Adjacent segment degeneration after single-segment PLIF: the risk factor for degeneration and its impact on clinical outcomes

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Abstract

Purpose To investigate: (1) the risk factors for radiologic cranial adjacent segment degeneration (ASD) after single-segment PLIF at the same level, and (2) the impact of the ASD on the clinical outcomes.

Methods From October 2004 to May 2009, 109 patients who underwent PLIF for degenerative instability at L4/5 and have more than 2 years follow-up were studied retrospectively. We measured the preoperative bone mineral density (BMD), lumbar lordosis, the lumbosacral joint angle, the lumbar inclination, the height and the dynamic angulation of the intervertebral space at the fused segments and the upper adjacent segment, the sliding displacement between L3 and L4. Clinical outcomes were evaluated using the Japanese Orthopedic Association (JOA) score and the Oswestry Disability Index (ODI). Patients were divided into two groups according to the progression of L3–L4 degeneration: Group A without progression of L3–L4 degeneration, Group B with progression of L3–L4 degeneration. Clinical outcomes and radiologic measurement index between the two groups were compared, and

the risk factors for progression of L3–L4 degeneration were analyzed. The correlation between clinical outcomes and progression of L3–L4 degeneration were also investigated. **Results** There were 11 patients (22%) classified into Group A. No significant difference was found between the two groups in terms of the lordosis angle at L1 and S1, the laminar inclination at L3, the pre-existing L3–L4 disk degeneration, the lordosis angle of L4–L5, the lumbosacral joint angle and preoperative BMD ($P > 0.05$). Significant differences were found between the two groups in age. No significant difference was found between the two groups in the ODI and the JOA score at the final follow-up ($P > 0.05$).

Conclusion Radiologic degeneration of the cranial adjacent segment after single-segment PLIF did not significantly correlate with clinical outcomes. Age was a risk factor for radiologic degeneration, however, there was no significant correlation between degeneration and preoperative radiologic factors and bone mineral density (BMD).

Keywords Lumbar fusion · Adjacent segment degeneration · Risk factor · Clinical outcome

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Introduction

Although posterior lumbar interbody fusion (PLIF) has shown satisfactory clinical results in management of degenerative spinal diseases that require decompression with stabilization, lots of previous studies have reported that accelerated adjacent segment degeneration (ASD) can occur after PLIF, especially at the cranial level [1–4]. The relationship between fusion surgery and adjacent segment degeneration remains controversial. Battie et al. [5] found that adjacent segment degeneration after fusion

was a natural process that was not related to the fusion surgery. However, some other researchers conducted in vitro mechanical studies and found that lumbar fusion may induce abnormal intradiscal pressure and too much movement at the adjacent spinal levels, resulting in adjacent segment degeneration [6]. Therefore, it appears that ASD may be partially caused by the abnormal discal stresses distribution that arised by lumbar fusion and fixation [7–9].

Recently, several authors have reported the risk factors for ASD and the correlation between ASD and clinical results [1], but it still remains controversial that (1) whether postoperative ASD can be detected from preoperative radiologic factor of lumbar spine and age, bone mineral density of patients or not? (2) Whether postoperative ASD could affect the clinical outcomes or not. To exclude confounding factors, we only recruited patients with degenerative instability at L4–L5 level who underwent posterior single-segment PLIF. Previous studies have focused on the nonadjacent mobile segments after spinal fusion, especially on lumbosacral fusion. But our study paid more attention to cranial segment degeneration (L3–L4).

The aims of this study are to analyze: (1) risk factors for radiologic cranial ASD after single-segment PLIF at the same level, and (2) the impact of the ASD on the clinical outcomes after lumbar fusion.

Materials and methods

From October 2004 to May 2009, 109 patients who suffered from lumbar degenerative instability and then underwent instrumented PLIF at single segment L4–L5 were included in this study. During operation, prospaces (Aesculap Company, Germany) combined locally autogenous bone grafting were used for intervertebral fusion. While MYKRES system (82 cases, Showa Ika Kohgyo Company) and ISOLA system (27 cases, DePuy Spine Inc.) were used for posterior transpedicular instrumentation. There were 49 males and 60 females. Mean age at surgery was 53.4 years (range 28–72 years). The average follow-up period was 39.3 months (range 24–52 months). The follow-up rate was 97.3%.

Cases with cranial adjacent segments that were rated higher than grade II according to the University of California at Los Angeles (UCLA) Grading Scale [10] for intervertebral Space Degeneration on preoperative radiographs were excluded from this study.

All the patients were underwent PLIF with the same technique by the same team. The surgical technique of PLIF was described [11]. Briefly, Posterolateral fusions PLIF were performed at each level.

