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Diagnostic efficacy of nerve root sedimentation sign in post-lumbar interbody fusion patients: an imaging evaluation and modification

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Abstract

Background The sedimentation sign offers an efficient method for evaluating lumbar spinal stenosis. However, limited research exists regarding its applicability to post-operative MRI scans. This study aims to assess the viability of utilizing the nerve root sedimentation sign (NRSS) and Schizas classification (SC) in the evaluation of post-operative lumbar stenosis.

Methods Patients were classified into seven groups using SC: A1, A2, A3, A4, B, C and D. The dural sac cross-sectional area (DSCA), anterior-posterior dural sac diameter (AP), and the Oswestry disability index (ODI) of each group were compared. The difference in DSCA between direct and indirect decompression surgery was also compared to confirm whether the deformation of the spinal canal will affect the results.

Results 232 postoperative patients were evaluated. The variance of analysis showed that DCSA, AP and ODI had significant differences among the SC groups and NRSS groups postoperatively ($P < 0.01$). Comparison of DSCA results between direct and indirect decompression postoperative patients showed significant differences between groups A1 and A2, A2 and A3. AP comparison results showed significant differences between groups A1 and A2. ODI comparison results showed significant differences between groups A2 and A3. Among OLIF patients, groups A1 and A2 had mean DSCA values greater than 100mm^2, while in the T/PLIF group, groups A1-4 had mean DSCA values greater than 100mm^2.

Conclusion Both sedimentation signs are applicable for the evaluation of postoperative lumbar spinal stenosis. We recommend updating the definition of negative nerve root sedimentation sign to nerve root sedimentation on the dorsal side of the dural sac, with an occupying area less than half, and greater than half considered positive sign. Sedimentation sign is mainly formed by the interaction of gravity, extradural pressure, and nerve root tension.

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Keywords Oblique lateral interbody fusion (OLIF), Nerve root sedimentation sign. spinal stenosis, Magnetic resonance imaging (MRI), Diagnostic imaging

Background

Lumbar spinal stenosis (LSS) is a degenerative condition characterized by the narrowing of the spinal canal, leading to compression of neural structures. With a prevalence of 11% in the general population and affecting up to 39% of individuals over 60 years old [1], LSS has become a significant healthcare burden in aging societies.

Despite an existing wide range of clinical, electrophysiologic and radiologic signs leading to the diagnosis the lumbar spinal stenosis (LSS), the indication for surgery has not yet been clearly defined, and guidance for clinicians is inconsistent and inadequate. The nerve root sedimentation sign (NRSS) was first proposed by Barz et al. in 2010 to assess lumbar stenosis [2]. Patients were kept in a supine position when they underwent magnetic resonance imaging (MRI) scanning. Two distribution patterns of the cauda equina nerve were observed in the axial scan of magnetic resonance: (1) Negative NRSS: normal spinal canal was indicated when the nerve tract sedimented to the dorsal spinal canal in supine-positioned patients; (2) Positive NRSS: the nerve roots were still suspended in the dural sac in supine-positioned patients, which indicated lumbar stenosis (Fig. 1).

Numerous studies have shown that NRSS can serve as effective and simple methods to assist in diagnosing LSS [3, 4]. However, in postoperative patients, NRSS application faces challenges due to the increased complexity of magnetic resonance images (as shown in Fig. 2). Currently there are few reports on whether the sedimentation sign is still applicable to postoperative MRI images. One reason is that most postoperative patients do not consider MRI as a routine examination [5]. Another is for direct decompression surgeries such as transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF) and anterior lumbar interbody fusion (ALIF) etc., images may be affected by irregular ossified spinal canals and factors such as local hematoma and tissue edema in the early postoperative period.

Schizas et al. reported another sedimentation sign which further subdivide the images into seven grades [3, 4] (Fig. 2). Although the two sedimentation signs have similar imaging appearances, there are significant differences in their definitions. NRSS evaluates images adjacent to the narrowest level, while SC directly assesses the narrowest level. Moreover, typical negative and positive NRSS presentations correspond to A1 and A3 types in the SC classification, respectively. However, SC defines Type A as mild or no apparent stenosis, which raises a series of questions: Should A3 type be classified as moderate stenosis (Type B)? Additionally, the position of A2 type in the NRSS is unclear. This study aims to explore the integration and optimization of these two sedimentation sign classification methods by comparing the differences in DSCA, AP, and ODI among patients with different sedimentation sign types after surgery. In addition, we separately compared these parameters in patients who underwent oblique lateral interbody fusion (OLIF) and T/PLIF, to verify whether the sedimentation sign is applicable to both indirect decompression and direct decompression surgery.

