Diagnostic Importance of Axial Loaded Magnetic Resonance Imaging in Patients with Suspected Lumbar Spinal Canal Stenosis

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■ OBJECTIVE AND BACKGROUND: **To study the efficacy of lumbar (AL) magnetic resonance imaging (MRI) in patients with suspected lumbar spinal stenosis (LSS), with and without AL compression. Supine MRI is used in the assessment of patients with LSS. However, MRI findings may poorly correlate with neurologic findings because of the morphologic changes of the lumbar spinal canal between upright standing and supine positions. In patients without significant stenosis in routine lumbar MRI, by applying AL, MRI can show significant LSS.**

■ METHODS: **This study included 103 consecutive patients (188 disc levels) who presented with neurogenic claudication with and without low back pain. AL was performed using a nonmagnetic compression device for 5 minutes. T1- and T2-weighted axial and sagittal sequences were obtained during AL applied to the spine. The dural sac cross-sectional area (DSCA) appeared to be narrow at each disc level of L4—5 to L5—S1 in all patients and was measured using T2-weighted images in routine supine and AL images.**

■ RESULTS: **The groups included patients with a reduction in the DSCA (>15 mm^2) according to patient age and DSCA in routine spine MRI. The mean DSCA of the disc levels without and with AL were 138 mm^2 and 123 mm^2, with a mean difference of 15 mm^2 at L4—5, 134 mm^2 and 125 mm^2 and a mean difference of 9 mm^2 at L5—S1, respectively.**

■ CONCLUSIONS: **The use of AL MRI in patients with clinically suspected LSS could reduce the risk of misdiagnosis of stenosis, leading to inappropriate treatment.**

INTRODUCTION

Supine magnetic resonance imaging (MRI) is routinely used to evaluate patients with degenerative lumbar spinal stenosis (DLSS). However, MRI findings sometimes correlate poorly with neurologic findings or patients' symptoms. The assessment of patients suspected of having DLSS may be Consequently, patients fall into a gray zone in which the most appropriate treatment is not obvious.[1] Basically, the treatment should be started with a conservative approach, preferably with a multimodal approach. Severe pain with extensive neurogenic claudication symptoms and unsuccessful conservative treatment should be treated surgically.

In spinal canal stenosis after surgery, removal of a facet joint and laminectomy may create iatrogenic instability. Lumbar dynamic or rigid lumbar instrumentation in many cases may be available.[2-4] There are no differences in the results in patients who have undergone decompression alone or fusion surgery; on the other hand, ameta-analaysis has advocated fusion surgery.[5,6]

Commonly in clinical practice, conservative treatments include long physical therapy, home exercise, analgesic drugs, or pain management. Many surgical modalities to treat lumbar spinal canal stenosis are described in the literature, such as total laminectomy, unilateral hemilaminectomy and unilateral root nerve decompression, facetectomy, and stability accomplished by dynamic or rigid lumbar fixation systems.[7,8]

Key words
- Axial loading
- Lumbar canal stenosis
- Lumbar magnetic resonance imaging

Abbreviations and Acronyms
AL: Axial loading
DLSS: Degenerative lumbar spinal stenosis
DSCA: Dural sac cross-sectional area
LSS: Lumbar spinal stenosis
MRI: Magnetic resonance imaging

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Table 1. Numbers of Patients with DSCA Reductions >15 mm^2 During Axial Loading According to Age Groups

Age Groups/Years	L4–5 Level, n (%)	L4–5 >15 mm^2, n (%)	L5–S1 Level, n (%)	L5–S1 >15 mm^2, n (%)
Group 1 (21–30)	17 (17)	3 (18)	16 (18)	1 (6)
Group 2 (31–40)	31 (31)	12 (38)	27 (31)	8 (29)
Group 3 (41–50)	19 (19)	10 (52)	18 (20)	4 (2)
Group 4 (>50)	33 (33)	16 (48)	27 (31)	8 (29)
Total	100	41	88	21

Surgical treatment of spinal stenosis is optional and is intended to improve symptoms and function rather than prevent neurologic complications. Urgent surgery is required when a patient presents with neurologic deficits such as progressive muscle weakness and bladder dysfunction.[2,8] In some patients, lumbar MRI findings do not correlate with patients' clinical symptoms. To prevent a catastrophic outcome after treatment, this patient group needs accurate diagnosis after treatment. For this reason, axial-loaded (AL) lumbar MRI with the patient in a supine position can improve diagnostic accuracy. The use of an axial compression device to apply the AL to the lumbar spine, morphologic changes of the spinal canal in the standing position can be simulated during MRI examination.[9,10]

We propose that lumbar MRI with AL can show significant lumbar spinal stenosis in patients with neurogenic claudication who have not significant stenosis in MRI without AL.Thus, we evaluated the effectiveness of MRI with AL in suspected lumbar spinal stenosis patients.

