CLINICAL ARTICLE

J Korean Neurosurg Soc 41 : 88-94, 2007

Predictable Risk Factors for Adjacent Segment Degeneration After Lumbar Fusion

Seung-Jae Hyun, M.D., Young-Baeg Kim, M.D., Hyun-Jong Hong, M.D., Jeong-Taik Kwon, M.D., Jong-Sik Suk, M.D., Byung-Kook Min, M.D.

Department of Neurosurgery, College of Medicine, Chung-Ang University, Seoul, Korea

Objective : The aim of this study is to investigate predictable risk factors for radiologic degeneration of adjacent segment after lumbar fusion and preoperative radiologic features of patients who underwent additional surgery with adjacent segment degeneration.

Methods : Between January 1995 and December 2002, 201 patients who underwent lumbar fusion for degenerative conditions of lumbar spine were evaluated. We studied radiologic features, the method of operation, the length of fusion, age, sex, osteoporosis, and body mass index. Special attention was focused on, preoperative radiologic features of patients who required additional surgery were studied to detect risk factors for clinical deterioration.

Results : Follow-up period ranged from 3 to 11 years. In our study, 61 (30%) patients developed adjacent segment degeneration, and 15 (7%) patients required additional surgery for neurologic deterioration. Age, the postoperative delay, facet volume, motion range, laminar inclination, facet tropism, and preexisting disc degeneration of adjacent segment considered as possible risk factors. Among these, laminar inclination and preexisting disc degeneration of adjacent segment were significantly correlated with clinical deterioration.

Conclusion : The radiologic degeneration of adjacent segment after lumbar fusion can be predicted in terms of each preoperative radiologic factor, age and the postoperative delay. Laminar inclination and preexisting disc degeneration of adjacent segment have shown as strong risk factors for neurologic deterioration. Thus, careful consideration is warranted when these risk factors are present.

KEY WORDS : Risk factor · Adjacent segment degeneration · Spinal fusion · Laminar inclination · Facet tropism .

Introduction

The prevalence of lumbar arthrodesis has continued to increase owing to emergence of newer techniques of spinal instrumentation and improved imaging modalities that allow for accurate recognition of spinal abnormalities. The levels involved in the arthrodesis typically are degenerative or unstable, and the ultimate goals are to provide relief of symptoms and to restore stability[6,16]. In the past, the finding of adjacent segment disease was noted in case reports as a relatively unusual complication of lumbar or lumbosacral fusions[3,39]. Since then, adjacent segment disease has been found to occur more often than initially thought and is now considered as a potential long-term complication of spinal arthrodesis[16]. With the dramatic increase in spinal fusions performed in recent years, adjacent segment disease is and will become much more prevalent[15]. However, it has also been emphasized that delayed adjacent segment degeneration is a normal evolution after lumbar fusion and must be accepted as a late consequence and not considered as a complication[41].

Adjacent segment degeneration after lumbar fusion represents an important and unavoidable problem. But, only few reports have brought attention specifically with this topic. Even more startling are the contradictory results from both in vitro and clinical studies, and the mixture of different pathologies (fractures, neoplasms, spondylolysis, degenerative problems) included in the series, though the initial status of the spine in these different conditions were inhomogeneous[17].

This study focuses on the long-term evolution of the adjacent segment in patients fused only for degenerative conditions of

• Received : June 28, 2006 • Accepted : December 16, 2006
• Address for reprints : Young-Baeg Kim, M.D., Department of Neurosurgery, College of Medicine, Chung-Ang University, 224-1 Heukseok-dong, Dongjak-gu, Seoul 156-755, Korea Tel : +82-2-6299-1595, Fax : +82-2-821-8409, E-mail : ybkim1218@cau.ac.kr

the lumbar spine such as degenerative spondylolisthesis, stenosis, and instability, excluding other pathologies. The purpose of this study is to clarify the predictable risk factors for radiologic degeneration of adjacent segment after lumbar fusion, and to evaluate the preoperative radiologic features of patients who underwent additional surgery with adjacent segment degeneration.

Definition

In this article, the terms "adjacent segment degeneration" and "adjacent segment disease" will be used to define different types of postarthrodesis adjacent level pathology. The term "adjacent segment degeneration" will be used to describe radiographic changes seen at levels adjacent to a previous spinal fusion procedure that do not necessarily correlate with any clinical findings. On the other hand, the term "adjacent segment disease" will be used to refer to the development of new clinical symptoms that correspond to radiographic changes adjacent to the level of a previous spinal fusion.

