Clinical Study

Clinical validity of the nerve root sedimentation sign in patients with suspected lumbar spinal stenosis

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Abstract

BACKGROUND CONTEXT: The nerve root sedimentation sign in transverse magnetic resonance imaging has been shown to discriminate well between selected patients with and without lumbar spinal stenosis (LSS), but the performance of this new test, when used in a broader patient population, is not yet known.

PURPOSE: To evaluate the clinical performance of the nerve root sedimentation sign in detecting central LSS above L5 and to determine its potential significance for treatment decisions.

STUDY DESIGN: Retrospective cohort study.

PATIENT SAMPLE: One hundred eighteen consecutive patients with suspected LSS (52\% women, median age 62 years) with a median follow-up of 24 months.

OUTCOME MEASURES: Oswestry disability index (ODI) and back and leg pain relief.

METHODS: We performed a clinical test validation study to assess the clinical performance of the sign by measuring its association with health outcomes. Subjects were patients referred to our orthopedic spine unit from 2004 to 2007 before the sign had been described. Based on clinical and radiological diagnostics, patients had been treated with decompression surgery or nonsurgical treatment. Changes in the ODI and pain from baseline to 24-month follow-up were compared between sedimentation sign positives and negatives in both treatment groups.

RESULTS: Sixty-nine patients underwent surgery. Average baseline ODI in the surgical group was 54.7\%, and the sign was positive in 39 patients (mean ODI improvement 29.0 points) and negative in 30 (ODI improvement 28.4), with no statistically significant difference in ODI and pain improvement between groups. In the 49 patients of the nonsurgical group, mean baseline ODI was 42.4\%; the sign was positive in 18 (ODI improvement 0.6) and negative in 31 (ODI improvement 17.7). A positive sign was associated with a smaller ODI and back pain improvement than negative signs (both \( p < .01 \) on \( t \) test).

CONCLUSIONS: 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, but this needs investigation in prospective randomized trials (Australian New Zealand Clinical Trial Registry, number ACTRN12610000567022). © 2014 Elsevier Inc. All rights reserved.

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EVIDENCE & METHODS

Context
The sedimentation sign helps to identify patients with severe stenosis. The authors assessed whether the sign was predictive of clinical outcomes.

Contribution
In surgically treated patients, the sign was not predictive of outcomes. In nonsurgically treated patients the outcomes were worse when a positive sign was present.

Implications
The findings are helpful for informed consent as patients decide between operative and nonoperative treatments.

Introduction
Lumbar spinal stenosis (LSS) is one of the most common disorders of the spine in elderly patients [1]. Since LSS was first described by Verbiest [2], an important research focus has been on the evaluation of clinical, radiological, and other diagnostic criteria to better describe this condition [3–9]. One major problem is that imaging findings do not always correlate with clinical symptoms [10]. Consequently, no consensus exists on radiological or pathologic criteria that define a symptomatic LSS.

Furthermore, there is an ongoing debate on what diagnostic criteria can aid decisions about the use of conservative or surgical treatment and the selection of specific surgical procedures. Randomized controlled trials comparing conservative with surgical treatment exist [11–15], and a recent systematic review of this evidence suggests that decompression surgery is associated with reduced pain, improved function, and better quality of life compared with conservative treatment [16]. However, the reviewers pointed out that the included studies used different radiological criteria to define LSS, some but not all studies included patients with spondylolisthesis, and not all defined neurogenic claudication as an absolute inclusion criterion. Although the evidentiary basis for the benefits of decompression surgery is growing, the uncertainty around the indication for surgery and the different surgical procedures remains.

The nerve root sedimentation sign has recently been described. In transverse magnetic resonance imaging (MRI) scans in supine position of patients with severe LSS, lumbar nerve roots do not sediment to the dorsal part, as a result of gravity, but remain in the ventral and central part of the dural sac [17]. The initial report of the sedimentation sign showed that this test discriminates well between cases with symptomatic LSS and controls with nonspecific low back pain. The next step in the evaluation of the sign involves measuring the clinical value of the new test in a representative patient population, to demonstrate whether the sedimentation sign can improve the identification of patients with clinically relevant central LSS.

