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Case Report

Consideration to a New Standard for the Diagnosis of Lumbar Central Canal Stenosis by Quantitative MRI Assessment

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Abstract

The first aim of this study is to assess the Dural Sac Cross-sectional Area (DSCA) of the lumbar spinal canal in healthy young individuals with the appropriate posture when using MRI. A secondary aim was to determine if obtained DSCA values are correlated with each symptom. The group of 15 healthy individuals (group I) were scanned in the flexed and extended knee posture. The DSCA and Spinal Canal Cross-sectional Area (SCCA) were measured at the center of the pedicle level of each vertebral body. A group of 42 symptomatic patients (group II) were scanned, and the correlation with each symptom was statistically evaluated. In group (I), the mean DSCA was 178 ± 5.1 mm^2 in the flexed posture and 158.9 ± 5.6 mm^2 in the extended knee posture. At each level, there was a significantly smaller DSCA in the extended posture. In group (II), the mean DSCA was almost two-third of that in group (I). The DSCA at L1/2 and L2/3 showed a mild correlation with the Japanese Orthopedic Association score - IV (JOA - IV) (urinary disturbance score) (r^2 = 0.16 and 0.21). Minimum DSCA was significantly correlated with JOA - IC (intermittent claudication) ($p = 0.0003$, $r^2 = 0.278$). The number of inter vertebral levels with severe and moderate stenosis was assessed and a significant negative correlation was found with JOA - IC and IV (p = 0.0046 and 0.0275. r^2 = 0.184 and 0.116, respectively).

It should be noted that these imaging values should be always considered with matched lumbar symptoms.

Keywords: COSMIC, Dural sac cross-sectional area; Healthy young individual; Lumbar canal stenosis; Quantitative assessment

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Abbreviations

COSMIC: Fat - suppressed three - dimensional Coherent Oscillatory State acquisition for the Manipulation of Image Contrast
DSCA: Dural Sac Cross - sectional Area
JOA: Japanese Orthopedic Association score
SCCA: Spinal Canal Cross - sectional Area

Introduction

Previously, many morphologic spinal canal studies have been done using a plain radiograph or CT with or without a contrast medium [1-4] and cadaver [5]. Recent advancements in radiological techniques have enabled us to perform a faster and less invasive diagnosis, which resulted in the development of a new assessment method for the spinal canal with magnetic resonance imaging [6-12]. Fat - suppressed three - dimensional Coherent Oscillatory State acquisition for the Manipulation of Image Contrast (COSMIC) is a sequence based on fast imaging employing steady - state acquisition, which are more appropriate angle sliced spinal canal images taken in shorter time. COSMIC images are obtained from reconstructed original 3D scanned images, which can easily produce various thin sliced planes.

Several previous studies also measured anteroposterior diameter of the lumbar spinal canal or Dural Sac Cross-sectional Area (DSCA) of patients involved disc level, and then attempted to apply the numerical data to lumbar symptoms statistically, which resulted in no correlation (Table 1) [2,13-16]. However, the previous studies' designs may have negatively affected the results. Moreover, some studies use upright MRI and axial loading of the spine [2,8,11,13,14]. Those studies suggest the importance of a more appropriate condition while taking images despite whether or not it is an expensive and complicated method. We decided on a unified, reasonable, and easy posture while taking images to avoid variable values in the same individual without using upright MRI or axial loading of the spine for daily clinical decisions.

Previous standards for lumbar central canal stenosis were <75 mm^2 or 100 mm^2 in the DSCA [2,3,15,16], which clinicians might not recognize as "lumbar canal stenosis" at a glance. Those standards could lead to many unimproved cases after decompression surgery. Furthermore, clinicians have to realize there may be coexisting stenotic lesions along with spinal canal stenosis when making decisions, as the Spine Patient Outcomes Research Trial (SPORT) study suggested [17]. This study might help achieve better patient outcomes when we decide to surgically treat lumbar central canal stenosis with decompression.

Objective

Clarifying the correlation between lumbar symptoms and 3 - dimensional radiographical data leads to clinical decision making for all the spine surgeons.

Material and Methods

Fifteen healthy Japanese individuals and 16 patients with lumbago and/or leg pain were examined in two separate studies. A MRI was taken in the supine position by using the three - dimensional COSMIC method without axial loading.