Adjacent segment degeneration consists of dehydration of the disc visible only on magnetic resonance imaging (MRI), narrowing of the disc space greater than 3mm, disc space vacuum, osteophyte formation, appearance or increase of degenerative retrolisthesis, antelisthesis or rotatory dislocation, spinal stenosis due to hypertrophy of the posterior facets, disc or ligament bulging, and instability with static or dynamic malalignment of the spine[17]. Radiographic evidence of instability was defined, as >4mm of translation and/or >10° of angular motion between adjacent end plates on lateral flexion and extension films when compared with the adjacent cephalad and caudad levels[48].

Materials and Methods

Two hundred and one patients who underwent lumbar fusion for degenerative conditions of the lumbar spine refractory to conservative treatment from January 1995 to December 2002 and followed for at least 3 years were included in this study. Follow-up rate in the current study was 71%. Patients who underwent lumbar fusion for other pathologies such as spondylolysis, trauma, and neoplasms were excluded. The study group included 69 male patients and 132 female patients. Mean age at surgery was 53 years (range, 17-78 years) and the average follow-up period was 73 months (range, 37-130 months). The medical records were carefully reviewed for recurrence of mechanical pain or neurologic deterioration after a period of postoperative relief. Posterolateral lumbar intertransverse fusion were performed in 128 patients, posterior lumbar interbody fusion (PLIF), and transforaminal lumbar interbody fusion (TLIF) in 69 and 4 cases, respectively. The surgical techniques of posterolateral fusion, PLIF, and TLIF were described elsewhere[29,32]. Screw-rod fixations were not performed in any of these patients.

Standard biplanar anteroposterior, lateral, flexion, and extension radiographs of the lumbosacral spine at preoperative visit as well as at last postoperative visit were reviewed in all patients. Lateral radiographs demonstrating neutral, flexion, and extension views were used to anteroposterior translation, lumbar lordosis, ranges of motion, and intervertebral disc height at each adjacent segment. Motion ranges of adjacent segment were measured using flexion-extension angle (FEA) (Fig. 1). The flexion-extension angle was defined as sum of flexion angle and extension angle, and that was measured from dynamic views of lumbar spine taken both at preoperative and postoperative period[36,49].

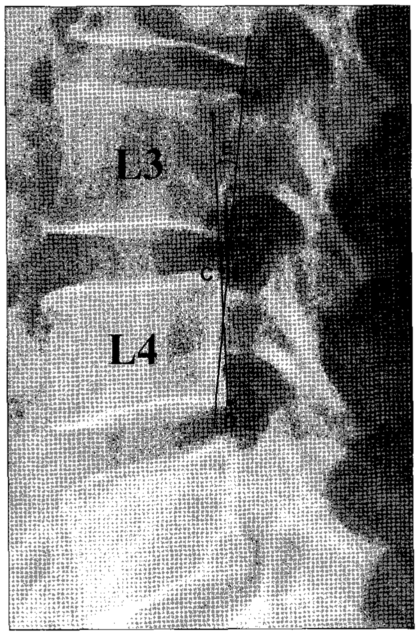

Fig. 1. Measurement of flexion-extension angle on lumbar spine on extension motion. A : Superior posterior point of L3 body, B : Inferior posterior point of L3 body, C : Superior posterior point of L4 body, D : Inferior posterior point of L4 body, E : Angle between line that is to continue A and B and line that is to continue C and D (Extension Angle).

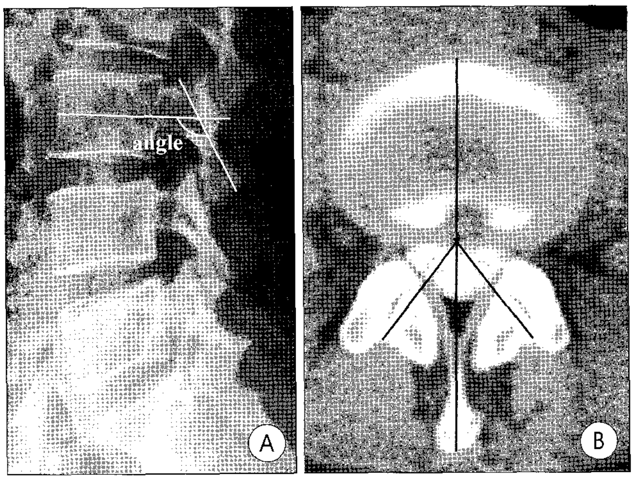

Fig. 2. A : Laminar inclination angle at L3 was defined as the angle formed by a straight line connecting the tip of the superior facet with the base of the inferior facet and a straight line connecting the midpoints of the anterior and posterior vertebral cortices on the lateral radiographs. B : Facet sagittalization and facet tropism at L3-4 were taken from the computed tomography cut that was coplanar with the disc and transected the facet joints.

Maximal intervertebral disc heights were measured using of lateral radiographs.

