Original Article

Global Spine Journal
2021, Vol. 11(8) 1190–1196

DOI: 10.1177/2192568220941457
journals.sagepub.com/home/gsj

Analysis of Temporal Changes in Dural Sac Morphology After XLIF Indirect Decompression

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Abstract

Study Design: Retrospective study.

Objective: To investigate temporal changes in dural sac morphology after extreme lateral interbody fusion (XLIF) indirect decompression for central lumbar spinal stenosis and to study the factors influencing the changes.

Methods: The morphology of the dural sac was categorized into 4 grades (A, minor; B, moderate; C, severe; and D, extreme) by partially modifying Schizas classification (m-Schizas). The study involved 38 patients and 47 intervertebral spaces treated with indirect decompression (grade C or D). We evaluated m-Schizas before surgery, immediately after surgery, and at final follow-up. We performed a statistical analysis on the risk factors of grade C or D stenosis (poor morphological improvement) at final follow-up. The factors evaluated were preoperative dural sac cross-section area (CSA), diagnosis, cage size, location of cage insertion, locked facets, bony lateral recess stenosis, end plate injury, and changes in the posterior disc height (PDH) and disc angle (DA).

Results: On morphological evaluation, improvement to grade A or B was seen in 10 intervertebral spaces (21.2%) immediately after the surgery, and improvement was achieved in 38 intervertebral spaces (80.8%) at final follow-up. The risk factor of poor morphological improvement was found to be small preoperative dural sac CSA (odds ratio 1.32, $P < .002$).

Conclusions: After XLIF indirect decompression, the morphological improvement of the dural sac was remodeled with time and further expansion was seen in many patients. However, the study suggested that sufficient morphological improvement may not be achieved in spinal stenosis whose preoperative state is severe.

Keywords

XLIF, dural sac morphology, indirect decompression, temporal changes

Introduction

Historically, surgical treatment for lumbar spinal stenosis with neurological symptoms, such as lower extremity pain and numbness and intermittent claudication, has been basically performed with direct neural decompression from a posterior approach, and spinal fusion has been performed in combination with the decompression when concurrent intervertebral instability is present. However, in recent years, a surgical modality with a completely different concept has been reported[1-3] in which stenotic dural sac and intervertebral foramen are indirectly decompressed with extreme lateral interbody fusion (XLIF), a technique for interbody fusion through the major psoas muscle from the retroperitoneal space, reported by Ozgur et al[4] in 2006, and it is said that this surgical modality has yielded the clinical results equivalent to those of the conventional modality.[5,6] In XLIF, placement of a large cage with the length of the transverse diameter of the vertebral body into the hard cortical rim creates strong fixation power, and the intervertebral foramen and spinal canal are decompressed by ligamentotaxis resulting from restoration of the intervertebral height without direct decompression from the posterior approach.[2,3] With indirect decompression with XLIF, all the ligaments supporting the spine can be completely conserved,

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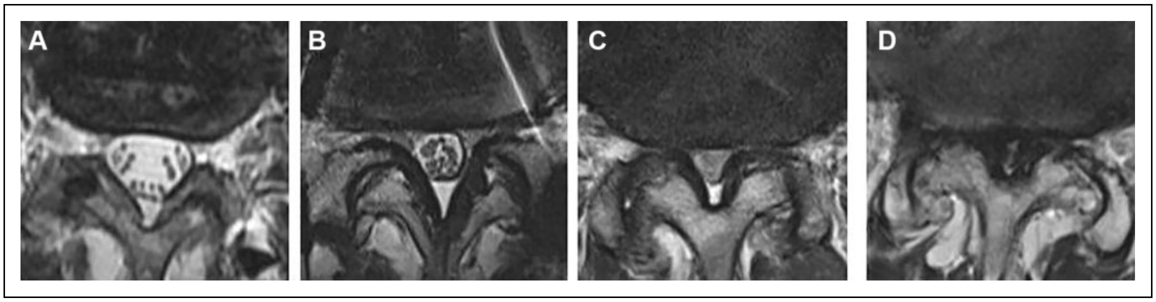

