Risk factors for radiologic adjacent segment degeneration after lumbar fusion

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ABSTRACT

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Adjacent segment degeneration (ASD) is one of the major complications after lumbar fusion. Several studies have evaluated the risk factors of ASD. Although the paraspinal muscles play an important role in spine stability, no study has assessed the relationship between paraspinal muscle atrophy and the incidence of ASD after lumbar fusion. The purpose of this clinical study was to verify the known risk factors of ASD such as body mass index (BMI), pre-operative adjacent facet joint degeneration, disc degeneration, and to investigate the relationship between paraspinal muscle atropy and ASD.

To calculate the appropriate sample size for the study, we performed a pre-study analysis of the paraspinal muscle cross-sectional area (CSA), and estimated that at least 35 cases would be needed for each group. Among the 510 patients who underwent posterior lumbar fusion for degenerative lumbar disease between January 2009 and October 2009, a total of 50 patients with

ASD after surgery were selected. Another group of 50 matched patients with degenerative lumbar disease without ASD after spinal fusion were selected as the control group. Each patient in the ASD group was matched with a control patient according to age, sex, fusion level, and follow-up period.

The risk factors considered were higher BMI, pre-operative adjacent segment disc and facet degeneration, and pre-operative paraspinal muscle atrophy and fatty degeneration. The radiographic data were compared between the ASD and control groups, to determine the predictive factors of adjacent segment degeneration after posterior lumbar fusion by using logistic regression analysis.

Multivariate logistic regression analysis indicated that higher BMI (OR: 1.353, p = 0.008), preoperative facet degeneration on computed tomography (CT) examination (OR: 3.075, p = 0.011), disc degeneration on magnetic resonance imaging (MRI) (OR: 2.783, p = 0.003), fatty degeneration (OR: 1.080, p=0.044), and a smaller relative cross sectional area (CSA) of the paraspinal muscle preoperatively (OR: 0.083, p = 0.003) were significant factors for predicting the development of ASD.

In conclusion, the occurrence of radiologic ASD is most likely multifactorial, and is associated with a higher BMI, pre-existing facet and disc degeneration

on preoperative examination, and a smaller pre-operative relative CSA of the paraspinal muscle on MRI.

Key words : adjacent segment degeneration, risk factors, paraspinal muscle atrophy, lumbar spinal fusion, posterior lumbar interbody fusion

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I. INTRODUCTION

Spinal fusion is currently the standard surgical treatment for various lumbar spinal diseases, ranging from degenerative disorders to deformities. Although posterior lumbar fusion with pedicle screw fixation has yielded satisfactory clinical results, solid fusion can accelerate degeneration of the adjacent unfused segment.[1,2,3,4,5,6] A long-term follow-up study after fusion surgery indicated the presence of degenerative changes such as segmental instability, spinal stenosis, intervertebral disc lesion, spondylolisthesis, and fracture at the adjacent segments.[7,8,9] Moreover, abnormal loading and increased mobility in the adjacent segments may explain the development of adjacent segment degeneration (ASD).[5,10,11,12,13]

Based on radiographic evidence, the prevalence of ASD is reported to be more than 40%, and the incidence of symptomatic ASD that requires revision surgery reportedly ranges from 5.2% to 18.5%.[5,14] Several risk factors for the development of ASD have

been proposed, including age, female sex, body weight, body mass index (BMI), postmenopausal state, osteoporosis, lumbar stenosis, preexisting degenerated disc at the adjacent level, fusion length, rigid pedicle screw instrumentation, injury to the facet joint of the adjacent segment, and sagittal mal-alignment.[5,15,16,17,18,19]

The spine consists of vertebral bodies, intervertebral discs, facet joints, spinal ligaments, and muscles. Similar to the other spine components, paraspinal muscles play an important role in spine stability.[20,21,22] A recent study reported that a decrease in the cross-section area (CSA) of the multifidus muscle is related to lumbar disc herniation.[23] Moreover, Onesti et al.[24] reported that paraspinal muscle atrophy, which occurs after spinal fusion surgery, causes failed back surgery syndrome. In addition, extensive degeneration and weakness of the lumbar extensor muscles are believed to be risk factors of ASD.[25] However, to our knowledge, no studies have analyzed the relationship between preoperative paraspinal muscle atrophy and ASD.

