The association between clinical symptoms of lumbar spinal stenosis and MRI axial imaging findings

学 位 論 文

The association between clinical symptoms of lumbar spinal stenosis and MRI axial imaging findings

（腰部脊柱管狭窄の臨床症状と MRI 横断像所見の関連）

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The association between clinical symptoms of lumbar spinal stenosis and MRI axial imaging findings

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Abstract:

Purpose: In diagnosing lumbar spinal stenosis (LSS), Magnetic Resonance Imaging (MRI) is appropriate to confirm the presence of anatomical stenosis of the spinal canal or compression of the nerve roots. However, it is known that morphological LSS is often present in asymptomatic subjects. There is still controversy about the relationship between anatomical LSS and symptomatic LSS. The aim of this study was to assess the association between qualitative imaging findings on MRI of the lumbar spine and symptomatic LSS.

Patients and methods: This was the cross-sectional study and 239 participants based on the epidemiological survey from a total of 1862 participants were analyzed. Four classifications on MRI of the lumbar spine were evaluated: morphological grading of central stenosis and of lateral recess stenosis, presence of the sedimentation sign, and severity of facet joint effusion. The relationship between these morphological evaluations and typical LSS symptoms as assessed by the lumbar spinal stenosis-self-administered, self-reported history questionnaire was investigated by multiple logistic regression analysis.

Results: The odds ratio of the most severe central stenosis to no stenosis was 15.5 (95% confidence interval:1.4-164.9). The most severe central stenosis was only associated with typical LSS symptoms, while not all cases with typical LSS symptoms due to severe central stenosis.

Conclusion: Extreme severe central stenosis was strongly related to typical LSS symptoms. However, although subjects with severe central stenosis showed symptoms suggestive of LSS, these subjects did not always show typical LSS symptoms.

Introduction

Lumbar spinal stenosis (LSS) is characterized by narrowing of the spinal canal including the central spinal canal, in the area under the facet joints (subarticular, lateral recess or foraminal stenosis), or far laterally (extraforaminal stenosis).[1-3] The anatomical condition of LSS causes variable clinical symptoms, such as gluteal and/or lower extremity pain, numbness and/or neurogenic intermittent claudication. These symptoms are thought to be caused by the diminished space available for the neural and vascular elements. However, the pathogenesis of LSS is not fully clarified, and there is no definition with clear criteria for the imaging findings and clinical symptoms.[1,4]

Magnetic resonance imaging (MRI) is appropriate to confirm the anatomical condition of the spinal canal or compression of the nerve roots. However, it is known that radiographic LSS is found in asymptomatic patients.[5] According to the North American Spine Society (NASS) Guideline of LSS, there is insufficient evidence for a correlation between clinical symptoms or function with the anatomic narrowing of the spinal canal on imaging.[4] One of the reasons for this situation might be variations in assessment methods due to the lack of clear criteria for the assessment of imaging findings.

In recent studies, the most commonly used method for evaluating anatomical spinal stenosis on imaging was dural sac cross-sectional area (DCSA).[4,6-10] However, the correlation between DCSA and symptoms is still controversial. In addition, the measurement of DCSA is not easy in the routine clinical setting; therefore, a well-defined and simple morphological classification for evaluating the severity of anatomical spinal stenosis would be useful. Moreover, DCSA is insufficient to evaluate nerve root impingement due to lateral recess stenosis (LRS), since DCSA does not include the lateral recess. LRS is most commonly caused by degenerative changes of the spine, such as facet joint osteoarthritis, ligamentum flavum hypertrophy, intervertebral disc degeneration, and endplate spurs.[2,11,12] Therefore, central stenosis and LRS should be evaluated separately for anatomical spinal stenosis. Furthermore, there are other findings associated with anatomical spinal stenosis, such as the sedimentation sign and facet joint effusion (FJE), which are considered to be related to symptomatic LSS.[13-17] However, evidence for a correlation between clinical symptoms and anatomic stenosis on imaging is still insufficient. Since most of the previous studies were hospital-based and the control group had diseases other than LSS, the results are unlikely to be generalizable. Therefore, they need to be examined in population-based studies with higher external validity. The main objective of this study was to evaluate the association between qualitative imaging findings on MRI axial images of the lumbar spine and symptomatic LSS in the community.

Materials and methods

This study was approved by the ethics committee of Fukushima Medical University School of Medicine (Approval No.295). All participants gave their written informed consent to participate in the study.

Participants

This cross-sectional study was based on the epidemiological survey from 2004, a total of 1862 people (697 males and 1165 females) enrolled when the public health survey was conducted by their local governments at Tadami Town, Tateiwa Village, and Ina Village in Fukushima Prefecture. Their age ranged from 19 to 93 years old.[18] Four hundred fifty-nine of 1862 agreed to undergo MRI for lumbar spine as the additional assessment. Participants who had not cerebral infarction or bleeding history and could walk independently were included. The exclusion criteria were if they were unable to walk independently, full out questionnaires due to visual impairment, had ever undergone brain or spinal surgery. Insufficient imaging findings of all classifications and missing data of questionnaire were excluded, finally, 239 of them were analysed in the present study (Figure 1).

Assessment of MRI

Axial T2-weighted images were obtained at each level of the vertebral bodies and intervertebral discs from L1 to S1. The details of the MRI imaging conditions are shown in Table 1.

