

Preoperative Risk Factors for Adjacent Segment Degeneration after Two-Level Floating Posterior Fusion at L3-L5

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Abstract:

Introduction: The aims of this study were to investigate how adjacent segment degeneration (ASD) occurs at the proximal and distal segments after L3-L5 fusion surgery, namely, floating fusion, and to identify the risk factors for ASD in patients who undergo this surgery.

Methods: Fifty patients who underwent floating fusion surgery at vertebrae L3-L5 and developed ASD were enrolled. The following parameters were evaluated: body mass index (BMI), diabetes status, dialysis status, lumbar lordosis, segmental lordosis between the L2 upper endplate and the L3 lower endplate, disc height, Cobb's angle, apical vertebral rotation using the Nash and Moe classification method, preoperative disc degeneration, surgical procedures, and the upper instrumented vertebra (UIV) tilt angle. The UIV tilt angle was defined as positive when the anterior side was directed caudally.

Results: Twenty-two (44%) of the 50 patients showed cephalad radiographic ASD (RASD) and 5 patients (10%) showed caudad RASD. Clinically symptomatic ASD was found at L2-L3 in 4 patients (8%) and at L5-S1 in 2 patients (4%). All the patients with clinically symptomatic cephalad ASD underwent revision procedures for radiculopathy or claudication because of degenerative pathology at L3-L4. Multivariate regression analysis showed a significant association of the absolute value of UIV tilt angle (mean IUIV tilt) with cephalad RASD (odds ratio 1.09, $p = 0.038$). Receiver-operating characteristic curve analysis showed a significant association of IUIV tilt $>10.3^\circ$ with RASD (sensitivity 67.9%, specificity 77.3%, area under the curve [AUC] 0.675).

Conclusions: RASD was more likely to occur at the adjacent segment on the cephalad side than at the adjacent segment on the caudad side after two-segment floating fusion of L3-L5. A preoperative UIV tilt angle $>10^\circ$ or UIV tilt $<-10^\circ$ was a risk factor for RASD.

Keywords:

Radiographic adjacent segment degeneration, risk factor, floating fusion, L3-L5

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Introduction

Lumbar fusion has become the preferred surgical treatment for many degenerative spinal diseases¹⁻⁴. However, with the increasing number of patients undergoing instrumented lumbar fusion, complications of fusion surgery, such as infection, implant failure, pseudoarthrosis, and adjacent segment degeneration (ASD) are becoming more common⁵⁻¹⁰. ASD occurs when pathology develops at the mobile segment adjacent to a lumbar or lumbosacral spinal fusion and has an adverse impact on postoperative performance status, sometimes leading to further surgery¹¹.

A variety of risk factors for ASD after lumbar spine fu-

sion surgery have been reported, including the length of the fusion, sagittal malalignment, age and sex, preoperative ASD, laminar inclination, facet tropism, and excessive disc distraction^{6,12-19}. It is known that the greater the number of fused segments the greater the risk of ASD. It has been reported that the longer lever arm produced with fusion of multiple segments puts greater stress on the remaining free segments^{6,8,20-25}. However, there is limited information on the incidence of ASD after floating fusion of two lumbar segments, particularly at L3-L5 without fusion to the sacrum.

The aims of this study were to investigate how ASD occurs at the proximal and distal segments after L3-L5 fusion surgery and to identify the risk factors for ASD in patients

