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The Risk Factor of Ligamentum Flavum Thickness, Disc Herniation Degree, Intervertebral Disc Space Narrowing, and Stenosis Level for the Severity of Neurogenic Claudication in Lumbar Spinal Canal Stenosis Patients

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ABSTRACT

Introduction: Lumbar Spinal Canal Stenosis (LSCS) is a degenerative spinal condition associated with the mechanical compression of spinal nerve roots, often leading to neurogenic claudication. This study aims to evaluate the roles of ligamentum flavum thickness, disc herniation degree, disc height narrowing, and stenosis level as risk factors for the development of neurogenic claudication in LSCS patients.

Material & methods: This case-control study was conducted at RSUP Prof. I.G.N.G. Ngoerah, Denpasar, involving LSCS patients diagnosed via MRI. Data were collected from 36 participants using the total consecutive sampling method. Ligamentum flavum thickness (>3.1 mm), disc height narrowing (<10.5 mm), disc herniation degree, and stenosis level (single-level or multi-level) were evaluated as predictors of the Neurogenic Claudication Outcome Score (NCOS).

Results: The results showed that disc herniation with extrusion posed a significantly higher risk of neurogenic claudication ($p < 0.001$) compared to protrusion-type herniation. Patients with disc height narrowing <10.5 mm were also at higher risk ($p = 0.003$). However, ligamentum flavum thickness >3.1 mm ($p = 0.939$) and multi-level stenosis ($p = 0.09$) did not significantly increase the risk of neurogenic claudication. Regression analysis concluded that the degree of disc herniation was the primary risk factor for neurogenic claudication among the other assessed factors in LSCS patients.

Conclusions: The degree of disc herniation and disc height narrowing are key risk factors for the development of neurogenic claudication in LSCS patients. These findings emphasize the need for a comprehensive diagnostic and therapeutic approach by integrating both clinical and radiological evaluations.

Keywords: Lumbar spinal stenosis, neurogenic claudication, ligamentum flavum hypertrophy, MRI diagnostics, disc herniation severity

INTRODUCTION

Degenerative spinal diseases, particularly Lumbar Spinal Canal Stenosis (LSCS), significantly impact the elderly, causing morbidity, reduced quality of life, and increased healthcare costs. LSCS results from spinal canal narrowing due to disc space narrowing, herniation, osteophyte formation, and ligamentum flavum hypertrophy, leading to pain, numbness, and intermittent claudication (Suyasa et al., 2018). Lumbar stenosis is the narrowing of the spinal canal, either congenital or due to degeneration. Factors like ligamentum flavum hypertrophy contribute to LSCS, requiring detailed understanding for effective management and treatment (Blom et al., 2017). Ligamentum flavum hypertrophy is a condition that causes partial closure of the posterior and lateral parts of the spinal canal. This hypertrophy directly contributes to mechanical compression of nerve fibers (cauda equina) or indirectly leads to vascular insufficiency, resulting in inadequate blood flow and oxygenation (Moon et al., 2012). The ligamentum flavum plays a crucial role in degenerative spinal disorders, particularly lumbar spinal canal stenosis. Research by Chokshi et al. (2010) states that a normal ligamentum flavum measures below 3.1 mm, while it is considered hypertrophic when it measures 3.1 mm or more. Another contributing factor to LSCS is intervertebral disc space narrowing (Jang et al., 2023; Sudhir et al., 2019; Yamada et al., 2021; Zhou et al., 2017). The intervertebral disc narrowing can occur due to various factors, including intervertebral disc degeneration. This reduction can exert additional pressure on surrounding structures, including the spinal canal, contributing to LSCS. Research by Abdollah states that a disc space height below 10.5 mm is considered narrowed, while >10.5 mm is classified as normal disc height (Moon et al., 2012). Disc herniation can reduce the space available within the spinal canal, causing pressure on the spinal cord and nerve roots. This is one of the common causes of LSCS. One contributing factor to LSCS is intervertebral disc prolapse (Moon et al., 2012). Intervertebral disc prolapse and extrusion increase spinal nerve pressure, causing pain, weakness, and sensory disturbances. MRI is essential for diagnosing LSCS by assessing disc degeneration, stenosis severity, and soft tissue changes. However, MRI findings may not always correlate with clinical symptoms, emphasizing the need for comprehensive patient evaluation. The Neurogenic Claudication Outcome Score (NCOS) can be used to assess the clinical outcomes of LSCS patients (Blom et al., 2017). NCOS is a newly developed questionnaire designed to measure the severity of neurogenic claudication in LSCS patients. This simplified outcome questionnaire specifically evaluates functionality in patients with neurogenic claudication. An NCOS score above 49.5 is considered a good outcome, whereas a score of 49.5 or lower is classified as a poor outcome (Azimi et al., 2012). By correlating the etiology of LSCS with MRI findings, we can identify distinct patterns associated with the factors triggering spinal canal narrowing. This study aims to determine the most dominant etiology causing LSCS through MRI examination. Identifying the primary cause will help guide the development of more effective prevention and treatment strategies.