The classifications of central stenosis, LRS, the sedimentation sign, and FJE were evaluated using MRI (Table 2).[2,13,19,20] Central stenosis, nerve root compression using classification of LRS, and FJE were evaluated at each axial image of the intervertebral disc level from L1-2 to L5-S1. For all findings, the highest grade was used as representative for analysis. To evaluate the intra/inter-observer reliabilities of each classification, two orthopaedic surgeons (YF & MN) evaluated two times every two weeks separately. According to the sample size calculation estimating ρ =0.8 with 0.4 of 95% confidence interval rated by two examiners, at least 20 subjects would be needed. Therefore, 30 subjects were randomly selected to determine using kappa analysis.[21] The intra-observer reliabilities were determined to be substantial for the assessment of central stenosis, the sedimentation sign, and FJE (0.68, 0.71, and 0.70, respectively) and moderate for the assessment of LRS (0.54). The inter-observer reliabilities were determined to be substantial for the assessment of central stenosis, the sedimentation sign, and FJE (0.65, 0.68, and 0.63, respectively) and fair for the assessment of LRS (0.31). Therefore, the intra-observer and inter-observer reliabilities were considered acceptable. Finally, one orthopaedic surgeon (YF) examined the images without any participants' information, including their symptoms. The highest severity of each classification in individual subjects was used as the representative value in the analysis.

Assessment of clinical symptoms

The presence or absence of typical LSS symptoms was determined using the validated LSS diagnostic support tool, which is a self-administered, self-reported history questionnaire (LSS-SSHQ) to standardize the symptoms. The LSS-SSHQ was developed for the identification of LSS based on self-reported patient information alone. This questionnaire is a just a screening tool for LSS, therefore not all symptomatic LSS cases could be detected. In order to identify symptomatic LSS by a self-reported questionnaire, the cut-off value is set even though false positive and negative cases were limitations for diagnosis of LSS. For the present study "symptomatic LSS as assessed by LSS-SSHQ" will be referred to as "typical LSS symptoms". It consists of 10 question items and has a sensitivity of 84%, specificity of 78%, positive likelihood ratio of 1.89, and negative likelihood ratio of 0.21 according to the validation study.[22] The evidence has been graded that the SSHQ can be useful to assist with providing clinical evidence of lumbar spinal stenosis as level II diagnostic evidence by the Degenerative Lumbar Spinal Stenosis Work Group of the North American Spine Society's Evidence-Based Clinical Guideline Development Committee.[4]

Statistical analysis

Baseline characteristics are described using appropriate summary statistics. Univariate analysis of the correlation between each MRI finding and typical LSS symptoms was performed using the chi-squared test and Cochran-Armitage's propensity test. Second, all MRI findings were then tested for multicollinearity. After variables were removed if they showed a correlation of over r=0.70 to any other variables in the model,[23] on multivariate analysis, adjusted odds ratios (ORs) were estimated using a logistic regression model with adjustment for age and sex. A two-sided $p < 0.05$ was considered significant. Statistical analyses were performed using IBM SPSS Statistics for Windows, ver. 26 (IBM Corp. Armonk, NY, USA) and R ver. 3.5.3 (The R foundation, Vienna, Austria).

Results

Demographic data

The 239 participants consisted of 86 men and 153 women. Their mean age was 65.3 years, and most participants were aged over 70 years. The demographic data are shown in Table 3.

The central stenosis of grade B or higher were observed 46% of the participants. LRS were observed 96.7%, with Grade 2 the most common, at 41.0%. The sedimentation sign was positive in 33.5% of the participants. With regard to the FJE, only 2.1% of participants were assessed as having no FJE, and 97.9% had the FJE. There were no significant differences in MRI findings of all classification between the sexes (Table 3). The distribution of grades in three classifications were shown in Table 4 and the almost all of severe MRI findings were observed at the L3/4 or L4/5. Furthermore, grades of MRI findings progressed with age in all classifications (Figure 2).

Association of grading on MRI findings and LSS symptoms in each classification

Comparison of characteristics with and without typical LSS symptoms as assessed by LSS-SSHQ were shown in Table 5. The prevalence of typical LSS symptoms was 58 of 239 participants (24.3%) and increased with age. The number of cases with typical LSS symptoms tended to increase significantly depending on the severity of central stenosis, LRS, and FJE, respectively ($p < 0.001$). Although participants without typical LSS symptoms, the highest grade of severity was found in each classification: central stenosis 0.6%, LRS 22.1%, and FJE 21.5%. The most severe grade in the combination of central stenosis (Grade D) and LRS (Grade 3) was only found significantly higher in the group with typical LSS symptoms than the group without typical LSS symptoms ($p < 0.05$) (Table 6). The sedimentation sign was found in 27 of 58 participants (46.6%) in the group with typical

LSS symptoms, significantly more than in the group without typical LSS symptoms (p=0.015) (Table 5). However, this sign was observed 29.3% of the group without typical LSS symptoms.

According to multivariate analysis, LRS showed the strong correlation (r>0.7) with central stenosis, therefore, analyses with all explanatory variables, excluding LRS from the explanatory variables are shown (Table 7). The Odds ratio (OR) of Grade D in the central stenosis was 15.5 (95% confidence interval:1.4-164.9), and it was the only significant explanatory variable (p=0.023).

Discussion

The present study evaluated the correlations between the presence or absence of typical LSS symptoms and four classifications of lumbar MRI: morphological grading of central stenosis and of LRS, presence of the sedimentation sign, and severity of FJE. It was found that only the most severe grade (D) of central stenosis was strongly associated with the presence of typical LSS symptoms**.**