MATERIALS AND METHODS

This study included 103 consecutive patients who presented with only neurogenic claudication and/or without low back pain. Patients who presented with radiating leg pain and/or only low back pain without neurogenic claudication were excluded from the study groups. There were 43 men and 60 women, ranging in age from 21 to 75 years (mean age, 44 years). Patients were examined in 4 subgroups according to their ages (Table 1).

A control group for all the age groups was not formed. However, we examined 3 asymptomatic patients (with no neurogenic claudication) with and without AL (Table 2).

MRI was performed on a 1.5-Tesla system (Gyroscan Intera, Philips Medical Systems, Best, and Holland) using a spine array coil. All patients were first examined by routine lumbar MR imaging in the supine psoas-relaxed position with slight flexion in the hips and knees. In this position, T1- and T2-weighted axial and sagittal plans of the same sequences were performed during AL applied to the spine. All patients were examined with and without AL MRI at the L4–5 and L5–S1 levels (Figure 1). The AL was applied for 5 minutes, which was easily tolerated by the patients, with no need for additional analgesics.

The AL procedure was performed with a nonmagnetic compression device (DynaWell L-spine; DynaWell Int. AB, Billdal, Sweden) including a specific patient vest, straps, cords, a footplate, and a compression mechanism (Figure 2). The patient wore the vest over the shoulders and upper chest in supine position with extended hips and knees. The feet were placed against the footplate of the compression device. The straps on the vest were tightened. Two adjustable cords on the opposite side of the vest were attached to the compression device. Axial compression was applied to the spine by tightening the cords.

The force of compression was adjusted by the compression device and was measured by the sensors in the footplate. The chosen load was 50% of the patient's body weight, which was distributed equally to both legs.

Table 2. Mean DSCA of the Disc Levels without and with Axial Loading in Healthy Individuals of the Control Group

Group	Without Axial Loading L4–5 Level DSCA (mm^2)	With Axial Loading L4–5 Level DSCA (mm^2)	Without Axial Loading L5–S1 Level DSCA (mm^2)	With Axial Loading L5–S1 Level DSCA (mm^2)
Control 1	159.2	155.5	128.1	124.0
Control 2	160.1	159.2	130.3	129.1
Control 3	158.3	156.8	129.2	127.2
Mean	159.2	157	129.2	126.7
Mean difference	159.2–157 = 2.2		129.2–1267.7 = 2.5	

DSCA, dural sac cross-sectional area.

