

Research Article

Radiological Spinal Canal Diameter as a Predictor of Surgical Outcome in Lumbar Canal Stenosis

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ABSTRACT

Background: Lumbar canal stenosis (LCS) is a degenerative disorder that is a frequent cause of neurogenic claudication and functional impairment. Radiological evaluation of the patient preoperatively might be an indicator of success in the surgery, especially the spinal canal diameter.

Objective: To assess the importance of the radiological spinal canal diameter as one of the predictors of postoperative outcomes in patients on lumbar decompression surgery.

Methods: The study was done as a cross-sectional study at Neurosurgery and Radiology Department of Punjab Institute of Neuroscience, Lahore from December 2024 to May 2025. 196 patients with confirmed degenerative LCS. Preoperative MRI was carried out on patients to measure the anteroposterior spinal canal diameter. The evaluation of postoperative outcomes was done by the Visual Analog Scale (VAS) and Oswestry Disability Index (ODI). The Chi-square tests were used to analyze the data with the help of SPSS 24.

Results: The median canal diameter was 9.8 ± 1.6 mm. Surgical success (minimal improvement in ODI of at least 50% percent) occurred in 77.6% of the patients. The canal diameters were found to be significantly related to the postsurgery pain and worse functional recovery ($p < 0.001$). The patients with mild stenosis had better success in surgery (86.2%), moderate (78.4%), and severe (63.4%) stenosis.

Conclusion: Preoperative spinal canal is an important predictor of the outcome of surgery in LCS. Proper radiological evaluation will help in surgical planning, better patient counseling, and higher recovery post-surgery.

Keywords: Lumbar Canal Stenosis, Spinal Canal Diameter, Decompression Surgery, Surgical Outcome.

INTRODUCTION

Lumbar canal stenosis (LCS) is a degenerative condition of the spine that is characterized by the acuity of the canal, indicating that it may trigger the compression of the elements of the neural canal, resulting in neurogenic claudication, radicular pain, and functional limitation.[1] LCS is more common with age, with an estimated one out of five persons who are more than 50 years of age and one out of every three persons who is above 70 years of

age having LCS, and thus is a big contributor to morbidity among the elderly.[2] The initial causes of gradual lumbar canal constriction are degenerative changes of the intervertebral disc, enlargement of the ligamentum flavum, and osteoarthritis of the facet joints.[3]

Lumbar canal stenosis is degenerative, and it involves a significant economic impact because of the costs incurred on healthcare services and productivity.[4] A range of symptoms is seen in the presentation of patients, from mild

intermittent back pains to severe neurogenic claudication, which restricts ambulation.[5] Clinical evaluation and radiological imaging are used in the diagnosis of the spinal canal being examined, and MRI is regarded as the gold standard of this diagnosis in measuring the spinal canal dimensions, compression of the nerve roots, and degenerative alterations.[6, 7] In several studies, it has been shown that although radiological results are usually associated with the extent of symptoms, great variation exists in this respect, and some individuals may have a pronounced radiological stenosis but remain the reportedly asymptomatic ones.[6, 8] This gap is what highlights the necessity of more specific predictors of surgical outcomes, as opposed to clinical assessment.

The ultimate treatment of symptomatic LCS patients who fail to respond to conservative interventions remains surgical decompression.[9] Nevertheless, the results may vary greatly in relation to full recovery of the symptoms to continuing pain and disability following surgery. Radiological examination, specifically measurement of the spinal canal size by use of magnetic resonance imaging (MRI) or computed tomography (CT), is a quantitative measure that could be correlated with clinical severity and inform surgical decision-making.[10, 11] It has been hypothesized that a smaller canal diameter can also be linked with more severe symptoms, but the predictive usefulness of preoperative canal diameter on postoperative outcomes has not been established, and the results between the literature have been inconsistent.[12]

The correlation between the radiological spinal canal size and surgical outcome requires understanding, which is essential in preoperative planning, patient education, and resource optimization. In case there is a valid correlation, clinicians would be more capable of determining which patients would be more receptive to surgical decompression and establishing appropriate expectations of recovery. The research question that was to be answered in this study was whether the lumbar spinal canal diameter as a radiological measurement could predict the outcome of surgery in patients undergoing decompression surgery for lumbar canal stenosis.

METHODOLOGY

This research has been carried out as a cross-sectional observational study to determine the significance of radiological spinal canal

diameter as an indicator of surgical outcome in patients with lumbar canal stenosis. The experiment was conducted in the Neurosurgery and Radiology Department of Punjab Institute of Neuroscience, Lahore from December 2024 to May 2025. Informed consent was sought, and ethical approval by the institutional review board was secured before all the participants were enrolled.

