The Egyptian Journal of Radiology and Nuclear Medicine (2014) **45**, 203–209

Egyptian Society of Radiology and Nuclear Medicine

The Egyptian Journal of Radiology and Nuclear Medicine

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REVIEW

The MRI finding of the nerve root sedimentation sign: Its clinical validity and operative relativity for patients with lumbar spinal stenosis

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Received 6 September 2013; accepted 27 November 2013
Available online 19 December 2013

KEYWORDS
Lumbar spinal stenosis;
Sedimentation sign;
MRI;
LSS

Abstract *Background:* Lumbar spinal stenosis (LSS) is increasingly being recognised as a cause of disabling low back and lower extremities pain in adult population. Advanced spinal imaging thought as confirmation tool for the diagnosis and as preoperative tool to delineate the extent and precise location of the pathology. Nerve roots normally sediment, due to gravity, to the dorsal part of the dural sac, which was known as negative sedimentation sign. If there is MRI finding of nerve roots in the ventral part of the dural sac the sedimentation sign is positive.
Objectives: To evaluate the presence of the MRI finding of positive sedimentation sign in patients clinically suspected to have lumbar spinal stenosis and to follow up operated cases to identify the absence of the radiological signs in the operated cases.
Material and methods: 70 patients clinically suspected to have lumbar spinal stenosis evaluated by MRI lumbosacral spine in supine position. A panel of two radiologists reviewed radiological data. MRI features were agreed by both radiologists in 48 patients. Out of these 48 patients; 25 were operated upon for central decompressive laminectomy, partial medial facetectomy and foraminotomy with instrumented fusion and fixation if indicated. Visual analogue score (VAS) collectively preoperative and postoperative was compared and the walking distance postoperative was reported and follow up MRI studies were done one year after the operation.

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Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

 http://dx.doi.org/10.1016/j.ejrnm.2013.11.011

Results: Operated patients' mean age was 58.2 years; nineteen patients were operated upon for simple decompressive laminectomy for the affected levels. Walking distance preoperative range 100–700 metres, improved postoperative to be 1474.0 ± 601.1. VAS for pain preoperative was 9.28 ± 0.84, improved at 12 month follow up to be 0.84 ± 0.62. Postoperative MRI done to evaluate the cross sectional area (CSA) became more than 80 mm^2 in the absence of the sedimentation sign and was negative in 22 cases.

Conclusion: The MRI finding of positive sedimentation sign is a good positive sign to rule in lumbar spinal stenosis with high specificity and sensitivity; negative sedimentation sign can be used in postoperative follow up of decompression patients.

Contents

1. Introduction

Lumbar spinal stenosis (LSS) is increasingly being recognised as a cause of disabling low back pain and lower extremities pain in adult population. A decrease in spinal canal volume has many causes like congenital abnormalities, disc herniation, and other space occupying lesions causing a decrease in spinal canal volume. The clinical syndrome of lumbar spinal stenosis most commonly occurs secondary to age related changes in the lumbar spine. Encroachment of the spinal canal in combination with residual motion leads to vascular and conduction changes in the neural elements thought to be responsible for clinical symptoms [1].

The clinical symptoms and signs include low back pain (95%), claudication (91%), leg pain (71%), weakness (33%) and voiding difficulties (12%). The typical symptoms for spinal stenosis are neurogenic claudication; include paresthesia and numbness in posterolateral legs and thighs. These symptoms are classically exacerbated with walking. Extension of the lumbar spine causes a decrease in the cross-sectional area (CSA) of the spinal canal therefore symptoms worsened in the upright position [1].

The use of advanced spinal imaging was thought as confirmation tool for the diagnosis of the stenosis and as preoperative tool to delineate the extent and precise location of the pathology. Myelography was the gold slandered in the evaluation of lumbar disc disease and stenosis, and this has been supplemented with the MRI, which is non-invasive and provides a highly detailed, multi-planner view of the spinal canal. Axial images may better demonstrate thecal sac compression and lateral recess narrowing which in turn is better to be diagnosed by CT scan because the osteophyte formation at the lateral recess around the facet joint has low signal intensity in T1 and T2 weighted images, thus MRI tends to over read the degree of encroachment [1,3].

The diagnostic difficulties of lumbar canal stenosis lie in the frequent absence of clinical symptoms at rest because pain and limited function occur only with physical activity. Conventional clinical scores correlate poorly with the grade of stenosis and the CSA of the dural sac in the MRI [4].

