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Scoring System for Factors Affecting Aggravation of Lumbar Disc Herniation

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Purpose: To investigate the various imaging factors associated with aggravation of lumbar disc herniation (LDH) and develop a scoring system for prediction of LDH aggravation.

Materials and Methods: From 2015 to 2017, we retrospectively reviewed the magnetic resonance imaging (MRI) findings of 60 patients (30 patients with aggravated LDH and 30 patients without any altered LDH). Imaging factors for MRI evaluation included the level of LDH, disc degeneration, back muscle atrophy, facet joint degeneration, ligamentum flavum thickness and interspinous ligament degeneration. Flexion-extension difference was measured with simple radiography. The scoring system was analyzed using receiver operating characteristic (ROC) analysis.

Results: The aggravated group manifested a higher grade of disc degeneration, back muscle atrophy and facet degeneration than the control group. The ligamentum flavum thickness in the aggravated group was thicker than in the group with unaltered LDH. The summation score was defined as the sum of the grade of disc degeneration, back muscle atrophy and facet joint degeneration. The area under the ROC curve showing the threshold value of the summation score for prediction of aggravation of LDH was 0.832 and the threshold value corresponded to 6.5.

Conclusion: Disc degeneration, facet degeneration, back muscle atrophy and ligamentum flavum thickness are important factors in predicting aggravation of LDH and may facilitate the determination of treatment strategy in patients with LDH. The summation score is available as supplemental data.

Keywords: Lumbar disc herniation; Disc degeneration; Back muscle atrophy; Facet joint degeneration; Aggravation; Magnetic resonance imaging

Original Article

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INTRODUCTION

Lumbar disc herniation (LDH) is one of the most common causes of lower back pain and radiating leg pain, which affects about 40% of all adults (1). The natural progression of LDH is generally satisfactory and most patients spontaneously recover with only conservative treatment within about 4 to 6 weeks (2-5). However, nearly 20% of the patients with LDH are strong candidates for surgical treatment (1). Until recently, patients were unaware of the benefits and risks of surgical treatment compared with prolonged conservative treatment, and most patients still believe that surgical treatment is associated with permanent disability and paralysis. However, early surgical treatment does not decrease the risk of unsatisfactory results during the 1 to 2 years

of follow-up. Although the risk of surgical treatment is relatively low, approximately 20% of the patients reported chronic or recurrent pain, disability and paralysis within 2 years after surgical treatment (6).

In magnetic resonance imaging (MRI) scans, disc herniation is defined as a localized or focal disc displacement beyond the confines of the intervertebral disc space. The disc material contains annular tissue, nucleus, cartilage, apophyseal bone or other combined materials. The terminology "localized" or "focal" is defined by less than 25% of the edge of disc (< 90 degrees). Disc displacement beyond the edge of the ring apophysis, and throughout the circumference of the disc, is known as "bulging", and not herniation (7).

Compared with spinal stenosis, which is usually unchanged or aggravated over time, LDH can show improvement, no change or aggravation. Several studies have investigated the factors that predict patients' response to conservative therapy successfully. Only a few studies analyzed the imaging factors that predict decrease in the size of LDH in response to conservative therapy (8).

To the best of our knowledge, no studies have investigated the cause of aggravation of LDH. We conducted a retrospective trial to investigate the various imaging factors associated with aggravation of LDH.

MATERIALS AND METHODS

Study Population

This retrospective study was approved by the Institutional Review Board, and the requirement to obtain informed consent was waived. We reviewed all lumbar spine MRI scans from 2015 to 2017 by searching the picture archiving and communication system (PACS) work station list (TechHeim, Seoul, Korea). We selected 30 patients who had disc herniation limited to the lumbar spine as the study group, who did not receive any surgical treatment during the follow-up period. Further, we selected 30 patients with no change in disc herniation as the control group. Since the average follow-up period of the disc aggravation group was 35.3 months, we selected these patients as the control group with a follow-up period of at least more than 30 months. The patients were selected in the order in which they were scanned most recently. The two groups were not matched for their age, gender, or body mass index (BMI). The study population comprised 33 men and 27 women that ranged in age from 18 to 69 years (mean age, 45.8 years). Table 1 summarizes and analyzes the demographic factors.