Author	Nation	Year	Modality	Up/AxL	Posture	Range	Subject	DSCA	Classification (mm2)	Claudication	Pain	Other Symptoms
Zeifang F	German	2008	T2		supine	L1_S1	patient	formula	70_100	gait distance	nm	nm
Sirvanci M	Turkey	2008	T2_T1		PRP	L2_5	patient	yes	75_100	nm	nm	ODI
Geisser M	USA	2007	T2		supine	T12_S1	patient normal	APD	nm	15min gait	MPQ_PDI	QBPDS
Madsen R	Denmark	2007	T1	Up AxL	PRP EXT	L1_S1	patient	yes	nm	nm	nm	nm
Lohman CM	Finland	2005	Ctmyelo	AxL	PRP	L3_S1	patient	yes	75_100	gait distance	VAS	ODI
Willen J	Sweden	1997	CTmyelo_ MRI	AxL	PRP	L3_S1	patient	yes	75_100	500m	nm	motor
Abbas J	Israel	2010	CT		EXT	L3_S1	patient normal	yes	nm	nm	nm	nm
Wang YC	Taiwan	2008	MRI	AxL	PRP	L2_S1	patient	yes_APD	nm	nm	nm	nm
Weiner KB	USA	2007	MRI		supine	L4/5	patient	formula	nm	NCOS	NCOS	nm
Zheng F	USA	2006	CTmyelo		supine	T12_S1	patient	yes	nm	nm	nm	nm
Sigmunds-son F	Sweden	2010	T1		supine	L1_5	patient	yes	70	gait distance	VAS	ODI_SF36_ EQ-5D
Schizas C	UK	2010	T2		supine	L1_5	patient	formula	nm	nm	nm	nm
Mauch F	German	2009	T1 T2	Up AxL	PRP	L3_5	athlete	yes APD	nm	nm	nm	nm
Tan SH	Singapore	2002	cadaver		nm	L1_5	normal	nm	nm	nm	nm	nm
Kanno H	Japan	2012	T2	AxL	EXT	L2_S1	patient	yes	nm	gait distance	VAS	JOA
Hamani-shi C	Japan	1994	T2		supine	L2_5	patient normal	formula	100	yes	nm	nm
Danielson B	Sweden	2001	T2	AxL	PRP	nm	normal	yes	100	nm	nm	nm
Park DK	USA	2010	nm		nm	L2_S1	patient	nm	nm	yes	yes	ODI_SF36_ MCS

Table 1: Recent representative studies of lumbar canal stenosis.

The study of Park DK et al., was a multicenter randomized trial

nm: not mentioned in the manuscript; Up: Upright MRI; AxL: Axial Loading; PRP: flexed knee posture; EXT: Extended Knee Posture; supine: posture not mentioned in detail; APD: Anteroposterior Diameter

Group (I) were 15 healthy individuals (mean age: 36.3 ± 3.3 years, 7 men and 8 women) who were scanned in the flexed and extended knee posture from Lumbar vertebra 1 (L1) to Sacral vertebra 1 (S1). Axial views were taken parallel to each intervertebral line (L1/2 - L5/S1) to acquire accurate slices by 3D remodeling. The DSCA and the Spinal Canal Cross-sectional Area (SCCA) at the center of the pedicle level of each vertebral body were measured in each posture to obtain the mean values of healthy Japanese people. We also assessed whether such an easy change of supine postures could make a significant difference.

Group (II) including 42 patients (mean age: 71.7 ± 1.8 years old, 26 men and 16 women) were enrolled. Each patient had a history of at least 12 weeks of symptoms of low back, leg pain or gait disturbance (e.g., intermittent claudication) and the degree of severity was ranged from mild to severe. They were scanned in the extended knee posture only (spinal extended position) to obtain the parameters, and then the correlation with each symptom was statistically evaluated. In order to assess the morphology of the spinal stenosis in 3 - dimension, the graphical parameters included as explanatory variables were the minimum DSCA in each patient's lumbar spine, the number of intervertebral levels with a DSCA < 40 mm^2 (severe stenosis) and < 80 mm^2 (moderate stenosis). Outcome measures included as dependent variables were VAS, total Japanese Orthopedic Association - lumbar score (total JOA), JOA - lumbago score that consists JOA - IA, JOA - gait ability that matches the JOA - IC and JOA - urinary disturbance which corresponds to the JOA - IV.

