

MR Imaging for the Differentiation of Early Infectious Spondylitis and Modic Type I Change in the Lumbar Spine¹

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Purpose: To evaluate magnetic resonance (MR) imaging findings for the differentiation of early infectious spondylitis and Modic type I change in the lumbar spine.

Materials and Methods: Contrast-enhanced lumbar spine MR images with bone marrow edema adjacent to the endplates of 25 patients (14 men, 11 women; mean age 53.7 years) were evaluated. Margin and enhancement in the bone marrow changes, erosion or destruction of endplates on T1-weighted sagittal MR images, T2 signal intensity and enhancement in the intervertebral disks, as well as the presence of paravertebral soft tissue were evaluated. The final diagnoses were 11 cases of infectious spondylitis and 14 cases of Modic type I change.

Results: The margin of bone marrow changes was more blurred in infectious spondylitis than in Modic type I change. The endplates for infectious spondylitis showed destructions, and Modic change erosions. On postcontrast images, all the cases except for only one with degenerative disease were enhanced in the vertebral bodies. Intervertebral disks showed T2 hyperintensities and were enhanced in both the infectious spondylitis and Modic change. Paravertebral soft tissue was seen more commonly in infectious spondylitis.

Conclusion: The useful findings of early infectious spondylitis include endplate destruction, blurred margins of the bone marrow changes on T1-weighted images, and the presence of paravertebral soft tissue.

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Bone marrow abnormalities of the lumbar spine adjacent to the endplates are commonly seen on MR images. These abnormalities are most frequently associated with degeneration. A diagnosis of degenerative subchondral abnormalities is usually not problematic. However, some cases of degenerative bone marrow changes are also present with inflammatory symptoms and imaging findings that may simulate infectious spondylitis (1, 2). Modic *et al.* (3) defined a commonly used MR imaging classification system for degenerative disk diseases. However, the type I signal alterations (hypointensity on T1-weighted and hyperintensity on T2-weighted images) may mimic MR imaging findings associated with infection (1, 2).

The MR findings of infectious spondylitis and degenerative disk disease have been well described in each (3–16). However, there are few reports comparing the imaging findings for both diseases. Moreover, no studies have compared the MR findings of early infectious spondylitis without abscess formation and a Modic type I change. The purpose of this study was to evaluate the MR imaging findings for the differentiation of degenerative disk disease with Modic type I change from early infectious spondylitis in the lumbar spine.

