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Painful Lumbar Disk Derangement: Relevance of Endplate Abnormalities at MR Imaging[1]

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Abbreviations:
NPV = negative predictive value
PPV = positive predictive value

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PURPOSE: To investigate the predictive value of magnetic resonance (MR) imaging of abnormalities of the lumbar intervertebral disks, particularly with adjacent endplate changes, to predict symptomatic disk derangement, with discography as the standard.

MATERIALS AND METHODS: Fifty patients aged 28–50 years with chronic low back pain and without radicular leg pain underwent prospective clinical examination and sagittal T1- and T2-weighted and transverse T2-weighted MR imaging. Subsequently, patients underwent lumbar discography with a pain provocation test (116 disks). MR images were evaluated for disk degeneration, a high-signal-intensity zone, and endplate abnormalities. Results of pain provocation at discography were rated independently of the image findings as concordant or as nonconcordant or painless. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated to assess the clinical relevance of MR abnormalities.

RESULTS: Normal disks on MR images were generally not painful at provocative discography (NPV, 98%). Disk degeneration (sensitivity, 98%; specificity, 59%; PPV, 63%) and a high-signal-intensity zone (sensitivity, 27%; specificity, 85%; PPV, 56%) were not helpful in the identification of symptomatic disk derangement. When only moderate and severe type I and type II endplate abnormalities were considered abnormal, all injected disks caused concordant pain with provocation (sensitivity, 38%; specificity, 100%; PPV, 100%).

CONCLUSION: Moderate and severe endplate abnormalities appear be useful in the prediction of painful disk derangement in patients with symptomatic low back pain.

There is general agreement that an extruded or sequestered disk with nerve compression seen on magnetic resonance (MR) images in a patient with acute radicular leg pain is a plausible explanation for the patient's pain. However, to our knowledge, the clinical relevance of other MR findings, including disk degeneration in patients with low back pain, remains unknown. When one considers the well-documented pathologic evidence of disk degeneration and herniation in the early decades of life and their increased prevalence with advancing age (1), it is not surprising that disk abnormalities are frequently depicted on MR images obtained in asymptomatic volunteers. Findings of several studies (2-6) have shown the occurrence of a wide spectrum of disk abnormalities, including disk degeneration, disk bulging, disk protrusion, and annular tears, as evidenced by high-signal-intensity zones in a substantial percentage of healthy volunteers.

In contrast, abnormalities of the endplate and adjacent bone marrow described by Modic et al (7,8) have been shown (6) to be uncommon in asymptomatic volunteers aged 20–50 years. Findings in two recent publications (9,10) suggested a possible relationship between endplate abnormalities revealed at MR imaging and discogenic pain.

The aim of this study was to determine the predictive value of MR imaging abnormalities, including disk degeneration, annular tears (ie, high-signal-intensity zones), and abnormalities of the endplate and adjacent bone marrow of the lumbar spine for symptomatic disk derangement, with discography as the standard.

Author contributions:
Guarantors of integrity of entire study, D.W., N.B.; study concepts and design, M.Z., J.H., N.B.; definition of intellectual content, M.Z., J.H., N.B.; literature research, D.W., N.B.; clinical studies, D.W., K.M., B.F., C.W.A.P.; data acquisition, D.W., K.M., B.F., C.W.A.P.; data analysis, J.H., M.Z., N.B.; statistical analysis, N.B., D.W.; manuscript preparation and editing, D.W., N.B.; manuscript review, M.Z., J.H., K.M., B.F., N.B.; manuscript final version approval, D.W., N.B.

MATERIALS AND METHODS

Study Population

Within the 20 months from January 1998 to August 1999, 50 consecutive patients (23 women, 27 men; mean age, 42.4 years; age range, 28–50 years) were prospectively enrolled in the study. All patients underwent both MR imaging of the lumbar spine and lumbar discography as part of a clinical evaluation of low back pain. MR imaging preceded discography in all patients. Inclusion was based on fulfillment of all of the following criteria:

1. Severe chronic low back pain of presumably discogenic origin (eg, pain aggravation with forward bending, pain during the night, and pain during prolonged sitting with or without referred leg pain [pseudoradicular leg pain into the anterior thigh]). Severe chronic low back pain was defined as low back pain that persisted for longer than 6 weeks and that was unresponsive to a trial of nonsurgical treatment, with surgery not indicated or not urgent on the basis of clinical findings.
2. Severe interference of the back pain with lifestyle and failure of an adequate trial of nonsurgical treatment of at least 6 months duration (ie, a potential indication for surgery in the case of pain provocation during discography).
3. Appropriateness of the candidate for surgery in the case of positive findings at discography.

