Correlation Between MR Imaging and Discography With Provocative Concordant Pain in Patients With Low Back Pain

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Objective: This study aimed to correlate magnetic resonance (MR) findings and discography with pain response at provocative discography in patients with low back pain.

Methods: Ninety-three patients who underwent MR imaging of the lumbar spine and subsequent provocation discography as part of a clinical evaluation of low back pain were enrolled in the study. MR images were then evaluated for disc degeneration, high-intensity zone (HIZ), and endplate abnormalities. In the procedure of discography, concordant pain was denoted as positive, whereas discordant pain and no pain were denoted as negative. Finally, MR and discographic findings were analyzed by χ^2 test based on results of concordant pain.

Results: Discography was conducted on 256 discs successfully, 116 discs of which presented with concordant pain, and the others presented with discordant pain. There were 141 discs were evaluated as Grade I-III on MR images, 17 of which presented with concordant pain; 115 were evaluated as Grade IV-V, 99 of which presented with concordant pain. HIZ was found in 60 discs, 52 of which had concordant pain. The endplate abnormalities were observed in 58 discs, 51 of which manifested concordant pain. Concordant pain was significant correlated with Type IV-V discs on discography ($\chi^2 = 144.08$, $r = 0.60$, $P < 0.01$), Grade IV-V disc degeneration on MR image ($\chi^2 = 137.11$, $r = 0.59$, $P < 0.01$), the presence of HIZ ($\chi^2 = 51.93$, $r = 0.41$, $P < 0.01$), and endplate abnormalities ($\chi^2 = 52.76$, $r = 0.41$, $P < 0.01$).

Discussion: Disc degeneration grades on MR imaging showed an association with discographic grades. Type IV-V discs on discography, Grade IV-V disc on MR images, the presence of HIZ, and endplate abnormalities might indicate discogenic pain in patients with chronic low back pain.

Key Words: magnetic resonance imaging (MRI), discography, concordant pain

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Low back pain (LBP) is the second of most common symptoms encountered by primary care physicians.[1] One of its prominent sources is the discogenic pain, a term synonymous with internal disc disruption (IDD). Crock[2] defined IDD as an "alteration in the internal architecture of the disc, specifically excluding the escape of the disc fragment from the confines of the space (annulus)." Discography as a pain provocation test is considered as the only method to relate a radiographic image to the patient's pain directly.[3] From an empirical standpoint, discography is the best tool to evaluate discogenic LBP. However, because of its invasiveness, radiation exposure, and infectious risk, discography has been controversial since its beginning. Magnetic resonance imaging (MRI) is a highly accurate method in detecting morphologic abnormalities of the degenerative discs. Although MRI was found to be sensitive for the identification of degenerative discs, it was unreliable at identifying the symptomatic disc levels. Some early studies have attempted to correlate the MRI features of disc degeneration with pain reproduction at discography; however, the results were controversial.[1,4–8] Therefore, in this study we tried to find out if discogenic lumbar pain was associated with discographic findings and magnetic resonance (MR) findings including disc degeneration (Pearce grade), high-intensity zone (HIZ), and endplate abnormality (Modic change) based on the pain response during discography.

METHODS

Participants

From January 2008 to November 2009, 93 consecutive patients (64 men and 29 women, mean age 40.11 y, age range 30 to 56 y) were enrolled in the study retrospectively. All patients underwent MRI of the lumbar spine followed by provocation discography as part of a clinical evaluation of LBP. Inclusion was based on the following criteria: (1) primary complaint of LBP for at least 1 year, (2) without neurologic deficits in physical examination, (3) no earlier surgery, (4) failure of an adequate trial of nonsurgical treatment of at least 6 months' duration, (5) MRI obtained during the current episode of pain, and MR images showed decreased signal intensity of the nucleus pulposus in at least one discs. The case was excluded based on MRI findings that were considered to be a potential source of nondiscogenic LBP and included the presence of disc extrusion or disc herniation, nerve root compression, spondylolisthesis, earlier lumbar disc surgery, and suspected spinal infection or neoplasm. Institutional review board approval was obtained for the study, and informed consent was obtained in all patients.

