Risk Factors for Reoperation at Same Level after Decompression Surgery for Lumbar Spinal Stenosis in Patients with Diffuse Idiopathic Skeletal Hyperostosis Extended to the Lumbar Segments

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Abstract:

Introduction: Diffuse idiopathic skeletal hyperostosis (DISH) extended to the lumbar segments (L-DISH) reportedly has adverse effects on the surgical outcomes of lumbar spinal stenosis (LSS). However, the risk factors in patients with L-DISH have not been clarified. The purpose of this study was to investigate the long-term risk factors for reoperation at the same level after decompression surgery alone for LSS in patients with L-DISH in a retrospective cohort study.

Methods: A postoperative postal survey was sent to 1,150 consecutive patients who underwent decompression surgery alone for LSS from 2002 to 2010. Among all respondents, patients who exhibited L-DISH by preoperative total spine X-ray were included in this study. We investigated risk factors for reoperation at the same level as the initial surgery among various demographic and radiological parameters, including the lumbar ossification condition and computed tomography (CT) or magnetic resonance imaging findings.

Results: A total of 57 patients were analyzed. Reoperations at the same level as that of the index surgery were performed in 10 patients (17.5%) and at 11 levels within a mean of 9.2 years. Cox proportional hazard regression analysis indicated that the independent risk factors for reoperation were a sagittal rotation angle ≥10° (adjusted hazard ratio: 5.17) and facet opening on CT (adjusted hazard ratio: 4.82). Neither sagittal translation nor the ossification condition in the lumbar segments affected reoperations.

Conclusions: A sagittal rotation angle ≥10° and facet opening on preoperative CT were risk factors for reoperation at the same level as that of the index surgery in patients with L-DISH. The surgical strategy should be carefully considered in those patients.

Keywords:

Diffuse idiopathic skeletal hyperostosis, lumbar spinal stenosis, reoperation, decompression surgery, sagittal rotation angle, facet opening

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Introduction

Lumbar spinal stenosis (LSS) is a common condition and the most frequent indication for requirement of spinal surgery in elderly patients. The gold standard surgical procedure is decompression by laminectomy, fenestration, or microscopic/microendoscopic procedures. Poor outcomes due to postoperative instability after decompression sometimes become problematic because of disruption of the posterior supporting structures, especially in patients with spondylolisthesis or scoliosis. Therefore, additional fusion procedures are considered for LSS with segmental instability. However, the criteria for recommending additional fusion procedures remain unclear, and a recent randomized clinical trial failed to indicate effectiveness of fusion surgery in patients with spondylolisthesis[1,2]. Therefore, determination of the thresh-

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old of decompression alone is an urgent issue in the surgical treatment of LSS.

Diffuse idiopathic skeletal hyperostosis (DISH) is a non-inflammatory skeletal disease characterized by calcification and ossification of soft tissues, predominantly ligaments and entheses. The spinal longitudinal ligaments and entheses slowly ossify, and the mobility in the affected region decreases until complete ankylosis has developed. DISH begins most frequently in the lower thoracic spinal segments and extends to the upper thoracic segments and lumbar spine[3,4]. In patients with extended DISH, the non-ossified segments are exposed to higher mechanical stress because of a longer lever arm in the spinal column. This highly concentrated mechanical stress has been thought to cause poor clinical results in cases of acute spinal trauma with DISH[5,6]. Although the same mechanism may affect postoperative instability and lead to poor outcomes after surgery for LSS, few reports have focused on postoperative outcomes in patients with extended DISH. One study indicated that DISH was an independent risk factor for pseudarthrosis or adjacent segment disease after lumbar fusion surgery[7]. Additionally, our previous study of 1,063 patients who underwent surgery for LSS, including decompression alone and additional fusion, indicated that DISH extended to the lumbar segments (L-DISH) almost doubled the risk of reoperation[8]. However, no detailed analysis to determine which patients with DISH are most likely to undergo a failed index surgery has been performed. We hypothesized that reoperation might increase in patients who underwent decompression at levels close to the lower end of DISH or with high ossification by DISH because of cumulative stress at the remaining mobile vertebral segments.

The purpose of this study was to clarify risk factors for reoperation at the same level as that of the index surgery after decompression alone for LSS in patients with L-DISH, including ossification status by DISH.

