Original Article

Morphometric Study of Lumbar Spine in Nepalese Adult Population attending a Diagnostic Center

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ABSTRACT

Background: Magnetic Resonance Imaging (MRI) is the modality of choice for the evaluation of the lumbar spine for the cause of backache and radiculopathy. The central spinal canal and neural foramen stenosis cause nerve root entrapment and radiculopathy and most of the spinal surgeries in adult patients are related to spinal stenosis. The development of a nomogram of the various morphological parameters of the central spinal canal, lateral recess, and neural foramina in the lumbar spine MRI is essential to determine the degree of acquired stenosis as well as a plan of intervention and instrumentation in surgeries.

Methods: A retrospective descriptive study of the lumbar spine MRI of 107 Nepalese population (59 male and 48 female) between 18 to 50 years with no central spinal canal or neural foramen narrowing and no history of congenital anomaly, trauma, or surgery were done for six months between 01 September 2020, and 28 February 2021. Thecal sac diameters, lateral recess depth/angle, and neural foramen dimensions were measured and tabulated. Calculation of the mean and standard deviation was done in Statistical Package for Social Sciences (SPSS) version 16.

Results: Nomogram of the thecal sac diameters, lateral recess depth/angle, and neural foramen dimensions were prepared for lumbar vertebra in a sample population. The mean lumbar anterior-posterior diameter and Transverse diameter of thecal sac in the study population were 11.38±1.27mm and 16.75±2.4mm respectively with no significant difference was found by gender ($p>0.05$).

Conclusions: Thecal sac diameters, lateral recess depth, and neural foramen anterior-posterior diameters show a gradual decrease in L1-L2 to L5-S1 level. A spinal morphometric nomogram of the Nepalese population is necessary for assessment of the canal and foraminal compromise as well as surgical approach, technique, instrumentation, and implant development.

Keywords: Lateral recess; lumbar spine; neural foramen; thecal sac

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INTRODUCTION

Low backache is one of the common complaints for which both young and adult patients visit the general physician or orthopedic surgeon. Though most of the time they are muscular spasmodic pain, some are related to discogenic and non-discogenic causes. Narrowing of the central spinal canal or neural foramen causing nerve root compression presents with radiculopathy. Most of the spinal surgeries in adult patients are related to spinal stenosis.[1] Magnetic Resonance Imaging (MRI) is the modality of choice for the diagnosis of the lumbar central spinal canal and neural foraminal stenosis.

Most of the previous morphometric studies of the lumbar spine available in the literature are done in Computed Tomography (CT) which defines the bony central spinal canal.[3,4,5,6] However, it is not the bony central spinal canal but the thecal sac that is the space available for the spinal cord and the nerve roots. Higher soft-tissue resolution in the MRI allows us to accurately delineate the boundary of the thecal sac.[7] A reference range for the thecal sac, lateral recess and neural foramen dimensions for the Nepalese population at each lumbar level for each sex is lacking. Such data will also be helpful to determine the degree of acquired stenosis.[8] Apart from the assessment of the stenosis, these measurements will also be helpful for the plan of intervention and instrumentation in surgeries.

This research was aimed to study the lumbar thecal sac diameters, lateral recess depth/angle, and neural foraminal diameters of the Nepalese Adult population attending a diagnostic center of Kathmandu.

MATERIALS & METHODS

This retrospective descriptive cross-sectional study was performed in Kundalini Diagnostic Center (KDC) in Kathmandu. Patients from multiple hospitals of Kathmandu valley as well as from the periphery are also referred to this center. This study was done in the MRI of patients from Shree Birendra Hospital (SBH) and other centers attending KDC for six months (01 September 2020 to 28 February 21). Administrative clearance from KDC was taken and ethics clearance was obtained from the Institutional review committee (IRC) of Nepalese Army Institute of Health Sciences (March 2021, Reg. No. 410).

