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Research Article

Anatomical Evaluation of Lumbar Spinal Canal on 3T MRI to Assess Spinal Canal Stenosis

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Abstract

Background: Lumbar spinal canal stenosis is a common degenerative condition resulting from narrowing of the central canal, lateral recesses, or neural foramina. MRI plays apivotalrolein anatomical evaluation and early identification of stenotic changes. This study provides a detailed morphometric assessment of the lumbar spinal canal using 3T MRI in a tertiary care population.

Aim: To perform an anatomical evaluation of the lumbar spinal canal on MRI and determine the prevalence, distribution, and morphological patterns of lumbar spinal canal stenosis in a regional patient population.

Materials and Methods: A retrospective observational study was conducted at MMU Hospital, Mullana, including 190 patients who underwent lumbar spine MRI between September and November 2025. Data were obtained from PACS and radiology reports. MRI examinations were reviewed for the presence of stenosis, type (central, lateral recess, foraminal), level-wise involvement, and severity. Demographic and clinical information were also recorded. Patients were classified into stenosis-positive (n = 76) and normal (n = 114) groups. Only complete and diagnostically interpretable MRI studies were included.

Results: Lumbar spinal canal stenosis was identified in 40% (76/190) of patients. Central canal stenosis was the most frequent pattern (76 findings), followed closely by lateral recess (75 findings) and foraminal stenosis (56 findings). The L4–L5 and L5–S1 levels showed the highest involvement. Among severity-documented cases, mild stenosis was most common (85.5%), while moderate and severe cases accounted for 4% and 10.5%, respectively. Normal MRI examinations constituted 60% of the cohort.

Conclusion: This study demonstrates a substantial prevalence of lumbar spinal canal stenosis within the evaluated population, with predominant involvement of the lower lumbar levels and mild degenerative narrowing as the most common presentation. High-resolution MRI provides essential anatomical insights for accurate diagnosis, characterisation of stenosis patterns, and informed clinical management.

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KEYWORDS: Lumbar spinal canal stenosis, MRI, central canal stenosis, lateral recess stenosis, foraminal stenosis, degenerative spine disease, MMU Hospital, Mullana.

1. INTRODUCTION

Lumbar spinal canal stenosis is a common degenerative disorder of the lower spine and represents one of the leading causes of chronic low-back pain and neurogenic claudication in adults. It is characterised by a progressive reduction in the diameter of the central canal, lateral recesses, or neural foramina, ultimately resulting in compression of the cauda equina or exiting nerve roots. With advancing age, cumulative mechanical loading and degenerative changes affect multiple spinal structures, including the intervertebral discs, facet joints, ligamentum flavum, and vertebral endplates, contributing collectively to canal narrowing [1,2]. As a result, lumbar spinal stenosis has become increasingly prevalent in clinical practice, particularly among middle-aged and elderly populations.

The degenerative processes underlying stenosis often occur gradually and may involve several coexisting anatomical alterations. Disc desiccation and bulging reduce the available canal space, while thickening of the ligamentum flavum and facet joint hypertrophy further encroach upon neural elements. These changes frequently manifest at the lower lumbar levels, which bear the greatest segmental motion and axial load. Consequently, patients may present with a spectrum of symptoms ranging from nonspecific back pain to classic neurogenic claudication or radicular deficits, depending on the severity and distribution of nerve-root compression [3,4].

Magnetic resonance imaging (MRI) has become the modality of choice for evaluating lumbar spinal canal stenosis because of its superior soft-tissue contrast and capacity to visualise thecal sac morphology, neural elements, and degenerative structures without the use of ionising radiation. MRI enables detailed assessment of canal dimensions, disc pathology, ligamentous thickening, and foraminal narrowing, making it essential for diagnosis, severity grading, and treatment planning [3–5]. Despite the central role of MRI, the relationship between radiological severity and clinical symptoms remains complex. Prior studies have emphasised that stenotic changes may be present even in asymptomatic individuals, highlighting the importance of integrating anatomical evaluation with clinical correlation [7,8].

