Additional decompression at adjacent segments leads to adjacent segment degeneration after PLIF

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Abstract

Purpose Adjacent segment degeneration (ASD) is one of the major complications of lumbar fusion. Several previous retrospective studies reported ASD after PLIF. However, few reports evaluated whether decompression surgery combined with fusion surgery increases the rate of complications in adjacent segments. The purpose of the current study was to investigate the degeneration in decompressed adjacent segments after PLIF.

Methods A total of 23 patients (12 men, 11 women; average age, 58.6) who underwent PLIF surgery [1 level ($n = 9$), 2 levels ($n = 8$), 3 levels ($n = 4$), 4 levels ($n = 2$)] were included. Additional adjacent decompression above or below the level of interbody fusion was performed at 25 levels and no adjacent decompression was performed at 15 levels. We retrospectively investigated ASD by X-ray films of all 40 adjacent segments (above and below fusion level) and clinical outcomes of all 23 cases.

Results Of the 40 adjacent segments, 19 (47.5 %) showed ASD and 9 (22.5 %) showed symptomatic ASD. In the 19 segments with ASD, ASD occurred in 16 of 25 (64.0 %) segments at decompressed sites compared with 3 of 15 (20.0 %) non-decompressed sites. The ratio of ASD in adjacent segments was significantly higher at decompressed sites than at non-decompressed sites ($p < 0.01$).

Conclusion ASD occurs frequently in association with additional decompression above or below the level of PLIF. In cases in which the adjacent segments require decompression, a surgical strategy that preserves as much of the posterior complex as possible should be selected.

Keywords Adjacent segment degeneration (ASD) · Posterior lumbar interbody fusion (PLIF) · Decompression surgery · Spinal canal stenosis

Introduction

Decompression surgery combined with fusion surgery is the conventional surgical strategy for multiple spinal canal stenoses with segmental instability. In these cases surgeons certainly hesitate over how many segments should be fused because of adverse effect of segmental fusing on the adjacent segment. Interbody fusion surgery is one of the ideal strategies for stabilization of the spine [28]. Posterior lumbar interbody fusion (PLIF) was first reported by Jaslow [22], and since then has become a widely used spinal surgery technique. PLIF with pedicle screw fixation can be used to obtain rigid fixation. Therefore, this method has shown satisfactory clinical results for spinal canal stenosis with segmental instability. However, several retrospective studies have reported adjacent segment degeneration (ASD) after PLIF [8, 33]. Patients with ASD usually suffer

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from low back pain and sciatica, often requiring revision surgery. It is therefore important to identify the risk factors for ASD after PLIF, which have not been previously reported.

Among decompression surgeries, laminectomy is the most conventional approach for spinal canal stenosis. However, the success rate of laminectomy has been reported to be only 64 %, with the lack of success partly attributed to the development of postoperative instabilities [42] possibly because it sacrifices widely the posterior supporting elements such as spinous process-inter/supra spinous ligament complex, yellow ligament, and paraspinal muscles. Therefore, it has been determined that removing long sections is disagreeable, which has resulted in the development of newer, less invasive techniques. Recently, less invasive surgical strategies using microsurgical and endoscopic techniques have been developed for the treatment of lumbar spinal canal stenosis [40].

Few studies have evaluated whether multiple segment decompression surgery combined with fewer segments fusion surgery increases the rate of complications in adjacent segments. In addition, no studies have evaluated the relationship between ASD and additional decompression surgery at adjacent segments when combined with PLIF. In cases where decompression at the adjacent segment is necessary for multiple spinal canal stenoses during fusion surgery, whether to employ the best surgical strategy or to fix all decompressed segments is not yet clear. The purpose of this study is to investigate degeneration in decompressed adjacent segments after PLIF.

Materials and methods

Patient population

A total of 23 patients (12 men, 11 women) who underwent PLIF with pedicle screw fixation for degenerative lumbar disorder between 2000 and 2004 were included. The mean age at surgery was 58.6 (range 27–79 years) and the mean follow-up period was 4.4 years (range 1.7–7.1 years). Diagnoses included spinal canal stenosis ($n = 11$), degenerative spondylolisthesis ($n = 8$), isthmic spondylolisthesis ($n = 2$), and disc herniation ($n = 2$). Involved PLIF levels were: L1–L5 ($n = 1$), L2–L3 ($n = 3$), L2–L5 ($n = 1$), L2–S ($n = 1$), L3–L4 ($n = 1$), L3–L5 ($n = 5$), L3–S ($n = 1$), L4–L5 ($n = 6$), L4–S ($n = 3$), and L5–S ($n = 1$). The following numbers of levels were subjected to PLIF: 1 level ($n = 9$), 2 levels ($n = 8$), 3 levels ($n = 4$), and 4 levels ($n = 2$). All patients had severe low back pain and sciatica that were unresponsive to conservative treatment. A total of 40 adjacent segments were involved in this study. Additional adjacent decompression (total

laminectomy) above or below the level of PLIF was performed at 25 levels, while no adjacent decompression was performed at 15 levels (Table 1).