Primary exclusion criteria were based on clinical findings, which included radicular leg pain, neurologic deficits or evidence of neurogenic claudication, and inappropriate illness behavior as defined by the criteria of Waddell et al (11). The criteria for inappropriate illness behavior included inappropriate descriptions of symptoms and inappropriate responses at physical examination of chronic low back pain.

Secondary exclusion criteria were based on MR imaging findings in the lumbar spine and included a normal MR image or the presence of disk extrusion or sequestration, nerve root compression, foraminal or central spinal stenosis, suspected spinal infection or neoplasm, spondylolisthesis, and moderate to severe facet joint osteoarthritis as revealed with the imaging studies. The secondary exclusion criteria were chosen to exclude patients with MR imaging findings that were currently considered to be a potential source of nondiscogenic low back pain.

All MR images were reviewed prior to the patient's inclusion into the study by two musculoskeletal radiologists working in consensus. The two radiologists who performed the initial MR evaluation were not involved further in the study.

During this initial MR evaluation, the following terms for disk abnormalities were used: normal, bulging, protrusion, extrusion, and sequestration (12,13). Since the presence of disk bulging and protrusion did not represent a secondary exclusion criterion, patients with these MR imaging findings were included in the study. Severity of facet joint osteoarthritis was based on MR findings and were classified as mild, moderate, or severe by using recently published criteria (14). This classification of severity of facet joint osteoarthritis has been shown (14) to have a good inter- and intraobserver correlation when simultaneously used with computed tomography and MR imaging.

The aforementioned diagnostic workup represents the current standard procedure in our spine service. Besides prospective data assessment and evaluation, no additional clinical procedures were performed for the purpose of the study. In accordance with the hospital's institutional review board, informed consent was obtained prior to both MR imaging and lumbar discography.

MR Imaging

MR imaging was performed with a 1.0-T unit (Impact Expert; Siemens, Erlangen, Germany) with a dedicated receive-only spine coil. The imaging protocol consisted of sagittal T1-weighted (700/12 [repetition time msec/echo time msec]) and sagittal T2-weighted (5,000/112) turbo spin-echo imaging of the entire lumbar spine. The image matrix was 512×210 or 512×192; field of view, 300×225 or 300×180 mm; section thickness, 4 mm; intersection gap, 0.5 mm; and echo train length, three or 15. In addition, transverse T2-weighted turbo spin-echo images (4,000/96; image matrix, 512×192; field of view, 150 mm; section thickness, 4 mm; intersection gap, 0.5 mm; echo train length, seven) were obtained of all abnormal disk levels and of at least one disk level with a normal MR appearance.

Lumbar Discography

All 50 patients underwent provocative discography of all abnormal intervertebral disks, as defined by the radiologists involved in the initial evaluation of MR images. In patients with concordant pain (see Pain Assessment for definition) at discography, a disk with a normal appearance on MR images was also injected. Evaluation of these presumably healthy disks served as an internal control.

An orthopedic spine surgeon (N.B.) performed discography in the surgical theater with use of fluoroscopy. The mean delay between MR imaging and discography was 27 days (range, 1–166 days). The patient was awake throughout the procedure and did not receive a sedative. Discography was carried out with a standard posterolateral approach by using a 22-gauge needle (Becton Dickson, Franklin Lakes, NJ). In patients with unilateral pain, the needle was always introduced from the side opposite the area of the pain; in patients with bilateral pain, we preferred to use the left side for convenience. Needle position was verified with fluoroscopic control in two planes. After accurate needle positioning, iopamidol (Iopamiro 300; Sintetica, Mendrisio, Switzerland) containing an iodine concentration of 300 mg/mL was injected into each disk by using a 5-mL syringe. The amount of contrast agent injected ranged from 0.8 to 4.0 mL. Nonionic contrast agent (iopamidol [Iopamiro 300]; Sintetica, Mendrisio, Switzerland) was injected with a 5-mL syringe until firm resistance to the injection was felt, until severe pain was provoked, or until contrast medium was seen to leak out of the disk into the spinal canal.

MR Image Evaluation

MR images in all 50 patients were evaluated together by two experienced musculoskeletal radiologists (M.Z., J.H.) not involved in decision making for treatment. The observers were completely blinded to patient data and clinical and discographic findings. All images were evaluated in random order. A consensus opinion was reached in all cases of disagreement between the two observers. Intra- and interrater reliability estimates for the identical readers were reported in a previous study (14) in which the same criteria were used. The evaluated MR imaging findings included extent of intervertebral disk degeneration, presence of a high-signal-intensity zone in the posterior aspect of the anulus fibrosus, and abnormalities of the endplates and adjacent bone marrow.

The extent of intervertebral disk degeneration was graded on midsagittal T2-weighted images according to the criteria of Eyre et al (15) and Pearce et al (16) (Table 1). For the purpose of this study, disks with grades 1 (normal adolescent disk) and 2 (normal adult disk) were grouped together as disks without degeneration. Similarly, disks with grades 3–5 (grade 3, slight degeneration; grade 4, moderate degeneration; and grade 5, severe degeneration) were grouped together as degenerated disks.

