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ORIGINAL ARTICLE

Reversibility of nerve root sedimentation sign in lumbar spinal stenosis patients after decompression surgery

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Abstract

Purpose The nerve root sedimentation sign (SedSign) is a magnetic resonance imaging (MRI) sign for the diagnosis of lumbar spinal stenosis (LSS). It is included in the assessment of LSS to help determine whether decompression surgery is indicated. Assessment of the reversibility of the SedSign after surgery may also have clinical implications for the decision about whether or not a secondary operation or revision is needed. This study investigated if lumbar decompression leads to a reversal of the SedSign in patients with LSS and a positive SedSign pre-operatively; and if a reversal is associated with more favourable clinical outcomes. If reversal of the SedSign is usual after sufficient decompression surgery, a new positive SedSign could be used as an indicator of new stenosis in previously operated patients.

Methods A prospective cohort study of 30 LSS patients with a positive pre-operative SedSign undergoing decompression surgery with or without instrumented fusion was undertaken to assess the presence of nerve root sedimentation (=negative SedSign) on MRI at 3 months post-operation. Functional limitation (Oswestry Disability Index, ODI), back and leg pain (Visual Analogue Scale, VAS), and treadmill walking distance were also compared pre- and 3 months post-operatively. The short follow-up period was chosen to exclude adjacent segment disease and the potential influence of surgical technique on clinical outcomes at longer follow-up times.

Results 30 patients [median age 73 years (interquartile range (IQR) 65–79), 16 males] showed a median pre-operative ODI of 66 (IQR 52–78), a median VAS of 8 (IQR 7–9), and a median walking distance of 0 m (IQR 0–100). Three months post-operation 27 patients had a negative SedSign. In this group, we found improved clinical outcomes at follow-up: median post-operative ODI of 21 (IQR 12–26), median VAS of 2 (IQR 2–4), and median walking distance of 1000 m (IQR 500–1000). These changes were all statistically significant ($p < 0.001$). Three patients had a positive SedSign at 3-month follow-up due to epidural fat ($n = 2$) or a dural cyst following an intra-operative dural tear ($n = 1$), but also showed improvements in clinical outcomes for ODI, VAS and walking distance.

Conclusion The reversibility of a pre-operative positive SedSign was demonstrated after decompression of the affected segmental level and associated with an improved clinical outcome. A persisting positive SedSign could be the result of incomplete decompression or surgical complications. A new positive SedSign after sufficient decompression surgery could be used as an indicator of new stenosis in previously operated patients.

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Keywords Nerve root sedimentation sign · Reversibility · Lumbar spinal stenosis · Decompression surgery

Introduction

Lumbar spinal stenosis (LSS), first described by Verbiest [1], is one of the most frequent spine surgery interventions performed in the United States [2] with variable revision rates, probably due to the lack of optimal indications for surgery [3–6].

In 2010, the nerve root sedimentation sign (SedSign) was introduced as a new radiological sign in LSS [7]. The SedSign is measured on lumbar transverse magnetic resonance imaging (MRI) scans with the patient in the supine position. A positive SedSign is defined as nerve roots being located in the ventral or central part of the dural sac as seen in patients with severe LSS. A negative SedSign is defined as all nerve roots being located in the dorsal part of the dural sac. Further studies have investigated the clinical validity of the SedSign and its association with health outcomes [8].

Clinical studies have consistently questioned the diagnostic value of a radiological assessment of the spinal canal [9]. We believe that deformity, sagittal imbalance and muscle decompensation may contribute to clinical symptoms as well as the narrow spinal canal; therefore, clear quantitative parameters as the basis of a morphological definition of spinal canal stenosis cannot be deduced. Functional parameters such as paraspinal electromyography (EMG) or epidural pressure measurement are much more informative than standard radiological morphology. Compared to morphological parameters, the SedSign is a qualitative sign of severe spinal stenosis.

Since it was first described, the SedSign has been established as an additional criterion for the indication for surgery in patients with suspected LSS [10]. The sensitivity of the SedSign to detect clinically defined LSS in orthopaedic clinic cohorts has been estimated at about 80% [11].Therefore, the SedSign does not allow a definitive differential diagnosis of central canal stenosis. It is a tool to help determine the appropriate treatment of choice. Surgical therapy of SedSign-positive patients is associated with favourable outcomes compared to non-surgical treatment [12]. Other classifications with morphological grading also include qualitative aspects of spinal canal or nerve root imaging in transverse MRI [13–15].