The study protocol was approved by the ethics committee of Kamitsuga General Hospital and the ethics committee of Chiba University Hospital.

Criteria for ASD

We evaluated all 40 adjacent segments in X-rays acquired pre- and post-surgery (final follow-up or before revision surgery). ASD was defined as a radiologic change in which narrowing of disc height was >3 mm, the progressive slipping of adjacent segments was >3 mm (in comparison with preoperative flexion and extension lateral radiographs), and the posterior opening of adjacent segments was $>5^\circ$. These definitions were based on previous reports [31].

Table 1 Patients' characteristics

N	23
Sex	
Male	12
Female	11
Mean age	58.6 (range 27–79 years)
Diagnosis	
Spinal canal stenosis	11
Degenerative spondylolisthesis	8
Isthmic spondylolisthesis	2
Disc herniation	2
Follow-up	53.2 months (range 22–85 months)
PLIF level	
L1–L5	1
L2–L3	1
L2–L5	3
L2–S	1
L3–L4	1
L3–L5	5
L3–S	1
L4–L5	6
L4–S	3
L5–S	1
The number of PLIF levels	
1 level	9
2 levels	8
3 levels	4
4 levels	2
The number of adjacent segment	40
Decompression (+)	25
Decompression (–)	15

In addition, symptomatic ASD was defined as ASD associated with neural symptoms.

The ratios of ASD and symptomatic ASD were calculated, and these ratios were compared between segments with and without additional adjacent decompression above or below the level of PLIF.

Clinical outcomes

All clinician records were available for review. Clinical outcomes were assessed using the scoring system proposed by the Japanese Orthopedic Association (JOA) for the management of low back pain. In all 22 patients, pre- and post-operative (final follow-up or before revision surgery) JOA scores were reviewed. Briefly, the JOA score consists of ratings of subjective symptoms (low back pain, 3 points; leg pain, 3 points; gait abnormality, 3 points), clinical symptoms (straight leg-raising test, 2 points; sensory abnormality, 2 points; motor disturbance, 2 points), activities of daily living (ADL) (14 points), and urinary bladder function (0–6 points) [46]. We examined 15 of 29 points, excluding the 14 ADL points due to the difficulty of evaluating ADL scores by clinician records. The recovery rate by JOA score in each case was calculated using Hirabayashi's method which indicated in (postoperative condition minus preoperative condition/normal condition minus preoperative condition) $\times$ 100 % [18], and the recovery rate by JOA score was compared between cases with and without ASD.

Statistical analysis

Sex differences in the patient population, the number of PLIF levels, and segments with or without additional adjacent decompression were compared between patients with and without ASD after PLIF using a χ^2 test. The mean age, mean follow-up period, and recovery rates as determined by JOA score were compared between patients with and without ASD after PLIF using an unpaired *t* test. The incidence of ASD between segments with additional adjacent decompression above or below the level of PLIF and segments with no additional adjacent decompression were compared using a χ^2 test. A *p* value <0.05 was considered statistically significant.

Results

Rate of ASD

ASD occurred in 19 segments in 14 patients (5 men, 9 women). The mean age at surgery was 63.4 years. The

mean follow-up period was 55.7 months. The number of levels that underwent PLIF among patients with ASD was as follows: 1 level (*n* = 5), 2 levels (*n* = 6), and 3 levels (*n* = 3). In the other 9 patients (7 men, 2 women) with no ASD, the mean age at surgery was 51.0. The mean follow-up period was 49.2 months. The number of levels that underwent PLIF in these patients was as follows: 1 level (*n* = 4), 2 levels (*n* = 2), 3 levels (*n* = 1), and 4 levels (*n* = 2). In the ASD group, there were significantly more females and older patients as compared with the non-ASD group (*p* < 0.05). Further, there were significantly more segments with additional, adjacent decompression in the ASD group than in the non-ASD group (*p* < 0.05). By contrast, there were no significant differences between the two groups in the follow-up period and the number of PLIF levels (Table 2).