Materials and Methods

Patients

This study included consecutive patients aged ≥50 years who underwent decompression alone for LSS from 2002 to 2010 at a single institution. We excluded patients with a history of spinal surgery, acute vertebral fracture, spinal malignant neoplasm, or spinal infection and those with missing or difficult-to-interpret preoperative standing whole-spine radiographs.

We distributed a postal survey to 1,150 consecutive patients who had undergone decompression alone, out of 2,363 patients who had undergone surgery for LSS aimed at investigating the >5-year postoperative clinical outcomes. The postal survey comprised two sections: 1) lumbar reoperation and 2) present patient-reported outcome measures (PROMs). The questions about reoperation concerned the reoperation period and procedure and whether the lumbar reoperation was performed in another hospital.

Patients who exhibited L-DISH by preoperative total spine X-ray were included in this study. DISH was evaluated according to the criteria proposed by Resnick and Niwayama[3] using preoperative standing whole-spine radiographs. L-DISH was defined as an ossified lumbar vertebra by DISH continuing from the thoracic spine.

There were four attending spine surgeons in the study period. All surgeons used the same decompression procedure (conventional bilateral fenestration with partial resection of the spinous process at the cranial level) and the same surgical indications and criteria for additional fusion for LSS. The surgical indications were symptoms of neurogenic intermittent claudication, intolerable leg pain or numbness despite conservative treatment, severe muscle weakness, or bladder/bowel dysfunction. The criteria for additional fusion procedures were spondylolisthesis with >2-mm translation on flexion-extension lumbar radiographs and/or a posterior opening disc angle on flexion radiographs, foraminal stenosis, or a lateral wedging segment due to degenerative scoliosis. Patients with comorbidities such as old age or poor general condition underwent decompression alone at the attending surgeon's discretion, even if the criteria for additional fusion were met.

Investigated parameters

We investigated reoperations at the same level as that of the index surgery using medical records of our hospital or the postal survey. Reoperation was defined as lumbar revision surgery performed for progression of lumbar degeneration or postoperative instability. Reoperations for insufficient decompression, postoperative hematoma or infection were excluded.

The potential confounders of the risk of reoperation were the patient's demographics, ossified condition of the lumbar spine, radiological findings on preoperative plain X-ray, computed tomography (CT), and magnetic resonance imaging (MRI). Demographic parameters were age, sex, body mass index, smoking at the time of the initial surgery, diabetes mellitus under treatment at the initial surgery, disease period, and preoperative symptom severity. Preoperative symptom severity was evaluated according to the Japanese Orthopedic Association score. Information on multiple-level decompression (≥3 levels), the surgical period (per 3 years), and the surgeon was also reviewed.

The ossified condition of the lumbar spine was evaluated on Mata's scoring system[9] using preoperative plain X-ray: (0) no ossification, (1) ossification without bridging, (2) ossification with incomplete bridging of the disc space, and (3) complete bridging (Fig. 1). The lumbar ossification score was defined as the sum of Mata's scores from L1-2 to L5-S (0-15). The number of completely fused segments by DISH was also evaluated. Evaluation using plain X-ray included assessment of spinal alignment, ≥10° Cobb angle in degenerative lumbar scoliosis, ≥10 mm disc height calculated as the mean between the anterior and posterior disc heights,