Digital Imaging and Communications in Medicine (DICOM) images of the participants were extracted from a record and reviewed. Patients between 18 to 50 years were included in the study. The developmental dimensions of the central spinal canal, lateral recess, and neural foramen are obtained by 17 to 20 years.[8] Therefore, MRIs of younger populations less than 18 years of age were excluded from this study. Inclusion of the older populations can include some components of the acquired degenerative narrowing of the dimensions hence patients of more than 50 years of age were also excluded. Cases with suspicious central spinal canal, lateral recess, or neural foramen narrowing on a qualitative assessment by a radiologist, congenital spinal deformity, infective or malignant pathology, history of previous spinal trauma, infection or surgery, and degenerative arthrosis of the lumbar spine were also excluded. All MRI included in the study were done in one machine, using Philips Achieva 3.0 Tesla® Scanner. Sagittal T2-weighted (repetition time ms/echo time ms, 3000/7, voxel of 1.0 x 1.37 x 4.0 mm, FOV 180 x 300 x 57 mm, 4 mm slice thickness) and Axial T2 weighted images (repetition time ms/echo time ms, 2300/85 , voxel of 0.61 x 0.81 x 4.0 mm, FOV 160 x 152 x 22 mm, 4 mm slice thickness; 5 slices per intervertebral

level). The calculation of the variables was done in the vendor provider console. All the images from all the different MR sequences were evaluated by the principal investigator and measurements were taken in the vendor-provided inbuilt MRI console.

Anterior-posterior (AP) and Transverse (TR) diameter of the thecal sac was calculated at the intervertebral level perpendicular to the vertical axis of the spine. Lateral recess is bordered laterally by the pedicle, posteriorly by the superior articular facet, and anteriorly by the vertebral body, endplate margin, and disc margin.[9] Angle and depth of the lateral recess were measured. Similarly the neural foramen was measured in the parasagittal image with maximum visualization of the foramen, as depicted in Figures 1 and 2.[10,11,12,13]

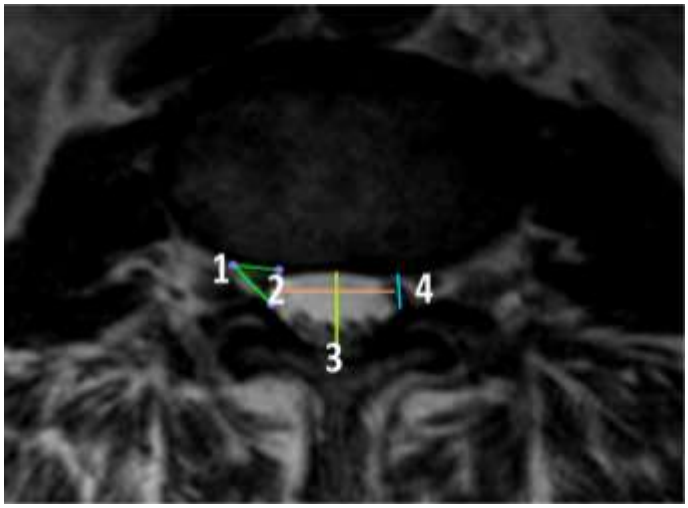

Figure 1: Measurements of parameters of the spinal canal. 1. Angle of the lateral recess 2. Transverse Diameter of thecal sac 3. Anterior-posterior diameter of dural sac; 4. Depth of the lateral recess

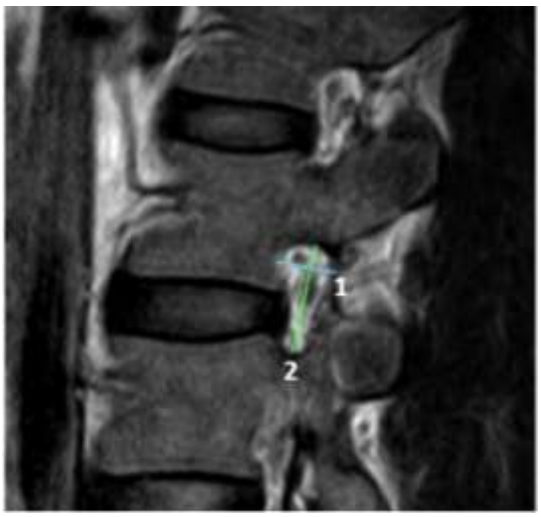

Figure 2: Measurement of 1. Anterior-posterior diameter and 2. Height of the neural foramen in sagittal images

The data obtained were tabulated in the Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 16 was used for analysis. Mean and standard deviation (SD) for the study population were calculated. Data were split by gender and Student's t-test was applied to see the difference in means of the two populations.

RESULTS

A total of 107 MRI of patients were selected for the study out of which 59 (55%) were males with a mean age of 32.49±7.06 years and 48 (45%) females (mean age 35.25±6.92 years). The AP diameter of the thecal sac, TR of the thecal sac, depth of the lateral recess, angle of the lateral recess as well as AP and TR of the neural foramina were measured and analyzed.