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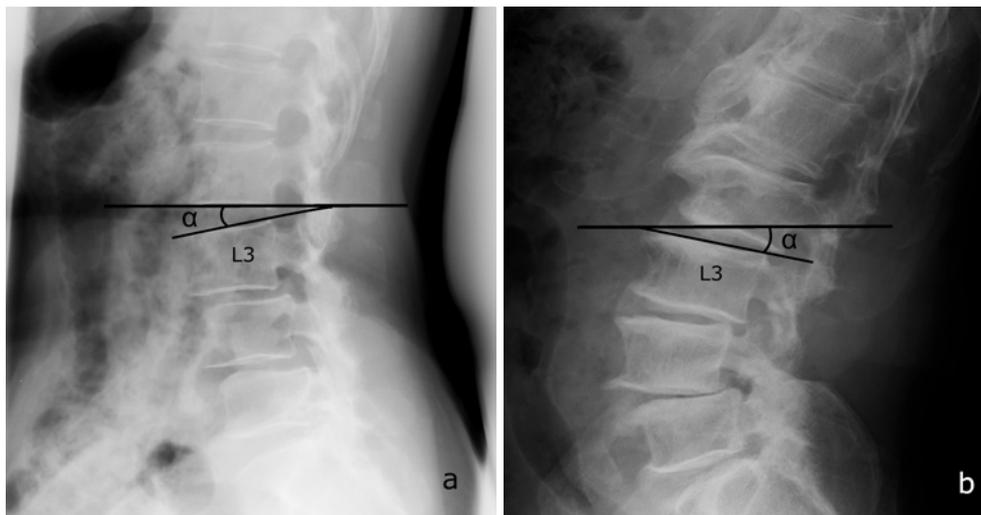


Figure 1. Radiograph showing measurement of the upper instrumented vertebra (UIV) tilt. (a) UIV tilt was defined as the angle formed by a horizontal line and an upper endplate line. The angle was defined as positive when the anterior side was directed caudally. (b) The angle was defined as negative when the posterior side was directed caudally.

who undergo this procedure.

Materials and Methods

Data were obtained for 51 patients who underwent floating fusion surgery for degenerative lumbar disease at L3-L5 in our institution between July 2010 and April 2017. One patient was lost to follow-up, leaving data on 50 patients for analysis. Mean follow-up duration was 44 (range, 12-94) months. Mean age at the time of surgery was 71 (range, 43-90) years. Surgical procedures performed were lumbar interbody fusion (IBF) and/or posterolateral fusion (PLF) of the transverse processes and lateral pars. Decompression was performed at L3-L4 and L4-L5 in all patients. IBF and PLF were performed using pedicle screws. Cages were filled with autologous local bone, iliac autograft, or artificial bone (Re-Fit; Hoya Technosurgical Corp., Tokyo, Japan) for IBF. Autologous local or iliac bone was transplanted for PLF. A soft lumbosacral corset was worn for at least 3 months postoperatively in all cases.

Data were collected for preoperative body mass index (BMI), diabetes status, and dialysis status. Using the Nash & Moe classification, we also measured lumbar lordosis from the lower endplate of T12 to the upper endplate of S1, segmental lordosis from the upper endplate of L2 to the lower endplate of L3, the disc height at L2-L3, the Cobb angle from the upper endplate of L2 to the upper endplate of L3, the upper instrumented vertebra (UIV) tilt angle (i.e., tilt at L3; Fig. 1), and apical vertebral rotation on preoperative lateral standing radiographs²⁶⁾. UIV tilt was defined as the angle between a line drawn parallel to the upper endplate of the UIV and a horizontal line, which was defined as positive when the anterior side was orientated caudally. Facet tropism¹⁷⁾ at L2-L3 was assessed on preoperative computed tomography images. The severity of disc degeneration

at the L2-L3 segment was assessed using the Pfirrmann classification on preoperative magnetic resonance images (MRI)²⁷⁾.

Based on a previous report²⁸⁾, radiographic ASD (RASD) at the L2-L3 and L5-S1 segments was defined as follows: radiographic degenerative change at the adjacent segments was considered present when anterior or posterior spondylolisthesis of >3 mm was found at the closest upper and lower segments; when the height of the intervertebral disc decreased by more than 3 mm; or when segmental motion instability of more than 5° was observed on sagittal radiographs obtained in flexion and extension at the last follow-up. Clinically symptomatic ASD (CASD) was defined as a need for revision surgery due to clinical findings compatible with adjacent segment pathology.

Statistical analysis was performed to identify correlates of a cephalad segment of RASD. Non-normally distributed variables were compared using the Mann-Whitney *U*-test and binary outcomes were compared using the Pearson's chi-square test. Variables with a *p*-value of <0.02 in univariate analysis were included in a logistic regression model. A *p*-value <0.05 was considered statistically significant. Statistical analysis was performed using EZR software version 1.33²⁹⁾.