Static examinations such as forced hyperextension do not sufficiently reflect the situation during physical activity [5]. However, under and over diagnosis of LSS are common when using CSA as a discriminator. Under diagnosis is observed in patients with (a) foraminal stenosis, (b) dynamic stenosis during physical activity, and (c) rapidly progressing stenosis. Over diagnosis appears in patients with a higher age who demonstrate clinical symptoms not related to LSS but show a pathologic CSA [6].

A positive sedimentation sign was defined as the absence of nerve root sedimentation in at least 1 axial MRI scan, at a level above or below, disregarding the location of the scan within the level and its proximity to the maximal stenosis (Fig. 1). It is not uncommon for a sign to refer to the absence of a finding, e.g., the positive Thompson test in which the absence of plantar flexion helps to confirm the diagnosis of an Achilles tendon rupture. As a rule, nerve roots normally sediment, due to gravity, to the dorsal part of the dural sac, which was defined as negative sedimentation sign. The only exception from this is the 2 nerve roots leaving the dural sac one segmental level below the stenosis. If there are nerve roots in the ventral part of the dural sac except for the ones exiting the dural sac, the sedimentation sign is positive. By this method, no intermediate or indeterminate results of the sedimentation sign are to be expected. The sedimentation sign was measured at a level above or below the maximal stenosis because, at the level

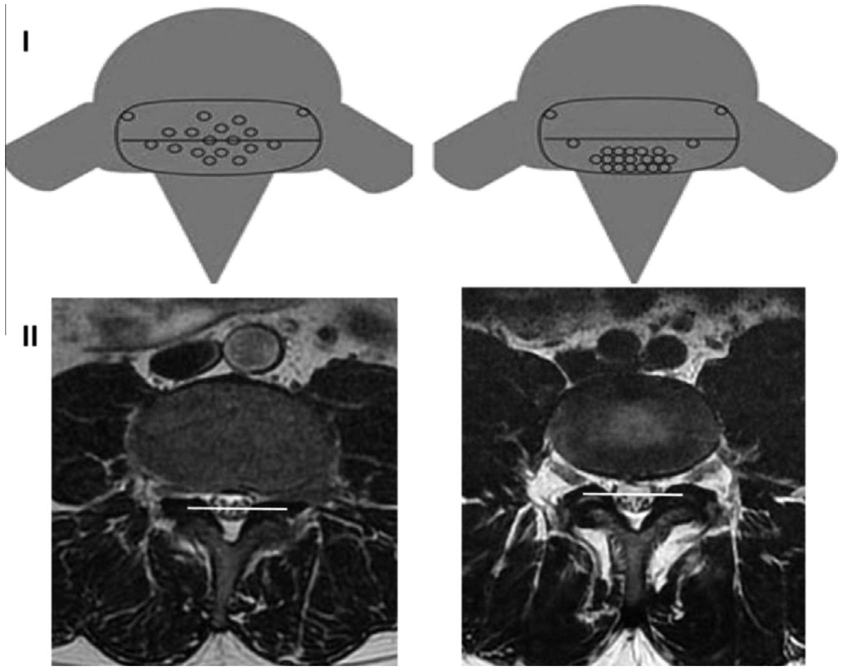

Fig. 1 (I) Illustrative figure about sedimentation sign (quoted from [11]). (II) Comparative MRI: (A) positive sedimentation sign (B) negative sedimentation sign.