Because of the lack of a clear definition of LSS, there is no accepted reference standard for this condition [18], and a meaningful diagnostic accuracy study is not feasible for the reporting of test sensitivity and specificity [19,20]. When a perfect reference standard does not exist, the ideal study design is a clinical test validation study that measures the associations between test results and relevant downstream outcomes, such as the success of surgery [21]. Using these concepts, we designed a retrospective blinded chart review of the clinical validity of the sedimentation sign. The aim of this study was to determine whether the sedimentation sign may provide valuable clinical information that can be used to aid treatment decisions and thereby improve health outcomes. We investigated associations between the sedimentation sign and patient history, clinical examination, cross-sectional area (CSA) of the dural sac in transverse MRI scans, and changes in disease severity scores before and after decompression surgery or nonsurgical treatment.

Materials and methods
The rationale and design of this study have been described previously [20]. In brief, we assessed the sedimentation sign’s ability to detect clinically relevant LSS by evaluating its association with clinical outcomes in a broad patient group with suspected LSS. A prospective evaluation of the sign independent of the currently used diagnostic tests would be ideal but was not possible because knowledgeable clinicians can detect the sign at a glance. Therefore, we performed a retrospective review of MRI scans of patients undergoing treatment before the sedimentation sign had been described. This study was approved by the participating clinic’s ethics committee.

All patients referred to our orthopedic spine unit between January 2004 and December 2007 were assessed for eligibility. Included were patients in whom LSS was suspected based on patient history and physical examination. We excluded patients who had contraindications for surgery or had undergone previous spine surgery, patients with an acute spinal disorder (eg, disc herniation), specific low back pain other than LSS, a history of inflammatory disease of the spine, primary or metastatic malignant disease in the spine, other musculoskeletal impairments compromising walking ability (eg, severe coxarthrosis/gonarthrosis), polyneuropathy, or peripheral arterial disease.

Using the method described by Barz et al. [17], the sedimentation sign was measured in transverse 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 always above, for stenosis level L4/L5 always above). A positive sedimentation sign was defined as the presence of
nerve roots being located in the ventral or central part of the dural sac. A negative sedimentation sign was defined as all nerve roots being located in the dorsal part of the dural sac—except for the two ventral nerve roots that leave the dural sac one level below the stenosis (Fig. 1).

One investigator gathered clinical information from patient charts, including patient history and self-assessment (Oswestry disability index [ODI] [22], visual analog scale [VAS] for back and leg pain), physical examination, treadmill test, and imaging (MRI with CSA measurement of the dural sac), and treatment administered (decompression surgery with or without fusion or nonsurgical treatment). The investigator also collected clinical information and patient self-assessment from the reports of follow-up examinations 24 (±12) months after the first presentation. Two other investigators, both spine surgeons, independently rated the sedimentation sign on baseline MRI scans performed at the time of first presentation. They were not treating physicians of study patients and were blinded to all other clinical information. Before further analyses, discordant initial sedimentation sign ratings of the two investigators were resolved in a consensus meeting. All data were entered into a relational Microsoft Access database to blind investigators to other study information.

The primary outcome measures were ODI and pain VAS change between baseline and follow-up examinations. These health outcomes were compared between sedimentation sign positives and negatives, in separate analyses for patients treated with decompression surgery (surgical group) and patients treated nonsurgically (nonsurgical group). On-treatment analyses were performed; thus, patients initially not planned for surgery but receiving delayed decompression surgery at the same level during the follow-up interval (ie, crossover from nonsurgical to surgical treatment) were assessed in the surgical group. Secondary outcomes included calculation of the rates of delayed surgery, cross-classification of the sedimentation sign with existing tests, and the interrater reliability of the initial sedimentation sign ratings of the two investigators.