In the present study, we aimed to verify the known risk factors of ASD, such as BMI, pre-operative adjacent facet joint degeneration, and disc degeneration,[17,18,19] and to assess the relationship between paraspinal muscle atrophy and ASD.

II. MATERIALS AND METHODS

1. Subjects

To calculate an appropriate sample size for the study, we performed a pre-study analysis of the CSA of the paraspinal muscles, which demonstrated differences between the ASD and non-ASD groups with an effect size of 0.60. With this effect size, to achieve a power of at least 80% using independent-samples *t*-test with a significance level of 0.05, at least 35 cases are needed for each group.

We retrospectively evaluated the results of 510 instrumental posterior lumbar or lumbosacral fusions performed using posterior lumbar interbody fusion (PLIF) combined with pedicle screw fixation at our institution for the treatment of degenerative conditions between January 2009 and October 2009. The mean follow-up duration was 20.5 months. We excluded patients treated for non-degenerative conditions, such as trauma, tumor, infection, or inflammation, and those who had undergone previous fusion surgery. We also excluded patients who had a pathological condition at a site other than the lumbar spine, as confirmed by whole spine sagittal magnetic resonance imaging (MRI). The initial diagnosis included spinal stenosis, isthmic and degenerative spondylolisthesis, degenerative disc disease, and disc herniation.

Among these 510 patients, we selected 50 patients with radiologic evidence of ASD. Radiologic ASD was diagnosed based on the presence of olisthesis of >4mm, angular changes of >10° on flexion/extension lateral radiography, loss of disc height by >10%, or deterioration of 2 or more grades on the UCLA disc degeneration scale (Table 1).[6, 14, 26, 27] Radiologic ASD was also diagnosed based on MRI findings, in cases where the modified Pfirrmann classification (Table 2) [28] indicated a grade of IV and V, or where spinal stenosis or disc herniation was detected at an adjacent level. We measured disc height on neutral lumbar radiographs by determining the distance between the upper and lower vertebral endplates perpendicularly, measured from a point equidistant on the bisector line, connecting the middle points of the anterior and posterior disc heights (Figure 1).[29] Angular motion at the adjacent segment was measured between the inferior endplate line of the upper vertebral body and superior endplate line of the lower vertebral body on flexion/extension lateral radiographs.

Table 1. Grading system for disc degeneration on plain radiographs

Grade	Disc space narrowing	Osteophytes	Endplate sclerosis
I	-	-	-
II	+	-	-
III	±	+	-
IV	±	±	+

Table 2. Modified Pfirrmann scale for disc degeneration on MRI

Grade	Signal intensity of the nucleus pulposus and structure	Distinction of the nucleus and anulus
I	Hyperintense or isointense to CSF: bright white and homogeneous	Clear
II	Hyperintense or isointense to CSF (white) and inhomogeneous	Clear
III	Intermediate to CSF (light gray) and inhomogeneous	
IV	Hypointense to CSF (dark gray) and inhomogeneous	
V	Low intensity as compared to CSF (black) and inhomogeneous	

Grade IV and V: degenerated discs.

CSF, cerebrospinal fluid; MRI, magnetic resonance imaging

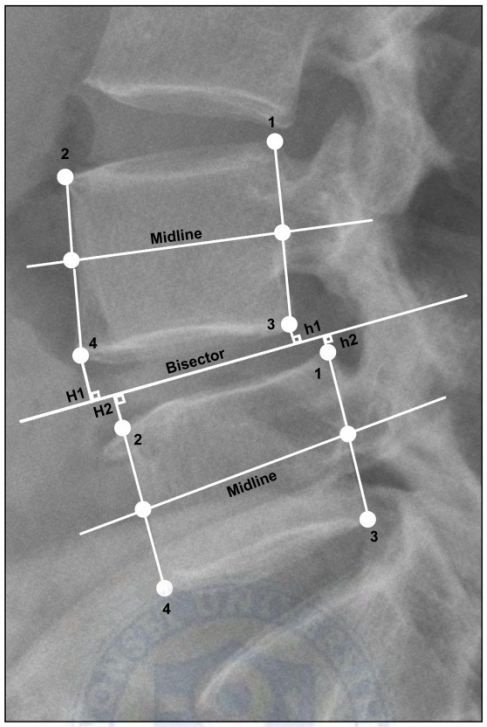

Figure 1. Measurement of disc height according to the Frobin method

The four corners of the vertebra are identified in the lateral radiographs (1, 2, 3, 4). The medial points, medial planes (midline), and the respective bisectors are marked. Disc height is then determined by the perpendicular distance between points 1 and 3 (dorsal height) and points 2 and 4 (ventral height). Disc height = (H1 + H2 + h1 + h2)/2.