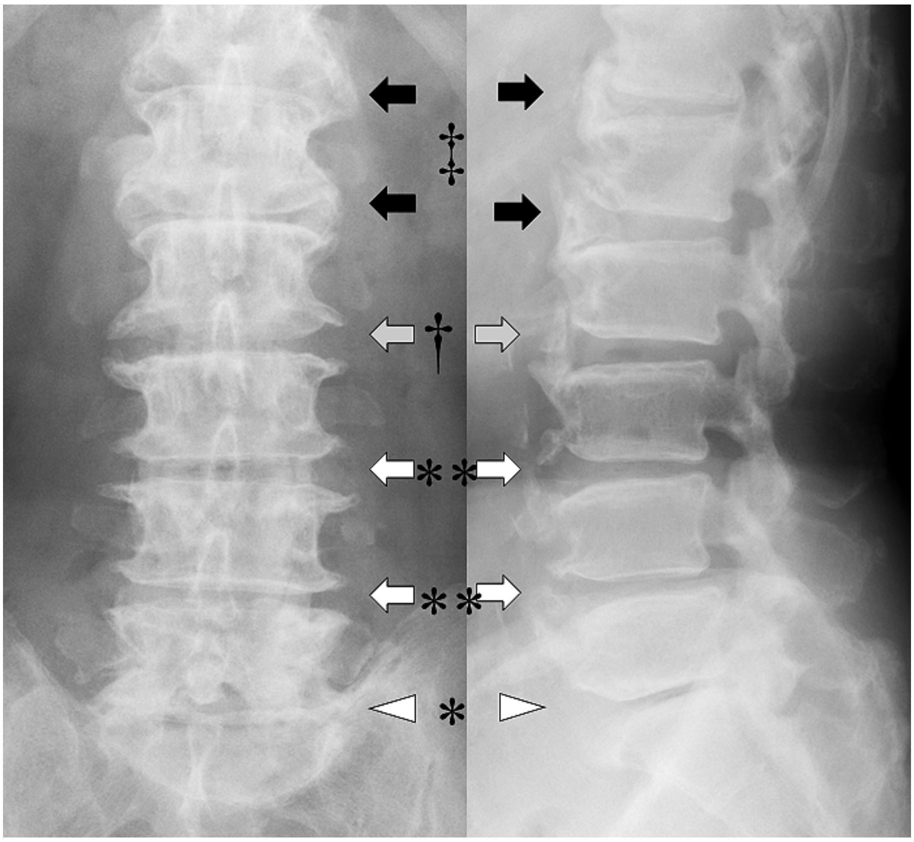

Figure 1. Lumbar ossification score. Each lumbar level was evaluated using Mata's scoring system: 0: no ossification (*), 1: ossification without bridging (**), 2: ossification with incomplete bridging of the disc space (†), and 3: complete bridging (‡). The lumbar ossification score was calculated by the sum of each score from L1-2 to L5-S.

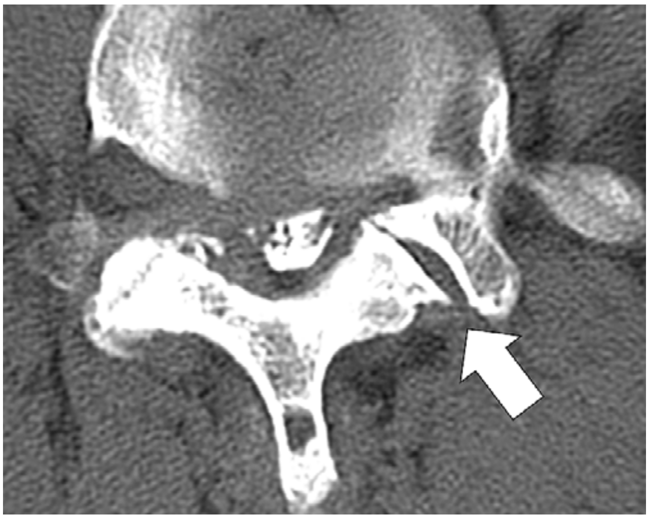

Figure 2. Facet opening. Facet opening was defined as a ≥2 mm opening (white arrow) on the axial plane of preoperative computed tomography.

and ≥3 mm anterior or posterior slip. Using flexion-extension dynamic radiographs at the left lateral recumbent position, we also investigated the occurrence of a ≥0° posterior opening at flexion, ≥3 mm translation, and ≥10° sagittal rotation angle. CT findings included intervertebral cleft, facet opening, facet bone cyst, and facet sclerosis. The middle images in the axial plane were used to evaluate the facet according to the previous report[10]. Facet opening was defined as a width of >2.0 mm (Fig. 2). The Pfirrmann grade (I-V)[11] and Modic change (types I-III)[12] were evaluated on sagittal MRI according to the original methods.

PROMs were evaluated using EQ5D-3L[13], Zurich Claudication Questionnaire (ZCQ)[14], and Oswestry Disability Index (ODI)[15] at the postal survey.

Statistical analysis

Results are presented as mean±standard deviation. Differences between reoperation and non-reoperation were evaluated in both units of patients and operated levels. Differences in categorical variables and continuous variables were examined using the chi-squared test and the Mann-Whitney U test, respectively. Cox proportional hazard regression with forward stepwise selection was used to identify risk factors and obtain the adjusted hazard ratio (aHR) with a 95% confidence interval (CI). To assess selection bias, the characteristics of the postal survey respondents were compared with those of non-respondents through multiple logistic regression analysis adjusted for age, sex, L-DISH, surgical period, and attending surgeon. A p-value<0.05 was considered to be statistically significant. All statistical analyses were performed using IBM SPSS Statistics, Version 19.0 (IBM Corp., Armonk, NY, USA).