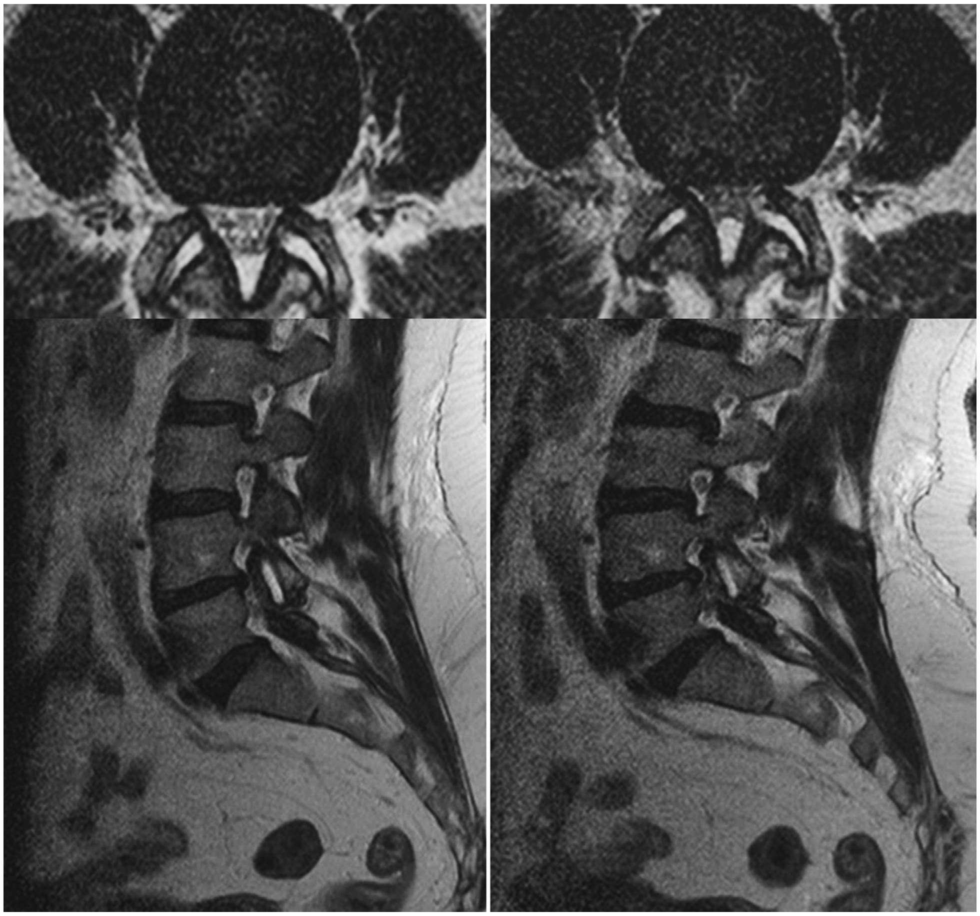

Figure 1. Axial and sagittal lumbar magnetic resonance images without and with axial loading.

Slices at the same level were used to measure the axial T2-weighted images of the routine supine and AL MRI. The selected image was the image in which the dural sac cross-sectional area (DSCA) appeared to be the smallest at each disc level of L4–5 to L5–S1. All measurements of the DSCA were performed by T2-weighted axial imaging in routine supine and AL MRI. The OsiriX imaging software (version 6.0.2; Bernex, Switzerland) was used to measure the DSCA with and without the AL MRI images. Relative stenosis was accepted as a DSCA of <100 mm^2 and absolute stenosis as DSCA of <75 mm^2 (**Figures 3** and **4**). The DSCA was assumed to be significantly reduced if it decreased by >15 mm SQ during AL.

RESULTS

A total of 188 disc levels of were assessed from 103 patients. The distribution of the total 188 disc levels of L4–L5, L4–L5/L5–S1, and L5–S1. The sampling numbers of disc levels were selected randomly and close to each other with minimum standard deviation. The number of patients with a reduction in DSCA of >15 mm^2 (during loading) are shown in **Table 2** and for each age group in **Table 3**.

Load-induced reductions in DSCA of >15 mm^2 were more common in older age groups (**Table 3**).

In evaluation of the DSCA, a significant decrease in the DSCA between routine supine and axial-loaded MRI was most commonly observed at the L4–5 levels (**Table 4**).

In the L4–5 levels, relative stenosis of the spinal canal was observed in 12 levels without AL and was observed in an additional 5 levels with AL. Absolute stenosis was identified in 7 levels without the AL and in an additional 1 level with AL.

In the L5–S1 level, relative stenosis of the spinal canal was observed in 16 levels without AL and in an additional 8 levels with AL. Absolute stenosis was identified in 6 levels without AL and in no other levels with the load. The mean DSCAs of the disc levels without and with AL were 138 mm^2 and 123 mm^2 at L4–5 and 134 mm^2 and 125 mm^2 at L5–S1, respectively (**Table 4**).

