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Original Article

Radiology Section

MRI Study of Lumbar Canal Stenosis by Morphological Grading and Thecal Sac Measurement: A Cross-sectional Study

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ABSTRACT

Introduction: Lumbar Spinal Stenosis (LSS) is a condition in which the spinal canal narrows to the point at which it can exert pressure on the nerves that travel through the spine. Aetiology is categorised into congenital, developmental and acquired (degenerative) causes. Magnetic Resonance Imaging (MRI) is an investigation of choice in the evaluation of patients with symptoms related to lumbar central canal stenosis.

Aim: To assess the morphologically grade of thecal sac in lumbar central canal stenosis on MRI.

Materials and Methods: This cross-sectional observational study was conducted from November 2017 to October 2019 at Department of Radiology of Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Gannavaram, Andhra Pradesh, India. Study included 100 patients who were referred with symptoms of lumbar stenosis and outcome was to determine the correlation between the morphological grade and thecal sac axial anteroposterior diameter grade. Correlation was assessed by Fisher's-exact test and Spearman's rank correlation coefficient test. A p-value <0.0001 was considered highly significant.

Results: Morphological Grade II corresponded to maximum number of cases, amounting to 46% with mean anteroposterior thecal sac diameter of 6.21 mm, followed by 36% of Grade III with mean thecal sac diameter of 4.57 mm. Grade I corresponded to 14% of cases mean thecal sac diameter of 8.35 mm and Grade IV corresponded to 4% of cases with mean thecal sac diameter of 1.1 mm. A significant correlation was obtained (r=0.78) in this study between the morphological grade and thecal sac measurement.

Conclusion: Morphological grade of the thecal sac has significant correlation with the canal measurements and it helps in quick assessment of the severity of the lumbar canal stenosis.

Keywords: Lumbar spine, Magnetic resonance imaging, Spinal canal stenosis, Thecal sac narrowing

INTRODUCTION

Spinal canal narrowing can be seen in stenosis which causes pressure effects on the nerves that travel through the spine. The aetiology of Lumbar Spinal Stenosis (LSS) is categorised into congenital, developmental and acquired (degenerative) causes [1]. Congenital LSS has a different epidemiology compared to acquired/degenerative LSS. It tends to affect patients at a younger age (30-50 years old). Developmental canal stenosis is a condition in which there is narrowed bony spinal canal; possibly defect in normal developmental process. In degenerative stenosis there is diminished space available for the neural and vascular elements in the lumbar spine secondary to degenerative changes in the spinal canal.

Symptoms of stenosis include pain in the groin, hips, and buttocks with numbness or weakness in the legs and lower back and in severe cases associated with bowel, bladder, and sexual dysfunction [2]. Magnetic Resonance Imaging (MRI) is investigation of choice in the evaluation of patients with symptoms related to lumbar canal stenosis. Various qualitative (thecal sac morphological/visual grading system) and quantitative (thecal sac/spinal canal diameters) parameters have been described in the literature for diagnosis of lumbar canal stenosis using MRI [3]. MRI had become modality of choice in patients suffering with lumbar canal stenosis related symptoms. Hence, the present study aimed to asses lumbar canal stenosis by morphological grading and thecal sac measurement.

MATERIALS AND METHODS

This was a cross-sectional observational study conducted for a period of two years, from November 2017 to October 2019 on 100 patients who were referred with symptoms of lumbar stenosis on MRI 1.5 Tesla Philips Achieva in the Department of Radiology of Pinnamaneni Siddhartha Institute of Medical Sciences and Research Foundation, Gannavaram, Andhra Pradesh, India. Study was conducted after obtaining approval from the Institutional Research and Ethics Committee (Approval no: PG-17-40). Informed consent from the respective patients had been taken related to the study.

Inclusion criteria: Patients with age more than 18 years and patients with symptoms related to spine were included in this study.

Exclusion criteria: Patient with spinal tumours, spinal fractures, spinal postoperative cases were excluded. Heart pacemakers and other metal implanted patients were also excluded from the study.