The lumbar MRI was performed with a 1.5T MRI unit (Signa Excite; GE Medical Systems, New York, NY, USA). Unenhanced T1- and T2-weighted images were obtained with variable settings. The T1-weighted spin-echo images were acquired with the following parameters: TR 400-500, TE 8-11, flip angle 90, slice thickness 4 mm, inter-slice gap 4.5 mm, matrix size 320 × 224, and FOV 18-29 cm. The T2-weighted spine-echo images were acquired with the following parameters: TR 3200-4000, TE 105-108, flip angle 90, slice thickness 4 mm, inter-slice gap 4.5 mm, matrix size 320 × 224, FOV 18-29 cm.

Image Analysis

All the images of the 60 patients were reviewed on a PACS work station with a 2000 × 2000-pixel-resolution gray-scale monitor by consensus among three authors (two well-trained musculoskeletal radiologists and a third-year resident). The three authors conducted a quantitative measurement of all imaging factors, and set the mean of those values as the representative value. In semi-quantitative grading, if the measured values of three authors matched, the values were considered representative; otherwise, a majority was set as the representative value.

Aggravation of LDH was defined as more than 10% increase in the AP length of the herniated disc on the axial image, more than 10% increase in the distance of herniated disc material from the vertebral endplate on the sagittal image and the occurrence of a new sequestrated disc material. We subjectively set the criterion of 10% to visualize the aggravation of LDH on an MRI scan.

The imaging factors included the level of LDH, disc degeneration, back muscle atrophy, facet joint degeneration, ligamentum flavum thickness, interspinous ligament degeneration and flexion-extension difference, which is measured on simple radiograph.

LDH was confined to 4 levels (L2-3, L3-4, L4-5 and L5-S1) without involving L1-2 in our patients. Our study did not compare the two groups at the same disc level.

We referred to Pfirrmann's grade for classification of disc degeneration based on T2-weighted axial and sagittal scans as follows: 1 (disc is homogeneous, hyperintense white signal intensity and normal disc height), 2 (disc is inhomogeneous, hyperintense white signal intensity, annulus and nucleus are clearly differentiated and a gray horizontal band present with normal disc height), 3 (disc is inhomogeneous with intermittent dark gray signal intensity, distinction between annulus and nucleus is

unclear, and normal or slightly decreased disc height), 4 (disc is inhomogeneous with a hypointense dark gray signal intensity, no more distinction between the annulus and nucleus and slightly or moderately decreased disc height), and 5 (same as above grade IV but with collapsed disc space) (9).

The grade of back muscle atrophy was categorized by the proportion of the fat component, as 0 (normal muscle), 1 (some fatty streaks), 2 (less than 50% fatty muscle atrophy), 3 (50% fatty muscle atrophy), and 4 (greater than 50% fatty muscle atrophy). The back muscle atrophy was measured at the corresponding LDH level and analyzed at the axial T1-weighted image.

The grade of facet joint degeneration was classified by Pathria et al. (10) as follows: grade 0 (normal facet joint space, 2-4 mm width), 1 (narrowing of the facet joint space < 2 mm ± small osteophytes ± hypertrophy of the articular processes), 2 (narrowing of the facet joint space ± moderate osteophytes ± moderate hypertrophy of the articular processes ± mild subarticular bone erosion), and 3 (narrowing of the facet joint space ± large osteophytes ± severe hypertrophy of the articular processes ± severe subarticular bone erosions ± subchondral cysts).

The thickness of ligamentum flavum was measured perpendicular to the thickest part of the LDH level except linear dark signal intensity of bony cortex on T2-weighted image axial scan (Fig. 1).

The grade of interspinous ligament degeneration was classified by Keorochana et al. (11) as follows: A (low- or iso-signal intensity on T1-weighted image and T2-weighted image or mixed signal intensity), B (high signal intensity on T1-weighted image and T2-weighted image), C (low signal intensity on T1-weighted image and high signal intensity on T2-weighted image), and D (low- or iso-signal intensity on T1-weighted image and T2-weighted image with hypertrophy or marrow alteration within spinous processes or narrowing of interspinous ligament interval).

The flexion-extension difference was measured on the lateral simple radiograph (Fig. 2). The angle was measured by drawing a line parallel to the lower endplate of the upper level vertebra and upper endplate of the lower level vertebra.

