Original Article

Comparison Accuracy in Determining the Degree of Lumbar Spinal Stenosis between Lumbar Spine MRI with Axial Loading and Routine Conventional MRI with Clinical Correlation

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Objective: To evaluate the accuracy in determining the degree of lumbar spinal stenosis in patients utilizing lumbar spine magnetic resonance imaging (MRI) with axial loading as compared to conventional lumbar spine MRI with clinical correlation. To assess the difference in the dural cross sectional area (DCSA) between lumbar spine MRI with axial loading and conventional lumbar spine MRI.

Materials and Methods: Thirteen patients with clinically diagnosed lumbar spinal stenosis, which comprised of three males and ten females, aged 20 to 80 years, and that had the severity of their stenosis clinically and radiologically graded by history taking, physical examination, and by performing both conventional and axial loaded MRI were included in this study.

Results: The present study found a statistically significant difference ($p<0.05$) after applying load at all lumbar levels. The L4-L5 level showed the greatest reduction at 12.8%, followed by L3-L4 and L2-L3, in which the DCSA was reduced by 11.2% and 9.0%, respectively. Comparing the clinical severity and degree of each lumbar spinotic level and the maximum severity per person, the results showed that the most accuracy was at the L3-L4 level followed by L5-S1 and L2-L3 levels. No accuracy between clinical severity and the degree of lumbar spinal stenosis at L1-L2 and L4-L5 levels were shown, suggesting that more than the DCSA change influence the clinical severity. To gain further insights, following up patients and a study with more patients are needed. The maximum severity by DCSA measurement, both pre- and post-loading, of individual patients compared with clinical severity showed concordance for three patients. No significant difference in accuracy was found between pre- and post-loading.

Conclusion: Changes in the DCSA of lumbar spinal stenosis after loading MRI was statistically significant especially at the moderate and severe stenotic levels particularly at the L3-4 level and L5-S1 level.

Keywords: Lumbar spine MRI; Axial loading; Lumbar spinal stenosis

Received 22 November 2021 | Revised 14 June 2022 | Accepted 22 June 2022

J Med Assoc Thai 2022;105(10):986-92

Website: http://www.jmatonline.com

Lumbar spinal stenosis is a common disease that can affect one's everyday practices. It is increasingly common due to the increasing number of aged people. Their symptoms include low back pain, lower limb pain, numbness, weakness, and neurogenic claudication. These symptoms are aggravated by standing or walking due to a narrowing of the dural sac canal(1-4). Diagnosis is made by clinical and radiological examination, however, sometimes the patient's clinical symptoms cannot be explained by this imaging.

Conventional magnetic resonance imaging (MRI) is a non-invasive and acceptable investigation for the diagnosis of lumbar spinal stenosis. However conventional MRI is performed in the supine position with psoas relaxation. This does not reflect the same position in which the symptoms occur during walking or standing due to the morphological change of the dynamic position. Therefore, conventional MRI is considered to underestimate the issue or may even miss the diagnosis completely(5,6).

Recently axial loading devices have become

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How to cite this article:

Chiewvit P, Ngamsombat C, Pornpunyawut P, Weankhanan J, Chotivichit A. Comparison Accuracy in Determining the Degree of Lumbar Spinal Stenosis between Lumbar Spine MRI with Axial Loading and Routine Conventional MRI with Clinical Correlation. J Med Assoc Thai 2022;105: 986-92.

DOI: 10.35755/jmedassocthai.2022.10.13679

Table 1. Lumbar stenotic degree according to clinical base

	Duration of symptoms	Walking distance	Neurological deficit
Mild	0 to 1 year	>200 m	None
Moderate	>1 to 2 year	100 to 200 m	May be paresthesia or paralysis when they walk for a distance
Severe	>2 year	<100 m	May be found paresthesia or paralysis by physical examination

available for use with the patients in a supine position when lumbar MRI scan is performed. This device helps to imitate the morphological change of the dural canal as if the patients were in a standing position(6-12). A previous study revealed there was a statistically significant decrease in the dural sac size in lumbar stenotic patients when performing MRI with axial loading(13), which had as minimal effect on asymptomatic patients(14). Nevertheless, the clinical impact from axial loading MRI compared with conventional MRI has not yet been reported.