Statistics

JMP 8 statistical software was used for statistical analysis in the study. When investigating the difference between groups, the Tukey - Kramer method was used. When investigating the correlation between graphical parameters and outcome measures, Pearson's correlation was used. The level of significance was set at 0.05.

Results

Group (I)

A typical sample of COSMIC images is shown in figure 1. The total mean DSCA was 178 ± 5.1 mm^2 in the flexed knee posture and 158.9 ± 5.6 mm^2 in the extended knee posture (Table 2). The mean DSCA at each disc level was not significantly different between postures and the values gradually decreased as the disc level moved caudally. The DSCA was significantly different at all disc levels in the flexed knee posture compared to the extended knee posture (p = 0.0196 at L1/2, 0.0017 at L2/3, 0.0002 at L3/4, <0.001 at L4/5, and 0.0002 at L5/S1), which resulted in a significantly decreased DSCA value at each level in the extended knee posture. Although the mean DSCA between each disc level did not reveal any statistically significant differences in the flexed knee posture, the mean DSCA at L1/2 was significantly larger compared to L5/S1 in the extended knee posture (p = 0.041). Moreover, the mean difference between DSCA in the flexed and extended knee posture was the largest at L5/S1 (29.33), which suggests that L5/S1 would be more influenced by dynamic spinal factors.

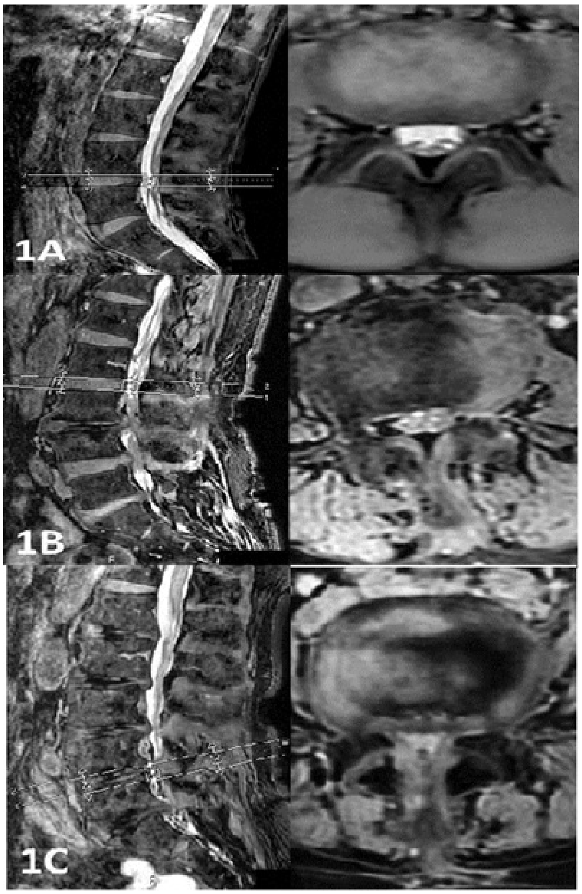

Figure 1: Examples of COSMIC images (A) Healthy individual/DSCA = 154 mm², (B) moderate stenosis/DSCA = 72 mm², and (C) severe stenosis/DSCA = 36 mm².

		DSCA		SCCA
		Knee-flexed	Knee-extended	Knee-extended
Mean value	Group (I)	178 ± 5.1	158.9 ± 5.6	203.6 ± 7.1
	Group (II)		104.4 ± 4.0	196.5 ± 3.5

Table 2: Total mean DSCA and SCCA in both groups.

The total mean SCCA was 203.6 ± 7.1 mm², and the mean at each mid pedicular level was similar and gradually decreased, which resulted in significantly smaller L5 SCCA compared to L1 ($p = 0.0484$) (Table 2). The mean DSCA and SCCA at each vertebral level for group (I) are shown in table 3.

		Group (I)			Group (II)
	Knee-flexed	Knee-extended	Knee-extended	Knee-extended	Knee-extended
	Mean DSCA	Mean DSCA	Mean SCCA	Mean DSCA	Mean SCCA
L1/2	192.4	182.1	231.4 (L1)	152.0	218.8 (L1)
L2/3	180.1	164.5	223.3 (L2)	120.1	211.8 (L2)
L3/4	180.6	158.3	201.7 (L3)	80.4	191.6 (L3)
L4/5	174.5	156.8	191 (L4)	71.7	177.5 (L4)
L5/S1	162.2	132.9	170.9 (L5)	123.8	173.0 (L5)

Table 3: Mean DSCA and SCCA at each disc level in both groups.