Patient was placed in supine position on MRI table. A 1.5 Tesla Philips Achieva MR scanner (16 channel) was used in the present study for obtaining scans. MRI of the lumbar spine was done. Essential sequences were:

(i) T1Weighted Axial and Sagittal images

(ii) T2W Fast Spin Echo/Turbo Spin Echo (FSE/TSE) axial and sagittal images for which MR parameters are as follows [Table/Fig-1]:

MR Parameters	T1W Sagittal	T1W Axial	T2W Sagittal	T2W Axial
• Time to Echo (TE)	8 msec	8 msec	120 msec	120 msec
• Repetition Time (TR)	400 msec	483 msec	3.1sec	2.5 sec
• Flip angle	90 degree	90 degree	90 degree	90 degree
• Slice thickness/ Slice gap	3.5 mm/ 0.4 mm	4.0 mm/ 0.4 mm	3.5 mm/ 0.4 mm	4.0 mm/ 0.4 mm
• Field of view	35 cm	16 cm	35 cm	16 cm

[Table/Fig-1]: Technical parameters used in MRI sequences.

MRI Image Interpretation and Analysis

Image stacks were transferred to advanced workstation and interpretation was done by a Radiologist with 20 years of experience. After acquiring the required scans, the dural sac morphology of the

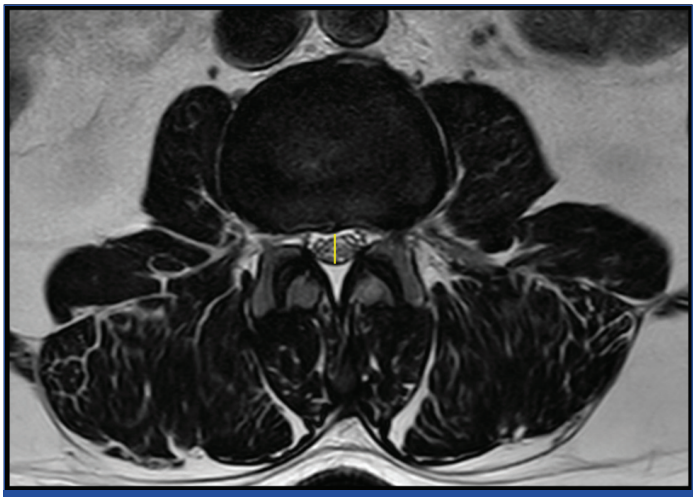
most significantly stenosed level was assessed and further graded based on the Cerebrospinal Fluid (CSF)/nerve rootlet ratio on T2W axial images. The morphological/visual grading of lumbar central canal on T2W axial MR image consists of four grades. Grading was done according to the Schizas C et al., grading system [Table/Fig-2-6] [4].

Grade I- Decreased anterior CSF space, CSF present between rootlets.

Grade II- Loss of anterior CSF space, still CSF presents between rootlets and they can be individualised.

Grade III- Complete obliteration of CSF and rootlets are clumped. Epidural fat can be normally delineated.

Grade IV- Complete obliteration of CSF and the epidural fat also cannot be delineated.



[Table/Fig-2]: T2W Axial MR image at lumbar disc level shows morphological Grade I thecal sac (i.e., decrease in the anterior thecal sac CSF signals, with normal visualisation of cauda equine nerve roots separated with CSF). The axial anteroposterior diameter was 7.4 mm and the patient presented with two months history of claudication pain.

