

Symptomatic Adjacent Segment Pathology after Posterior Lumbar Interbody Fusion for Adult Low-Grade Isthmic Spondylolisthesis

Hironobu Sakaura¹ Tomoya Yamashita¹ Toshitada Miwa¹ Kenji Ohzono¹ Tetsuo Ohwada¹

¹Department of Orthopaedic Surgery, Kansai Rosai Hospital, Hyogo, Japan

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Address for correspondence Hironobu Sakaura, MD, PhD, Department of Orthopaedic Surgery, Kansai Rosai Hospital, 3-1-69 Inabaso, Amagasaki, Hyogo, 660-8511, Japan (e-mail: sakaura04061023@yahoo.co.jp).

Abstract

The incidence of symptomatic adjacent segment pathology (ASP) after fusion surgery for adult low-grade isthmic spondylolisthesis (IS) has been reported to be relatively low compared with other lumbar disease entities. However, there has been no study of symptomatic ASP incidence using posterior lumbar interbody fusion (PLIF) with pedicle screw instrumentation. We investigated the incidence of symptomatic ASP after PLIF with pedicle screw instrumentation for adult low-grade IS and identified significant risk factors for symptomatic ASP. We retrospectively studied records of 40 consecutive patients who underwent PLIF with pedicle screw instrumentation at the Department of Orthopaedic Surgery, Kansai Rosai Hospital, Amagasaki, Japan. The patients were followed for ≥ 4 years. Patients' medical records were retrospectively examined for evidence of symptomatic ASP. Age at time of surgery, sex, fusion level, whole lumbar lordosis, segmental lordosis, preexisting laminar inclination angle, and facet tropism at the cranial fusion segment were analyzed to identify risk factors for symptomatic ASP. Four patients (ASP group) developed symptomatic ASP at the cranial segment adjacent to the fusion. There were no significant differences in age, sex, fusion level, lumbar lordosis, segmental lordosis, or facet tropism at the cranial segment adjacent to the fusion between the ASP and the non-ASP groups. In contrast, laminar inclination angle at the cranial vertebra adjacent to the fusion was significantly higher in the ASP group than in the non-ASP group. Four patients (10%) developed symptomatic ASP after PLIF with transpedicular fixation for adult low-grade IS. Preexisting laminar horizontalization at the cranial vertebra adjacent to the fusion was a significant risk factor for symptomatic ASP.

Keywords

- ▶ isthmic spondylolisthesis
- ▶ posterior lumbar interbody fusion
- ▶ adjacent segment pathology
- ▶ laminar horizontalization

Symptomatic adjacent segment pathology (ASP) has been considered as a problematic potential long-term complication of lumbar or lumbosacral fusion. Many studies have reported a wide range of symptomatic ASP occurrence and various potential risk factors associated with ASP. However, almost all of these studies had significant limitations in terms of differing etiologies and fusion procedures, as well as numbers of fused segments.¹ There have been only a few

studies concerning the incidence of and risk factors for symptomatic ASP after lumbar arthrodesis including patients with the same diagnosis (L4 degenerative spondylolisthesis), the same numbers of fused segments (single segment fusion) and the same fusion technique (posterior lumbar interbody fusion [PLIF]).^{2,3} In contrast, the incidence of symptomatic ASP may vary according to disease entity and fusion method. In fact, some surgeons have reported that the incidence of

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symptomatic ASP after lumbar or lumbosacral fusion for adult low-grade isthmic spondylolisthesis (IS) ranged from 0 to 2.2%, which was relatively lower than that seen with other lumbar disease entities.⁴⁻⁸ However, there has been no report including PLIF with pedicle screw instrumentation in the English literature. Only one study including the same fusion technique (360-degree fusion) investigated exclusively radiologic ASP.⁹ Thus, the purposes of the present study were to investigate the incidence of symptomatic ASP after single-level PLIF with transpedicular fixation in a homogenous patient population with adult low-grade IS and to clarify risk factors associated with symptomatic ASP.