Group (II)

Upon receiving the results of group (I), we decided to only measure the DSCA in the extended knee posture because the extended posture is suitable for the diagnosis of lumbar canal stenosis. The mean DSCA of all the lumbar spinal level was 104.4 ± 4.0mm² and the mean SCCA was 196.5 ± 3.5 mm² (Table 2). The mean DSCA in group (II) was almost two - third of group (I). The mean SCCA at each mid pedicular level was similar to that in group (I), even though these two groups have big difference in mean age. The SCCA at L1 and 2 was significantly larger compared to L4 and 5 ($p < 0.01$). The DSCA at L1/2, 2/3, and 5/S1 was also larger compared to L3/4 and 4/5 ($p < 0.005$) (Table 3). Other patients' demographical data were shown in table 4.

Number of severely affected levels	25
Number of moderately affected levels	75
Number of patients who have severely affected single level	15
Number of patients who have severely affected multilevel	4
Number of patients who have moderately affected single level	13
Number of patients who have moderately affected multilevel	25
Number of patients who underwent previous lumbar surgery	4

Table 4: Patients demographic data.

When considering the relationship between disc level and each symptom, the DSCA value at L1/2 and 2/3 was significantly correlated with the JOA - IV (urinary disturbance score) ($p = 0.0078$ and 0.0022), however, showed only mild correlation ($r^2 = 0.16$ and 0.21).

The mean minimum DSCA was 47.6 ± 4.7 mm². There were no significant correlations between the minimum DSCA and VAS, total JOA, JOA - IA, and JOA - IV ($p = 0.3345$, 0.1243, 0.1634, and 0.1024, respectively). However, a significant correlation was found between minimum DSCA and JOA - IC ($p = 0.0003$, $r^2 = 0.278$) (Table 5); therefore, the patient who had a lower minimum DSCA was more likely to have intermittent claudication.

	Minimum DSCA	# <40 mm2 DSCA	# <80 mm2 DSCA
VAS	0.3345	0.6515	0.5663
total JOA	0.1243	0.1681	0.0715
JOA-IA	0.1634	0.4186	0.6153
JOA-IC	0.0003* (0.278)	0.0046* (0.184)	0.0090* (0.159)
JOA-IV	0.4366	0.0275* (0.116)	0.0079* (0.164)

Table 5: Correlation between minimum DSCA, # of levels with stenosis, and each symptom.

$p < 0.05$* was defined as significant; r^2 values are demonstrated inside the parentheses

The relationship between symptoms and the number of intervertebral levels with severely stenosis (DSCA < 40 mm²) was assessed. As a result, no correlation was found between VAS, total JOA, and JOA - IA ($p = 0.6515$, 0.1681, and 0.4186, respectively); however, a significant negative correlation was found with JOA - IC and IV ($p = 0.0046$ and 0.0275, $r^2 = 0.184$ and 0.116). The results show that the number of severely narrowed (DSCA < 40 mm²) levels is significantly related to intermittent claudication and urinary disturbance. Subsequently, the number of intervertebral levels with moderate stenosis (DSCA < 80 mm²) was assessed. The data revealed the correspondence with those of the number of severely affected levels (Table 5).

Discussion

Previous studies of lumbar canal stenosis attempted to assess the relationship between symptoms and acquired values using various imaging modalities. There were some reports that found negative results [2,13-16]; however, we thought that the presence of more accurate study conditions when assessing the acquired values would lead to less pseudo-negative results, which would benefit clinicians who have to accurately diagnose conditions in outpatient settings daily.

In the group (I) session, healthy young Japanese individuals had almost the same DSCA (mean: 158.9 ± 5.6 mm^2) regardless of the intervertebral level, except for between L1/2 and L5/S1 in the extended knee posture. We thought the constant DSCA value could be acceptable as a definition when assessing spinal canal stenosis. To regulate the settings conveniently when taking an MRI, the knee posture was assessed. The extended knee posture significantly made the DSCA narrower compared to the flexed knee posture. The extended knee posture was thought to be ideal due to its convenience without using either axial loading or upright MRI. Moreover, the COSMIC method always provides an accurate cross-sectional plane by using 3D remodeling. Previous reports did not necessarily specify the posture when taking images and the precision of the angle of the acquired plane. Recently, the cross-sectional area can be instantly measured by drawing the contour of the dural sac without any formula, such as Hamanishi et al., [9,12,16,18].