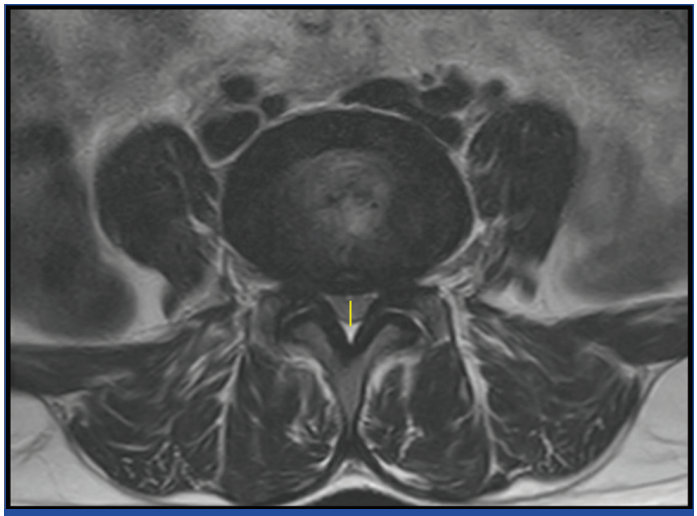
[Table/Fig-3]: Axial T2W image of the lumbar spine shows morphological Grade II with ligamentum flavum hypertrophy contributing to canal stenosis at disc level.

STATISTICAL ANALYSIS

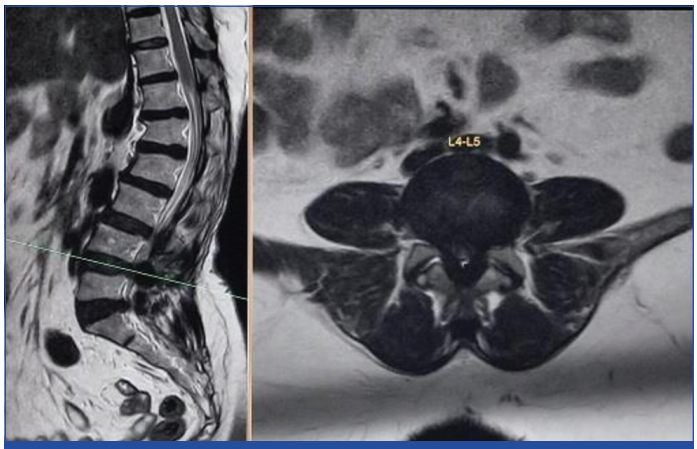
All statistical analysis was done through Statistical Package for the Social Sciences (SPSS) Windows Version 24.0. Correlation was assessed by Fischer-exact test and Spearman's rank correlation coefficient test. A p-value <0.0001 was considered highly significant.

RESULTS

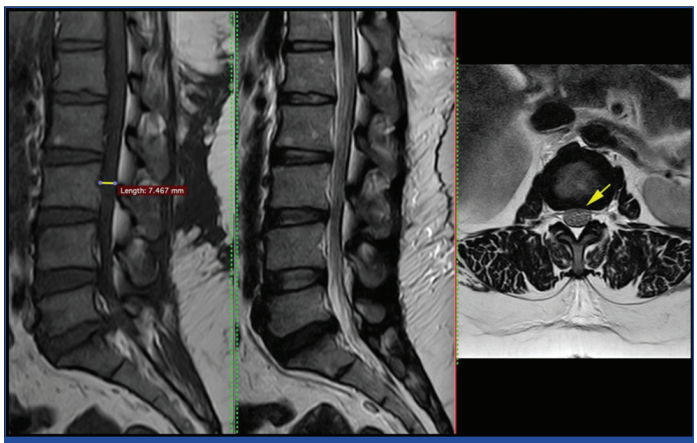
During the period of 24 months, out of 100 patients 46% were males and 54% are females. Age of the patients ranged from 18 years to 78 years with mean age of 49.73±13.29. Maximum i.e., 29% of the cases were in the age group of 36-45 years, followed by 26% in the age group of 46-55 years [Table/Fig-7].



[Table/Fig-4]: Axial MR image at lumbar disc level shows morphological Grade III with thecal sac anteroposterior diameter of 4.3 mm.



[Table/Fig-5]: Sagittal and axial MR image at L4-L5 disc level shows morphological Grade IV of the thecal sac with compression of epidural fat posteriorly. Ligamentum flavum thickening is also contributing to thecal sac compression at this level.



[Table/Fig-6]: Sagittal and Axial T2W images of the lumbar spine shows developmental bony canal stenosis with the canal measuring 7.4 mm in anteroposterior diameter at L3 vertebral level. Crowding of cauda equine nerve roots seen on axial image.