Methods

Study design

A total of 232 patients with postoperative lumbar stenosis in the orthopedics department of a tertiary hospital from January 2019 to June 2023 were included in this study. The inclusion criteria were as follows: (1) Patients were diagnosed with lumbar stenosis preoperatively. (2) The surgical segments ranged from L1 to L5. (3) The cauda equina could be discriminated in T2-weighted imaging (T2WI) lumbar vertebra MRI images. The exclusion criteria were as follows: (1) When non-vertebral diseases, such as intraspinal space-occupying lesions, were involved. (2) Irreversible damage of neurological function caused by severe injury before the surgery. (3) The distribution of nerve roots in the image is not clearly visible, and there are no enough nerve roots to be able to distinguish grades. (4) After severe scoliosis surgery, multilevel OLIF surgery, etc., which significantly changes the lumbar lordosis or lateral curvature. (5) Patients with multilevel LSS who underwent surgery on only some segments. LSS had no clear diagnostic criteria. Therefore, imaging stenosis was employed as the criteria, such as DSCA [6] smaller than $75mm^2$ and positive NRSS. Besides, clear clinical symptoms must be present, including angina cruris, numbness, and radiating pain in lower limbs [7]. Ethical approval was obtained from ethics committee of Sir Run Run Shaw Hospital, Zhejiang University School of Medicine(Reference number: Research 20190522-2). Informed consent from each patient was obtained.

Cases were grouped by surgical approach: OLIF group (indirect decompression) and T/PLIF group (direct decompression including TLIF/PLIF/ALIF/posterior laminectomy without fusion). Subgroups were created based on Schizas classification (A1-D) and NRSS (positive/negative) for comparison.

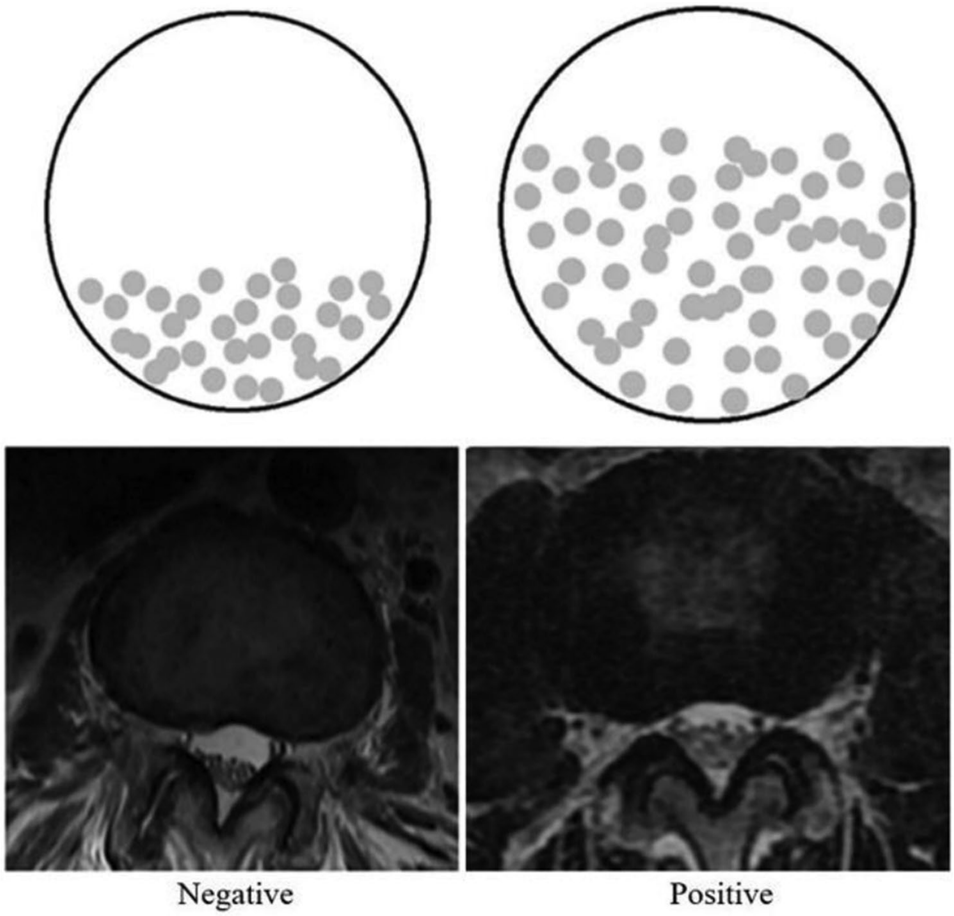

Fig. 1 T2-weighted imaging MRI cross-section image of lumbar vertebra. The dural sac inside the spinal canal was equally divided into ventral and dorsal parts. Negative, The negative nerve root sedimentation sign. All nerve tracts located in the dorsal parts of spinal canal except the tracts leaving the dural sac. Positive, The positive nerve root sedimentation sign. All nerve tracts located in the ventral parts of the spinal canal, except the tracts leaving the dural sac

Image analysis

The MRI inspection and measurement employed the Signa CV/I type 1.5T MRI instrument (GE Company, MA, USA). The T1-weighted spin-echo sequence of lumbar vertebra vertical plane [repetition time (TR)/echo time (TE) = 550ms/11ms, visible bandwidth of 31.2 kHz], the fast spin-echo (FSE) sequence T2WI of vertical plane (TR/TE = 4000ms/83ms, visible bandwidth of 15.6 kHz), and the FSE sequence T2WI of cross-section (TR/TE = 3610 ms/94ms, visible bandwidth of 15.6 kHz) were scanned with a layer thickness of 4.0 mm, layer distance of 1.0 mm, matrix dimension of 320 × 256, excitation number of 3, vertical plane view of 28 × 28, and cross-section view of 20 × 20.