Materials and Methods

Patients

Forty consecutive patients with adult Meyerding grade I or II IS underwent single-level PLIF between February 2004 and September 2008. All patients were considered for surgery because of a poor response to conservative treatment such as medication and/or epidural block. All 40 patients were enrolled in the study and were followed for ≥ 4 years following surgery. There were 26 men and 14 women, and the mean age of the patients at the time of surgery was 58.6 years (range, 23 to 79 years). Fusion areas were from L5 to S1 in 27 patients, L4 to L5 in 9 patients, L3 to L4 in 1 patient, L5 to L6 in 1 patient, L4 to S1 in 1 patient, and L6 to S1 in 1 patient. The mean duration of follow-up was 66.8 months (range, 48 to 97 months). The hospital institutional review board approved the protocol, and full informed consent was obtained from all participants.

Surgical Procedure

Through the midline approach, our PLIF procedure was performed using interbody cages (DePuy Spine, Inc., Raynham, Massachusetts, United States) filled with a local bone graft from the lamina and spinous process and posterior instrumentation with pedicle screws. After intervertebral disc material and cartilaginous end plates were removed, two cages were inserted into the intervertebral space, and local bone blocks were inserted lateral to the cages (**Fig. 1**).

Clinical and Radiologic Evaluations

Medical records were examined by a single observer (H.S.) who was not involved in patient care. Clinical results were assessed using the Japanese Orthopaedic Association (JOA) scoring system for assessment of the results of treatment for low-back pain.¹⁰ In brief, the JOA score consists of subjective symptom ratings for (low-back pain, 3 points; leg pain, 3 points; and gait, 3 points), clinical signs (straight-leg-raising test, 2 points; sensory disturbance, 2 points; and motor disturbance, 2 points), restriction of activities of daily living (14 points), and urinary bladder function (minus 6 points). Thus, a total JOA score is 29 points in normal populations. Patients' medical records were retrospectively examined for evidence of symptomatic ASP. Newly developed or aggravated neurologic symptoms due to ASP were defined as symptomatic ASP.



Fig. 1 Radiographs of the lumbar spine after our posterior lumbar interbody fusion (PLIF). Our PLIF procedure was performed using the interbody fusion cages and posterior instrumentation with pedicle screws.

Radiographs of the lumbar spine were taken before surgery and at regular intervals thereafter. Lumbar lordosis was measured as the angle between the inferior end plate of T12 and the superior end plate of S1 preoperatively and just after the primary surgery with lateral radiographs of the lumbar spine in the neutral position. The lordosis of fused levels was also measured as the angle between the superior end plate of the cranial vertebra of the fusion area and the inferior end plate of the caudal vertebra of the fusion area. We measured the laminar inclination angle at the cranial vertebra adjacent to the fusion using multiplanar reconstruction computed tomography (CT) of the lumbar spine taken before the primary surgery. The laminar inclination angle was defined as the angle formed by a line connecting the base of superior articular process with the base of inferior articular process and a line connecting the midpoints of the anterior and posterior vertebral cortices on a sagittal reconstruction image of CT (**Fig. 2**).¹¹ Facet tropism measurement was taken from an axial reconstruction image of CT that was coplanar with the intervertebral disc and transected the facet joints. A line

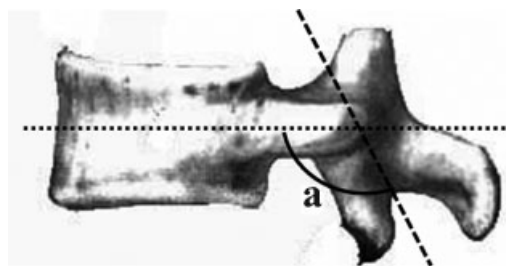


Fig. 2 The laminar inclination angle (a) was measured as the angle formed by a line connecting the base of superior articular process with the base of inferior articular process and a line connecting the midpoints of the anterior and posterior vertebral cortices.