To identify the risk factors for ASD, we selected a control group from the fusion population who were matched in a 1:1 manner to the ASD patients according to age, sex, fusion level, and follow-up duration; however, the groups were not matched by body height, body weight, BMI, and bone mineral density (BMD). The medical records and radiological study findings of the ASD and control groups were retrospectively reviewed.

2. Radiological assessments

We assumed that risk factors on preoperative CT and MRI would include disc and facet degeneration of the adjacent segment, paraspinal muscle atrophy, and paraspinal muscle fatty degeneration.

MRI was performed using 1.5-Tesla equipment (Magnetom Avanto, Siemens, Germany). Individuals were placed in the supine position with a foam wedge underneath the knees, to keep the hips and knees slightly flexed, and to maintain a standardized lumbar position and symmetric alignment of the lower limbs. In the axial plane, T2-weighted fast spin echo MR images (repetition time/echo time: 3500/118 ms, slice thickness: 4 mm, intersection gap: 0.4 mm, matrix: 336 × 384, and field of view: 250 mm) were obtained and analyzed.

Two neurosurgeons, who were blinded to all clinical information, graded the degeneration of the disc and facet joints in the proximal or distal adjacent segment to which the ASD subsequently developed.

The measurements were performed twice for each patient, with the average grade used for statistical analyses. Moreover, intra-and inter-examiner reliability analyses were performed. (Table 3)

Table 3. Intra-and inter examiner reliability using weighted kappa statistic.

	Intra-examiner	Inter-examiner
Preoperative facet degeneration grade on CT	0.73	0.72
Preoperative disc degeneration grade on MRI	0.88	0.88

CT, computed tomography; MRI, magnetic resonance imaging

The segment graded in the control group was the same as the matched patient in the disease group (Figure 2).

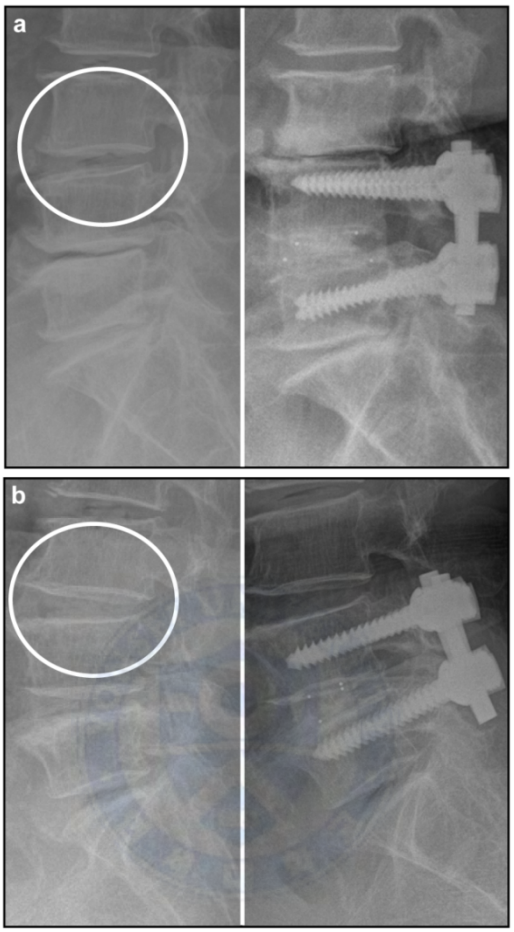

Figure 2. Grading degeneration of disc and facet joint after lumbar fusion

(a) Grading of disc and facet joint degeneration in the proximal or distal adjacent segment to which ASD subsequently developed, using preoperative MRI and CT; (b) the segment graded in the control group is the same as the matched patient in the disease group.

Disc degeneration on MRI was rated from grade 1 to 5 by using the classification system of Pfirrmann et al.[28], whereas facet joint degeneration on CT was rated from grade 0 to 3 according to the criteria of Weishaupt et al.[30] (Table 4) (Figure 3 and 4).