MATERIALS & METHODS

This study employs a case-control study design to investigate the thickness of the ligamentum flavum, the degree of disc herniation, disc space narrowing, and the level of stenosis as risk factors for neurological claudication in patients with lumbar canal spinal stenosis. Data collection is planned to take place at Orthopaedic

Polyclinic RSUP Prof. Dr. IGNG Ngoerah Denpasar. The study will be conducted from March 2024 to August 2024.

Patient Selection

Patients included in this study are Patients who diagnosed with Lumbar Spinal Canal Stenosis based on clinical assessment and MRI examination, are over 40 years old, and are willing to participate in the study. With excluded criteria are: history of trauma, autoimmune disease; SLE, rheumatoid Arthritis, consume corticosteroids and NSAIDs, chronic diseases, Other neurological diseases.

Data Extraction

The characteristics, demographics, and results of objective and subjective measurements are compiled and presented in a master table manually. The data summarized in the master table is then divided into two groups: Patients with an NCOS > 49.5 are classified into the case group. Patients with an NCOS < 49.5 are classified into the control group. The thickness of the ligamentum flavum and disc herniation are measured from the axial cross-section of the MRI examination in patients with Lumbar Spinal Canal Stenosis.The disc space narrowing and stenosis level are measured from the sagittal T2-weighted sequence of the MRI examination in patients with Lumbar Spinal Canal Stenosis. Once the data is grouped, analysis is conducted.

Data Analysis

To find out whether the thickness of the ligamentum flavum, the degree of disc herniation, narrowing of the disc joint space and the level of stenosis are risk factors for neurogenic claudication, the chi-square test will be used. Data analysis was carried out using the path analysis method to identify and test the extent to which these variables contribute to neurologic claudication. Estimation of path coefficients and significance tests will provide insight into the cause and effect between these variables.

Operational Definition

1. Ligamentum flavum hypertrophy can be assessed by MRI. In patients with LSCS, the thickness of the LF is >3.1mm, while in normal patients the thickness of the LF is <3.1mm.
2. Disc herniation refers to a condition when the nucleus pulposus, the gelatinous material in the intervertebral disc, protrudes or comes out of its proper place. The degree of disc herniation is divided into two main categories according to Disc protrusion and Disc extrusion
3. Disc space narrowing categorized if the size of the joint space is below 10.5 mm and is categorized as normal if the size is > 10.5 mm.
4. The number of levels of Stenosis in this study refers to the level of narrowing of the spinal canal on radiological images, with a separation between stenosis at one level (single-level) and stenosis at more than one level (multi-level).
5. Neurogenic claudication. NCOS > 49.5 was said to be good, and NCOS < 49.5 was said to be bad.

RESULT

The demographic characteristics of the patients are listed in The total number of LSCS patients in this study was 48. The mean age of the sample patients was 57.44 ± 11.32 years. The majority of patients were female, with a total of 29 individuals (60.4%). The number of patients with comorbid diabetes was 5 (10.4%), while 16 patients (33.3%) had hypertension. The average ligament thickness across all patients was 3.35 ± 0.89 mm. The average disc space narrowing was 9.57 ± 2.70 mm. Additionally, the mean NCOS score was 54.22 ± 11.27. (Table 1)

Table 1. Based Characteristics

Variables	**Total (%) (N=48)**
Sex: n (%)	
Male	19 (39,6)
Female	29 (60,4)
Diabetes	
Yes	5 (10,4)
No	43 (89,6)
Hypertension	
Yes	16 (33,3)
No	32 (66,7)
History of Corticosteroid	
Yes	0 (0)
No	48 (100)
Ages (mean ± s.b)	57.44 ± 11.32
Thickness of Ligamentum Flavum,	3.35 ± 0.89
Intervertebral Disc Space Narrowing	9.57 ± 2.70
NCOS score	54.22 ± 11.27