Figure 1. Modified Schizas classification (m-Schizas). (A) The cerebrospinal fluid (CSF) is clear, and rootlets are unevenly situated. (B) Each of the rootlets is distinguishable, but the entire dural sac was occupied. (C) Both the rootlets and CSF are not distinguishable. (D) The epidural fatty layer is also not distinguishable.

and direct operation to the nerve tissue and epidural venous plexus can be avoided. Thus, XLIF is said to be able to reduce the intraoperative blood loss as compared with the conventional modality,[5,7] and is expected to be used in more patients in the future. However, indications for use of XLIF indirect decompression for central stenosis have not been defined yet.

The purpose of this study was to investigate temporal changes in dural sac morphology after XLIF indirect decompression combined with percutaneous pedicle screw (PPS) fixation for central stenosis and to study the factors influencing the changes.

Materials and Methods

This study was performed after approval was obtained from the ethics committee of Chiba Central Medical Center. From April 2014 to June 2016, 81 intervertebral spaces in 61 patients were treated with XLIF indirect decompression in Chiba Central Medical Center for the purpose of neural decompression for lumber spinal stenosis with instability. Patients with decreased muscle strength with score 3 or lower on the manual muscle test (MMT) of the lower extremities, patients with concurrent protruding intervertebral disc herniation or cyst-like lesion, and patients with spinal fracture were considered ineligible for this surgical modality. For morphological classification of central stenosis, Schizas classification[8] is widely used. In this classification, the severity of stenosis is graded on a scale of 1 to 7 on the basis of the cerebrospinal fluid (CSF)/rootlet ratio on T2-weighted axial images of magnetic resonance imaging (MRI). Grade A represents "no or minor stenosis," grade B "moderate stenosis," grade C "severe stenosis," and grade D "extreme stenosis." Although grade A is further classified into 4 grades (A1 to A4), we used modified Schizas (m-Schizas) classification with no subclassification of grade A in this study (Figure 1). This study involved 50 intervertebral spaces in 40 patients that were classified as grade C or grade D on preoperative MRI, treated with indirect decompression with combination of XLIF and PPS fixation, and followed up for at least 1 year. We excluded 3 intervertebral spaces in 2 patients who underwent an additional posterior approach endoscopic laminectomy due to inadequate improvement of lower extremity pain during the clinical course (1 and 10 months after the first surgery). The patients consisted of 20 men and 18 women with a mean age of 70 years (54-82 years) and the mean observation period was 22 months (12-18 months, 10 people; 18 months to 2 years, 13 people; 2-3 years, 12 people; $\geq$3 years 3 people). Preoperatively, lumber spinal stenosis was diagnosed in 11 patients, and degenerative spondylolisthesis in 27 patients. Regarding the surgically treated levels, 5 intervertebral spaces were treated at L2/3, 16 intervertebral spaces at L3/4, and 26 intervertebral spaces at L4/5. Regarding the number of intervertebral spaces fixed, 1 intervertebral space was fixed in 29 patients, and 2 intervertebral spaces were fixed in 9 patients (Table 1).

Surgical Modality

The retroperitoneal cavity was approached through a skin incision of about 5 cm made in the area corresponding to the level to be surgically treated while the patient was in the complete right lateral decubitus position, and the greater psoas muscle was confirmed under direct vision. After the greater psoas muscle was split under nerve monitoring, the intervertebral space was fixed. As for the intervertebral cage, polyether ether ketone (PEEK) cage (CoRoent XL, NuVasive) of 18 mm width and with a lordotic angle of 10° was used. The inside of the cage was filled with autologous bone graft from the pelvis and hydroxyapatite-coated collagen sponge. Posterior fixation was performed in a single-stage approach using PPSs, and posterior decompression was not performed in any of the patients.

Table 1. Patients' Demographic Data.

Characteristic	Value
Males:females, n	20:18
Age, years, mean (Range)	70 (54-82)
Observation period, mo, mean (range)	22 (12-37)
Diagnosis, n	
Canal stenosis	11
Spondylolisthesis	27
Vertebral level	
L2-L3	5
L3-L4	16
L4-L5	26
No. of intervertebral spaces	
1	29
2	9

Table 2. Temporal Changes in Dural Sac Cross-Sectional Area (CSA).