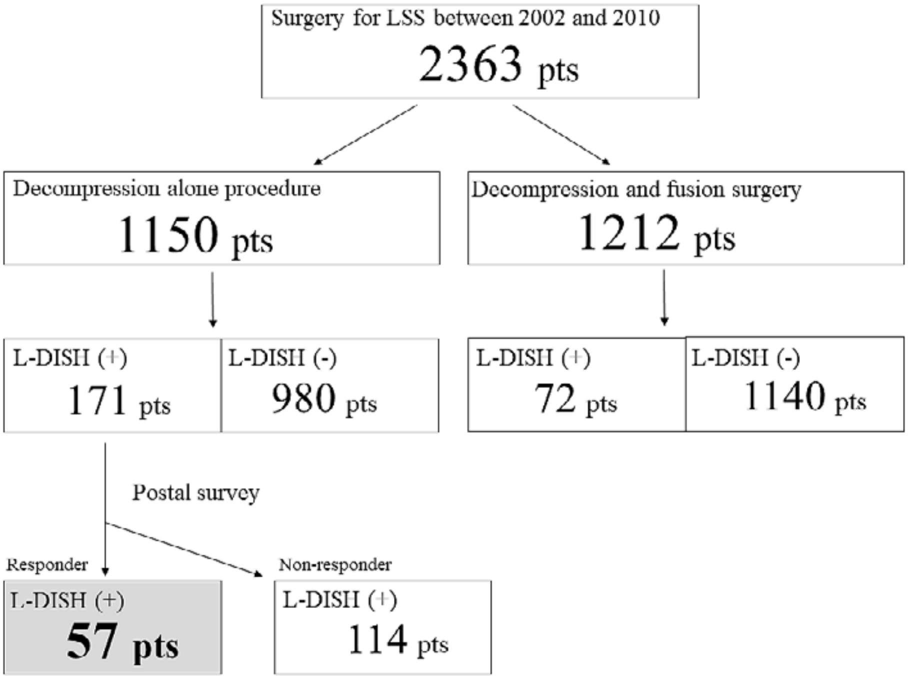

Figure 3. Flow diagram of the study. L-DISH was observed in 171 of 1,150 patients who underwent decompression surgery alone. A total of 57 patients completely responded to the postal survey.
DISH: diffuse idiopathic skeletal hyperostosis, L-DISH: DISH extended to the lumbar segments

Table 1. Patients' Demographics.

	N=57
Age, years	69.5±6.4
Sex, male/female	48/9
Number of ossified segments by DISH	8.82±2.49
Lower end of DISH: L1	32 (56)
L2	20 (35)
L3	2 (3.5)
L4	3 (5.3)
Ossification score of lumbar spine*	5.3±3.0
Number of decompression levels	1.77±0.80
Follow-up period, months	110.8±23.1

Data are presented as mean±standard deviation or n (%).
* Sum of Mata's score (0–3) from L1-2 to L5-S (0–15)
DISH: diffuse idiopathic skeletal hyperostosis

Results

Among the 1,150 patients who had undergone decompression alone, L-DISH was observed in 171 patients. This study finally included 57 patients who completely responded to the postal survey among patients with L-DISH who had undergone decompression alone (Fig. 3). The patients' demographics are listed in Table 1. The number of ossified segments by DISH was 8.82±2.49. The numbers of lower end ossified vertebrae by DISH were as follows: L1, 32 (56%); L2, 20 (35%); L3, 2 (3.5%); and L4, 3 (5.3%). The ossification score of the lumbar spine was 5.3±3.0.

Reoperation after decompression surgery in patients with L-DISH

After surgery among 57 patients and 97 decompression levels, 10 patients (17.5%) and 11 levels (11.3%) underwent reoperations at the same level as that of the index surgery within 9.2±1.9 years. The reoperation was performed 24.4±21.3 months after the index surgery. Four patients and eight levels underwent reoperations at levels different from that of the index surgery.

Risk factors for reoperation at the same level as that of the index surgery in patients with L-DISH

Table 2 presents the differences between the characteristics of patients with and without reoperations at the same level as that of the index surgery. No significant differences were found in any factors, including the number of ossified segments by DISH or the lumbar ossification score, between the two groups. Additionally, no significant factors were found after the multivariate analysis among all patients' characteristics.