Consequently, the purpose of the present study was to evaluate the accuracy between lumbar spine MRI with axial loading and the conventional MRI based on clinically determining the degree of lumbar spinal stenosis of the patients and to assess the difference in the dural cross sectional area (DCSA) between lumbar spine MRI with axial loading and the conventional MRI.

Materials and Methods

Thirteen patients, comprising of three males and ten females, aged 20 to 80 years old, were enrolled in the present study. The inclusion criteria were patients with low back pain, sciatica pain or neurogenic claudication who attended Siriraj Hospital between September 2016 and January 2017. The exclusion criteria were patients with contraindication to MRI being performed, previous lumbar surgery, severe osteoporosis, vertebral fracture, and vertebral/spinal tumor. The present study was approved by the Institutional Review Board (IRB) of Siriraj Hospital, Mahidol University, COA no. Si 546/2017.

Orthopedists clinically evaluated all consecutive patients to determine the degree of the lumbar spinosis as mild, moderate, or severe (Table 1). Then, they were screened, and the exclusion criteria were applied by assessing the patient's history, and by performing a physical examination and plain lumbar radiography. After completing the informed consent processes, first, the patients underwent conventional psoas-relaxed MRI, which took 30 minutes. and then additional axial loaded MRI was performed, which took a further 15 minutes.

MRI was performed using the 3.0T system (Phillips Ingenia, software 5.1.7.2). Each patient was initially examined in the supine position. The following sequences were performed in these positions: sagittal T2-weighted (repetition time [TR]: 2,115 ms, echo time [TE]: 108 ms, thickness: 4 mm, field of view [FOV]: 150×300 mm, matrix: 184×347), sagittal T1-weighted (TR: 400 ms, TE: 6.6 ms, thickness: 4 mm, FOV: 150×300 mm, matrix: 168×300), sagittal STIR (TR/TI: 3,927/180 ms, TE: 75 ms, thickness: 4 mm, FOV: 250×300 mm, matrix: 280×232), coronal STIR (TR/TI: 3,931/180 ms, TE: 70 ms, thickness: 4 mm, DFOV: 586×300 mm, matrix: 280×232), axial T1-weighted (TR: 474 ms, TE: 7.4 ms, thickness: 3 mm, FOV: 120×160 mm, matrix: 180×177), axial T2-weighted (TR: 6110 ms, TE: 140 ms, thickness: 3 mm, FOV: 120×160 mm, matrix: 168×170) and myelogram.

After the conventional study, axial loading was applied. The axial loading device, DynaWell® L-spine, is a medical compression device that facilitates the diagnosis of specific lumbar spine disorders by simulating the lumbar spine in an upright position. It is approved by the U.S. Food and Drug Administration. This device comprises of non-magnetic harness jacket with straps (Figure 1a) and a compression part (Figure 1b). The patients wear the harness jacket with nylon straps tightened at the lower chest to axially load the lumbar spine and to avoid pressure on the shoulders (Figure 1c). The load is added to approximately 50% of the patient's body weight and is applied for 15 minutes at a time with the pressure distributed equally on both legs. During the examination, the patients were checked and asked about any pain or any uncomfortable feeling. The pressure could be released immediately by knee flexion if the patients experienced unfavorable symptoms. Previous studies have reported no evidence of pain or termination during the examination. After applying axial loading, two additional sequences were obtained; sagittal T2-weighted (TR: 2115 ms, TE: 108 ms, thickness: 4 mm, FOV: 150×300 mm, matrix: 184×347) and axial T2-weighted (TR: 6110 ms, TE: 140 ms, thickness: 3 mm, FOV: 120×160 mm, matrix: 168×170) images.

The images were individually interpreted and measured by two experienced neuroradiologists for

Figure 1. The axial loading device, DynaWell® L-spine, composed of nonmagnetic harness jacket with straps (a) and compression part (b). The patients wear harness jacket with nylon straps tightening at lower chest to load axially the lumbar spine onto both legs equally (c).

Table 2. Lumbar stenotic degree according to measurement of dural cross sectional sac area

Measurement of the dural sac area	
>130 mm^2	Normal
130 to 100 mm^2	Mild stenosis
75 to 100 mm^2	Moderate stenosis
<75 mm^2	Severe stenosis

assessing the DCSAs. The radiologists were blinded about the patient's clinical context. The degree of lumbar spinal canal stenosis was considered following quantitative studies (Table 2).

