

Magnitude of dural tube compression does not show a predictive value for symptomatic lumbar spinal stenosis for 1-year follow-up: a prospective cohort study in the community

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Background: The North American Spine Society states that lumbar spinal stenosis (LSS) is a clinical syndrome, and there is insufficient evidence to make a recommendation for or against a correlation between clinical symptoms or function and the presence of anatomic narrowing of the spinal canal on MRI. The main purpose of this study was to assess the influence of the magnitude of dural tube compression on MRI on LSS symptoms at the cross-sectional and 1-year follow-up.

Methods: This was a prospective cohort study of 459 participants who were assessed for LSS using a questionnaire and conventional MRI of the lumbar spine. After 1 year, 335 subjects (follow-up rate 73.0%) were assessed for LSS using the same questionnaire. The time course of the clinical subjective symptoms of LSS and the relationship between the said symptoms of LSS and magnitude of dural tube compression on MRI were analyzed in a cross-sectional and longitudinal fashion.

Results: 1) The dural sac cross-sectional area (DCSA) decreased with age. 2) Severe dural tube compression had a strong influence on the presence of symptomatic LSS; however, 40%–70% of participants with severe dural tube compression did not show clinical symptoms of LSS. 3) At the 1-year follow-up, >50% of the LSS-positive participants in the initial year were reclassified as LSS negative, and 10% of the LSS-negative participants were reclassified as LSS positive. 4) The magnitude of the DCSA on MRI did not directly affect the presence of LSS at the 1-year follow-up.

Conclusion: LSS symptoms were changeable. Anatomical dural tube compression on MRI did not predict the presence of clinical LSS symptoms at the 1-year follow-up.

Keywords: lumbar spinal stenosis, epidemiology, natural history, quality of life, prognostic factors, comorbidities, cross-sectional area, MRI

Introduction

The clinical guidelines for degenerative lumbar spinal stenosis (LSS) by North American Spine Society (NASS) mention that LSS is a clinical syndrome, which is associated with diminished space available for the neural and vascular elements in the lumbar spine secondary to degenerative changes in the spinal canal.¹ LSS is diagnosed through subjective symptoms, physical findings, such as neurological findings, and radiological abnormalities. The symptoms of LSS have certain characteristic provocative (neurogenic claudication) and palliative (symptom relief with forward flexion, sitting, and/or recumbency) features.^{2–6}

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As stated in the NASS guidelines, dural tube compression is indicative of symptomatic LSS; however, dural tube compression does not always have symptoms.^{1,7-9} Measurement of the dural sac cross-sectional area (DCSA) has been accepted as a way to evaluate the severity of dural tube compression for central stenosis. Up to now, it has been accepted that the borderline DCSA for diagnosing absolute spinal stenosis is $<75 \text{ mm}^2$ and for relative spinal stenosis is $<100 \text{ mm}^2$.^{10,11} However, controversy remains regarding the relationship between the severity of dural tube compression and clinical symptoms or quality of life (QoL).¹²⁻¹⁹

Recently, a diagnostic support tool for LSS has become available.²⁰ Using this diagnostic support tool, epidemiologic studies for the prevalence²¹⁻²³ and 1-year follow-up of LSS²⁴ have been reported. However, the epidemiology of symptomatic LSS (diagnosed by subjective symptoms and radiological findings) and asymptomatic LSS (diagnosed by only radiological findings) is still unclear.

The main purpose of this study was to assess the influence of the magnitude of dural tube compression on MRI on LSS symptoms at the cross-sectional and 1-year follow-up.

Participants and methods

This was a prospective cohort study of 459 participants (male: 148 and female: 311) who were assessed for LSS using a questionnaire and conventional MRI of the lumbar spine. Most participants were aged 70–79 years. The participants comprised ~5.6% of local residents of Tadami town, Tateiwa village, and Ina village in Fukushima prefecture, Japan (Table 1). These 3 places are located in mountainous areas. All participants were self-sufficient (living in their own houses without the need for supplemental care and walking independently with or without support, such as a cane or a walker).^{22,24}

After 1 year, 335 participants (male: 103 and female: 232) (follow-up rate 73.0%) were assessed for LSS using the same questionnaire. No subjects underwent surgery for LSS during the 1-year period.