Recent studies investigating the SedSign have concentrated on patients without previous lumbar surgery [12]. From clinical observations, we know that a positive SedSign usually turns negative after decompression surgery; however, not all patients seem to develop a negative SedSign post-operation. It is unknown why in some cases lumbar decompression does not lead to a reversal of the SedSign and whether such a reversal is associated with more favourable clinical outcomes. Answers to these questions have the potential to improve our understanding of LSS and may lead to insights to refine the indications for decompression surgery. If reversal of the SedSign is the natural history after sufficient decompression surgery, the SedSign could be used as an additional tool for assessing the indication for surgery, revision of surgery, or in previously operated patients with a second stenosis at another level.

Therefore, the primary research question of the present study was if surgical decompression leads to reversal of the SedSign. Our secondary question was if the reversal of the SedSign is associated with favourable clinical outcomes.

We hypothesized that a positive SedSign turns negative after successful decompression surgery, and that patients with a reversal of the pre-operative positive SedSign benefit from spine surgery.

Materials and methods

This study investigated a prospective cohort of 30 patients with a diagnosis of LSS and a positive pre-operative SedSign attending the Department of Orthopaedics of a German University Teaching Hospital from March until December 2013.

Study eligibility criteria are listed in Table 1. All patients underwent decompression surgery with or without fusion. The type of surgical procedure was chosen based on factors such as sagittal balance, instability, and frontal deformity regardless of the severity of the stenosis. Decompression surgery was performed on all affected levels. In 16 patients, decompression was combined with instrumented fusion. Instrumentation did not interfere with the assessment of the SedSign in any cases.

All patients were assessed for functional limitation pre-operatively and at 3-month post-operation using the Oswestry Disability Index (ODI) [16], Visual Analogue Scale (VAS) for leg and back pain [17], and walking distance on the treadmill [18].

All patients had magnetic resonance imaging (MRI) of the lumbar spine pre-operatively and 3 months post-operation. The "smallest CSA" of the dural sac was calculated as the mean of three measurements of the dural sac from the transverse MRI scan pre-operatively and post-operatively.

Three months was chosen as the follow-up time point because at this stage wound healing is completed [19]. Post-operative complications such as adjacent segment

Table 1 Patient eligibility criteria

Inclusion criteria	Patient history of neurogenic claudication and clinico-radiological diagnosis of lumbar spine stenosis
	MRI showing a positive sedimentation sign
	Decompression surgery with or without fusion performed
	No previous spine surgery
Exclusion criteria	Claudication due to non-neurogenic causes, such as hip or knee arthritis or vascular claudication
	No MRI available
	Surgery contraindicated due to general patient condition
	Disc herniation shown on MRI
	Acute or past history of spondylitis/discitis
	Spine tumour
	Polyneuropathy
	Congenital stenosis

MRI magnetic resonance imaging, *ODI* Oswestry Disability Index, *VAS* Visual Analogue Scale

degeneration, implant loosening and pseudarthrosis do not arise until this time point so that clinical outcomes are not compromised by these factors during the follow-up period [20].

MRI scans (T2-weighted transverse layers of 4 mm thickness, 20% gap size, Siemens Symphony 1.5 Tesla) were assessed three times for each patient on three different days by two spine surgeons as experienced independent investigators. During the examination, the patients adopted a standardized supine position with hips and knees bent over a wedge. Patients were rated by two investigators as SedSign positive or negative (Fig. 1). A positive sedimentation sign is defined as the absence of nerve root sedimentation in at least 1 transverse MRI scan, at a level above or below, disregarding the location of the scan within the level and its proximity to the maximal stenosis [7]. Where there was a disagreement between raters, a consensus was reached among both investigators, assisted by another experienced independent investigator as a third opinion. MRIs were evaluated using InovisionProfessional® Software (Version 5.2.2, Nexus-Inovit, Ismaning, Germany).

We calculated the incidence of patients with a negative SedSign 3 months post-operatively and computed the 95% Wilson score confidence limits of this estimate. Median and interquartile range (IQR) of pre-operative to post-operative changes in smallest CSA, ODI, VAS, and walking distance were calculated and presented separately for SedSign positives and negatives. Where appropriate, we tested for the statistical significance of changes in these outcomes using Wilcoxon's signed-rank test.

