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FULL PAPER

Modic changes in lumbar spine: prevalence and distribution patterns of end plate oedema and end plate sclerosis

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Objective: The purpose of this study is to evaluate the distribution of end plate oedema in different types of Modic change especially in mixed type and to analyze the presence of end plate sclerosis in various types of Modic change.

Materials and methods: 276 patients with low back pain were scanned with 1.5-T MRI. Three radiologists assessed the MR images by T_1 weighted, T_2 weighted and fat-saturation T_2 weighted sequences and classified them according to the Modic changes. Pure oedematous end plate signal changes were classified as Modic Type I; pure fatty end plate changes were classified as Modic Type II; and pure sclerotic end plate changes as Modic Type III. A mixed feature of both Types I and II with predominant oedematous signal change is classified as Modic I-II, and a mixture of Types I and II with predominant fatty change is classified as Modic II-I. Thus, the mixed types can further be subdivided into seven subtypes: Types I-II, Types II-I, Types I-III, Types III-I, Types II-III, Types III-II and Types I-III. During the same period, 52 of 276 patients who underwent CT and MRI were retrospectively reviewed to determine end plate sclerosis.

Results: (1) *End plate oedema:* of the 2760 end plates (276 patients) examined, 302 end plates showed Modic changes, of which 82 end plates showed mixed Modic changes. The mixed Modic changes contain 92.7% of oedematous changes. The mixed types especially Types I-II and Types II-I made up the majority of end plate oedematous changes. (2) *End plate sclerosis:* 52 of 276 patients were examined by both MRI and CT. Of the 520 end plates, 93 end plates showed Modic changes, of which 34 end plates have shown sclerotic changes in CT images. 11.8% of 34 end plates have shown Modic Type I, 20.6% of 34 end plates have shown Modic Type II, 2.9% of 34 end plates have shown Modic Type III and 64.7% of 34 end plates have shown mixed Modic type.

Conclusion: End plate oedema makes up the majority of mixed types especially Types I-II and Types II-I. The end plate sclerosis on CT images may not just mean Modic Type III but does exist in all types of Modic changes, especially in mixed Modic types, and may reflect vertebral body mineralization rather than change in the bone marrow.

Advances in knowledge: End plate oedema and end plate sclerosis are present in a large proportion of mixed types.

INTRODUCTION

The signal intensity changes in the the vertebral body bone marrow adjacent to the end plates are commonly seen on MRI. Initially, it was described by Modic et al^{1,2} who classified them into: (1) Type I that includes low T_1 and high T_2 signals, (2) Type II with high T_1 signal and iso-intense or slightly hyperintense T_2 signal and (3) Type III characterized by low T_1 and T_2 signals. Type I is considered to be the earliest and most active stage in the process of evolution of end plate changes. The presence of different types of Modic changes within the end plate was later regarded as mixed Modic changes, such as mixed Types I-II and Types II-III.³

Initially, attempts were made to correlate the MRI appearance with clinical symptoms and histological findings.

Although the precise clinical evaluation of Modic change is controversial, many authors have reported a correlation between Modic change and chronic low back pain, especially for Modic Type I.⁴⁻⁶ Recent studies show the satisfactory results of lumbar disc replacement in patients with Modic changes. Total disc arthroplasty provides good results in the management of chronic low back pain, and the best clinical improvements were seen to be present in patients with Type I Modic change.⁷ Hence, it is very important to provide an accurate assessment of classification and distribution of Modic changes, especially in Type I. The purpose of this study was to evaluate the end plate oedema in different types of mixed Modic changes.

It has been suggested that end plate sclerosis exists only in Modic Type III,^{1,2,8} whereas Modic Type I and Type II have

Figure 1. Pure Modic I signal changes at L5–S1 level. MRI images of Modic change Type I. (a) T_1 weighted image, (b) T_2 weighted image, (c) T_2 weighted image-fat saturation.

shown no definite correlation with sclerosis in radiographic images. We suspect that Modic Type III might not be the only type with end plate sclerosis. Therefore, the other purpose of this study is to evaluate the presence of end plate sclerosis in different Modic types.

METHODS AND MATERIALS

Participants

276 patients (104 males, 172 females; age 20–68 years; mean age, 47 years) referred to Jiangsu Province Hospital between November 2013 and March 2014 were reviewed. The lumbar vertebrae L1–S1 were examined using 1.5-T MRI. Altogether 2760 end plates were examined. During the same duration, 52 patients (18 males, 34 females; age 32–65 years; mean age, 49 years) who underwent lumbar 64-row multislice CT and 1.5-T MRI were included. Altogether 520 end plates were examined. All the patients met our inclusion criteria, *i.e.* people with no specific low-back pathology, no fracture, no neoplasia, no spondylolysis, no infectious or rheumatic spinal diseases or no recent history of spinal operative procedures.