Of the 40 adjacent segments, 19 (47.5 %) showed ASD and 10 (25.0 %) were symptomatic. In the 19 segments with ASD, ASD occurred in 16 of 25 (64.0 %) segments at decompressed sites as compared with 3 of 15 (20.0 %) non-decompressed sites. The rate of ASD was significantly higher in segments that underwent additional decompression surgery than in segments that did not undergo additional decompression surgery (*p* < 0.01) (Fig. 1). In addition, in the 10 adjacent segments with symptomatic ASD, symptomatic ASD occurred in 9 of 25 (36.0 %) segments at decompressed sites as compared with 1 of 15 (6.7 %) non-decompressed sites. The rate of symptomatic ASD was significantly higher in segments that underwent additional decompression surgery than in segments that did not (*p* < 0.05) (Fig. 2).

Table 2 Patients' characteristics: cases with ASD versus cases without ASD

	ASD (+)	ASD (−)	<i>p</i>
N	14	9	
Sex			
Male	5	7	
Female	9	2	0.05
Mean age	63.4	51.0	0.05
Follow-up	55.7 months	49.2 months	N.S.
The number of PLIF levels			
1 level	5	4	
2 levels	6	2	
3 levels	3	1	
4 levels	0	2	N.S.
The number of adjacent segments	19	21	
Decompression (+)	16	9	
Decompression (−)	3	12	0.01

Fig. 1 Rate of ASD. The rate of ASD was significantly higher in segments with additional decompression surgery than in segments with no additional decompression surgery. (* $p < 0.01$, 2×2 Chi-square test)

Fig. 2 Rate of symptomatic ASD. The rate of symptomatic ASD was significantly higher in segments with additional decompression surgery than in segments with no additional decompression surgery. (* $p < 0.01$, 2×2 Chi-square test)

Clinical outcomes

The mean preoperative JOA score was 6.0 points (range 3–9 points), and it improved to 11.2 points (range 6–15 points). The mean recovery rate by JOA score was 58.9 % (range 20–100 %). Among all 23 cases, 14 (60.9 %) experienced ASD and 9 (39.1 %) did not. There were 7 asymptomatic ASD cases (30.4 %), 7 symptomatic ASD cases (30.4 %), and 2 cases (8.7 %) that required revision surgery due to deterioration of adjacent segment instability. The mean recovery rate by JOA score was 49.8 % (range 10–90.9 %) in the 14 cases with ASD. In contrast, in the 9 cases with no ASD after PLIF, the mean recovery rate by JOA score was 72.9 % (range 12.5–100 %). The recovery

Fig. 3 Recovery rate by JOA. The recovery rate by JOA score was significantly lower in cases with ASD than in cases with no ASD. (* $p < 0.05$, unpaired t test)

rate by JOA score was significantly lower in cases with ASD than in cases with no ASD ($p < 0.05$) (Fig. 3).

Discussion

In this retrospective study, additional decompression above or below the level of PLIF resulted in ASD and symptomatic ASD very frequently, and clinical outcomes in cases with ASD were worse than in cases without ASD. Many authors have previously reported a long-term rate of ASD after spinal fusion surgery of 8–100 % [1, 16, 20, 25, 29, 34, 39]. This broad range reflects the retrospective nature of the studies as well as differences in surgical methods, ASD criteria, surgery level, and patient populations. Overall, Paul reported that ASD is radiographically common [33]. In the current study, using the ASD criteria previously reported by Okuda et al. [31], we found that ASD was radiographically common; thus, the results of the present study are similar to those of previous reports. In contrast, the incidence of symptomatic ASD has been reported to be 5.2–18.5 % [3, 15, 16, 23, 25, 26]. However, in the current study, symptomatic ASD occurred more frequently (30.4 %).

In this study, we detected significant differences between patients with and without ASD after PLIF with regard to gender (female), mean age, and segments with additional adjacent decompression. A major controversy exists as to whether ASD is caused by aging or is secondary to mechanical stress after fusion [2, 13, 14, 36, 41, 45, 46]. In an attempt to determine the etiology of ASD, several authors have tried to identify the risk factors for ASD, and have reported the following risk factors: postmenopausal status [11], fusion length [37, 44], sagittal

alignment [11, 38, 43], lamina horizontalization [32], facet tropism [32], and rigid instrumentation [11, 19]. Etebar et al. [11] concluded that the risk of ASD appears to be especially high in postmenopausal women. Therefore, it is considered that osteoporosis might be a risk factor for ASD. However, in a study of a small number of patients, Chen et al. reported that there is no significant correlation between degeneration and bone mineral density. They concluded that the results of their study need to be confirmed by additional high-quality clinical studies with larger numbers of patients [4].