Statistical Analysis

To determine the relationship between the demographic data and MR findings, the differences between the aggravated group and the control group in terms of sex, the level of LDH, grades of disc degeneration, back muscle atrophy, facet joint osteoarthritis, and interspinous ligament degeneration were analyzed using chi-squared or Fisher's exact tests. The age, follow-up period, height, weight and BMI of the two groups was analyzed using Student's t-test.

In addition, we decided to include the summation score of the grade of statistically significant factors as the imaging factor. The summation score was analyzed using Student's t-test and ROC analysis. The ROC analysis produces area under the curve (AUC), a 2-dimensional graph with specificity and sensitivity plotted on the X- and

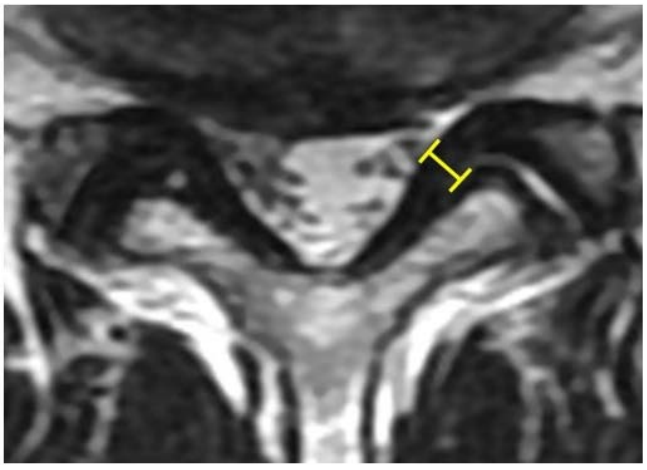


Fig. 1. Measurement perpendicular to the thickest portion of ligamentum flavum at the herniated disc level on T2-weighted image axial scan.

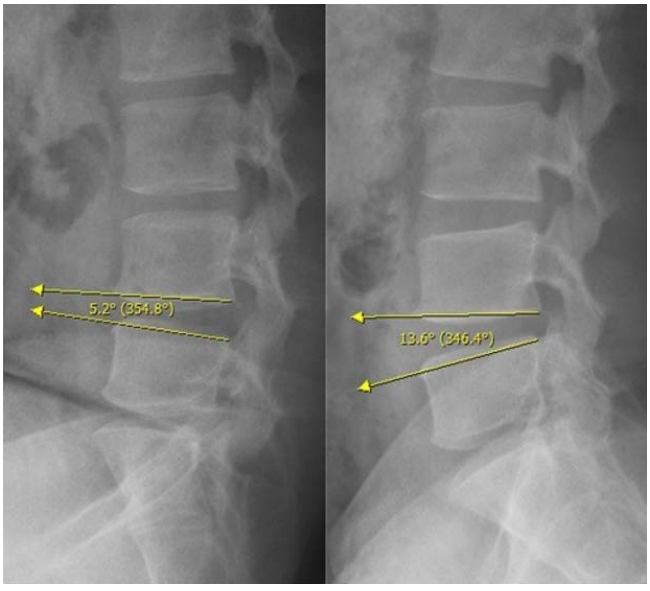


Fig. 2. The flexion-extension difference was measured on lateral simple radiograph.

Y-axes, respectively, representing the range of potential optimum threshold values. The accuracy of diagnostic test was interpreted based on the AUC and was non-informative if the AUC was 0.5, less accurate if AUC was 0.5-0.7, moderately accurate if AUC was 0.7-0.9, highly accurate if AUC was 0.9-1.0, and perfect if AUC was 1 (12).

Table 1. Demographic Characteristics of the Two Groups of Patients

		Non-changing (n = 30)	Aggravated (n = 30)	P-value
		N (%) or mean (SD)		
Follow-up period (months)		45.3 (21.0)	36.9 (30.5)	0.218
Sex	F	16 (53.3)	11 (36.7)	0.299
	M	14 (46.7)	19 (63.3)	
Age (years)		47.7 (11.3)	43.9 (13.8)	0.241
Height (cm)		164.6 (8.9)	167.9 (10.4)	0.791
Weight (kg)		65.4 (13.3)	66.7 (12.1)	0.697
BMI		24.1 (4.1)	23.6 (3.2)	0.600

