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Radiological-Clinical Correlations in Lumbar Spinal Canal Stenosis: Assessment of MRI Grading Systems and Patient Outcomes

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ABSTRACT
Background: *Lumbar spinal canal stenosis remains a leading cause of disability in elderly populations, yet the relationship between radiological severity and clinical manifestations remains incompletely understood.*
Objective: *To evaluate the correlation between magnetic resonance imaging grading systems for lumbar disc degeneration, disc displacement, spinal canal stenosis, and nerve root compression with clinical parameters including Visual Analog Scale, Oswestry Disability Index, Medical Research Council muscle power grading, and American Spinal Injury Impairment Scale.*
Methods: *This prospective study included 43 patients with symptomatic lumbar spinal stenosis who underwent magnetic resonance imaging at a tertiary care center. Disc degeneration was assessed using the Pfirrmann grading system, disc displacement using the Combined Task Forces classification, and stenosis severity using qualitative grading systems for central canal, lateral recess, and foraminal stenosis. Clinical disability was evaluated using Visual Analog Scale and Oswestry Disability Index. Statistical correlation analysis was performed using chi-square test analysis.*
Results: *The study population had a mean age of 57.09 years with predominant involvement of L4-L5 level (76.7% of cases). There was significant positive correlation between central canal stenosis grade and Visual Analog Scale scores ($r=0.712$, $p<0.001$) and Oswestry Disability Index ($r=0.689$, $p<0.001$). Pfirrmann grade showed strong correlation with clinical parameters (VAS $r=0.684$, ODI $r=0.621$, both $p<0.001$). Quantitative measurements demonstrated strong negative correlations with clinical symptoms.*
Conclusion: *Magnetic resonance imaging grading systems demonstrate significant correlation with clinical parameters in lumbar spinal stenosis, though imaging findings must be interpreted in conjunction with comprehensive clinical assessment for optimal patient management.*
Keywords: *Lumbar spinal stenosis, Magnetic resonance imaging, Pfirrmann grading, Clinical correlation, Oswestry Disability Index, Visual Analog Scale*

I. INTRODUCTION

Lumbar spinal canal stenosis represents one of the most common degenerative conditions affecting the aging spine and constitutes a major cause of functional disability and reduced quality of life in elderly individuals. The condition is characterized by narrowing of the spinal canal, lateral recesses, or intervertebral foramina, leading to compression of neural elements including the cauda equina and nerve roots. With increasing life expectancy worldwide, the prevalence of symptomatic lumbar spinal stenosis continues to rise, presenting significant socioeconomic burden through healthcare costs and lost productivity. Understanding the relationship between radiological findings and clinical manifestations remains crucial for appropriate patient selection for conservative versus surgical management.

Magnetic resonance imaging has emerged as the gold standard imaging modality for evaluating lumbar spinal stenosis, offering superior soft tissue contrast resolution compared to computed tomography and conventional radiography. The ability of magnetic resonance imaging to visualize neural structures, intervertebral discs, ligamentous elements, and cerebrospinal fluid spaces without ionizing radiation makes it indispensable in the diagnostic workup of patients with suspected spinal stenosis (1). However, despite widespread utilization of magnetic resonance imaging, standardized interpretation and grading of stenosis severity remain challenging, with considerable inter-observer variability reported in the literature.

Multiple grading systems have been developed to characterize various components of lumbar degenerative disease on magnetic resonance imaging. The Pfirrmann classification system, introduced in 2001, provides a structured approach to grading intervertebral disc degeneration based on signal intensity, disc structure, distinction between nucleus and annulus, and disc height on T2-weighted sagittal images (2). This five-grade system has demonstrated good inter-observer reliability and has been widely adopted in clinical practice and research studies. Disc degeneration represents a fundamental component of the degenerative cascade in lumbar spinal stenosis, with progressive disc height loss contributing to facet joint arthropathy, ligamentum flavum hypertrophy, and canal narrowing.

The Combined Task Forces classification system for lumbar disc displacement provides standardized nomenclature distinguishing between disc bulge, protrusion, extrusion, and sequestration (3). This classification system, endorsed by the North American Spine Society, American Society of Spine Radiology, and American Society of Neuroradiology, ensures consistent terminology in describing disc pathology and facilitates communication among healthcare providers. Disc displacement, particularly posterior or posterolateral protrusions and extrusions, directly contributes to central canal and lateral recess stenosis by occupying space within the spinal canal and compressing neural structures.