Given the variability in lumbar canal morphology across individuals and populations, establishing accurate imaging-based characterisation is crucial for early diagnosis and management. Understanding the distribution, types, and anatomical contributors of stenosis in a specific population can provide meaningful insights for clinical decision-making, surgical planning, and prognostic evaluation. This study, therefore, focuses on an anatomical assessment of lumbar spinal canal features on MRI to identify stenosis prevalence, level-wise involvement, severity patterns, and degenerative characteristics within a regional patient cohort.

To conduct a comprehensive MRI-based anatomical evaluation of the lumbar spinal canal in a regional patient population, to determine the prevalence, distribution, and morphological patterns of lumbar spinal canal stenosis using standardised imaging criteria.

2. OBJECTIVES

1. To systematically evaluate the anatomical morphology of the lumbar spinal canal on MRI and document variations relevant to the assessment of spinal canal stenosis.
2. To determine the overall prevalence of lumbar spinal canal stenosis within the study population of 190 patients and distinguish stenosis-positive cases from normal examinations.
3. To identify and categorise the morphological types of stenosis—central canal, lateral recess, and foraminal—and analyse their distribution across affected lumbar levels.
4. To quantify level-wise involvement of stenosis, with special emphasis on determining the frequency of narrowing at commonly affected lumbar segments.
5. To assess the severity of stenosis in patients with a proportion of mild, moderate, andsevere narrowing.

3. REVIEW OF LITERATURE

1. MRI-Based Morphometric Analysis of Lumbar Spinal Canal Stenosis in a Tertiary Care Population

A prospective MRI study conducted by Sharma et al. evaluated 210 patients with suspected lumbar spine pathology at a tertiary care radiology centre. Data were obtained using standardised 1.5T and 3T MRI protocols, and each examination was reviewed independently by two senior radiologists. Canal diameters, dural sac dimensions, and foraminal heights were documented systematically. The study reported L4–L5 as the most commonly stenotic level and observed that mild to moderate stenosis was more frequent than severe narrowing in the evaluated population.

2. Prevalence and Patterns of Lumbar Spinal Canal Stenosis on 3T MRI: A Cross-Sectional University Hospital Study

Nair et al. performed a cross-sectional analysis of 168 lumbar spine MRI examinations conducted in a university hospital setting. Patient demographics, clinical presentations, and MRI parameters were collected using a structured data sheet. All scans were acquired using a 3T MRI unit, and morphometric measurements were performed on both axial and sagittal T2-weighted sequences. The study demonstrated central canal stenosis as the most predominant type, followed by lateral recess narrowing, particularly in individuals above 50 years of age.

3. Retrospective MRI Evaluation of Degenerative Lumbar Canal Stenosis in a Regional Imaging Centre

Khan and colleagues conducted a retrospective review of 250 lumbar spine MRI studies retrieved from a regional hospital's PACS database. Data collection included canal diameter measurements, ligamentum flavum thickness, disc contour evaluation, and facet joint morphology. The study categorised cases into normal, mild, moderate, and severe stenosis using established radiological criteria. Their findings revealed a high prevalence of multilevel and multi-compartment involvement, with many patients showing concurrent central canal and foraminal stenosis, highlighting the multifactorial degenerative process of the lumbar spine.

4. MATERIALS AND METHODS

Study Design and Setting

A retrospective observational study was conducted at MMU Hospital, Mullana (Maharishi Markandeshwar Medical College and Hospital), utilising MRI lumbar spine examinations performed over three months. All data were obtained from the hospital's radiology database and Picture Archiving and Communication System (PACS). The study aimed to perform a detailed anatomical evaluation of the lumbar spinal canal to assess the prevalence, severity, and morphological patterns of lumbar spinal canal stenosis.

Study Population and Data Source

A total of 190 patients who underwent MRI of the lumbar spine or whole-spine screening between September and November 2025 were included. The dataset consisted of demographic information, clinical indications, and complete MRI reports. Of these, 76 patients demonstrated lumbar spinal canal stenosis, while 114 patients showed normal canal morphology. All MRI examinations were retrieved directly from MMU Hospital, Mullana, ensuring consistency in imaging quality and reporting standards.