Table 1 Proportion of participants by age group in the community

Age (years)	Participants (n)	Rate (%)
<40	18	1.2
40–49	24	2.1
50–59	74	5.5
60–69	151	9.8
70–79	160	9.3
80+	32	3.0
Total	459	5.6

Note: Participants aged between 60 and 70 years were majority and covered 9.3%–9.8% of the community members.

All participants provided written informed consent in each initial analysis (2004) and 1-year follow-up (2005).

LSS symptoms

The presence of LSS was determined by a specially designed and validated LSS diagnostic support tool, which was a self-administered, self-reported history questionnaire (LSS-SSHQ). This questionnaire consisted of 10 yes/no questions (Table S1). The sensitivity of the questionnaire was 85.5% with the derivation data and 79.1% with the validation data. The specificity of this questionnaire was 84.3% with the derivation data and 78.1% with the validation data. The area under the receiver operating characteristic curve was 0.782.²⁰ According to the result of LSS-SSHQ, participants were divided into 2 categories: LSS positive and LSS negative.

Evaluation of leg symptom intensity and disease-specific QoL

Leg symptom intensity was evaluated using an 11-point numerical rating scale (NRS; 0: absence of pain/numbness and 10: worst pain/numbness). The Roland–Morris Disability Questionnaire (RDQ) (Japanese version) was used to measure disease-specific disability.²⁵⁻²⁸ A Japanese version of the RDQ provides the national normative RDQ score and SD values (20–79 years old, male/female). All data regarding LSS-SSHQ, NRS of leg symptoms, and RDQ were collected by a self-report.

Evaluation of MRI findings

Axial T2-weighted images were obtained at the midpoint of each intervertebral disc from L1/2 to L5/S1 using 3 MRI machines. The details of these machines are described in Table 2. Transverse slices were aligned as parallel as possible to each intervertebral disc. The DCSA of L1/2–L5/S1 on the T2-weighted image was measured using the conventional formula described by Hamanishi et al.²⁹ This formula is suitable for DCSA measurement because of its simplicity and reliability. The interobserver reliability of this formula was reported as 0.92. In addition, the correlation

Table 2 Detail of MRI manufacturers

Manufacturers	Hitachi	Philips	Toshiba
Product name	AIRIS mate	Gyroscan Intera Power	EXCELART/P2 Pianissimo
Tesla	0.2 T	1.0 T	1.5 T
Slice thickness (mm)	6	5	5
Slice gap (mm)	1	0.5	1
TE (ms)	120	120	108
TR (ms)	3,500	4,500	4,000
No. of participants	214	170	75

Abbreviations: TE, echo time; TR, repetition time.

coefficient for DCSA measured using this formula and the digitizer method was 0.96. In this study, intraobserver reliability of 2 investigators (KO and TN) was 0.91 and 0.90, respectively. The interobserver reliability between the 2 investigators was 0.87.

Both KO and TN were experienced spine surgeons. KO, in particular, was an attending surgeon licensed by the Japanese Society for Spine Surgery and Related Research.

The intra- and interobserver reliability was considered acceptable and the first measurement by KO was used for analysis. The smallest DCSA of L1/2–L5/S1 in each participant was divided into 5 categories: $<25 \text{ mm}^2$, $25\text{--}49.9 \text{ mm}^2$, $50\text{--}74.9 \text{ mm}^2$, $75\text{--}99.9 \text{ mm}^2$, and $\geq 100 \text{ mm}^2$. The number of intervertebral discs of which the smallest DCSA was $<50 \text{ mm}^2$ (ranged 0–5) was also analyzed.

Statistics

The presence of correlation between the 5 categories of the smallest DCSA and age was analyzed using Spearman's rank correlation. The Mann–Whitney *U* test was used to examine the relationship between LSS positive/negative and the 5 categories of the smallest DCSA or the number of intervertebral discs of which DCSA was $<50 \text{ mm}^2$. A multiple logistic regression analysis was performed with the presence of LSS at the 1-year follow-up as the dependent variable, and age, gender, RDQ score, NRS of leg pain/numbness, presence of LSS at the initial analysis, smallest DCSA, and the number of intervertebral discs with DCSA $<50 \text{ mm}^2$ as independent variables. All statistical analyses were performed using the STAT View software package (version 5.0, SAS Institute Inc., Cary, NC, USA). A *P*-value of <0.05 was considered statistically significant.