	Before surgery	Immediately after surgery	Final follow-up	*P* Preoperative – immediate postoperative	*P* Immediate postoperative – final follow-up
Dural sac CSA (mm^2)	37 (6.3-71.8)	57.9(22.7-112.6)	91.5 (24.4-159.7)	<.001	<.001
Mean enlargement rate (%)		56.4	147.2		

Temporal Changes in Dural Sac Morphology

We measured the dural sac cross-section area (CSA) and graded the severity of stenosis by m-Schizas by using T2-weighted axial images of MRI obtained before the surgery, immediately after the surgery, and at the time of final follow-up. The severity grading was performed by 2 spinal surgeons. When the severity was graded differently between the surgeons, the grade was determined after discussion.

Study of Factors Associated With Poor Improvement of Dural Sac Morphology

The intervertebral spaces assessed as grade A or grade B on m-Schizas at the time of final follow-up were classified as good morphological improvement (group G), and those assessed as grade C or grade D were classified as poor morphological improvement (group P). We evaluated the following factors: (1) preoperative dural sac CSA; (2) diagnosis; (3) the height of the cage used; (4) the position of cage insertion (the lower level vertebral body was divided into three portions on computed tomography (CT) sagittal images, and the position of the center of the cage was classified as anterior, middle, or posterior); (5) locked facets (facets with surrounding bone formation on preoperative CT axial images[9]; (6) bony lateral recess stenosis[10]; (7) end plate injury (injury of at least 2 mm immediately after the surgery on CT sagittal images as compared with the preoperative state); and (8) changes in the posterior disc height (PDH) and disc angle (DA) (difference between the values obtained before the surgery and immediately after the surgery on CT sagittal images (Δ pre-post), and difference between the values obtained immediately after the surgery and at the time of final follow-up (Δ post-final). A statistical comparison about these factors was made between group G and group P. In addition, we performed a logistic multivariate analysis with the poor morphological improvement at the time of final follow-up (group P) as the dependent variable and significant items on the comparison between the groups as the independent variables.

Clinical Assessment

The Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ) was administered before surgery and final follow-up. It consists of 5 domains (low back pain, lumbar function, walking ability, social life function, and mental health) and 25 evaluation items. The evaluation items are assessed for each domain, the highest score being 100, and a higher score indicates a better condition.[11] The scores for each domain (postoperative score – preoperative score) were compared between group G and group P to evaluate treatment effects.

Statistical Analysis

We performed the statistical analysis by using SPSS Statistics version 23.0 (IBM Japan Ltd). We used Wilcoxon signed-rank test to change the dural sac CSA. The univariate analysis of comparison between group P and group G used the chi-square test, Fisher exact test, and Mann-Whitney *U* test. Logistic regression analysis was used to analyze a significant risk factor of poor morphological improvement of the dural sac at the time of final follow-up. *P* value of less than .05 was considered as a significant difference.

Results

Temporal Changes in Dural Sac Morphology

The dural sac CSA significantly increased with time as shown by the measurements of 37 mm^2 (6.3-71.8 mm^2) before the surgery, 57.9 mm^2 (22.7-112.6 mm^2) immediately after the surgery, and 91.5 mm^2 (24.4-159.7 mm^2) at the time of final follow-up (Table 2). On m-Schizas classification, 39 intervertebral spaces were classified as grade C and 8 intervertebral spaces were classified as grade D before the surgery. Immediately after the surgery, 3 intervertebral spaces were classified as grade A (6.3%), 7 intervertebral spaces as grade B (14.8%), 33 intervertebral spaces as grade C (70.2%), and 4 intervertebral spaces as grade D (8.5%). At the time of final follow-up, 32 intervertebral spaces were classified as grade A (68%), 6 intervertebral spaces as grade B (12.7%), 9 intervertebral spaces as grade C (19.1%), and no intervertebral space as grade D (Figure 2).