MRI Protocol

All scans were performed using 3 Tesla MRI systems available in the radiology department. The following standard sequences were included for each patient:

- Sagittal T1-weighted
- Sagittal T2-weighted
- Axial T2-weighted through all lumbar levels
- Optional STIR or T2 fat-suppressed sequences when indicated

The field of view included the L1–S1 region, ensuring complete anatomical assessment of the lumbar canal and neural foramina. Measurements were obtained from both sagittal and axial planes for accuracy.

Data Collection and Anatomical Evaluation

Each MRI report was reviewed for:

- Presence or absence of spinal canal stenosis
- Type of stenosis (central canal, lateral recess, foraminal)
- Number of levels involved
- Level-wise distribution (L1–L2 to L5–S1)
- Severity (mild, moderate, severe), when documented
- Associated degenerative findings (disc bulge, disc desiccation, ligamentum flavum hypertrophy, facet arthropathy, spondylolisthesis)

Demographic details such as age, sex, and clinical symptoms were also recorded.

Inclusion Criteria

- Patients who underwent lumbar spine MRI at MMU Hospital, Mullana
- Patients aged 4–80 years
- MRI studies with complete sequences and interpretable image quality
- Reports clearly documenting lumbar spinal canal morphology
- Both stenosis-positive and normal lumbar spine examinations

Exclusion Criteria

- Incomplete MRI studies or missing sequences
- Poor image quality prevents anatomical evaluation
- Post-operative lumbar spine patients
- Cases with traumatic, infectious, neoplastic, or congenital spinal deformities
- Patients with missing demographic information or incomplete reports

Clinical Distribution

Clinical presentation was extracted from MRI requisition forms and electronic records. The most common presenting complaints were:

- Chronic low-back pain
- Radiating pain or sciatica
- Suspected disc herniation
- Neurogenic claudication
- Lower-limb numbness or weakness
- Screening for degenerative lumbar disease

Patients were divided into two major clinical categories:

1. **Stenosis Group (n = 76)** – Patients exhibiting central canal stenosis, lateral recess narrowing, foraminal stenosis, or multi-compartment involvement.
2. **Normal Group (n = 114)** – Patients with preserved canal dimensions and no evidence of stenotic narrowing.

Ethical Considerations

All data were anonymised before analysis. The study utilised retrospective radiology records from MMU Hospital, Mullana, and complied with institutional norms for patient privacy and data confidentiality. No patient consent was required due to the retrospective nature of the study.

5. RESULTS

A total of 190 MRI examinations performed for lumbar spine evaluation were included. The cohort consisted of 91 males (47.9%) and 99 females (52.1%). The mean age was 45.0 years, with an age range of 4–80 years.

In the present study involving 190 individuals who underwent MRI evaluation of the lumbar spine, 76 patients (40%) demonstrated radiologically confirmed lumbar spinal canal stenosis, whereas 114 patients (60%) showed no detectable narrowing of the spinal canal. This pattern indicates that a significant proportion of the study population exhibited structurally meaningful stenotic changes, underscoring the considerable prevalence of lumbar degenerative alterations in the sampled cohort. The high proportion of stenosis-positive cases also reflects the increasing burden of age-related and biomechanical stress-induced spinal changes within the clinical setting.

Table1: Gender-wise Distribution of Patients

Gender	Percentage	No. Of patients
Male	**47.9%**	**91**
Female	**52.1%**	**99**

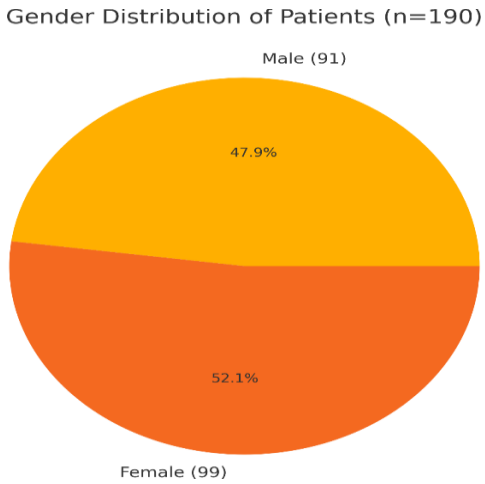


Figure 1. Overall distribution of patients on the basis of gender.

Table 2. Severity-wise distribution of cases.