This study received an approval from our institutional review board.

Imaging method

CT imaging

The CT imaging was performed using a 64-slice CT scanner (Siemens Definition AS) with a detector configuration of 64×1.25 mm. A standard lumbar spinal protocol with a tube voltage of 130 kV, tube current with CARE Dose 4D (80–520 mAs) and rotation time of 0.8 s was used. The slice thickness and reconstruction interval were 1.25 and 3 mm, respectively.

MRI

The MRI examination was performed with a 1.5-T scanner (Sigma HDxt Echospeed; GE Healthcare, Milwaukee, WI). Sagittal T_2 weighted fast spin echo [repetition time (TR)/echo time (TE), 3000/109], sagittal T_1 weighted (T_1 W) sequences (TR/TE, 640/8.5) and sagittal fat-saturation (FS) T_2 weighted (T_2 W) sequences (TR/TE, 3220/107) were obtained using a matrix of 320×224 , 320-mm field of view and 4/0.5-mm

Figure 2. The mixed Modic signal changes at L4–L5 level (Modic II–I). MRI images of Modic change Types II–I. (a) T_1 weighted image, (b) T_2 weighted image (T_2 WI), (c) T_2 WI-fat saturation. MRI shows a mixture of fatty and oedematous signal changes at L4–L5, with predominant fatty change.

Figure 3. The mixed Modic signal changes at the L3–L4 level (Modic I–III). MRI images of Modic change Types I–III. (a) T_1 weighted image, (b) T_2 weighted image (T2WI), (c) T2WI-fat saturation. MRI shows a mixture of oedematous and sclerotic changes at L3–L4, with predominant oedematous change.

section thickness/gap. Axial T_2 weighted fast spin echo (TR/TE, 2640/118) sequences were obtained using a matrix of 320×192 , 200-mm field of view and 4/0.5-mm section thickness/gap.

Image analysis

Image evaluation was performed at first by two independent radiologists (one musculoskeletal radiologist with 10 years' of experience and the other musculoskeletal radiologist with 3 years' of experience) who were blinded to clinical data. Each radiologist separately analyzed each set of images. If they had some incompatible results about the classification of Modic changes, a third radiologist (musculoskeletal radiologist with 15 years' of experience) would decide the grade of the classification of Modic changes. The final diagnosis was based on diagnostic concordance by three panelists. The Modic changes were evaluated from MR images. Classification of Modic changes was based on the T1W image (T1WI), T2W image (T2WI) and T2WI-FS MR images. T2WI-FS is much sensitive to identify end plate oedema, thus it is helpful in accurate assessment of Modic Type I. The reviewers assessed the ratio of oedema, assessed fatty and sclerosis signal changes of the end plates on successive slices and graded the end plate signal changes. Pure oedematous end plate signal changes were classified as Modic Type I (Figure 1), pure fatty end plate changes as Modic Type II and pure end plate sclerotic changes as Modic Type III. A mixture of Types I and II but with predominant oedematous signal change (estimated as $>50\%$ of oedematous signal changes) is classified as Modic I–II, and a mixture of Types I and II with predominant fatty change (estimated as $>50\%$ of fatty signal changes) is classified as Modic II–I (Figure 2).

A mixture of Types I and III with predominant oedematous signal change (estimated as $>50\%$ of oedematous signal changes) is classified as Modic I–III (Figure 3), and a mixture of Types I and III with predominant sclerotic change (estimated as $>50\%$ of sclerotic signal changes) is classified as Modic III–I. A mixture of Types II and III (estimated as $>50\%$ of fatty signal changes) with predominant fatty change is classified as Modic II–III; and a mixture of Types II and III with predominant sclerotic change (estimated as $>50\%$ of sclerotic signal changes) is classified as Modic III–II. A mixture of end plate oedematous, fatty and sclerotic signal changes were classified as Modic I–II–III.^{3,9}

Classification of Modic changes in 52 patients were first carried out on the basis of T1WI, T2WI and T2WI-FS MR images. The end plates were graded into Modic I, II, III, I–II, II–I, I–III, III–I, II–III, III–II and I–III, as defined previously. The end plate sclerosis was evaluated from the CT images and was qualitatively analyzed by comparing the sagittally reconstructed CT and MR images at a workstation. The results of end plate sclerosis were defined as yes or no.