Study of Factors Associated With Poor Improvement of Dural Sac Morphology

Thirty-eight intervertebral spaces showing improvement to grade A or grade B on m-Schizas at the time of final follow-up were classified as good morphological improvement (group G), and 9 intervertebral spaces remaining grade C or grade D were classified as poor morphological improvement (group P). In the comparison between group G and group P, statistically

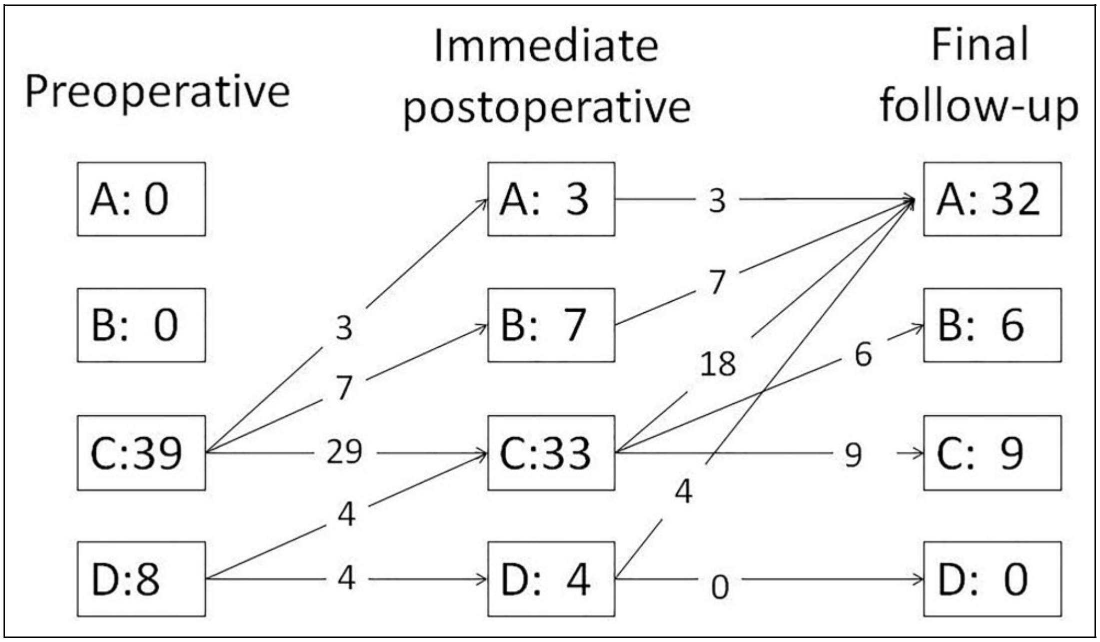

Figure 2. Temporal changes in modified Schizas classification (m-Schizas).

Table 3. Comparison Between Group G and Group P.

	Group G[a] (n = 38)	Group P[b] (n = 9)	*P*
Preoperative dural sac cross-sectional area (mm^2)	42 ± 11.3	20.1 ± 10.1	<.001
Diagnosis			
Canal stenosis	11	5	.131
Spondylolisthesis	27	4	
Cage size, mm			
8	12	1	.466
9	13	4	
10	13	4	
Position of cage insertion			
Anterior	6	4	.154
Middle	31	5	
Posterior	1	0	
Locked facet present (%)	7 (18.4)	3 (30)	.285
Bony lateral recess present (%)	6 (15.7)	5 (55.5)	.02
End plate injury present (%)	7 (18.4)	1 (11.1)	.516
Posterior disc height, mm			
Preoperative	5.5 ± 1.8	6.3 ± 2	.25
ΔPreoperative – postoperative	2.1 ± 1.1	1.9 ± 1.4	.61
ΔPostperative – final follow-up	−1.1 ± 1.7	−1.3 ± 1.1	.35
Disc angle, deg			
Preoperative	5.4 ± 3.6	6 ± 4.4	.59
ΔPreoperative – postoperative	1.7 ± 2.8	1.6 ± 4.4	.69
ΔPostoperative – final follow-up	−0.8 ± 2.2	0.7 ± 4.7	.49