The presence of a high-signal-intensity zone was noted on sagittal T2-weighted turbo spin-echo images. A high-signal-intensity zone was defined as a focal zone of high signal intensity within the posterior aspect of the anulus fibrosus that was clearly dissociated from the pulpy nucleus, without focal protrusion or extrusion of the disk (17). The high-signal-intensity zone has been reported (17) to represent annular tears.

The readers were asked to classify the endplates and adjacent bone marrow abnormality on sagittal MR images according to the definitions of Modic et al (7,8) for each category as follows: no abnormality; type I, low signal intensity on T1-weighted images and high signal intensity on T2-weighted images when compared with fatty bone marrow; type II, high signal intensity with both images; and type III, low signal intensity with both images. When two types were present on both sides of the intervertebral space, only one diagnosis was applied: first priority, type I; second priority, type II; last priority, type III.

In the presence of an endplate abnormality, the readers were asked to grade the abnormality with regard to extent as follows: none, minimal, moderate, or severe (Figs 1–3). Severity of endplate abnormalities was defined as follows: none, no evidence of endplate abnormalities on both T1- and T2-weighted images; minimal, largest cranial or caudal extent of endplate abnormality involving equal to or less than 25% of the vertebral height as measured on a midsagittal image; moderate, largest cranial or caudal extent of the endplate abnormality between 25% and 50% of the vertebral height measured on a midsagittal image; or severe, largest cranial or caudal extent equal to or more than 50% of the vertebral height as measured on a midsagittal MR image (Figs 1–3). When endplate abnormalities were present on both sides of the intervertebral disk, the endplate abnormality with the larger cranial or caudal extent was used for further evaluation.

Pain Assessment

During discography, patients were asked to grade the pain they experienced on a scale of 0 (no pain or pressure) to 10 (worst pain imaginable). They were further asked to grade the pain according to the Dallas Discogram Description (18) as no sensation, pressure, dissimilar pain, similar pain, or exact pain reproduction. For the purpose of this study, pain sensation during discography was defined as concordant if the patient had exact pain reproduction or felt similar pain. Accordingly, nonconcordant pain was defined as pressure, dissimilar pain sensation, or no pain provocation.

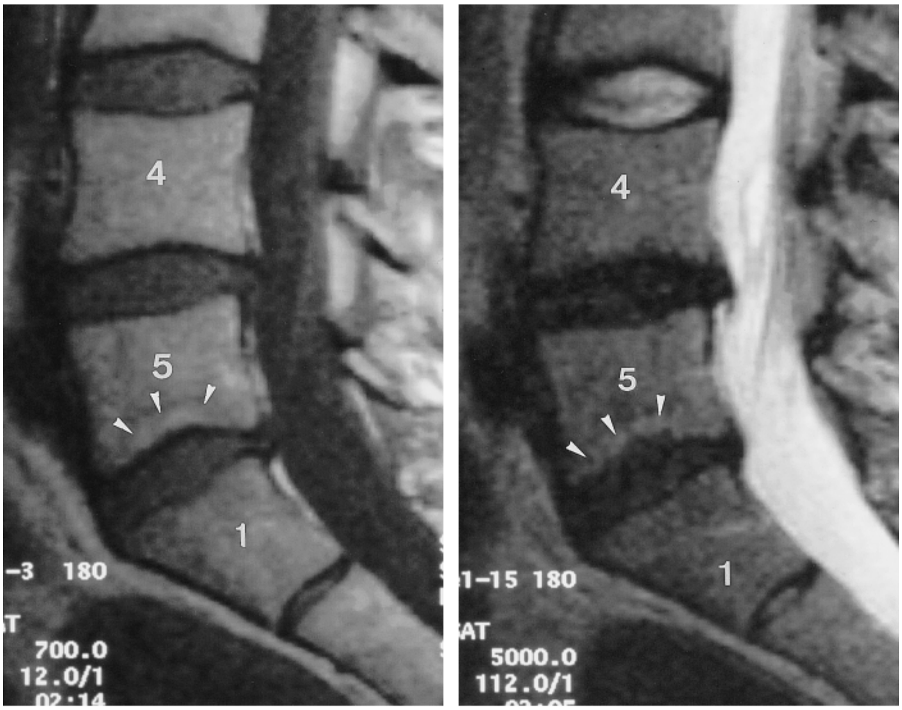
Morphologic Discogram Evaluation

Each discogram was reviewed by the orthopedic spine surgeon who performed discography. Evaluation of disk morphologic characteristics was performed with conventional radiographs by using the classification of Adams et al (19). This