In the group (II) session, each patient's minimum DSCA did not correlate with low back pain scores or urinary disturbance, such as VAS and JOA-IA/IV, but did correlate with JOA-IC, which indicates that even one level severe stenosis could cause gait disturbance as expected. Sigmundsson et al., reported that minimal DSCA did not correlate with estimated walking distance as a preoperative status [10]; however, this quantitative parameter does not accord with neurological intermittent claudication, which indicates that further research is needed.

It is known that some patients with radiographic spinal stenosis remain asymptomatic [19,20]; however, some patients have symptoms such as neurological claudication or pain. Ishimoto et al., reported that severe central stenosis was significantly associated with clinical symptoms, but only 17.5% of participants with severe central stenosis were symptomatic [21]. It is unclear why such differences are seen. We should also clarify the definition of "spinal stenosis." The Wakayama Spine Study qualitatively rated canal stenosis according to the classification included in a general guideline [22]. Until recently, a DSCA of < 100 mm^2 was most often used as a definition of spinal stenosis [6,18] while recent studies use a value of 70 - 80 mm^2 as a definition of spinal stenosis [10,23]. Some authors divided the extent of stenosis in two points (DSCA of 75 -100 mm^2) [2,3,15]. However, most of the studies have failed to demonstrate positive results when examining the relationship with symptoms. We considered the necessity of a clinically relevant classification, and as mentioned above, DSCA of < 40 mm^2 was used as the objective diagnostic criterion for "severe spinal stenosis", and DSCA of < 80 mm^2 as "moderate spinal stenosis." As a result, the number of severely or moderately affected levels did not correlate with the VAS of leg pain but did correlate with JOA - IC as intermittent claudication and JOA - IV as urinary disturbance, however, the severity of stenosis did not make difference. In a recent multicenter randomized trial, the Spine Patient Outcome Research Trial (SPORT), patients with multilevel spinal stenosis (with or without degenerative spondylolisthesis) were more likely to report neurogenic claudication [17]. They also reported that single level spinal stenosis patients were more likely to have a radicular distribution of their pain and depression compared to patients with more than 3 levels of stenosis. When we consider these results, the initial stage of spondylosis, such as one level of stenosis and a radiographically mildly compressed level, even though that is multilevel lesion, would more likely cause leg pain. In the later stage, spondylosis has developed to cause intermittent claudication by wide-expanding toward sagittal and axial, affecting the multilevel or single level. In short, the results of our study and the SPORT may have analyzed the same phenomenon from a different aspect.

Throughout the present study, total JOA and JOA - IA (low back pain) never correlated with DSCA. A few authors stated that total lumbar JOA scores were significantly correlated only with postoperative lower extremity VAS scores but not with the preoperative VAS and VAS for low back pain [24], which corresponds with our results. Low back pain occurs from various pathologies; therefore, we believe the total JOA score, including lumbar pain, is less likely to be associated with the radiographical values.

There were few reports that mentioned the relationship between the degree of dural sac compression and bladder symptoms. Tsai et al., concluded that anteroposterior diameter of the dural sac on an MRI was correlated with the American Urological Association Symptom Score [25]. Previous research has reported that the incidence of urinary disturbance was significantly higher in patients with disc herniation at L1/2 and 2/3 compared to lower levels (L3/4 - L5/S1) [26], which is similar to the result of the current study.

Finally, it should be noted that from a spine surgeon perspective, the decision for surgery will never be based on some DSCA value, but rather on both imaging data and clinical presentation because our study could not show the moderate/strong correlation between any imaging value and symptoms.

Conclusion

The COSMIC method is a useful, fast, and noninvasive technique to quantify the lumbar canal and dural sac. When researching spinal stenosis, the posture used when performing MRI has to be specified to obtain accurate numeric values. The patient analysis revealed that upper lumbar stenosis was correlated with urinary disturbance, neurogenic claudication was correlated with the minimum DSCA. The number of affected levels was correlated with intermittent claudication and urinary disturbance. The JOA and VAS of leg pain never correlated with radiographical stenotic values.

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