Table 3 lists the differences between decompression levels in patients with and without reoperations at the same level as that of the index surgery. A sagittal rotation angle ≥10° was more frequently observed at the level of reoperations (36% and 7%, respectively; p=0.014). Facet opening on CT was more frequently detected at the level of reoperations (55% and 16%, respectively; p=0.009). The distance between the decompression level and the lower end of DISH

Table 2. Differences in Demographics of Patients with and without Reoperation at Same Level as That of the Index Surgery.

	Reoperation (+) n=10 patients	Reoperation (−) n=47 patients	p
Age, years	71.0±4.7	69.2±6.7	0.468
Sex, male	9 (90)	39 (83)	0.51
BMI, <18.5 kg/m^2	0 (0)	1 (2)	0.076
18.5–24.9 kg/m^2	7 (70)	13 (28)	
25.0–30.0 kg/m^2	3 (30)	27 (29)	
>30.0 kg/m^2	0 (0)	6 (13)	
Smoking	3 (30)	6 (13)	0.177
Diabetes mellitus	4 (40)	9 (19)	0.155
Ossification segments by DISH	8.1±2.7	9.0±2.5	0.24
Lumbar ossification score*	5.0±3.0	5.3±3.0	0.75
DLS with Cobb angle of ≥10°	1 (10)	7 (15)	0.571
Thoracic kyphosis	24.2±5.4	29.2±9.0	0.122
Lumbar lordosis	40.4±8.9	38.9±11.0	0.666
Pelvic tilt	22.4±5.6	24.5±7.1	0.235
Pelvic incidence	50.7±7.0	50.4±9.4	0.834
Sagittal vertical axis	33.0±25.3	36.0±30.5	0.975
Disease period, months	30.4±45.7	74.3±118.8	0.166
Preoperative JOA score	14.2±4.3	13.5±38	0.434
Multilevel decompression at ≥3 levels	1 (10)	8 (17)	0.501
Surgical period, 2002–2004	5 (50)	9 (19)	0.093
2005–2007	4 (40)	23 (49)	
2008–2010	1 (10)	15 (32)	
Surgeon, A	4 (40)	13 (28)	0.613
B	1 (10)	7 (15)	
C	3 (30)	9 (19)	
D	2 (20)	18 (38)	

Data are presented as mean±standard deviation or n (%).

* Sum of Mata's score (0–3) from L1-2 to L5-S (0–15)

BMI: body mass index, DLS: degenerative lumbar scoliosis, DISH: diffuse idiopathic skeletal hyperostosis, JOA: Japanese Orthopedic Association

was not related to reoperation (p=0.684). Cox proportional hazard regression analysis (Table 4) indicated that the independent risk factors for reoperation were a sagittal rotation angle ≥10° (aHR, 5.17; 95% CI, 1.49-17.94) and facet opening on CT (aHR, 4.82; 95% CI, 1.46-15.91).

An additional analysis regarding a potential radiological risk factor was performed between the level of reoperation and other levels in patients with reoperation. A sagittal rotation angle ≥10° was more frequently observed at the level of reoperations than at the other lumbar levels (36% and 5%; p =0.017). Facet opening on CT was more frequently seen at the level of reoperations than at the other lumbar levels (55% and 5%; p=0.001). However, a translation ≥3 mm did not differ between the level of reoperation and the other levels (18% and 5%, p=0.206).

Patient-reported outcomes in the patients without reoperation

PROMs at a postal survey between the patients with and without reoperation did not differ on any of the questionnaires (EQ5D, each domain of the ZCQ, and ODI, Table 5).

Selection bias of postal survey

L-DISH was more often observed in patients who underwent decompression alone (171/1,151, 14.9%) than in those who underwent an additional fusion procedure (72/1,212, 5.9%) (p<0.001) (Fig. 3). A multiple logistic regression analysis was performed to investigate the differences between the postal survey respondents and non-respondents to assess selection bias in patients who underwent decompression. L-DISH was not associated with differences between the respondents and non-respondents (p=0.15); however, a younger age (p<0.001), recent initial surgery (p<0.001), and treatment by the most experienced surgeon (p=0.006) were associated with a greater response rate.