BMI = body mass index; F = female; M = male; SD = standard deviation

Table 2. Analysis of Imaging Factors of the Two Groups of Patients

	Grade	Non-changing (n = 30)	Aggravated (n = 30)	P-value
		N (%) or mean (SD)		
Disc degeneration	1	0 (0.0)	1 (3.3)	0.002
	2	7 (23.3)	4 (13.3)	
	3	20 (66.7)	9 (30.0)	
	4	3 (10.0)	14 (46.7)	
	5	0 (0.0)	2 (6.7)	
Back muscle atrophy	0	0 (0.0)	1 (3.3)	0.000
	1	18 (60.0)	2 (6.7)	
	2	11 (36.7)	26 (86.7)	
	3	1 (3.3)	1 (3.3)	
Facet joint degeneration	0	0 (0.0)	4 (13.3)	0.000
	1	11 (36.7)	0 (0.0)	
	2	18 (60.0)	16 (53.3)	
	3	1 (3.3)	10 (33.3)	
Thickness of ligamentum flavum		1.8 (0.5)	2.6 (0.5)	0.000
Interspinous ligament degeneration	A	12 (40.0)	13 (43.3)	0.959
	B	12 (40.0)	11 (36.7)	
	C	0 (0.0)	0 (0.0)	
	D	6 (20.0)	6 (20.0)	
Flexion-extension difference (on simple radiographs)		9.7 (5.7)	9.3 (7.0)	0.791
Summation score		5.33 (1.26)	7.16 (1.36)	0.000

SD = standard deviation

RESULTS

We analyzed demographic and imaging factors of patients in the two groups. The follow-up period, sex, age, weight and height were not significantly different in the aggravated and control groups (P = 0.241, 0.299, 0.697, 0.188, 0.600 respectively, Table 1). The aggravated group showed a higher grade of disc degeneration than the control group (P = 0.002) along with back muscle atrophy and facet degeneration (P = 0.000). The ligamentum flavum thickness in the aggravated group was thicker than in the control group (aggravated group: mean = 2.6 cm, control group: mean = 1.8 cm, P = 0.000). Neither the level of LDH, the grade of interspinous ligament degeneration nor flexion-extension differences was significantly different in the two groups (P = 0.405, 0.959, 0.791 respectively) (Table 2).

The summation score was defined as the sum of all the grades of disc degeneration, back muscle atrophy and facet joint degeneration, excluding the thickness of ligamentum flavum due to grading difficulty. The summation score of the grade of disc degeneration, back muscle atrophy and facet joint degeneration in the aggravated group was higher than in the control group (P = 0.000) with an inflection point between 6 and 7 (Fig. 3). The AUC for the identification of optimum threshold value to predict the aggravation of LDH was 0.832 (Fig. 4). The threshold value yielding the highest validity corresponded to a summation score of 6.5. This threshold value provided a sensitivity of 70%, specificity of 87%, positive predictive value of 0.84%, negative predictive value of 74%, and accuracy of 78%.

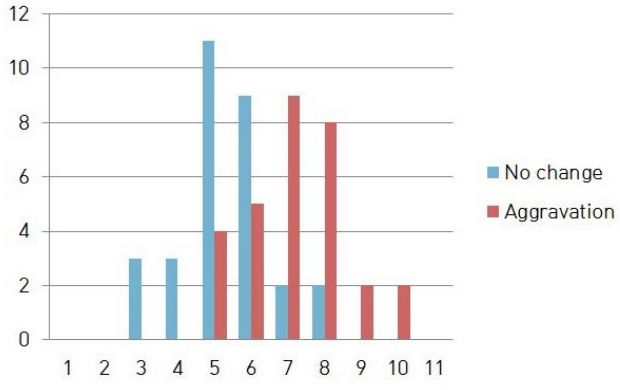


Fig. 3. The graph showing the number of patients for each summation score of the Pfirrmann disc degeneration grade, back muscle atrophy, and facet joint degeneration.

DISCUSSION

LDH is one of most common causes of lower back pain and radiating leg pain. Conservative treatment may be the first option including physical therapy, short periods of bed rest and medications, unless severe motor and sphincter symptoms from the onset warrant emergency surgery. Surgical treatment is considered the first option for patients manifesting emergency symptoms. Clinically, the natural progression of LDH is generally satisfactory and most patients spontaneously recover within about 4 to 6 weeks with only conservative treatment (2-5). The remaining 20% of patients manifest strong symptoms warranting surgical treatment (1). Except for urgent surgery, although early surgical treatment quickly resolves symptoms, results during 1-2 years of follow-up were similar in both groups. Early surgery leads to rapid symptom recovery. However, the relative benefits of surgical treatment were not significant by 6 months of follow-up, and the primary result was not statistically significant clinically (6).