We also measured laminar inclination angle, facet sagittalization, facet tropism, facet joint volume[5,18)], preexisting disc degeneration and stenosis at the adjacent level, sagittal alignment at the fused segment, and adjacent segment motion range. Lumbar lordosis at L1 and S1 and lordosis at the fused segment were measured by Cobb's method with anteroposterior and lateral standing radiographs[24)]. The laminar inclination angle at adjacent segment 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 as described[28)] (Fig. 2A). Facet sagittalization and tropism at adjacent segment were evaluated from the computed tomography (CT) image that was coplanar with the disc and transected the facet joints as described[44)] (Fig. 2B). The sum of the right and left facet angles, and the difference between the two angles were defined as facet sagittalization and facet tropism, respectively. Preexisting disc degeneration at adjacent segment was evaluated on preoperative MRI using Christian's grading system[10)] (Table 3). These measurements were done by one of the authors (S.J.H.).

We also checked the method of operation, the length of fusion, age, sex, osteoporosis, and body mass index. The body mass index (BMI), calculated as weight / height^2 (kg/m^2), was used as the index of relative weight. Furthermore, preoperative radiologic features of patients required additional surgery were studied to determine the risk factors for clinical deterioration.

Table 1. Distribution of subgroups according to postoperative delay, existence of ASD*, and need for operation

Group	Follow-up (years)	Additional surgery	No. of patients	Percentage of total series
1: with ASD			61	30
1.A		Reoperated	15	7 (25)
1.A.a	>5	Reoperated	11	5 (18)
1.A.b	<5	Reoperated	4	2 (7)
1.B		Not reoperated	46	23 (75)
1.B.a	>5	Not reoperated	36	18 (59)
1.B.b	<5	Not reoperated	10	5 (16)
2: without ASD			140	70
2.a	>5		82	41 (59)
2.b	<5		58	29 (41)

*ASD : adjacent segment degeneration, The numbers in parentheses represent the percentages in the subgroups compared with the main groups 1 and 2

Table 2. Baseline characteristics and radiologic data for patients in Group 1, 2, and 1.A

	Group 1	Group 2	Group 1.A
Number of patients	61	140	15
Women (No. of patients)	42 (69)	90 (64)	10 (67)
Age at surgery (years)	57±12*	51±12	58±7
Body mass index (kg/m^2)	25±3	24±3	24±4
Lumbar lordosis (°)	37±13*	39±13	37±15
Laminar inclination angle (°)	134±8*	125±8	138±10*
Facet sagittalization (°)	73±17*	75±12	72±21
Facet tropism (°)	10±4*	6±2	11±3
Facet joint volume (mm^2)	189±43*	177±18	195±55
Preexisting disc degeneration (grade)	3.6±0.8*	3.1±0.5	3.7±0.6*
Preexisting stenosis (No. of patients)	36 (59)	71 (51)	5 (33)
Lordosis at the fused segment (°)	15±10	13±7	13±8
Flexion-extension angle (°)	9±5*	7±3	9±4
Length of fusion	1.5±0.8	1.3±0.6	1.6±1.2
Instrumentation (No. of patients)	50 (82)	128 (91)	12 (80)

*p<0.05, Values represented as the means±standard deviations, The numbers in parentheses represent the percentages compared with each groups

Table 3. Classification of disc degeneration*

Grade	Structure	Distinction of nucleus and anulus	Signal intensity	Height of intervertebral disc
I	Homogeneous, bright white	Clear	Hyperintense, isointense to cerebrospinal fluid	Normal
II	Inhomogeneous with or without horizontal bands	Clear	Hyperintense, isointense to cerebrospinal fluid	Normal
III	Inhomogeneous, gray	Unclear	Intermediate	Normal to slightly decreased
IV	Inhomogeneous, gray to black	Lost	Intermediate to hypointense	Normal to moderately decreased
V	Inhomogeneous, black	Lost	Hypointense	Collapsed disc space

*This grading system for the assessment of lumbar disc degeneration used contemporary magnetic resonance (MR) imaging technique. In this grading system, signal intensity of intervertebral disc was evaluated on T2-weighted sagittal MR image

Statistical analysis

Data were analyzed using a commercially available statistical software package (SPSS for Windows, version 10.0. 1999; SPSS, Inc., Chicago, IL). Categorical variables were compared using the Fisher exact two-tailed test, the Pearson chi-square test, or the test for linear trend. Continuous variables were compared between groups by applying the Mann-Whitney U-test or t-tests. Univariate association of continuous variables was tested using Spearman rank correlation coefficients (r_s). Univariate and multivariate odd ratios and 95% confidence intervals of risk factors for adjacent segment degeneration were analyzed with the aid of unconditional logistic regression. P value less than 0.05 was considered significant.