Age interval (in years)	No. of patients	Percentage
15-25	2	2
26-35	12	12
36-45	29	29
46-55	26	26
56-65	17	17
66-75	13	13
>75	1	1
Total	100	100

[Table/Fig-7]: Age distribution of subjects.

Grade I morphological grade was seen in 14% patients who had the thecal sac axial anteroposterior diameters ranging from 7.4 to 9.4 mm and mean anteroposterior thecal sac diameter of 8.35 mm [Table/Fig-8]. Grade II morphological grade was seen in 46% of patients who had the thecal sac axial anteroposterior diameters ranging from 2.8 to 8.4 mm and mean anteroposterior thecal sac diameter of 6.2 mm.

Grade III morphological grade was seen in 36% patients who had the thecal sac axial anteroposterior diameters ranging from 3.2 to 5.9 mm and mean anteroposterior thecal sac diameter of 4.5 mm.

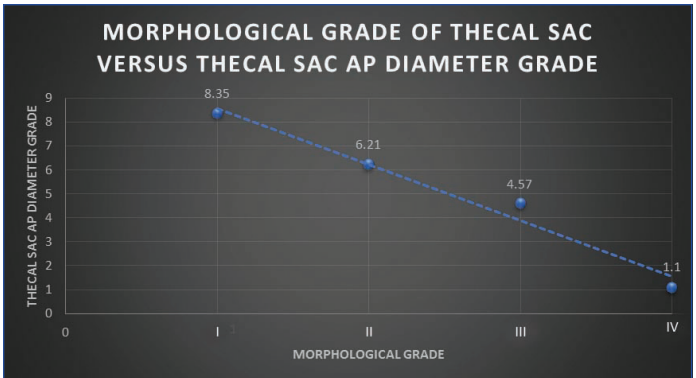
Grade IV morphological grade was seen in 4% patients who had the thecal sac axial anteroposterior diameters ranging from 0-2.2 mm and mean anteroposterior thecal sac diameter of 1.1 mm.

Morphological grade	No. of patients	Thecal sac axial anteroposterior diameter (mm)			Fishers-exact value	p-value
		Range	Mean	SD		
I	14	7.4-9.4	8.35	0.75	73.12	<0.0001
II	46	2.8-8.4	6.21	1.14		
III	36	3.2-5.9	4.57	0.68		
IV	4	0-2.2	1.1	1.55		

[Table/Fig-8]: Morphological grade versus thecal sac (axial anteroposterior) diameter at disc level.

A significant correlation was obtained in this study between the morphological grade and thecal sac axial anteroposterior diameter grade with a significant p-value <0.0001 [Table/Fig-9]. The correlation coefficient between morphological grading and thecal sac diameter was r=0.78 which indicates a strong correlation.

A 19% of the patients had severe form of developmental bony canal stenosis in the present study [Table/Fig-10].



[Table/Fig-9]: Scatter plot shows significant correlation between morphological grade and thecal sac diameter grade.

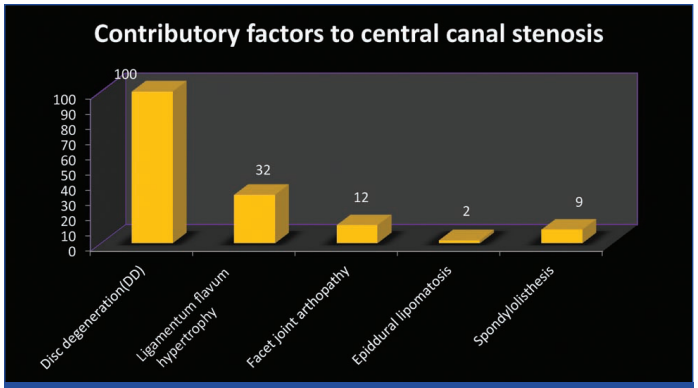
Developmental bony canal stenosis	Number of patients	Percentage (%)
Present	19	19%
Absent	81	81%
Total	100	100%

[Table/Fig-10]: Distribution of developmental bony canal stenosis.