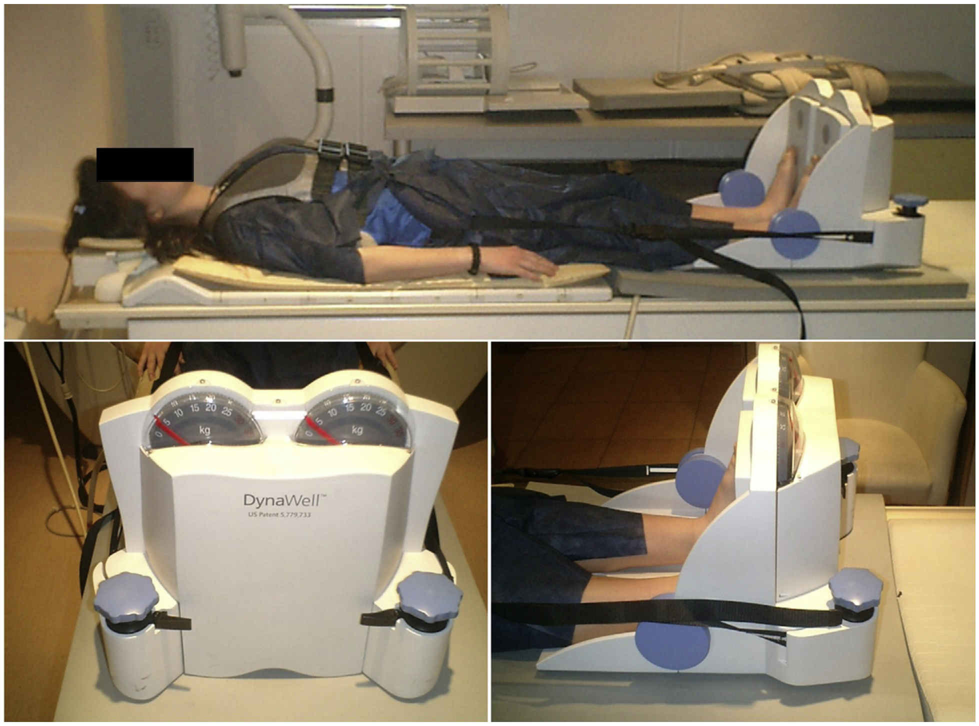

Figure 2. Establishment of nonmagnetic compression device DynaWell L-spine (DynaWell Int. AB, Billdal, Sweden) with magnetic resonance imaging performed on a 1.5-Tesla system (Philips Gyroscan) using a spine array coil.

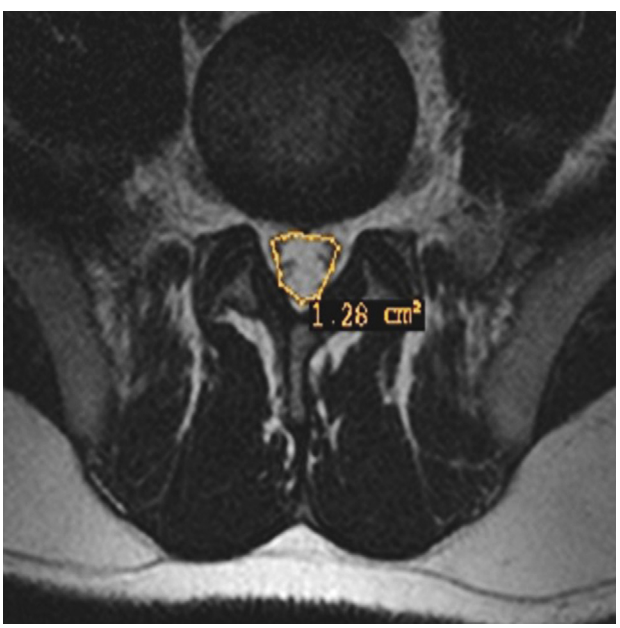

Figure 3. Measurement of dural sac cross-sectional area (DSCA) in an axial magnetic resonance imaging scan.

In the control group, 6 disc levels were demonstrated. Measurement of the DSCA with and without AL showed very limited changes in the DSCA with AL. The mean decrease in the DSCA was 2.2 m^2 (range, 1.2–4 m^2). (Table 2).

DISCUSSION

A decreased disc height with AL is also observed in the lumbar spine of healthy individuals.[11] However, these dynamic changes are restricted in healthy individuals. It is expected that the decrease in the DSCA will be limited. In our control group, there were very limited changes in the DSCA with AL and the results were consistent with those observed in the literature in healthy individuals. Our results showed that the significant reduction in the DSCA by AL was more prominent in the smaller cross-sectional area.

Biomechanic studies in the literature have shown no impinging of the spinal roots in the foramina after AL until recently.[12] However, we propose that this finding does not explain why patients do not have foraminal stenosis and how this can be addressed during surgical decompression. Similar to previous studies in the literature, only DSCA changes with AL were considered in this study. It is suggested that measuring changes in the foraminal diameter can be used in effective decompression surgery to treat foraminal stenosis with spine canal stenosis.