Recently, the focus has been on the association between anatomical central stenosis on imaging and clinical symptoms. There are previous studies that the morphological stenosis compared with the LSS symptoms in a hospital-based survey.[7-10,24-26] According to these studies, it has remained controversial whether the morphological stenosis correlated with or without clinical LSS symptoms, even though the various assessments of morphological stenosis, such as measurement of spinal canal area or diameter, each classification of stenosis grading, were used for analyses.[27,28] In the general population study by Ishimoto et al, the prevalence of clinical symptoms significantly increased with increasing severity of central stenosis.[27] In the present study, the prevalence of typical LSS symptoms tended to increase significantly according to the severity of central stenosis and LRS, respectively. In addition, the agreement between the two studies suggests that the correlation between severe central stenosis and the presence of symptomatic LSS is more certain. Furthermore, to evaluate imaging findings for LSS, not only central canal stenosis but also lateral recess stenosis should be considered. It has been reported that the cross-sectional area of the lateral recesses was significantly smaller in the symptomatic LSS group than in the asymptomatic group.[28] Another study reported that there was a weak correlation between the Oswestry disability index and LRS grade in low back pain patients without central stenosis. However, the participants had low back pain, and it did not evaluate specific radicular symptoms.[11] In the present study, the prevalence of typical LSS symptoms increased significantly according to the severity of LRS compared with the group without typical LSS symptoms. It is known that degenerative spinal stenosis is primarily caused by age-related degeneration, such as protruding discs, osteophytes, hypertrophy of facet joints, and accompanying thickening of the ligamentum flavum.[1,12] Therefore, it is likely that advanced central stenosis is often associated with LRS. In the present study, the higher severity grades combination of central stenosis (Grade C, D) and LRS (Grade 2, 3) were approximately 15% and half of them were symptomatic LSS group. Since LRS showed the strong correlation ($r>0.7$) with central stenosis in the present study, it was considered inappropriate to include both central stenosis and LRS in the logistic regression analysis due to their multicollinearity; therefore, the correlation between LRS and central stenosis was not evaluated. The present study showed that only the most severe central stenosis was strongly related to the presence of typical LSS symptoms. Conversely, in the present study and another study[27] were found that not all of the higher severity grades of MRI imaging cases presented with typical LSS symptoms. In the present study, LSS-SSHQ score of one case with Grade D central stenosis but determined not to have typical LSS symptoms was 2 points in Q1-4 and 1 point in Q5-10. This case showed some symptoms suggestive of LSS, but did not meet the definition of LSS symptoms in the LSS-SSHQ. And the severity of stenosis on MRI was not associated with preoperative disability and pain, or clinical outcome at 1 year.[26] Furthermore, the natural history of symptomatic LSS was shown that more than half of symptomatic LSS subjects improved their symptoms, whereas 10% of asymptomatic LSS subjects developed clinically diagnosed symptomatic LSS at 1 year follow up.[6] According to the abovementioned studies, morphological spinal stenosis might not be equal to the presence of typical LSS symptoms.

The sedimentation sign was reported in the original paper as a finding with high sensitivity and specificity for symptomatic LSS.[13] The presence of positive sedimentation sign was greater depending on the more severe the morphological grade.[29] However, validation of the sedimentation sign is insufficient in patients with mild to moderate anatomical LSS.[29,30] Although the prevalence of the positive sedimentation sign was significantly higher in the group with typical LSS symptoms (46.4%) than in the group without typical symptoms (29.3%), logistic regression analysis showed that the sedimentation sign was not a significant explanatory variable in the present study. These results suggested that the sedimentation sign itself was not associated with the presence or absence of typical LSS symptoms, just associated with the presence of anatomical central stenosis. This may be due to the fact that the present study involved the general population, and various degrees of anatomical LSS were included; therefore, these results might indicate a more generalized association between imaging findings and symptoms.

It has recently been reported that FJE may be associated with symptomatic LSS. In degenerative lumbar spinal disorders, high levels of inflammatory cytokines in facet joint tissue have been found to be released into the spinal canal, which is suspected to be the cause of pain.[11,16,17] In addition, increased facet fluid on MRI has been reported to be highly predictive of the dynamic reduction of DCSA detected on axial-loaded MRI in the clinical assessment of LSS.[14,15] In the present study, the severity of FJE was not associated with the presence or absence of typical LSS symptoms. However, in the present analysis, the highest severity was used as a representative value of the respective findings, and the level and right/left sides of occurrence points were not taken into account. These points might be useful for the improvement of accuracy to detect symptomatic LSS.

The presence and severity of each MRI finding were often related to each other, suggesting a correlation between findings. Correlations strong enough to suggest multicollinearity were found only between central stenosis and LRS, but correlations between independent variables may have influenced the results of multivariate analysis. It was also necessary to evaluate whether combining each finding would result in a correlation with the presence or absence of symptoms; however, statistical analysis was difficult because the correlation between each finding resulted in a large bias in the distribution of the number of cases. A larger sample size may reduce the influence on multivariate analysis and allow us to analyze the association between the combination of findings and the presence of symptoms.

The strength of this study is that four different kinds of MRI evaluation items were performed in all participants. In addition, the distribution of each MRI item with and without typical LSS symptoms were evaluated and association between them were analyzed using a logistic regression model. Therefore, various morphological findings were compared the possibility of pathogenesis for symptomatic LSS. The second strength is that the data were obtained from a large community-dwelling population and various analyses series have been performed included the present study. Therefore, comparing a hospital-based survey, the results in the present study would be shown in a real-world setting and relevant for pathogenesis of LSS.

This study has several limitations. First, all participants in this study were volunteers and it is possibility that the participants who have any symptoms or more severe LSS symptoms might be allow to take MRI. However, each item of MRI findings was distributed in all grades and participants without symptoms were agree to undergo MRI. Therefore, comparing to the hospital-based study, the benefit of this study was that all grades of morphological stenosis included mild and no stenotic cases would be evaluated. Second, the most severe grade was taken as representative of each finding, therefore, detailed analysis for the relationship with the responsible anatomical stenosis level inferred from the site of the symptoms or multiple level lesions was not considered. Because there is no established method of evaluation that takes into account multiple level lesions, and because it requires detailed grouping combined with the severity of the disease, a larger number of cases is considered necessary for the analysis. Third, since the research location was in a rural and mountainous area, one may not be completely able to extrapolate the findings to the typical Japanese population. Finally, this was a cross-sectional study, therefore the causal relationship between morphological and symptomatic LSS could not be concluded.

