A Practical MRI Grading System for Lumbar Foraminal Stenosis

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OBJECTIVE. This study aimed to evaluate the reproducibility of a new grading system for lumbar foraminal stenosis.

MATERIALS AND METHODS. Four grades were developed for lumbar foraminal stenosis on the basis of sagittal MRI. Grade 0 refers to the absence of foraminal stenosis; grade 1 refers to mild foraminal stenosis showing perineural fat obliteration in the two opposing directions, vertical or transverse; grade 2 refers to moderate foraminal stenosis showing perineural fat obliteration in the four directions without morphologic change, both vertical and transverse directions; and grade 3 refers to severe foraminal stenosis showing nerve root collapse or morphologic change. A total of 576 foramina in 96 patients were analyzed (from L3–L4 to L5–S1). Two experienced radiologists independently assessed the sagittal MR images. Interobserver agreement between the two radiologists and intraobserver agreement by one reader were analyzed using kappa statistics.

RESULTS. According to reader 1, grade 1 foraminal stenosis was found in 33 foramina, grade 2 in six, and grade 3 in seven. According to reader 2, grade 1 foraminal stenosis was found in 32 foramina, grade 2 in six, and grade 3 in eight. Interobserver agreement in the grading of foraminal stenosis between the two readers was found to be nearly perfect (κ value: right L3–L4, 1.0; left L3–L4, 0.905; right L4–L5, 0.929; left L4–L5, 0.942; right L5–S1, 0.919; and left L5–S1, 0.909). In intraobserver agreement by reader 1, grade 1 foraminal stenosis was found in 34 foramina, grade 2 in eight, and grade 3 in seven. Intraobserver agreement in the grading of foraminal stenosis was also found to be nearly perfect (κ value: right L3–L4, 0.883; left L3–L4, 1.00; right L4–L5, 0.957; left L4–L5, 0.885; right L5–S1, 0.800; and left L5–S1, 0.905).

CONCLUSION. The new grading system for foraminal stenosis of the lumbar spine showed nearly perfect interobserver and intraobserver agreement and would be helpful for clinical study and routine practice.

Keywords: foraminal stenosis, lumbar vertebrae, neural foramen, sagittal MRI

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Lumbar foraminal stenosis is defined as the narrowing of the bony exit of the nerve root caused by a decrease in the height of an intervertebral disk, osteoarthritic changes in the facet joints, cephalad subluxation of the superior articular process of the inferior vertebra, and buckling of the ligamentum flavum or protrusion of the annulus fibrosus [1].

MRI is widely used in the evaluation of lumbar foraminal stenosis; however, there is no widely used diagnostic criterion or grading system for lumbar foraminal stenosis on MRI. For clinical studies with the objective of comparing different therapeutic methods for lumbar foraminal stenosis, an adequate grading system that has good reproducibility is necessary. In addition, in daily routine practice, a grading system for lumbar foraminal stenosis is necessary for writing radiologic reports.

There have been few reports on the grading or classification of lumbar foraminal stenosis on MRI [2, 3]. The grading system suggested by Wildermuth et al. [2] focused on only the degree of epidural fat obliteration. The classification of lumbar foraminal stenosis proposed by Kunogi and Hasue [4] included the anteroposterior, cephalocaudal, and circumferential types without stenosis grade. The grading system of Wildermuth et al. and the classification proposed by Kunogi and Hasue do not consider direct nerve root compression or deformity, which may be important. In our department, we have created a new grading system; it is a modification of the previous systems that takes into consideration the type of stenosis, amount of fat obliteration, and presence of nerve root compression.

The purpose of this study was to evaluate the reproducibility of this new grading system for lumbar foraminal stenosis and to discuss its clinical relevance.

Materials and Methods

Establishment of MRI Grading System for Lumbar Foraminal Stenosis

After several meetings with two radiologists, two orthopedic surgeons, and three neurosurgeons, we determined the criteria for lumbar foraminal stenosis on sagittal MRI. Sagittal T1-weighted imaging was the main sequence evaluated with T2-weighted imaging also used as an additional tool to exclude false-positive findings resulting from the misinterpretation of perineural cysts or nerve root swelling. This grading system was established without changing the classic MRI protocol in the lumbar spine. Four grades were developed using a modification of the classification by Kunogi and Hasue [4], as illustrated in Figure 1. Grade 0 refers to the absence of foraminal stenosis; grade 1 refers to mild foraminal stenosis showing perineural fat obliteration surrounding the nerve root in the two opposing directions (vertical or transverse). It involves contact with the superior and inferior portions of the nerve root or anterior and posterior portions of the nerve root. No evidence of morphologic change in the nerve root is shown. Grade 2 refers to moderate foraminal stenosis showing perineural fat obliteration surrounding the nerve root in the four directions without morphologic change in both vertical and transverse directions. Grade 3 refers to severe foraminal stenosis showing nerve root collapse or morphologic change.