[a] Group G: The intervertebral space is Grade A or Grade B on m-Schizas at the time of final follow-up.
[b] Group P: The intervertebral space is Grade C or Grade D on m-Schizas at the time of final follow-up.

significant differences were observed in the preoperative dural sac CSA (group G, 42 ± 11.3 mm^2; group P, 20.1 ± 10.1 mm^2; $P < .001$) and bony lateral recess stenosis (group G, 6 patients [15.7%]; group P, 5 patients [55.5%]; $P = .02$) (Table 3). On the basis of the results of the stepwise logistic multivariate analysis, the preoperative dural sac CSA was found to be a significant risk factor of poor morphological improvement of the dural sac at the time of final follow-up (odds ratio 1.32, $P < .002$, 95% confidence interval [CI] 1.109-1.585).

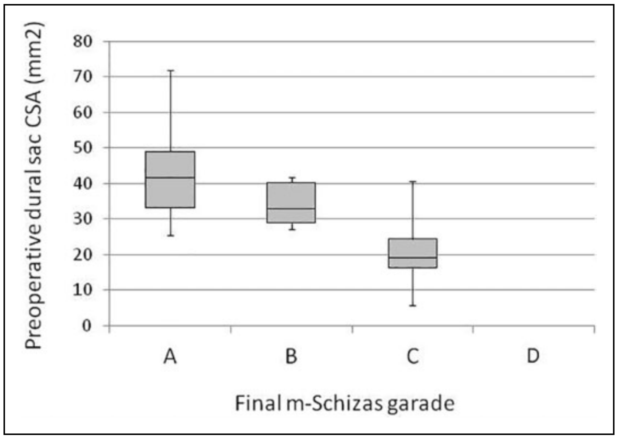

Figure 3. Relation between preoperative dural sac cross-section area (CSA) and final modified Schizas classification (m-Schizas) grade.

Relation Between the Preoperative Dural Sac CSA and the Final m-Schizas Classification

The median of the preoperative dural sac CSA of each m-Schizas grade at the time of final follow-up was 42.6 mm^2 (25-71.8 mm^2) for grade A, 34.3 mm^2 (27.1-41.7 mm^2) for grade B, and 21.1 mm^2 (6.3-30.1 mm^2) for grade C. Improvement to grade A or grade B was not seen in any intervertebral spaces with 25 mm^2 or smaller preoperative dural sac CSA (Figure 3).

Clinical Assessment

The scores for each domain of JOABPEQ showed no significant difference between group P and group G (Table 4).

Case Presentation

A 76-year-old woman presented with a chief complaint of intermittent claudication. She had a severe stenosis at L4 associated with degenerative spondylolisthesis of Meyerding grade I at the same site (Figure 4a and b). She was treated with XLIF and posterior PPS fixation for L4/5 (Figure 4c and d). On MRI, the dural sac CSA was 32.5 mm^2 and grade C on m-Schizas before the surgery (Figure 4e). The dural sac CSA increased to 85.5 mm^2 immediately after the surgery but remained grade C on m-Schizas (Figure 4f). However, 26 months after the surgery, the dural sac CSA was increased to 127.2 mm^2 and improved to grade A on m-Schizas (Figure 4g).

Table 4. The Scores for Each domain of JOABPEQ.

	Group G (n = 31)	Group P (n = 7)	*P*
Low back pain	48.8 ± 22.8	36.7 ± 21.5	.21
Lumbar function	26.7 ± 29.7	17.1 ± 26.3	.38
Walking ability	44 ± 32.8	40 ± 22.7	.59
Social life function	27 ± 20.8	31 ± 13.4	.45
Mental health	16 ± 17.5	21 ± 12	.42

Abbreviations: JOABPEQ, Japanese Orthopaedic Association Back Pain Evaluation Questionnaire.

Discussion

It has been reported that the increase in the vertebral height by XLIF also enlarges the intervertebral foramen,[12] and intervertebral foraminal damage is said to be the most reasonable indication for indirect decompression.[13] On the other hand, it is difficult to predict how effective indirect decompression can be with the ligamentotaxis effects associated with increased vertebral height for treating central stenosis caused by ligamentum flavum hypertrophy, facet joint deformity, intervertebral disc bulging, etc.