On the other hand, with respect to rigid instrumentation, several authors concluded that immediate rigidity produced by rigid instrumentation causes more stress, leading to accelerated ASD [11, 19]. A further increase in rigidity may similarly explain the higher risk for ASD that is observed after the addition of a PLIF to an instrumented posterolateral fusion (PLF) [37]. In contrast, whether additional, adjacent decompression above or below the level of PLIF is a risk factor for ASD remains unclear. Few reports have evaluated whether decompression surgery combined with PLF surgery increases the complication rate in adjacent segments. Ekman reported that patients who undergo total laminectomy above the level of PLF had a significantly higher incidence of ASD as compared to non-laminectomy patients [10]. Lai concluded that damaging the integrity of the posterior complex at adjacent segments by total laminectomy led to adjacent instability in a retrospective study of 101 patients who had undergone PLF [27]. This was the first study to evaluate whether multiple segments' decompression surgery combined with fewer segments' PLIF surgery increases the rate of complications in adjacent segments. In this study, as in previous reports about PLF, ASD occurred very frequently in patients who underwent additional decompression above or below the level of PLIF by total laminectomy. Additional, adjacent decompression above or below the level of PLIF by total laminectomy may thus be a risk factor for ASD. Therefore, in cases in which the adjacent segment requires decompression above or below the level of PLIF, decompression should not be performed by total laminectomy. Recently, several authors have reported strategies for surgical decompression, in such patients, which are less invasive to the spinal structure. A unilateral approach for bilateral spinal canal decompression using a microscope or a microendoscope has been reported as one such effective strategy, and is less invasive than conventional decompression surgery. This surgery can often preserve not only central spinal structures, including spinous processes and interspinous ligaments, but also the paravertebral muscles and facet joints on the unapproached side [7, 21, 24]. On the other hand, Hatta et al. [17] reported a muscle-preserving interlaminar decompression technique that can

minimize damage to posterior stabilizing structures, such as the intervertebral facet joints, paravertebral muscles, dorsolumbar fascia, supra- and interspinous ligaments, while preserving the function of the spinous processes as lever arms for lumbar extension. These surgical strategies can be considered as optimal for decompression in patients such as those in this study.

Moreover, for reducing ASD in such patients, we have another possible surgical strategy of semi-rigid dynamic stabilization for segments, which requires decompression above or below the level of PLIF. Recently, some authors have reported the efficacy of a semi-rigid dynamic segment stabilization system for lumbar spinal diseases [6, 12]. However, Putzier M et al. [35] concluded that there were no clinical benefits in using dynamic fixation of the adjacent segment in lumbar spinal surgery, in their study, comparing single-level fusion only and fusion with adjacent segment dynamic fixation. Therefore, further study and discussion is required when we consider applying this technique in cases in which the adjacent segment requires decompression above or below the level of PLIF.

In this study, the recovery rate, as per JOA score, in cases with ASD after PLIF was worse than that of cases without ASD after PLIF. The correlation between ASD and clinical outcomes remains controversial [8, 33]. Several studies failed to reveal a high degree of correlation between postoperative ASD and clinical outcome [16, 20]. Radiographic ASD does not always correlate with a poor prognosis [20, 30]. Furthermore, many previous studies showed that clinical outcomes are largely unaffected in patients with asymptomatic ASD [1, 15, 16, 25, 29]. In contrast, in a prospective randomized study on the long-term effects of PLF, Ekman concluded that the clinical importance of ASD appears to be limited, with only the more severe forms affecting outcome [10]. Symptomatic ASD occurred more frequently in the current study than in previous reports [3, 15, 16, 23, 25, 26]. Therefore, clinical outcomes in cases with ASD after PLIF were worse than those of cases without ASD.

This study has some limitations. First, the number of patients in this study—to evaluate whether decompression combined with PLF surgery increases the rate of complications in adjacent segments—is low. Second, we did not evaluate Cobb angles and sagittal balance of patients' spines. Some authors have reported that spinal sagittal alignment is a risk factor for ASD [9, 25]. However, whether spinal sagittal alignment causes ASD remains controversial. Other researchers have not reported an association between ASD and spinal sagittal alignment [4, 5]. Therefore, further clinical studies are needed to clarify these points.

In conclusion, ASD and symptomatic ASD occur frequently with additional decompression above or below the

level of PLIF. Due to a high occurrence of asymptomatic ASD, clinical outcomes in cases with ASD after PLIF were worse than those of cases without ASD after PLIF. We recommend that in cases in which adjacent segments require decompression, a surgical strategy that preserves as much of the posterior complex as possible should be selected.

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Conflict of interest None.

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