Conclusion

The most severe central stenosis was found to be strongly related to typical LSS symptoms. However, although subjects with severe central stenosis showed symptoms suggestive of LSS, these subjects did not always show typical LSS symptoms. And mild central and lateral recess stenosis may or may not present with typical LSS symptoms. Further studies are needed to clarify the mechanism of onset and induction of LSS symptoms and its relationship to anatomical and radiological stenosis.

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Conflict of Interest Disclosure

The authors declare no conflicts of interest associated with this manuscript.

References

1. Siebert E, Prüss H, Klingebiel R, et al. Lumbar spinal stenosis: syndrome, diagnostics and treatment. Nat Rev Neurol, **5**:392-403, 2009.
2. Bartynski WS, Lin L. Lumbar root compression in the lateral recess: MR imaging, conventional myelography, and CT myelography comparison with surgical confirmation. AJNR Am J Neuroradiol, **24**:348-360, 2003.
3. Kitamura M, Eguchi Y, Inoue G, et al. A case of symptomatic extra-foraminal lumbosacral stenosis ("far-out syndrome") diagnosed by diffusion tensor imaging. Spine (Phila Pa 1976), **37**:E854-E857, 2012.
4. North American Spine Society Clinical Guidelines. III. Definition and Natural History of Degenerative Lumbar Spinal Stenosis [homepage on the Internet]. North American Spine Society; 2011. Available from: https://www.spine.org/Portals/0/Assets/Downloads/ResearchClinicalCare/Guidelines/LumbarStenosis.pdf Accessed May 1, 2020.
5. Boden SD, Davis DO, Dina TS, et al. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. J Bone Joint Surg Am, **72**:403-408, 1990.
6. Otani K, Kikuchi SI, Yabuki S, et al. Prospective one-year follow-up of lumbar spinal stenosis in a regional community. J Pain Res, **11**:455-464, 2018.
7. Ogikubo O, Forsberg L, Hansson T. The relationship between the cross-sectional area of the cauda equina and the preoperative symptoms in central lumbar spinal stenosis. Spine (Phila Pa 1976), **32**:1423-1428;

discussion 1429, 2007.

8. Kuittinen P, Sipola P, Saari T, et al. Visually assessed severity of lumbar spinal canal stenosis is paradoxically associated with leg pain and objective walking ability. BMC Musculoskelet Disord, **15**:348, 2014.
9. Kim YU, Kong YG, Lee J, et al. Clinical symptoms of lumbar spinal stenosis associated with morphological parameters on magnetic resonance images. Eur Spine J, **24**:2236-2243, 2015.
10. Andrasinova T, Adamova B, Buskova J, et al. Is there a Correlation Between Degree of Radiologic Lumbar Spinal Stenosis and its Clinical Manifestation? Clin Spine Surg, **31**:E403-E408, 2018.
11. Splettstößer A, Khan MF, Zimmermann B, et al. Correlation of lumbar lateral recess stenosis in magnetic resonance imaging and clinical symptoms. World J Radiol, **9**:223-229, 2017.
12. Kushchayev SV, Glushko T, Jarraya M, et al. ABCs of the degenerative spine. Insights Imaging, **9**:253-274, 2018.
13. Barz T, Melloh M, Staub LP, et al. Nerve root sedimentation sign: evaluation of a new radiological sign in lumbar spinal stenosis. Spine (Phila Pa 1976), **35**:892-897, 2010.
14. Kim YK, Lee JW, Kim HJ, et al. Diagnostic advancement of axial loaded lumbar spine MRI in patients with clinically suspected central spinal canal stenosis. Spine (Phila Pa 1976), **38**:E1342-E1347, 2013.
15. Kanno H, Ozawa H, Koizumi Y, et al. Increased Facet Fluid Predicts Dynamic Changes in the Dural Sac Size on Axial-Loaded MRI in Patients with Lumbar Spinal Canal Stenosis. AJNR Am J Neuroradiol, **37**:730-735, 2016.
16. Igarashi A, Kikuchi S, Konno S. Correlation between inflammatory cytokines released from the lumbar facet joint tissue and symptoms in degenerative lumbar spinal disorders. J Orthop Sci, **12**:154-160, 2007.
17. Vardeh D, Mannion RJ, Woolf CJ. Toward a Mechanism-Based Approach to Pain Diagnosis. J Pain, **17**:T50-T69, 2016.
18. Otani K, Kikuchi S, Yabuki S, et al. Lumbar spinal stenosis has a negative impact on quality of life compared with other comorbidities: an epidemiological cross-sectional study of 1862 community-dwelling individuals. ScientificWorldJournal, **2013**:590652, 2013.
19. Schizas C, Theumann N, Burn A, et al. Qualitative grading of severity of lumbar spinal stenosis based on

the morphology of the dural sac on magnetic resonance images. Spine (Phila Pa 1976), **35**:1919-1924, 2010.