TABLE 1
Classification of Disk Degeneration on Sagittal T2-weighted MR Images

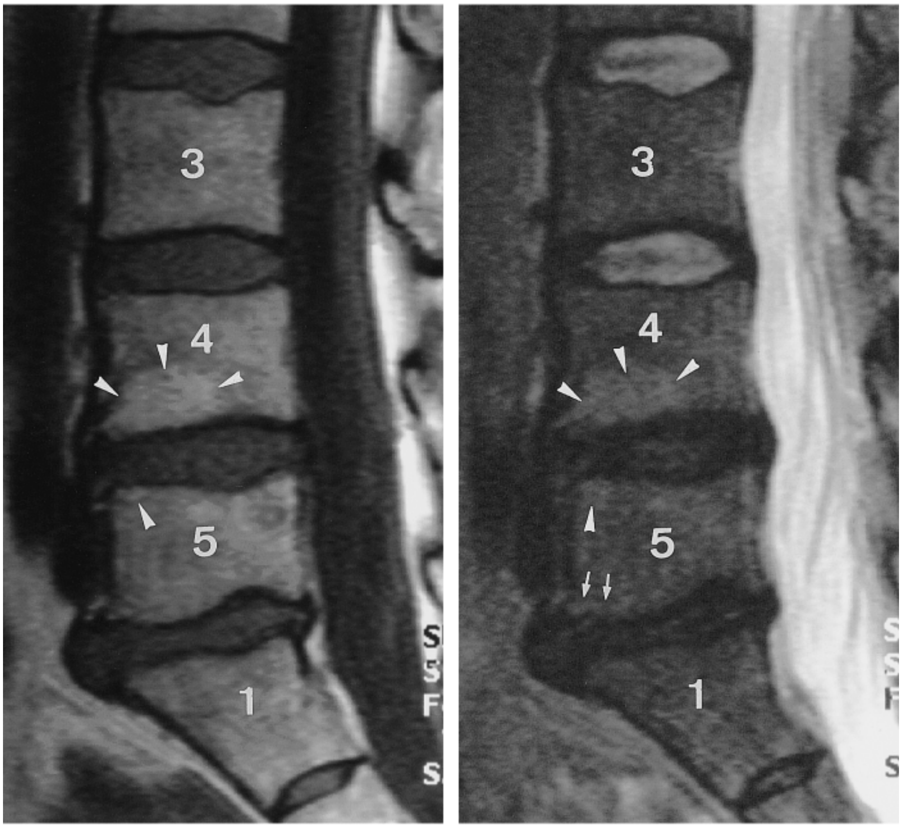
Grade	Differentiation of Nucleus Pulposus from Anulus	Signal Intensity of Nucleus Pulposus	Disk Height
1	Yes	Homogeneously hyperintense	Normal
2	Yes	Hyperintense with horizontal dark band	Normal
3	Blurred	Slightly decreased, minor irregularities	Slightly decreased
4	Lost	Moderately decreased, hypointense zones	Moderately decreased
5	Lost	Hypointense, with or without horizontal hyperintense band	Collapsed

Note.—Modified from the classification of Pearce et al (16).



a. b.

Figure 1. MR images of the lumbar spine in a 32-year-old woman with discogenic low back pain demonstrate the criteria used to identify mild endplate abnormalities. Sagittal **(a)** T1-weighted (700/12) and **(b)** T2-weighted (5,000/112) turbo spin-echo MR images demonstrate a small band of increased signal intensity (arrowheads) of bone marrow (cranial or caudal extent ≤25% of the vertebral height as measured on a midsagittal image) adjacent to the upper endplate at the intervertebral disk level of L5 (*5*) to S1 (*1*) (type II endplate abnormality). There is grade 3 degeneration at the L5-to-S1 intervertebral disk level with disk bulging and grade 4 degeneration of the intervertebral disk at L4 (*4*) to L5 with disk bulging.



a. b.

Figure 2. MR images of the lumbar spine in a 46-year-old woman with discogenic low back pain demonstrate the criteria used to identify moderate endplate abnormalities. Sagittal **(a)** T1-weighted (700/12) and **(b)** T2-weighted (5,000/112) MR images demonstrate a thick semicircular band of increased signal intensity (upper arrowheads) of bone marrow adjacent to the upper aspect of the endplate at the intervertebral disk level of L4 (*4*) to L5 (*5*) (cranial or caudal extent between 25% and 50% of the vertebral height measured on a midsagittal image) and a small focus of increased signal intensity (lower arrowhead) of marrow at the inferior aspect of this level. Image findings are consistent with a moderate type II endplate abnormality. There is grade 3 degeneration at the L4-to-L5 intervertebral disk level with disk bulging and grade 4 degeneration at the intervertebral disk level of L5 to S1 (*1*) with mild type II endplate abnormalities (arrows in **b**) and disk bulging. *3* = L3 vertebra.

classification system includes five stages of disk degeneration distinguished by their morphologic appearance on discograms. For the purpose of this study, disks of nondegenerative types I (cotton ball) and II (lobular) were grouped together as normal; those of types III (irregular), IV (fissured), and V (ruptured) were grouped as degenerative (ie, abnormal) disks.