An experienced spine surgeon and a radiologist performed the assessment and data collection to determine the sedimentation sign in postoperative images. The DICOM format images achieved by MRI inspection were imported into the Surgimap Spine 1.2.1.86 software (Nemaris Company, NY, USA) to measure the DSCA in the narrowest plane. The time interval between surgery and MRI review of each patient was recorded. Two sedimentation signs were measured in transverse MRI scans of level L1/L2–L4/L5. The SC, DSCA, AP is evaluated at the level of maximum stenosis, while the NRSS is evaluated above or below the maximum stenosis. Spinal canal was divided into ventral and dorsal parts using the mid-sagittal diameter of the dural sac as the dividing line.

Statistical methods

The SPSS 19.0 statistical software (IBM Company, NY, USA) was employed for statistical processing. The DSCA, AP and ODI [8] scoring were expressed with the format of $\bar{x}\pm s$. The DSCA and ODI data among the groups of Schizas classifications were processed with chi square statistic. We also separately compared these parameters of patients underwent with OLIF and T/PLIF, to verify whether these sedimentation signs are applicable to both indirect decompression and direct decompression

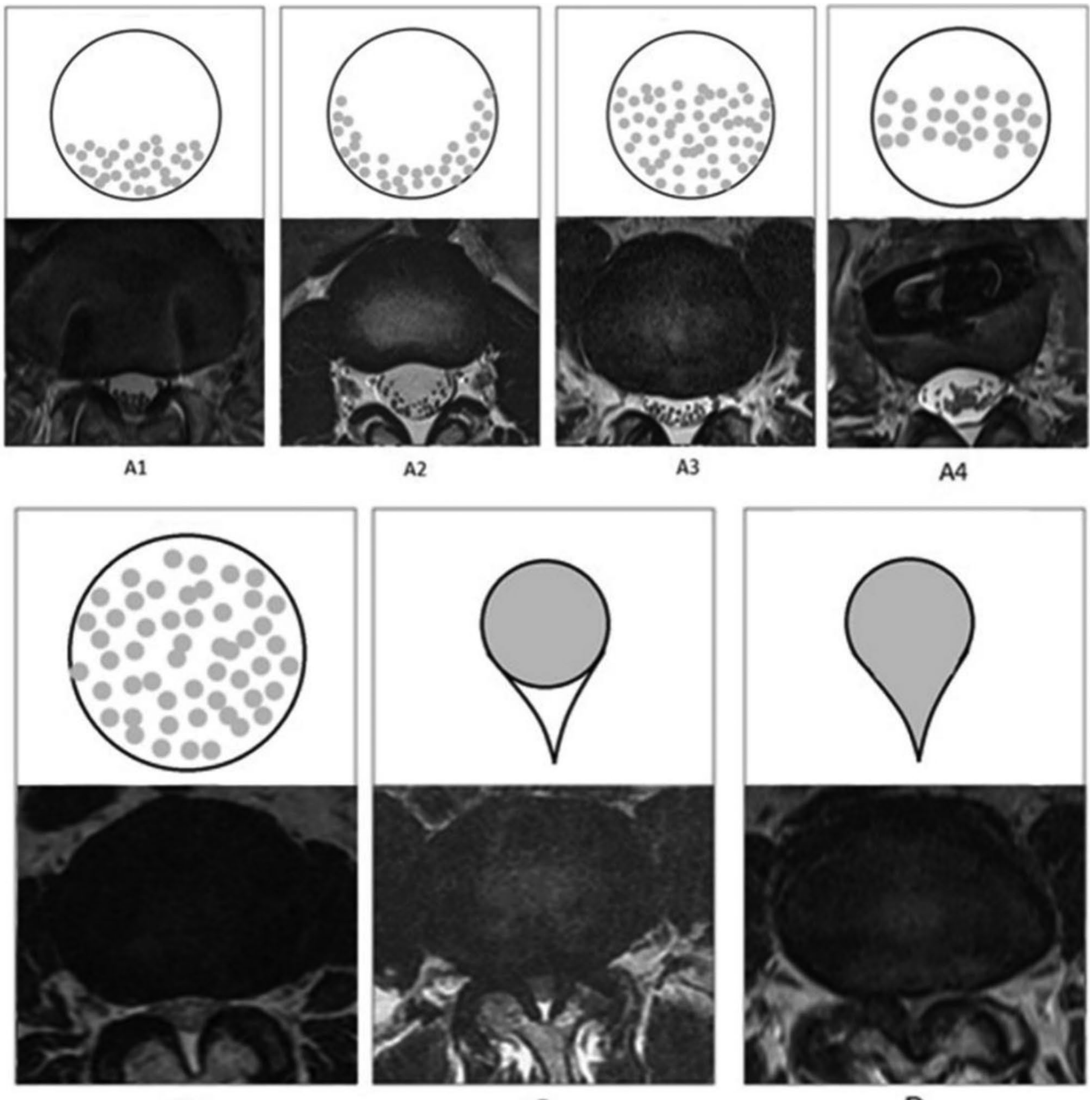

Fig. 2 Schizas classification of distributions of cauda equina nerve tracts in the T2WI MRI cross-section image. (**A**1) Cauda equina nerve tracts located on the dorsal side of the dural sac occupying less than half of the area of the dural sac. (**A**2) Cauda equina nerve tracts located on the dorsal side of the dural sac with horseshoe distribution. (**A**3) Cauda equina nerve tracts located on the dorsal side of the dural sac occupying more than half of the area of the dural sac. (A4) Cauda equina nerve tracts located in the middle part of the dural sac occupying most of the areas. (**B**) Cauda equina nerve tracts occupying all areas of the dural sac, while the fascicular structure of nerve could be observed. (**C**) Uniform gray signal was observed inside the dural sac, and the CSF and nerve tract could not be discriminated. The fat signal could be observed in the interval between the dorsal view of the spinal canal and the dural sac. (**D**) Uniform gray signal was observed inside the dural sac, and no fat signal was observed in the dorsal parts