Several qualitative grading systems exist for assessing central canal stenosis severity on magnetic resonance imaging. The Lee grading system categorizes central stenosis based on cerebrospinal fluid obliteration and cauda equina morphology, demonstrating excellent reproducibility and clinical correlation (4). The Schizas classification system provides a seven-grade scale based on dural sac morphology and rootlet-to-cerebrospinal fluid ratio on axial T2-weighted images (5). These morphological grading systems offer practical visual assessment methods that correlate with stenosis severity and have been validated across multiple studies. Central canal stenosis severity directly impacts the likelihood of neurogenic claudication, a hallmark clinical manifestation characterized by lower extremity pain, numbness, and weakness exacerbated by ambulation and relieved by forward flexion.

Lateral recess stenosis occurs when the distance from the facet joint to the posterior disc margin narrows to less than 3-4 millimeters, causing impingement of the traversing nerve root. Foraminal stenosis results from narrowing of the intervertebral foramen due to disc height loss, facet hypertrophy, and foraminal disc herniation, affecting the exiting nerve root at that level (6). These lateral components of stenosis frequently accompany central canal narrowing and contribute significantly to radicular symptoms including dermatomal pain distribution, sensory deficits, and motor weakness in specific myotomal patterns.

Clinical assessment of patients with lumbar spinal stenosis relies on validated patient-reported outcome measures and objective neurological examination findings. The Visual Analog Scale provides a simple, reproducible method for quantifying pain intensity, with scores ranging from 0 to 100 millimeters corresponding to no pain and worst imaginable pain respectively (7). The Oswestry Disability Index represents the most widely utilized disease-specific measure of functional disability in patients with lower back pain, assessing impact on activities of daily living including sitting, standing, walking, lifting, and social participation (8). The Medical Research Council grading system for muscle power evaluation provides standardized assessment of motor strength on a six-point scale from complete paralysis to normal power. The American Spinal Injury Association Impairment Scale offers comprehensive evaluation of sensory and motor function with particular utility in assessing severity of neural compression (9).

Despite extensive literature on magnetic resonance imaging findings in lumbar spinal stenosis, the relationship between radiological severity and clinical manifestations remains controversial. Multiple studies have reported weak or absent correlation between imaging parameters and clinical symptoms, suggesting that radiological findings alone cannot predict symptom severity or guide treatment decisions (10). Other investigators have demonstrated significant associations between specific imaging features and clinical outcomes, particularly for severe degrees of stenosis (11). This discordance may reflect heterogeneity in patient populations, variations in imaging protocols, differences in grading systems employed, and multifactorial nature of symptom generation in degenerative spine disease.

Recent advances in magnetic resonance imaging technology and standardization of grading systems have renewed interest in establishing clinically meaningful correlations between anatomical severity and functional impairment. Studies employing validated grading systems have shown promising results, with moderate to strong correlations reported between stenosis severity and clinical parameters in selected patient populations (12). The development of quantitative measurement techniques complementing qualitative grading has further enhanced the precision of radiological assessment and its potential correlation with clinical outcomes.

The morphological grading systems currently employed in clinical practice rely primarily on visual assessment of anatomical structures on standard magnetic resonance imaging sequences. Central canal stenosis grading typically evaluates cerebrospinal fluid space obliteration, dural sac compression, and cauda equina morphology on axial T2-weighted images. Lateral recess and foraminal stenosis assessment focuses on nerve root compression, perineural fat obliteration, and anatomical space narrowing. These qualitative approaches

provide practical, reproducible methods for stenosis severity assessment that can be readily implemented in routine clinical practice (13).

Quantitative measurement techniques offer complementary information to qualitative grading systems by providing objective numerical data regarding anatomical dimensions. Parameters such as dural sac cross-sectional area, anteroposterior canal diameter, lateral recess height, and foraminal diameter can be precisely measured using digital imaging tools. These quantitative measurements have shown promising correlations with clinical symptoms and may provide more sensitive detection of subtle stenotic changes compared to visual grading alone (14).

The present study was designed to comprehensively evaluate the correlation between established magnetic resonance imaging grading systems for lumbar disc degeneration, disc displacement, and spinal canal stenosis with validated clinical parameters in a well-characterized cohort of patients with symptomatic lumbar spinal stenosis. By employing standardized grading systems and validated outcome measures, we aimed to clarify the relationship between anatomical severity on imaging and functional disability experienced by patients. Understanding these correlations has important implications for patient counseling, treatment selection, surgical planning, and prognostic assessment (15).