In the report by Oliveira et al,[2] the spinal canal enlargement rate with stand-alone XLIF was slightly low because of postoperative cage subsidence and loss of correction as shown by the preoperative measurement of 147.4 mm^2 and the postoperative measurement of 159.8 mm^2 (enlargement rate 8.4%). On the other hand, for XLIF performed in combination with posterior fixation, high enlargement rates have been reported by Park et al[3] and Elowitz et al.[1] In the report by Park et al,[3] the preoperative measurements were 91.4 ± 39.7 mm^2 and the postoperative measurements were 116.5 ± 45.2 mm^2 (enlargement rate 36.5%). In the report by Elowitz et al,[1] the preoperative measurements were 107.9 ± 72.4 mm^2 and the postoperative measurements were 190.9 ± 67.2 mm^2 (enlargement rate 143%). In our study involving patients with central stenosis with mean preoperative dural sac CSA of 36.6 mm^2, significant enlargement of spinal canal was achieved immediately after the surgery as shown by the mean enlargement rate of 51.6%. Also, thereafter, enlargement with the mean rate of 146.6% was achieved with spinal canal remodeling with time.

In many reports on changes of the dural sac after indirect decompression, the dural sac CSA on MR images is evaluated. However, it has been pointed out that the dural sac CSA is weakly correlated with clinical symptoms.[8,14] Schizas et al[8] is the first to report the morphological classification by MRI, which is correlated with clinical symptoms in order to address this problem. To date, there have been no reports examining changes in the dural tube using the Schizas classification after indirect decompression. According to our results, morphological improvement following indirect decompression (grade A or grade B on m-Schizas) was poor at 20% immediately after the surgery, however, high improvement at 76% was obtained 1 year or more after the surgery.

In this study, most cases show improvement in clinical symptoms in the short term. However, there was no significant difference between postoperative dural sac morphology and postoperative clinical outcome. Why did the clinical symptoms improve even if the dural sac morphology did not improve? It is considered that the postoperative enlargement of daral sac CSA occurred slightly and that stability was obtained by posterior fixation. In cases where postoperative improvement of Dural sac morphology was not obtained, long-term observation of clinical symptoms is required.

There have been some reports on study of factors influencing the outcome of indirect decompression. In the report by Oliveria et al,[2] indirect decompression is relatively