Table 4. Criteria for grading osteoarthritis of the facet joints

Grade	Criteria
0	Normal facet joint space (2 ± 4 mm width)
1	Narrowing of the facet joint space (<2 mm) and/or presence of a small number of osteophytes and/or mild hypertrophy of the articular process
2	Narrowing of the facet joint space and/or presence of a moderate number of osteophytes and/or moderate hypertrophy of the articular process and/or mild subarticular bone erosions
3	Narrowing of the facet joint space and/or presence of a large number of osteophytes and/or severe hypertrophy of the articular process and/or severe subarticular bone erosions and/or subchondral cysts

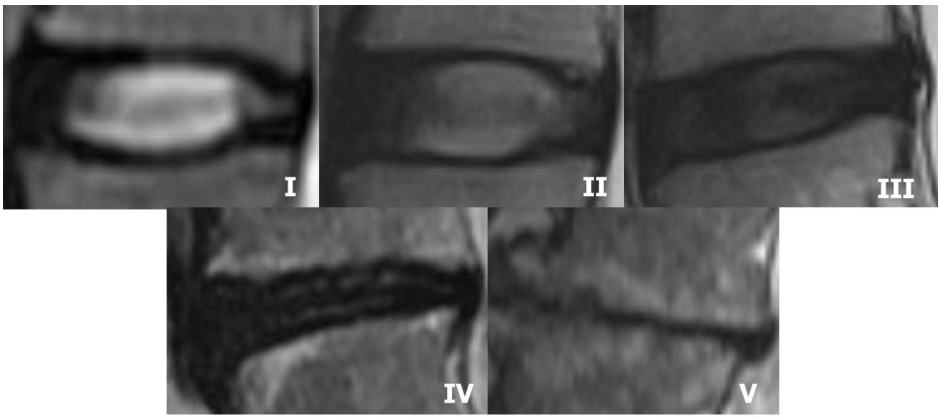

Figure 3. The five Pfirrmann magnetic resonance classification grades of lumbar intervertebral disc degeneration.

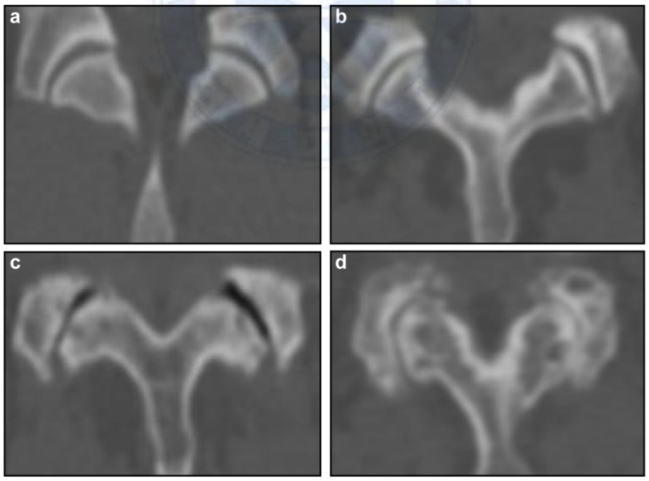

Figure 4. The four facet joint degeneration grades, as seen on CT.

The CSA of both sides of the paraspinal muscles (multifidus and erector spinae) and psoas major muscle were measured by drawing their outlines using the region of interest (ROI) of the PACS program (Centricity 3.0, General Electric Medical System, Milwaukee, WI, USA), and were calculated in mm^2. In the present study, the multifidus and erector spinae muscles were measured together as the paraspinal muscles. The maximum anatomical CSA (mm^2) of the paraspinal muscles was located between the L3/4 and L4/5 intervertebral disc levels in the neutral posture, whereas the CSA of the psoas major muscle was largest at the L4/5 disc level [31]. Therefore, the mean CSA of both sides of the paraspinal muscles (the multifidus and erector spinae) and the psoas major muscle was measured by drawing their outlines using the ROI in the L4/5 IV disc level with axial T2 weighted MRI, as described previously. For the analysis, we measured the CSA of the bilateral paraspinal muscles (PSM), the CSA of the bilateral psoas major muscles (PT), and the CSA of the disc (disc). Thereafter, we calculated the relative CSA (rCSA), which is the ratio of the CSA of the muscles to that of the disc at the same level. This ratio was used to control for the influence of body shape, body weight, and height on the CSA of the muscles (Figure 5).