The OpenEpi, Version 3, was used to calculate the sample size, with a 95% confidence level, 5% margin of error, and a predicted prevalence of 50% of the lumbar canal stenosis of success in patients, which gives a required sample size of 196 patients.[13] The research utilized simple random sampling to select the group of patients to include in the study sample out of all the patients scheduled to undergo lumbar decompression surgery within the study period. The study population comprised of patients with known degenerative lumbar canal stenosis on MRI aged 40-80 years, who were to undergo elective decompression surgery and had given informed consent to the study. The patients whose lumbar spine had undergone previous surgery, trauma to the spine, spinal tumor or spinal infection, congenital spinal defects, or severe comorbidities that did not permit surgery were not included in the study.

The structured proforma was used to collect the data. Demographic data, clinical history, and preoperative neurological examination were taken. A review of preoperative MRI scans was made to determine the anteroposterior lumbar spinal canal at the level with the highest stenosis through conventional radiological methods. They were performed by trained neurosurgeons, and the outcomes at 6 weeks and 3 months were measured using validated outcome measures, such as pain relief, perceived functional improvement, and neurological recovery. The data collection method guaranteed patient confidentiality and adherence to standard measures of reliability in measurements.

All of the statistical analysis was conducted using SPSS version 24. The Shapiro- Wilk test was used to test the normality of continuous variables such as spinal canal diameter, age, preoperative pain scores, and postoperative functional scores. The descriptive statistics were reported using mean \pm standard deviation as the statistic of normally distributed continuous variables and median and interquartile range for non-normally distributed variables. Categorical variables such as gender, comorbidity, and stenosis severity were

explained in the form of frequencies and percentages. Pearson correlation was used to test how spinal canal diameter was related to the postoperative outcomes, and chi-square tests were used to examine the relationships that exist between categorical variables and surgical success. Continuous outcomes were compared between groups using independent t-tests. The statistically significant p-value was taken to be less than 0.05.

RESULTS

There were 196 patients with lumbar canal stenosis who participated. The average age of

the participants was 62.5 ± 8.4 years, with a somewhat more substantial number of males 57.1% than females, 42.9%. The prevalence of common comorbidities was hypertension (39.8%), diabetes mellitus (22.9%), and 9.2% patients had both. The average preoperative pain level estimated by the Visual Analog Scale (VAS) was 7.6 ± 1.2, and the average preoperative functional disability rate estimated by the Oswestry Disability Index (ODI) was 52.3 ± 10.5, which was a moderate-severe level of functional disability before surgery (Table 1).

Table 1. Demographic and Clinical Characteristics of Patients (n = 196)

Variable	n (%) or Mean ± SD
Age (years)	62.5 ± 8.4
Gender	
Male	112 (57.1)
Female	84 (42.9)
Comorbidities	
Hypertension	78 (39.8)
Diabetes Mellitus	45 (22.9)
Both	18 (9.2)
Preoperative Pain Score (VAS 0–10)	7.6 ± 1.2
Preoperative Functional Score (Oswestry Disability Index, 0–100)	52.3 ± 10.5

Radiological analysis showed that the average anteroposterior spinal canal diameter at the stenosis most critical was 9.8 mm on average and 1.6 mm in standard error. According to the measured canal diameter, 29.6% of the patients had mild stenosis (10mm-12mm),

49.5% moderate stenosis (7mm-9mm), and 20.9% severe stenosis (less than 7mm). In terms of stenosis, 61.7% of patients had single-level stenosis, and 38.3% had multilevel involvement (Table 2).

Table 2. Radiological Characteristics

Variable	Mean ± SD or n (%)
Spinal Canal Diameter (mm)	9.8 ± 1.6
Severity of Stenosis	
Mild (10–12 mm)	58 (29.6)
Moderate (7–9 mm)	97 (49.5)
Severe (<7 mm)	41 (20.9)
Levels of Stenosis	
Single level	121 (61.7)
Multiple levels	75 (38.3)

At the three-month post evaluation, the clinical outcomes improved significantly. The average postoperative pain scale was reduced to 2.9 ± 1.1, and the average ODI was 22.4 ± 8.7, which indicated significant functional recovery. In

total, 152 patients (77.6%), met the definition of surgical success, which was 50% improvement in ODI, and 44 patients (22.4%), remained with persistent symptoms (Table 3).