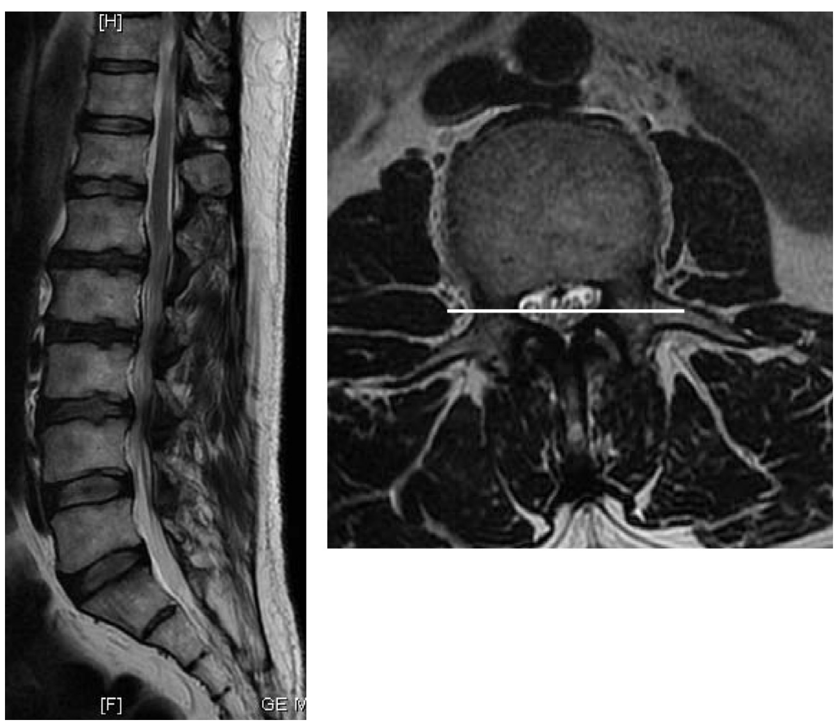

Fig. 2 T2WI MRI shows lumbar spinal stenosis and positive sedimentation sign. (A) Sagittal T2WI shows spinal canal stenosis at L1–2, L2–3 and L3–4. (B) Axial T2WI shows a positive sedimentation sign.

of the stenosis, nerve roots lie tightly packed in the dural sac and, therefore, cannot be identified and judged adequately [7,11].

The aim of the treatment is to improve the level of function and decrease lower extremities discomfort. The use of epidural steroid injections in elderly patient with stenosis is common and may provide dramatic pain relief, however many patients will have recurrent symptoms. For that surgery should be considered in those patients with clinical symptoms of spinal stenosis with an unacceptable quality of life after other treatment modalities have been exhausted. The primary objective of the surgery is to decompress the neural elements. Many operative techniques have been addressed to do the decompression including laminectomy or limited laminotomy, decompression of neural elements, decompression and fusion when associated with spondylolisthesis and instrumented fusion to maintain correction of deformity or with gross instability [8].

2. Materials and methods

Between March 2010 and March 2011; 70 consecutive patients admitted to our department of neurosurgery for inpatient or outpatient treatment with symptoms of typical neurogenic claudication, back pain and leg pain where sent to the radiology department for further evaluation by MRI lumbosacral spine in supine position.

All the 70 patients underwent MRI of the lumbar spines using the GE medical system, HDE 1.5 T machine. All patients were asked to get rid of any metallic subjects as well as they were asked about any contraindication to MRI examination (artificial heart valve, cardiac pacemaker, metallic stents or joint prosthesis except that made of titanium). The patients were informed about the duration of the examination, the position of the patient and the importance of being motionless. MRI study was done with the patients in the supine position using a standard phases-array surface coil for imaging the spine. The imaging protocol included Sagittal and axial T2WI spin echo sequences (2617/120/90/2(TR/TE/angle/NSA sequences)) with 4 mm thickness in axial study.

Using a picture archiving system (PACS) with integrated digital area measurement (GE health care centricity PACS), two experienced independent radiologists aware of the clinical information of the patients evaluated separately the MRI of the 70 patients for the following

1. The CSA, measured between L1 and L5. Inclusion criterion was for patients with CSA $< 80\ mm^2$.
2. Positive sedimentation sign looking for the absence of nerve root sedimentation in at least 1 axial MRI scan, at a level above or below, disregarding the location of the scan within the level and its proximity to the maximal stenosis (Fig. 2).

Using the method described by ***Barz* et al.** [7], the sedimentation sign was measured in axial MRI scans of level L1/L2–L4/L5. The measurement was performed at the approximate mid-height of the vertebral body above or below the maximal stenosis (for stenosis level L1/L2 was always below, for stenosis level L4/L5 was always above). In our study the horizontal line to detect the sign was placed at the anterior aspect of the facet joints above or below the level of the stenosis because at the mid level the nerve roots are clumped (e.g. in Fig. 2).

A panel of two radiologists reviewed radiological data of the 70 patients and disagreement was solved by consensus. The combined MRI features were agreed by both radiologists in 48 patients.

Out of the 70 patients, combined CSA and positive sedimentation sign were present in 48 (Table 1). Out of these 48 patients; only 25 patients accepted surgical option for definitive treatment for their pathology. All the 25 patients underwent dynamic X-rays and subjected to a standardised ambulatory treadmill test with reporting the walking distance preoperatively to experience the symptoms of the claudication, all patients were operated upon for central decompressive laminectomy, partial medial facetectomy and foraminotomy of the nerve roots for the decompressed levels and if more than 3 levels of laminectomy were performed and posterolateral fusion and instrumented fixation were performed on the same setting in cases with preoperative finding of minimal spondylolisthesis grade 1 where managed intra-operatively by bony posterolateral fusion, if the spondylolisthesis is more than grade 1 or unstable in dynamic preoperative X-ray instrumented fixation where pedicular screws were used and posterolateral fusion was performed.