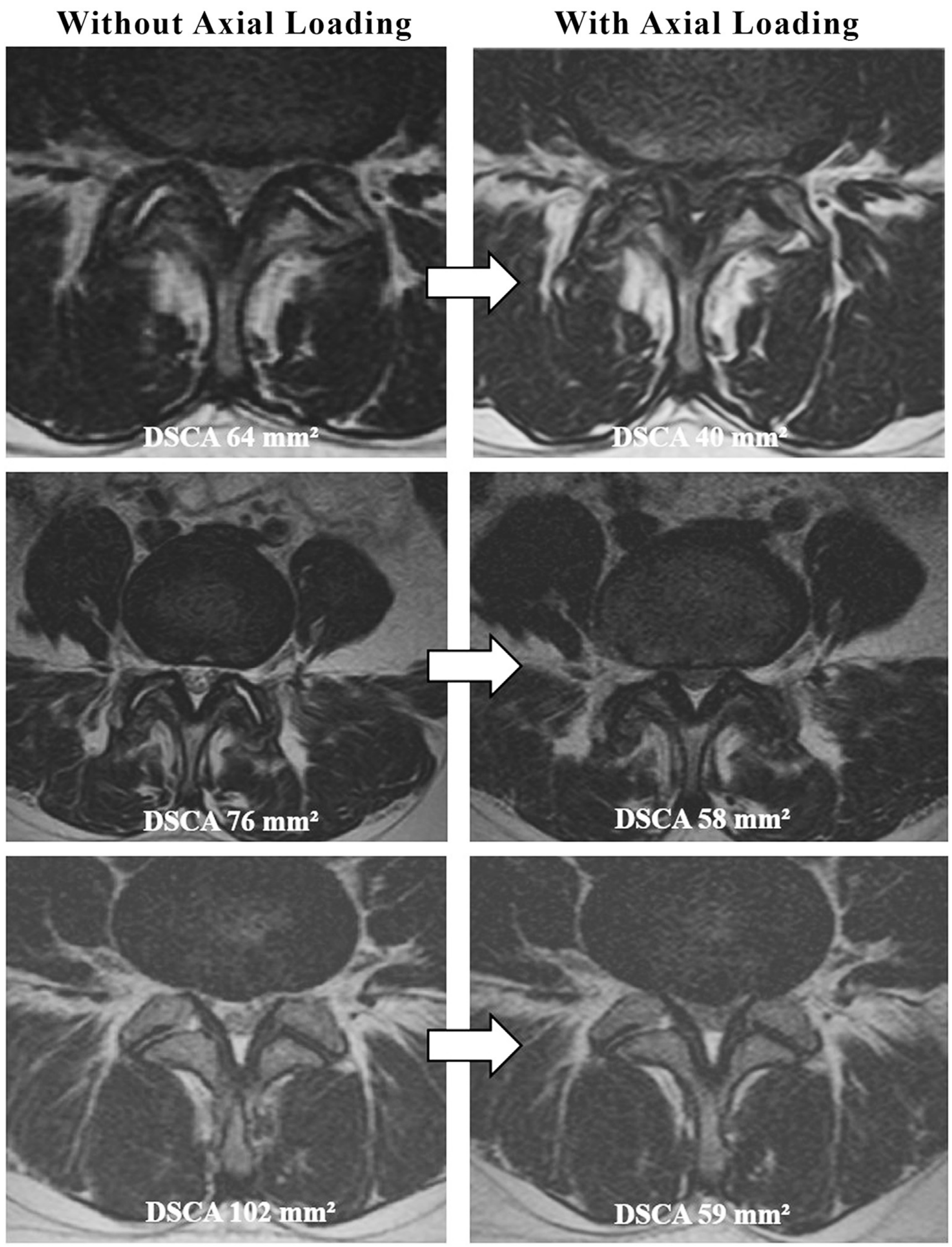

Figure 4. Representative axial magnetic resonance images in patients with neurogenic claudication (pain) without and with axial loading.

Aging and degeneration are factors that affect the reduction in DSCA. If destructive changes are not balanced by regeneration, then degeneration can occur in younger tissues.[13] Nevertheless, the incidence of disc degeneration and disc protrusion increases with age; therefore, a significant reduction in the DSCA can be explained by reaching 30 years of age. Therefore, aging plays a major role in spine degeneration.

Although the study by Willen et al.[9] is similar to our study, those authors did not evaluage DSCA according to age groups. Owiing to increasing age, spinal canal stenosis increases.