MRI

MRI was carried out with a 1.5-T imager (Gyroscan Intera Master, Philips Medical Systems, Netherlands) by using a phased array spine coil or a spine coil. The imaging protocol consisted of sagittal spin-echo (SE) T1-weighted imaging [range of repetition time (TR) ms/echo time (TE) ms: 350 ms/20 ms], and turbo spin-echo

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(TSE) sagittal, and axial T2-weighted imaging (TR/TE: 1800 to 3000 ms/90 to 150 ms). Typical MR parameters were slice thickness, 4-5 mm; intersection gap, 1 mm; matrix, 256×256; flip angle 90 degree; 2 excitations.

MR images were read by 2 experienced musculoskeletal radiologist who were blinded to the results of discography. The evaluated data of the MR images included the grading of disc degeneration (Pearce grade), the presence of HIZ, and the presence of endplate abnormalities (Modic changes).

Disc degeneration was graded on mid-sagittal T2-weighted images according to the modified criteria of Pearce et al[9]: Grade I, preserved differentiation of the nucleus pulposus from the annulus, homogeneously hyperintense signal of the nucleus pulposus; Grade II, preserved differentiation of the nucleus pulposus from the annulus, hyperintense signal of the nucleus pulposus with a horizontal dark band; Grade III, mild degeneration, blurred differentiation of the nucleus pulposus from the annulus, slightly decreased signal of the nucleus pulposus with minor irregularities; Grade IV, moderate degeneration, a loss of differentiation of the nucleus pulposus from the annulus, moderately decreased signal of the nucleus pulposus with hypointense zones; and Grade V, severe degeneration, a loss of differentiation of the nucleus pulposus from the annulus, hypointense signal of the nucleus pulposus with or without a horizontal hyperintense band.

Endplates and adjacent bone marrow abnormalities were classified on sagittal MR images according to the densification of Modic et al.[10] Modic Type I, low signal intensity on T1-weighted images and high signal intensity on T2-weighted images; Modic Type II, high signal intensity on both images; and Modic Type III, low signal intensity on both images. HIZ was defined as a focal zone of high signal intensity on sagittal T2-weighted images within the posterior aspect of the annulus fibrosus.[5]

Discography

Discography was conducted by 2 musculoskeletal radiologists (discographer) and 1 orthopedist. The cases for discography were selected by the orthopedist according to the following criteria: All abnormal discs of 93 patients underwent provocation discography, as defined by the initial evaluation of MR images. When patients had concordant pain during discography, we tested adjacent discs with normal appearance or subtle degeneration. The 2 discographers were blind to the results of MRI during discography. Patients were located in a comfortable prone position during the procedure. Local infiltration anesthesia with 1% lidocaine was used for disc injections. Discography was then conducted with an 18-gauge 5-in, introducer needle placed at the outer margin of the annulus fibrosus of the disc and advancement of an 8-in, 22-gauge needle through this outer needle and into the center of the disc using C-arm fluoroscopy (Philips DSA V3000). The needle position was confirmed in both the anteroposterior and lateral projections before contrast injection, to ensure that the central disc has been accessed. Nonionic contrast medium (Omnipaque; GE Healthcare) was injected into each disc with a 5 mL syringe. Until firm resistance to the injection was felt, until sever pain was provoked, or until contrast medium was seen to leak out of the disk into the spinal canal. The amount of contrast agent injected was recorded. Contrast injection is assessed fluoroscopically to ensure the filling of the nucleus pulposus and to exclude an annular injection.

During injection, pain response was recorded into 3 grades: no pain, unfamiliar pain, and familiar pain and the use of the numeric rating scale [range 0 (no pain) to 10 (worst pain that could ever be experienced)]. Designation as a disc with concordant pain by discography required the presence of a pain response on the numeric rating scale of 6 or higher, pain described by the participant as familiar. Lateral and anteroposterior radiographs of the lumbosacral spine were obtained in all patients.

Discography was reviewed by 2 experienced musculoskeletal radiologist. Evaluation of disc morphology was conducted with conventional radiographs according to the classification of Adams: Type I cotton ball; Type II, lobular; Type III, irregular; Type IV, fissured; and Type V, ruptured.[11] Types I and II are normal discographic findings. Concordant pain during discography was considered as positive, whereas discordant pain and no pain were considered as negative.