In addition to the measurement of the CSA, a fat composition assessment can be used to estimate the degree of atrophy of the paraspinal muscle.[32] Fatty degeneration of the paraspinal muscle was estimated according to the method of Ranson et al.[33] using a threshold of 120 for the gray scale, to exclude the pixels representing fat content from each muscular CSA. This method has been used previously to quantify

the area of muscle tissue,[34] but it can also be used to quantify fatty infiltration. The amount of fat was calculated by subtracting the muscle without the fat value from the total muscle value. The images were adjusted with image-processing software (ImageJ, version 1.48, National Institutes of Health, USA) (Figure 6).

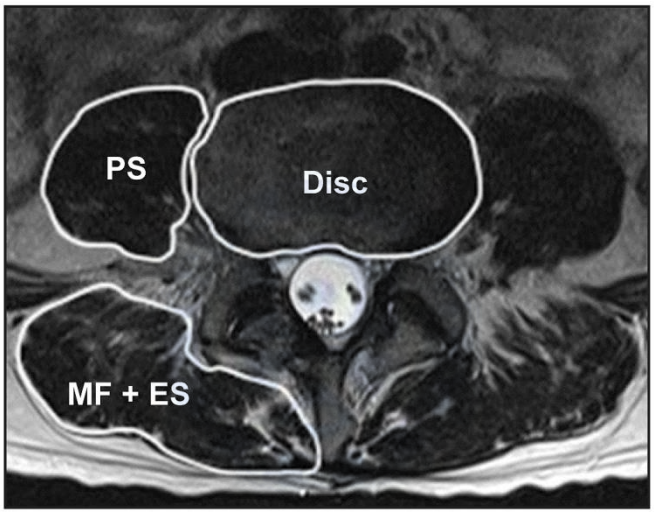

Figure 5. Cross-sectional area of the paraspinal muscles. T2 axial images obtained at the L4-L5 level, showing the lumbar paraspinal muscles. MF, multifidus muscle; ES, erector spinae muscle; PS, psoas muscle; Disc, intervertebral disc; MF+ES, paraspinal muscle.

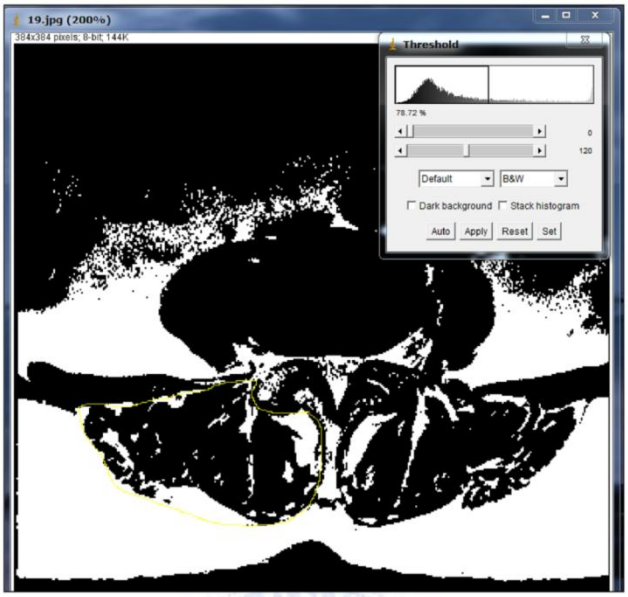

Figure 6. Region of interest (ROI) used to calculate the functional cross-sectional area (threshold, 0 = minimum and 120 = maximum) of the paraspinal muscles (the multifidus and erector spinae).

3. Statistical analysis

SPSS software (version 20.0) was used for the statistical analysis. Student's t-tests were used to compare demographic and radiologic data between the patients with and without ASD. *p* values of <0.05 were considered statistically significant. Logistic regression analysis was used to analyze the assumed risk factors with backward

elimination, in which variables with a significance level of >0.10 were removed. The confidence interval of the odds ratio was 95%. This study protocol was approved by the institutional review board of our institution. (IRB 3-2015-0088).