We used median and interquartile range (IQR = 25th to 75th percentile) to summarize the study results. In both treatment groups, we tested for a difference in the mean within-patient change in ODI and pain VAS between sedimentation sign positives and negatives using Student t test. Cohen kappa was calculated to assess interrater agreement between the initial sedimentation sign ratings of the two investigators. A statistical significance level of 5% was used. Statistical analyses were conducted with the use of the Stata 11 software package (Stata, College Station, TX, USA).

Results

Patients

A total of 175 patients presenting with possible LSS during the observation period met the inclusion criteria. Of these, 54 did not have a follow-up examination within the defined interval, and 3 had to be excluded because of missing outcome values (Fig. 2). The final study sample comprised 118 patients with a median age of 62 years (IQR 53–69) and 61 (52%) women.

After baseline assessment, 55 (47%) patients were scheduled to undergo surgery. Median time from baseline assessment to surgery was 1.6 months (IQR 0.0–2.6). In the remaining 63 patients, no surgery was planned; their treatment generally included physical therapy and oral pain medication [23]. In 14 of the 63 patients initially not planned to have surgery, the treatment decision was revised during the follow-up period, and these patients received surgery and their median time interval between baseline assessment and delayed surgery was 8.3 months (IQR 4.4 to 22.1). In patients who did not receive surgery, the median time between baseline and follow-up examination was

Fig. 1. Measuring the nerve root sedimentation sign. Magnetic resonance imaging scans with a negative sign (left) and a positive sign (right). Adapted with permission from Barz et al. [17].
24.2 months (IQR 21.7–26.0). The median time interval between surgery and follow-up examination was 22.3 months (IQR 18.3–26.5) in the immediate surgery group and 12 months (IQR 0.5–16.8) in the delayed surgery group. Hence, for outcome assessment, there were 69 patients in the surgical group, of whom 28 received decompression surgery alone and 41 underwent decompression surgery plus fusion, and 49 patients in the nonsurgical group (Fig. 2). In the surgical group, fusion surgery was added on to decompression when preoperative back pain exceeded 5 VAS points, in cases of degenerative spondylolisthesis, degenerative scoliosis, instability in functional imaging, multisegment stenosis, and a central stenosis that was accompanied by bilateral foraminal stenosis. Baseline characteristics of the included patients are given in Table 1.

Outcomes

Table 2 presents the baseline values and improvement in outcome in the two treatment groups, contingent on the sedimentation sign result. The changes from baseline to follow-up are depicted in Figs. 3–8. Nearly all patients receiving decompression surgery improved after treatment, whereas the outcomes in the nonsurgical group were less favorable. There were no statistically significant differences in outcome improvements among patients undergoing decompression alone or decompression plus fusion surgery.

In the 69 patients in the surgical group, the sedimentation sign was positive in 39 patients and negative in 30. In patients with a positive sign, the ODI improved on average by 29.0 points, compared with 28.4 points in sign negatives. The difference between sign positives and negatives was not statistically significant. Similarly, back pain on VAS improved on average by 3.9 in sign positives and 3.0 in sign negatives, and leg pain improved by 4.2 in sign positives and 4.3 in sign negatives. These differences in change of pain between sign positives and negatives were again not statistically significant (Table 2).

In the 14 patients with delayed surgery, the sedimentation sign had been positive in six patients and negative in eight. In the six patients with a positive sign, the median baseline ODI was 46 (IQR 44–54) and the CSA 62.5 mm² (IQR 60–65). In the eight patients with a negative sign, the median baseline ODI was 59 (IQR 45–67) and CSA 152.5 mm² (IQR 115–200). The risk of undergoing delayed surgery was not significantly higher in sign positives than in sign negatives (relative risk 1.22, 95% confidence interval 0.48–3.08). Five patients underwent decompression surgery alone; the sign had been negative at baseline in all of them. In nine patients, decompression surgery plus fusion was performed, the sign had been positive in six and negative in three. Overall, the mean ODI improvement after delayed surgery was 24.3 points, back pain improved by 2.7 and leg pain by 4.1. There were no statistically significant differences in these outcomes between sign positives and negatives.
In the 49 patients in the nonsurgical group, the sedimentation sign was positive in 18 patients and negative in 31. In sign positives, the ODI improved on an average by 0.6, whereas in sign negatives, it improved by 17.7. The ODI improvement was significantly smaller in sign positives compared with sign negatives (p < .01). Back pain improved on an average by 0.4 VAS points in sign positives and 2.4 points in sign negatives, again significantly less in sign positives (p < .01). The improvement in leg pain was 0.6 in sign positives and was 2.0 in sign negatives, which were almost statistically significant (Table 2).