Data and Statistical Analyses

The prevalence of all MR abnormalities were calculated, and the data were compared with disk morphologic characteristics (19) and pain responses, as evidenced at discography. The data obtained from pain assessment during discography was further used to determine painful disk derangement. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy (20) for each predictor variable (ie, disk degeneration, high-signal-intensity zone, and endplate abnormalities) were calculated; the result of the pain response during discography was the standard.

RESULTS

A total of 122 disks in 50 patients were included in this study. The L5-to-S1 level was not accessible in six patients, and they were therefore excluded from the analyses. The results of the injection at the L5-to-S1 level would not have influenced the treatment decision in any of these patients. On the other hand, the L5-to-S1 level was successfully accessed in all patients in whom the result relevant to the clinical decision. Therefore, discography was performed in 116 disks in 50 patients, and the following results were used for further evaluation: eight (6.9%) disks at the L2-to-L3 level, 34 (29.3%) at the L3-to-L4 level, 46 (39.7%) at the L4-to-L5 level, and 28 (24.1%) at the L5-to-S1 level.

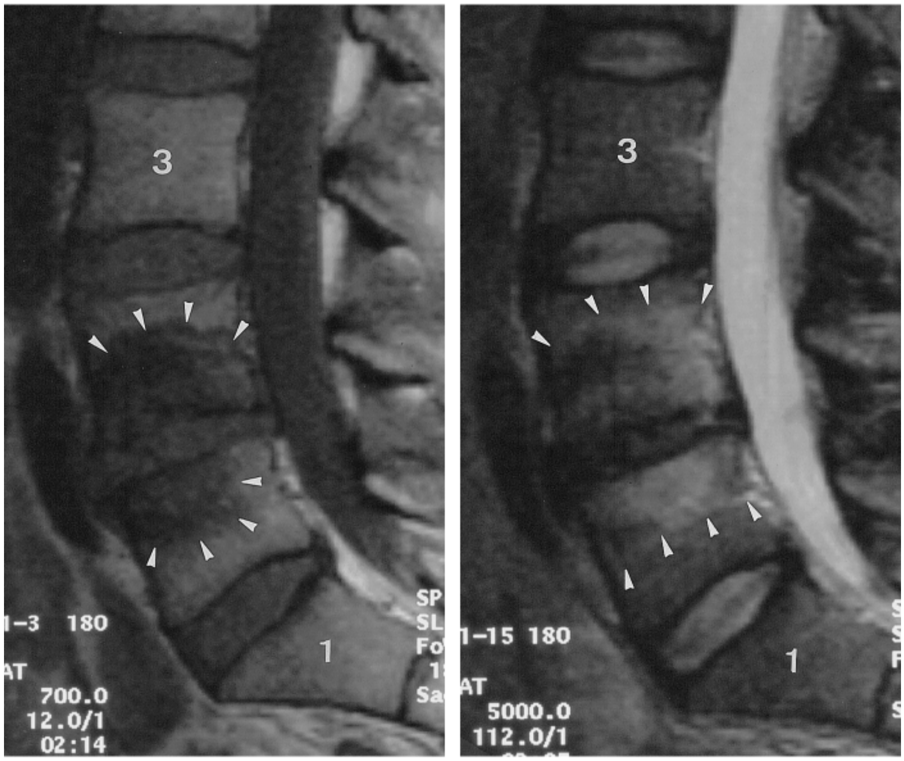
The prevalence of discographic and MR imaging findings in the 116 disk levels where discography was performed are shown in Table 2. On MR images, 37 (31.9%) of 116 disks were considered nondegenerated (grades 1 and 2) normal disks without any of the assessed abnormalities. Disk degeneration, high-signal-intensity zone, and/or endplate abnormalities were present in 79 (68.1%) disks. No type III endplate abnormality was present at any disk level.

A comparison of the discographic findings (according to the classification of Adams et al [19]) and the MR imaging appearance of the disk revealed no case of a type IV (fissured) or V (ruptured) disk when the MR images were normal (Table 2).

None of the patients who reported concordant pain with provocation graded the pain intensity below 6 on the 10-point scale. Sixteen (44%) of 36 patients with concordant pain reported the worse pain they ever experienced.

In a subset of 37 patients with concordant pain with provocation, at least one normal disk on MR images (ie, no disk degeneration or other MR abnormality) was injected . All but one patient had a negative pain provocation test: Twelve patients had no sensation; 22, only pressure; and two, dissimilar pain. The remaining patient reported similar pain with injection of contrast medium. The NPV of a normal disk on MR images in terms of pain provocation was 97% (37 of 38 patients).