Results

The patients were distributed into groups according to the existence of adjacent segment degeneration or not. Subgroups were defined according to the length of follow-up (minimum 3 years and minimum 5 years) and the need for reoperation or not. Sixty-six percent of our study group had minimal 5-year follow-up. The results are listed in Table 1. There were 140 patients (70%) in Group 2 who showed neither radiologic degeneration of adjacent segment nor neurologic deterioration. On the other hand, there were 61 patients (30%) in Group 1 who showed radiologic degeneration of adjacent segment with or without neurologic deterioration. Group 1.A included 15 patients (7%) who required reoperation for neurologic deterioration among the main Group 1. As expected, the degeneration of cranial adjacent segments was more frequently detected than that of caudal adjacent segments. Fifty-six patients (92%) showed radiologic degeneration of cranial adjacent segment, but only five patients (8%) showed that of caudal adjacent segment. Statistically significant differences were found in age at surgery (p=0.002), the postoperative delay (p=0.017), facet volume ($p<0.001$), motion range ($p<0.001$), laminar inclination ($p<0.001$), facet tropism ($p<0.001$), and preexisting disc degeneration ($p<0.001$) of adjacent segment between each group (Table 2). Among these, laminar inclination (p=0.028) and preexisting disc degeneration (p=0.017) of adjacent segment were significantly correlated with reoperation.

Table 4. Detail data for patients in group 1.A

Case No.	Age /Sex	Radiologic results		Symptom before 2nd operation	Time to 2nd operation (month)	Segment of degeneration	2nd operation
		LI	DD				
1	67/M	139	4	Radiculopathy	62	Cranial	Fusion extension
2	53/F	140	4	Cauda equina	79	Caudal	Fusion extension
3	42/M	143	4	Motion induced back pain	14	Cranial	PLIF
4	40/F	138	3	Radiculopathy	24	Cranial	Laminectomy
5	66/F	140	3	Motion induced back pain	60	Cranial	Fusion extension
6	67/F	137	4	Radiculopathy	62	Cranial	Laminectomy
7	59/F	137	4	Radiculopathy	73	Cranial	Laminectomy
8	70/F	138	4	Motion induced back pain	65	Cranial	Fusion extension
9	55/M	136	3	Radiculopathy	62	Cranial	Laminectomy
10	59/M	133	4	Radiculopathy	71	Caudal	Laminectomy
11	64/F	137	4	Radiculopathy	18	Cranial	Laminectomy
12	56/F	138	4	Cauda equina	64	Cranial	Laminectomy
13	58/F	139	4	Radiculopathy	36	Cranial	ALIF
14	55/M	135	4	Radiculopathy	64	Cranial	Laminectomy
15	61/F	139	3	Cauda equina	68	Cranial	Laminectomy

LI : laminar inclination angle, DD : disc degeneration according to Table 3., PLIF : posterior lumbar interbody fusion, ALIF : anterior lumbar interbody fusion

We observed that the incidence of adjacent segment degeneration was much higher in olderly patients, especially older than 60 years of age. The postoperative delay (the length of postoperative follow-up) clearly influenced the existence of secondary degeneration of the adjacent motion segments. The mean delay for appearance of junctional degeneration was 63 months. This explains why, in the subgroup of 72 patients with less than 5 years' follow-up, there are only 14 patients (19%) who developed problems, whereas, in the group of patients with greater than 5 years' follow-up, 47 of 129 showed degeneration of adjacent segment (36%). Interestingly, the ratio between reoperated and nonreoperated patients presenting degeneration of adjacent motion segment was higher in the group with less than 5 years' follow-up (28% reoperation rate) than in the group with greater than 5 years' follow-up (23% reoperation rate). This could signify that the most severe alterations, leading to instability or neurologic problems, occur earlier period. Laminar inclination angle and preexisting disc degeneration at adjacent segment in reoperated group (Group 1.A) were observed more significantly than those in non-reoperated group. Laminar inclination angle of adjacent segment was 130° ±8° in Group 1.B, 125°±8° in Group 2, and 138°±10° in Group 1.A. Preexisting disc degeneration at adjacent segment was 3.4±0.7 in Group 1.B, 3.1±0.5 in Group 2, and 3.7±0.6 in Group 1.A according to Christian's grading system.

Reoperations

Among 61 patients who developed the degeneration of adjacent segments, 15 required second operations because of radicular pain as well as severe back pain or the development of instability with back pain and neurologic deficits. Nine patients showed radiculopathy, other three developed cauda equina syndromes and the remaining three experienced motion induced back pain. An average period between the initial surgery and second operation was 54 months (range, 14-79 months). The detailed data are described in Table 4.