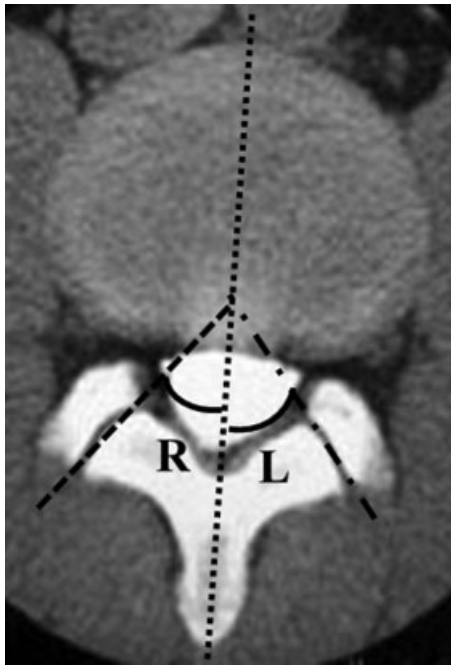


Fig. 3 The facet angle between the facet line and the midsagittal line was measured on each side of the spine (right [R] and left [L]) and facet tropism was calculated as the difference between R and L facet angles ($|R - L|$).

was drawn between the two margins of each of the superior articular facets. The midsagittal line was defined as a line passing through the center of the intervertebral disc and the center of the base of the spinous process. The facet angle between the facet line and the midsagittal line was measured on each side of the spine, and facet tropism was calculated as the difference between right and left facet angles (►Fig. 3).¹²

Fusion status was assessed at the final follow-up. A solid fusion was defined as the condition in which osseous continuity between the vertebra and the grafted bone both on anteroposterior and lateral radiographs was achieved, with neither loosening of the pedicle screws nor motion at the fused segments on flexion and extension lateral radiographs.

Statistical Analysis

Fisher exact probability test, unpaired *t* test, and Mann-Whitney *U* test were used for statistical analysis with JMP 5.0.1 software (SAS Institute, Cary, North Carolina, United States), as appropriate. Values of $p < 0.05$ were considered significant.

Results

Clinical Results

In 36 patients without symptomatic ASP (non-ASP group), the mean JOA score improved significantly from 16.0 ± 3.7 points before surgery to 23.6 ± 3.7 points at the latest follow-up, yielding a mean recovery rate of 59.6%. On the other hand, 4 patients (10%, ASP group) showed initial improvement of symptoms after the primary surgery, but they developed neurologic deterioration due to ASP. In the ASP group, the

mean JOA score improved significantly from 13.3 ± 6.8 points before surgery to 23.5 ± 3.7 points at the maximal recovery (a mean recovery rate, 68.7%) and then decreased to 14.5 ± 3.9 points just before the additional surgery (a mean recovery rate, -13.4%) (►Table 1).

At the latest follow-up, solid fusion at the primary operated segment was confirmed in all 40 patients.

Symptomatic Adjacent Segment Pathology

All 4 patients in the ASP group developed symptomatic ASP at the cranial segment adjacent to the fusion. Etiologies were degenerative spondylolisthesis in 2 patients, disc herniation in 1 patient, and spinal canal stenosis in 1 patient (►Table 1). Additional surgery was indicated because of failure to respond to conservative treatment such as medication and/or epidural block. As a result, all 4 patients underwent additional surgery for symptomatic ASP. The mean period between the primary surgery and the additional surgery was 38 months (range, 24 to 66 months; ►Table 1). Surgical procedures at the additional surgery were PLIF in 3 patients and decompressive laminotomy in 1 (►Table 1). After the additional surgery, all 4 patients displayed improvement of symptoms.

Risk Factor for Symptomatic Adjacent Segment Pathology

There were no statistically significant differences in sex, age at surgery, preoperative JOA score, fusion level, postoperative lumbar lordosis, lordosis at the fused segment, or facet tropism at the cranial intervertebral segment adjacent to the fusion between the ASP and the non-ASP groups (►Table 2). On the other hand, the laminar inclination angle at the cranial vertebra adjacent to the fused level was significantly higher in the ASP group than in the non-ASP group (►Table 2). The mean laminar inclination angle was 134.8 degrees (range, 130 to 138 degrees) in the ASP group, whereas it was 127.0 degrees (range, 118 to 134 degrees) in the non-ASP group ($p < 0.01$, ►Tables 1 and 2).