The results of the analysis of subject characteristics showed that the variables of gender, comorbid diabetes, and comorbid hypertension did not have a statistically significant difference in proportion between the NCOS ≤ 49.5 and NCOS > 49.5 groups in LSCS patients. Therefore, no confounding variables were found in this study. (Table 2)

Table 2. Basic Sample Characteristic Analysis

Characteristics	**Patient's Group**		**Amount n=48 (%)**	**P Value**
	NCOS ≤ 49,5 (n=29) (%)	**NCOS > 49,5 (n=19) (%)**		
Sex				
Male	12 (41,4)	7 (36,8)	19 (39.6)	0,753*
Female	17 (58,6)	12 (63,2)	29 (60.4)	
Comorbid				
Diabetes				
Yes	2 (6,9)	3 (15,8)	5 (10,4)	0,302*
No	27 (93,1)	16 (84,2)	43 (89,6)	
Hypertension				
Yes	7 (24,1)	9 (47,4)	16 (33,3)	0,095*
No	22 (75,9)	10 (52,6)	32 (66,7)	
History of Corticosteroid				
Yes	0 (0)	0 (0)	0 (0)	-
No	29 (100)	19 (100)	48 (100)	

Table 3. shows that the degree of extrusion herniation is a risk factor for Neurologic Claudication, with a statistically significant difference in proportion ($p < 0.001$). Further analysis yielded an Odds Ratio of 20.44 (4.446 – 94.013), indicating that patients with extrusion herniation are 20.44 times more likely to develop Neurologic Claudication compared to those with protrusion herniation.

Table 3. Chi-Square Test Results for the Degree of Disc Herniation in the Lumbar Spinal Canal Stenosis Patient Group

Variabel	**Case Group (NCOS ≤ 49,5 n=29)**	**Control Group (NCOS > 49,5 n=19)**	**p**	**OR (95% CI)**
Ekstrusion Protrusion	16 (84,2) 3 (15,8)	6 (20,7) 23 (79,3)	<0,001	20,44 (4,446 – 94,013)

Table 4. shows that multilevel stenosis is not a risk factor for Neurologic Claudication, as the difference in proportion is not statistically significant (p = 0.099). Further analysis yielded an Odds Ratio of 3.259 (0.77 - 13.802), indicating that patients with multilevel stenosis are 3.259 times more likely to develop Neurologic Claudication compared to those with single-level stenosis.

Table 4. Chi-Square Test Results for Stenosis Level in the Lumbar Spinal Canal Stenosis Patient Group

Variables	Case Group (NCOS ≤ 49,5 n=29)	Control Group (NCOS > 49,5 n=19)	p	OR (95% CI)
Multilevel *Single level*	16 (84,2) 3 (15,8)	18 (62,1) 11 (37,9)	0,099	3,259 (0,77- 13,802)

Table 5. shows that ligamentum flavum hypertrophy > 3.1 mm is not a risk factor for Neurologic Claudication, as the difference in proportion is not statistically significant (p = 0.939). Further analysis yielded an Odds Ratio of 1.048 (0.317 - 3.466), indicating that patients with ligamentum flavum hypertrophy > 3.1 mm are 1.048 times more likely to develop Neurologic Claudication compared to those with ligamentum flavum thickness ≤ 3.1 mm.

Table 5. Chi-Square Test Results for Ligamentum Flavum Hypertrophy in the Lumbar Spinal Canal Stenosis Patient Group

Variable	Case Group (NCOS ≤ 49,5 n=29)	Control Group (NCOS > 49,5 n=19)	p	OR (95% CI)
LF Thickness: > 3,1 mm ≤ 3,1 mm	 12(63,2) 7(36,8)	 18(62,1) 11(37,9)	 0,939	 1,048 (0,317- 3,466)

Table 6. shows that disc height ≤ 10.5 mm is a risk factor for Neurologic Claudication, with a statistically significant difference in proportion (p = 0.008). Further analysis yielded an Odds Ratio of 5.32 (1.485 – 19.064), indicating that patients with a disc height ≤ 10.5 mm are 5.32 times more likely to develop Neurologic Claudication compared to those with a disc height > 10.5 mm.