Currently, although MRI findings do not always correlate with clinical symptoms (13, 14), a few studies investigated the association between imaging findings and progression

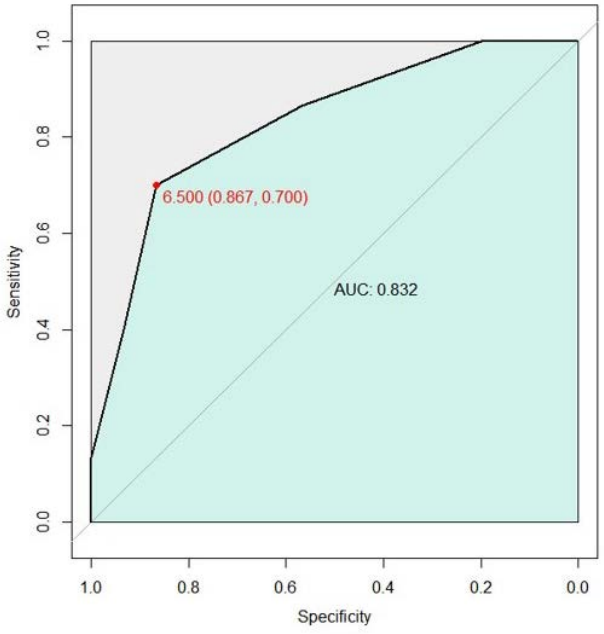
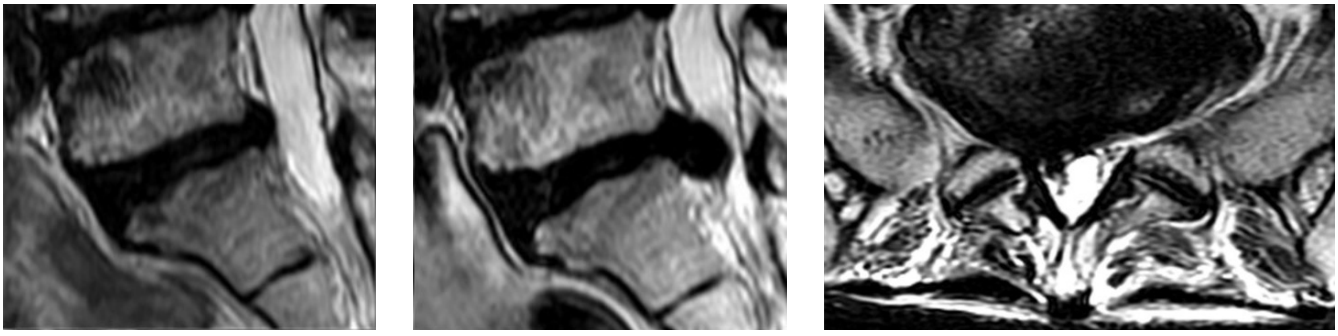


Fig. 4. Receiver operating characteristic curve showing the threshold value of the summation score of the Pfirrmann disc degeneration grade, back muscle atrophy, and facet joint degeneration to predict the aggravation of lumbar disc herniation.

of LDH using MRI. Motiei-Langroudi et al. (15) reviewed 134 patients with LDH and reported that Pfirrmann disc degeneration grade predicted the probability of conservative therapy failure and the need for surgery. Other factors were herniation type (extrusion and protrusion), more laterally located discs, and larger disc material, which also obviate the need for conservative treatment later.

In our study, a lumbar MRI scan was performed and conservative treatment was administered to all patients without previous surgery. The patients were categorized subsequently based on aggravation of LDH. The results show that MRI findings including Pfirrmann disc degeneration grade, the grades of back muscle atrophy and facet joint degeneration, and ligamentum flavum thickness were statistically different between the two groups. The higher the level of aggravating factors, the higher was the probability of LDH exacerbation during the follow-up period.