Thirteen patients (87%) showed radiologic degeneration of cranial adjacent segment, but only two patients (13%) showed that of caudal adjacent segment. Four patients required a one-level extension of the fusion, three laminectomies at the junctional level, and one anterior fusion. Two patients required a multilevel extension of the posterior instrumentation and fusion. The surgical approach was selected according to the presence or absence of instability. If there was segmental instability, a extension of the fusion was selected. If there was no instability, decompression alone (laminectomy) was selected. After the second operation, most of the patients improved of neurologic symptoms. However, the reoperations were in certain cases, considered as heavy burden especially in elderly patients.

Discussion

Based on radiographic analysis, several investigators have argued that the degeneration of adjacent segment after spinal fusion is nothing more than the normal degenerative process rather than a consequence of biomechanical stresses[2,35]. These investigators emphasized that most spinal fusions are performed for severe degenerative disease that is likely not isolated to the treated segments. Studying 16 patients who had undergone anterior interbody fusions with age and gender matched controls, Van Horn and Bohnen did not find any significant increase in degeneration or instability between fusion and control groups[43]. Seitsalo et al. evaluated 227 patients treated either conservatively or with segmental fusion for spondylolisthesis and also noted no marked difference in adjacent segment degeneration between the two groups[40]. Similar results were obtained by Hambly et al. after radiographically evaluating 42 patients who had undergone posterolateral fusions[20]. In contrast, a recent study by Guigui et al. comparing posterolateral fusion patients with age and gender matched controls found significantly higher rates of degenerative changes next to fused segments[19]. Although the development of adjacent segment degeneration can be considered as a part of the normal aging and degenerative process, this phenomenon appears to be at least partly influenced by the altered stresses that arise as a consequence of lumbar fusion[31,37].

Individual patient characteristics may also affect the occurrence of adjacent segment degeneration[35]. In particular, age at surgery was a potential risk factor for the radiologic degeneration of adjacent segment in this study, especially older than 60 years of age. Authors suspected that age was likely related to the decreased ability of the aged spine to accommodate the biomechanical alterations imposed by a fusion. Aota et al. observed that the incidence of adjacent segment degeneration was much higher in patients older than 55 years of age[4]. Several other clinical studies have further corroborated a trend of increasing adjacent segment degeneration with older age[13,23,38,47]. Osteoporosis also has been reported as a potential risk factor for adjacent segment degeneration by several investigators, but the significance of the such risk remains uncertain in this study[4,13].

Although the exact mechanism remains uncertain, altered biomechanical stresses appear to play a key role in the development of adjacent segment degeneration[2,12,21]. Lee and Langrana studied the effect of a L5-S1 posterior midline, anterior interbody, and posterior intertransverse fusion in a multisegment (L3-S1) cadaveric spine model[26]. Compression-bending loads were used to flex spinal specimens to 20° of flexion followed by extension to the neutral position before and after fusion. Each fusion technique specifically shifted the center of rotation leading to increased stress on the facets and/or disc of the adjacent mobile segment. Preexisting facet hypertrophy of adjacent segment may deteriorate more easily after fusion because of the increased stress on the facet[9,33,35,45]. In this study, the more facet volume, the more adjacent segment degenerations. Besides the facet hypertrophy of adjacent segment, increased FEA was associated with the degeneration of adjacent segment[36]. For the compensation of the fixed motion range on fused segment, both the range of motion and the dynamic stress on adjacent motion segment increased. This may lead to the consequent degeneration of adjacent segment[36,49].

The preoperative condition of the adjacent disc has been another factor implicated in adjacent segment degeneration based on the assumption that an already degenerated disc is more likely to deteriorate[8,29]. In a similar manner, investigators have argued that certain spinal conditions predispose patients to adjacent segment degeneration. Guigui et al. retrospectively studied 102 patients who underwent posterolateral fusion for a variety of indications and found a significantly higher incidence of adjacent segment degeneration in patients of lumbar stenosis[19]. The presence of lumbar stenosis was considered as indicative of a degenerated spine that would be less likely to tolerate the increased stress caused by the fusion process[1]. However, preexisting stenosis does not seem to be related with the development of adjacent segment degeneration in this study. In addition to facet loading and increased mobility, in vitro investigations involving finite element models with the same imposed load and human cadaveric spine studies with the same imposed motion before and after fusion have shown that increased intradiscal pressure would develop in the disc immediately neighboring a fused segment[7,9,46]. Using human cadaveric lumbar spines examined under the same imposed motion, Cunningham et al. found that the adjacent intradiscal pressures were up to 45% higher after instrumented posterior fusion[11]. Therefore, patients with a preexisting degenerated disc have much more chances of adjacent segment disease because of increased intradiscal pressure on adjacent motion segment[42].