Source of funding

This study was supported by a grant from the Fukushima Society for the Promotion of Medicine and a grant from Fukushima Prefectural Hospitals Office. These grants were mainly used for the cost of MRI, research assistance, and printing and posting the questionnaire.

Ethical approval

This study was approved by the ethical committee of Fukushima Medical University.

Results

Relationship between the smallest DCSA and age at the initial assessment

The magnitude and the average of the smallest DCSA decreased with age. There was a statistical correlation between the 5 DCSA categories and age ($P<0.01$) (Table 3). This indicates that degenerative changes to the spine strongly affect the magnitude of the smallest DCSA.

Relationship between the smallest DCSA and the presence of LSS at the initial assessment

The number of participants judged as LSS positive was 27 of 48 (56.3%) in the group with the smallest DCSA of $<25 \text{ mm}^2$, 27 of 102 (26.5%) in the $25\text{--}49.9 \text{ mm}^2$ group, 32 of 108 (29.6%) in the $50\text{--}74.9 \text{ mm}^2$ group, 17 of 76 (22.4%) in the $75\text{--}99.9 \text{ mm}^2$ group, and 25 of 125 (20%) in the group with DCSA of $\geq 100 \text{ mm}^2$. There was a statistically significant difference in the distribution of the smallest DCSA between the participants with LSS positive and negative ($P=0.0003$) (Table 4). Similarly, a statistically significant difference was observed in the number of intervertebral discs of which the smallest DCSA of $<50 \text{ mm}^2$ between the participants with LSS positive and negative ($P=0.0116$) (Table 5). Among 57 participants with ≥ 2 DCSA of $<50 \text{ mm}^2$, 31 (54.4%) were judged as LSS negative.

LSS evaluated by questionnaire at the 1-year follow-up

In the 2004 LSS-positive group, 48 of 107 (44.9%) participants remained LSS positive in 2005, whereas 59 of 107 (55.1%) were reclassified as LSS negative. On the other hand, 205 of 228 participants (89.9%) in the LSS-negative group

Table 3 Relationship between the smallest DCSA and age

Age (years)	N	The smallest DCSA (mm^2)					Av (95% CI)
		<25	$25\text{--}49.9$	$50\text{--}74.9$	$75\text{--}99.9$	≥ 100	
<40	18	0 (0)	2 (11.1)	5 (27.8)	1 (5.6)	10 (55.6)	101 ± 45 (78.5–123.4)
40–	24	2 (8.3)	4 (16.7)	3 (12.5)	3 (12.5)	12 (50)	101 ± 54 (78.3–124.0)
50–	74	5 (6.8)	13 (17.1)	16 (21.6)	11 (14.9)	29 (39.2)	88 ± 43 (77.9–97.6)
60–	151	12 (7.9)	33 (21.9)	40 (26.5)	32 (21.2)	34 (22.5)	74 ± 41 (67.3–80.6)
70–	160	26 (16.3)	44 (43.1)	34 (27.5)	25 (15.6)	31 (19.4)	64 ± 38 (57.6–69.5)
80+	32	3 (9.4)	6 (18.8)	10 (31.3)	4 (12.5)	9 (28.1)	74 ± 42 (59.0–89.1)

Notes: The magnitude and average size of the smallest DCSA increased with age. There was a statistical correlation between the 5 grades of DCSA and age ($P<0.01$).

Abbreviations: Av, average; DCSA, dural sac cross-sectional area.

Table 4 Relationship between the smallest DCSA and LSS symptoms

	The smallest DCSA (mm ²)				
	<25	25–49.9	50–74.9	75–99.9	≥100
Av age (years) (95% CI)	70±9.0 (67.0–72.2)	68±10 (65.5–69.5)	66±11 (63.7–67.9)	66±10 (63.5–67.8)	62±14 (59.5–64.4)
LSS symptoms					
Negative	21	75	76	59	100
Positive	27	27	32	17	25
Total	48	102	108	76	125

Note: There was a statistically significant difference in the distribution of the smallest DCSA between participants with LSS positive and negative ($P=0.0003$).

Abbreviations: Av, average; DCSA, dural sac cross-sectional area; LSS, lumbar spinal stenosis.

in 2004 were still in the LSS-negative group in 2005, with the other 23 of 228 (10.1%) having been reclassified as LSS positive (Table 6).