Sensitivity, specificity, NPV, PPV, accuracy, and disease prevalence are shown in Table 3. Disk degeneration as seen on MR images had a high NPV (98%) but a low specificity (59%) in terms of pain prediction. The presence of a high-signal-intensity zone showed a high specificity (85%) but a low PPV (56%) in terms of pain reproduction. PPV and specificity of both type I and type II endplate abnormalities were 88% and 96%, respectively, when slight, moderate, and severe endplate changes were encountered. When only moderate and severe endplate abnormalities of both type I and type II were considered abnormal, all injected disks caused concordant pain with provocation (PPV, 100%; specificity, 100%).



a. b.

Figure 3. MR images of the lumbar spine in a 35-year-old woman demonstrate the criteria used to identify severe endplate abnormalities. **(a)** Sagittal T1-weighted (700/12) turbo spin-echo image shows extensive bone marrow abnormalities of low signal intensity (arrowheads) (cranial or caudal extent ≥50% of the vertebral height as measured on a midsagittal MR image) adjacent to both endplates at the L4-to-L5 disk intervertebral level. **(b)** Sagittal T2-weighted (5,000/112) turbo spin-echo image shows an increase in signal intensity (arrowheads) of bone marrow, consistent with a severe type I endplate abnormality. There is grade 4 degeneration of the L4-to-L5 intervertebral disk. *1* = S1 vertebra, *3* = L3 vertebra.

DISCUSSION

Discogenic pain in the lumbar spine is common and is characterized by nonradicular pain. Discogenic pain has a somatotropic rather than dermatomal pattern of pain projection (21). Therefore, the use of symptoms and clinical findings to localize the level of abnormality is difficult. The source of discogenic pain is still unknown. Degeneration of the intervertebral disk, annular tears, and endplate abnormalities have been discussed (8,9, 22,23) as causative factors.

MR imaging provides an unique means to evaluate the morphologic status of intervertebral disks and their relationship to neural structures in patients with low back pain. Moreover, the technique allows assessment of the biochemical status of the disk on T2-weighted spin-echo and fast spin-echo MR images (16). Loss of disk height and loss of brightness of the pulpy nucleus reflect the decreased proteoglycan concentration in degenerated disks (16). Yu et al (24) demonstrated in a postmortem study that with the use of MR imaging accurate detection of annular tears is possible. However, although MR imaging provides detailed information with regard to the whole spectrum of abnormalities, the role of MR imaging in the evaluation of discogenic pain has not been well defined (25,26).

The clinical relevance of abnormal MR findings in patients with back pain has been questioned by several investigators (2–6) in studies of asymptomatic volunteers. In addition, MR imaging often demonstrates several abnormal intervertebral disk levels in symptomatic patients; thereby, it is not helpful in the identification of symptomatic intervertebral disk levels. Therefore, the question arises as to which signs on MR images, if any, can be used to differentiate symptomatic findings from asymptomatic ones.

Today, MR imaging has surpassed standard discography in the depiction of internal disk structure. However, discography as a pain provocation test is considered the only method that can be used to directly relate a radiologic image to the patient's pain (26). This procedure is, therefore, still the standard in the diagnosis of painful disk derangement. The rationale for back pain is related to the fact that, during injection of contrast medium into the disk, breakdown products such as neuropeptides or cytokines are expelled from the disk and cause nociception at the outer annular fibers that are innervated (27). With the use of current techniques, a specificity of 100% with discography in the detection of painful lumbar disks is reported (28). Prior MR imaging, however, is considered a prerequisite with regard to determination of the levels that should be injected at discography (26).

The results of our study show that the presence of a degenerated disk on T2-weighted turbo spin-echo images was not a reliable marker for a symptomatic disk. The results are in accordance with those of Collins et al (29), who reported on a prospective study of 29 patients with chronic low back pain who were being considered for spinal surgery. In the study by Collins et al (29), all symptomatic disks were degenerated at MR imaging (as indicated by decreased signal intensity on T2-weighted images) and at discography. Of the 57 degenerated disks detected with discography, only 23% were symptomatic. The poor predictive value of a painful disk in the presence of disk degeneration on MR images is supported by the results of three other studies (30-32), as well as the fact that disk degeneration on MR images has a high prevalence in healthy volunteers aged 20–50 years (4,6).