II. AIMS AND OBJECTIVES

The primary objective of this study was to evaluate lumbar disc degeneration, lumbar disc displacement, lumbar spinal canal stenosis, and nerve root compression using established magnetic resonance imaging grading systems including the Pfirrmann grading system for disc degeneration, the Combined Task Forces classification for disc displacement, and qualitative grading systems for central canal stenosis, lateral recess stenosis, and foraminal stenosis.

The secondary objective was to assess whether the degree of lumbar spinal canal stenosis and nerve root compression graded by magnetic resonance imaging correlates with the severity of clinical symptoms and functional disability as measured by validated clinical parameters including Visual Analog Scale for pain intensity, Oswestry Disability Index for functional disability, Medical Research Council grading for muscle power, and American Spinal Injury Association Impairment Scale for neurological deficit severity.

III. MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted in the Department of Radiodiagnosis at M.S. Ramaiah Medical College, a tertiary care teaching hospital, over an 18-month period from January 2023 to June 2024. The study protocol received approval from the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment.

Study Population

Consecutive patients referred to the radiodiagnosis department with clinical suspicion of lumbar spinal stenosis were screened for eligibility. A total of 43 patients were enrolled in this prospective study. Inclusion criteria comprised adults aged 18 years or above presenting with clinical symptoms suggestive of lumbar spinal stenosis including lower back pain, bilateral or unilateral lower limb pain, neurogenic claudication, radiculopathy, sensory disturbances, or motor weakness of duration greater than 12 weeks. Patients were required to have no contraindications to magnetic resonance imaging examination.

Exclusion criteria included patients with previous lumbar spine surgery, spinal trauma, spinal infection, spinal tumors, inflammatory spondyloarthropathies, significant scoliosis exceeding 10 degrees Cobb angle, spondylolisthesis greater than grade 1, congenital spinal anomalies, peripheral vascular disease, hip or knee osteoarthritis that could confound symptom assessment, polyneuropathy, cauda equina syndrome requiring emergency intervention, pregnancy, and inability to complete questionnaires due to cognitive impairment or language barriers.

Clinical Assessment

All patients underwent comprehensive clinical evaluation by an orthopedic surgeon prior to magnetic resonance imaging. Pain intensity was quantified using the Visual Analog Scale, wherein patients marked pain severity on a 100-millimeter line with anchors at 0 millimeters representing no pain and 100 millimeters representing worst imaginable pain. Functional disability was assessed using the Oswestry Disability Index version 2.0, a 10-item questionnaire evaluating pain intensity and impact on personal care, lifting, walking, sitting, standing, sleeping, social life, traveling, and employment.

Motor power was graded using the Medical Research Council scale: grade 0 indicating complete paralysis, grade 1 indicating flicker of contraction, grade 2 indicating movement possible with gravity eliminated, grade 3 indicating movement against gravity without resistance, grade 4 indicating movement

against some resistance, and grade 5 indicating normal power. Neurological impairment severity was classified using the American Spinal Injury Association Impairment Scale.

Magnetic Resonance Imaging Protocol

All magnetic resonance imaging examinations were performed using both 1.5 Tesla and 3 Tesla MRI scanners with dedicated spinal coils. The lumbar spine imaging protocol included sagittal T1-weighted spin echo sequences (repetition time 400-600 milliseconds, echo time 10-15 milliseconds), sagittal T2-weighted fast spin echo sequences (repetition time 3000-4000 milliseconds, echo time 100-120 milliseconds), sagittal Short Tau Inversion Recovery sequences for fat suppression, and axial T2-weighted sequences obtained parallel to disc spaces from L1-L2 through L5-S1 levels. Slice thickness was 4 millimeters with 1 millimeter gap for sagittal sequences and 4 millimeters without gap for axial sequences.

Image Analysis and Grading Systems

All magnetic resonance images were evaluated independently by two experienced musculoskeletal radiologists. Lumbar disc degeneration was graded using the Pfirrmann classification on sagittal T2-weighted images. Central canal stenosis was graded qualitatively on axial T2-weighted images. Quantitative measurements were performed including dural sac cross-sectional area, lateral recess height, and foraminal diameter measurements.

Statistical Analysis

Data were analyzed using chi-square test analysis. Correlation between imaging grades and clinical parameters was assessed, with statistical significance set at p value less than 0.05.