Statistical Analysis

All statistical analyses used the SPSS software (version 13.0). $P < 0.05$ was considered statistically significant. The association of discography type, disc degeneration grade on MRI, HIZ, and endplate abnormalities with concordant pain was all analyzed by the χ^2 test. Contingency table was tested by χ^2 test. Sensitivity, specificity, positive likelihood ratio (LR+) and negative likelihood ratio (LR−) for each predictor variable were calculated, respectively.

RESULTS

Discography was successfully carried out on 256 discs in 93 patients at the following levels: 12 discs (4.7%) at the L2 to L3 level, 93 discs (36.3%) at the L3 to L4 level, 93 discs (36.3%) at the L4 to L5 level, and 58 discs (22.7%) at the L5 to S1 level. Evaluated by the discography classification system, there were 17 (6.6%) Type I discs, 25 (9.8%) Type II, 91 (35.5%) Type III, 77 (30.1%) Type IV, and 46 (18.0%) Type V (Table 1). One hundred and thirty-three discs were classified as Type I-III, 12 of which had concordant pain, whereas 123 discs were classified as Type IV-V, 104 of which had concordant pain. Totally, there were 116 discs with concordant pain, and 140 discs with discordant pain in the procedure of discography. Type IV-V discs classified by discography grades showed a significant correlation with the concordant pain ($x^2 = 144.08$, $r = 0.60$, $P < 0.01$) (Table 2). The volume of injected

TABLE 1. Correlation Between Discography Adams Type and MRI Pearce Grade

	Pearce Grade					
Adams Type	**I**	**II**	**III**	**IV**	**V**	**Total**
I	11	5	1	0	0	17
II	4	10	8	3	0	25
III	3	12	45	26	5	91
IV	3	4	22	41	7	77
V	2	3	8	15	18	46
Total	23	34	84	85	30	256

$\chi^2 = 160.87$, $P < 0.01$, $r = 0.62$.

TABLE 2. Correlations of MRI and Discography With Concordant Pain

Imaging Finding	Concordant Pain (%)	Discordant Pain or Painless (%)	*P*	χ^2	*r*
Type IV-V at Discography	89.7 (104/116)	13.6 (19/140)	< 0.01	144.08	0.60
Grade IV-V at MRI	85.3 (99/116)	11.4 (16/140)	< 0.01	137.11	0.59
HIZ*	44.8 (52/116)	5.7 (8/140)	< 0.01	51.93	0.41
Endplate abnormalities	44.0 (51/116)	5.0 (7/140)	< 0.01	52.76	0.41

*Types I, II, and III were combined.

contrast agent was from 0.5 to 4 mL. The volume of contrast for concordant pain, nonconcordant pain, and no pain groups was shown in Table 3.

On MRI, disc degeneration was graded as following: 23 discs as Grade I (9.0%), 34 discs as Grade V (11.7%). The distribution of the grades in disc degeneration was shown in Table 1. Totally, there were 141 discs graded as I-III, only 17 (12.1%) of which had concordant pain; whereas 115 were Grade IV-V, 99 (86.1%) of which had concordant pain. Discographic grades showed a significant correlation with the grades of disc degeneration at MRI ($\chi^2 = 160.87$, $r = 0.62$, $P < 0.01$) (Table 1). Grade IV-V degeneration of discs on MR image showed a significant correlation with the concordant pain ($x^2 = 137.11$, $r = 0.59$, $P < 0.01$) (Table 2).

HIZ was found in 60 discs of Grade IV-V (Fig. 1), 52 of which (86.7%) had concordant pain, but not in discs of Grade I-III. One hundred ninety-six discs did not have HIZ, 64 of which (32.7%) presented with concordant pain. The presence of HIZ was significantly correlated with concordant pain ($\chi^2 = 51.93$, $r = 0.41$, $P < 0.01$) (Table 2).

The endplate abnormalities were observed in 58 discs (22.7%): 23 (39.7%) Modic Type I discs, 19 (32.8%) Type II (Fig. 2), and 16 (27.6%) Type III. Fifty-one discs of all had concordant pain. One hundred and ninety-eight discs showed normal endplates, 65 of which (32.8%) showed pain provocation. The presence of endplate abnormalities was significantly associated with the pain provocation during discography ($\chi^2 = 52.76$, $r = 0.41$, $P < 0.01$) (Table 2).