The clinical relevance of a posterior high-signal-intensity zone on T2-weighted MR images, which is considered to represent a severe form of a combined radial and concentric annular tear (17), is controversial. Aprill and Bogduk (17) reported an 86% PPV of a high-signal-intensity zone at painful discography in 500 patients. The high PPV of a high-signal-intensity zone for painful annular tears has been validated by other investigators (32–34). Conversely, Ricketson et al (35) were not able to demonstrate a statistically significant correlation between the presence of a high-signal-intensity zone and pain concordant with the usual symptoms during provocative discography. In the current study, the correlation between the presence of a high-signal-intensity zone and concordant pain was low (Fig 4). In light of a prevalence of

TABLE 2
Comparison of Results of MR Imaging and Discography in 116 Disks of 50 Patients with Discogenic Pain

		MR Imaging Findings								
		Disk Degeneration*					Endplate Abnormality†			
							Type I		Type II	
Discographic Findings	No. of Disks	Grades 1–2	Grade 3	Grade 4	Grade 5	High-Signal-Intensity Zone	All	Only Moderate and Severe	All	Only Moderate and Severe
Disk Morphology‡										
Type I	16	14	2	0	0	1	1	0	0	0
Type II	25	18	5	2	0	2	0	0	1	0
Type III	22	9	8	4	1	2	2	0	1	1
Type IV	45	0	19	22	4	14	9	8	7	5
Type V	8	0	4	4	0	4	4	3	1	1
Pain response										
Nonconcordant pain	68	40	17	10	1	10	2	0	1	0
Concordant pain	48	1	21	22	4	13	14	11	9	7

* Classification by Pearce et al (16).
† Classification from Modic et al (7,8).
‡ Classification by Adams et al (19).

TABLE 3
Diagnostic Performance of MR Abnormalities of the Intervertebral Disk in the Prediction of Symptomatic Intervertebral Disks

MR Abnormalities	Prevalence* (n = 116)	TP	FN	FP	TN	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Disk degeneration grades 3–4	75 (64.7)	47	1	28	40	98	59	63	98	75
High-signal-intensity zone	23 (19.8)	13	35	10	58	27	85	56	62	61
Endplate abnormalities										
Modic type I										
All	16 (13.8)	14	34	2	66	29	97	88	66	69
Only moderate and severe	11 (9.5)	11	37	0	68	23	100	100	65	68
Modic type II										
All	10 (8.6)	9	39	1	67	19	98	90	63	65
Only moderate and severe	7 (6.0)	7	41	0	68	15	100	100	62	65
Modic types I and II										
All	26 (22.4)	23	25	3	65	48	96	88	72	76
Only moderate and severe	18 (15.5)	18	30	0	68	38	100	100	69	74

Note.—The numbers of false-negative (FN), false-positive (FP), true-negative (TN), and true-positive (TP) findings are based on positive prediction of a symptomatic intervertebral disk as evidenced by pain response during discography.
* Numbers in parentheses are percentages.

56% (5,6), a high-signal-intensity zone may not be predictive of discogenic pain.

Recently, debate has focused on endplate abnormalities as an indicator of symptomatic disk degeneration. Three types of such abnormalities have been described by Modic et al (7,8). Correlations between MR imaging and discographic findings have suggested that endplate abnormalities may be predictive for discogenic pain (9,10). In our study population, endplate abnormalities were demonstrated adjacent to 26 disks, 23 of which produced concordant pain at provocative discography. When only moderate and severe endplate abnormalities of types I and II were considered abnormal, all disks with endplate abnormalities caused concordant pain, which resulted in a PPV of 100%.

McCall et al (9) and Braithwaite et al (10) reported remarkably similar findings with regard to the prevalence and clinical relevance of endplate abnormalities in patients with discogenic pain. In a retrospective study of 58 patients with discogenic pain, Braithwaite et al (10) found a prevalence of 48% with endplate abnormalities and a PPV of 97% as a marker for a painful disk. The likelihood of the clinical relevance of endplate abnormalities in patients with discogenic pain is supported by the low prevalence of endplate abnormalities in an asymptomatic population (6) of the same age as that of patients in the present study.

Although our data are encouraging, preoperative provocative discography may still be needed to identify symptomatic disk derangement, even in patients with moderate or severe endplate abnormalities. The need for discography in the assessment of patients with discogenic pain is also substantiated by the fact that not all discogenic pain is caused by endplate abnormalities. Clearly, more data must be provided until the need for provocative discography can be eliminated in patients with presumably discogenic pain and endplate changes on MR images.