MRI

All patients underwent imaging using a 1.5-T imager (Gyroscan Intera Achieva, Philips Healthcare) with a Synergy Spine Coil (Philips Healthcare). The patients were placed in the supine position with a cushion under both knees. T1-weighted spin-echo sagittal and axial images and T2-weighted fast spin-echo (FSE) sagittal and axial images were obtained (TR/TE, 500/15 for T1-weighted images and 3,600/120 for T2-weighted images; slice thickness, 4 mm; slice gap, 0.4 mm; field of view, 32 cm for sagittal images and 16 cm for axial images; matrix, 512 × 512; flip angle, 90°; and excitations, 3).

Case Selection

Our study was approved by the institutional review board. Informed consent was not required for this MRI analysis. All 440 consecutive patients were selected from a database of MR examinations of the lumbar spine performed at our institution in June 2007.

The exclusion criteria were patients under 60 years old; evidence of infection, tumor, or fracture on MRI; previous lumbar operation; and evidence of foraminal disk extrusion with superior migration. Thus, 344 patients were excluded and 96 patients were included in this study. The average patient age was 69.35 years (range, 60–86 years) and there were 35 men (36.5%) and 61 women (63.5%).

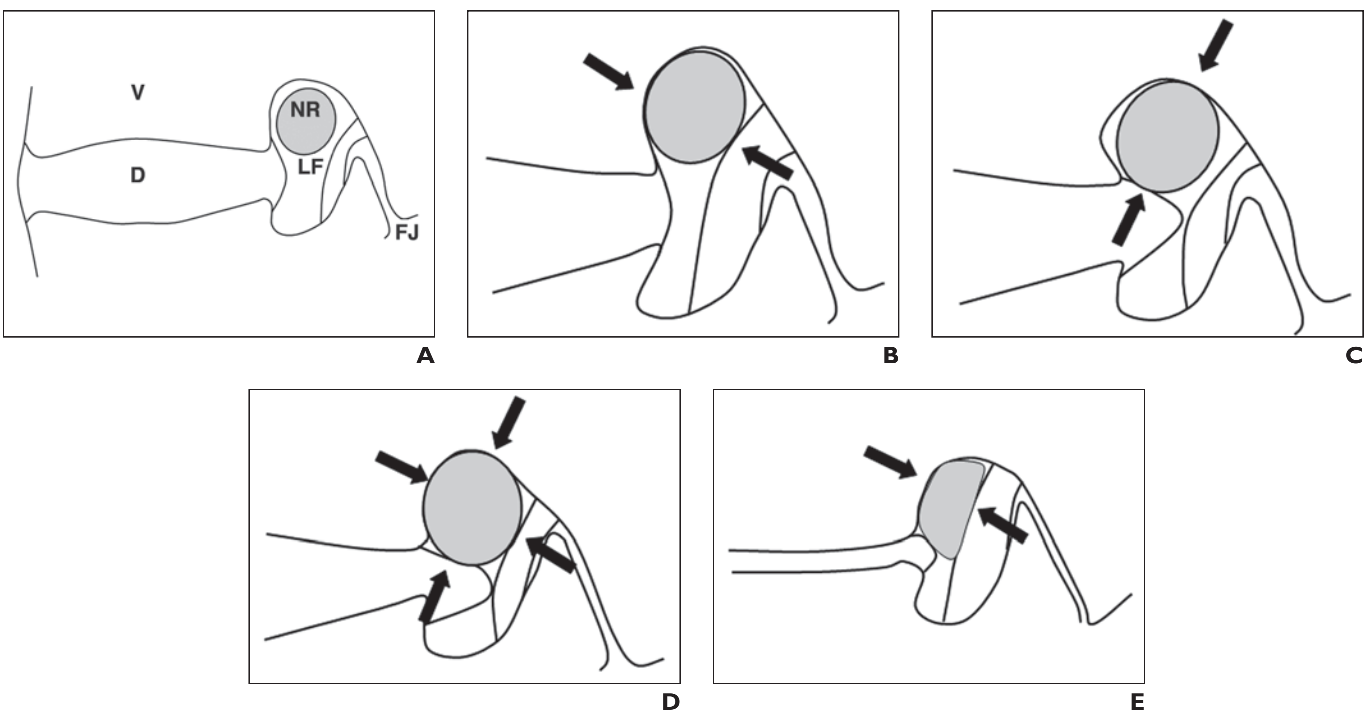

Fig. 1—Schematic illustrations of 4-point-scale for grading foraminal stenosis in sagittal MRI of lumbar spine.
A, Grade 0 (normal). Schematic diagram of sagittal cross section through foramen shows relationships between foramen and surrounding structures. NR = nerve root, V = vertebral body, D = intervertebral disk, LF = ligamentum flavum, FJ = facet joint.
B, Grade 1 (mild degree of foraminal stenosis). Schematic diagram shows perineural fat obliteration surrounding nerve root in transverse direction (*arrows*). There is narrowing of superior foraminal width due to disk space narrowing and thickened ligamentum flavum. No evidence of morphologic change in nerve root is seen.