Representative case

A 71-year-old man with DISH from T7 to L1 (Fig. 4A) underwent L4-5 and L5-S decompression alone for treatment of intolerable bilateral leg pain. His dynamic X-ray before the initial surgery showed a sagittal rotation angle of 10°, and CT showed a facet opening at the left L4-5 level

Table 3. Differences in Radiographic Findings Between Levels with and Those without Reoperation at the Same Level as That of the Index Surgery.

	Reoperation (+) n=11 levels	Reoperation (−) n=86 levels	p
Multilevel decompression at ≥3 levels	2 (18)	25 (29)	0.359
No. of segments from the lower end of DISH	2.5±1.1	2.4±1.1	0.684
Ossification score*	0.45±0.69	0.66±0.85	0.51
Level, L1-2	0 (0)	0 (0)	0.123
L2-3	1 (9)	3 (3)	
L3-4	0 (0)	20 (23)	
L4-5	9 (82)	44 (53)	
L5-S	1 (9)	19 (22)	
Plain X-ray findings			
Disc height ≥10 mm	8 (73)	45 (52)	0.335
Anterior slip ≥3 mm	0 (0)	5 (6)	0.9999
Posterior slip ≥3 mm	0 (0)	9 (10)	0.592
Posterior opening at flexion ≥0°	1 (9)	5 (6)	0.524
Translation between flexion and extension ≥3 mm	2 (18)	5 (6)	0.179
Sagittal rotation angle ≥10°	4 (36)	6 (7)	**0.014**
CT findings			
Intervertebral cleft	5 (45)	24 (28)	0.296
Facet opening	6 (55)	14 (16)	**0.009**
Facet bone cyst	4 (36)	27 (31)	0.74
Facet sclerosis	7 (64)	50 (58)	0.9999
MRI findings			
Pfirrmann grade II	0 (0)	2 (2)	0.273
grade III	2 (18)	18 (21)	
grade IV	9 (82)	46 (53)	
grade V	0 (0)	18 (21)	
Modic change, none	11 (100)	70 (81)	0.542
type I	0 (0)	1 (1)	
type II	0 (0)	7 (8)	
type III	0 (0)	6 (7)	

Data are presented as mean±standard deviation or n (%).
* Mata's scoring system (0–3)
DISH: diffuse idiopathic skeletal hyperostosis, CT: computed tomography, MRI: magnetic resonance imaging

Table 4. Cox Proportional Hazard Regression Analysis for Variable Prediction Reoperation at the Same Level as That of the Index Surgery.

	Coefficient	aHR	95% CI	p
Sagittal rotation angle ≥10°	1.644	5.173	1.492–17.940	0.010
Facet opening on CT	1.574	4.824	1.462–15.916	0.010

The Cox proportional hazard model was performed using a stepwise increasing method. Candidate predictor variables: multilevel decompression, number of segments from the lower end of DISH, ossification grade, lumbar level, disc height, anterior slip, posterior slip, translation, sagittal rotation angle, intervertebral cleft on CT, facet opening on CT, facet bone cyst on CT, facet sclerosis on CT, Pfirrmann grade on MRI, and Modic change on MRI.
aHR: adjusted hazard ratio, CI: confidence interval, CT: computed tomography, MRI: magnetic resonance imaging, DISH: diffuse idiopathic skeletal hyperostosis

(Fig. 4B). His leg pain completely disappeared after surgery; however, the left leg pain recurred 10 months postoperatively. MRI indicated disc herniation at L4-5 (Fig. 4C), and the patient underwent revision herniotomy 14 months after the index surgery.

Discussion

In this analysis of long-term follow-up of 57 patients with L-DISH, the rate of additional surgery at the same level as that of the index surgery after decompression alone for LSS was relatively high (17.5%). The independent predictors of reoperation were a sagittal rotation angle ≥10° (aHR, 5.17) and facet opening on CT (aHR, 4.82). To our knowledge, this study is the first to identify radiographic parameters that lead to unfavorable outcomes of decompression alone for LSS in patients with L-DISH.

Table 5. Differences in PROMS Between Patients with and Those without Reoperation at the Same Level as That of the Index Surgery.