20. Chaput C, Padon D, Rush J, et al. The significance of increased fluid signal on magnetic resonance imaging in lumbar facets in relationship to degenerative spondylolisthesis. Spine (Phila Pa 1976), **32**:1883-1887, 2007.
21. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics, **33**:159-174, 1977.
22. Konno S, Kikuchi S, Tanaka Y, et al. A diagnostic support tool for lumbar spinal stenosis: a self-administered, self-reported history questionnaire. BMC Musculoskelet Disord, **8**:102, 2007.
23. Vatcheva KP, Lee M, McCormick JB, et al. Multicollinearity in Regression Analyses Conducted in Epidemiologic Studies. Epidemiology (Sunnyvale), **6**:227, 2016.
24. Kapural L, Mekhail N, Bena J, et al. Value of the magnetic resonance imaging in patients with painful lumbar spinal stenosis (LSS) undergoing lumbar epidural steroid injections. Clin J Pain, **23**:571-5, 2007.
25. Sigmundsson FG, Kang XP, Jönsson B, et al. Correlation between disability and MRI findings in lumbar spinal stenosis: a prospective study of 109 patients operated on by decompression. Acta Orthop, **82**:204-210, 2011.
26. Weber C, Giannadakis C, Rao V, et al. Is There an Association Between Radiological Severity of Lumbar Spinal Stenosis and Disability, Pain, or Surgical Outcome?: A Multicenter Observational Study. Spine (Phila Pa 1976), **41**:E78-E83, 2016.
27. Ishimoto Y, Yoshimura N, Muraki S, et al. Associations between radiographic lumbar spinal stenosis and clinical symptoms in the general population: the Wakayama Spine Study. Osteoarthritis Cartilage, **21**:783-738, 2013.
28. Majidi H, Shafizad M, Niksolat F, et al. Relationship Between Magnetic Resonance Imaging Findings and Clinical Symptoms in Patients with Suspected Lumbar Spinal Canal Stenosis: a Case-control Study. Acta Inform Med, **27**:229-233, 2019.
29. Laudato PA, Kulik G, Schizas C. Relationship between sedimentation sign and morphological grade in symptomatic lumbar spinal stenosis. Eur Spine J, **24**:2264-2268, 2015.

30. Zhang L, Chen R, Xie P, et al. Diagnostic value of the nerve root sedimentation sign, a radiological sign using magnetic resonance imaging, for detecting lumbar spinal stenosis: a meta-analysis. Skeletal Radiol, **44**:519-527, 2015.

Figure legends

Figure 1. Flow chart of the analysis for evaluation of MRI.

Figure 2. The distribution of grades in each classification by age.

(A) The rate of severe central stenosis increases with age. (B) The rate of severe LRS increases with age. (C) The sedimentation sign increases with age. (D) The rate of Grade 2 FJE increases with age.

Abbreviations: LRS, lateral recess stenosis; FJE, facet joint effusion.

Table 1 MRI specifications and utilization

Manufacturer	Philips	Toshiba
Product name	Gyroscan	EXCELART/P2
	Intera Power	Pianissimo
Tesla	1.0 T	1.5 T
Slice thickness (mm)	5	5
Slice gap (mm)	0.5	1
TE (ms)	120	108
TR (ms)	4,500	4,000
No. of participants	170	69

Abbreviations: MRI, magnetic resonance imaging; TE, echo time; TR, repetition time.

Table 2 Classifications of MRI findings

Central stenosis		Schizas C et al.[19]
Grade A	There is clearly CSF visible inside the dural sac, but its distribution is inhomogeneous.	
Grade B	The rootlets occupy the whole of the dural sac, but they can still be individualized. Some CSF is still present giving a grainy appearance to the sac.	
Grade C	No rootlets can be recognized, the dural sac demonstrating a homogeneous gray signal with no CSF signal visible. There is epidural fat present posteriorly.	
Grade D	In addition to no rootlets being recognizable, there is no epidural fat posteriorly.	
Lateral recess stenosis (LRS)		Bartynski WS et al.[2]
Grade 0	Normal	
Grade 1	Reduced size of the corner of the lateral canal or recess; trefoil shape to the lateral recess, either congenital or acquired; early acute angular narrowing of the corner of the canal and thecal sac; nerve root is visualized and not widened, flattened, or altered.	
Grade 2	Reduced size of the corner of the lateral canal or lateral recess; trefoil shape and narrowing of the lateral recess; angular pinch-like shape and narrowing of the lateral canal and thecal sac; nerve root judged compressed in the small trefoil recess or angled pinch but recess judged not totally obliterated; nerve root may be deviated medially.	
Grade 3	Severe facet hypertrophy and disc/end plate changes; no CSF or space identified in the lateral recess or corner of the canal; severe angular pinch of the lateral corner of the canal; root may or may not be clearly visible; root may be seen coursing through the compressed lateral recess; root may be seen as medially displaced.	
Sedimentation sign		Barz T et al.[13]
Positive	The absence of nerve root sedimentation.	
Facet joint effusion (FJE)		Chaput C et al.[20]
Grade 0	No effusion	
Grade 1	Measurable effusion < 1.5 mm	
Grade 2	Large effusion > 1.5 mm	

Abbreviations: CSF, cerebrospinal fluid.

Table 3 Demographic characteristics of participants

	Total n=239	Male n=86	Female n=153
Age (y) (mean ±SD)	65.3±11.0	65.4±11.3	65.3±10.9
BMI (kg/m^2)	23.4±3.1	23.3±3.0	23.4±3.1
Distribution of age (y) (n [%])			
<50	18 (7.5)	7 (8.1)	11 (7.2)
50-59	46 (19.2)	17 (19.8)	29 (20.0)
60-69	78 (32.6)	26 (30.2)	52 (34.0)
≥70	97 (40.6)	36 (41.9)	61 (39.9)
Classifications of MRI (n [%])			
Central stenosis			
Grade A	129 (54.0)	44 (51.2)	85 (55.6)
Grade B	73 (30.5)	28 (32.6)	45 (29.4)
Grade C	30 (12.6)	11 (12.8)	19 (12.4)
Grade D	7 (2.9)	3 (3.5)	4 (2.6)
LRS			
Grade 0	8 (3.3)	3 (3.5)	5 (3.3)
Grade 1	67 (28.0)	25 (29.1)	42 (27.5)
Grade 2	98 (41.0)	30 (34.9)	68 (44.4)
Grade 3	66 (27.6)	28 (32.6)	38 (24.8)
Sedimentation sign			
Positive	80 (33.5)	28 (32.6)	52 (34.0)
Negative	159 (66.5)	58 (67.4)	101 (66.0)
FJE			
Grade 0	5 (2.1)	1 (1.2)	4 (2.6)
Grade 1	171 (71.5)	59 (68.6)	112 (73.2)
Grade 2	63 (26.4)	26 (30.2)	37 (24.2)

Abbreviations: LSS, lumbar spinal stenosis; LRS, lateral recess stenosis; FJE, facet joint effusion.