C, Grade 1 (mild degree of foraminal stenosis). Schematic diagram shows perineural fat obliteration surrounding nerve root in vertical direction (*arrows*). There is narrowing of foraminal height due to disk space narrowing and diskoosteophytic protrusion in foraminal zone. No evidence of morphologic change in nerve root is seen.
D, Grade 2 (moderate degree of foraminal stenosis). Schematic diagram shows perineural fat obliteration surrounding nerve root in four directions (vertical and transverse) (*arrows*) without morphologic change. There is narrowing of foraminal width and height due to disk space narrowing, thickened ligamentum flavum, facet arthropathy, and diskoosteophytic protrusion in foraminal zone. No evidence of morphologic change in nerve root is seen.
E, Grade 3 (severe degree of foraminal stenosis). Schematic diagram shows nerve root collapse or morphologic change (*arrows*) due to severe disk space narrowing, severe thickened ligamentum flavum, facet arthropathy and diskoosteophytic protrusion in foraminal zone.

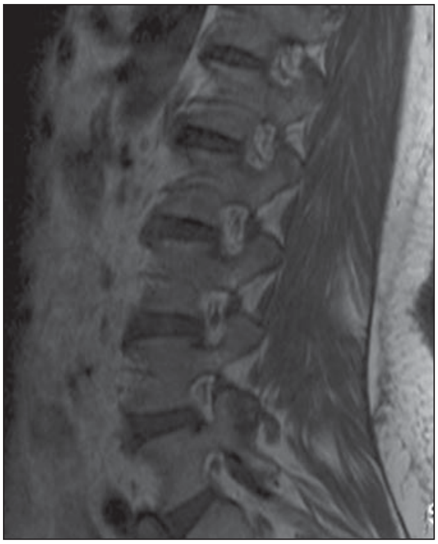

Fig. 2—Case of grade 0 foraminal stenosis. T1-weighted sagittal image of 62-year-old woman with lower back pain shows normal nerve root without compression.

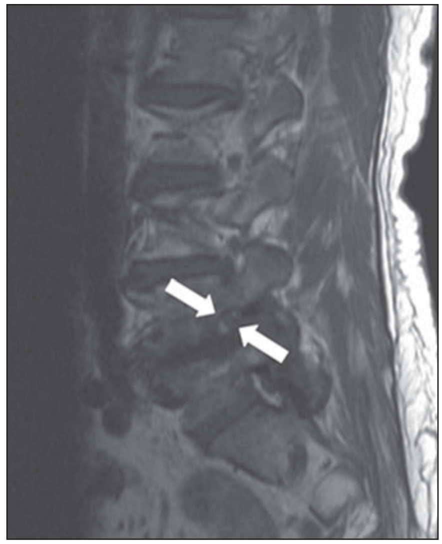

Fig. 3—Case of grade 1 foraminal stenosis in transverse direction. T1-weighted sagittal image of 69-year-old woman with right lower extremity pain shows that narrowing of transverse width of neural foramen and thick ligamentum flavum decrease anteroposterior width of right L4–L5 neural foramen. Perineural fat obliteration surrounding nerve root in transverse direction (*arrows*) is noted.