Discussion

Symptomatic ASP has been considered as a problematic potential long-term complication of lumbar or lumbosacral fusion. Several studies have investigated the incidence of symptomatic ASP after lumbar or lumbosacral fusion for adult low-grade IS and clarified risk factors for symptomatic ASP.⁴⁻⁸ The incidence of symptomatic ASP has been reported ranging from 0 to 2.2%,⁴⁻⁸ and the incidence was relatively low when compared with other etiologies. To the best of our knowledge, there has been no report in the English literature regarding the incidence of symptomatic ASP after fusion surgery for adult low-grade IS including a same surgical procedure as well as evaluating risk factors associated with symptomatic ASP. The incidence and risk factors must be investigated in patients undergoing the same fusion surgery, because the incidence of symptomatic ASP may tend to vary with differing fusion techniques. Therefore, the present study is the first report investigating the incidence of symptomatic ASP after

Table 1 Detailed data for patients with symptomatic ASP

Case no.	Age (y)/sex	Fused segment	Laminar inclination angle (degrees)	Adjacent segment pathologic condition	Time between first and second surgery (mo)	Additional surgery for symptomatic ASP
1	46/F	L5-S1	136	L4 spondylolisthesis	25	L4-5 PLIF
2	40/M	L5-S1	138	L4-5 disc herniation	66	L4-5 PLIF
3	61/F	L5-S1	135	L4 spondylolisthesis	24	L4-5 PLIF
4	67/M	L5-S1	130	L2-3-4-5 canal stenosis	37	L2-3-4-5 fenestration

Abbreviations: ASP, adjacent segment pathology; PLIF, posterior lumbar interbody fusion.

Table 2 Clinical and radiologic data for patients with or without symptomatic ASP

	ASP group	Non-ASP group
No. of patients	4	36
Sex (male/female)	2/2	24/12
Age at surgery (y)	53.5 ± 12.6	59.1 ± 15.1
Preoperative JOA score	13.3 ± 6.8	16.0 ± 3.7
Fusion level (floating/lumbosacral)	0/4	11/25
Postoperative lumbar lordosis (degrees)	46.8 ± 12.7	35.3 ± 11.0
Postoperative lordosis at the fused segment (degrees)	9.8 ± 7.1	12.6 ± 5.8
Laminar inclination angle (degrees)	134.8 ± 3.4 ^a	127.0 ± 4.7
Facet tropism (degrees)	8.3 ± 6.8	5.3 ± 4.5

Abbreviations: ASP, adjacent segment pathology; JOA, Japanese Orthopaedic Association.

Note: Results are mean ± standard deviation.

^a*p* < 0.01.

PLIF with transpedicular fixation for adult low-grade IS and identifying risk factors for symptomatic ASP.

Many authors have reported the following potential risk factors for ASP: age, sex, osteoporosis, preexisting degenerated intervertebral discs or facet joints at the adjacent segments, instrumentation, injury to the facet joints of the adjacent segment due to placement of the cranial pedicle screws, PLIF, fusion length, and sagittal alignment.¹ Preexisting degenerated discs and facet joints at the adjacent segments were not examined in the present study, mainly because magnetic resonance imaging data prior to surgery was available on not all 40 patients. Moreover, there have been debates on the relevance of the preexisting degenerative changes in intervertebral discs and facet joints. Some surgeons have reported that preexisting degeneration of intervertebral discs and facet joints plays a role in developing ASP.^{13,14} In contrast, others have reported that these preexisting degenerative changes have no relationship to ASP.^{15,16} In the present study, as potential risk factors associated with symptomatic ASP, there were no statistically significant differences in sex, age at surgery, fusion level, postoperative lumbar lordosis, lordosis at the fused segment, and preexisting facet tropism at the cranial segment adjacent to the fusion between the ASP and the non-ASP groups. In contrast, only the preexisting laminar inclination angle at the cranial vertebra adjacent to the fused level was significantly higher in the ASP group than in the non-ASP group. Interestingly, Okuda et al reported quite similar results to those in the present study.² They reported that risk factors for symptomatic ASP after PLIF with transpedicular fixation for L4 degenerative spondylolisthesis, including age at surgery, sagittal alignment, and preexisting intervertebral disc degeneration, had no