Data were analyzed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). The intraclass correlation coefficient was used to evaluate interobserver agreement, which could be described at 0.8 to 1.0 for excellent agreement, 0.6 to 0.79 for good agreement, 0.40 to 0.59 for moderate agreement, 0.2 to 0.39 for fair agreement, and 0 to 0.19 for poor agreement. The accuracy between clinical and radiological severity was evaluated by crosstabulation. The mean ± standard deviation (SD) DSCA of each lumbar levels and the change between pre- and post-loading were calculated by a paired samples test. Significance was considered at a p-value was less than or equal to 0.05.

Results

Thirteen patients, with 65 lumbar intervertebral levels from the L1-2 level to the L5-S1 level in each patient, were enrolled in the present study. They comprised of three males or 23% and ten females or 77%. Their mean age was 59 years with a range of 24 to 72 years. Their mean weight was 61 kg with a range of 47 to 76kg. They all passed the examination without any complaint and the time of examination was 45 minutes.

Measurement of the DCSA of each intervertebral level pre-loading (PL) and post-loading (AL) (Figure 2-4) was performed by two experienced neuroradiologists. The interobserver agreement was excellent as evaluated by the intraclass correlation coefficient (Table 3).

The mean DSCA of each lumbar intervertebral level and the change between pre- and post-loading are summarized in Table 4. The present study found a statistically significant change ($p<0.05$) after applying load at all the lumbar levels. The L4-L5 level showed the greatest reduction at 12.8%, followed by L3-L4 and L2-L3 with the DCSA reduced by 11.2% and 9.0%, respectively.

The authors compared the results between clinical severity and the degree of each lumbar spinotic level, and the maximum severity per person

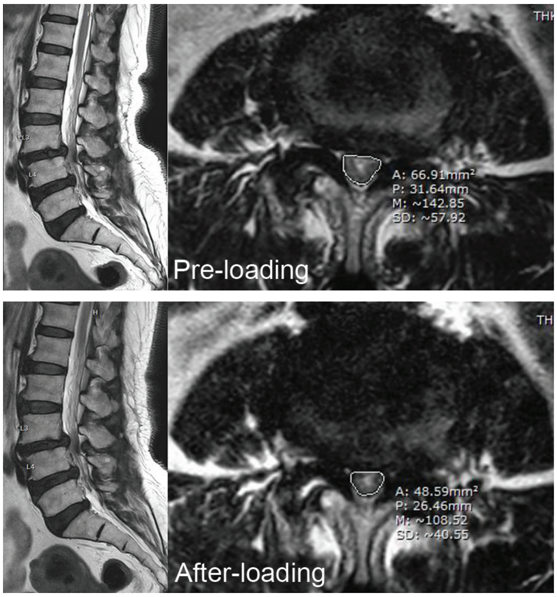

Figure 2. Sagittal and axial T2-weighted MRI showed 66.91 mm^2 of pre-loading DCSA (severe) and 48.59 mm^2 of after-loading DCSA (severe).

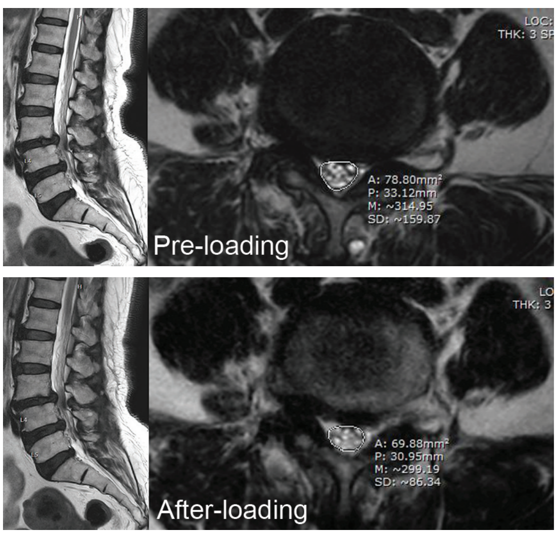

Figure 3. Sagittal and axial T2-weighted MRI showed 78.80 mm^2 of pre-loading DCSA (moderate) and 69.88 mm^2 of after-loading DCSA (severe).