In summary, the results suggest concordant pain was significantly more common in the following situations: Type IV-V disc at discography, Grade IV-V disc degeneration at MRI, the presence of HIZ and endplate abnormality. Their sensitivity, specificity, positive likelihood ratio, and negative likelihood ratio were shown in Table 4.

DISCUSSION

The LBP without radicular pain and without neurogenic claudication has been defined as "discogenic LBP," which first proposed by Crock[2] in 1970. Cohen et al[12] reported that 65% of chronic back pain was owing to discogenic LBP. The cause of discogenic LBP is still unclear. Degeneration of the discs, annular tears, and endplate abnormalities has been thought to be causative factors. Discogenic pain has a somatotropic rather than dermatomal pattern of pain projection. Therefore, it is difficult to use the symptoms and clinical findings to localize the level of abnormality. Discography, as a pain provocation test is considered as the only method that can be used to relate a radiologic image to the patient's pain directly.[3] This technique is still the standard in the diagnosis of discogenic LBP.[8] In our study, 104 of 116 discs of Type IV (fissured) or V (ruptured) discs had concordant pain during the procedure of discography, showed a significant correlation with the concordant pain. Fissured and ruptured discs had a high specificity (86.4%) and a high sensitivity (89.6%) for pain prediction. The mechanism of back pain is related to the fact that, during injection of contrast medium into the disc, breakdown products such as neuropeptides or cytokines are expelled from the disc and cause nociception at the outer annular fibers that are innervated.[3] The injection of the contrast medium into the disc space also can increase the pressure in the disc, and may cause the patient to experience pain.

MR imaging provides a unique means to evaluate the morphologic status of discs in a postmortem study. Yu et al[13] showed that it was possible to use of MRI in detection of annular tears. However, Osti and Fraser[14] reported that discography was more accurate than MRI in detecting annular pathology. In our study, MRI showed a significant correlation with the discography findings in evaluating disc degeneration. Most of the discs with normal morphology on MRI were also normal on discography. For degenerative discs of Grade IV and Grade V at MR imaging, 70.4% (81/115) showed annular tear on discography. However, although MRI provided detailed information with regard to the whole spectrum of abnormalities, the role of MRI in the evaluation of discogenic pain had not been well defined.[3–8,15]

In the earlier report by Milette et al,[16] loss of disc height, or decreased central disc signal intensity on T2-weighted images in patients with chronic LBP, was highly predictive of annular tears extending into or beyond the outer annulus, and the majority of these tears were probably responsible for these symptoms. Lim et al[1]

TABLE 3. The Volume of Contrast for Concordant, Nonconcordant, and No Pain Groups

Grading of MRI	Volume of Contrast Agent ($\bar{x} \pm s$) mL	Concordant Pain	Unconcordant Pain or No Pain
I (n = 23)	0.60 ± 0.18	0	23
II (n = 34)	0.79 ± 0.22	2	32
III (n = 84)	1.60 ± 0.30	15	69
IV (n = 85)	2.62 ± 0.49	76	9
V (n = 30)	2.92 ± 0.50	23	7
Total (n = 256)	1.90 ± 0.89	116	140