	Reoperation (+) n=10 patients	Reoperation (−) n=47 patients	p
EQ5D*	0.707 (0.146)	0.779 (0.170)	0.346
ZCQ SS	2.54 (0.71)	2.27 (0.84)	0.279
ZCQ PF	1.78 (0.88)	1.75 (0.66)	0.866
ZCQ PS	1.87 (0.60)	1.88 (0.80)	0.857
ODI	21.3 (13.5)	21.0 (16.8)	0.864
Follow period, months	118.8 (20.6)	109.1 (23.5)	0.204

Data are presented as mean±standard deviation or n (%).

*EQ5D was evaluated by EQ5d-3L

ZCQ: Zurich Claudication Questionnaire, SS: Symptom Severity, PF: Physical Function, PS: Patient Satisfaction, ODI: Oswestry Disability Index

The rate of reoperation after decompression for LSS reportedly varies from 5% to 23% during 7 to 10 years of follow-up[16-19]. The rate of reoperation at the same level in this study population, patients with L-DISH, was higher than that in a previous Japanese study of 5,838 patients within 10 years after fenestration procedures (2.7%)[18]. Risk factors for reoperation in patients with LSS include age[17,19], smoking[20], prior surgery[17], preoperative symptom severity[19], and decompression alone for spondylolisthesis[16]. The impact of DISH on clinical outcomes after surgery for LSS has been given less attention. The high reoperation rate in this study indicated that L-DISH might be related to reoperation at the same level after decompression.

The condition of DISH was not associated with reoperation even after adjustment for potential confounders in the present study, despite the hypothesis that reoperation might increase at levels close to the lower end of DISH or in patients with high ossification scores. Nevertheless, our study results provide interesting findings regarding features of patients with L-DISH.

L-DISH was more frequently observed in patients who had undergone decompression alone than in those who had