Table 3. Postoperative Outcomes at 3 Months

Outcome	Mean ± SD or n (%)
Pain Score (VAS 0–10)	2.9 ± 1.1
Functional Score (ODI 0–100)	22.4 ± 8.7

Surgical Success ($\geq 50\%$ improvement in ODI)	152 (77.6)
Persistent Symptoms	44 (22.4)

The analysis of correlation showed that the diameter of the spinal canal and the postoperative outcomes have a significant negative correlation. The bigger the canal diameter, the lower the postoperative pain scores ($p < 0.001$) and the higher the score on

functional improvement ($p < 0.001$). Further, the level of stenosis was also an important predictor of the success of surgery, and those with mild stenosis were more likely to record good results than those with severe stenosis ($p = 0.001$) (Table 4).

Table 4. Correlation between Spinal Canal Diameter and Postoperative Outcome

Variable	Correlation Coefficient (r)	p-value
Spinal Canal Diameter vs. Postoperative Pain Score	-0.52	<0.001
Spinal Canal Diameter vs. Postoperative Functional Score	-0.48	<0.001
Severity of Stenosis vs. Surgical Success	$\chi^2 = 15.6$	0.001

Further comparison of the results according to the severity of stenosis demonstrated that patients with mild stenosis reported lower postoperative pain (2.5 ± 0.9) and functional scores (19.8 ± 7.5) than signals on moderate and severe stenosis. The success rates of surgery decreased with the severity of stenosis;

in mild stenosis, 86.2% of the stenosis were successful, in moderate stenosis, 78.4% of the stenosis were successful, and in severe stenosis, 63.4% of the stenosis were successful, which suggests that the canal diameter could be a useful predictor of postoperative recovery (Table 5).

Table 5. Comparison of Outcomes Based on Severity of Stenosis

Severity of Stenosis	Pain Score (VAS) Mean \pm SD	Functional Score (ODI) Mean \pm SD	Surgical Success n (%)
Mild	2.5 ± 0.9	19.8 ± 7.5	50 (86.2)
Moderate	3.0 ± 1.1	22.5 ± 8.3	76 (78.4)
Severe	3.6 ± 1.2	27.1 ± 9.2	26 (63.4)

DISCUSSION

The results of our study indicate a strong relationship between a smaller preoperative spinal canal diameter and worse postoperative outcome at 3-month follow-up in both pain and functional status in 196 patients with degenerative lumbar canal stenosis (LCS). The increased canal diameter was associated with an increase in VAS and ODI scores, and surgical success was higher among patients who had mild stenosis than those with severe narrowing. This is in line with the idea that the severity of radiological stenosis may affect clinical outcome following decompression surgery.

Even though the extent of research on anteroposterior (AP) diameter as a predictor of surgical outcome has not been conducted directly, previous studies have indicated the significance of proper quantitative measurement of canal dimensions. An example is in a study that focused on 2025 and highlighted that MRI scales down the lumbar spinal canal cross-sectional area relative to CT imaging, especially in severe stenosis, which

may impact the decision-making and postoperative anticipation when MRI captured diameters are exclusively used.[14] This confirms that accurate radiological evaluation is important in outcome prediction, an observation that is supported by our results that radiological severity was associated with postoperative recovery.

It is also possible to demonstrate through advanced decompression procedures how canal size changes can correlate with clinical outcomes. The author found significant postoperative changes in the spinal canal area and a positive change in the pain and functional scores in patients who underwent extreme lateral interbody fusion (XLIF) in a study conducted on patients in 2025.[15] This research explored the concept of indirect decompression, but instead of preoperative, the authors focused on postoperative diameters; yet this study confirms the hypothesis that the greater the increase in canal size post-surgery, the greater the clinical outcome.

A recent retrospective study of dynamic stenosis and the shortcomings of MRI showed that stenosis severity might be underestimated on up to 10% of occasions with conventional supine MRI compared with myelographic testing.[16] This implies that traditional imaging is not necessarily a complete measure of anatomical constriction- perhaps explaining some instances in which radiological severity was not an outcome predictor in isolation- a fact which is consistent with related concerns about imaging and operative planning.

Our findings are also consistent with the current studies on predictive modeling that focus on detailed radiological feature analysis. As an example, machine learning models have been designed to predict the levels of decompression needed in LCS based on radiomic features of CT myelography, which demonstrates that more detailed measures of imaging (e.g., radiomic features) can be used to enhance surgical decisions.[17] Although these superior models go beyond traditional diameter measurements, it highlights the new trend of using complex radiology data to predict the outcome of surgery.