In central canal stenosis, most commonly L4-L5 level was affected in 64% of population followed by L3-L4 level in 20% of cases; 7% at L5-S1, 7% at L2-L3 and 2% at L1-L2.

Among contributory factors to central canal stenosis, Disc Degeneration (DD) accounted for central canal stenosis in all the cases. Ligamentum flavum hypertrophy contributed to canal stenosis in 32% of patients. Facet joint arthropathy was seen in 12% of patients contributing to canal stenosis [Table/Fig-11].

Single level stenosis was seen in majority i.e., 63%, 18% of patients had two level stenosis and multilevel stenosis was seen in 19% of patients. Both single and multiple level stenosis is more commonly reported in females, 32 and 12, respectively. Posterior annular fissure was seen in 30 patients.



[Table/Fig-11]: Contributory factors to central canal stenosis.

DISCUSSION

Term Lumbar Spinal Stenosis (LSS) refers to the anatomical narrowing of the spinal canal. The annual incidence of LSS is reported to be five cases per 100,000 individuals [5]. Characteristic symptom is neurogenic claudication [6]. Diagnosis of LSS relies primarily on imaging to provide objective evidence of neurovascular compromise. MRI is suggested as the most appropriate, non invasive test to diagnose LSS [7]. Qualitative imaging findings in stenosis of the lumbar spine may be broadly classified into the specific causes spine include disc herniation, facet joint hypertrophic arthropathy, and ligamentum flavum hypertrophy. MRI is the preferred modality for the assessment of central canal stenosis, as it provides superior soft tissue resolution and nerve rootlets can be assessed with greater resolution [8]. Morphological grade II corresponded to maximum number of cases, i.e., 46%, followed by 36% of grade III. Grade I corresponded to 14% of cases and grade IV corresponded to 4% of cases. In the study done by Lee S et al., grade 1 foraminal stenosis was found in 34 foramina, grade 2 in eight, and grade 3 in seven [9]. More number of morphological grade III patients are associated with mild grade of clinical symptomatology as per the clinical protocol. This explains that pathological process may exceed the underlying clinical symptomatology in most of the subjects.

Though the patients present with mild clinical symptoms, the presence of pre-existing age related degenerative changes in the spine may aggravate the morphological grade of the study population as was observed by Yuan S et al., and Haig AJ et al., in their study [10,11]. Significant association was obtained in the present study between the morphological grade and the thecal sac measurements with a strong positive rank correlation, which was in accordance with study done by Sigmundsson FG et al., and Park HJ et al., [12,13]. Dynamic changes in the dural sac cross-sectional area on axial loaded MR imaging was evaluated to see whether there is difference between Degenerative Spondylolisthesis (DS) and Spinal Stenosis (SpS). The change in the DCSA induced by axial loading was significantly larger in the DS group (17±12 mm^2) compared with the SpS group (8±8 mm^2). Axial loaded MR imaging may therefore be a more useful tool to decrease the risk of underestimating the spinal canal narrowing in patients with DS than in those with SpS [14]. Study done by Ozawa H et al., concluded axial loaded MR imaging demonstrated significantly smaller DCSA in the DS group (35±22 mm^2) than in the SpS group (50±31 mm^2), though conventional MR imaging did not showed any differences between the two groups [15].

Limitation(s)

Clinical significance of the proposed morphological grade was not explained in the present study. The quantitative assessment of the clinical parameters was not carried out in the present study.

CONCLUSION(S)

The morphological grade of the thecal sac has significant correlation with the canal measurements as described in the present study. Traditional analysis of the lumbar central canal stenosis by canal

diameters and cross-sectional areas are time-consuming and are operator dependent. Morphological grade of the thecal sac helps in quick assessment of the severity of the lumbar canal stenosis. Hence, morphological grading system helps the radiologist in rapid and reliable determination of lumbar central canal stenosis.

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