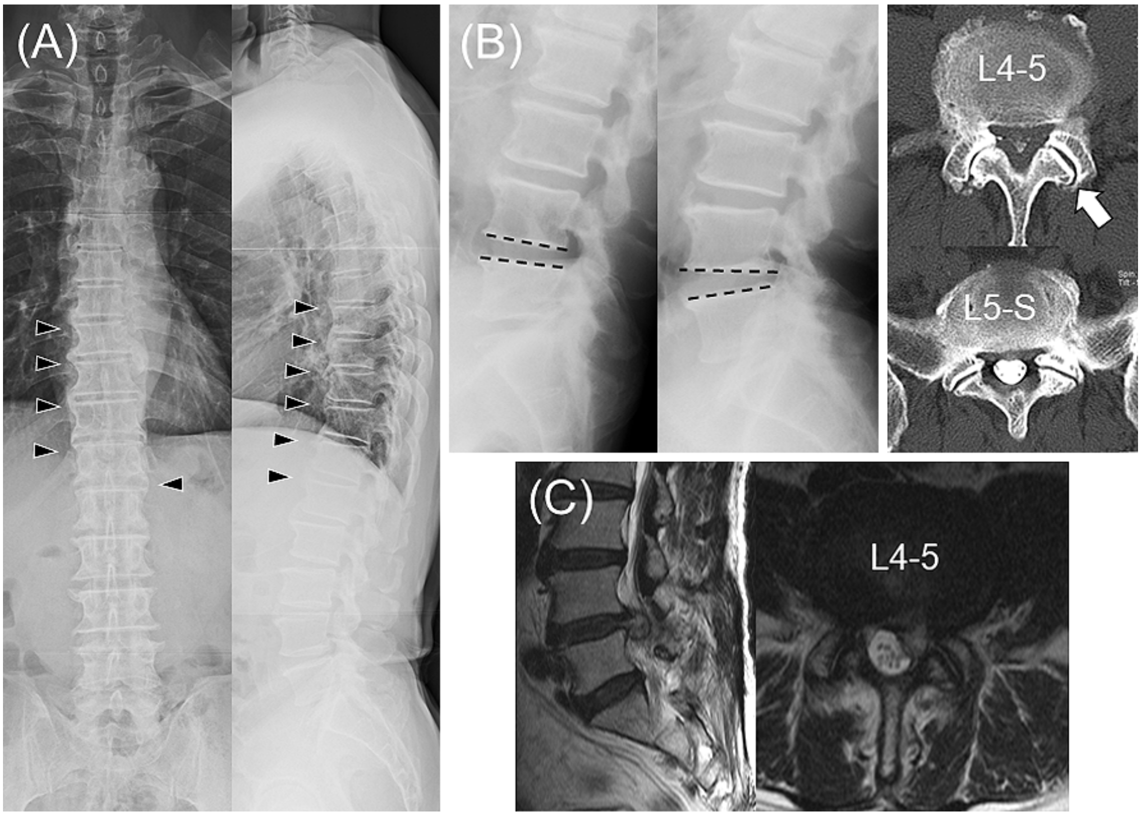

Figure 4. Representative case of a 71-year-old man. (A) Preoperative standing whole radiograph indicated diffuse idiopathic skeletal hyperostosis from T7 to L1 (triangle). (B) Left: Preoperative flexion and extension radiograph showed a 10° of sagittal rotation angle at L4-5. Right: preoperative computed tomography showed facet opening at L4-5. (C) Magnetic resonance imaging showed disc herniation at L4-5 1 year after L4-5 and L5-S decompression surgery, and the patient underwent revision decompression surgery at L4-5.

undergone additional fusion procedures in this series; regardless, we did not consider the presence of L-DISH when determining whether to perform additional fusion. This may have arisen from the fact that patients with L-DISH sometimes have partial ossification of the anterior/lateral vertebrae in the remaining mobile segments (Fig. 2)[9]. Partial ossification restricts anterior slip or translation. Thus, it is possible that patients with L-DISH were considered not to require additional fusion.

Although Blumenthal et al.[21] indicated that >1.25 mm of motion at spondylolisthesis-affected segments, disc height >6.5 mm, and facet angle >50° were risk factors for poor outcomes following decompression for grade I lumbar spondylolisthesis, we found no relationship between either slip length or translation and reoperation. Patients with L-DISH sometimes have restricted sagittal translation because of partial ossification in the remaining mobile segment. Thus, translation is not suitable for evaluating segmental instability in patients with L-DISH.

The sagittal rotation angle was reported as a risk factor for poor outcomes after laminectomy for LSS in a minimum 10-year follow-up[22]. The authors considered that increased sagittal rotation stimulates nerve endings in and the area around the fibrous tissue of the disc and facet joint, leading to poor outcomes. Additionally, facet opening on CT was reported as a parameter related to segmental instability[23]. Axial rotational motion increased with cartilage degeneration of the facet joints, leading to cartilage thinning. This may cause capsular ligament laxity, allowing for abnormal motion or hypermobility of the facet joint. This study indicated that these parameters might be useful for evaluation of preoperative segmental instability in patients with DISH.

This study had some limitations in that it is a retrospective cohort study that used postal survey, and the analyzed sample was small; therefore, the multivariate model was unstable because of a wide 95% CI. The response rate was one cause of this, although it was not unusual[24]. With respect to selection bias, the presence of L-DISH was not associated with either the respondents or non-respondents. Therefore, the main findings of risk factors for reoperation in patients with L-DISH are valid for discussion.

The proportion of L-DISH in LSS was not high, i.e., 10.3% (243/2,363, Fig. 1). The detailed analysis including radiological examinations in such an uncommon pathology was a strong point of this study, despite the small sample size. Lack of evaluations of preoperative PROMs was another limitation of this study. Therefore, further studies with larger numbers of patients using registry systems are required to clarify whether the ossification condition is related to clinical outcomes.

This study proposed thresholds for decompression alone for patients with LSS and L-DISH. The surgical strategy for patients with a large sagittal rotation angle or facet opening is an urgent issue. A possible surgical option is additional fusion surgery. However, fusion surgeries for patients with DISH have other problems that include screw loosening, cage sinking, or non-union[7]. Recent lateral interbody fusion procedures could reduce such problems by the large anterior column support, but the evidence is insufficient for patients with DISH at this time. By contrast, the decompression procedure used in this study was conventional fenestration. Less invasive decompression procedures preserving posterior elements could improve clinical outcomes in patients with segmental instability[25,26]. The results of such less invasive decompression procedures for patients with L-DISH remain unknown. Therefore, the best surgical strategy for patients with DISH warrants further research.

In conclusions, a sagittal rotation angle ≥10° and a facet opening on preoperative CT were risk factors for reoperation at the same level as that of the index surgery after decompression surgery in patients with L-DISH. The surgical strategy for LSS should be carefully considered in patients with L-DISH with a large sagittal rotation angle or facet opening.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Ethical Approval: This study was approved by the Institutional Review Board of Wajokai Eniwa Hospital (Approval No: 33, Approval date: 22/Jul/2015).

Informed Consent: Informed consent was obtained by all participants in this study.

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