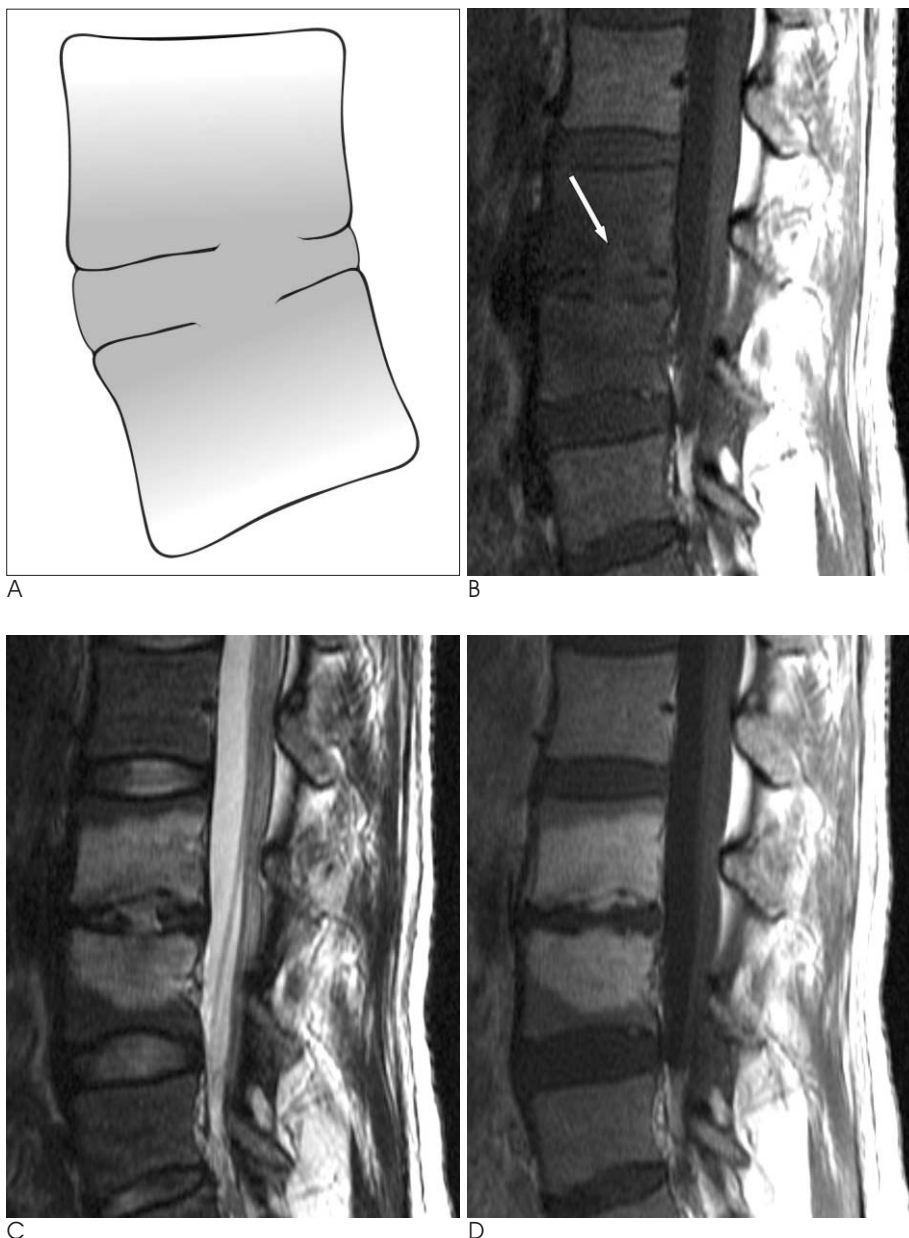


Fig. 1. Infectious spondylitis in a 33-year-old woman with lower back pain. A. Schematic picture illustrating the change of infectious spondylitis.

B. The T1-weighted sagittal image (TR/TE = 350/17 msec) shows decreased signal intensities of the vertebral bodies of L3 and L4. There are focally destructed vertebral endplates at the inferior aspect of L3 (arrow) and the superior aspect of the L4 vertebral body. The margins of bone marrow changes in the L3 and L4 vertebral bodies are not demarcated.

C. The T2-weighted sagittal image (TR/TE = 2200/102 msec) shows increased signals of the adjacent portions of the L3 and L4 vertebral bodies. Hyperintensity equivalent to fluid is seen in the L3–4 disk.

D. The contrast enhanced T1-weighted sagittal image (TR/TE = 350/17 msec) shows discrete patchy enhancement in the vertebral bodies of L3 and L4.

Materials and Methods

Patients

This retrospective study included the evaluation of 25 patients. Our institutional review board granted study approval and waived informed consent. This study was Health Insurance Portability and Accountability Act compliant.

Patients criteria for inclusion in this study consisted of the presence of bone marrow abnormalities adjacent to the endplates with low signal intensity (SI) on T1-weighted images and high SI on T2-weighted images,

the availability of MRI with pre- and post-contrast T1- and T2-weighted images before a biopsy or antibiotic treatment, a clinical follow-up of at least six months after presentation, and clinical or pathological confirmation. Patients that underwent previous surgery, a recent fracture, and metastatic disease were excluded. For the selection of early infectious spondylitis, we excluded the advanced infectious spondylitis with abscess formation as seen in the MR imaging.