III. RESULTS

1. Demographic results

A total of 510 patients were retrospectively reviewed. The mean follow-up duration was 20.5 months. Of the 510 patients examined, 100 were eventually included in the study (50 for ASD, 50 for control). Of the 50 ASD patients, symptomatic ASD requiring surgery was observed in 8 patients. The demographic characteristics and procedural data of the patients are summarized in Table 5. The mean age at time of surgery was 60.80 years for the ASD group and 60.82 years for the control group, with no significant difference between the two groups ($p = 0.99$). The average follow-up duration was 42.98 months for the ASD group and 40.83 months for the control group, with no significant difference between the groups ($p = 0.51$). In terms of BMD, the average T-score was -2.38 for the ASD group and -2.26 for the control group, with no significant difference between the groups ($p = 0.69$). The average BMI for the ASD (24.86 kg/m^2) was higher than that for the control group (23.70 kg/m^2) ($p = 0.04$). No significant differences were observed between the two groups in terms of sex ratio, body height, body weight, BMD, or number of fused segments.

Table 5. Demographic results and surgery-related factors of the patients

Characteristics	ASD (n = 50)	Control (n = 50)	*p* value
Age (years)	60.80 ± 6.61	60.82 ± 6.43	0.99
Sex, n (%)			
Male	15 (30%)	15 (30%)	
Female	35 (70%)	35 (70%)	
Body Height (cm)	158.34 ± 7.87	159.98 ± 7.18	0.28
Body Weight (kg)	62.44 ± 9.40	60.84 ± 9.29	0.39
BMI (kg/m^2)	24.86 ± 2.78	23.70 ± 2.74	0.04
BMD (T-score)	-2.38 ± 0.91	-2.26 ± 1.41	0.69
No. of fused segments	1.68 ± 0.62	1.68 ± 0.62	1.00
F/U duration (months)	42.98 ± 16.73	40.83 ± 15.59	0.51

*Between-group comparisons were performed with Student's *t*-test.

BMI, body mass index; BMD, bone mineral density; F/U, follow up

2. Risk factors

With regard to the risk factors, the average facet degeneration grade was grade 1.50 in the ASD group and grade 0.92 in the control group ($p < 0.01$). The average change

in degenerative disc grade was 2.96 grades in the ASD group and 2.08 grades in the control group ($p < 0.01$).

The mean CSA of the disc did not differ significantly between groups ($p = 0.36$). The mean CSA and rCSA of the paraspinal muscles were significantly smaller in the ASD group than in the control group (both $p < 0.01$). However, the mean CSA and rCSA of the PT were not significantly different between the two groups (CSA, $p = 0.96$; rCSA, $p = 0.72$). The degree of fatty degeneration in the paraspinal muscle was significantly greater in the ASD group than in the control group ($p < 0.01$) (Table 6).

Table 6. Radiologic data for patients

Characteristics	ASD (n=50)	Control (n=50)	*p* value
Facet degeneration grade on CT	1.50 ± 0.54	0.92 ± 0.77	<0.01
Disc degeneration grade on MRI	2.96 ± 0.84	2.08 ± 0.83	<0.01
Paraspinal muscle fatty degeneration degree(%)	19.84 ± 9.13	13.62 ± 7.06	<0.01
CSA of the disc (mm^2)	1968 ± 271.63	1922 ± 235.78	0.36
CSA of the PSM (mm^2)	3438 ± 820.88	3905 ± 789.87	0.01
Relative CSA of the PSM	1.77 ± 0.44	2.04 ± 0.39	<0.01
CSA of the PT (mm^2)	1690 ± 681.65	1697 ± 646.62	0.96
Relative CSA of the PT	0.86 ± 0.31	0.88 ± 0.31	0.72

*Between-group comparisons were performed with Student's *t*-test

CSA, cross sectional area; PSM, paraspinal muscle; PT, psoas major muscle; CT, computed tomography; MRI, magnetic resonance imaging

3. Statistical results

A multivariate logistic regression analysis demonstrated that higher BMI (OR: 1.353, $p = 0.008$), preoperative facet degeneration on CT examination (OR: 3.075, $p = 0.011$), disc degeneration on MRI (OR: 2.783, $p = 0.003$), fatty degeneration (OR: 1.080, $p = 0.044$), and smaller rCSA (OR: 0.083, $p = 0.003$) of the preoperative paraspinal muscle were significant predictors of ASD (Table 7).