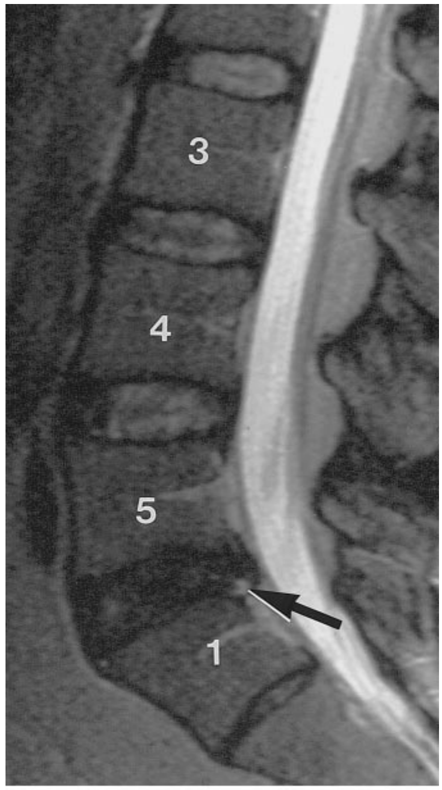
The cause of endplate abnormalities is not well understood. Recent data suggest that they may develop as a result of inflammatory alterations within the disk matrix in symptomatic patients. Boos et al (36) showed that symptomatic disk herniations exhibited T1 and T2 relaxation times that were substantially lower than those of matched asymptomatic herniations. The authors concluded that symptomatic and morphologically matched asymptomatic disk herniations differ with regard to disk matrix composition.

This hypothesis has been substantiated by Burke et al (37) who biochemically examined disk specimens that were harvested during discectomy for sequestrated disks and fusion operations for discogenic back pain. In both diagnostic groups, the authors detected high levels of interleukin-6 and interleukin-8. The authors hypothesized that the high level of proinflammatory mediators may indicate that a specific inflammatory form of disk degeneration exists. This finding may explain why some degenerated disks cause low back pain while other morphologically similar disks do not. These findings and interpretations are intriguing with regard to pain pathogenesis and deserve further attention and evaluation.

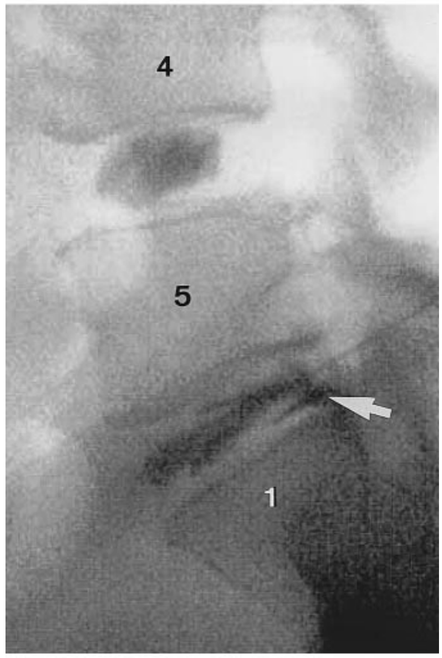
We acknowledge limitations of our study. Inclusion of only patients who were appropriate for surgery may have caused a selection bias. However, because discography is an invasive procedure with a small but existing complication rate (26), discography should be performed only as a preoperative assessment with a direct influence on treatment in patients with a positive pain response (26). It must be stressed that a presumably normal disk (as an internal negative control) was injected only in patients with concordant pain with provocation. The risk of performing surgery (ie, spinal fusion) on the basis of false-positive pain provocation results is substantially higher than the rate of iatrogenic disk infection. However, injection of a normal disk in patients without a concordant pain response is not justifiable because it has no effect on clinical decision making (ie, the patients are excluded from surgery anyway because of the negative pain response).

Other limitations are related to the evaluation of discograms, as well as MR images, and the applied imaging protocol. The fact that discograms were reviewed by the orthopedic spine surgeon who performed discography may have affected discographic grading. Since evaluation of MR images was performed by two readers working in consensus, determination of interobserver variability in grading the extent of endplate abnormalities was not assessed. Nonuse of fat-suppression techniques may have led to underestimation of subtle endplate abnormalities. Furthermore, intravenous application of a contrast agent was not part of the imaging protocol. Because annular tears might not be detected without application of contrast material (5), this omission could have influenced our results.

In conclusion, our results indicate that disk degeneration and the presence of a high-signal-intensity zone may not correspond directly to painful disk degeneration and should, therefore, not be used to identify symptomatic intervertebral disks. Conversely, moderate and severe endplate type I and type II abnormalities on MR images may indicate painful disk derangement in patients with low back pain.



a.



b.

Figure 4. MR image of the lumbar spine and discogram at the intervertebral levels of L4 (*4*) to L5 (*5*) and L5 to S1 (*1*) in a 42-year-old woman. **(a)** Sagittal T2-weighted (5,000/112) turbo spin-echo MR image shows grade 3 disk degeneration with disk bulging and a high-signal-intensity zone (arrow) within the posterior aspect of the anulus fibrosus at the L5-to-S1 intervertebral disk level. The L4-to-L5 intervertebral disk level is normal. *3* = L3 vertebra. **(b)** Lateral discogram of the L5-to-S1 intervertebral disk shows type IV degeneration with a radial fissure (arrow) leading to the outer edge of the anulus. Discogram is normal at the L4-to-L5 level. The patient had no pain at either injection site.

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