Severity	Number	Percentage
Mild	65	85.5%
Moderate	3	4%
Severe	8	10.5%

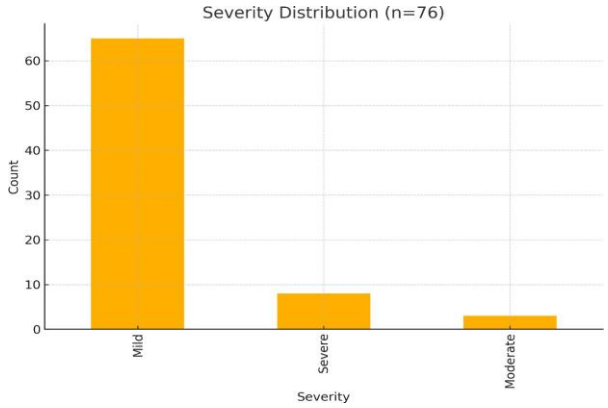


Figure 2. Distribution of Cases based on Severity.

Table 3. Comparison Of Stenosis and Normal Cases.

	STENOSIS	NORMAL
No. Ofpatients	**76**	**114**
Percentage	**40%**	**60%**

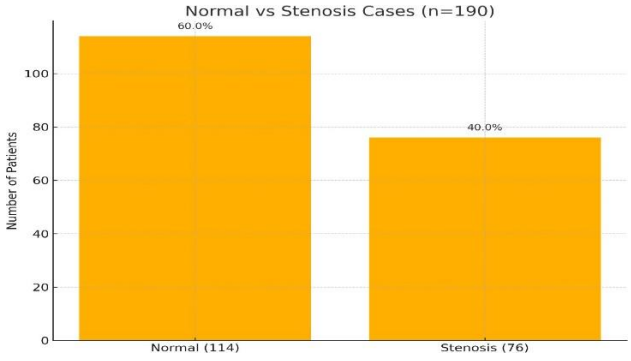


Figure 3. Comparison between normal and stenosis cases.

Table 4. Types Of Stenosis

Type	Count
Central canal	76
Lateral recess	75
Foraminal	56

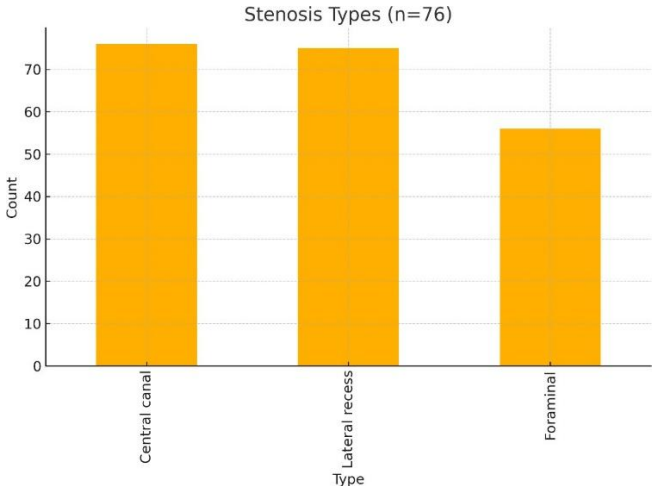


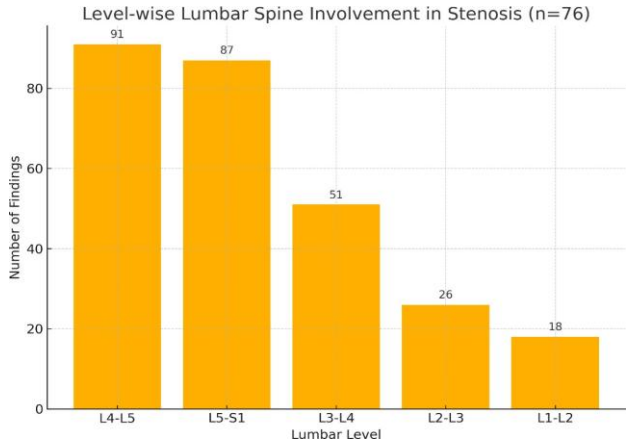
FIGURE 4. Central canal stenosis was the most frequent type, with similar rates of lateral recess stenosis and lower rates of foraminal stenosis. Several patients exhibited multiple stenosis types, resulting in higher overall finding counts.