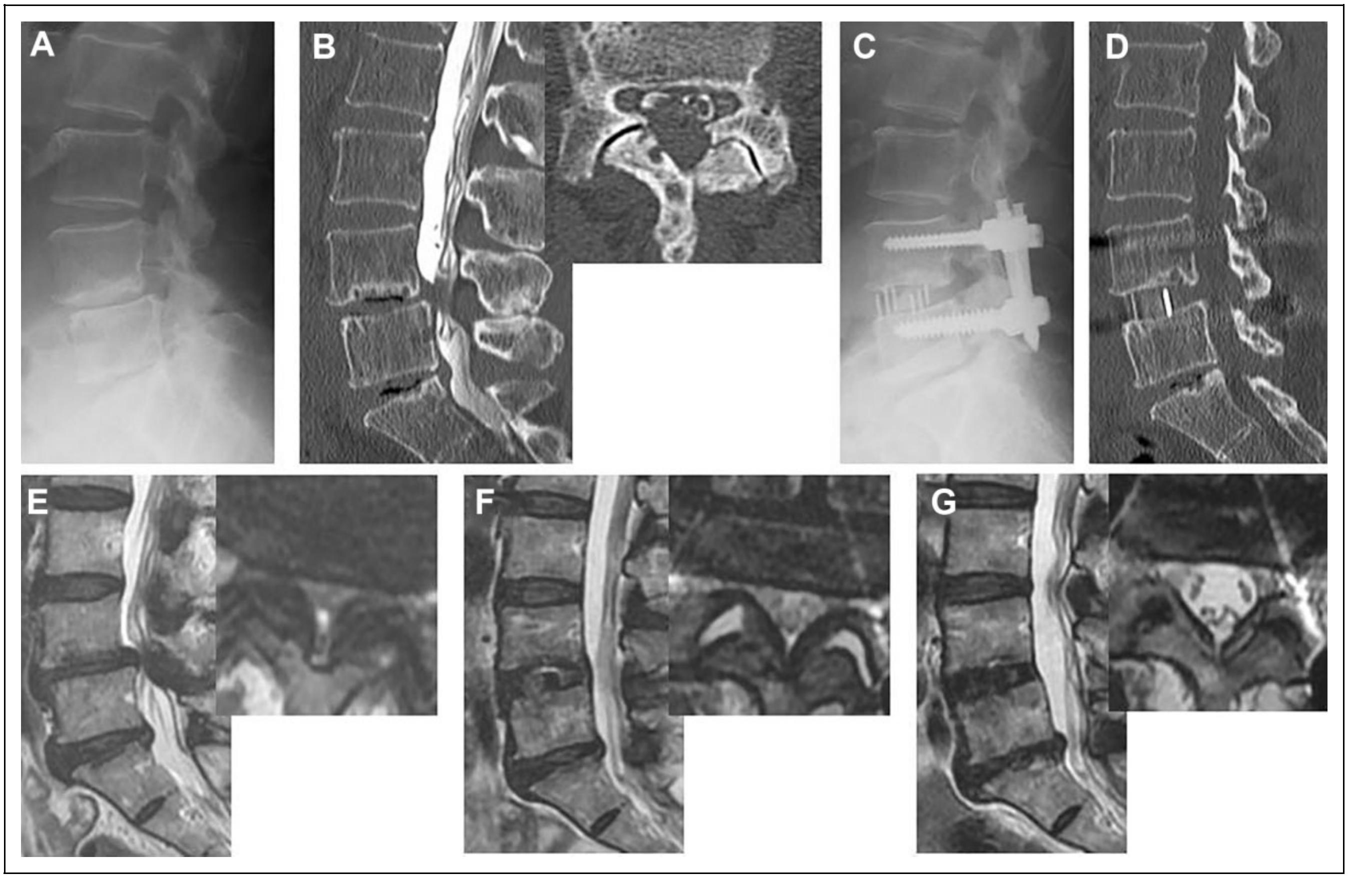

Figure 4. Case presentation. (a) Preoperative lateral X-ray: grade I degenerative spondylolisthesis of L4. (b) Preoperative computed tomography (CT) myelography: central stenosis at L4/5. (c) Postoperative lateral X-ray. (d) Postoperative lateral CT: cage insertion at the middle position. (e) Preoperative magnetic resonance imaging (MRI): dural sac cross-sectional area (CSA) 32.5 mm^2, grade C. (f) Immediate postoperative MRI: dural sac CSA 85.5 mm^2, Grade C. (g) 26-month postoperative MRI: dural sac CSA 127.2 mm^2, grade A.

contraindicated for severe central spinal stenosis and not indicated for locked facet or congenital stenosis. On the other hand, in the report by Navarro-Ramirez et al,[9] locked facet is not excluded in the indications. Park et al[3] reports that the position of cage insertion does not influence the indirect decompression. Wang et al[10] regards preoperative presence of bony lateral recess stenosis as a risk factor of poor ODI improvement following indirect decompression. As shown by the above, no factor in worsening the outcome of indirect compression has been established until now. In the result of our study, the preoperative dural sac CSA was the risk factor of poor outcome. Furthermore, improvement was poor in all patients with the preoperative dural sac CSA of 25 mm^2 or less.

However, there are some limitations in this study. This study employed a retrospective and noncontrolled design. Patients were underrepresented, and the observation period was short. Thus, additional studies are warranted.

Conclusion

Although morphological improvement of spinal stenosis on MRI is relatively slight immediately after the surgery, it was found that the spinal canal is remodeled with time and further improvement is seen in many cases. However, a possibility was suggested that morphologically sufficient improvement may not been achieved in patients with spinal stenosis that is preoperatively severe.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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