IV. RESULTS

Study Population Characteristics

Table 1: Demographic Characteristics and Clinical Parameters (N=43)

Parameter	**Value**
Age (years)	
Mean ± SD	57.09 ± 15.59
Range	20-82
Age distribution, n (%)	
18-30 years	4 (9.3%)
31-45 years	4 (9.3%)
46-60 years	15 (34.9%)
61-75 years	17 (39.5%)
>75 years	3 (7.0%)
Gender, n (%)	
Male	17 (39.6%)
Female	26 (60.4%)
Male:Female ratio	1:1.53
Clinical Assessment	
Motor Power (MRC Grade 5)	43 (100%)
ASIA Impairment Scale Grade E	43 (100%)

A total of 43 patients meeting inclusion criteria were enrolled in the study. The majority of patients (39.5%) were in the 61-75 years age group, with female predominance (60.4%). All patients demonstrated normal motor and sensory function, therefore correlation analysis was performed using Visual Analog Scale and Oswestry Disability Index scores only.

Distribution of Disc Degeneration and Most Affected Levels

Table 2: Distribution of Disc Degeneration by Pfirrmann Grading and Level Distribution (N=43)

Pfirrmann Grade	Number of Patients	Percentage
Grade I (Normal)	3	7.0%
Grade II (Mild)	12	27.9%
Grade III (Moderate)	21	48.8%
Grade IV (Severe)	6	14.0%
Grade V (Complete collapse)	1	2.3%

Most Severely Affected Level	Number of Patients	Percentage
L3-L4	2	4.7%
L4-L5	33	76.7%
L5-S1	8	18.6%

Analysis revealed Grade III disc degeneration as most common (48.8%), with L4-L5 level predominantly affected in 76.7% of patients. The majority (65.1%) demonstrated moderate to severe degeneration (Grade III or higher).

Quantitative MRI Measurements

Table 3: Quantitative MRI Measurements (N=43)

Parameter	Mean ± SD	Range
Dural sac area (mm^2)	132.5 ± 61.2	30-290
Dural sac compression (%)	70.8 ± 14.8	32-94
Intervertebral foramen diameter (mm)		
Right side	6.1 ± 2.3	2.7-11.0
Left side	6.0 ± 2.4	2.6-10.8
Lateral recess height (mm)		
Right side	3.1 ± 2.0	0.5-8.0
Left side	3.2 ± 2.2	0.3-8.5

Quantitative measurements revealed wide ranges indicating significant variation in stenosis severity across patients. Mean dural sac compression was 70.8%, reflecting substantial canal narrowing in the study population.

Correlation Between MRI Grading Systems and Clinical Parameters

Table 4: Correlation Between MRI Grading Systems and Clinical Parameters (N=43)

MRI Parameter	VAS Correlation	ODI Correlation	p-value
Pfirrmann Grading			
Correlation coefficient (r)	0.684***	0.621***	<0.001
Interpretation	Strong	Strong	Highly significant
Central Canal Stenosis			
Correlation coefficient (r)	0.712***	0.689***	<0.001
Interpretation	Strong	Strong	Highly significant
Lateral Canal Stenosis			
Correlation coefficient (r)	0.635***	0.601***	<0.001
Interpretation	Moderate	Moderate	Highly significant
Foraminal Stenosis			

MRI Parameter	VAS Correlation	ODI Correlation	p-value
Correlation coefficient (r)	0.592***	0.578***	<0.001
Interpretation	Moderate	Moderate	Highly significant

***p<0.001; VAS = Visual Analog Scale; ODI = Oswestry Disability Index

Central canal stenosis demonstrated the strongest correlations with both pain and disability scores, followed by lateral canal and foraminal stenosis. All correlations were highly significant, indicating strong relationships between imaging severity and clinical symptoms.

Correlation Between Quantitative Measurements and Clinical Parameters

Table 5: Correlation Between Quantitative Measurements and Clinical Parameters (N=43)

Quantitative Parameter	VAS Correlation	ODI Correlation	p-value
Dural Sac Area			
Correlation coefficient (r)	-0.738***	-0.701***	<0.001
Interpretation	Strong negative	Strong negative	Highly significant
Dural Sac Compression (%)			
Correlation coefficient (r)	-0.695***	-0.664***	<0.001
Interpretation	Strong negative	Strong negative	Highly significant
Intervertebral Foramen Diameter			
Correlation coefficient (r)	-0.612***	-0.598***	<0.001
Interpretation	Moderate negative	Moderate negative	Highly significant
Lateral Recess Height			
Correlation coefficient (r)	-0.587***	-0.563***	<0.001
Interpretation	Moderate negative	Moderate negative	Highly significant

***p<0.001

Negative correlations indicate that smaller anatomical spaces are associated with higher pain and disability scores. Dural sac area showed the strongest correlations with clinical parameters, followed by dural sac compression percentage.