Table 5. Level-Wise Involvement.

LEVEL	FREQUENCY
L4-L5	Highest involvement
L5-S1	Second highest
L3-L4	Moderate
L2-L3	Low
L1-L2	Least

This distribution reflects the concentration of mechanical stress in the lower lumbar spine.

Figure 5. Showing The Level-Wise Involvement of The Lumbar Spine in Stenosis.



6. DISCUSSION

Lumbar spinal canal stenosis represents a major cause of lower back pain and neurogenic claudication, particularly in middle-aged and elderly populations. In this study, stenosis was

identified in 40% of all evaluated patients, indicating a substantial burden of degenerative spinal disease within the examined cohort. This prevalence aligns with global literature, which reports increasing rates of lumbar stenosis associated with ageing, mechanical stress, and lifestyle changes [1,2]. The predominance of stenosis in the later decades of life reflects cumulative degenerative changes, including disc dehydration, facet arthropathy, ligamentum flavum hypertrophy, and osteophyte formation—each contributing to progressive narrowing of the central canal, lateral recess, or neural foramina [3].

Among the stenosis-positive cases, central canal stenosis emerged as the most frequent morphological pattern, followed closely by lateral recess narrowing and foraminal stenosis. This multi-compartment involvement is consistent with the multifactorial nature of lumbar degeneration, where structural changes rarely occur in isolation. Previous studies have noted that central canal compromise often coexists with lateral recess and foraminal narrowing due to shared degenerative mechanisms, particularly at biomechanically vulnerable levels such as L4–L5 and L5–S1 [4,5]. The level-wise distribution observed in this study showed a clear concentration of pathology at these lower lumbar segments, reinforcing established biomechanical evidence that these levels bear greater axial load and exhibit higher mobility, thus predisposing them to cumulative degenerative insult [6].

Stenosis severity analysis demonstrated that mild stenosis formed the majority of cases with documented grading, while severe stenosis accounted for a smaller but clinically meaningful subset. This trend may reflect the increasing use of MRI for early evaluation of back pain, resulting in higher detection of early-stage degenerative narrowing. Additionally, the lack of direct correlation between age and severity noted in this study is consistent with earlier findings suggesting that symptom severity and radiological severity do not always progress in parallel, and that individual anatomical variability plays a significant role in determining clinical manifestations [7].

The presence of a substantial number of normal MRI examinations (60% of the cohort) underscores the importance of appropriate clinical–radiological correlation. Several studies emphasise that mild degenerative changes or minimal stenosis may be present even in asymptomatic individuals, and that MRI findings should be interpreted within the context of clinical presentation rather than in isolation [8]. This highlights the diagnostic value of anatomical evaluation but also reinforces caution against over-reliance on imaging without consideration of clinical relevance.

Overall, the study supports the role of high-resolution MRI as the primary imaging modality for evaluating lumbar spinal canal stenosis. MRI enables direct visualisation of the thecal sac, neural elements, and degenerative structures, allowing comprehensive assessment of canal dimensions and stenosis morphology. The detailed anatomical insights provided by MRI enhance diagnostic accuracy, aid in treatment selection, and support prognostic evaluation in patients presenting with lumbar spine symptoms. The findings of this study contribute valuable regional data on stenosis prevalence, level-wise involvement, and morphological patterns, and may assist clinicians in refining diagnostic thresholds and tailoring patient management strategies.

7. CONCLUSION

This study provides a detailed MRI-based assessment of lumbar spinal canal stenosis in a cohort of 190 patients, among whom 76 demonstrated lumbar spinal canal stenosis. Central canal stenosis emerged as the most frequent finding, with the L4–L5 and L5–S1 levels showing the highest involvement, reflecting the biomechanical vulnerability of the lower lumbar segments. Most stenosis cases were mild, indicating early-stage degenerative changes as the predominant presentation in this population. The study underscores the value of MRI in accurately identifying canal narrowing, characterising stenosis patterns, and supporting clinical decision-making. These findings contribute region-specific data that may assist in improving diagnostic accuracy and guiding future research on lumbar spinal canal stenosis.

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