Results

Twenty-two (44%) of the 50 patients had cephalad RASD and five had caudad RASD (Table 1). Four of the 22 patients with cephalad RASD also had caudad RASD. Only 1 patient had caudad ASD alone. Sixteen (72.7%) of the 22 patients with cephalad RASD had a decrease in disc height. Anterior or posterior spondylolisthesis occurred in only the patients with caudad RASD. Anterior slip was seen in patients with spondylolisthesis and a positive preoperative UIV

tilt angle (Fig. 2), and posterior slip was observed in patients with a negative preoperative UIV tilt angle (Fig. 3). Four (8%) of the 50 patients had CASD at L2-L3 and 2 patients (4%) had CASD at L5-S1. All the patients with cephalad CASD had undergone a second surgical procedure for radiculopathy or claudication as a result of degenerative pathology at L2-L3. The average duration until the second surgery was 55.8 (range, 25-91) months. The 50 patients were then grouped according to whether or not they had cephalad ASD (Table 2). There was no significant between-group difference in age, BMI, sex, diabetes status, dialysis status, segmental or lumbar lordosis, facet tropism, preoperative disc height, Cobb angle, Nash and Moe grade, Pfirrmann grade, or fusion method used. The only significant difference was in the mean absolute UIV tilt angle ($p < 0.05$). On multivariate regression analysis, there was a significant association between the absolute UIV tilt value and occurrence

of cephalad RASD (odds ratio 1.09, $p = 0.038$; Table 3). Receiver-operating characteristic curve analysis demonstrated a significant association between an absolute tilt angle $>10.3^\circ$ at L3 and the likelihood of RASD (sensitivity 67.9%, specificity 77.3%, area under the curve [AUC] 0.675). When an absolute tilt angle $>10^\circ$ was used as the cutoff, the odds ratio was 5.16 and the 95% CI was 1.37-21.64 ($p = 0.012$; Table 4).

Discussion

ASD is defined as any abnormal state that develops in a mobile segment adjacent to a spinal fusion, such as disc degeneration, listhesis, instability, hypertrophic facet joint arthritis, herniated nucleus pulposus, or stenosis⁶. ASD is generally caused by a combination of changes in the biomechanics at the adjacent segments as a result of spinal fusion and age-related degenerative changes. Ekman et al. in their study demonstrated that spinal fusion accelerates the normal degenerative changes occurring at the adjacent level¹². Furthermore, the incidence rates of RASD and CASD after lumbar fusion surgery involving more than one segment have been reported to range from 5.2% to 100%⁶ and from 1% to 36.1%, respectively^{6,14,30}. In a study that included 1,250 patients, Ghasemi et al. reported that the incidence of CASD was 1.04% in the 5 years after surgery and that increased BMI, preoperative ASD, and a disc bulge on MRI were risk factors for development of CASD¹⁴. Meanwhile, Ghiselli et al. in their study reported that the incidence of CASD requiring additional surgery in 215 patients was

Table 1. Incidence and Characteristics of Cephalad and Caudad Radiographic Adjacent Segment Degeneration.

Radiographic ASD	Cephalad	Caudad
n	22	5
Decrease of disc height >3 mm	16	4
Anterior or posterior spondylolisthesis >3 mm	5	0
Segmental motion instability $>5^\circ$	1	1
Reoperation of adjacent segment	4	2

Duplications of cephalad and caudad ASD are present. ASD, adjacent segment degeneration