Table 3. Numbers of Patients with DSCA Reductions >15 mm^2 During Axial Loading According to DSCA in Routine Spine MRI

DSCA (mm^2)	L4–5 Level, n	With Axial Loading L4–5 DSCA >15 mm^2, n (%)	L5–S1 Level, n	With Axial Loading L5–S1 DSCA >15 mm^2, n (%)
Group 1 (<75)	7	1 (14)	6	0 (0)
Group 2 (75–00)	12	5 (42)	16	8 (50)
Group 3 (101–130)	29	10 (34)	17	5 (29)
Group 4 (>130)	52	25 (48)	49	8 (16)
Total	100	41	88	21

DSCA, dural sac cross-sectional area; MRI, magnetic resonance imaging.

Therefore, in the patients in increasing age groups, there is more need for AL, and we think that the age factor is an indication for AL.

In similar studies, CT and MRI are used as criteria. The sensitivity and specificity of CT and MRI are different.[9,10,14,15] However, in our study, the use of MRI increased the specificity of the study; Also 103 patients were studied as multilevel.

Madson et al.[16] investigated the effect of body position and AL of the lumbar spine along with disc height, lumbar lordosis, and DSCA. They concluded that extension of the lumbar spine was the dominant cause, rather than compression, in reducing DSCA. Furthermore, the AL was not considered to have a clinically relevant effect on the spinal canal diameter. In the current study, lumbar MRI with AL was performed in an asymptomatic patient (no neurogenic claudication). No changes were found in the DSCA without and with AL.

Radiologic measurement of the DSCA was performed to evaluate the narrowing of the spinal canal using axial MR images.[9,17] However, many previous studies have shown that there is a poor correlation between the DSCA measured and the severity of clinical symptoms.[18-20] These findings result from the use of conventional MRI, which cannot determine the actual condition of the lumbar spinal canal, causing symptoms in patients in the standing position. To evaluate the positional changes of the lumbar spinal canal, myelography in the standing position has frequently been used. Myelography has become relatively obsolete for routine standard imaging, although it has played an important role in making treatment decisions for lumbar spinal stenosis. In the study by Kanno et al.,[21] the significant correlations between AL MRI and standing position myelography was shown.

Table 4. Mean DSCA of Disc Levels with and without Axial Loading in Spinal Canal Stenosis Patients with Only Neurogenic Claudication with and without Low Back Pain

Spinal Canal Stenosis	L4–5 (n = 100)	L5–S1 (n = 88)
Mean DSCA in routine MRI	138 mm^2	134 mm^2
Mean DSCA in axial loading MRI	123 mm^2	125 mm^2
Mean difference	15 mm^2	9 mm^2

DSCA, dural sac cross-sectional area; MRI, magnetic resonance imaging.

Several studies have reported the use of stress-loading imaging technologies, particularly for spine imaging.[22-24] The standard clinical MRI scanners containhould remain motionless during the scanning, depending on the examination time. This may present a problem, especially for those with claustrophobia or anxiety. Technically, these images have high resolution and shorter acquisition time because of the highest magnetic field strength (at least 1.0–3.0 Tesla). On the other hand, upright-standing or positional MRI, which is a type of open MRI system, has been developed in recent years. Upright MRI provides imaging under physiologic stress and more flexibility in patient positioning, and that is beneficial for those with claustrophobia. However, it has low magnetic field strengths (maximum field strength of 0.6 Tesla), and that is associated with lower image quality and more time requirement to obtain images.[25] Moreover, slower image acquisition with upright MRI may cause difficulty for patients unable to remain longer in a standing or sitting position. The main advantages of upright MRI include the ability to scan the selected area (spine or joints) in different positions and evaluate the effects of dynamic movements.[25]

In our study, 62 disc levels (32.9%) showed significant changes in the DSCA with AL (>15 mm^2), most frequently at L4–L5 (n= 41). This rate was consistent with those of previous studies reporting additional valuable information for symptomatic patients.[26,27] In addition, patients with a >15 mm^2 change in the DSCA on AL MRI had more severe symptoms compared with the patients with changes of spinal canal stenosis <15 mm^2.[28] The main purpose of our study was to determine whether AL supine MRI could reveal significant lumbar spinal stenosis in symptomatic patients without significant stenosis on routine lumbar spine MRI. Consequently, 21 disc levels (11.1%) showed additional relative or absolute lumbar spinal stenosis with AL in our study.

One limitation of this study is that supine MRI with AL was performed to simulate the upright position. Nevertheless, it may not truly reflect postural spinal changes. Upright positional MRI systems may enable more accurate assessment and measurement of postural spinal changes for the demonstration of spinal stenosis,[25,29] but these systems are not commonly used.

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