Table 4 Distribution of MRI findings

Classifications of MRI (n [%])	L1/2	L2/3	L3/4	L4/5	L5/S1
Central stenosis					
Grade A	212 (88.7)	200 (83.7)	171 (71.5)	158 (66.1)	233 (97.5)
Grade B	26 (10.9)	34 (14.2)	51 (21.3)	55 (23.0)	2 (0.8)
Grade C	1 (0.4)	5 (2.1)	16 (6.7)	20 (8.4)	3 (1.3)
Grade D	0 (0.0)	0 (0.0)	1 (0.4)	6 (2.5)	1 (0.4)

	Left					**Right**				
	L1/2	L2/3	L3/4	L4/5	L5/S1	L1/2	L2/3	L3/4	L4/5	L5/S1
LRS										
Grade 0	180 (75.3)	113 (47.3)	56 (23.4)	23 (9.6)	107 (44.8)	176 (73.6)	113 (47.3)	58 (24.3)	25 (10.5)	113 (47.3)
Grade 1	49 (20.5)	89 (37.2)	111 (46.4)	110 (46.0)	91 (38.1)	42 (17.6)	82 (34.3)	105 (43.9)	104 (43.5)	89 (7.2)
Grade 2	10 (4.2)	32 (13.4)	58 (24.3)	60 (25.1)	32 (13.4)	21 (8.8)	35 (14.6)	56 (23.4)	70 (29.3)	29 (12.1)
Grade 3	0 (0.0)	5 (2.1)	14 (5.9)	46 (19.2)	9 (3.8)	0 (0.0)	9 (3.8)	20 (9.4)	40 (16.7)	8 (3.3)
FJE										
Grade 0	130 (54.4)	101 (42.3)	89 (37.2)	96 (40.2)	108 (45.2)	142 (59.4)	107 (44.8)	92 (38.5)	105 (43.9)	109 (45.6)
Grade 1	105 (43.9)	120 (50.2)	139 (58.2)	129 (54.0)	125 (52.3)	92 (38.5)	111 (46.4)	129 (54.0)	123 (51.5)	124 (51.9)
Grade 2	1 (1.7)	18 (7.5)	11 (4.6)	14 (5.9)	6 (2.5)	5 (2.1)	21 (8.8)	18 (7.5)	11 (4.6)	6 (2.5)

Abbreviations: LRS, lateral recess stenosis; FJE, facet joint effusion.

Table 5 Comparison of characteristics between participants with and without typical LSS symptoms as assessed by LSS-SSHQ

	Typical LSS symptoms (-) n=181	Typical LSS symptoms (+) n=58	*p*
Distribution of age (y) (n [%])			0.005
<50	18 (9.9)	0 (0.0)	
50-59	40 (22.1)	6 (19.3)	
60-69	58 (32.0)	20 (34.5)	
≥70	65 (35.9)	32 (55.2)	
Sex (n [%])			0.875
Male	66 (36.5)	20 (34.5)	
Female	115 (63.5)	38 (65.5)	
Classifications of MRI (n [%])			
Central stenosis			<0.001
Grade A	103 (56.9)	26 (44.8)	
Grade B	61(33.7)	12 (20.7)	
Grade C	16 (8.8)	14 (24.1)	
Grade D	1 (0.6)	6 (10.3)	
LRS			<0.001
Grade 0	8 (4.4)	0 (0.0)	
Grade 1	52 (28.7)	15 (25.9)	
Grade 2	81 (44.8)	17 (29.3)	
Grade 3	40 (22.1)	26 (44.8)	
Sedimentation sign			0.015*
Positive	53 (29.3)	27 (46.6)	
Negative	128 (70.7)	31 (53.4)	
FJE			<0.001
Grade 0	4 (2.2)	1 (1.7)	
Grade 1	138 (76.2)	33 (56.9)	
Grade 2	39 (21.5)	24 (41.4)	

Notes: *: Sex: The chi-squared test was used to compare between the typical LSS symptoms (+) and (-). Others: The Cochran-Armitage's propensity test was used to compare between the typical LSS symptoms (+) and LSS (-).

Abbreviations: LSS, lumbar spinal stenosis; LRS, lateral recess stenosis; FJE, facet joint effusion.

Table 6 Distribution for combination of LRS and central stenosis with and without typical LSS symptoms as assessed by LSS-SSHQ

	Total (Typical LSS symptoms [-]/Typical LSS symptoms [+]) (n=239)			
	LRS			
	Grade 0	Grade 1	Grade 2	Grade 3
Central stenosis				
Grade A	8 (8/0)	62 (50/12)	55 (42/13)	4 (3/1)
Grade B	0 (0/0)	4 (1/ 3)	41 (38/3)	28 (22/6)
Grade C	0 (0/0)	1 (1/0)	2 (1/1)	27 (14/13)
Grade D	0 (0/0)	0 (0/0)	0 (0/0)	7 (1/6)*

Notes: *$p<0.05$: The chi-squared test was used to compare between the typical LSS symptoms (+) and (-).

Abbreviations: LSS, lumbar spinal stenosis; LRS, lateral recess stenosis.