Concordance of sedimentation sign with other tests

Baseline test results for subjects with a positive and negative sedimentation sign are shown in Table 3. Patients with a positive sign more often had smaller CSA, shorter walking distance on the treadmill, and more functional limitations in the ODI at baseline than patients with a negative sign. A loss of leg strength was more common in patients with a positive sign; however, paresthesia in the lower limbs was more prevalent in sign negatives. Similar levels of back and leg pain were observed regardless of sedimentation sign rating. Fifty-three percent of patients with a positive sign indicated their preference for decompression surgery, whereas 66% of those with a negative sign preferred nonsurgical treatment.

Interrater agreement of initial sedimentation sign ratings

The two spine surgeons who rated the sedimentation sign agreed in 111 of the 118 MRI scans (94%). Both classified the sign as positive in 53 patients and negative in 58. The resulting kappa coefficient was 0.88 (95% confidence interval 0.80–0.97).

Discussion

This study evaluated the clinical meaning of the nerve root sedimentation sign in detecting central LSS above L5. After the initial report of the sign, which demonstrated its ability to detect LSS under ideal circumstances [17], the present study moves the evaluation of the sign a step further by assessing the clinical implications of a positive and negative test finding in a broader patient group. In patients

![Fig. 3. Change in Oswestry disability index (ODI) from baseline to follow-up in treatment groups. The diagonal line represents no change: points below the line show ODI improvement and points above the line show ODI deterioration (open circles denote sedimentation sign positives and filled circles denote sign negatives).](image)

![Fig. 4. Change of Oswestry disability index (ODI) in treatment groups according to sedimentation sign classification.](image)
treated with decompression surgery or nonsurgical treatment, changes in ODI and pain from baseline to 24-month follow-up were compared between sedimentation sign positives and negatives. Patients in the surgical group had similar outcomes regardless of the sign. In contrast, in the cohort receiving nonsurgical treatment, patients with a positive sign showed less improvement than patients with a negative sign. Compared with the results of other diagnostic tests, the sedimentation sign was consistent in identifying patients suggestive of LSS; on average, their CSA of the dural sac was small, and they were only able to walk short distances. The independent sedimentation sign ratings of two spine surgeons showed excellent agreement.

The most intriguing result of this study concerns the patients with a positive sedimentation sign who were not treated with surgery. Conservative treatment showed virtually no change in the outcome in these patients, whereas conservative treatment in patients with a negative sign was associated with improved outcomes. In contrast, the results of the sedimentation sign were not associated with different outcomes after surgery. Decompression surgery (with or without fusion) was effective in nearly all patients, including those who were initially treated conservatively but received delayed surgery (with similar improved outcomes recorded at shorter follow-up time).

The existence of a difference in nonsurgically treated patients, in the absence of similar differences after surgery where all patients seem to improve, suggests that those with a positive sedimentation sign represent a group of patients in whom surgery might be effective. In addition to the positive sign, these patients also had higher ODI and higher leg pain levels at baseline (albeit not statistically significant),

Fig. 5. Change of visual analog scale (VAS) back pain from baseline to follow-up in treatment groups. The diagonal line represents no change: dots below the line show pain improvement and dots above the line show pain deterioration (open circles denote sedimentation sign positives and filled circles denote sign negatives). The size of dots corresponds to the number of patients.

