral levels and concluded that L3 remains the centre point for

transition in the dimensions and hence more susceptible to stenosis and spinal nerve compression.[14] The present study also supports the fact that L3 is more prone for stenosis. As in the other populations studied, the widest mid-sagittal diameter of the lumbar spinal canal measured in the present study was at the level of L1.

According to Davis, in most individuals the L1 level coincides with the region of functional transition between the relatively immobile thoracic spine and the mobile lumbar segment. In addition, this level houses the lower end of the conus medullaris. Hence, the width of the canal at this level may be a reflection not only of the size of its contents, but also of an adaptation to ensure protection of those transitional regions. At this level also, there is a change in the curvature of the spine from the thoracic convexity to the lumbar concavity. The effect is that the lower end of the spinal cord would tend to be displaced dorsally in the erect posture and therefore the sagittal diameter has to be capacious enough to accommodate it. [15]

Amonoo Kuofi suggested that the tendency for an increase in this dimension at L5 is as an adaptation to accommodate the sacral nerve roots or else these would bowstring during angular movement between the mobile lumbar segment and the immobile sacrum at the lumbosacral junction. [7]

Eisenstein and Verbiest were of the view that a midline sagittal diameter of neural canal less than 12mm is pathological and spinal canals with midsagittal diameter ≤10mm can produce cauda equina compression in the absence of any additional compressive agents.[5,8] Thus, in this study, narrowing of the spinal canal mainly at the L3 level could have been the cause for symptoms of LBP with or without radiculopathy.

But at L1& L2 level, the female canal was slightly wider as compared to the male canal, perhaps due to greater differences in general somatic size in women. Similar findings have been reported by Eisenstein in the South African population and also by Malas et al, in the Turkish population where females had wider diameters than males.[5, 16] In the present study, there was no statistical gender difference of the mid-sagittal diameter of the lumbar canal. This is supported by the data in studies by Amonoo Kuofi, Al-Anazi, Shukri et al. & Varol et al. [7, 10-12]

The inter-pedicular distance increased steadily from L1 to L5 in both the sexes in all populations. [Table No.4] [4, 6, 13, 17-19] It may be explained by the fact that caudal to L1, L2, there lies cauda equina whose nerves may be going laterally to their respective intervertebral foramina for exit thus increasing transverse diameter of neural canal. Generally, at all levels, the mean diameters of the canals in males were larger than those of females. A difference

Table 2: Relationship of the transverse diameter with gender (Mean & SD)

Level	Mean Transverse diameter Mean±SD (mm)			
	Males	Females	'P' value	Total Population
L1	23.32 ±2.00	21.69 ±1.38	<0.0001*	22.42
L2	23.41 ±2.16	22.00 ±1.29	<0.001*	22.64
L3	24.30 ±1.99	22.76 ±1.36	<0.0002*	23.45
L4	25.23 ±2.37	23.93 ±1.53	<0.006*	24.52
L5	27.89 ±2.76	27.50 ±2.50	0.520	27.68

**Statistically significant.*

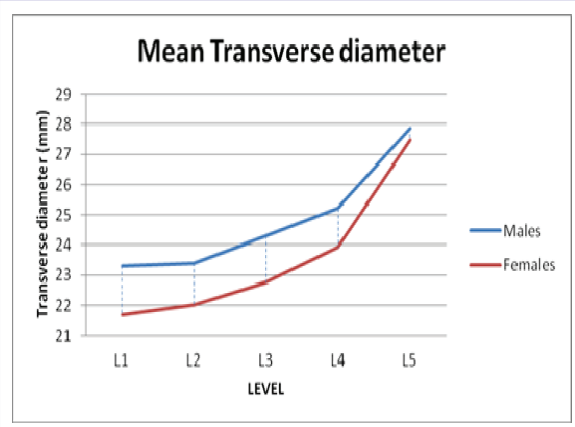

Figure 4: Relationship of the Transverse diameter with Gender (Mean dimensions).

of 1-1.5 mm was observed between the mean values of the transverse diameters of both the sexes from L1 to L4 which were statistically significant. These findings are consistent with those of Tacar et al., who studied the transverse diameter in the Turkish population and found that the diameter was 1-1.5 mm higher in the males than the females.[18]