Eleven patients were diagnosed with infectious spondylitis, while 14 patients were diagnosed with degenerative disk disease. Infectious spondylitis was considered to be present when blood culture results were

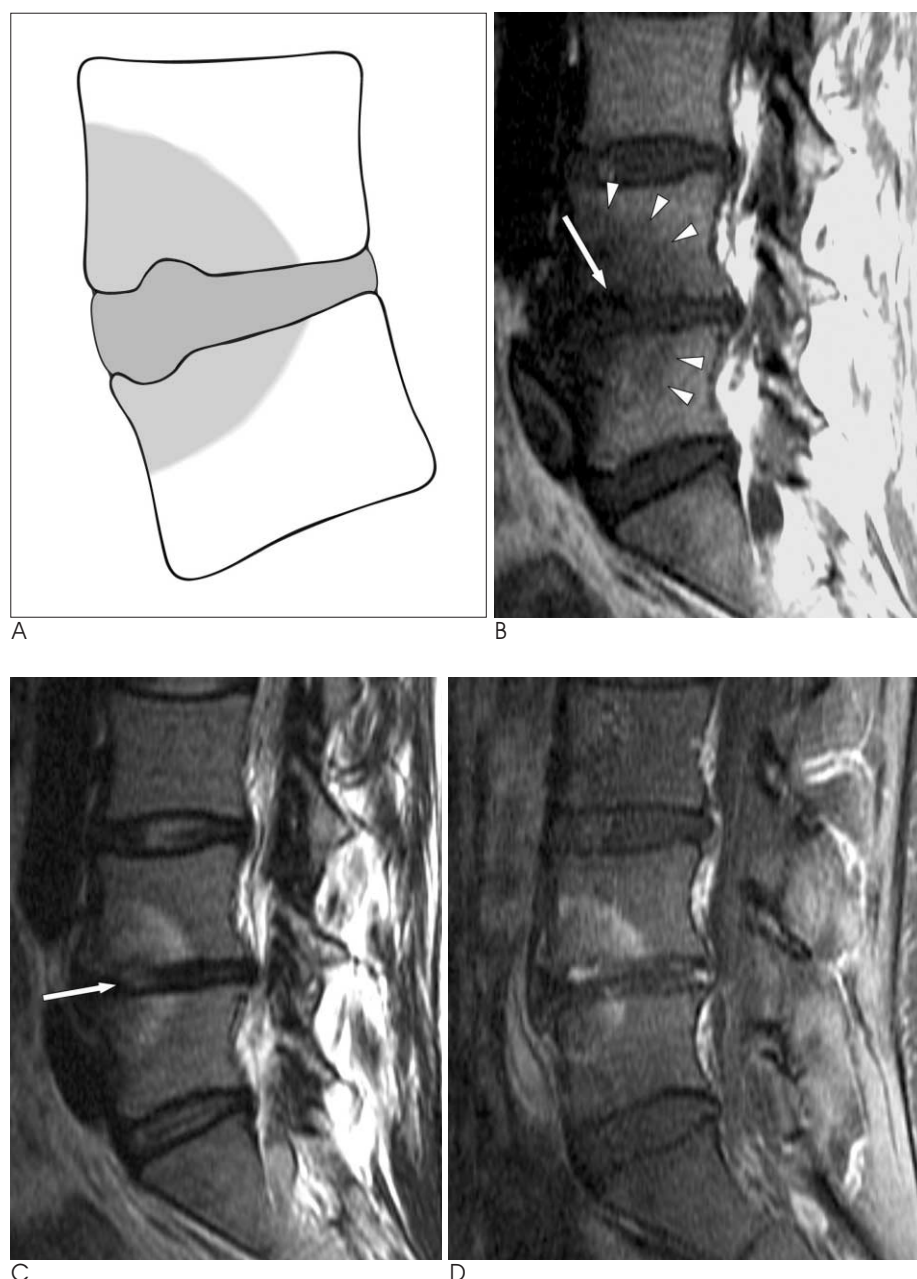


Fig. 2. Modic type I change in a 37-year-old woman with low back pain.

A. Schematic picture illustrating the changes of Modic type I change.

B. The sagittal T1-weighted fast spin-echo MR image (TR/TE = 650/17 msec) shows relatively well-demarcated bone marrow abnormalities of low signal intensity at the L4 and L5 bodies (arrowheads). There is an eroded endplate with an irregular low signal line of the inferior aspect of L4 (arrow).

C. The T2-weighted image (TR/TE = 3000/110 msec) reveals increased signal intensity involving the disk (arrow) and adjacent vertebral bodies. An eroded endplate is also seen at the inferior aspect of L4.