In the current study, both laminar inclination and facet tropism were related to adjacent segment degeneration after fusion. Horizontalization of the lamina has been thought to be related to the development of degenerative spondylolisthesis[27,31]. Nagaosa et al. performed a retrospective case-control study and concluded that horizontalization of the lamina was a pathoanatomic risk factor that could predispose to the development of degenerative spondylolisthesis[28]. Facet tropism is defined as an asymmetry in the facet joint[22]. It has been postulated that this could result in disc pathology because abnormal rotation of the spinal motion segment would occur when tropism exists, resulting in increasing torsional stress to the intervertebral disc[14,30,44]. We hypothesize that laminar inclination may affect sagittal instability and that facet tropism may affect rotational instability. In 1967, Farfan and Sullivan first suggested the correlation between the facet tropism and the development of lumbar disc degeneration[14]. Noren et al. also emphasized the association facet tropism with the development of disc herniation and degeneration at all lumbar levels[30]. Further, Park et al. described that differences in the degree of facet tropism and disc degeneration might be considered a key factor in distinguishing the development of far lateral lumbar disc herniation from that of posterolateral lumbar disc herniation[34].

In the current study, there were obvious differences in laminar inclination and preexisting disc degeneration, respectively, between reoperated group and the other groups. Most patients who required reoperations because of neurologic deterioration showed both horizontalization of the adjacent lamina and the degeneration of adjacent disc. Our data suggest that, when both of the factors that may lead to segmental instability are present, spondylolisthesis or thickening of the ligamentum flavum would be accelerated and may led to radiculopathy or cauda equina syndrome[25]. These results suggest that existence of horizontalization of the lamina and disc degeneration at adjacent segment may be the major risk factors for neurologic deterioration after lumbar fusion.

Conclusion

The radiologic degeneration of adjacent segment after lumbar fusion can be predicted in terms of each preoperative radiologic factor, age and the postoperative delay. Laminar inclination and preexisting disc degeneration of adjacent segment may be important risk factors for neurologic deterioration resulting from accelerated degenerative change of adjacent segment after lumbar fusion. Thus, decision on the level of fusion area needs more careful attention, when risk factors are present. Further, we suggest that if lamina horizontalization and disc degeneration above the fused segment exist, patients should be informed about possible extension of the fusion area that may be necessary in the future.

• Acknowledgement
This Research was supported by the Chung-Ang University Research Grants in 2003.