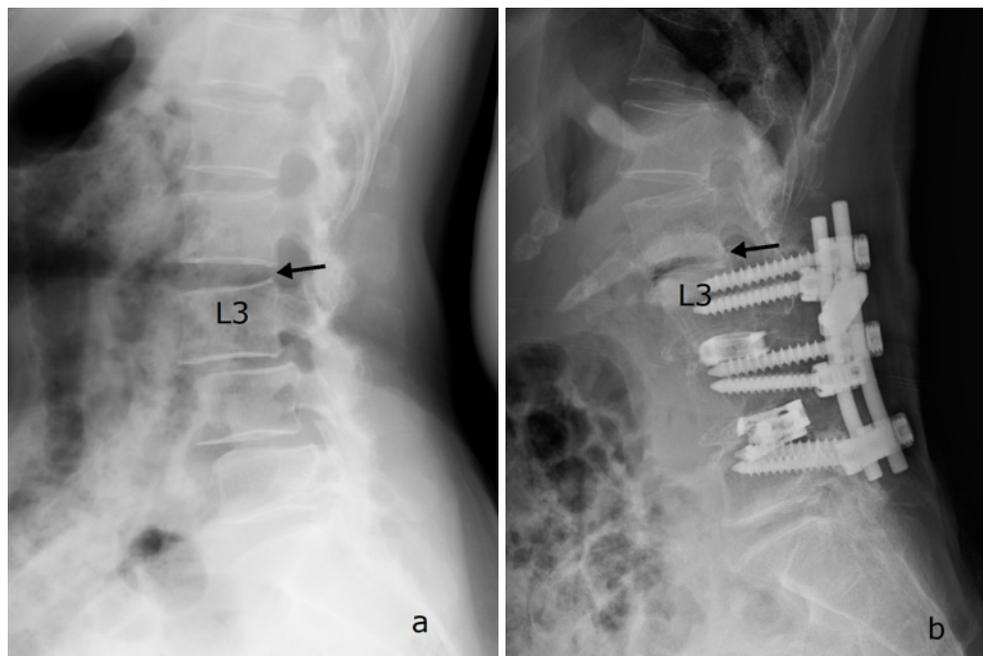


Figure 2. An example of radiographic adjacent segment degeneration at L2-L3 in a patient who underwent posterior interbody fusion for degenerative spondylolisthesis at L3-L5. (a) Preoperative lateral view showing degenerative spondylolisthesis at L3-L4 and L4-L5. (b) Postoperative view of 3 years after surgery showing new degenerative spondylolisthesis at L2-L3 and disc space narrowing.

