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Magnetic resonance imaging of the lumbar spine with axial loading: A review of 120 cases

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A B S T R A C T

Purpose: To evaluate the imaging findings of patients with clinical symptoms of lower back pain who underwent magnetic resonance imaging (MRI) of the lumbar spine with axial loading.
Materials and methods: We examined 120 patients by MRI, before and after axial loading, using a compression device that applied 50% of their body weight for a load time of 5 min. The dural sac cross area (DSCA) was examined by two experienced radiologists before and after axial load, and their findings were compared. Degenerative abnormalities within and adjacent to the spinal canal were also analyzed.
Results: A reduction in DSCA greater than 15 mm^2 after axial load was defined as significant, and was found in 81 patients (67.5%) and 138 disc spaces (38.3%). Reduction was most frequent at L4-L5 (n = 55). For other disorders, a 9% increase in cases of bulging disc was seen during axial loading, and seven disc spaces showed protrusion/extrusion only after load. Facet joint synovial cysts, foraminal stenosis, and hypertrophy of the flavum ligaments showed almost no differences, pre- and post-load.
Conclusion: For adequate evaluation of lumbar symptoms, examination should be performed with axial loading, especially in cases of suspected spinal stenosis.
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1. Introduction

Lower back pain from degenerative changes in the lumbar spine commonly occurs in patients over 50 years. Bulging discs, hernias, facet joint synovial cysts, foraminal stenosis, spinal canal stenosis, ligamentous hypertrophy, and other degenerative changes are common in this age group [1,2]. In the cases of spinal stenosis, changes in posture and certain physical activities are known to have a dramatic effect on symptoms. Typically, standing, walking, and sometimes even sitting can increase the severity of symptoms by reducing the available space within the spinal canal [3], exacerbating the degenerative changes. Previous studies have questioned the validity of diagnostic imaging, including tomography and magnetic resonance imaging (MRI) performed in supine position, in evaluating patients with lower back pain [4–6].

MRI has replaced other diagnostic tools in examining patients with lower back pain because of its multiplanar capability, and the high contrast seen between different tissues. The disadvantage of MRI is that it is performed in a supine relaxed position. Previous studies indicated that during MRI of the lumbar spine for evaluation of back pain, the application of axial loading might improve diagnostic accuracy [7,8]. Moreover, degenerative changes in patients with hernias, facet joint synovial cysts, foraminal stenosis, and ligament hypertrophy could be identified or further evaluated only after the application of axial load. The aim of this study was to assess changes in lumbar spine MRI, pre- and post-axial load, in 120 patients with lower back pain.

2. Materials and methods

This study included 120 patients (60 men and 60 women), aged between 20 and 92, with no history of spinal surgery, who under-

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went lumbar spine MRI, with and without axial load. All patients were symptomatic, presenting with sciatic or neurogenic claudication. Patients gave signed informed consent, and the study was approved by the ethics committee of the institution.

MRI was performed in a 1.5 T system (Symphony, Siemens, Germany). Each patient was initially examined in the supine position with the psoas muscle relaxed and minimal hip flexion. The following sequences were performed in this position: sagittal T2-weighted (repetition time [TR]: 2320 ms, echo time [TE]: 116 ms, thickness: 4 mm, field of view [FOV]: 310/100 mm, matrix: 384/70); sagittal T1-weighted (TR: 548, TE: 10, thickness: 4 mm, FOV: 310/100, parent: 320/80); axial T1-weighted (TR: 730, TE: 10, thickness: 4 mm, FOV 220, matrix: 320/70); and axial T2-weighted (TR: 4280, TE: 108, thickness: 4 mm, FOV 220, matrix: 320/85).

After the conventional study, axial loading was applied using a nonmagnetic compression device, consisting of a vest over the shoulders with strips leading to a platform positioned against the feet. Two adjustable cords on opposite sides of the vest are attached to the medical compression device. By tightening the cords to a desired and measured load it is possible to compress the spinal cord in a way that is similar to that of upright posture. Applied axial load was equivalent to 50% of the patient's body weight, distributed equally on both legs, as previously described [2,5]. The load was applied for at least 5 min. During loading, we acquired T2-weighted sequences in the sagittal and axial planes, using the parameters described above. Despite the use of the load there was no degradation of images by motion artifacts. The disc spaces L3-L4 to L5-S1 were evaluated with cross-sections oriented parallel to the examined disc. Patients were instructed to inform our staff in case of any symptoms during the examination, especially during compression. We do not find in the literature any reports of adverse effects with the use of load.

Two experienced radiologists independently evaluated the images obtained before and after axial load application using a workstation (Leonardo, Siemens, Germany). Information about the axial loading was omitted. In cases of disagreement, decisions were made by consensus. Abnormalities assessed for all patients, pre- and post-axial loading, were bulging disc, disc protrusions/extrusions, facet joint synovial cysts foraminal narrowing, and hypertrophy of the flavum ligaments. Terminologies and definitions were based on current literature [9]. The dural sac of cross-sectional area (DSCA) was measured at L3-L4, L4-L5 and L5-S1. Three measurements were performed for each disc space, and values were averaged. Absolute stenosis was defined as DSCA less than 75 mm^2, and relative stenosis was defined as less than 100 mm^2 [4,7,8]. DCSA was considered significantly reduced when it exceeded 15 mm^2 after axial load application [4,7].