In this study, standing X-ray images of anterior–posterior and lateral positions were taken to evaluate scoliosis (Cobb angle $\geq 10^\circ$), degenerative spondylolisthesis (anterolisthesis or retrolisthesis), and spondylolysis or isthmic spondylolisthesis. These X-ray image findings did not influence the presence of symptomatic LSS evaluated by LSS-SSHR at the initial assessment and 1-year follow-up (data not shown).

Analysis of predictors for LSS at the 1-year follow-up

According to a multiple logistic regression analysis, only 2 factors, the presence of LSS symptoms (OR 4.480) and the score below the normative RDQ score (OR 5.169) at the initial assessment, had statistically significant influence on the presence of LSS symptoms at the 1-year follow-up (Table 7).

Discussion

In the present study, some controversial issues regarding etiology of LSS arose. First, in the group with the smallest DCSA of <25 mm², which is considered severe dural tube compression, only half of the participants were judged as

LSS positive (Table 4). Second, more than half of the participants with ≥ 2 DCSA of <50 mm² were categorized as LSS negative (Table 5). Third, more than half of the participants with LSS positive were reclassified as LSS negative at the 1-year follow-up (Table 6). Fourth, the magnitude of dural tube compression, assessed by the smallest DCSA or the number of intervertebral discs of which the smallest DCSA of <50 mm², was not a predictive factor for the presence of LSS after 1 year (Table 7). Overall, these findings suggest that severe dural tube compression did not always show LSS symptoms, LSS symptoms seemed not to be stable for 1-year period and the magnitude of dural tube compression was not a predictive factor for the presence of LSS at the 1-year follow-up.

In degenerative spine disease, it is well known that degenerative changes do not always cause symptoms.^{7–9} In patients with symptomatic LSS, operative treatment is preferred to improve pain, disability, and QoL compared with non-operative treatment.^{30,31} However, Herno reported that post-operative DCSA was not associated with these outcomes.³² Similarly, in the preoperative LSS patients, it is still controversial whether DCSA and the magnitude of symptoms or QoL are correlated or not.^{13–19} Several reasons are considered to explain the discrepancy between the magnitude of DCSA and occurrence of LSS symptoms. First, conventional MRI was obtained in the supine position; however, patients usually

Table 5 Relationship between the number of intervertebral discs with smallest DCSA of <50 mm² and LSS symptoms

	The number of intervertebral discs whose DCSA was <50 mm ²			
	0	1	2	≥3
LSS symptoms				
Negative	233	67	21	10
Positive	73	29	20	6
Total	306	96	41	16

Notes: There was a statistically significant difference in the number of intervertebral discs with the smallest DCSA of <50 mm² between participants who were LSS positive and negative ($P=0.0116$). However, all participants who had 3 or more intervertebral discs with DCSA of <50 mm² and were not judged as LSS positive.

Abbreviations: DCSA, dural sac cross-sectional area; LSS, lumbar spinal stenosis.

Table 6 LSS symptoms at the 1-year follow-up

	1-year follow-up		Total
	LSS-positive	LSS-negative	
Initial analysis			
LSS-positive	48	59	107
LSS-negative	23	205	228
Total	71	264	335

Notes: At the 1-year follow-up, some participants who were initially judged as LSS positive were re-categorized as LSS negative (59/107, 55.1%) and some participants who were initially LSS negative were re-categorized as LSS positive (23/228, 10.1%). LSS symptoms seemed unstable.

Abbreviation: LSS, lumbar spinal stenosis.

Table 7 Predictors for LSS symptoms at the 1-year follow-up

	OR	95% CI	P-value
Age (years)	0.997	0.941–1.057	0.9177
Gender			
Male	Ref.	–	–
Female	0.351	0.108–1.141	0.0818
Normative RDQ score (50= normative value)			
≥50	Ref.	–	–
<50	5.169	1.662–16.075	<u>0.0045</u>
NRS of leg pain/numbness	1.195	0.933–1.530	0.1582
LSS at the initial analysis			
Negative	Ref.	–	–
Positive	4.480	1.451–13.834	<u>0.0091</u>
The smallest DCSA	0.988	0.965–1.011	0.3156
No. of DCSA of <50 mm ²			
0	Ref.	–	–
1	0.242	0.037–1.581	0.1382
2	0.248	0.032–1.924	0.1822
≥3	0.143	0.007–2.925	0.2067

Notes: Contribution ratio (R^2) was 0.275. Both the presence of LSS symptoms and the score below the normative RDQ score at the initial assessment statistically influenced the presence of LSS symptoms at the 1-year follow-up. The magnitude of dural tube compression was not considered as a predictive factor for the presence of LSS at the 1-year follow-up. Underlined values represents statistical significance.