RESULTS

End plate oedema

A total of 302 end plates (altogether 2760 end plates) were estimated to present Modic changes and analyzed in this study. Tables 1 and 2 give the overall grades of Modic changes. 92.7% mixed Modic changes showed end plate oedema. End plate oedema made the majority of mixed types, especially Types I–II and Types II–I. Modic changes were found to be most common at L4–L5 and L5–S1. In this study, 76% of the changes were

Table 1. The classification of Modic changes

Classification				
Modic I	Modic II	Modic III	Mixed Modic changes	Total
64	151	5	82	302
21.2%	50.0%	1.7%	27.2%	100%

Table 2. The classification of mixed Modic changes

Classification of mixed Modic changes							
Types I–II	Types II–I	Types I–III	Types III–I	Types II–III	Types III–II	Types I–III	Total
39	24	7	5	4	2	1	82
47.6%	29.3%	8.5%	6.1%	4.9%	2.4%	1.2%	100.0%

located at these two levels (Table 3, Figure 4). End plate oedema was also found to be the most common at L4–L5 and L5–S1.

End plate sclerosis

A total of 520 end plates were evaluated by the two radiologists who were blinded to clinical data. Each radiologist separately analyzed each set of images. If they had some incompatible results about the classification of Modic changes, the third radiologist would decide the grade of the classification of Modic changes. Then, the end plate sclerosis was qualitatively analyzed from the sagittally reconstructed CT images by comparing the MR images on one workstation by the two radiologists. The results of end plate sclerosis were defined as yes or no, if the two radiologists had some incompatible results, the third radiologist would decide the results of the end plate sclerosis. The results are given in Table 4. 34 (36.6%) end plates with Modic changes had sclerosis in CT images. But Modic Type III does exist in all types of Modic changes, especially in mixed Modic types. Figures 5 and 6 demonstrate Modic change Type I and Type II in MRI in two different patients with sclerosis in CT.

DISCUSSION

The cartilaginous end plate consists of a thin layer of hyaline cartilage between the disc and the vertebral bodies. It has an

average thickness of about 0.5 mm and is generally thin at the region of the nucleus pulposus. Modic changes are end plate lesions adjacent to degenerative lumbar intervertebral discs.^{1,2}

Modic changes were identified in 20–50% of patients with low back pain, and their incidence increased with age.⁶ The Modic classification is constant and reliable in nature, hence several authors have made an attempt to correlate Modic changes with clinical outcomes. Kjaer et al¹⁰ stated that Modic changes played a major role in the degenerative process around the disc in relation to the history of low-back pain and clinical findings. Biological findings share a similar relationship with the clinical inflammatory profile. Reports of patients with chronic low back pain and Modic Type I changes have been reported with increased levels of C-reactive protein in the serum and increased expression of tumour necrosis factor alpha in vertebral end plates.¹¹ Modic Type I change is considered to be the earliest and most active stage in the process of evolution of end plate changes. Weishaupt et al¹² have demonstrated that Modic Type II changes can be much painful; however, being a more quiescent stage in the process of evolution of end plate changes, Modic Type II can be reasonably expected to produce less pain than Modic Type I;¹³ hence, it is very important to give an accurate assessment of classification and distribution of Modic changes, especially the end plate oedema. In this study, we used T1WI,

Table 3. Total number of Modic changes at different levels ($n = 302$) and the number (proportion) of end plate oedema with changes

Modic changes	Level					Total
	L1–L2	L2–L3	L3–L4	L4–L5	L5–S1	
I	4	3	8	35	14	64
II	9	14	20	56	52	151
III	0	1	1	1	2	5
I–II	2	3	2	12	20	39
II–I	0	2	1	11	10	24
I–III	0	1	0	4	2	7
III–I	0	1	0	0	4	5
II–III	0	1	0	2	0	4
III–II	0	0	0	2	0	2
I–III	0	0	0	0	1	1
Total	15	26	33	123	105	302
End plate oedema	6	10	11	62	51	140

Figure 4. Total number of Modic changes at different levels ($n = 302$) and the number (proportion) of end plate oedema with changes.

T2WI and T2WI-FS sequences to evaluate the Modic changes of all patients. FS MR images have several important potential advantages over conventional spin-echo images in the detection of bony oedematous lesions. The reduced background signal intensity of marrow fat makes the high-signal-intense lesions more conspicuous. The dynamic range of image display is expanded when the high signal intensity of fat is suppressed, followed by the contribution of improved tissue contrast.¹⁴ Therefore, T2WI-FS is very important to detect the Modic Type I and mixed types.