Cohen's kappa [21] was calculated to assess interrater agreement between the initial SedSign ratings of the two investigators.

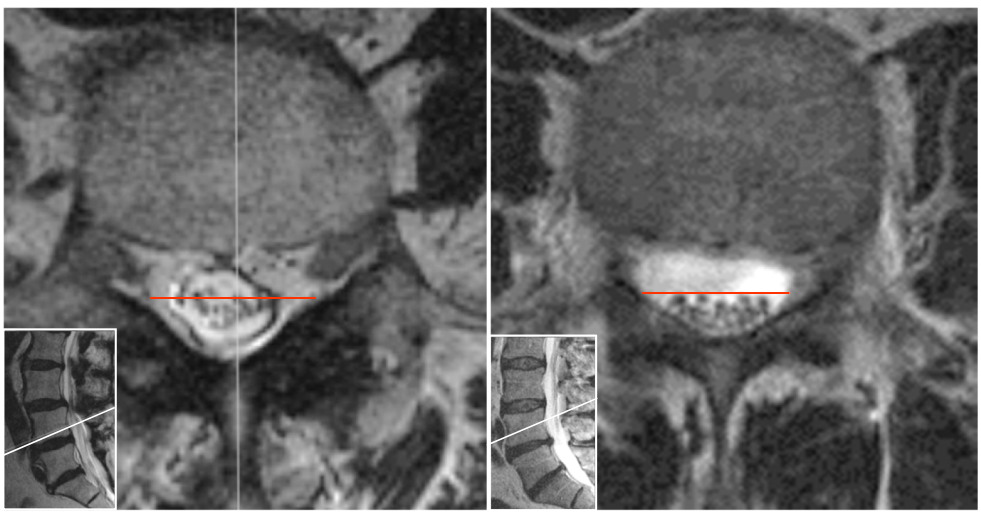

Fig. 1 Nerve root sedimentation sign (SedSign): *left panel*, positive SedSign; *right panel*, negative SedSign

Results

Of the 30 patients, 16 were male and the median age of the whole group was 73 years (IQR 65–79). At pre-operative assessment, the median ODI was 66 (IQR 52–78), the median VAS was 8 (IQR 7–9), and the median walking distance was 0 m (IQR 0–100) (Table 2).

The initial SedSign ratings of the two independent investigators differed for three pre-operative and three post-operative assessments, demonstrating an interrater reliability of $k = 0.86$.

After review, the three discrepant pre-operative cases were assessed as SedSign positive, and the three discrepant post-operative cases were assessed as SedSign negative. All three discrepant pre-operative cases were due to an atypical nerve root position with the roots pressed into the posterior part due to spondylolisthesis in some images. Assessment of the SedSign in the three discrepant post-operative cases was complicated by a narrow spinal canal. In all discrepant cases, the disagreement was resolved by repeated dynamic assessment scrolling through the series of MRI scans.

At 3 months post-operation, 27 patients had a negative SedSign (incidence of reversal 90%, 95% confidence interval 74–97%) (Fig. 2). In this group of patients with a negative SedSign, clinical outcomes improved post-operation, with a median ODI of 21 (IQR 12–26), median VAS of 2 (IQR 2–4), and median walking distance of 1000 m (IQR 500–1000) at 3 months (Table 2). In this group, the median smallest pre-operative CSA of the dural sac was 55 mm^2 (IQR 45–72) and the median smallest post-operative CSA was 148 mm^2 (IQR 127–188). The difference was statistically significant ($p < 0.001$, Table 2).

One of the patients with a negative SedSign post-op suffered from persisting post-operative leg pain and neurological deficit. The immediate post-operative MRI showed an insufficient surgical result after decompression surgery and a positive SedSign. The patient had a revision operation 1 day later and, consequently, demonstrated a negative Sign at 3-month follow-up. He suffered a neurological deficit but with improvement of ODI and VAS (Fig. 3).

The median ODI improvement of the 27 SedSign negative patients was 39 (IQR 24–54), the median pain improvement 5 VAS points (IQR 5–7). The median improvement of the walking distance was 890 m (IQR 500–1000). These changes were all statistically significant ($p < 0.001$).