Table 7 Associations of MRI findings with the presence or absence of typical LSS symptoms as assessed by LSS-SSHQ in multivariant regression analysis

	OR	95% CI	p value
Sex (Female)	1.211	0.609-2.405	0.585
Age	1.049	1.012-1.088	0.009
Classifications of MRI findings			
Central stenosis			
Grade A	Ref.		
Grade B	0.561	0.234-1.346	0.195
Grade C	2.518	0.793-7.997	0.117
Grade D	15.453	1.448-164.94	0.023
LRS			
Grade 0			
Grade 1	–	–	–
Grade 2	–	–	–
Grade 3	–	–	–
Sedimentation sign (Positive)	0.846	0.334-2.141	0.723
FJE			
Grade 0	Ref.		
Grade 1	1.033	0.093-11.454	0.979
Grade 2	2.314	0.201-26.58	0.501
R2		0.209	

Abbreviations: LSS, lumbar spinal stenosis; LRS, lateral recess stenosis; OR, odds ratio; CI, confidence interval; FJE, facet joint effusion.

Figure 1: Flow chart of the analysis for evaluation of MRI.

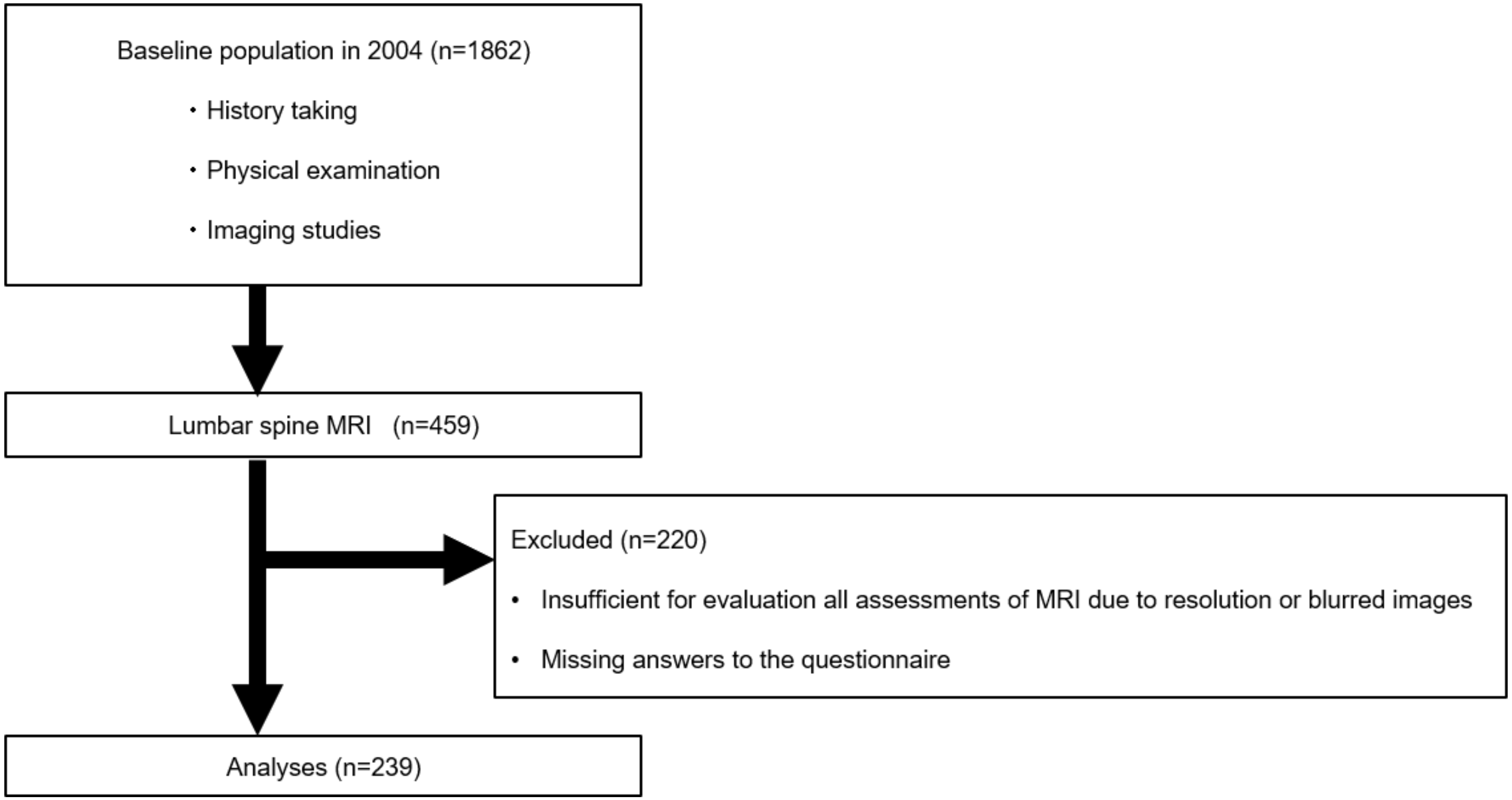
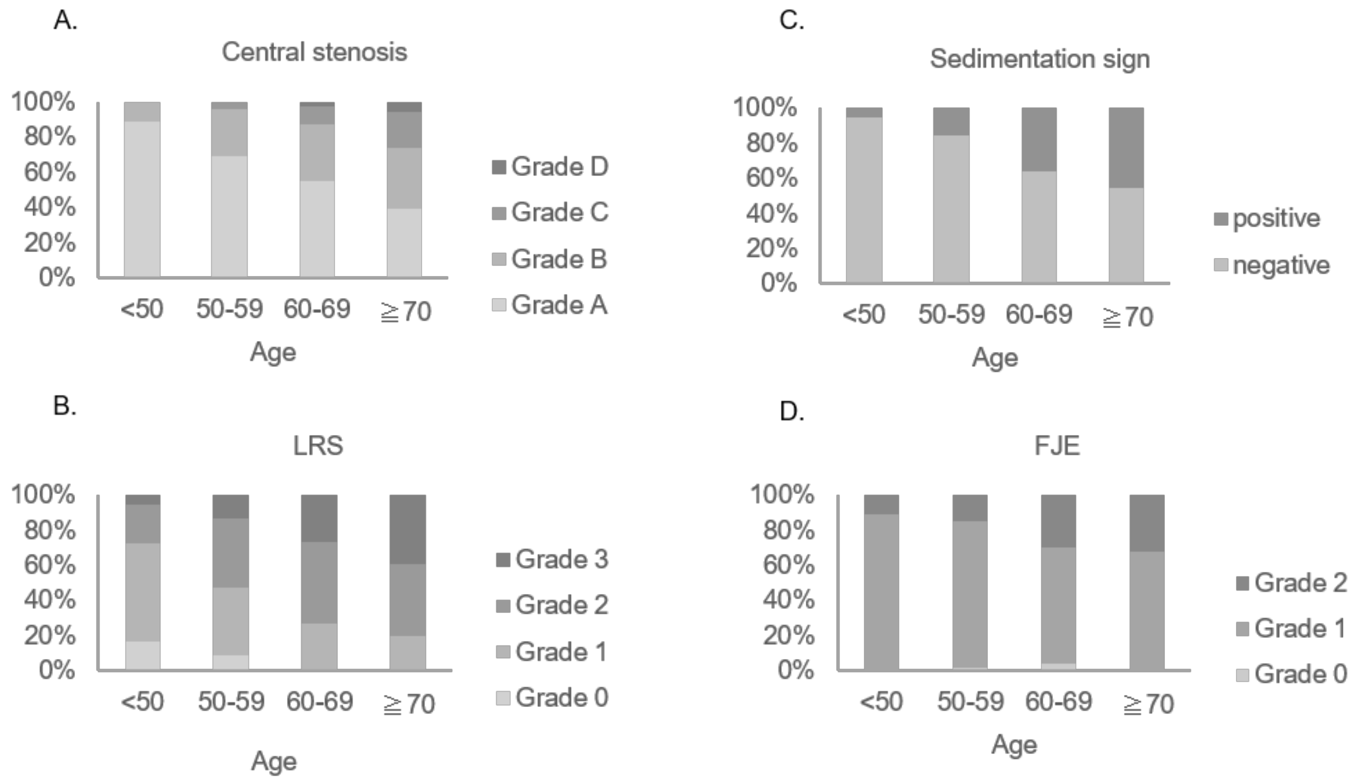