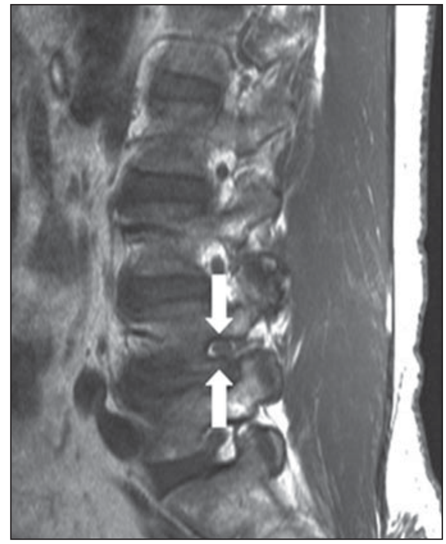

Fig. 4—Case of grade 1 foraminal stenosis in vertical direction. T1-weighted sagittal image of 63-year-old man with left lower extremity weakness shows that narrowing of intervertebral disk space decreases height of left L4–L5 neural foramen. Vertical abutting of nerve root (*arrows*) is noted.

MRI Imaging Analysis

Two experienced spine radiologists (readers 1 and 2), who had 7 and 10 years of experience, respectively, at the time of MR analysis, were blinded to the clinical information and radiologic reports. To assess reproducibility, they evaluated the sagittal MR images of the selected cases independently, and reader 1 evaluated the sagittal MR images of the selected cases after more than 12 months. The examinations were reviewed in a random order to avoid bias.

A total of 960 foramina and corresponding nerve roots in 96 patients were qualitatively analyzed (six foramina/person) from L1–L2 to L5–S1. A total of 384 foramina of the L1–L2 and L2–L3 levels were excluded because of the rarity of foraminal stenosis on these levels. A total of 576 foramina were assessed for possible foraminal stenosis through a combination of both T1- and T2-weighted sagittal images. Each radiologist assessed the presence and grade of foraminal stenosis according to the new grading system previously described.

Statistical Analysis

Interobserver agreement between the two radiologists and intraobserver agreement (reader 1) were analyzed by using kappa statistics. A kappa value of less than 0.20 indicated slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81 or greater, nearly perfect agreement [5]. The Statistical Package for the Social Sciences for Windows (version 13.0, SPSS) was used for statistical analyses.

Results

MR images of varying degrees of foraminal stenosis are shown in Figures 2–6. Reader 1 detected 29 patients with foraminal stenosis on the MR examinations of 96 patients; reader 2 detected foraminal stenosis in 30 patients; Also, reader 1 again detected foraminal stenosis in 31 patients after more than 12 months. According to reader 1, grade 1 foraminal stenosis was found in 33

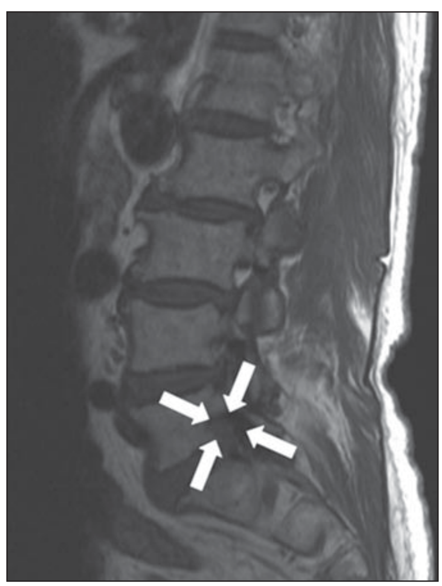

Fig. 5—Case of grade 2 foraminal stenosis. T1-weighted sagittal image of 65-year-old woman with right lower extremity pain shows narrowing of intervertebral disk space, thickened ligamentum flavum, and focal disk protrusion in foraminal zone cause perineural fat obliteration surrounding nerve root of left L5–S1 in both vertical and transverse directions (*arrows*).

Fig. 6—Case of grade 3 foraminal stenosis. T1-weighted sagittal image of 82-year-old woman with right lower extremity pain shows collapse of right L4–L5 nerve root (*arrows*). This finding is compatible with grade 3 foraminal stenosis.

foramina, grade 2 in six, and grade 3 in seven. According to reader 2, grade 1 foraminal stenosis was found in 32 foramina, grade 2 in six, and grade 3 in eight. After more than 12 months, reader 1 found grade 1 foraminal stenosis in 34 foramina; grade 2 in eight; and grade 3 in seven.

Interobserver agreement in the grading of foraminal stenosis between the two readers on sagittal MRI was found to be nearly perfect (κ value: right L3–L4, 1.0; left L3–L4, 0.905; right L4–L5, 0.929; left L4–L5, 0.942; right L5–S1, 0.919; and left L5–S1, 0.909). Intraobserver agreement by reader 1 also was found to be nearly perfect (κ value: right L3–L4, 0.883; left L3–L4, 1.00; right L4–L5, 0.957; left L4–L5, 0.885; right L5–S1, 0.800; and left L5–S1, 0.905).