relationship to the development of symptomatic ASP.² They did, however, report that laminar horizontalization at the cranial fusion segment significantly affected symptomatic ASP.^{2,3} Laminar horizontalization has been regarded to have a relationship to the etiology of degenerative lumbar spondylolisthesis.^{17,18} Nagaosa et al also concluded that laminar horizontalization was a pathoanatomic risk factor for development of degenerative lumbar spondylolisthesis in their retrospective case-control study.¹¹ Because laminar horizontalization may affect sagittal instability, preexisting laminar horizontalization at the cranial vertebra adjacent to the fusion may lead to the progression of symptomatic ASP after surgery. In the present study, laminar inclination angle was measured at L3, L4, or L5 in 39 of 40 patients except for 1 patient undergoing PLIF at the L3-4 segment. Although Nagaosa et al reported that laminar inclination angles increased from L3 to L5, in patients with neither spondylolisthesis nor segmental instability, the difference of mean laminar inclination angles between L3 and L5 was only 2 degrees, and all mean angles at L3, L4, and L5 were less than 120 degrees.¹¹ In the present study, laminar inclination angle at the cranial vertebra (L4) adjacent to the fused segment was ≥ 130 degrees in all 4 patients in the ASP group. Okuda et al also reported that 19 of their 20 patients (95%) who developed symptomatic ASP after L4-5 PLIF for L4 degenerative spondylolisthesis showed laminar inclination angle ≥ 130 degrees at L3.³ When considering available data, a laminar inclination angle ≥ 130 degrees at the cranial fused segment might be a significant risk factor for symptomatic ASP after PLIF in the mid to lower lumbar spine regardless of the surgical fusion level.

The incidence of symptomatic ASP after lumbar or lumbosacral fusion for adult low-grade IS reached 10% in the present study. However, the incidence has been reported ranging from 0 to 2.2%, which is relatively low when compared with other etiologies.⁴⁻⁸ Ohkohchi et al reported that none of their 30 patients (0%) undergoing stand-alone PLIF for adult low-grade IS developed symptomatic ASP with a mean follow-up period of 13.9 years, although 6 patients (20%) showed pseudarthrosis and 4 of them (13%) needed revision surgery to add posterior instrumentation.⁵ A systematic review concerning ASP after lumbar or lumbosacral fusion identified PLIF, instrumentation, and injury to the facet joints of the adjacent segment due to placement of the superior pedicle screws as potential risk factors for ASP.¹ Given these results, the high incidence of symptomatic ASP in the present study might be due to PLIF procedure with transpedicular fixation. Moreover, 16 of the 40 patients (40%) in the present study showed a laminar inclination angle ≥ 130 degrees at the cranial fused segment. Therefore, another reason for the high incidence of symptomatic ASP is that the patient population in the present study might be susceptible to developing symptomatic ASP after PLIF.

In conclusion, 4 of the 40 patients (10%) developed symptomatic ASP after single-level PLIF with transpedicular fixation for adult low-grade IS. The preexisting laminar inclination angle at the cranial vertebra adjacent to the fused level was significantly higher in the ASP group than in the

non-ASP group, and it was ≥ 130 degrees in all 4 patients in the ASP group. Thus, preexisting laminar inclination angle ≥ 130 degrees at the cranial vertebra adjacent to the fused segment might be a significant risk factor for symptomatic ASP after PLIF. These results should be kept in mind, and such information should be included in informed consent.

Disclosures

Hironobu Sakaura, None
Tomoya Yamashita, None
Toshitada Miwa, None
Kenji Ohzono, None
Tetsuo Ohwada, None

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