Abbreviations: DCSA, dural sac cross-sectional area; LSS, lumbar spinal stenosis; NRS, numerical rating scale; RDQ, Roland–Morris Disability Questionnaire.

show LSS symptoms while standing and/or walking. Takahashi et al reported that a higher epidural pressure during standing and/or walking induces LSS symptoms compared with lower epidural pressure in the supine position.^{33,34} Many studies have reported the difference in DCSA in the supine position with and without axial loading. The size of DCSA in the supine position with axial loading was considered to be similar to that in the standing position. DCSA in the supine position with axial loading is statistically smaller than that without the loading.^{35–39} Second, it is not easy to detect the dynamic factor of so-called instability or occult spondylolisthesis on conventional MRI taken in just 1 static position.^{38,40–43} Third, whether they are aware of it or not, people with a smaller DCSA may adopt a forward-bending posture to either reduce or avoid LSS symptoms. Fourth, magnitude of DCSA represents only the degree of central stenosis and not lateral stenosis and foraminal stenosis that induce radicular symptoms.^{17,29}

There are several limitations to this study. First, lateral stenosis and foraminal stenosis were not assessed. Second, there was no evaluation of the severity of LSS symptoms. Third, the follow-up rate of 77.3% is relatively low. Fourth, the 1-year follow-up period seemed to be too short to effectively judge any newly occurring LSS symptoms. Fifth, there was no evaluation of comorbidities, such as hip

osteoarthritis (OA), knee OA, internal medicine problem, and more. Sixth, the research location was in a rural and mountainous area, so the data may not extrapolate completely to the typical Japanese population. Finally, all the participants in this study were volunteers and as such, there could be an unintentional sample bias. In spite of these limitations, the present study might still be worth because it shows that the magnitude of dural tube compression was not equal to the occurrence of symptomatic LSS at the 1-year follow-up in the community. This is the first prospective study to show the relationship between LSS symptoms and image findings in the community setting. Further study is needed to investigate the occurrence of LSS in a long-term follow-up and risk factors of LSS for the maintenance of health in the elderly.

Conclusion

At the 1-year follow-up, the magnitude of DCSA had not affected the presence of LSS directly. Dural tube compression is an anatomical cause for LSS; however, LSS is not always symptomatic. The relationships between symptomatic and asymptomatic LSS in people with dural tube compression remain unclear.

Acknowledgments

The authors wish to thank Dr Akira Onda, Dr Kazuya Yamauchi, Dr Yoshiaki Takeyachi, Dr Ichiro Takahashi, Dr Hisayoshi Tachihara, and Dr Bunji Takayama for participating in the data collection. The authors would also like to thank 5 public nurses (Nobuko Fujita, Nakako Hoshi, Misako Hoshi, Naoko Imada, and Seiko Kanno) for their support in carrying out this study. This study was supported by a grant from the Fukushima Society for the Promotion of Medicine and a grant from the Fukushima Prefectural Hospitals Office.

Author contributions

Conception and design: KO, SI Kikuchi, and SI Konno; data analysis: KO and TN; manuscript preparation: KO and SI Kikuchi.

Disclosure

All authors report no conflicts of interest in this work. This study was presented at the 39th Annual Meeting of International Society for the Study of the Lumbar Spine (May 2012, Amsterdam, the Netherlands).

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Supplementary material

Table S1 Lumbar spinal stenosis-self-administered, self-reported history questionnaire (LSS-SSHQ)

1: Numbness and/or pain in the thighs down to the calves and shins. Yes/No
2: Numbness and/or pain increases in intensity after walking for a while, but are relieved by taking a rest. Yes/No
3: Standing for a while brings on numbness and/or pain in the thighs down to the calves and shins. Yes/No
4: Numbness and/or pain are reduced by bending forward. Yes/No
5: Numbness is present in both legs. Yes/No
6: Numbness is present in the soles of both feet. Yes/No
7: Numbness arises around the buttocks. Yes/No
8: Numbness is present but pain is absent. Yes/No
9: A burning sensation arises around the buttocks. Yes/No
10: Walking nearly causes urination. Yes/No

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