D. The contrast enhanced T1-weighted image (TR/TE = 650/17 msec) shows patchy enhancement in the L4 and L5 vertebral bodies.

positive ($n = 5$). In five cases, follow-up MRI showed an increase in paravertebral inflammatory tissue along with an epidural abscess and bone destruction (Figs. 1, 2). In three cases, infectious spondylitis was diagnosed on the basis of clinical and laboratory findings (elevated erythrocyte sedimentation rate and C-reactive protein). Percutaneous bone biopsies were performed in five patients but no infectious agent was found in the tissue culture. Degenerative disk disease was diagnosed if a favorable outcome without antibiotic treatment was seen as well as when the findings from the laboratory data and the clinical signs were negative after 6 months. Bone biopsies were performed in two patients with degenerative disk disease and the histology results showed no inflammatory tissue.

MR Imaging Protocol

MR imaging was performed using a 1.5-T superconducting system (Signa; General Electric Medical Systems, Milwaukee, WI USA) with a dedicated phased-array coil (CTL; GE Medical Systems). Sagittal T1-weighted (TR/TE, 380–720/9–23) and sagittal T2-weighted fast spin-echo (2200–4500/96–126) sequences were obtained with an image acquisition matrix of 512×192 , 512×256 , or 512×294 , a field of view of 260×260 mm or 290×290 mm, and a section thickness of 4 mm. In addition, axial T1-weighted and axial T2-weighted fast spin echo sequences were obtained with an image acquisition matrix of 256×256 , a field of view of

200×200 mm, and a slice thickness of 4 mm. Contrast-enhanced axial and sagittal T1-weighted MR images were obtained in all patients by using a spin echo sequence. Gadopentetate dimeglumine (Magnevist; Schering AG, Berlin, Germany) at a dose of 0.1 mmol per kilogram of body weight was used as an intravenous contrast agent.

Evaluation of the MR Images

MR images of 25 lumbar spines in 25 patients (11 women, 14 men; mean age: 53.7 years; age range: 28–85 years) were reviewed. All MR images were evaluated in conference by two investigators (J.W.K. and Y.C.Y.). The observers were unaware of the clinical and other imaging findings. Images obtained with different sequences in one MR examination were reviewed together as a group.

We evaluated the sharpness of the margin of bone marrow changes in the affected vertebral bodies on pre-contrast T1-weighted sagittal images, and determined whether the image was blurred or sharply demarcated. The vertebral endplates of the affected spinal segments were graded on precontrast T1-weighted MR images as intact, eroded (focal areas of bone loss without disruption of the hypointense cortical signal), or destroyed (disruption of the cortical signal). On contrast-enhanced images, the presence of any enhancement of the vertebral bodies was evaluated.

At the affected level, the presence of hyperintense

Table 1. Data on Eleven Patients with Infectious Spondylitis

Patient #	Sex	Age	Level	Vertebral body			Disk		Paravertebral Soft Tissue	Standard of Reference
				Margin of Bone Marrow Change on T1WI	Endplate on T1WI	Enhancement	High SI on T2WI	Enhancement		
1	M	70	L4/5	blurred	destroyed	+	+	+	+	follow-up MRI, laboratory
2	M	49	L4/5	blurred	destroyed	+	+	+	–	laboratory
3	M	65	L1/2	blurred	destroyed	+	+	+	+	blood culture (Brucella)
4	M	37	L3/4	sharp	eroded	+	+	–	–	follow-up MRI, laboratory
5	F	68	L4/5	blurred	destroyed	+	–	–	+	blood culture (methicillin-resistant Staphyococcus aureus)
6	F	67	L4/5	sharp	eroded	+	+	–	+	follow-up MRI, blood culture (methicillin-resistant coagulase negative staphylococci)
7	M	54	L4/5	blurred	destroyed	+	+	+	+	follow-up MRI, Blood culture (Streptococcus milleri)
8	F	33	L3/4	blurred	destroyed	+	+	+	–	laboratory
9	F	73	L3/4	blurred	destroyed	+	–	+	+	laboratory
10	F	47	L3/4	sharp	destroyed	+	+	+	+	follow-up MRI, operation
11	M	85	L5/S1	blurred	destroyed	+	+	+	–	follow-up MRI, blood culture (β -hemolytic streptococci Group B)