surgery. We used the DSCA classification described by Schonstrom [9] as a reference: DSCA > 130 mm^2 as no stenosis, DSCA < 130 mm^2 as mild stenosis,<100 mm^2 as moderate stenosis, and < 75 mm^2 as severe stenosis. A p values < 0.05 was accepted as statistically significant.

Results

A total number of 232 patients (131 males and 101 females) whose age ranged from 40 to 75 years (average age, 60.2 ± 7.23 years) were included in this study. There were 63 patients who underwent the OLIF. 169 patients were assigned to the T/PLIF group (163 patients underwent T/PLIF,4 patients underwent posterior laminectomy without fusion and 2 patients underwent ALIF). Moreover, 179 patients (77.2%) had the lesion segments located in the L4-5 intervertebral disk. 45 patients (19.4%) had the lesion segments in the L3-4 intervertebral disk. 8 patients (3.4%) had the lesion segments in the L2-3 intervertebral disk.

OLIF patients demonstrated a follow-up duration ranging from 3 days to 1 year (mean: 1.6 ± 27.9 months), while T/PLIF patients exhibited longer follow-up periods, spanning from 3 days to 12 years (mean: 44 ± 52.4 months). Spearman correlation analysis showed no significant correlation between DSCA and follow-up duration ($P > 0.05$). The data of patients grouped by SC are listed in Table 1. All measurement data showed normal distribution.

Changes in early postoperative (within one month) MRI fellow-up

In the T/PLIF group, within the first month of follow-up MRI, 13 cases exhibited negative NRSS, with 2 patients reporting leg pain. Conversely, 7 cases showed positive NRSS, of which 6 experienced lower limb symptoms, predominantly leg pain, and 1 necessitated reoperation. The NRSS demonstrated a specificity of 84.6% and a sensitivity of 85.7%.

In the OLIF group, comprising 65 cases (including 48 cases within 1 week), 11 displayed positive NRSS, with only 1 case presenting a DSCA exceeding 100 mm². Considering patient symptomatology, the sensitivity was calculated at 90.1%. Among the 54 negative cases, 1 exhibited a DSCA below 100 mm², yielding a specificity of 98.1%.

The comparison results among T/PLIF patients

Significant variations in DSCA, AP, and ODI were observed among T/PLIF patients. The DSCA differences between groups demonstrated statistical significance ($F = 11.14$, $P < 0.001$). Figure 3a illustrates the groups exhibiting significant differences between adjacent categories. Notably, groups A1 and A2, A2 and A3, A4 and B, and B and C displayed significant disparities ($P < 0.001$), while groups C and D showed no substantial differences ($P > 0.05$). The mean DSCA values for groups A1 and A2 exceeded 130 mm²; group B was below 100 mm²; and groups C and D were less than 75 mm² (Table 1). Pairwise comparisons of AP revealed significant differences between all adjacent groups only for groups A1 and A2 ($P < 0.001$) (Fig. 3b). The ODI differences were statistically significant ($F = 6.04$ and $P < 0.001$). No significant differences were observed between groups A2 and A3 ($P < 0.001$) (Fig. 3c).

The DSCA comparison results among OLIF patients

The DCSA difference among the OLIF groups demonstrated statistical significance ($F = 11.67$, $P < 0.001$). Notably, no grade A4 was observed in OLIF patients in this study. Pairwise comparisons revealed significant differences only between groups A1 and A2, as well as A2 and A3 ($P < 0.001$). (Fig. 3e) Interestingly, intra-group comparisons between identical Schizas classifications in OLIF and T/PLIF groups showed no statistically significant differences (Table 1).

The comparison results among NRSS classification

In the OLIF group, 18 cases exhibited negative signs, while 45 cases presented positive signs. The T/PLIF group demonstrated 117 cases of negative signs and 46 cases of positive signs. A statistically significant difference in DSCA and AP was observed between the negative and positive groups ($P < 0.01$) in both OLIF and T/PLIF groups (Table 2).