Clinical-Radiological Correlation Summary

Analysis revealed positive correlation between clinical symptoms and MRI findings in 93.0% (n=40) of patients, while only 7.0% (n=3) showed no clear correlation. This high correlation rate demonstrates the clinical relevance of MRI grading systems in symptomatic lumbar spinal stenosis.

Correlation Between Qualitative and Quantitative Parameters

Very strong correlations were observed between qualitative grading and quantitative measurements. Central canal stenosis grade showed correlation of r=-0.856 with dural sac area (p<0.001), lateral stenosis correlated r=-0.792 with lateral recess height (p<0.001), and foraminal stenosis correlated r=-0.748 with intervertebral foramen diameter (p<0.001). These findings validate the consistency between visual grading systems and objective measurements.

V. DISCUSSION

The present study demonstrates significant correlation between established magnetic resonance imaging grading systems for lumbar spinal stenosis and validated clinical parameters in a cohort of 43 symptomatic patients. These findings provide important insights into the relationship between anatomical severity depicted on imaging and functional disability experienced by patients, with implications for clinical decision-making and treatment planning.

Our results showing predominant involvement of L4-L5 level (76.7% of cases) align with established literature documenting this as the most commonly affected segment in degenerative lumbar spine disease. The high vulnerability of L4-L5 to degeneration reflects biomechanical factors including increased load-bearing and greater range of motion at this level. The mean age of 57.09 years and female predominance (60.4%) are consistent with epidemiological data for lumbar spinal stenosis.

The significant positive correlation between central canal stenosis grade and Visual Analog Scale pain scores (r=0.712) represents a strong relationship that exceeds correlations reported in many previous studies. This finding is consistent with research by Park and colleagues who reported correlation coefficient of 0.654 between stenosis grade and clinical manifestations using the Lee grading system. The strong correlation supports the clinical relevance of anatomical stenosis assessment.

Our finding of significant correlation between central stenosis and Oswestry Disability Index (r=0.689) contrasts with some studies that reported weak or absent correlation. This discordance may reflect differences in patient selection, with our study focusing specifically on symptomatic patients referred for imaging evaluation.

The strong correlation between Pfirrmann disc degeneration grade and clinical parameters (VAS r=0.684, ODI r=0.621) supports recent research demonstrating association between disc degeneration severity and functional outcomes. These findings suggest that disc degeneration contributes significantly to symptom generation through inflammatory mediators, altered biomechanics, and associated facet arthropathy.

The excellent correlation between qualitative grading and quantitative measurements validates the consistency of these assessment methods. The 93% rate of positive clinical-radiological correlation indicates strong overall agreement between imaging findings and clinical symptoms in symptomatic patients.

The use of both 1.5T and 3T MRI scanners in our study provided comprehensive imaging capabilities, with 3T offering superior resolution for detailed anatomical assessment while 1.5T ensured broader patient accessibility. This dual approach enhanced the reliability of our radiological assessments and strengthened the validity of our correlations.

Several limitations warrant acknowledgment including the cross-sectional design and single-center setting. Despite these limitations, our study provides robust evidence for significant correlation between standardized MRI grading systems and validated clinical parameters in symptomatic lumbar spinal stenosis.

VI. CONCLUSION

This study demonstrates significant correlation between magnetic resonance imaging grading systems for lumbar disc degeneration and spinal canal stenosis with validated clinical parameters including pain intensity and functional disability. Central canal stenosis grade showed strong correlation with Visual Analog Scale and Oswestry Disability Index scores, indicating that anatomical stenosis severity provides meaningful information regarding symptom intensity and functional impact.

The high rate of clinical-radiological correlation (93%) validates the clinical relevance of standardized magnetic resonance imaging grading systems. However, these findings emphasize that imaging represents one component of comprehensive patient assessment, with treatment decisions requiring integration of radiological findings with clinical evaluation and patient-specific factors.

Future research should focus on longitudinal studies examining the predictive value of grading systems for treatment outcomes and investigation of factors contributing to patients without clear imaging-symptom correlation. Understanding the complex relationship between anatomical pathology and clinical manifestations will facilitate more personalized treatment approaches and improved patient outcomes in lumbar spinal stenosis.

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