Table 2 Patient demographic characteristics and comparison of pre- versus post-operative clinical–radiological characteristics for patients with and without post-operative reversal of SedSign, $n = 30$

Characteristic	Pre-operative Median (IQR)	Post-operative[a]	Pre- vs post-op difference	p value[b]
Sex, *n*				
Male	16			
Female	14			
Age, years	73 (65–78)			
SedSign, *n*				
Positive	30	3		
Negative	0	27		
ODI				
SedSign pos	66 (52–78)	31 (4–35)	32 (24–51)	
SedSign neg		21 (12–26)	39 (24–54)	<0.001
VAS				
SedSign pos	8 (7–9)	2 (0–3)	7 (4–7)	
SedSign neg		2 (2–4)	5 (5–7)	<0.001
Walking distance (m)				
SedSign pos	0 (0–100)	500 (100–1000)	480 (100–600)	
SedSign neg		1000 (500–1000)	890 (500–1000)	<0.001
CSA (mm^2)				
SedSign pos	55 (45–72)	117 (103–125)	53 (34–83)	
SedSign neg		148 (127–188)	88 (47–121)	<0.001

CSA cross sectional area, *IQR* interquartile range, *n* number, *neg* negative, *ODI* Oswestry Disability Index, *pos* positive, *SedSign* sedimentation sign, *VAS* Visual Analogue Scale

[a] Post-operative SedSign pos = no SedSign reversal, post-operative SedSign neg = SedSign reversal

[b] Test for difference in pre-op versus post-op values, assessed for group with negative SedSign post-operatively, $n = 27$

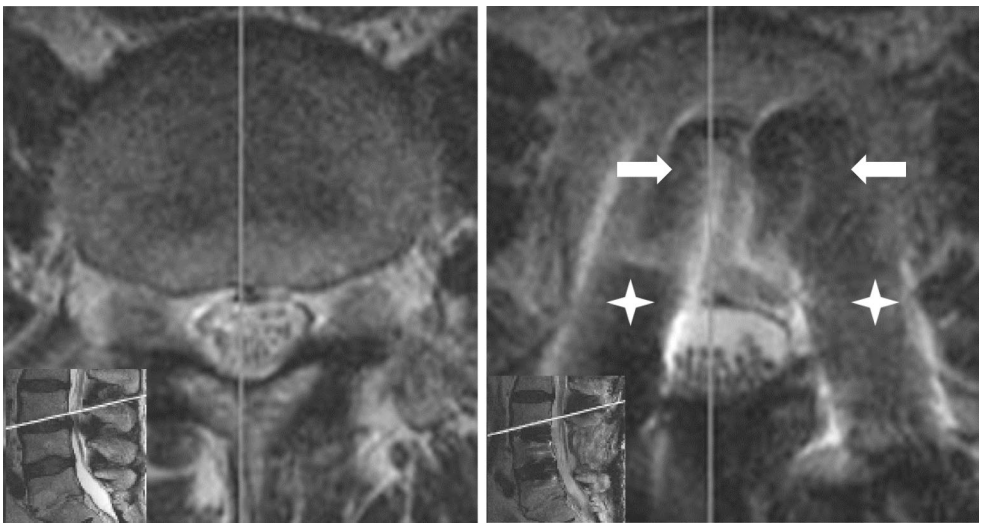

Fig. 2 MRI (t2 image) of patient with a pre-operative positive SedSign (*left*) and post-op negative SedSign (*right*). Visible artefacts due to inserted pedicle screws (*asterisk*) and cages (*arrows*) cause minor disturbance to evaluation of the SedSign