Regarding the frequency of foraminal stenosis, there were four instances (4.16%) at the level of right L3–L4, six (6.25%) at left L3–L4, eight (8.33%) at right L4–L5, 10 (10.42%) at left L4–L5, seven (7.29%) at right L5–S1, and 11 (11.46%) at left L5–S1 for reader 1. For reader 2, there were four instances (4.16%) at the level of right L3–L4, five (5.21%) at left L3–L4, eight (8.33%) at right L4–L5, 10 (10.42%) at left L4–L5, six (6.25%) at right L5–S1, and 13 (13.54%) at left L5–S1. For reader 1 (after more than 12 months), there were five instances (5.21%) at the level of right L3–L4, six (6.25%) at left L3–L4, eight (8.33%) at right L4–L5, nine (9.38%) at left L4–L5, nine (9.38%) at right L5–S1, and 12 (12.50%) at left L5–S1. A higher incidence of foraminal stenosis was found in the left side and lower lumbar segments.

Discussion

In this study, the new grading system for lumbar foraminal stenosis showed high interobserver and intraobserver agreements. The existing qualitative grading system by Wildermuth et al. [2] is described as follows: grade 0 indicates normal foramina (normal dorsolateral border of the intervertebral disk and normal form at the foraminal epidural fat [oval or inverted pear shape]); grade 1, slight foraminal stenosis and deformity of the epidural fat, with the remaining fat still completely surrounding the exiting nerve root; grade 2, marked foraminal stenosis with epidural fat only partially surrounding the nerve root; and grade 3, advanced stenosis with obliteration of the epidural fat. However, this scoring system lacks characteristics of the morphologic nerve root change.

Hasegawa et al. [1], in a cadaveric study, showed that significant nerve root compression is commonly associated with a foraminal height of 15 mm or less and a posterior disk height of 4 mm or less. They concluded that these critical dimensions might be indicators of lumbar foraminal stenosis. As the superior facet continues to subluxate, the alteration of biomechanical forces contributes to the development of a hypertrophic ligamentum flavum and bony spurs, which may diminish the volume of the foramen to a greater extent. This combination of disk space narrowing and overgrowth of structures anterior to the facet joint capsule may lead to anteroposterior stenosis (transverse stenosis). The exiting nerve root is compressed between the superior articular facet and the posterior vertebral body in a transverse direction.

An additional cause of foraminal stenosis is craniocaudal compression (vertical stenosis). Posterolateral osteophytes from the vertebral endplates protrude into the foramen along with a laterally bulging annulus fibrosis or herniated disk, compressing the nerve root against the superior pedicle. In this case, the posterior aspect of the foramen may remain patent to palpation, possessing adequate amounts of fat despite significant compromise of the available space for the nerve root [6]. A combination of these two types of static changes in foraminal volume may develop and cause severe circumferential stenosis [1]. However, critical dimensions for foraminal stenosis differ according to race, sex, and age.

Compared with the previous grading systems that focused on perineural fat obliteration only or quantitative assessment of the foraminal dimension, our grading system for lumbar foraminal stenosis includes both perineural fat obliteration and nerve root morphology on the basis of sagittal MR images. This system is more practicable for grading foraminal stenosis considering the frequency of radiculopathy caused by nerve root irritation.

A higher incidence of foraminal stenosis is found in the left side and lower lumbar segments. According to previous reviews [1, 7], the most common roots involved were the fifth lumbar root, followed by the fourth, third, and second.

The higher incidence of disk degeneration and spondylosis at the L4–L5 and L5–S1 levels leading to subluxation and foraminal narrowing contributes to the increased susceptibility of the L4 and L5 nerve roots to static and dynamic compression. The lower lumbar nerve roots are also characterized by a more oblique course throughout the lateral canal, increasing their susceptibility to the effects of pedicular kinking and foraminal stenosis [6].

There are several limitations to our study. One limitation was that our grading system is based on sagittal MR morphology without symptomatic correlation. Symptomatic foraminal stenosis may be caused by dynamic changes, such as lumbar extension, which cannot be detected in the closed MR system. Therefore, future studies will be necessary that include correlation of the dynamic positional effects on the foraminal stenosis with clinical symptoms in open or closed MR systems. A second limitation was that direct comparison with previous grading systems was not conducted in this study.

In conclusion, preliminary results suggest that our new grading system for foraminal stenosis is reproducible and may be helpful in the diagnosis and grading of lumbar foraminal stenosis. Further studies will be required to determine its clinical utility.

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