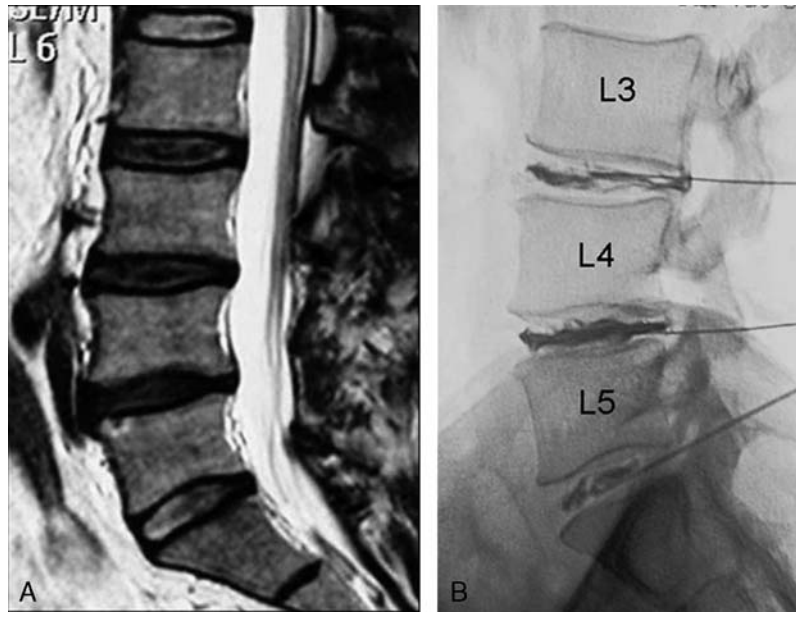

FIGURE 1. A 45-year-old man had suffered from chronic LBP for 1 year. Sagittal (A) T2-weighted MR images showed grade IV degeneration at the L3-to-L4 and L4-to-L5 intervertebral disk levels. B, Lateral discograms showed a ruptured pattern of Type V at L3-to-L4 intervertebral disk levels, and a fissured pattern of Type IV at L4-to-L5 levels; the patient had concordant pain at these 2 levels during discography.

reported that concordant pain was significantly more common than discordant pain or no pain in Grade IV or V discs degeneration on MRI. In this study, there were 115 Grade IV-V discs, 99 of which showed concordant pain. Grade IV-V degeneration of discs on MR image showed a significant correlation with the concordant pain, and obtained a high specificity (88.6%) and a high sensitivity (85.3%) for pain prediction. The results were consistent with the earlier one.

The clinical relevance of a posterior HIZ on T2-weighted MR images, which is considered to represent a severe form of a combined radial and concentric annular

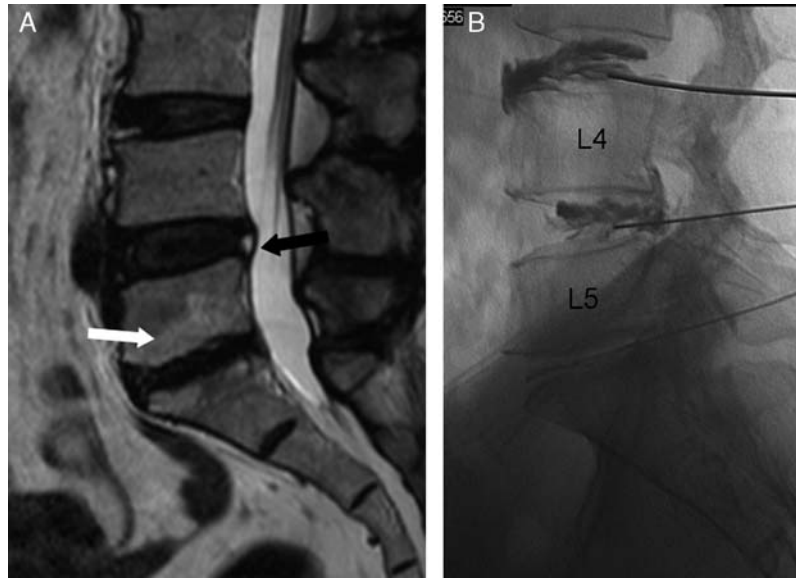

FIGURE 2. A 45-year-old woman had suffered from chronic LBP for 36 months. Sagittal (A) T2-weighted MR images showed grade V degeneration at the L3-to-S1 intervertebral disk levels. The L4-to-L5 intervertebral disk levels had a HIZ (black arrow), the L5-to-S1 intervertebral disk level with endplate abnormalities (white arrow). B, Lateral discography showed a rupture of anterior annulus fibrosis at L3-to-L4 intervertebral disk level, the patient had discordant pain during discography. A posterior annulus fibrosis was shown at L4-to-L5 intervertebral disk level; the patient had concordant pain during discography. We did not find a ruptured disk at L5-to-S1 levels, but the patient had intense concordant pain during discography.