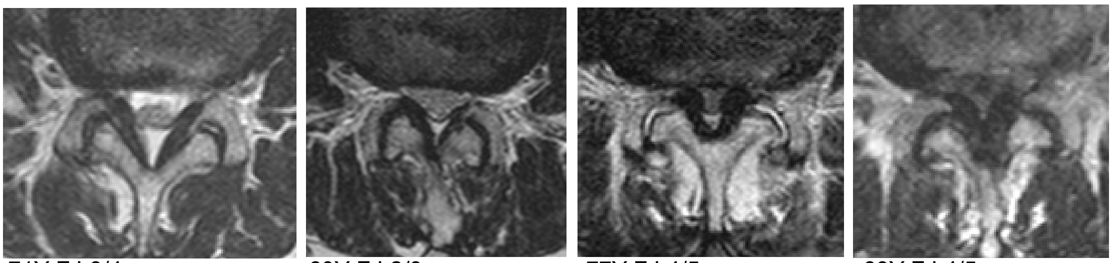
Figure 2: The distribution of grades in each classification by age.



Supplementary data

Central stenosis

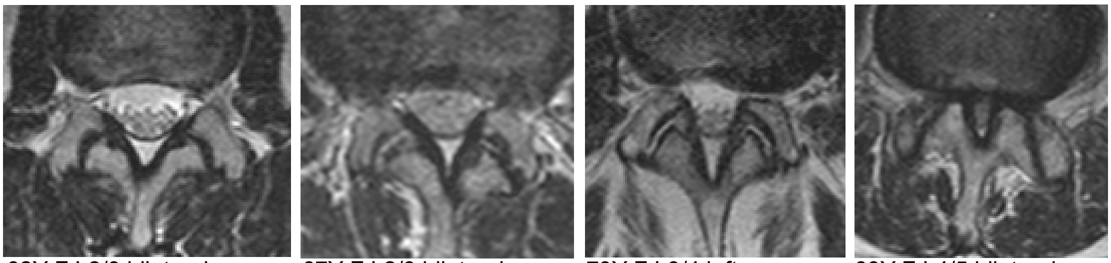
Grade A **Grade B** **Grade C** **Grade D**



71Y F L3/4 60Y F L2/3 77Y F L4/5 69Y F L4/5

Lateral recess stenosis (LRS)

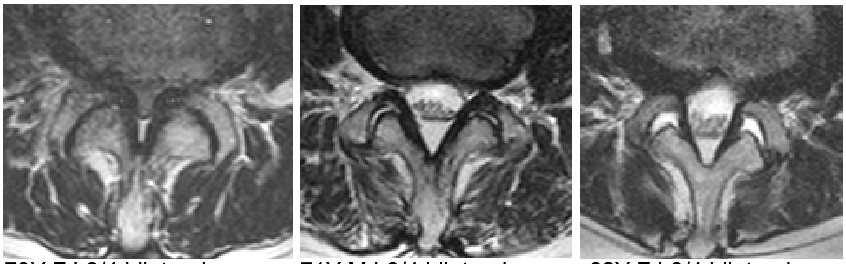
Grade 0 **Grade 1** **Grade 2** **Grade 3**



62Y F L2/3 bilateral 67Y F L2/3 bilateral 79Y F L3/4 left 68Y F L4/5 bilateral

Facet joint effusion (FJE)

Grade 0 **Grade 1** **Grade 2**



79Y F L3/4 bilateral 71Y M L3/4 bilateral 62Y F L3/4 bilateral

Abbreviations: LRS, lateral recess stenosis; FJE, facet joint effusion.