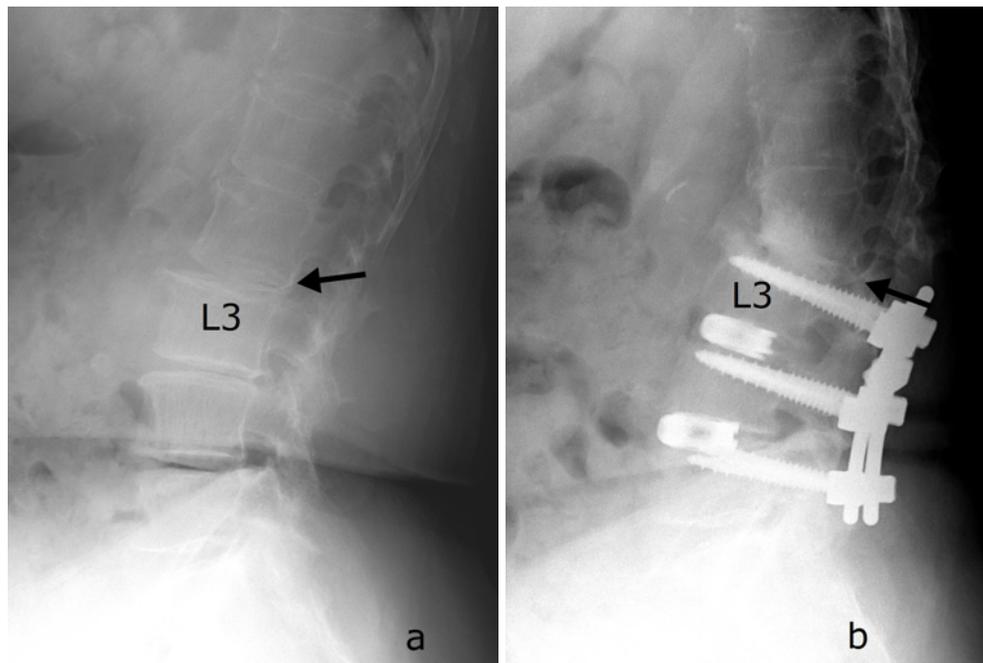


Figure 3. An example of radiographic adjacent segment degeneration at L2-L3 in a patient who underwent posterior interbody fusion for degenerative spondylosis at L3-L5. (a) Preoperative lateral view showing degenerative spondylosis at L3-L4 and L4-L5. (b) Postoperative view of 3 years after surgery showing new posterior degenerative spondylolisthesis at L2-L3 and disappearance of the disc space.

16.5% at 5 years and 36.1% at 10 years³⁰). Moreover, Sakura et al. in their study reported an incidence of CASD of 10% in 92 patients who underwent one-segment fusion in the 2 years after surgery and an incidence of CASD of 20% in 20 patients who underwent two-segment fusion³¹). Other studies have also found a correlation between the number of segments fused and the risk of ASD^{11,32,33}). Our finding of the incidence rates of 44% and 8% for RASD and CASD, respectively, in 50 patients who underwent two-segment fusion surgery is consistent with the previous reports.

Weinhoffer et al. performed a cadaveric study in which they found that the intradiscal pressure at the L3-L4 segment in an L4-S1 fusion model was greater than that at the L4-L5 segment in an L5-S1 fusion model³⁴). Their report suggested that multiple intervertebral fusion has a greater effect than single fusion on the adjacent segments. In a finite element analysis of the floating fusion model at the L4-L5 segment, it was shown that the suprajacent disc was subjected to more stress than the infrajacent disc³⁵). Disch et al. in their study reported that risk of ASD was significantly higher in patients who underwent floating fusion at L4-L5 than it was in those who underwent L5-S1 fusion (46% vs. 20%)³⁶). In our study, RASD was also more likely to occur after multiple-segment fusion at the adjacent segment on the cephalad side than at the adjacent segment on the caudad side. Therefore, in view of all the evidence to date, we speculate that floating fusion of multiple spinal segments is one of the risk factors for cephalad ASD.

Various risk factors for ASD after one-segment fusion

have been reported, including age and sex, preoperative adjacent disc degeneration, sagittal malalignment, number of segments fused, laminar inclination, facet tropism, and excessive distraction of the disc space^{6,12-19}). However, in the present study, there was no significant association of age, sex, or preoperative disc degeneration with RASD, and the only risk factor was a preoperative absolute value of UIV tilt $>10^\circ$ (i.e., preoperative UIV tilt $>10^\circ$ or UIV tilt $<-10^\circ$). A possible explanation for this finding is that there is an increase in the moment force of body weight applied to the cephalad disc at the inclination of the fusion end, so RASD is likely to occur.

Compared with lumbar fusion, surgical procedures that preserve motion are less likely to require reoperation for CASD or RASD³⁷). Our finding of a significant association between cephalad RASD and cephalad CASD suggests that the risk of cephalad RASD could be decreased by fusing as few segments as possible in patients with a preoperative UIV tilt angle $>10^\circ$ or UIV tilt $<-10^\circ$. Patients in whom this is not possible should be followed up very carefully after surgery.

This study has some limitations. One limitation is that we could not evaluate the sagittal alignment of the entire spine. It is known that development of postoperative spinopelvic balance is associated with a good clinical outcome in adult patients with spinal deformity^{38,39}). In contrast, spinopelvic imbalance has been reported to be associated with ASD and an unsatisfactory clinical outcome, even in short fusion cases that were not performed to correct spinal align-

Table 2. Comparison of Potential Risk Factors in Patients with and without Cephalad Radiographic Adjacent Segment Degeneration.