The spinal segment is a functional structure in which facet joint and intervertebral disc provide stability together. Therefore, the degeneration of these functional structures leads to abnormal movement of spinal segment or segmental instability (16-19). Progressive degeneration of spinal segment leads to a shortage of water from the nucleus, which severely damages its normal functional ability. Moreover, a decrease in intervertebral disc height and pretension load in the ligaments induces mechanical instability described by abnormal segmental movements (20). Disc degeneration, facet joint degeneration, and ligamentum flavum hypertrophy define segmental



a b c

Fig. 5. A 63-year-old woman with right subarticular disc extrusion, L5-S1. (a) Initial sagittal T2-weighted image shows disc degeneration grade 4. (b) Sagittal T2-weighted image shows lumbar disc herniation aggravation after 58 months. (c) Initial axial T2-weighted image shows back muscle atrophy grade 3, facet joint degeneration grade 1 and ligamentum flavum thickness 2.2 mm. The summation score is 8.

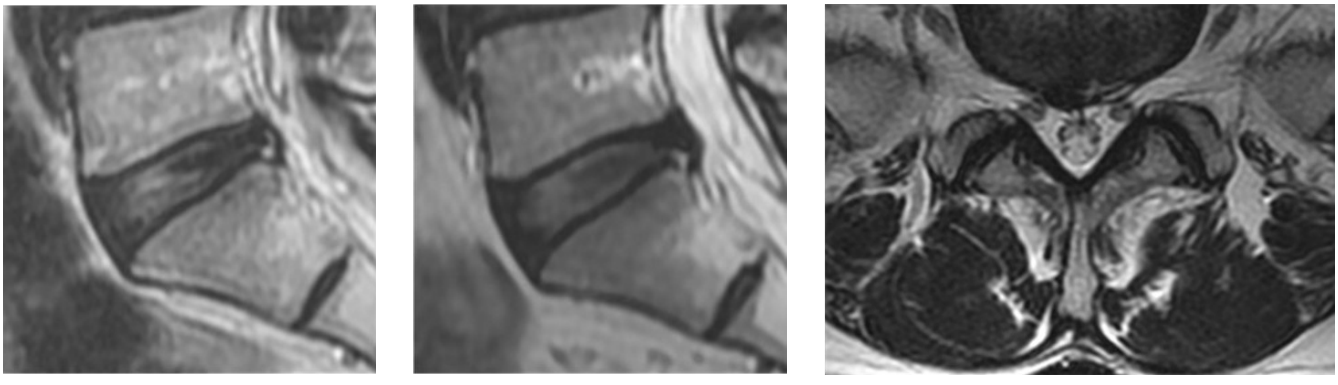


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Fig. 6. A 58-year-old woman with right central disc protrusion, L5-S1. (a) Initial sagittal T2-weighted image shows disc degeneration grade 2. (b) Sagittal T2-weighted image shows no significant change in lumbar disc herniation after 47 months. (c) Initial axial T2-weighted image shows grade 1 back muscle atrophy, facet joint degeneration grade 1 and ligamentum flavum thickness 1.9 mm. The summation score is 4.

instability (21), which is the key factor that predicts LDH aggravation (Figs. 5, 6). Further, in 1944, Knutsson et al. (22) investigated flexion-extension differences based on lateral simple radiograph of the lumbar spine to test segmental instability. Flexion-extension radiograph is most often used to diagnose segmental instability of lumbar spine because of its cost-effectiveness, simplicity and availability (19). However, the accuracy of flexion-extension radiograph is not available for daily or routine diagnosis of segment instability of lumbar spine. Furthermore, it is characterized by poorly reproducible measurement and a deficit of appropriate methods for measuring lumbar displacement (18). A minor variation in the patient's position, movement or the direction of exiting X-ray beam may result in a 10-15 percent variance in the range of lumbar displacement (19). In our study, the flexion-extension difference was not statistically significant.

Finally, the summation score was used as an imaging factor because the various factors affect the kinetics of spine, which is related to the LDH aggravation. In the estimation of ROC curve, the AUC predicting the aggravation of LDH was 0.832, suggesting moderate accuracy. The threshold value that provided the highest validity corresponded to a summation score of 6.5. However, the factors used in the summation score were discrete-quantitative data associated with single-grade unequal differences. Therefore, the summation score cannot facilitate direct prediction of LDH exacerbation, and is used only as a supplementary tool in determining the treatment strategy.

This study had a few limitations. First, all radiological assessments were conducted by three radiologists, and intra-observer/inter-observer variability was not assessed. Second, relatively few cases were used in statistical analysis and larger cohorts are needed for statistical rigor.