The mean and SD of AP and TR of the dural sac, depth, and angle of the right and left lateral recess as well as AP and TR of the right and left neural foramina at different levels of a lumbar vertebra in total population, males and females are presented in (Table 1), (Table 2) and (Table 3) respectively. The tables show gradual decrease in thecal sac AP and TR dimensions, lateral recess

depth, and NF-AP dimensions from L1-L2 to L5-S1 level in both male, female as well as total population. The tables show that NF height increased from L1-L2 to L3-L4 level and gradually decreased from L3-L4 to L5-S1 level in both male, female as well as total population. The mean lumbar anterior-posterior diameter and Transverse diameter of thecal sac in the study population was 11.38±1.27mm and 16.75±2.4mm respectively with no significant difference were found by gender (p= 0.94 and 0.69 respectively). (Table 4) gives the mean and standard deviation of various variables studied in the population from L1 to S1 for total study population and gender along with p-value for gender differences.

Table 1: Total population thecal sac, lateral recess, and neural foramen dimensions

Level		TS (AP) mm	TS (TR) mm	RT LR DT mm	RT LR ANG (°)	LT LR DT mm	LT LR ANG (°)	RT NF HT mm	RT NF AP mm	LT NF HT mm	LT NF AP mm
L1-L2	Mean	13.22	19.22	7.03	47.34	7.26	47.70	18.28	6.14	18.12	5.97
	SD	1.09	1.40	0.90	3.52	0.88	4.01	1.62	1.10	1.66	1.13
L2-L3	Mean	12.13	18.59	6.49	45.06	6.71	45.48	19.74	5.54	19.53	5.59
	SD	1.13	1.69	0.89	3.60	0.84	3.47	1.73	1.11	1.90	1.20
L3-L4	Mean	11.16	17.28	6.07	43.52	6.28	43.90	20.75	5.35	20.47	5.42
	SD	1.42	1.82	0.86	3.99	0.82	3.86	1.71	1.10	1.86	1.25
L4-L5	Mean	10.53	15.94	5.77	43.29	5.90	42.95	18.35	4.85	18.06	4.84
	SD	1.82	2.14	0.78	3.79	0.81	4.15	1.95	1.25	1.87	1.30
L5-S1	Mean	10.09	13.09	5.64	43.10	5.81	43.09	15.64	4.75	15.44	4.72
	SD	1.92	2.54	1.03	3.75	1.08	3.97	2.16	1.16	2.04	1.17

Abbreviations: TS: Thecal sac; AP: Anterior-posterior; TR: Transverse; RT: Right; LT: Left; DT: Depth; LR: Lateral Recess; ANG: Angle in degrees; NF: Neural foramen; HT: Height; SD: Standard deviation

Table 2: Male thecal sac, lateral recess, and neural foramen dimensions

Level		TS (AP) mm	TS (TR) mm	RT LR DT mm	RT LR ANG (°)	LT LR DT mm	LT LR ANG (°)	RT NF HT mm	RT NF AP mm	LT NF HT mm	LT NF AP mm
L1-L2	Mean	12.94	19.66	7.10	47.13	7.29	47.50	19.27	6.35	19.07	6.13
	SD	0.94	1.25	0.87	2.71	0.84	3.32	1.84	0.90	1.84	0.90
L2-L3	Mean	11.85	18.70	6.14	44.53	6.52	45.47	20.46	5.64	20.08	5.74
	SD	1.04	1.74	0.81	3.37	0.76	3.15	1.58	1.20	1.88	1.23
L3-L4	Mean	11.00	17.39	5.99	44.07	6.19	44.14	21.46	5.50	21.07	5.65
	SD	1.37	1.89	0.76	3.29	0.72	3.75	1.73	1.17	1.90	1.36
L4-L5	Mean	10.50	16.27	5.90	43.55	6.07	43.31	19.00	5.11	18.55	5.16
	SD	1.77	2.25	0.74	3.57	0.76	3.99	2.11	1.30	2.19	1.41
L5-S1	Mean	10.45	13.35	5.84	43.58	5.99	43.57	16.12	5.04	15.79	5.01
	SD	1.86	2.43	1.03	3.82	1.14	3.78	2.16	1.18	2.27	1.25

Abbreviations: TS: Thecal sac; AP: Anterior-posterior; TR: Transverse; RT: Right; LT: Left; DT: Depth; LR: Lateral Recess; ANG: Angle in degrees; NF: Neural foramen; HT: Height; SD: Standard deviation