	With RASD (cephalad)	Without RASD (cephalad)	p-value
Mean age (years)	70.96±6.85	70.96±10.87	0.868
Body mass index	21.4±9.31	20.17±9.03	0.470
Sex (n)			0.804
Male	7	8	
Female	15	20	
Diabetes mellitus (n)			0.631
Yes	6	6	
No	16	22	
Hemodialysis (n)			0.371
Yes	0	1	
No	16	26	
Mean SL (°)	6.19±6.49	5.72±7.13	0.718
Mean SL (°)	6.97±5.6	7.68±4.86	0.358
Mean LL (°)	26.11±14.83	29.26±13.38	0.379
Mean LL (°)	26.41±14.27	29.26±13.38	0.379
Mean UIV tilt (°)	4.59±13.81	1.24±11.17	0.257
Mean UIV tilt (°)	12.35±7.3	8.74±6.88	0.028*
Mean facet tropism (°)	6.37±4.21	5.54±3.89	0.395
Mean disc height (mm)	6.51±1.79	6.59±2.42	0.440
Mean segmental cobb angle (°)	3.93±2.78	2.87±3.49	0.167
Nash and Moe grade (n)			0.324
0	5	7	
I	7	14	
II	9	5	
III	1	2	
IV	0	0	
Pfirrmann grade (n)			0.548
I	2	0	
II	0	2	
III	3	7	
IV	12	11	
V	5	6	
Fusion method (n)			0.413
PLF alone	9	7	
IBF alone	11	16	
PLF+IBF	2	5	
CASD (n)			0.032
Yes	4	0	
No	18	28	

CASD, clinically symptomatic adjacent segment degeneration; RASD, radiographic adjacent segment degeneration; SL, segmental lordosis; |SL|, absolute value of SL; LL, lumbar lordosis; |LL|, absolute value of LL; PLF, posterior lumbar fusion; IBF, lumbar interbody fusion; * $p < 0.05$ UIV tilt, upper instrumented vertebra tilt; |UIV tilt|, absolute value of UIV

Table 3. Multiple Logistic Regression Analysis of Risk Factors for a Poor Postoperative Outcome.

Variable	OR	p-value	95% CI
UIV tilt	1.09	0.038*	1.000-1.190
Segmental Cobb angle	1.10	0.340	0.906-1.340

CI, confidence interval; OR, odds ratio; |UIV|, absolute value of upper instrumented vertebra tilt. * $p < 0.05$

ment^{40,41}). In a study by Matsuoka et al. that included 70 patients who underwent single-level L4-L5 fusion, preoperative small sagittal vertebral axis and thoracic kyphosis with small pelvic incidence were identified as risk factors for RASD⁴²). Therefore, further studies are needed to determine the relationship between multilevel floating fusion and sagittal alignment of the spine. However, the UIV tilt angle is a predictor of RASD that can be measured easily on an X-ray image of the lumbar spine in the standing or sitting position. A second limitation is that the number of patients with

Table 4. Relationship between Radiographic Adjacent Segment Degeneration and Absolute Instrumented Vertebra Tilt Angle.

	RASD (cephalad)		
	Yes	No	p-value
UIV tilt >10°	Yes	17	0.00954*
	No	5	

RASD, radiographic adjacent segment degeneration; UIV tilt, absolute value of upper instrumented vertebra tilt. * $p < 0.05$

CASD was small, so it was not possible to examine all potential risk factors involved. A third limitation is that a minimal five-year follow-up should be needed for analysis of the incidence of ASD after spinal fusion surgery. Further investigations in larger numbers of patients with follow-up for over the 5 years used in this study are necessary to identify the risk factors for ASD in patients who undergo floating fusion procedures.

Conclusion

In this study, RASD was more likely to occur at the adjacent segment on the cephalad side than at the adjacent on the caudal side after two-segment floating fusion at L3-L5. A preoperative UIV tilt angle $>10^\circ$ or UIV tilt $< -10^\circ$ was identified as a risk factor for RASD.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Experimental design: SU, HT; data collection: SU, TY, HI, MY, SK, and AO; data analysis and interpretation: SU, HT; and manuscript preparation: SU, HT. All authors have read and approved the final version of the manuscript.

Informed Consent: Informed consent was obtained from all patients whose data were used in this study.

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