Table 6. Chi-Square Test Results for Joint Space Narrowing in the Lumbar Spinal Canal Stenosis Patient Group

Variable	Case Group (NCOS ≤ 49,5 n=29)	Control Group (NCOS > 49,5 n=19)	p	OR (95% CI)
Discus Narrowing: ≤ 10,5 mm > 10,5 mm	 14(73,7) 5(26,3)	 10(34,5) 19(65,5)	 0,008	 5,32 (1,485 – 19,064)

This test aims to assess the risk factors for Neurogenic Claudication in LSCS patients. The analysis was conducted by including all independent variable indicators and evaluating their influence on NCOS ≤ 49.5 in LSCS patients. The bivariate test identified that the variables meeting the criteria for multivariate logistic regression analysis were extrusion disc herniation degree, multilevel stenosis level, and disc height < 10.5 mm. The results of this multivariate analysis can be seen in Table 7.

Table 7. Logistic Regression Test on Risk Factors for NCOS ≤ 49.5 in LSCS Patients

Predictors	B Coefficient	SE	Wald Statistics	p	Exp(B)	Odds Ratio (95%CI)
Step 1						
Constant	0,384	1,050	0,133	0,044	0,354	
Degree of Disc Herniation (1)	2,924	0,931	9,869	0,002	18,608	3,003-115,31
Discus Narrowing (1)	0,003	1,045	0,000	0,998	1,003	0,129-7,781
Stenosis Level (1)	0,384	1,050	0,133	0,715	1,468	0,187-11,488
Step 2						
Constant	-1,037	0,501	4,291	0,038	0,354	
Degree of Disc Herniation (1)	2,925	0,801	13,342	< 0,001	18,632	3,879-89,503
Stenosis Level (1)	0,385	0,923	0,174	0,677	1,47	0,241-8,97
Step 3						
Constant	-0,981	0,479	4,198	0,04	0,375	
Degree of Disc Herniation (1)	3,018	0,778	15,028	< 0,001	20,444	4,446-94,013

Multivariate logistic regression analysis produces an equation to estimate the magnitude of the risk that influences the occurrence of Neurogenic Claudication in LSCS patients as follows:
P(0) = 1/(1+exp[-(Y)]), where Y = -0,981 + 3,018 (degree of disc herniation)

Notes:
P(0): Probability
exp: Natural exponent
Degree of disc herniation: 1 = Extrusion, 0 = Protrusion
The results of the probability equation show that if there are patients with an extrusion disc herniation degree, the probability of neurogenic claudication occurring is 88.46%, with the calculation of equation Y = -0.981 + 3.018 (1). Meanwhile, in patients with a protrusion disc herniation degree, the probability of neurogenic claudication occurring in LSCS patients is 22.7%, with the calculation of equation Y = -0.981 + 3.018 (0).
The results of the Hosmer and Lemeshow test showed that the equation above had good calibration (x2 = 1.811, df = 3, p = 0.613). Then, the analysis was continued for the AUC predictive model on the ROC curve showing strong accuracy with a sensitivity of 79.3% and a specificity of 85% (AUC = 0.818, 95% CI: 0.689 - 0.947). The results are presented in Table 8 and Figure .

Tabel 8. Results of the Area Under the ROC Curve Test Results of Multivariate Logistic Regression Analysis

Area	Std. Error	*p*	95%CI
0,818	0,066	0,000	0,689 – 0,947

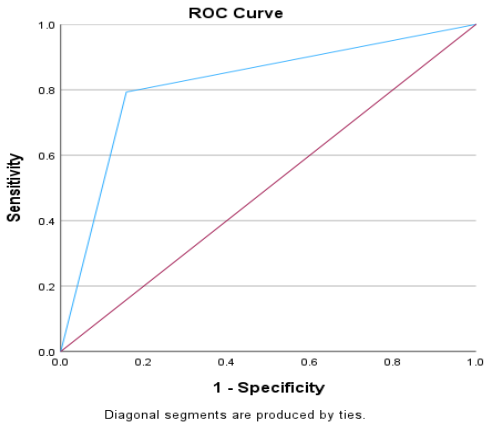

Figure 1. ROC Curve Accuracy for predicting the occurrence of neurogenic claudication based on logistic regression results

DISCUSSION

In this study, the results showed that ligamentum flavum hypertrophy > 3.1 mm is not a risk factor for neurogenic claudication in LSCS patients (p=0.939; OR=1.048; CI=0.317–3.466). This finding is supported by previous studies demonstrating that ligamentum flavum thickness is not directly associated with neurogenic claudication symptoms in LSCS patients. The ligamentum flavum in LSCS patients exhibits significant differences in collagen and elastic fiber composition compared to those with lumbar disc herniation, suggesting that structural changes alone may not be related to neurogenic claudication symptoms (Amoudong, 2017). On the other hand, many studies have concluded that there is a relationship between ligamentum flavum thickness and neurogenic claudication symptoms in LSCS patients. A study by Akarsh et al. found that ligamentum flavum thickening is associated with age, lower lumbar levels, and symptoms such as neurogenic claudication (Akarsh et al., 2023). Similarly, Benyamin et al. reported that among 302 LSCS patients, those experiencing neurogenic claudication also had ligamentum flavum thickening (Cao et al, 2016).