TABLE 4. Sensitivity, Specificity, Positive and Negative Likelihood Value for Concordant Pain Based on Discography, and MRI

Imaging Finding	Sensitivity (%)	Specificity (%)	LR+	LR−
Discography findings				
Type IV-V	89.7 (104/116)	86.4 (121/140)	6.596	0.119
MRI abnormalities				
Grade IV-V	85.3 (99/116)	88.6 (124/140)	7.482	0.166
HIZ	44.8 (52/116)	94.2 (132/140)	7.724	0.586
Endplate abnormities	44.0 (51/116)	95.0 (133/140)	8.800	0.590

LR+: Positive likelihood ratio; LR+ = sensitivity/(1-specificity).
LR−: Negative likelihood ratio, LR− = (1-sensitivity)/specificity.

tear.[5] The HIZ represents fluid or mucoid material associated with granulation tissue and new blood vessels entrapped between torn fibers of the outer annulus or underneath the posterior longitudinal ligament complex.[13] Aprill and Bogduk[5] showed a significant correlation between the presence of a HIZ and annular tear, and reported an 86% positive predictive value (PPV) of a HIZ on painful discography in 500 patients. Schellhas et al[17] also reported that HIZ was a reliable marker for the annular tear. The high PPV of a HIZ for painful annular tears has been validated by other investigators.[18,19] Conversely, Ricketson et al[6] noted that HIZs are not necessarily associated with a concordant pain response during the lumbar discography. Weishaupt et al[8] reported that the correlation between the presence of a HIZ and concordant pain was low, a HIZ may not be predictive of discogenic pain. In this study, HIZ was present in 60 discs, 52 of which produced concordant pain at provocative discography. The presence of HIZ was correlated with concordant pain, which resulted in a low sensitivity of 44.8%, and a high specificity of 94.3%. Our result was consistent with the earlier studies.[5,17–19] However, the relatively low sensitivity might be owing to the lower occurrence of HIZ in our study.

Abnormalities of the vertebral endplate and subchondral bone marrow, also named Modic changes (MC), were described by Modic et al in 1988.[10] The cause of MC is not well understood. The microfractures and fissures in the endplates through the biomechanical mechanism may be an important source of MC.[20] Compared with the biomechanical mechanism, more studies have been carried out for the biochemical mechanism of MC. Crock[2,21] suggested that upregulation of inflammatory mediators in the nucleus pulpous could result in a local inflammation associated with LBP. Therefore, MC possibly resulted from the inflammatory reaction by the toxic substances from degenerative disc.[7] Correlations between MRI and discographic findings have suggested that endplate abnormalities may be predictive for discogenic pain.[7,8] In a retrospective study of 58 patients with discogenic pain, Braithwaite et al[7] found a prevalence of 48% with endplate abnormalities and a PPV of 97% as a marker for a painful disc. In Weishaupt's[8] study, endplate abnormalities were found adjacent to 26 discs, 23 of which showed concordant pain on provocative discography. However, in Lim's[1] study, endplate abnormalities were found in 14% (14/97) of cases, concordant pain was not associated with endplate abnormalities. In our study, endplate abnormalities were found adjacent to 58 degenerative discs, 51 of which had concordant pain during discography. The results suggest that concordant pain was associated with endplate abnormalities, in a high specificity 95.0%. Although not all discogenic pain is caused by endplate abnormalities, our results suggested that endplate abnormalities might be an important cause for discogenic pain.

A limitation of this study was that, we did not apply a manometer to measure intradiscal pressure during discography. In the earlier studies, discographers estimated the intradiscal pressure according to the resistance of injection and volume of contrast. In recent studies, researchers think that pressure of injection is influential on the evaluation of concordant pain.[22,23] Therefore the current literature supports the use of manometer. Alhough we did not use a manometer in this study, we injected contrast under a low pressure during discography depending on the injection resistance and contrast volume. Another limitation was that our study included patients with chronic LBP who underwent discography; patients without LBP but with disc degeneration on MR images were not included as a control group. Therefore, we did not assess the association between disc degeneration on MR images and concordant pain during discography in asymptomatic patients.

In conclusion, our results indicated that disc degeneration grades on MRI showed an association with discographic grades. Type IV-V discs at discography, Grade IV-V disc on MR images, the presence of a HIZ, and endplate abnormalities may indicate discogenic pain in patients with chronic LBP.

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