Visual analogue score (VAS) collectively preoperative and postoperative was compared and the walking distance postoperative was reported and follow up MRI studies were done one year after the operation to the 25 patients.

Approval from the medical ethics committee was obtained prior to the study.

Table 1 MRI findings of the 70 patients clinically suspected to have lumbar canal stenosis.

MRI criteria	Number of patients
Cross sectional area (CSA) $< 80\ mm^2$	
Present	51
Absent	19
Positive sedimentation sign	
Present	50
Absent	20
Combined CSA and positive sedimentation sign	
Present	48
Absent	22
Post-operative follow up of combined CSA ($> 80\ mm^2$) and negative sedimentation sign in 25 patients	
Present	22
Absent	3

Table 2 Patient's demographics and clinical signs of the 25 operated patients.

Age x ± SD	58.2 ± 8.68 years	
Sex		
Female	10	40%
Male	15	60%
Level affected		
L4–5	9	36%
L3–4/ L4–5	7	28%
L4–5/L5-S1	2	8%
Other levels	7	28%
Walking distance preoperative	328 ± 191.5	
Range	100–700	
Motor only	2	8%
Sensory only	3	12%
Both motor + sensory	3	12%
Both negative	17	68%
Type of operation		
Laminectomy	19	76%
Laminectomy + fixation	6	24%

3. Results

Out of the 25 patients operated upon 10 males and 15 females with mean age of 58.2 years, levels operated upon were L4–5 in 9 cases, L3–4 and L4–5 in 7 cases, L4–5 and L5-S1 in 2 cases and other levels were in 7 cases. Out of the 25 patients 2 patients presented with motor deficit, 3 with sensory deficit, 3 patients had combined sensory and motor deficit and 17 patients had neither sensory nor motor deficit (Table 2).

Nineteen patients were operated upon for simple decompressive laminectomy for the affected levels and instrumentation were used in 6 patients (Table 2).

Table 3 Pre- and post-operative of walking and visual analogue score (VAS) ($N = 25$).

	x ± SD	Pt	*P* value
Walking pre	328.0 ± 191.5		
Walking post	1474.0 ± 601.1	12.97	0.0001
VAS pre	9.28 ± 0.84		
VAS 1 month	1.68 ± 0.95	32.9	0.0001
VAS 3 month	1.24 ± 0.78	41.1	0.0001
VAS 6 month	1.12 ± 0.67	45.4	0.0001
VAS 12 month	0.84 ± 0.62	51.4	0.0001

Walking distance preoperative range 100–700 metres, with an average of 328 ± 191.5, improved postoperative to be 1474.0 ± 601.1 with a significant *P* value 0.0001.

Visual analogue score for pain (VAS) preoperative were 9.28 ± 0.84, improved at 12 month follow up to be 0.84 ± 0.62 which was also statistically significant (Table 3).

Postoperative MRI done to evaluate the CSA became more than 80 mm^2 in the absence of the sedimentation sign and was negative in the 22 cases (88%) (Table 1, Figs. 3 and 4).

Two patients had postoperative wound infection, none of the patients had postoperative cerebrospinal fluid leak inspire that 3 patients had intra-operative incidental dural tear at the time of the original surgery.

4. Discussion

Our study compared the radiological sign of positive sedimentation sign in patients with symptomatic lumbar spinal stenosis and compared the preoperative findings with the postoperative outcome to relay on this sign as reliable sign in diagnosis and postoperative follow up in diagnosed patients.

Barz and colleagues first identified the positive sedimentation sign in 94 patients with symptomatic lumbar spinal stenosis and they concluded that a positive sedimentation sign can rule in lumbar spinal stenosis with high sensitivity (94%) [7].