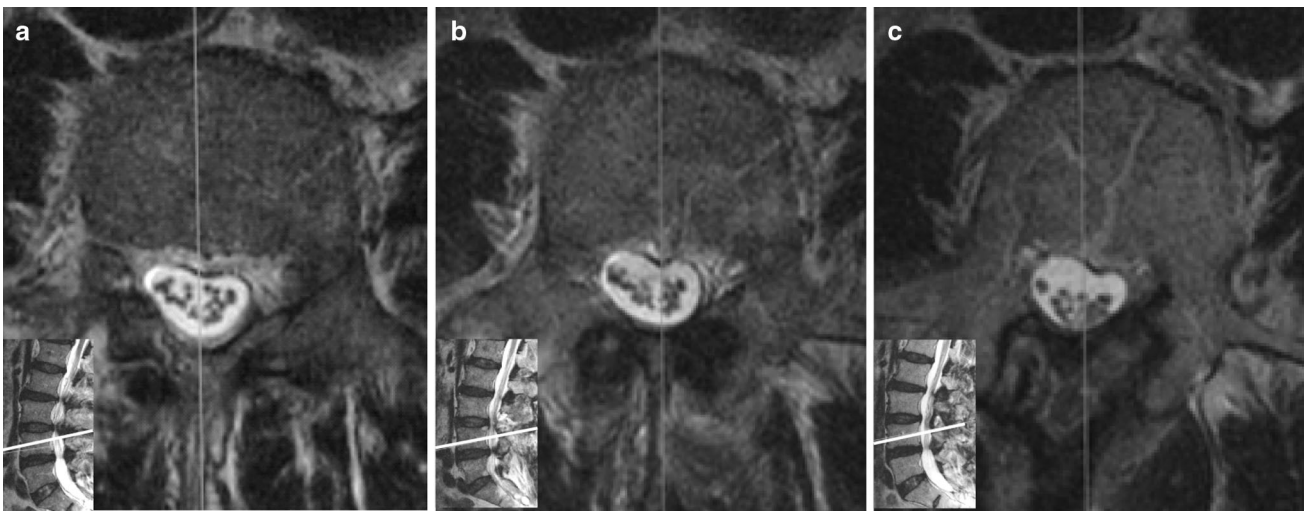

Fig. 3 MRI (t2 image) of patient with a: **a** pre-operative positive SedSign; **b** post-operative positive SedSign; **c** post-operative negative SedSign at 3-month follow-up

In three patients, the SedSign remained positive 3 months post-operation. They had a positive SedSign due to epidural fat ($n = 2$) or a dural cyst ($n = 1$) following an intra-operative dural tear. In these three patients, the post-operative ODI improvement was 24, 32, and 51 points, respectively. The pain improvement was four points in one patient and seven points in the other two patients. The improvement of the walking distance was 100, 480, and 600 m.

Given the small number of patients with a positive post-op SedSign ($n = 3$), it was not appropriate to perform statistical tests to compare the clinical improvement between patients with a negative versus positive post-op Sign. Hence, it was not possible to formally test the hypothesis about the association of SedSign reversal and surgical outcome.

Discussion

This study demonstrated the reversibility of a pre-operative positive SedSign after decompression of the affected segmental level. Reversibility appeared to be associated with an improved clinical outcome at 3 months compared to pre-operative outcomes. The previously reported high interrater reliability of the SedSign in the MRI was confirmed with this study [11, 22].

The immediate reversibility of SedSign of this prospective study at 3-month follow-up as well as the persisting reversibility of the SedSign shown in a retrospective study [23] strongly supports the concept that underlying mechanical reasons may be responsible for the phenomenon of lumbar nerve root sedimentation [24].

Local arachnoiditis can be excluded as an explanation [25]. In fact, an increased epidural pressure was found intra-op in LSS patients with a positive SedSign [24]. It can be speculated that the increased pressure directly leads to clinical complaints [26]. If that can be confirmed, epidural pressure measurement may become an important pre-operative diagnostic tool for patient selection and an intra-operative objective measure to limit the amount of surgical tissue resection and in turn limit the degree of lumbar segmental instability [27].

If symptom relief after lumbar decompression is not sufficient or symptoms recur after a period of relief, MRI is normally repeated to evaluate spinal canal dimensions [28, 29]. However, sometimes instrumentation with pedicle screws and cages averts direct evaluation of the spinal canal at disc level. This study demonstrated that the high interrater reliability of the SedSign could be reached with present instrumentation (Fig. 2). A new positive SedSign could be used as an indicator of new severe stenosis in previously operated patients.

Our investigation confirms that LSS patients with a positive SedSign may benefit from surgical treatment [8, 10]. Functional limitation, pain, and walking distance improved in patients with the reversal of a pre-operative positive Sign.

We observed three patients without reversal of the SedSign after decompression surgery. These patients also appeared to benefit from surgery. This must be interpreted in relation to non-stenosis mechanisms for the SedSign in these three cases, epidural fat in two cases and an epidural cyst in one case. The only patient with a positive post-operative SedSign related to stenosis in the immediate post-operative MRI required urgent revision surgery [30].