The idea that a smaller AP canal diameter is connected with anatomic and clinical severity is supported by other literature. In 2024, a large prospective MRI study found that smaller AP diameter, anatomical alterations of redundant nerve roots, combined with several level stenosis and epidural fat thickening, were associated with anatomic changes, which are usually predictive of poorer clinical presentation and poorer outcomes unless surgically removed.[18] Although this research did not directly compare the outcomes of the postoperative period, it highlights the importance of radiological markers of severity as being indicative of underlying pathology that influences recovery.

The predictive factors of symptomatic degenerative LCS, as investigated by machine learning research has indicated that canal and vertebral body measurements, particularly in certain levels of lumbar levels such as L4 and L5, are important determinants of symptomatic degenerative LCS that need treatments thus, anatomical measurements should be included in outcome predictive models.[19] This is in addition to our findings that highlight the significance of canal diameter as a part of various anatomical predictors.

In addition to imaging, there is research in morphological and clinical predictors of operative success, which highlights that clinical

severity (e.g., preoperative neuropathic pain) and morphological changes have joint effects in their consequences. An example of this is a 2024 study, which found that although decompressive surgery is associated with functional improvement, an already severe neuropathic pain was a significant predictor of poor patient satisfaction despite radiological decompression.[20] These results confirm that predictive models should incorporate both radiology and clinical variables, which is also reflected in our methodology, in which anatomical and clinical data were combined.

A 2021 national FInSpine study on population-level registry data showed that angles and sizes of canals (preoperative radiographic predictors) and patient factors were important predictors of 1-year follow-up surgical outcomes.[21] Despite the other demographic and clinical factors that are used in the registry analyses, they confirm that the anatomical severity determined through radiographies is a pertinent constituent in the outcome stratification. Lastly, although some of the recent technological advances are dedicated to AI and predictive models of radiographic evaluation, not all are directly linked to the measurement of diameter and results. Nevertheless, they indicate the direction in which the field is evolving towards more sophisticated, objective, and reproducible measures that can further improve surgical outcome prediction.[22]

To conclude, we believe that our results, indicating that smaller canal diameters are associated with worse surgical outcomes, are in line with the new evidence that specific radiological measurements, particularly when analyzed in combination with clinical factors, are significant predictors. Nonetheless, the fluctuation in imaging modalities, the role of dynamic stenosis, and the incorporation of sophisticated predictors (e.g., radiomic features and AI classifiers) prove that the predictive landscape is changing. Further studies with standardized imaging and multimodal prediction models are needed to further explain how standard anatomical measures, such as canal diameter, can be reliably used in preoperative prognostication.

Transient radicular pain was the most frequently reported postoperative complication in our study, with 12 patients (6.1%), followed by wound infection with 5 patients (2.6%), and dural tears in 3 patients (1.5%). The complications were all dealt with successfully without any long-term morbidity. There were

no reports of long-lasting impairment of the nervous system. These results are consistent with other sources, which suggest that despite the overall safety of decompression surgery, temporary neuropathic symptoms and wound complications are minor and may occur during the postoperative period, and are to be addressed during preoperative consultation.

This study was limited in some ways, even though it made important contributions. To begin with, the research has been done in one center, and this could restrict the extent to which the results can be applied to other groups. Second, there was a short follow-up period (three months); there was no evaluation of the long-term outcomes and recurrence rates. Third, other variables such as the ligamentum flavum hypertrophy, facet joint degeneration, and dynamic canal changes (which impact surgical outcomes) were not quantitatively included, even though spinal canal diameter measurement was done with great accuracy using MRI. Also, patient-reported outcomes, though standardized, are prone to subjective bias. Future research using multicenter data, extended follow-up, and multimodal imaging outcomes would enhance the evidence base on the use of radiological predictors on surgical outcomes.

CONCLUSION

This paper has shown that preoperative radiological spinal canal diameter has a considerable predictive value of surgical outcomes in lumbar canal stenosis, whereby smaller diameters are related to poorer postoperative pain relief and functional outcome. Patients who were mildly stenosed had better rates of surgical success than patients with severe stenosis. Radiation evaluation, directed by accurate radiological assessment, can help in deriving the surgical decision, enhancing patient counseling, and raising expectations after surgery. The use of quantitative imaging measures in the standard preoperative evaluation can contribute to personalized treatment planning and finally lead to better patient outcomes.

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