Table 7. Multivariate regression model of the predictors for radiologic ASD

Risk factor		Logistic regression	
	p value	Odds ratio	95% Confidence interval
BMI	0.008	1.353	1.081–1.695
Facet degeneration	0.011	3.075	1.290–7.330
Disc degeneration	0.003	2.783	1.422–5.447
Paraspinal muscle fatty degeneration	0.044	1.080	1.002–1.163
Paraspinal muscle rCSA	0.003	0.083	0.016–0.420
Psoas muscle rCSA	0.585		

Nagelkerke $R^2 = 0.553$

rCSA, relative cross sectional area; BMI, body mass index ; ASD, adjacent segment degeneration

IV. DISSCUSSION

In recent years, decompression combined with instrumented spinal fusion has become a standardized procedure for the treatment of degenerative lumbar disease. However, spinal fusion changes the normal biomechanics of the spine, and the loss of motion at the fused level is compensated by increased motion and load at the other unfused segments.

In 2004, Hilibrand et al.[35] defined ASD as a radiological change occurring in the adjacent segment after spinal fusion, regardless of the patient's symptoms. Previous studies have reported variable incidence rates for ASD after spinal fusion. Cheh et al.[14] reported that radiographic ASD occurred in 42.6% (80 of 188) of patients, and that clinical ASD developed in 30.3% (57 of 188) of patients at a minimum follow-up of 5 years. Park et al.[5] reviewed the results of 56 studies, and found that the incidence of ASD ranged from 8% to 100% when using only radiographic criteria; however, the incidence of symptomatic ASD was much lower, ranging from 5.2% to 18.5% during 44.8 to 164 months of follow-up. Aiki et al.[36] performed reoperations for symptomatic adjacent segment stenosis in 7.7% of patients who had undergone posterior lumbar fusion, after a minimum follow-up of 2 years. In the present study, 9.8% of patients had radiologic ASD, and additional surgery for ASD was required in 8 patients (1.6%)

at a mean follow-up of 20.5 months, indicating a relatively low incidence. However, the incidence is expected to increase as the follow-up duration increases.

As ASD is a major complication of fusion surgery, a considerable amount of effort has been made to identify the risk factors for ASD in order to predict and prevent this condition. Ou et al.[19] reported that higher BMI is a risk factor for ASD after lumbar fusion. Liang el al.[17] determined that higher BMI, preoperative adjacent disc degeneration, and preoperative adjacent disc bulging were risk factors for ASD. Moreover, Lee et al.[18] reported that preexisting facet degeneration is associated with a high risk of adjacent segment problems. In the present study, higher preoperative BMI, adjacent segment facet degeneration, and adjacent segment disc degeneration were significant risk factors for ASD. Park et al.[5] also identified the following as risk factors: older age, osteoporosis, female sex, post-menopausal state, addition of instrumentation, and fusion length. However, in the present study, we selected a control group by 1:1 matching with ASD patients according to age, sex, fusion level, and follow-up period; hence, there was no difference in these characteristics between the ASD and control patients.

We measured the CSA of the paraspinal muscle, psoas major muscle, and intervertebral disc in the lumbar spine in order to quantitatively evaluate muscle atrophy. We found that a smaller rCSA and lesser fatty degeneration of the paraspinal

muscle were risk factors for ASD. The lumbar paraspinal muscle is important for maintaining lumbar segmental stability, and defects in the paraspinal muscles are believed to cause disc degeneration. Advancing age is associated with marked changes in the spine, such as lumbar paraspinal muscle atrophy with CSA reduction, biochemical degenerative changes of the intervertebral disc with decreased disc height, and dehydration and increased intramuscular fat infiltration.[37] Paraspinal muscle atrophy is an important independent predictor of the presence and severity of back pain.[38, 39]

An increase in the load on the lumbar spine leads to a reduction in intervertebral disc height and in the ability to absorb force. In addition, increased loading of the lumbar spine also increases the load on the surrounding facet joints and spinal ligaments.[40, 41] Therefore, paraspinal muscle atrophy, with continuous increased spinal loading, would lead to the progression of disc and facet degeneration and spinal ligament hypertrophy. Moreover, lumbar fusion caused adjacent biomechanical alterations in simulated fusion models. Umehara et al.[16] reported a significant increase in the load burden and weight shearing of the posterior column at the adjacent segments after lumbar fusion. Weinhoffer et al.[42] reported that the intradiscal pressure increased significantly in the levels above the fused segments. Considerable biomechanical evidence has indicated the presence of increased segmental motion and increased intervertebral mechanical stress adjacent to fusion segments,[43,44,45] and such increases

are believed to be the primary causes of ASD. Many studies also have reported that an abnormal increase in the movement of the spinal segment may occur in cases of severe degeneration of the disc, facet, and posterior ligament structure .[46,47,48,49] Through such changes in intradiscal pressure, facet contact loading, and segmental motion after lumbar fusion, paraspinal muscle atrophy potentially adds more stress to the adjacent levels and accelerates the degenerative pathway.[19]