Kapoor et al. in a cadaveric study of the lumbar vertebrae of the South Indian population recorded the transverse diameter to increase steadily from L1-L5 which is similar to the present study. [14] Contrarily Sethi R et al. in their recent study stated that the difference in the transverse diameter of both the sexes was non-significant and moreover the diameter was found to be higher in females.[20]

Earlier studies correlated with the stature of the individuals and reported that the interpedicular distances were higher in males, and found it reasonable to suggest

Table 3: Gender wise comparison of mean mid-sagittal (antero-posterior) diameter of the lumbar canal between the present and previous studies

Parameter	Mean mid-sagittal diameter in mm													
Author	AmonooKuofi[7]		El-Rakhawy et al. [9]		Al-Anazi[10]		Shukri et al[11]		Varol et al [12]		Alam et al [13]		Present study	
Type of study	Cadaveric study		Cadaveric study		CT study of normal adults		MRI study of normal adults		CT study of symptomatic adults		CT study of symptomatic adults		MRI study of symptomatic adults	
Population	Nigerian		Egyptian		Saudi		Iraqi		Turkish		Pakistani		Indian	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
L1	16.60	15.80	13.10	13.20	--	--	16.73	16.44	--	--	17.70	16.70	14.28	14.38
L2	15.80	15.10	14.60	13.40	--	--	15.61	15.45	--	--	16.26	16.28	13.33	13.51
L3	14.90	14.20	12.30	11.50	16.60	16.20	14.89	14.87	--	--	15.48	15.31	12.63	12.12
L4	15.60	14.10	11.70	11.00	16.70	16.90	15.17	14.89	13.94	13.33	14.77	14.28	12.88	12.54
L5	16.00	14.60	9.90	9.50	17.80	17.60	16.45	15.40	16.31	15.96	15.25	13.76	13.91	13.40

Table No.4: Gender wise comparison of mean transverse diameter (interpedicular distance) of the lumbar canal between the present and previous studies

Parameter	Mean transverse diameter in mm													
Author	Hinck et al. [4]		Amonoo Kuofi[6]		Piera et al. [17]		Tacar et al. [18]		Nirvan et al. [19]		M Alam et al.[13]		Present study	
Type of study	Plain Radiographic study normal adults		Plain Radiographic study normal adults		Plain Radiographic study normal adults		Plain Radiographic study normal adults		Plain Radiographic study normal adults		CT study of symptomatic adults		MRI study of symptomatic adults	
Population	Americans		Nigerian		Spanish		Turkish		Indian		Pakistani		Indian	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
L1	25.9	24.3	22.6	21.3	27.79	25.66	26.71	25.37	24.0	23.3	24.20	23.50	23.32	21.69
L2	26.5	24.9	22.7	22.5	28.39	26.25	27.36	25.99	25.4	24.3	24.34	23.46	23.41	22.00
L3	26.8	25.4	24.5	23.7	29.44	27.53	28.47	27.20	26.4	25.8	24.13	22.36	24.30	22.76
L4	27.6	26.9	26	25.4	30.89	29.53	29.91	28.67	27.9	27.0	24.48	23.81	25.23	23.93
L5	30.7	29	28.7	28.4	34.31	33.39	34.01	32.56	30.9	29.8	28.43	25.96	27.89	27.50

that growth of the vertebral column and definitive build of the individual play important roles in determining the width of the lumbar spinal canal. [6]

A comparison between the present data and the data published on transverse diameter at lumbar levels of other populations also shows that there are marked differences between the mean values reported for the population of different geographic areas. The reason for this may possibly be interplay of racial, ethnic and environmental factors.

CONCLUSION

In the present study, there was no statistical gender difference of the mid-sagittal diameter of the lumbar canal. The narrowest mid-sagittal diameter was observed at the L3 level for both the genders which indicates the significance of development of spinal stenosis and low back pain.

The mean mid-sagittal diameter of both sexes was slightly smaller in our study compared to previous other studies. But the transverse diameter of the lumbar canal shows sexual dimorphism.

The mean transverse diameter of both the genders at all lumbar levels was almost similar to the Nigerian and Pakistani populations. Knowledge of the mid-sagittal and transverse diameters of neural canal is useful in the detection of conditions like LSS.

Also since transverse diameter was the largest dimension of spinal canal, it indicates that mid-sagittal diameter is clinically the most significant dimension of spinal canal. So we hope that these findings will serve as a useful tool for doctors to treat patients and carry out future research work.