Furthermore, 55 patients exhibited positive NRSS at both the narrowest level and adjacent levels. Nineteen patients experienced difficulty in distinguishing nerve roots at the narrowest level (SC grade C and D) and displayed positive NRSS at adjacent levels. Notably, 17 cases demonstrated positive NRSS exclusively at the maximum stenosis level, while showing negative NRSS at levels above or below. According to Barz's definition, these cases would be classified as negative NRSS. The average DSCA for these cases was 105.81mm^2, with an average AP of 10.02 mm. When comparing these 17 cases separately to the negative and positive groups, their DSCA and AP values exhibited significant differences with the negative group ($P < 0.01$), but not with the positive group ($P > 0.05$). Based on these findings, we propose

Table 1 The dural sac cross-sectional area (mm^2) of schizs classification groups

	A1	A2	A3	A4	B	C	D
OLIF	185.6 ± 52.11	132.8 ± 52.62	98.6 ± 13.21	0	83.8 ± 16.34	70.9 ± 10.79	53.3 ± 11.64
N	18	23	5	0	9	6	2
T/PLIF	182.3 ± 63.76	142.8 ± 45.80	136.5 ± 68.13	136.3 ± 25.17	90.9 ± 27.09	63.5 ± 19.07	48.6 ± 16.67
N	123	4	11	7	13	9	2
p	0.826	0.726	0.2557	-	0.495	0.381	0.933

OLIF, Oblique lateral interbody fusion. T/PLIF, Transforaminal lumbar interbody fusion / posterior lumbar interbody fusion. p, Comparison results of DSCA between OLIF and T/PLIF patients in the same Schizas classification group

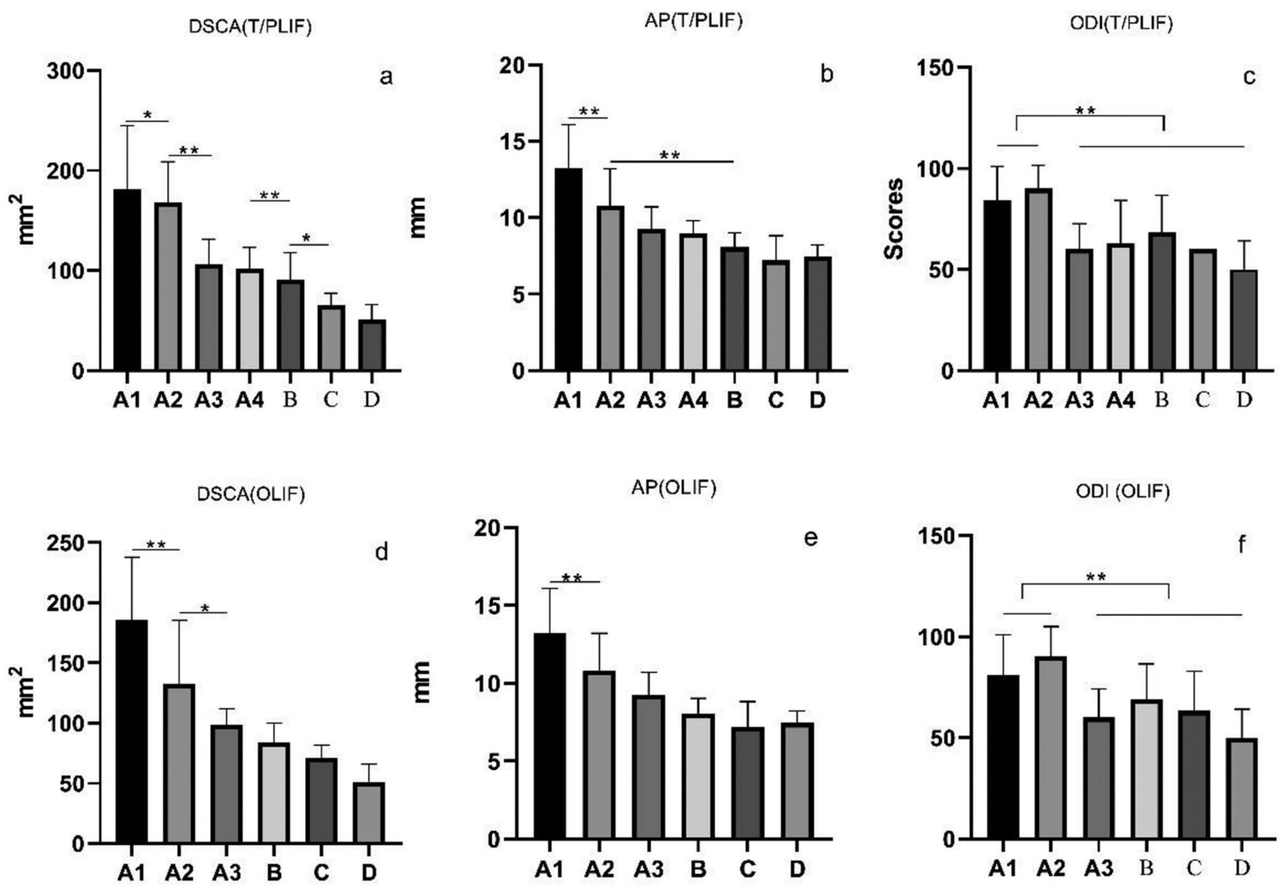

Fig. 3 The postoperatively parameters comparison results between Schizas groups. **a**. The parameters comparison results of T/PLIF patients. **b**. The AP comparison results of T/PLIF patients. **c**. The Oswestry disability index (ODI) comparison results of T/PLIF patients. **d** The DCSA comparison results of OLIF patients. e. The AP comparison results of OLIF patients. **f**. The Oswestry disability index (ODI) comparison results of OLIF patients

Table 2 The dural sac cross-sectional area (mm^2) of nerve root sedimentation sign groups

	Negative	Positive	*P*
All patients	181.8 ± 62.09	115.6 ± 46.49	0.001**
N	141	91	-
OLIF	185.6 ± 52.11	107.3 ± 47.45	0.001**
N	18	45	-
T/PLIF	181.2 ± 63.66	96.2 ± 36.21	0.001**
N	123	46	-

OLIF, Oblique lateral interbody fusion. T/PLIF, Transforaminal lumbar interbody fusion / posterior lumbar interbody fusion. p, Comparison results of DSCA between negative and positive groups, ** $p < 0.01$

that classifying these cases as positive signs may be more appropriate.