There might be a correlation between a post-operative positive SedSign and limited symptom relief after decompression. Due to the small sample of post-operative SedSign positive cases, we were unable to answer the second research question, whether SedSign reversal is associated with more favourable clinical outcomes.

Possible reasons for a positive SedSign after decompression are presented in Table 3. It is essential to check a post-operative positive SedSign for potential reasons other than insufficient decompression. In patients with no alternative explanations, post-operative measurement of the SedSign indicating insufficient decompression could possibly help to anticipate the patient's prognosis.

Possible reasons that may lead to deterioration after surgery are presented in Table 4.

Due to commonly low revision rates of about two percent within 1 month [31] and per year [3], it will be difficult to answer the question if a post-operative positive SedSign is associated with worse outcome and higher reoperation rates. A matched-pair analysis of completed register data could help to address this question.

Table 3 Possible reasons for a positive SedSign after surgical decompression

Insufficient decompression
Post-operative hematoma
Excessive post-operative scar tissue
Post-operative wound infection without abscess
Post-operative arachnoiditis without stenosis
Epidural lipomatosis
Newly occurred stenosis in the same or adjacent segment
Severe deformity, such as scoliosis/spondylolisthesis

Table 4 Possible reasons for deterioration after decompression surgery of central spinal stenosis

Residual stenosis (lateral recess stenosis, foraminal stenosis)
Deformity (sagittal and frontal curve), instability
Facet arthrosis, kissing spine
Wound infection, epidural abscess, discitis
Osteoporosis with/without vertebral fracture
Multilevel surgery with muscular decompensation

One case of dural tear with a dural cyst was observed in our patients. Dural tears may cause arachnoiditis in combination with neuropathic pain generation. However, in our study and as previously published there was no correlation between dural tears and clinical outcomes [32].

We saw that epidural lipomatosis is another reason for a persisting positive SedSign. This is a rare disease entity, which has recently been diagnosed more frequently and can be accompanied by neurological deficits. It may be associated with endo- or exogenous steroid excess (secondary form), or remain idiopathic often associated with high body mass index (primary form). There is no evidence-based treatment option for both the primary and secondary forms [33]. Therefore, the SedSign cannot be used as a surgery indication in patients with epidural lipomatosis (Fig. 4).

A recent study reported a 95% sensitivity of the SedSign in cases of severe stenosis [34]. The SedSign may support an indication for surgery in stenosis patients but it is not a suitable tool for distinguishing between patients with symptomatic stenosis and nonspecific low back pain, because many of these patients have other underlying reasons for their clinical symptoms such as lateral recess and foraminal stenosis or have mild to moderate forms of stenosis that can be treated non-surgically.

A simple radiological definition of LSS seems unachievable, but qualitative items such as SedSign

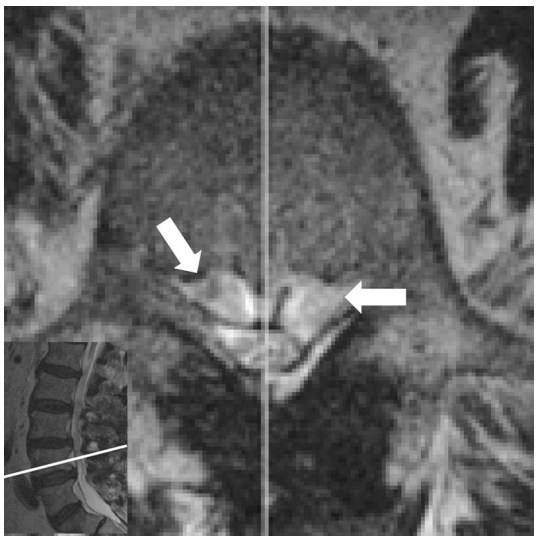

Fig. 4 MRI (t2 image) of patient with post-operative positive SedSign due to epidural lipomatosis (*white arrows*)

combined with other variables might be a step forward to objectively determine the clinical syndrome and to define a reference standard for central LSS [35–37].

Conclusion

A positive SedSign turns negative after sufficient surgical decompression. The reversibility of a positive SedSign may be used as a post-op indicator for effective decompression surgery in LSS. A new positive SedSign after sufficient decompression surgery could be used as an indicator of new stenosis in previously operated patients.

Compliance with ethical standards

Conflict of interest We have no potential conflict of interest.

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