The disc height, the dynamic intervertebral space angulation, the displacement of the cranial vertebral body at L3–L4 and L4–L5, the laminar inclination angle at L3, the lumbosacral joint angle, the lordosis at L4–L5 and lumbar lordosis at L1–S1 were measured respectively. The lordosis angle was measured by Cobb's methods. The height of the corresponding intervertebral disc was the mean of the sum of the vertical distance between the anterior and posterior edges of the vertebral end plates; the dynamic intervertebral space angulation was the sum of the angulation between the connecting lines of the anterior and posterior edges of the end plates of the adjacent vertebral bodies in hyperextension/hyperflexion X-ray films; and the interfacial sliding distance was the distance between the vertical lines perpendicular to the posterior edge of the vertebral body (Fig. 1). The laminar inclination angle at L3 was defined as the angle formed by a straight line connecting the tip of the superior facet with the base of the inferior facet and a straight line connecting the midpoints of the anterior and posterior vertebral cortices on the lateral radiographs [12] (Fig. 2). All the patients underwent bone mineral density scanning of the lumbar spine in the anteroposterior (frontal) view.

The criteria for postoperative progression of radiologic degeneration at L3–L4 were as follows [1]: (1) disc height was greater than 3 mm; (2) the dynamic intervertebral space angulation was greater than 5 degrees; (3) the slip-page of L3 vertebral body was greater than 3 mm. Patients were divided into two groups according to progression of L3–L4 degeneration at the final follow-up: Group A with

Fig. 1 Image measurement indices: height of the intervertebral disc = $(a + b)/2$; angle α = angulation of the intervertebral space; angle γ = lordosis angle of the lumbar spine; angle β = lumbosacral joint angle

Fig. 2 Image measurement indices: The laminar inclination angle at L3 was defined as the angle formed by a straight line connecting the tip of the superior facet with the base of the inferior facet and a straight line connecting the midpoints of the anterior and posterior vertebral cortices on the lateral radiographs

no progression of degeneration and Group B with progression degeneration.

As for clinical results, the Oswestry Disability Index (ODI) [13] and the JOA score [14] were used to evaluate patient outcomes before and after surgery and at the last follow-up. The postoperative recovery rate was calculated using the Hirabayashi method [14]: recovery rate = (postoperative score – preoperative score) × 100/(total score – preoperative JOA score).

Statistical analysis

All the data were analyzed using SPSS, version 16.0, statistical software (SPSS, Chicago, IL, USA). The *t* test was used to compare data of the two groups. The correlation between the degeneration of the L3/4 segment and the

imaging data was analyzed using Spearman correlation coefficient analysis. A statistically significant difference was indicated by $P < 0.05$.

Results

At the final follow-up, 85 patients (78%) in group A did not show radiologic degeneration at L3–L4 and there were 24 patients (22%) in group B who showed radiologic degeneration at L3–L4. The age of patients undergoing surgery in groups A and B showed statistically significant differences ($P < 0.05$), which was 49.6 and 62.8 years, respectively. No significant differences were found in preoperative bone mineral density (BMD), the lordosis angle at L1 and S1, the lumbosacral joint angle, the lordosis at L4–L5, the disc height at L4–L5, the slippage of L4 vertebral body, the laminar inclination angle at L3 between the two groups preoperatively ($P > 0.05$, Table 1).

According to clinical outcome evaluation, there were no significant differences in the recovery rate of ODI and JOA score between the two groups ($P > 0.05$, Table 2).

Discussion

Although ASD may be considered as a part of the normal aging process and degenerative change, many authors thought it is partly influenced by the change in the stress acting on the adjacent segment after spinal fusion [7, 9, 10]. An increased pressure and motion in adjacent discs has clearly been demonstrated in biomechanical studies in vitro [15, 16]. Umehara et al. [17] conducted a biomechanical study and found that the load burden and the shear stress of the posterior column at the adjacent segments after lumbar fusion increased significantly, and this increase was considered a main cause of adjacent segment degeneration.

Because ASD may be a cause of failed back surgery syndrome, many researchers have studied the biomechanics, risk factors and the correlation between ASD and the clinical results after PLIF. However, these remain unclear.

Table 1 Comparison of preoperative image measurement indices of the lumbar spine between the two groups of patients

	Group A (no degeneration) <i>n</i> = 85	Group B (degeneration) <i>n</i> = 24	<i>P</i> *
Age at surgery	49.6 ± 9	62.8 ± 10	0.03
Bone mineral density	−1.12 ± 0.19	−1.23 ± 0.23	0.08
Laminar inclination angle at L3	121° ± 7°	127° ± 6°	0.08
Lordosis angle of lumbar spine	21.43 ± 9.32	24.99 ± 8.15	0.11
Lumbosacral joint angle	11.35 ± 0.53	9.41 ± 1.03	0.17
Intervertebral disc height of L4/5	0.72 ± 0.09	1.16 ± 0.53	0.21
Lordosis angle of L4/5	14.56 ± 0.65	14.58 ± 1.29	0.13
Sliding distance of L4 Vb	0.17 ± 0.03	0.14 ± 0.02	0.09