Discussion

Through this study, we have demonstrated that both sedimentation signs remain applicable for assessing the severity of lumbar spinal stenosis (LSS) in the majority of postoperative patients. Although postoperative imaging presentations are more complex than preoperative findings, we have successfully elucidated the underlying causes by systematically collecting and analyzing various irregular imaging patterns. Furthermore, we have proposed a refined definition of the sedimentation sign, significantly expanded its applicability and enhanced its utility in clinical practice. These insights not only deepen our understanding of postoperative LSS but also provide a more robust framework for evaluating patient outcomes.

Analysis of the causes and influencing factors of sedimentation sign

When Barz initially proposed NRSS, he believed its cause was related to gravity, but recent studies have called this view into question [10]. Based on the current literature on the NRSS, we believe that this sign is mainly formed by the interaction of gravity, extradural pressure, and nerve root tension. The role of nerve root tension is rarely mentioned in current literature. Kishan Patel's [11] study showed that the sedimentation sign can still exist in upright MRI images, and it shows a stronger correlation with DSCA and the anterior-posterior diameter of the spinal canal, indicating that there is a certain tension in the nerve roots themselves after removing the effect of gravity. When there is no increase in extradural pressure caused by spinal stenosis, the nerve root is still fixed on the dorsal side of the dural sac, showing a negative sedimentation sign. Jun Yang et al.'s study showed [12] that in prone position MRI images, nerve roots are affected by gravitational force and sink towards the ventral side, while in the lateral position, nerve roots sink towards the lateral side. This indicates that under normal circumstances, the tension of nerve roots is less than the influence of gravity, and the nerve roots are distributed relatively loosely in the dural sac. However, in pathological conditions such as spinal canal stenosis, intervertebral disc herniation, spinal scoliosis, and hypertrophy of the ligamentum flavum, the compression and traction on the nerve roots increase significantly, leading to a significant increase in nerve root tension. In accordance with this theory, we found that in some patients after multi-level OLIF surgery, due to the large deformation of the bony spinal canal (changes in intervertebral disc height, lordosis, etc.), the nerve roots would undergo reverse sedimentation (Fig. 4).

Comparison and improvement of two sedimentation signs

Barz et al. suggested that [2] the sedimentation sign should be evaluated at the level above or below the maximum stenosis to avoid the nerve roots being tightly bound in the spinal canal, which would make it difficult to evaluate accurately. They also pointed out in their later study [13] that a positive sedimentation sign is formed by the increase in extradural pressure caused by spinal canal stenosis, but this pressure (about 22 mmHg) only exists at the level of maximum stenosis, and the pressure quickly drops to normal levels (about 8–9 mmHg)

Fig. 4 61-year-old male patient underwent OLIF surgery at L3/4 L4/5. **a**, preoperative MRI, L1/2 is positive sign/A3 grade, and dural sac cross-sectional area (DSCA) is 172 mm^2. **b**, MRI on the second day postoperatively. **b1**, the intervertebral space after OLIF surgery is significantly widened, causing the cauda equina nerve to be straightened, **b2**, the cauda equina nerve is all pulled to the ventral side, positive sign/A4 grade, DSCA is 178 mm^2. **c**, Re-examination 18 months after surgery, **c1**, the nerve root morphology has largely returned to its preoperative state, possibly due to either nerve adaptation to traction or reduced intervertebral space height following fusion implant embedding in the endplate; **c2** the distribution of the nerve roots has returned to a similar state as preoperative (positive sign/A3 grade, DSCA 140mm^2)