Table 3: Female thecal sac, lateral recess, and neural foramen dimensions

Level		TS (AP) mm	TS (TR) mm	RT LR DT mm	RT LR ANG (°)	LT LR DT mm	LT LR ANG (°)	RT NF HT mm	RT NF AP mm	LT NF HT mm	LT NF AP mm
L1-L2	Mean	13.44	19.01	7.26	47.67	7.35	48.83	17.68	5.61	17.43	5.43
	SD	1.77	1.91	1.07	4.87	1.19	3.94	1.28	1.14	1.38	1.18
L2-L3	Mean	12.46	18.31	6.90	45.77	6.93	45.59	18.93	5.40	18.86	5.41
	SD	1.59	1.97	1.13	5.00	1.17	5.09	2.03	1.28	2.38	1.43
L3-L4	Mean	11.30	17.05	6.16	43.64	6.38	43.68	19.96	5.19	19.75	5.17
	SD	1.89	2.11	1.19	5.14	1.23	5.04	1.78	1.30	2.02	1.50
L4-L5	Mean	10.43	15.34	5.60	43.00	5.71	42.75	17.56	4.51	17.50	4.49
	SD	2.29	2.47	1.07	4.76	1.07	5.31	2.25	1.62	1.84	1.57
L5-S1	Mean	9.43	12.40	5.37	42.42	5.56	42.49	15.09	4.39	15.19	4.40
	SD	2.32	2.93	1.33	4.57	1.43	5.25	2.69	1.57	2.25	1.41

Abbreviations: TS: Thecal sac; AP: Anterior-posterior; TR: Transverse; RT: Right; LT: Left; DT: Depth; LR: Lateral Recess; ANG: Angle in degrees; NF: Neural foramen; HT: Height; SD: Standard deviation

Table 4: Mean and SD of various study variables for total population and gender

		TS (AP) mm	TS (TR) mm	RT LR DT mm	RT LR ANG mm	LT LR DT mm	LT LR ANG mm	RT NF HT mm	RT NF AP mm	LT NF HT mm	LT NF AP mm
Male	Mean	11.35	17.06	6.19	44.57	6.41	44.80	19.26	5.53	18.91	5.54
	SD	1.05	2.45	0.52	1.48	0.53	1.72	2.01	0.52	1.99	0.46
Female	Mean	11.41	16.42	6.26	44.50	6.39	44.66	17.85	5.02	17.75	4.98
	SD	1.59	2.65	0.82	2.18	0.77	2.62	1.83	0.55	1.73	0.50
Total	Mean	11.38	16.75	6.23	44.54	6.40	44.73	18.55	5.27	18.33	5.26
	SD	1.27	2.43	0.64	1.76	0.62	2.09	1.96	0.57	1.86	0.54
p value		0.94	0.69	0.88	0.95	0.95	0.93	0.28	0.17	0.35	0.10

DISCUSSION

Low back pain is the second most common complaint encountered by primary care physicians (after the common cold) and up to 80% of all individuals will experience low back pain at some point in their lives.[14] X-ray, CT, and MRI are the imaging modalities for evaluation of the cause of the back pain. Symptoms of radiculopathy are associated with the thecal sac, lateral recess, and neural foramen compromise. The narrowing of the lateral recess causes compression of the traversing nerve root and narrowing of the neural foramen causes the compression of the exiting nerve roots.

Knowledge of the normal dimensions of the thecal sac, lateral recess, and neural foramina is useful for defining the stenosis as well as for surgical approaches and instrumentation. Steurer et al conducted a systematic review of quantitative radiologic criteria, performed in CT as well as MRI, and compiled cut-offs for central spinal canal and foraminal stenosis. A mid-sagittal diameter of the dural sac less than 10 mm was shown to be consistent with stenosis and for evaluation of the neuroforamen, anteroposterior diameter of the foramen less than 3 mm on sagittal images and lateral recess depth less than

3mm or lateral recess angle less than 30 degrees was also evidence of stenosis.[1] Many authors like Mansur et al[3] and Mallik et al[4] have studied the morphometry of the lumbar spine in the CT study in Nepal but no studies are done in the MRI.