3. Results

A total of 360 disc spaces were assessed from the 120 patients in this study. Only 14 patients had normal MRI findings. The pre-load results found at least 510 disorders involving hernias (protrusions, extrusions), bulging discs, facet joint synovial cysts, foraminal stenosis, and hypertrophy of the flavum ligaments. After applying axial load, an additional 45 changes were observed, which was an 8% increase in the prevalence of abnormal findings. The main results are summarized in Table 1.

Evaluating the DSCA of the disc spaces pre- and post-loading showed that the L4-L5 level showed the greatest reduction, with a decline of 10.2% (Fig. 1), followed by L5-S1, which declined by 7.0%, and L3-L4, which decreased by 3.7%.

One hundred and eighty five disc bulges were seen pre-load in the 120 cases studied (51%), and 223 (62%) post-load. The L3-L4 disc was the most affected, with a 25% increase in cases detected after loading, compared to 20% at L4-L5, and 15% at L5-S1. The mean DSCA of these disc spaces, pre- and post-load, were 185 mm^2 and 179 mm^2 at L3-L4, 171 mm^2 and 152 mm^2 at L4-L5, and 168 mm^2 and 155 mm^2 at L5-S1.

Protrusions and extrusions were seen in 20 patients (16.6%), with changes in 25 disc spaces pre-load, and 7 cases (5%) (7 disc spaces) detected only after axial load. Disc L4-L5 was the most affected by pre-load MRI (n = 14), followed by L5-S1 (n = 10) and L3-L4 (n = 1). This relationship remained unchanged after load, with an increase of four cases at L4-L5, three at L5-S1, and none at L3-L4. In these patients, the average DSCA pre- and post-load was 165 mm^2 and 153 mm^2 at the L3-L4 disc, 153 mm^2 and 138 mm^2 at L4-L5, and at least 148 mm^2 and 136 mm^2 at L5-S1.

Almost no difference was observed in interfacet cysts or in foraminal stenosis and hypertrophy of the flavum ligaments after load. Five levels with facet joints cysts, and four with foraminal stenosis were seen only after axial load, and were more common at L4-L5 (n = 6) (Fig. 2). Only two levels of flavum ligament hypertrophies were observed only after load. No signs of facet joint osteoarthritis were seen after load.

Relative stenosis of the spinal canal was seen in 15 patients before axial loading, and in an additional three cases after load. L5-S1 was the most commonly affected disc space, with 15 cases of relative stenosis after load. Absolute stenosis was identified in five cases before axial load, and in an additional 10 after load. The disc space L4-L5 was the most commonly involved, with abnormalities in 10 cases after axial load.

At 15 mm^2, the reduction in DSCA was significantly greater after axial load in 81 patients (67.5%), and in 138 disc spaces (38.3%). It was more frequent at L4-L5 (n = 55), followed by L3-L4 (n = 51), and L5-S1 (n = 32). We also found that the effect of load was higher when the patient had some degree of stenosis. Among patients with a normal DSCA, 40% showed reduction to under 100 mm^2, while patients with relative stenosis showed a reduction of 72%, and patients with absolute stenosis showed 60% reduction.

4. Discussion

In this study, we evaluated 120 patients with lower back pain, using lumbar spine MRI before and during the application of axial load. We found 510 degenerative changes pre-load, with 45 additional abnormalities seen only after load. Moreover, 18 patients with relative stenosis and 15 with absolute stenosis pre-load showed a significant reduction in DSCA when load was applied.

A few studies have compared the morphology of the discs, ligaments, and facet joints by MRI, pre- and post-load. Willén et al. [4] reported that of 80 disc spaces examined, 13 showed narrowing of the lateral recess, and only one had a large disc protrusion. Choy [10] identified an increase in the level of disc herniation in 50% of studied patients. Similarly, our study showed almost no difference pre- and post-load in the prevalence of, facet joint synovial cysts, foraminal stenosis, or hypertrophy of the flavum ligaments. However, disc herniations increased by 29.17% after the application of axial load (24 before/31 after).

Several studies have emphasized the importance of performing MRI of the lumbar spine before and during application of axial load in symptomatic patients, especially in those with suspected spinal stenosis [1–4,7–9,11–13]. Danielson et al. [3] studied lumbar spine MRI with axial load in 34 patients. In 37/81 (46%) disk levels, a significant decrease in the DSCA was found after application of load. Furthermore, at 10 levels, the DSCA decreased to less than 100 or 75 mm^2 after load was applied. Willén et al. [4] evaluated 34 patients (80 disc levels) by MRI with axial load. In 50% of the levels, a significant decrease in DSCA was seen after load application, and in 16 levels (20%), DSCA reductions were to values of

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