Note.— Plus sign (+) = present, minus sign (–) = absent.

disk signal was equivalent to that of fluid and was evaluated from T2-weighted images. On contrast-enhanced images, the presence of enhancement in the disk was noted. We also evaluated the soft tissue changes of the paravertebral area on axial and sagittal images. MR imaging criteria for the presence of paravertebral inflammatory tissue were discrete hypointensity on T1-weighted MR images and hyperintensities on T2-weighted MR images, as well as contrast enhancement (5, 8).

Review of the Clinical Data

One of investigators who were not involved in image analysis reviewed the medical records and laboratory reports. For each patient, it was noted whether antibiotic treatment was administered or a surgical intervention was performed after MR imaging. Associated medical conditions were reviewed from the patient records. The pathology and microbiology reports for the collected biopsy samples and the results of blood cultures were reviewed.

Statistical Analysis

Mean and standard deviation values were calculated for continuous data. Differences for dichotomous variables were tested using Fisher's exact test and the Pearson's Chi-squared test. Statistical calculations were performed with the SPSS software package (SPSS, version 13; SPSS, Chicago, IL USA). A *p*-value of less than 0.05 was considered to indicate a statistically significant difference.

Results

Tables 1 and 2 summarize the MRI features of all enrolled patients. The signal alteration of the bone marrow in the affected vertebral body on T1-weighted sagittal images were sharp in three (27.3%) and blurred in eight (72.7%) patients with infectious spondylitis. In contrast, the images were sharp in ten (71.4%) and blurred in four (28.6%) patients with a degenerative disk disease ($p = 0.028$). Endplates of infectious spondylitis showed erosions in two cases (18.2%) and destructions (Fig. 1) in nine cases (81.2%) as seen on T1-weighted sagittal images. For the degenerative disk disease, the vertebral bodies had intact endplates in two cases (14.3%) and eroded endplates (Fig. 2) in 11 cases (78.6%). Endplate destruction with cortical disruption was seen in only one degenerative disk disease case (7.1%) ($p = 0.01$). On postcontrast images, all the cases except for one degenerative disk disease case were homogeneously enhanced in the low T1 signal areas of the vertebral bodies ($p = 1.00$).

Hyperintensity equivalent to fluid on T2-weighted images was seen in nine (81.2%) intervertebral disks of the affected levels for the infectious spondylitis cases. In the degenerative disk disease, 10 (71.4%) intervertebral disks showed hyperintensity ($p = 0.661$). On post-contrast images, intervertebral disks were focally or peripherally enhanced in eight cases (72.7%) of infectious spondylitis. Intervertebral disks of Modic type I change were enhanced in 11 cases (78.6%) ($p = 1.00$).

Paravertebral soft tissue changes on axial and sagittal

Table 2. Data on Fourteen Patients with Modic Type I Change

Patient #	Vertebral body						Disk		Paravertebral Soft tissue
	Sex	Age	Level	Margin of Bone Marrow Change on T1WI	Endplate on T1WI	Enhancement	High SI on T2WI	Enhancement	
12	M	53	L4/5	blurred	eroded	+	+	-	+
13	M	40	L4/5	sharp	eroded	+	+	+	-
14	F	42	L4/5	sharp	intact	+	+	+	-
15	M	72	L5/S1	sharp	intact	+	+	+	-
16	M	50	L4/5	sharp	eroded	+	-	+	-
17	M	49	L5/S1	sharp	eroded	+	+	+	-
18	M	30	L4/5	sharp	eroded	+	-	+	-
19	F	70	L4/5	sharp	eroded	+	+	+	-
20	F	38	L5/S1	blurred	eroded	+	+	+	-
21	F	37	L4/5	blurred	eroded	+	+	+	-
22	M	68	L5/S1	sharp	eroded	+	+	-	-
23	M	28	L2/3	sharp	eroded	-	+	-	-
24	F	55	L5/S1	blurred	destroyed	+	-	+	+
25	F	62	L3/4	sharp	eroded	+	-	+	-

images were seen in seven cases (63.6%) of infectious spondylitis and two cases (14.3%) of a degenerative disk disease, respectively ($p = 0.017$).