This study has some limitations. First, the study was conducted retrospectively by case selection, and was not randomized and controlled. Second, the length of the postoperative follow-up period was too short to evaluate the long-term results. However, this is the first study to assess paraspinal muscle atrophy as a risk factor of ASD. Nevertheless, future studies that include a long-term follow-up with a larger number of patients are needed.

IV. CONCLUSION

The occurrence of radiologic ASD is most likely multifactorial. Similar to previous studies, this study found that higher BMI, pre-exiting disc degeneration, and pre-exiting facet degeneration increase the risk of ASD. In addition, our results showed that pre-exiting paraspinal muscle atrophy and pre-exiting paraspinal muscle fatty degeneration are associated with a high risk of ASD.

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ABSTRACT(IN KOREAN)

요추 유합술 후 발생하는 방사선학적 인접마디 퇴행성 변성의 위험인자 분석

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인접마디 퇴행성 변성(adjacent segment degeneration; ASD)은 요추 유합술의 주요한 합병증의 하나이며, 그 위험 인자에 관한 많은 연구들이 지금껏 있어왔다. 척추인접 근육은 척추의 안정성을 유지시키는데 중요한 역할을 하는 것으로 알려져 있지만, 지금까지 척추 인접 근육의 위약과 ASD의 발생의 연관성에 대해서 시행된 연구는 없는 상태이다. 본 연구의 목적은 이제껏 발표된 연구들에서 밝혀졌던 ASD의 위험 인자인 높은 body mass index (BMI)와 수술 전 인접마디의 선행하는 후관절 및 수핵의 퇴행성 변화가 인접 마디 변성의 위험인자 인지를 다시 한번 확인하고, 새롭게는 척추 인접 근육의 위약과 ASD의 발생이 연관이 있는지를 밝히는데 있다.

통계학적으로 유의한 샘플 수를 결정하기 위해서 연구 전 선행 분석을 시행하였으며, 실험군과 대조군에 각각 최소한 35명의 환자가 필요한 것으로 계산되었다. 2009년 1월부터 2009년 10월까지 연세대학교 강남 세브란스 병원 신경외과에서 퇴행성 요추 질환으로 후방 유합술을 시행하고 추적관찰 중이던 510명의 환자 중 50명의 ASD 발생 환자를

선별 할 수 있었다. 또한, 실험군과 나이, 성별, 유합술 범위, 추적관찰 기간을 1대 1로 짝지은 ASD가 발생하지 않은 대조군을 선별하였다.

높은 BMI와 선행하는 인접마디의 후관절과 수핵의 퇴행성 변화, 그리고 수술 전 척추 인접 근육의 위약 및 지방변성이 ASD의 위험인자일 것으로 생각하고 분석을 시행하였다.

다중 로지스틱 회귀분석상 높은 BMI (OR : 1.353, p=0.008), 수술 전 인접 마디 후관절의 퇴행성 변화 (OR : 3.075, p=0.011), 수술 전 인접마디 수핵의 퇴행성 변화 (OR :2.783, p=0.003), 수술 전 척추 인접 근육의 작은 단면적 (OR=0.083, p = 0,003) 과 지방 변성 (OR 1.080, p= 0.044)이 ASD의 발생과 통계학적으로 유의성이 있음을 알 수 있었다. .

따라서 본 연구에서는 높은 BMI와, 수술 전 선행하는 인접마디의 후관절 및 수핵의 퇴행성 변화, 수술 전 척추 인접 근육의 위약 및 지방변성이 요추 유합술 후 인접 마디 퇴행성 변성의 위험인자라고 결론 지을 수 있었다.

핵심되는 말 : 인접 마디 퇴행성 변성, 위험 인자, 척추 인접 근육, 후방 요추 유합술, 척추 고정술