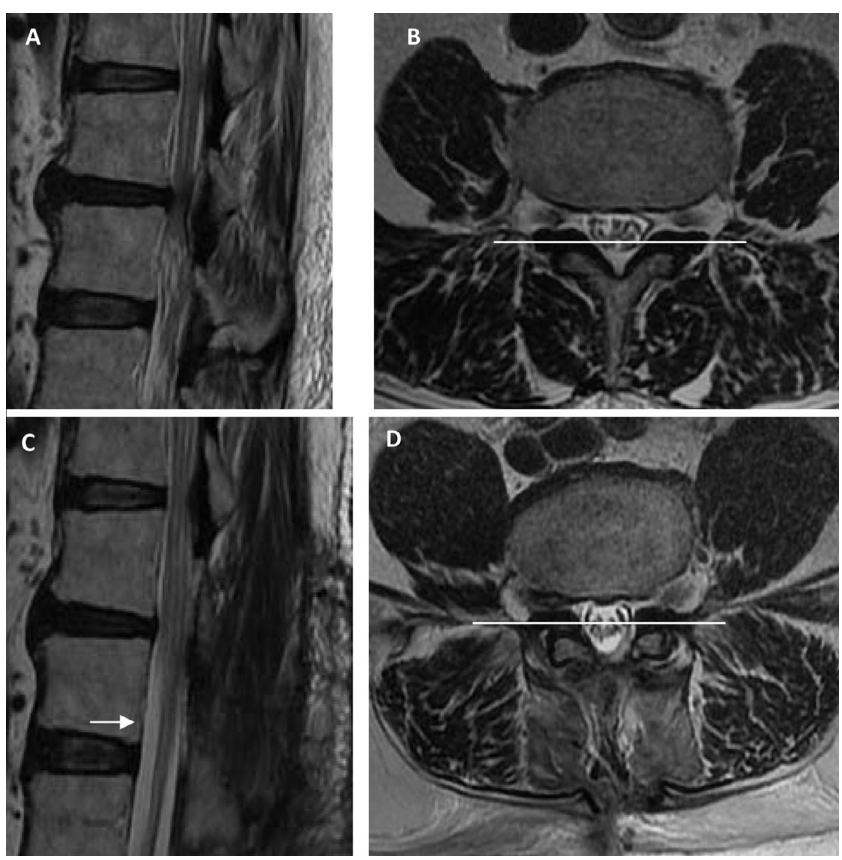

Fig. 3 Pre- and post-operative lumbar spinal stenosis. (A) Sagittal T2WI shows spinal stenosis at L2–3 and L3–4. (B) Axial T2WI shows a positive sedimentation sign. (C and D) Axial and sagittal T2WI post-operative laminectomy shows negative sedimentation sign and widening of CSF spaces (arrow).