Discussion

The differential diagnosis for early infectious spondylitis without an abscess and a Modic type I change is sometimes difficult in both an imaging and clinical setting (1, 2). In patients with the clinical possibility of the infectious spondylitis, MR imaging should be considered as the imaging technique of choice. Plain films, radionuclide scans, and CT scans may provide false-negative findings, and if the scans show signs of infectious spondylitis, most patients will undergo MR imaging to assess the full soft-tissue extent and potential neural compromises (13, 15, 17).

Bone marrow abnormalities adjacent to the endplates are commonly associated with the degeneration of lumbar disks. In the presence of Modic type I changes, presumably relating to active remodeling of bone with loose vascularized fibrous tissue, these abnormalities may simulate the involvement of the bone marrow by infectious spondylitis. Although the characteristic histological findings are present in infection, such as an increased number of polymorphonuclear leukocytes, there are some similarities in the histological appearance of Modic type I degenerative disk disease and infectious spondylitis (2, 3, 5, 6, 12, 18). In the resolved or resolving infection, the absorption or resolution of the inflammatory exudate and ischemia with healing results in a degenerated disk with fibrous scar tissue, are surrounded by vertebral bodies with some degree of new bone formation (5). Many of Modic type I changes present with inflammatory symptoms may mimic infectious spondylitis (1, 2). Toyone et al. (19) stated that 73% of patients with a Modic type I change had significant lower back pain.

The differential diagnosis between infectious spondylitis and degenerative disk disease is usually based on clinical presentation (septic or not) and the presence of vertebral body abnormalities. Erosions that are small, located near areas of endplate sclerosis, and with sharp margins, suggest a diagnosis of degenerative change (20). Degenerative disk disease is suspected in patients with sclerosis of the adjacent endplates that may extend into the vertebral bodies with sharp margins (1). Sclerosis occurs less frequently with infectious spondylitis than with degenerative disease. In the pre-

sent study, the endplates of degenerative change had either eroded or maintained intact margins. In the case of infectious spondylitis, destruction of the endplates was evident. The signal alteration in the affected vertebral bodies had blurred margins in infectious spondylitis, but relatively sharp margins in degenerative changes. We think these findings result from the difference of disease progression. Modic type I changes are assumed to be associated with an ongoing active degenerative process (3). However, infectious spondylitis progresses more rapidly. Thus, reactive sclerosis of the endplate tend to develop less often and the margins of the affected bone marrow changes are blurred. In addition, it is likely that the degenerative changes may be more reflective of biomechanical stress and micro motion rather than true inflammatory changes. It has been reported that abnormal SI in the vertebral bodies usually involves the whole vertebra in infectious spondylitis (14, 21). Most of our patients with infectious spondylitis, however, had partial involvement of the adjacent vertebral bodies as seen on T1-weighted, T2-weighted, and contrast-enhanced MR images, because we included only the early stage of infectious spondylitis that did not have abscess formation.

On T2-weighted MR images, infected disks have been considered hyperintense compared to normal adjacent disks (4, 5, 8, 10, 14). Most of the patients in the present study also had hyperintensity or fluid-equivalent SI on T2-weighted MR images. Only two infected disks in this study were seen as not being hyperintense. However, hyperintensity of the disks on T2-weighted MR images is not specific to infectious spondylitis (3, 6, 9). In our study, 10 of 14 disks with degenerative changes also showed hyperintensity. Degenerated disks usually show hypointensity on T2-weighted images, and are presumed to be secondary to the dehydration (6). However, there can be linear or focal areas of high signal intensity within the decreased signal intensity on T2-weighted images that are thought to represent free fluid within the cracks or fissures of the degenerated complex (6). After contrast material administration, the infected disks almost invariably enhance. Only three patients in our study group with proven infectious spondylitis did not have disk enhancement (Fig. 2) (7). Lack of enhancement of infected disks has been rarely reported (7, 10). Enhancement of the disk can increase reader confidence for the diagnosis of infection when there are equivocal findings from non-enhanced MR imaging (7). However, this is also not a specific finding for infectious spondyli-