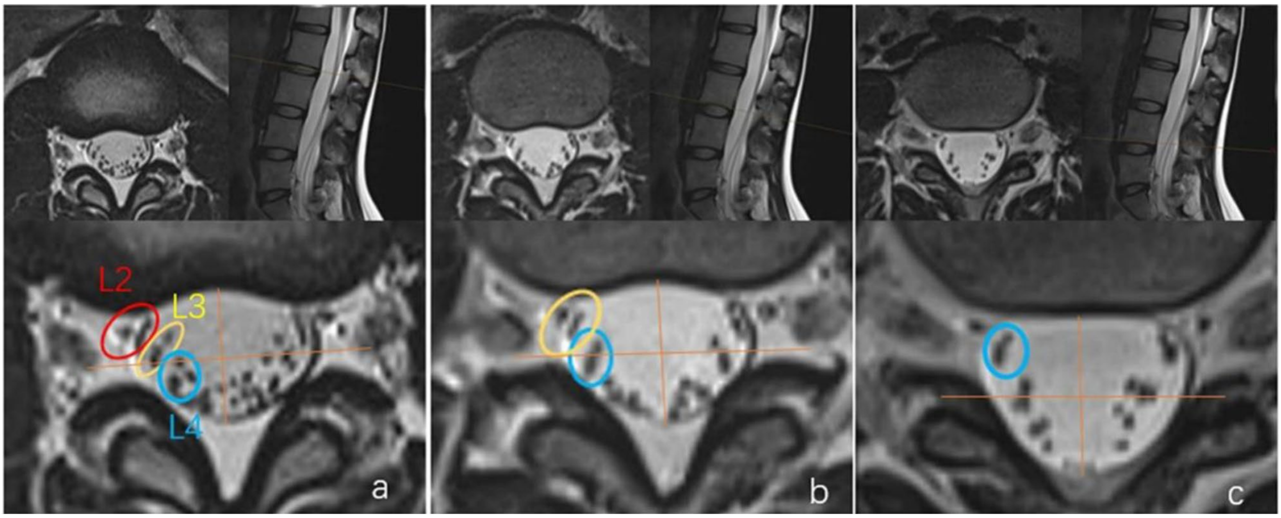

Fig. 5 A typical A2 grade is shown in the transverse image of the lumbar spine MRI of a 45-year-old healthy male. The red circle represents the L2 nerve root, the yellow circle represents the L3 nerve root, and the blue circle represents the L4 nerve root. a, L2/3. b, L3/4. c, L4/5

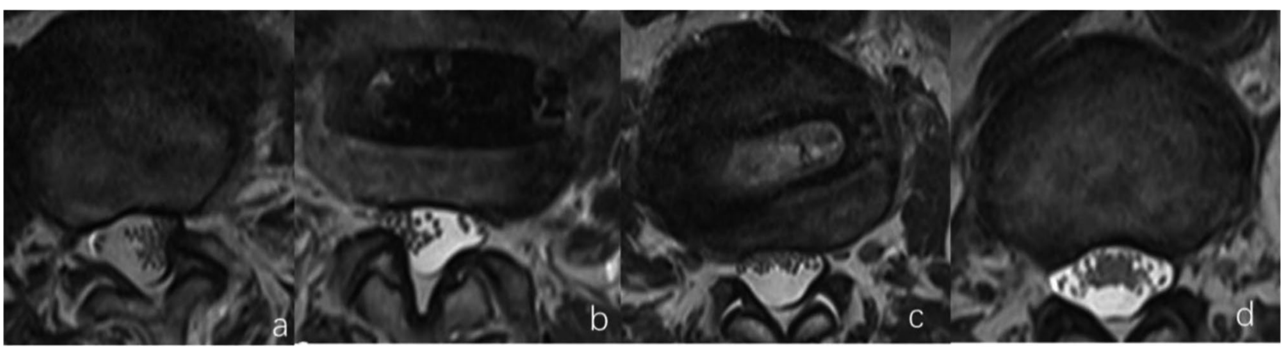

Fig. 6 Irregular axial MRI images following multi-level oblique lateral interbody fusion (OLIF). All cases demonstrate a dorsal spinal canal area (DSCA) greater than 130 mm^2. **a**, 70-year-old female, 3 days postoperatively. **b**, 77-year-old male, 30 days postoperatively. **c**, 64-year-old male, 2 days postoperatively. **d**, 72-year-old female, 7 days postoperatively

at the levels above and below. Only in severe stenosis (SC C or D), when the nerve roots are significantly stretched at the level of maximum stenosis, will a positive sign be observed. In cases of mild stenosis, it is possible for the sedimentation sign to be positive at the level of maximum stenosis while negative at adjacent levels, which can affect the accuracy of the evaluation. Therefore, we suggest that in cases of severe stenosis, such as SC C or D, the NRSS can be evaluated at adjacent levels, while in cases of stenosis less severe than SC B, evaluation at the level of maximum stenosis may be more accurate.

We found that nerve roots on the ventral side are currently about to leave the dural sac in an A2 images (Fig. 5). But most lumbar spine MRI scans only cover the intervertebral disc level, resulting in discontinuity of images, it is not easy to estimate whether the ventral nerve roots will leave the dural sac in the next segment. Besides, there are still noticeable differences in the images between the A1 and A2 grades. The comparison results of DSCA and AP between the A1 and A2 groups in this study also show significant differences. Therefore, although both are classified as NRSS negatives, the spinal canal of the A2 grade is relatively narrower compared to the A1 grade. Additionally, the distribution of nerve roots in postoperative patients is often irregular (Fig. 6). Based on the distribution characteristics of A1 and A2 grades, we recommend revising the definition of negative sign to indicate nerve root sedimentation on the dorsal side, with a distribution area less than half of the dural sac area. If the distribution area exceeds half, it should be considered positive. In the images of Fig. 6, the abnormal distribution of the nerve roots is due to traction, with all of their DSCA greater than 130mm^2. It seems that regardless of the morphological distribution of the nerve roots, if the occupied area is less than half of the dural sac area, it can be defined as negative NRSS, indicating no obvious spinal canal stenosis. We will attempt to verify this hypothesis in future studies.

Changes in early postoperative MRI fellow-up

Previously, it was believed that postoperative MRI images would be unclear or show false stenosis due to factors such as bleeding and edema especially in the early period. Therefore, MRI was not recommended as a good postoperative examination. However, in this study, we found that this situation was much less common than expected. By comparing the images of patients who underwent MRI follow-up more than twice in this study, it was found that the DSCA was largest at around 1 month after surgery, slightly smaller within 1 week after surgery, possibly due to the resolution of local bleeding and edema, and decreased again after 3 months or longer, possibly due to fusion cage settling, re-adaptation, and loss of correction of the lumbar lordosis angle. The analysis showed no correlation between DSCA and follow-up time ($P > 0.05$). We believe that early postoperative MRI can accurately reflect the improvement of spinal canal stenosis in most patients.