CONFLICT OF INTEREST:

The authors declared no conflict of interest.

FUNDING: Nil

REFERENCES

1. Nelson MA. Lumbar spinal stenosis. *J Bone & Joint Surg*. 1973; 55 B(3):506-512.
2. Shobeiri E, Khalatbari MR, Taheri MS, Tofighirad N, Moharamzad Y. Magnetic resonance imaging characteristics of patients with low back pain and those with sciatica. *Singapore Med J*. 2009; 50(1):87-93.
3. Ullrich CG, Binet EF, Sanecki MG, Kieffer SA. Quantitative assessment of the lumbar spinal canal by computed tomography. *Radiol*. 1980; 134:137-143.
4. Hinck VC, Clark WM, Hopkins CE. Normal interpedicular distance (minimum& maximum) in children & adults. *Am J Roentgen*. 1966; 97:141-153.
5. Eisenstein S. The morphometry and pathological anatomy of the lumbar spine in South African Negroes and Caucasoid with specific reference to spinal stenosis. *J Bone Joint Surg Br*. 1977; 59:173-80.
6. Amonoo-Kuofi HS. Maximum and minimum lumbar interpedicular distances in normal adult. *Nigerians J Anatomy*. 1982; 135, 225-233.
7. Amonoo-Kuofi HS. The sagittal diameter of the lumbar vertebral canal in normal adult. *Nigerians J Anatomy*. 1985; 140(Pt 1): 69-78.
8. Verbiest H. The significance and principles of computerized axial tomography in idiopathic developmental stenosis of the bony lumbar vertebral canal. *Spine*. 1976; 4(4):369-378.
9. El-Rakhawy M, El-Shahat AR, Ibrahim L, Abdulaziz E. Lumbar vertebral canal stenosis: concept of morphometric and radiometric study of the human lumbar vertebral canal. *Int J Experimental Clin Anatomy*. 2010; 4:51-62.
10. Al-Anazi AR. Sagittal diameter of the lumbar spinal canal and canal/body ratio in normal adult Saudis. *Pan Arab J Neurosurg*. 2009; 13(2):53-56.
11. Imad GS, Kawa AM, Shakhawan A, Abdul Rahman. A morphometric study of the lumbar spine in asymptomatic subjects in Sulaimani city by Magnetic Resonance Imaging. *JSMC*. 2013; 3(1):172-75.
12. VarolT, IyemC, CezayirliE, ErturkM, KayaliogluG and Hayretdag C. Comparative Morphometry of the Lower Lumbar Vertebrae: Osteometry in Dry Bones and Computed Tomography Images of Patients with and Without Low Back Pain. *J Int Med Res*. 2016; 34:316 -330.
13. AlamM Muhammad, Waqas M, Hussain S, Gohar J. Lumbar morphometry: A study of lumbar vertebrae from a Pakistani population using computed tomography scans. *Asian Spine J*. 2014; 8(4):421-426.
14. Kapoor Y,Sherke AR, Krishnaiah M, Suseelamma D. Morphometry of the lumbar vertebrae and its clinical significance. *Scholars J Appl Med Sci*. 2014; 2(3C):1045-1052.
15. Davis PR. The thoracolumbar mortice joint. *J Anatomy*. 1955; 89:370-377.
16. Malas MA, Salbacak A, Aler A, Yardimci C. Midsagittal diameters of the lumbar vertebral canal determined by magnetic resonance imaging. *SDU Tip Fakultesi Dergisi*. 1997; 4(3):7-11.
17. Piera V, Rodroguez A, Cobos A, Hernandez R, Cobos P. Morphology of lumbar vertebral canal. *Acta Anatomica*. 1988; 131:25-40.
18. Tacar O, Demirant A, Nas K, Altindag O. Morphology of the lumbar spinal canal in normal adult Turks. *Yonsei Med J*. 2003; 44(4):679-685.
19. Nirvan AB, Pensi CA, Patel JP, Shah GV, Dave RV. A study of inter-pedicular distances of the lumbar vertebrae measured in plain antero-posterior radiograph in Gujaratis. *J Anat Soc India*. 2005; 54 (2):1-9.
20. Sethi R, Singh V, Chauhan BKS, Thukral BB. A study of transverse diameter of lumbar vertebral canal in North Indian population. *Int J Anat Res*. 2015; 3(3):1371-75.