tis, and intervertebral disks of degenerative change are enhanced after contrast administration. Most of our patients showing degenerative change, except for three, showed enhancement of the intervertebral disks. Disk enhancement in patients with degenerative disk disease is a well known phenomenon (3, 6, 9). This enhancement probably is due to the vascularization of the disk tissue secondary to the endplate or annular degeneration (11). In some patients, disk degeneration is followed by ingrowth of vascularized granulation tissue causing secondary vascularization of the disk material (11). It is important to note that areas of enhancement are hyperintense on T2WI. Therefore, these hyperintense areas correspond to areas of inflammation, and not an abscess.

The presence of paravertebral inflammatory tissue is often described for a spinal infection, and its presence may help considerably in establishing the diagnosis (4, 8). In patients with infectious spondylitis, seven cases showed evidence of paravertebral inflammatory tissue, which is a reliable finding. Ledermann et al., however, reported that more than 90% of infectious spondylitis patients showed evidence of paravertebral inflammatory tissue, which was a higher level than found in the present study (15). This difference was thought to occur, since our study included only patients with an early stage of infectious spondylitis without abscess formation. In our study, two cases with a Modic change showed paravertebral soft tissue change. Modic type I changes are related with an active degenerative process, resulting in paravertebral soft tissue change (3, 22).

There are some limitations of this study. First, our study was retrospective. Therefore, we could not obtain STIR (short-tau inversion recovery) images or fat saturated T2-weighted images, which are useful in demonstrating bone marrow change. Second, the sample size ($n = 25$) was small. However, we set strict criteria for inclusion in the study. To include only early infectious spondylitis patients, we excluded infectious spondylitis cases with rim enhancing abscesses of even a very small size. Third, because our hospital is a tertiary referral center, it was impossible to confirm whether our patients had been treated with oral antibiotics before their arrival at our hospital. Thus we could not exclude the possibility that the culture results were influenced by previous treatment elsewhere.

In conclusion, the most useful differential findings for early infectious spondylitis without abscess formation are endplate destruction and a blurred margin of mar-

row signal alteration. When the endplates are intact or eroded and the margin of the bone marrow change is relatively sharply demarcated, a follow-up MRI may be sufficient and can replace a biopsy.

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요추의 초기 감염성 척추염과 Modic I형 변화의 감별: 자기공명영상 소견을 중심으로¹

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목적: 요추에서 초기 감염성 척추염과 Modic I형 퇴행성 척추 변화는 자기공명영상에서 유사한 신호강도를 보여 감별이 어려울 수가 있다. 본 연구에서는 초기 감염성 척추염과 Modic I형 퇴행성 척추변화를 감별하는 도움이 되는 자기공명영상 소견을 알아보고자 하였다.

대상과 방법: 조영 증강 자기공명영상에서 척추종판 주위 골수에 부종이 있는 25명의 환자(11예의 감염성 척추염과 14예의 Modic I형 퇴행성 척추)를 대상으로 하였다. 골수 변화의 경계와 조영증강 여부, T1 강조영상에서 척추 종판의 미란 또는 파괴 여부, T2 강조영상에서 추간판의 신호강도 변화와 조영증강 여부, 그리고 척추 주위 연부조직 병변 여부 등을 분석하였다.

결과: 감염성 척추염에서 골수 병변의 경계가 더 흐리게 보였으며, 척추 종판에 파괴가 보였고, Modic 변화에서는 척추 종판의 미란이 보였다. 조영 증강 영상에서 퇴행성 척추 1예를 제외하고 모두 척추체에 조영증강이 보였다. 감염성 척추염과 퇴행성 변화 모두 추간판은 T2 강조영상에서 신호강도가 증가하여 있고 조영증강이 되었다. 척추주위 연부조직 병변은 감염성 척추염에서 더 많이 보였다.

결론: 초기 감염성 척추염의 유용한 소견으로는 척추 종판의 파괴, T1 강조영상에서 흐린 골수 병변의 경계, 그리고 척추 주위 연부 조직 병변 등이 있다.