(Table 5). The results showed the most accuracy at the L3-L4 level for pre-loading, n=5, and post-loading, n=6, followed by L5-S1 for pre-loading, n=4, and post-loading, n=4 and L2-L3 for pre-loading, n=3, and post-loading, n=3, as orderly levels. No accuracy between clinical severity and degree of lumbar spinal stenosis at the L1-L2 and L4-L5 levels were shown. The maximum severity by DCSA measurement,

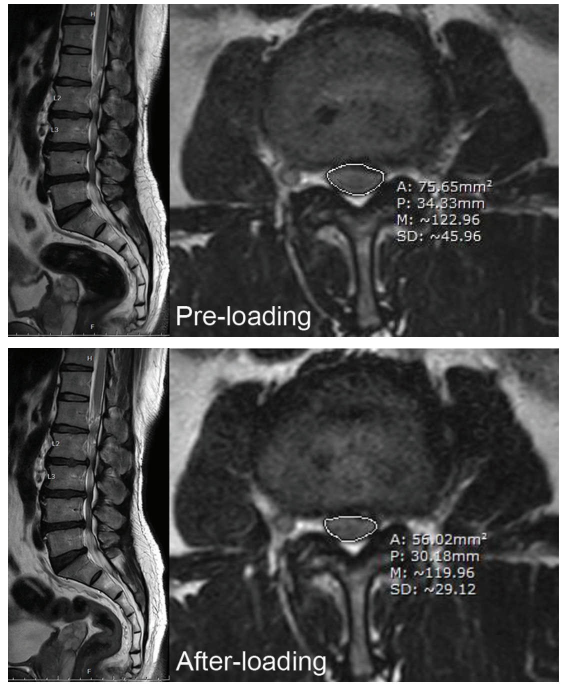

Figure 4. Sagittal and axial T2-weighted MRI showed 75.65 mm^2 of pre-loading DCSA (moderate) and 56.02 mm^2 of after-loading DCSA (severe).

Table 3. Intraclass correlation coefficient for interobserver agreement

Lumbar levels	Intraclass correlation coefficient (95% CI)	
	Preload	Afterload
L1-L2	0.957 (0.871 to 0.987)	0.968 (0.901 to 0.990)
L2-L3	0.955 (0.863 to 0.986)	0.970 (0.906 to 0.991)
L3-L4	0.953 (0.856 to 0.985)	0.982 (0.944 to 0.995)
L4-L5	0.941 (0.821 to 0.982)	0.964 (0.886 to 0.989)
L5-S1	0.991 (0.972 to 0.997)	0.992 (0.974 to 0.997)

both pre- and post-loading, of the individual patients compared with clinical severity had concordance for three patients. Additionally, no significant difference in accuracy between pre- and post-loading was found in the present study (Table 5).

Discussion

The axial loading device is a more practical and an inexpensive way to reproduce axial load and mean, so buying an upright MRI instrument is not necessary. The disadvantage of the axial loading technique is that it takes longer than routine MRI by five to ten minutes and it induces pain during the procedure.

Axial loaded MRI has been reported[2,3,14] to demonstrate morphological changes caused by

Table 4. Mean DSCA of each lumbar intervertebral level and the change between pre-and after-loading

Lumbar levels	Preload (PL); mean±SD	Afterload (AL); mean±SD	PL-AL; mean±SD (%)	p-value
L1-L2	167.93±36.06	154.50±37.63	13.45±10.45 (8.0)	0.001
L2-L3	128.39±39.22	116.78±35.16	11.61±11.12 (9.0)	0.003
L3-L4	99.04±40.56	87.98±41.40	11.06±8.86 (11.2)	0.001
L4-L5	63.79±34.73	55.65±39.86	8.14±8.80 (12.8)	0.006
L5-S1	96.59±43.43	90.66±42.21	5.93±6.18 (6.1)	0.005

SD=standard deviation

Table 5. Accuracy of clinical severity with degree of the lumbar spinal stenosis by comparing pre- and after-loading

Lumbar levels	Accuracy	
	Preload (case)	Afterload (case)
L1-L2	0	0
L2-L3	3	3
L3-L4	5	6
L4-L5	0	0
L5-S1	4	4
Maximum severity of each patient	3	3

compression of the lumbar spine, which includes a bulging disc, a thickening of the ligamentum flavum, a change in the shape of the dorsal fat pad, as well as a deformation of the dural sac.