Comparison of sedimentation sign between direct (T/PLIF) and indirect (OLIF) decompression surgeries

We analyzed OLIF and T/PLIF patients separately to compare the differences between indirect decompression and direct decompression. OLIF and T/PLIF groups showed significant differences in DSCA among Schizas groups. In addition, OLIF groups showed smoother reducing DSCA in graph, maybe because of no damage to the spinal canal structure. There was no A4 grade in the OLIF group, perhaps because of the small sample size.

This study had some limitations. First, MRI has not yet become a routine examination for postoperative follow-up. and the sample size of positive NRSS is even smaller. Secondly, as this study is a retrospective study, when calculating the ODI, it can only be assessed based on the symptoms recorded in the cases, which do not include all scoring items, which affects the test efficiency to a certain extent.

Conclusions

In summary, both sedimentation signs are applicable for the evaluation of postoperative lumbar spinal stenosis. Negative nerve root sedimentation sign and Schizas classification A1, A2 grade indicate no significant spinal canal stenosis, while positive nerve root sedimentation sign and Schizas classification A3-D grade indicate varying degrees of spinal canal stenosis. We recommend updating the definition of negative nerve root sedimentation sign to nerve root sedimentation on the dorsal side of the dural sac, with an occupying area less than half, and greater than half considered positive sign. When the maximum stenosis level is difficult to evaluate, the sedimentation sign can be evaluated at the level above or below.

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Author contributions

Fengdong Zhao conceived and designed the study. Zhenhua Feng collected the data. Jia Chen and Zhikun analyzed the data and wrote the manuscript. Hao WU revised the manuscript. All authors read and approved the final manuscript.

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None.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from ethics committee of Sir Run Run Shaw Hospital, Zhejiang University School of Medicine. Informed consent from each patient was obtained. The Manuscript submitted does not contain information about medical device(s)/drug(s).

Consent for publication

All authors have consented to the submission and publication of this manuscript, and agree to the publication of the final version. The authors confirm the authenticity of the content and take responsibility for the article.

Competing interests

The authors declare no competing interests.

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References

1. Kalichman L, Cole R, Kim DH, et al. Spinal stenosis prevalence and association with symptoms: the Framingham study. Spine J. 2009;9:545–50.
2. Barz T, Melloh M, Staub LP, et al. Nerve root sedimentation sign: evaluation of a new radiological sign in lumbar spinal stenosis. Spine (Phila Pa 1976). 2010;35:892–7.
3. Ogikubo O, Forsberg L, Hansson T. The relationship between the cross-sectional area of the cauda equina and the preoperative symptoms in central lumbar spinal stenosis. Spine (Phila Pa 1976). 2007;32:1423–8. discussion 1429.
4. Schizas C, Theumann N, Burn A, et al. Qualitative grading of severity of lumbar spinal stenosis based on the morphology of the dural sac on magnetic resonance images. Spine (Phila Pa 1976). 2010;35:1919–24.
5. Barz C, Melloh M, Staub LP, Lord SJ, Merk HR, Barz T. Reversibility of nerve root sedimentation sign in lumbar spinal stenosis patients after decompression surgery. Eur Spine J. 2017;26:2573–80.
6. Leonardi MA, Zanetti M, Saupe N, Min K. Early postoperative MRI in detecting hematoma and dural compression after lumbar spinal decompression: prospective study of asymptomatic patients in comparison to patients requiring surgical revision. Eur Spine J. 2010;19:2216–22.
7. Dora C, Walchli B, Elfering A, Gal I, Weishaupt D, Boos N. The significance of spinal Canal dimensions in discriminating symptomatic from asymptomatic disc herniations. Eur Spine J. 2002;11:575–81.

8. Fairbank JC. Use and abuse of Oswestry disability index. Spine (Phila Pa 1976). 2007;32:2787–9.
9. Schonstrom N, Lindahl S, Willen J, Hansson T. Dynamic changes in the dimensions of the lumbar spinal Canal: an experimental study in vitro. J Orthop Res. 1989;7:115–21.
10. Zhang Q, Mesregah MK, Patel K, Buser Z, Wang JC. The correlation between negative nerve root sedimentation sign and gravity: A study of upright lumbar Multi-Positional magnetic resonance images. Global Spine J. 2023;13:1011–6.
11. Patel K, Son SM, Zhang Q, Wang JC, Buser Z. An investigation into the relationship between the sedimentation sign and lumbar disc herniation in upright magnetic resonance images. Global Spine J. 2024;14:2088–94.
12. Yang J, Feng Z, Chen N, et al. Gravity determines the direction of nerve roots sedimentation in the lumbar spinal Canal. BMC Musculoskelet Disord. 2021;22:154.
13. Barz T, Melloh M, Staub LP, Lord SJ, Lange J, Merk HR. Increased intraoperative epidural pressure in lumbar spinal stenosis patients with a positive nerve root sedimentation sign. Eur Spine J. 2014;23:985–90.

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