In conclusion, disc degeneration, facet degeneration, back muscle atrophy and ligamentum flavum thickness are key factors in predicting aggravation of LDH and may facilitate the determination of treatment strategy in patients with LDH. The summation score is available as a supplementary material for the determination of treatment strategy.

REFERENCES

1. Frymoyer JW. Lumbar disk disease: epidemiology. Instr Course Lect 1992;41:217-223
2. Fager CA. Observations on spontaneous recovery from intervertebral disc herniation. Surg Neurol 1994;42:282-286
3. Weber H. Lumbar disc herniation. A controlled, prospective study with ten years of observation. Spine (Phila Pa 1976) 1983;8:131-140
4. Weber H, Holme I, Amlie E. The natural course of acute sciatica with nerve root symptoms in a double-blind placebo-controlled trial evaluating the effect of piroxicam. Spine (Phila Pa 1976) 1993;18:1433-1438
5. Hofstee DJ, Gijtenbeek JM, Hoogland PH, et al. Westeinde sciatica trial: randomized controlled study of bed rest and physiotherapy for acute sciatica. J Neurosurg 2002;96:45-49
6. Peul WC, van den Hout WB, Brand R, Thomeer RT, Koes BW, Leiden-The Hague Spine Intervention Prognostic Study Group. Prolonged conservative care versus early surgery in patients with sciatica caused by lumbar disc herniation: two year results of a randomised controlled trial. BMJ 2008;336:1355-1358
7. Fardon DF, Williams AL, Dohring EJ, Murtagh FR, Gabriel rothman SL, Sze GK. Lumbar disc nomenclature: version 2.0: recommendations of the combined task forces of the North American Spine Society, the American Society of Spine Radiology and the American Society of Neuroradiology. Spine J 2014;14:2525-2545
8. Choi SJ, Song JS, Kim C, et al. The use of magnetic resonance imaging to predict the clinical outcome of non-surgical treatment for lumbar intervertebral disc herniation. Korean J Radiol 2007;8:156-163
9. Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine (Phila Pa 1976) 2001;26:1873-1878
10. Pathria M, Sartoris DJ, Resnick D. Osteoarthritis of the facet joints: accuracy of oblique radiographic assessment. Radiology 1987;164:227-230
11. Keorochana G, Taghavi CE, Tzeng ST, et al. MRI classification of interspinous ligament degeneration of the lumbar spine: intraobserver and interobserver reliability and the frequency of disagreement. Eur Spine J 2010;19:1740-1745
12. Greiner M, Pfeiffer D, Smith RD. Principles and practical application of the receiver-operating characteristic analysis for diagnostic tests. Prev Vet Med 2000;45:23-41
13. Haldeman S. North American Spine Society: failure of the pathology model to predict back pain. Spine (Phila Pa 1976) 1990;15:718-724
14. Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. J Bone Joint Surg Am 1990;72:403-408

15. Motiei-Langroudi R, Sadeghian H, Seddighi AS. Clinical and magnetic resonance imaging factors which may predict the need for surgery in lumbar disc herniation. Asian Spine J 2014;8:446-452
16. Berne D, Goubier JN, Lemoine J, Saillant G. The aging of the spine: natural evolution. Eur J Orthop Surg Traumatol 1999;9:125-133
17. Fujiwara A, Tamai K, An HS, et al. The relationship between disc degeneration, facet joint osteoarthritis, and stability of the degenerative lumbar spine. J Spinal Disord 2000;13:444-450
18. Kim KA, Wang MY. MRI-based morphological predictors of SPECT positive facet arthropathy in patients with axial back pain. Neurosurgery 2006;59:147-156
19. Leone A, Guglielmi G, Cassar-Pullicino VN, Bonomo L. Lumbar intervertebral instability: a review. Radiology 2007;245:62-77
20. Tsantrizos A, Ito K, Aebi M, Steffen T. Internal strains in healthy and degenerated lumbar intervertebral discs. Spine (Phila Pa 1976) 2005;30:2129-2137
21. Jang SY, Kong MH, Hymanson HJ, Jin TK, Song KY, Wang JC. Radiographic parameters of segmental instability in lumbar spine using kinetic MRI. J Korean Neurosurg Soc 2009;45:24-31
22. Knutsson F. The instability associated with disc degeneration in the lumbar spine. Acta Radiologica 1944;25:593-609