Our study showed that the mean values of AP and TR of the thecal sac decrease from L1-L2 to L5-S1 vertebral level from the mean value of 12.94±0.94 x 19.66±1.25 mm (AP x TR) at L1-L2 level to 10.45±1.86 x 13.35±2.43 mm (AP x TR) at L5-S1 level in male and 13.44±1.77 x 19.01±1.91 mm (AP x TR) at L1-L2 level to 9.43±2.32 x 12.40±2.93 mm (AP x TR) at L5-S1 level in female. Similar findings were noted in the study of the Italian population by Pierro et al. which also showed by MRI a gradual decrease in the midsagittal thecal sac diameter from L1 to S1 level with mean AP diameter at L1 level measuring 15.3±1.7 mm to 9.9±3.0 mm at S1 level.[15] A study was done in the Indian lumbar vertebrae by Londhe et al[5] in cadavers showed a gradual decrease in bony central spinal canal diameter from first to last lumbar vertebra from mean 15.20 x 19.74 (AP x TR) at the L1 level to 13.02 x 24.34 mm (AP x TR) at L5 level which correlates with our study. However, a study in the Chinese population done by Griffith, et al[8] in CT scan had shown decreased central bony spinal canal AP diameter from L1 to L3 level and increase from L3 to L5 level which contradicts our study.

Our study found the mean thecal sac AP diameter in the L5-S1 level in the Nepalese population as 10.09±1.92 (10.4 mm±1.48 in males and 9.4±2.32 mm in females) which corresponds to the cut off value of 10 mm described by Steurer et al for lumbar canal stenosis hence this criterion is not appropriate in Nepalese population especially in females.[1]

The mean right lateral recess depth gradually decreased from L1-L2 to L5-S1 level in our study with the mean depth of 7.10±0.87 mm at L1-L2 level to 5.84±1.03 mm at L5-S1 level in male and 7.26±1.07 mm at L1-L2 level and 5.37±1.33 mm at L5-S1 level in females. The mean left lateral recess depth also gradually decreased from L1-L2 to L5-S1 level with the mean depth of 7.29±0.84 mm at L1-L2 level to 5.99±1.14 mm at L5-S1 level in male and 7.35±1.19 mm at L1-L2 level and 5.56±1.43 mm at L5-S1 level in females. Our study correlates with the CT study done by Yadav et al which also showed a gradual decrease in the lateral recess depth from the D12 to S1 level.[6] There was an associated gradual decrease in the lateral recess angle from L1-L2 to L4-L5 level in males in our study with the mean angle of 47.13±2.71° in right and 47.50±3.32° in left at L1-L2 level and 43.55±3.57 ° in right and 43.31±3.99° in left L4-L5 level. Slightly increased mean angle noted in the L5-S1 level in male population only whereas in female population there was a gradual decrease in the lateral recess angle from L1-L2 to L5-S1 level with the mean angle of 47.67±4.87° in right and 48.83±3.94° in left at L1-L2 level and 42.42±4.57° in right and 42.49±5.25° at L5-S1 level.

The neural foramen AP diameter gradually decreased from L1-L2 to L5-S1 level in our study with the mean AP diameter of 6.35±0.90 mm on the right side and 6.13±0.90 mm on the left side at L1-L2 level to 5.04±1.18 mm in right and 5.01±1.25 mm in left at L5-S1 level in male and 5.61±1.14 mm in the right side and 5.43±1.18 mm in the left side at L1-L2 level to 4.39±1.57 mm in right and 4.40±1.41 mm in left at L5-S1 level in female. Our study correlates with the CT study done by Yadav et al which also shows a gradual decrease in the neural foramen diameters from the D12 to S1 level. However, the

height of the neural foramen shows a gradual increase from L1-L2 to L3-L4 level then decrease from L3-L4 to L5-S1 level in both sides in both male and female population in the study by Yadav et al.[6]

There are some limitations to our study. Ideally, normal healthy volunteers should be used to develop the nomogram however our study was conducted in patients undergoing MRI for various other reasons. We tried to reduce this bias by including only those MRIs having no canal or foraminal stenotic pathology. Since this is a pilot project with a limited sample size the findings cannot be generalized for the whole population.

CONCLUSION

Thecal sac AP and TR dimensions, lateral recess depth, and NF-AP dimensions show a gradual decrease in L1-L2 to L5-S1 level whereas NF height increased from L1-L2 to L3-L4 level and gradually decreased from L3-L4 to L5-S1 level. Spinal morphometry nomogram of the Nepalese population is necessary for assessment of the canal and foraminal compromise as well as surgical approach, technique, instrumentation, and implant development.

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