* Comparison of indices between the two groups of patients

Table 2 Comparison of clinical outcomes between the two groups of patients

	Group A (no degeneration) (<i>n</i> = 38)			Group B (degeneration) (<i>n</i> = 11)			<i>P</i> *
	Before surgery	Final follow-up	Recovery rate (%)	Before surgery	Final follow-up	Recovery rate (%)	
ODI	35.7 ± 8.2	8.6 ± 4.2	76.1 ± 31.4	36.9 ± 8.9	11.2 ± 5.5	69.7 ± 22.1	0.20
JOA	14.3 ± 5.1	16.3 ± 6.1	75.4 ± 29.3	12.3 ± 4.2	15.9 ± 3.7	72.2 ± 21.4	0.14

ODI Oswestry Disability Index, JOA Japanese Orthopaedic Association

* Comparison of recovery rate between the two groups

In a retrospective study of 217 patients who underwent lumbar fusion with more than 2 years follow-up, Yang et al. [18] found that the impact of ASD on clinical outcome after fusion showed a significant correlation. However, Okuda and Iwasaki [1] observed that it did not necessarily correlate with clinical symptoms. In the current study, we reviewed 109 patients who underwent instrumented lumbar fusion at L4–L5 with an average of 39.3 months of follow-up and found that 22% of the patients developed radiologic adjacent segment degeneration of the cranial segments. However, the clinical outcomes of these patients did not show the worsening tendency and the recovery rate of ODI and the JOA score were not significantly different between the two groups, which is consistent with the previous report that radiologic degeneration of adjacent segments was not significantly correlated with clinical outcomes [19].

Although the risk factors for adjacent segment degeneration have well been described, there are still controversial views about that. Some authors believe that adjacent segment degeneration is related to age, sex, length of fusion segments, spinal sagittal alignment, and menopause [2, 19, 20]. Cho et al. [21] found that elder patients was associated with higher incidence of adjacent segment degeneration after PLIF, therefore he thought that age was an important risk factor. Aota et al. [22] found that the incidence of adjacent segment degeneration might increase significantly in patients older than 55 years. Meanwhile, they thought that osteoporosis and postmenopausal status in women were also the factors that should be considered. However, Okuda et al. [1] did not find a significant association between age and adjacent segment degeneration. According to the follow-up results, we found that the mean age of the patients with cranial ASD after PLIF was significantly higher than that of patients without degeneration, which predicted that age may be a risk factor for developed ASD after lumbar fusion. However, there was no significant difference of preoperative BMD between the two groups, which predicted that there was no correlation between ASD and preoperative BMD. This need to be confirmed by further research.

Some authors intend to predispose for the development of ASD by measuring the radiological factor

preoperatively. Djurasovic et al. [19] thought that spinal sagittal alignment was a risk factor for ASD. Kumar et al. [20] observed 83 patients who underwent lumbar fusion and found that changes of the middle axis of the spine and/or sacral inclination angle increased the incidence of adjacent segment degeneration. However, other researchers, such as Cheh et al. [23], did not report an association between adjacent segment degeneration and spinal sagittal alignment. Nagaosa et al. [12] performed a retrospective case–control study and concluded that horizontalization of the lamina was a pathoanatomic risk factor that could be predispose for the development of ASD. However, Okuda [1], in a retrospective study of 87 patients who underwent PLIF at L4–L5, observed that there were no significant differences of Lumbar inclination between the patients who show ASD and those who did not at final follow-up. In our current study, we also did not found significant differences between the two groups in the lumbar inclination, the lumbosacral joint angle, the lordosis at L4–L5 and lumbar lordosis at L1–S1 and the disc height, the dynamic intervertebral space angulation, the slippage of the cranial vertebral body at L3–L4 and L4–L5. Briefly, in this study, risk radiological factors for postoperative ASD could not be detected in terms of each preoperative radiologic factor.

In a prospective clinical study, Ekman et al. [24] found that postoperative adjacent segment degeneration occurred in all the patients receiving decompressive laminectomy and posterior fusion with fixation, and that its incidence was significantly higher than that in patients not undergoing decompressive laminectomy. They speculated that decompressive laminectomy was a risk factor for adjacent segment degeneration.

Aota et al. [22] found that, radiologic degeneration of adjacent segments after lumbar fusion occurred after an average of 25 months. Others have reported an average time of 26.8 months from the fusion surgery to the occurrence of imaging degeneration of adjacent segments [25]. Therefore, the patients that involved in this study were followed up at least 2 years. We also excluded patients with adjacent segments not include in the fusion that were rated higher than grade III according to the UCLA classification to minimize the effect of natural disc degeneration and the aging process. Most previous studies

were limited in that they involved patients with different diagnoses, different fixation segments, and different fixation techniques; the results may have been affected by these differences. So, in order to limited the affection, we limited the patients to those with degenerative spondylolisthesis at L4 using the same fusion technique. However, this study also had limitations. This study did not use magnetic resonance imaging to evaluate the adjacent segments, which may provide more important radiologic information for the study. Therefore, the results of this study need to be confirmed by additional high-quality clinical studies.

In summary, the following conclusions can be drawn from this study: The radiologic degeneration of the cranial adjacent segment after single-segment PLIF is not significantly correlated with clinical outcomes. Patient's age may be related to ASD. However, no significant correlation is detected between adjacent segment degeneration and the preoperative radiologic factors and BMD.

Conflict of interest None.

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