This study found that a disc height of less than 10.5 mm is a risk factor for neurogenic claudication in LSCS patients (p=0.008; OR=5.32; CI=1.485–19.064). Intervertebral disc height plays a crucial role in lumbar canal stenosis, as a decrease in disc height can lead to spinal canal narrowing. This narrowing may cause neurogenic claudication, characterized by pain and discomfort while walking due to nerve compression (Azimi et al., 2012).

The findings on intervertebral disc height in this study are supported by previous research examining the relationship between disc height and neurogenic claudication. Majidi et al. compared symptomatic and asymptomatic LSCS patients and found a significant difference in intervertebral disc height, with the symptomatic group having an average disc height of 9.58 ± 3.49 mm, while the asymptomatic group had a higher average of 12.71 ± 3.18 mm (p < 0.001) (Majidi et al., 2019). The opposite findings were explained by Morishita et al., in 2014 who stated that neurogenic claudication is significantly influenced by variations in dynamic mechanical pressure on the spinal nerve roots rather than the static pressure caused by intervertebral disc height. This pressure varies with postural changes, such as lumbar spine extension, which increases local pressure on the intervertebral foramen and affects nerve root function. Patients with lumbar spinal canal stenosis experience changes in local pressure during movement, which correlates with their walking ability, suggesting that dynamic factors are more important than the static height of the disc (Sudhir et al., 2019).

This study found that disc extrusion herniation is a risk factor for neurogenic claudication in LSCS patients (p<0.001; OR=20.44; CI=4.446–94.013). This finding is supported by previous studies analyzing the relationship between the degree of disc herniation and the occurrence of neurogenic claudication in LSCS patients. Benyamin et al. demonstrated that out of 302 LSCS patients with neurogenic claudication, 274 had bulging discs, and 97 of them progressed to disc herniation (Azimi et al., 2012). On the other hand, Kim et al. demonstrated that disc herniation has a negative correlation with the severity of neurogenic claudication in patients with single-level LSCS (OR = 0.99 [0.98–1.00]; p = 0.048) (Kim et al., 2015). This discrepancy in findings can be explained which highlights that factors such as walking capacity, fear-avoidance behavior, and physical function play a role in symptom manifestation, suggesting that disc protrusion alone may not account for the full spectrum of symptoms (Azimi et al., 2012).

This study found that multilevel stenosis is not a risk factor for neurogenic claudication

in LSCS patients (p=0.099; OR=3.259; CI=0.77–13.802). This finding is supported by previous studies analyzing the relationship between the level of stenosis and the occurrence of neurogenic claudication in LSCS patients. The lack of association between stenosis level and neurogenic claudication may be attributed to several factors, including individual anatomical variability and the subjective nature of symptoms (Rustom et al., 2024). On the other hand, the relationship between stenosis level and neurogenic claudication can be explained by spinal canal narrowing due to degenerative changes that compress the nerve roots. This compression can lead to symptoms such as radiating pain and neurogenic claudication, especially when the lateral recess and foramen undergo severe stenosis. The resulting pain restricts movement, leading to the inhibition of multifidus muscle contraction. Long-term inhibition of contraction can worsen multifidus muscle atrophy and degeneration, creating a feedback loop that further disrupts lumbar spine stability and exacerbates symptoms associated with neurogenic claudication (Shah et al., 2017).

CONCLUSION

This study found that ligamentum flavum hypertrophy greater than 3.1 mm is not a risk factor for neurogenic claudication in patients with Lumbar Spinal Canal Stenosis. However, a disc height of less than 10.5 mm and the degree of disc extrusion herniation are identified as risk factors for neurogenic claudication in these patients. In contrast, multilevel stenosis does not appear to be a significant risk factor. The study concludes that the degree of extrusion herniation is the most influential predictive parameter for neurogenic claudication in LSCS patients based on the NCOS score.

Declaration by Authors

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