References

1. Aiki H, Ohwada O, Kobayashi H, Hayakawa M, Kawaguchi S, Takebayashi T, et al : Adjacent segment stenosis after lumbar fusion requiring second operation. **J Orthop Sci 10** : 490-495, 2005
2. Akamaru T, Kawahara N, Tim Yoon S, Minamide A, Su Kim K, Tomita K, et al : Adjacent segment motion after a simulated lumbar fusion in different sagittal alignments : a biomechanical analysis. **Spine 28** : 1560-1566, 2003
3. Anderson CE : Spondyloschisis following spine fusion. **J Bone Joint Surg 38A** : 1142-1146, 1956
4. Aota Y, Kumano K, Hirabayashi S : Postfusion instability at the adjacent segments after rigid pedicle screw fixation for degenerative lumbar spinal disorders. **J Spinal Disord 8** : 464-473, 1995
5. Barry M, Livesley P : Facet joint hypertrophy : the cross-sectional area of the superior articular process of L4 and L5. **Eur Spine J 6** : 121-124, 1997
6. Booth KC, Bridwell KH, Eisenberg BA, Baldus CR, Lenke LG : Minimum 5-year results of degenerative spondylolisthesis treated with decompression and instrumented posterior fusion. **Spine 24** : 1721-1727, 1999
7. Chen CS, Cheng CK, Liu CL : A biomechanical comparison of posterolateral fusion and posterior fusion in the lumbar spine. **J Spinal Disord Tech 15** : 53-63, 2002
8. Chosa E, Goto K, Totoribe K, Tajima N : Analysis of the effect of lumbar spine fusion on the superior adjacent intervertebral disk in the presence of disk degeneration, using the three-dimensional finite element method. **J Spinal Disord Tech 17** : 134-139, 2004
9. Chow DH, Luk KD, Evans JH, Leong JC : Effects of short anterior lumbar interbody fusion on biomechanics of neighboring unfused segments. **Spine 21** : 549-555, 1996
10. Christian WA, Metzdorf A, Zanetti M : Magnetic resonance classification of lumbar intervertebral disc degeneration. **Spine 26** : 1873-1878, 2001
11. Cunningham BW, Kotani Y, McNulty PS, Cappuccino A, McAfee PC : The effect of spinal destabilization and instrumentation on lumbar intradiscal pressure : an in vitro biomechanical analysis. **Spine 22** : 2655-2663, 1997
12. Eck JC, Humphreys SC, Hodges SD : Adjacent-segment degeneration after lumbar fusion : a review of clinical, biomechanical, and radiologic studies. **Am J Orthop 28** : 336-340, 1999
13. Etebar S, Cahill DW : Risk factors for adjacent-segment failure following lumbar fixation with rigid instrumentation for degenerative instability. **J Neurosurg 90** : 163-169, 1999
14. Farfan HF, Sullivan JD : The relation of facet orientation to intervertebral disc failure. **Can J Surg 10** : 179-185, 1967
15. Ghiselli G, Wang JC, Bhatia NN, Hsu WK, Dawson EG : Adjacent segment degeneration in the lumbar spine. **J Bone Joint Surg 86A** : 1497-1503, 2004
16. Glaser J, Stanley M, Sayre H, Woody J, Found E, Spratt K : A 10-year follow-up evaluation of lumbar spine fusion with pedicle screw fixation. **Spine 28** : 1390-1395, 2003
17. Gillet P : The fate of the adjacent motion segments after lumbar fusion. **J Spinal Disord Tech 16** : 338-345, 2003
18. Grobler LJ, Robertson PA, Novotny JE, Pope MH : Etiology of spondylolisthesis : assessment of the role played by lumbar facet joint morphology. **Spine 18** : 80-91, 1993
19. Guigui P, Lambert P, Lassale B, Deburge A : Long-term outcome at adjacent levels of lumbar arthrodesis. **Rev Chir Orthop Reparatrice Appar Mot 83** : 685-696, 1997
20. Hambly MF, Wiltse LL, Raghavan N, Schneiderman G, Koenig C : The transition zone above a lumbosacral fusion. **Spine 23** : 1785-1792, 1998
21. Hilibrand AS, Robbins M : Adjacent segment degeneration and adjacent segment disease : the consequences of spinal fusion? **Spine J Suppl 6** : 190-194, 2004
22. Javedan SP, Dickman CA : Cause of adjacent-segment disease after spinal fusion. **Lancet 354** : 530-531, 1999
23. Kumar MN, Baklanov A, Chopin D : Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. **Eur Spine J 10** : 314-319, 2001
24. Lai PL, Chen LH, Niu CC, Chen WJ : Effect of postoperative lumbar sagittal alignment on the development of adjacent instability. **J Spinal Disord Tech 17** : 353-357, 2004
25. Lai PL, Chen LH, Niu CC, Fu TS, Chen WJ : Relation between laminectomy and development of adjacent segment instability after lumbar fusion with pedicle fixation. **Spine 29** : 2527-2532, 2004
26. Lee CK, Langrana NA : Lumbosacral spinal fusion. A biomechanical study. **Spine 9** : 574-581, 1984
27. Macnab I : Spondylolisthesis with an intact neural arch. **J Bone Joint Surg 32B** : 325-333, 1950
28. Nagaosa Y, Kikuchi S, Hasue M : Pathoanatomic mechanisms of degenerative spondylolisthesis : a radiographic study. **Spine 23** : 1447-1451, 1998
29. Nakai S, Yoshizawa H, Kobayashi S : Long-term follow-up study of posterior lumbar interbody fusion. **J Spinal Disord 12** : 293-299, 1999
30. Noren R, Trafimow J, Andersson GB, Huckman MS : The role of facet joint tropism and facet angle in disc degeneration. **Spine 16** : 530-532, 1991