Previous studies[14-16] demonstrated that a decrease in DCSA by more than 15 mm² induced by axial loading could be considered a significant change, increased the diagnostic specificity of spinal stenosis, and influenced the indication for surgical treatment.

In the present study a statistically significant change of DSCA was found between pre- and post-loading in lumbar spinal stenotic patients. The accuracy of clinical severity and imaging severity by DCSA measurement were in concordance at the L3-L4 level, L5-S1 level, and L2-L3 level, respectively, while there was a discordance at L1-L2 and L4-L5. No significant difference of accuracy between pre- and post-loading in term of clinical correlation was present. The severity of spinal stenosis was more advanced after applying axial loading for seven lumbar levels (n=7/65) in six different patients (n=6/13). One patient had change in two lumbar levels. Most of those were from moderate to severe stenosis.

The authors found that a reduction of DCSA after loading is predominant on the severe stenotic lumbar levels (17.6%), followed by the moderate stenosis levels (9.7%) and mild stenosis levels (7.4%), respectively. In normal lumbar levels, there was only a 7.1% DCSA reduction, which corresponded with the previous study by Danielson et al[17]. This result showed a prior moderate or severe stenotic lumbar level had more effect on axial loading than the normal or mild dural stenosis.

However, the post-loading images could not clearly explain the clinical severity and its clinical significance was uncertain. In the present study, the DCSA did not correlate to the subjectively grade clinical severity. In addition, the use of axial loading, simulating a standing position and reducing the DCSA, did not increase the correlation between the clinical grading and the radiologically grading.

In the present study, a decreased DSCA did not correlate with the clinical symptoms suggesting that there may be other factors contributing to the clinical symptoms and a small sample size.

As opposed to the study by Kanno et al[18], the present study showed that clinical symptoms were significantly worse in patients that had a decreased in DCSA of more than 15 mm². The DCSA from axial loaded MRI demonstrated valuable radiologic findings that correlated with the severity of clinical symptoms in lumbar spinal canal stenosis patients.

Although imaging determined that the severity of lumbar spinal stenotic patients did not match with the clinical severity, the authors' suggestion is to follow up patients to get more information about the clinical and imaging correlation and the impact on patient's treatment. Consideration for the future use of axial loading in lumbar spinal stenosis should be of concern as it took more than 15 minutes during axial loading, which may need significant change of DSCA to have good correlation.

There are limitations of the present study, such as the small sample size, inability to clinically evaluate the stenotic levels separately, and lack of worldwide standard clinical criteria for assessing the severity degree in mild, moderate, or severe levels of lumbar spinal stenotic patients.

Conclusion

The present study demonstrated that the DCSA of lumbar spinal stenosis in MRI after loading was statistically significant especially at prior moderate and severe stenotic levels such as the L3-4 and L5-S1 levels. The accuracy of clinical severity and imaging severity by DCSA was not good, which may suggest that there may be other factors that have an effect on clinical severity. Following up patients longer could help getting more information.

What is already known on this topic?

DCSA from axial loading MRI of lumbar spine was statistically significant especially at prior moderate and severe lumbar stenosis and is most accurate at L3-L4 level.

DCSA did not correlate to subjectively grade clinical severity.

What this study adds?

Axial loading MRI shows excellent inter-observer agreement.

Degree of lumbar stenosis assessed by DSCA from axial loading MRI is most accurate at L3-L4 level when compare with clinical severity.

DCSA did not correlate to subjectively grade clinical severity, which created difficulty in making an accurate diagnosis and precise indications for surgery.

Acknowledgement

The authors would like to thank Assist. Prof. Dr. Chulaluk Komoltri from Clinical Epidemiology Unit of Siriraj Hospital for help in statistics, and the medical personnel staffs at the Magnetic Resonance Imaging Unit at Chalermprakiet Building, Siriraj Hospital for excellent assistance at all study examinations.

Conflicts of interest

The authors declare no conflict of interest.

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