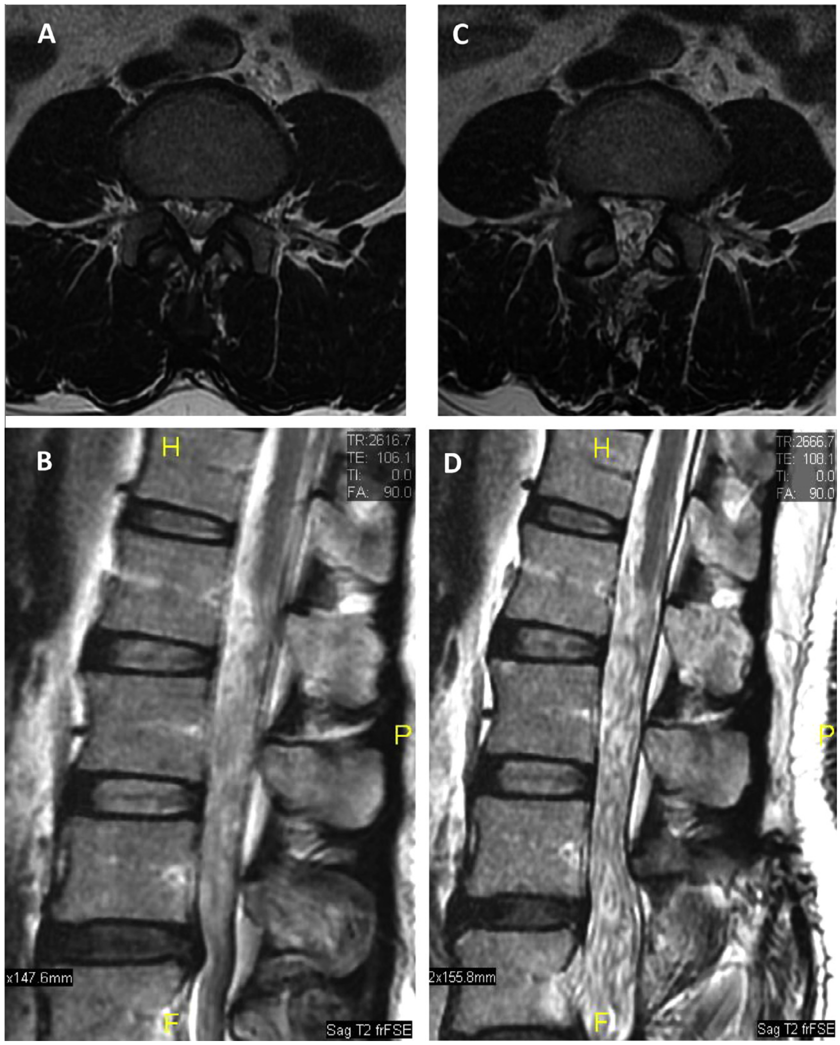

Fig. 4 Pre- and post-operative lumbar spinal stenosis. (A and B) Axial and Sagittal T2WI shows spinal canal stenosis at L3–4 with positive sedimentation sign. (C and D) Axial and sagittal T2WI post-operative laminectomy shows negative sedimentation sign with widening of CSF spaces.

The present study included 70 patients. Out of the 70 patients, combined CSA and positive sedimentation sign were present in 48 as agreed by two independent radiologists (sensitivity 68.6%) in disagreement with [7] who reported a sensitivity of 94%, but this may be explained by the former sensitivity which was found in the spinal canal stenosis group only with exclusion of the low back pain group, however in our study the negative cases were either due to discogenic cause or absent sign. Post-operative follow up of combined CSA (>80 mm^2) and negative sedimentation sign in the 25 operated patients was found in 22 patients (88%).

Discussion is growing over the use of the sedimentation sign as a much needed clinical diagnostic tool to enhance decision making when it comes to surgical intervention. The smallest CSA of the dural sac has been used as a discriminatory tool for LSS, yet this and other existing techniques have already been questioned for their efficacy. Sirvanci et al. [9] measured a poor correlation between conventional clinical scores and the grade of stenosis and CSA of the dural sac in MRI. Similarly, Sigmundsson et al. [12] determined a poor correlation between the CSA of the dural sac on MRI and leg and back pain levels, walking distance, Oswestry Disability Index, 36-Item Short Form Health Survey, and EuroQol-5D; they concluded that clinical scores correlate only to “a limited extent” with morphological changes on MRI [2].

Still decompressive laminectomy with partial medial facetectomy and foraminotomy is the main worldwide used surgical approach used in the treatment of lumbar spinal stenosis added to it the instrumentation and the fusion if indicated, our results compared to other studies showed excellent results regarding the improvement of the preoperative symptoms and improvement in the walking distance postoperatively, **Athivirahman and colleagues** reported that the higher preoperative disability in such patients was associated with greater postoperative improvement in their questionnaire score [10].

Given that the sedimentation sign is positive when the nerve roots are displaced anteriorly within the thecal sac, it may be potential for false-negative results when there is a substantial contribution to lumbar stenosis from a prominent disc bulge, protrusion, or extrusion (i.e., dorsally directed compression from the ventrally located disc). In most cases of typical degenerative stenosis; the nerve roots will be displaced anteriorly secondary to ligamentum flavum hypertrophy and facet arthropathy. However, it is also important to remember that the sedimentation sign's use is for the evaluation of central, rather than foraminal stenosis [13].

However, it is a complex equation about how we will guide our patients to decide whether they should consider surgical intervention for the treatment of LSS. As the authors pointed out, a positive sedimentation sign does not mean that a given level must necessarily be decompressed; Boden et al. [14] have clearly shown that radiographic findings do not always correlate with a patient's symptoms. We agree with Fazal et al. [2] that a negative sedimentation sign in a patient who is otherwise being considered for lumbar decompressive surgery may lead the spine surgeon to review his or her decision and see if there is an alternate explanation for that patient's symptoms (such as a peripheral compressive neuropathy) or consider additional testing such as diagnostic injections, electromyogram studies, treadmill test, or computed tomography imaging.

It is important to mention that in patients commonly treated with decompression surgery, the sedimentation sign does not appear to predict surgical outcome. In nonsurgically treated patients, a positive sign is associated with more limited improvement. In these cases, surgery might be effective [15].

5. Conclusion

The MRI finding of positive sedimentation sign is a good positive sign to rule in lumbar spinal stenosis with high specificity and sensitivity; negative sedimentation sign can be used in postoperative follow up of decompression patients. Added that patients who chose to have surgery have improvement on their preoperative pain complains and increase in their walking distance which was significant.

6. Conflict of interest

The authors have no conflict of interest to declare.

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