Fig. 6. Change of visual analog scale (VAS) back pain in treatment groups according to sedimentation sign classification.

Fig. 7. Change of visual analog scale (VAS) leg pain from baseline to follow-up in treatment groups. The diagonal line represents no change: dots below the line show pain improvement and dots above the line show pain deterioration (open circles denote sedimentation sign positives and filled circles denote sign negatives). The size of the dots corresponds to the number of patients.

Fig. 8. Change of visual analog scale (VAS) leg pain in treatment groups according to sedimentation sign classification.
indicating more severe LSS compared with sign negatives, who improved after nonsurgical treatment.

In this study, the rate of delayed surgery was not associated with a positive sedimentation sign. Factors other than the clinical severity of LSS, such as patient preference, may have played an important role in the initial decision against surgery. Furthermore, other indications for surgery, for example, segmental instability, kyphosis, or foraminal stenosis, were the reason for a later decision to perform surgery in some of these patients.

The results of this study suggest that the sedimentation sign provides additional information to other diagnostic tests and can help in identifying patients who may benefit from decompression surgery. Given that almost all patients referred to a spine specialist with suspected LSS undergo MRI examination, the sedimentation sign does not incur additional costs. Its use is very simple, fast, and does not require taking any measurements. Moreover, the sign visualizes the stenosis in a way that can be clearly and simply conveyed to patients when making recommendations about surgery in clinical practice. It is a (qualitative) relative measure of nerve root compression within the individual anatomy of the spinal canal, unlike the (quantitative) absolute measure of the CSA of the dural sac, for which no threshold can be defined that is applicable to all patients. We believe that combining the sedimentation sign with CSA measurement and functional assessment using treadmill tests can improve the diagnosis of clinically relevant LSS.

This study has some limitations. First, patients were selected into treatment groups based on conventional test results and other factors; therefore, patient outcomes cannot be used to draw conclusions about the relative effects of surgery versus conservative treatment. We were not able to conduct an unbiased formal test for interaction to examine whether the sedimentation sign can be used to define a patient group who are more or less likely to benefit from surgery. Even so, our analyses of the prognostic significance of the sign in patients selected to each treatment option were valuable to explore the sedimentation sign’s potential importance for treatment decisions. As such, this study should be regarded as an exploratory pilot study, which has established that the sedimentation sign holds sufficient promise to warrant a larger definitive trial. Second, to reflect actual practice in which the sedimentation sign is proposed to be used, we analyzed outcomes with an on-treatment approach. Even when comparing outcomes according to the intention-to-treat principle, based on the intended combination of baseline assessment, a positive sign was associated with worse outcomes in the nonsurgical group, albeit to a lesser extent (results not reported). Third, the timing of follow-up examinations could not be controlled, and we accepted follow-up intervals ranging between 12 and 36 months. Too short follow-up may not allow enough time to demonstrate full recovery and benefits after spinal fusion, whereas too long follow-up may impair outcomes because of adjacent segment degeneration and consecutive instability or even spinal fractures. Most of our patients were followed up between 20 and 26 months after baseline examination. Furthermore, outcomes of decompression surgery do not appear to change over time after the initial postoperative improvements [24], and multivariate analyses of our data showed no significant influence of variations in follow-up interval on outcomes (results not shown).

Further research of the nerve root sedimentation sign needs to demonstrate the applicability of our results to different clinical settings. Retrospective studies similar to the one reported here are currently underway. More practical guidance for clinicians is needed, detailing how the sedimentation sign should be read and interpreted in more complex cases such as multilevel LSS. In addition, a rigorously conducted reliability study of the sedimentation sign is essential [25]. Prospective studies that incorporate both testing and treatment should also be carried out. Unbiased estimates of the effects of using the sedimentation sign on patient health outcomes can ultimately only be obtained in randomized controlled trials. The aim of such trials should be to properly assess the value of the sign as a predictive marker for treatment selection.

Conclusions

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, but this needs investigation in prospective randomized trials.

References