31. Okuda S, Iwasaki M, Miyauchi A, Aono H, Morita M, Yamamoto T : Risk factors for adjacent segment degeneration after PLIF. **Spine 29** : 1535-1540, 2004
32. Ozgur BM, Hughes SA, Baird LC, Taylor WR : Minimally disruptive decompression and transforaminal lumbar interbody fusion. **Spine J 6** : 27-33, 2006
33. Panjabi MM, Oxland T, Takata K, Goel V, Duranceau J, Krag M : Articular facets of the human spine. Quantitative three-dimensional anatomy. **Spine 18** : 1298-1310, 1993
34. Park JB, Chang H, Kim KW : Facet tropism : a comparison between far lateral and posterolateral lumbar disc herniations. **Spine 26** : 677-679, 2001
35. Park P, Garton HJ, Gala VC, Hoff JT, McGillicuddy JE : Adjacent segment disease after lumbar or lumbosacral fusion : review of the literature. **Spine 29** : 1938-1944, 2004
36. Park SW, Kim YB, Hwang SN, Choi DY, Min BK, Suk JS : Differences in biomechanical factors for fusion transition syndrome of lumbar spine between pedicle screw fixation and posterior lumbar interbody fusion groups. **J Korean Neurosurg Soc 33** : 252-258, 2003
37. Quinell RC, Stockdale HR : Some experimental observations on the influence of a single floating fusion on the remaining lumbar spine. **Spine 6** : 263-267, 1981
38. Rahm MD, Hall BB : Adjacent-segment degeneration after lumbar fusion with instrumentation : a retrospective study. **J Spinal Disord 9** : 392-400, 1996
39. Schlegel JD, Smith JA, Schleusener RL : Lumbar motion segment pathology adjacent to thoracolumbar, lumbar, and lumbosacral fusions. **Spine 21** : 970-981, 1996
40. Seitsalo S, Schlenzka D, Poussa M, Osterman K : Disc degeneration in young patients with isthmic spondylolisthesis treated operatively or conservatively : a longterm follow-up. **Eur Spine J 6** : 393-397, 1997
41. Steib JP : Resultats des osteosynthese-arthrodeses lombaires et lombo-sacrees : correlation radio-clinique a propos de 113 cas revus avec 3,8 annees de recul moyen. **Rev Chir Orthop 86** : 127-135, 2000
42. Throckmorton TW, Hilibrand AS, Mencio GA, Hodge A, Spengler DM : The impact of adjacent level disc degeneration on health status outcomes following lumbar fusion. **Spine 28** : 2546-2550, 2003
43. Van Horn JR, Bohnen LM : The development of discopathy in lumbar discs adjacent to a lumbar anterior interbody spondylodesis. A retrospective matched-pair study with a postoperative follow-up of 16 years. **Acta Orthop Belg 58** : 280-286, 1992
44. Vanharanta H, Floyd T, Ohnmeiss DD, Hochschuler SH, Guyer RD : The relationship of facet tropism to degenerative disc disease. **Spine 18** : 1000-1005, 1993
45. van Schaik JP, van Pinxteren B, Verbiest H, Crowe A, Zuiderveld KJ : The facet orientation circle. A new parameter for facet joint angulation in the lower lumbar spine. **Spine 22** : 531-536, 1997
46. Weinhoffer SL, Guyer RD, Herbert M, Griffith SL : Intradiscal pressure measurements above an instrumented fusion. A cadaveric study. **Spine 20** : 526-531, 1995
47. Wiltse LL, Radecki SE, Biel HM, DiMartino PP, Oas RA, Farjalla G, et al : Comparative study of the incidence and severity of degenerative change in the transition zones after instrumented versus noninstrumented fusions of the lumbar spine. **J Spinal Disord 12** : 27-33, 1999
48. Wiltse LL, Winter RB : Terminology and measurement of spondylolisthesis. **J Bone Joint Surg 65A** : 768-772, 1983
49. Yeo SJ, Park SW, Kim YB, Hwang SN, Choi DY, Suk JS, et al : The Change of Motion Ranges of Adjacent Vertebral Joints after Lumbar Fusion Operation. **J Korean Neurosurg Soc 29** : 1456-1460, 2000

Commentary

Although previous reports have described adjacent segments degeneration (ASD) after lumbar fusion, it has not been possible to determine clearly whether this results from normal aging and degenerative process or is secondary to the altered stress, but it appears to be at least partly influenced by the increased stress that arise as a consequence of the fusion. Numerous biomechanical studies have confirmed that the fusion process imposes significant amounts of stress at the adjacent segments.

In general, the radiographic finding of ASD appears to be very common, with some studies even reporting a 100% incidence. Symptomatic ASD, in contrast, seems to occur less frequently with incidence ranging from 5.2 to 18.5%. There are a few reports of risk factors for ASD after lumbar fusion in terms of preoperative radiologic findings and other various factors. This is probablely due to the difficulties because of varieties in degenerative lumbar diseases, fused levels, numbers of fused segments, and fusion techniques. The higher incidence rate of ASD was reported among patients who underwent multisegments transpedicular fixation likely reflect the earlier interval to the development of ASD that has been associated with rigid instrumentation or the potential injury to the facet joint of the adjacent segment that can occur during placement of the superior pedicle screws.

In this study, three different fusion methods were used with the intertransverse fusion performed in about 64% of cases, which is less solid than PLIF (used in 34%) and TLIP (2%). The different fixation methods together with the short follow-up duration have resulted in relatively long mean delay (63months) before the appearance of ASD and low incidence rate (30%) of ASD compared to other studies. The authors suggested that horizontalization of the lamina and disc degeneration at the adjacent segment may bo the major risk factors for neurologic deterioration after lumbar fusion. But various risk factors for ASD after lumbar fusion have been well described including age, sex, pedicle screw fixation, fusion length, preexisting degenerative changes, facet sagittalization, facet tropism, lumbar lordosis, scoliosis, laminar inclination, and others.

Larger number of solid fixation cases other than intertransverse fusion and longer follow-up, at least more than 10 years instead of 3 years, are necessary for more detailed determination of preoperative risk factors for ASD after lumbar fusion.

Soohan Kim, M.D.
Department of Neurosurgery
Chonnam National University Hospital