In the current study, 27.2% vertebral end plates showed mixed signals depending on the experience of the observers. This mixed signal corresponds to the conversion of each type of Modic changes described earlier.^{13,15} Many authors suggest

that all Modic changes can progress from one type to another type presenting different stages of the same pathological process. Mixed Modic changes are assumed to develop before the conversion of the true Modic type takes place. The natural conversion of Type I to Type II takes place over 2–3 years and is probably a continuum.¹²

An important finding in our study was end plate oedema that made a large proportion in all types of Modic changes and in mixed types. In recent years, many scholars discussed the effect of Modic end plate changes on the clinical results of lumbar fusion and lumbar disc replacement. Weishaupt et al¹⁶ found superior results after lumbar fusion in patients with Modic Type I. Blondel et al⁶ analyzed the influence of Modic type on the clinical results of total lumbar arthroplasty with a 2-year follow-up, and the clinical results were best seen in patients with Modic Type I on MR images. End plate oedema represents an active inflammatory phase of disc degeneration. Performing a discectomy during the active inflammatory process may be more beneficial in the reduction of radicular pain, whereas vertebral end plate abrasion helps in improving fusion rate in case of arthrodesis.¹⁷ Thereupon having a precise concept of Modic changes is important for patient selection and in pre-operative patient counseling. The combination of T1WI, T2WI and T2WI-FS is highly effective for the evaluation of Modic changes.

It has been suggested that only Modic Type III shows end plate sclerosis, and the Modic Type III changes are presented by decreased signal intensity on both T1WI and T2WI, whereas it appears as obvious high density on CT image. Modic Type I and Type II show no definite correlation with sclerosis on radiography, but according to our knowledge, there are few literature studies that demonstrate the comparison of end plate sclerosis and a specific Modic change. In the current study, Modic Type I, Modic Type II and mixed Modic changes were also associated with end plate sclerosis. It clearly states that end plate sclerosis exist in all types of Modic changes. Therefore, in clinical work, end plate sclerosis on CT image may not just mean Modic Type III which

Table 4. The results of Modic changes and end plate sclerosis

Modic changes	Sclerosis		Total
	CT		
	Yes [<i>n</i> (%)]	No [<i>n</i> (%)]	
Type I	4 (44.4)	5 (55.6)	9 (100%)
Type II	7 (14.8)	47 (85.2)	54 (100%)
Type III	1 (100)	0 (0.0)	1 (100%)
Types I–II	6 (46.2)	7 (53.8)	13 (100%)
Types II–III	6 (100)	0 (0.0)	6 (100%)
Types I–III	8 (100)	0 (0.0)	8 (100%)
Types I–III	2 (100)	0 (0.0)	2 (100%)
Total	34 (36.6)	57 (63.4)	93 (100%)

Figure 5. A patient with a sclerotic Type I Modic change at the L4-L5 disc level. (a) T_1 weighted image, (b) T_2 weighted image (T2WI), (c) T2WI-fat saturation. Pure Modic I signal changes at the L4-L5 disc level. (d) Sagittal reconstructed CT images show sclerosis at the upper and lower end plates of L4-L5.

is a stable stage in the process of evolution of end plate changes but may also be associated with patients' clinical outcome.

MRI could not obviously show the appearance of calcification and bone sclerosis. To some extent, the mixed signal of oedema, fat and sclerosis may affect the observer's evaluation. Modic Type I changes are associated with subchondral oedema and has been described as disruption and fissuring of end plate with some regions of degeneration, regeneration and vascular granulation tissue.¹ Pathological analysis of trauma, inflammation and tumour reveals woven bone or immature osteoid formation, which reflects the healing process of the lesion. Shaikh et al¹⁸ observed low signal intensity reactive sclerosis in both T1WIs and T2WIs in osteoblastoma. Histopathological studies of reactive sclerosis show heavy mineralization of matrix associated with increased fibrovascular tissue within the marrow and perivascular infiltration of lymphocytes and plasma cells.¹⁹ Osteosclerosis can be defined as a quantitative increase in bone volume. Sclerosis may be fully or partly mineralized in which the amount of calcium deposition is less compared with fully mineralized sclerosis.²⁰ The signal intensity on MR is mainly a reflection of the vertebral body marrow contents, whereas the plain radiograph and CT reflect the dense mineralized bony

content of the vertebral body rather than the marrow contents. The amount of mineralization in reactive sclerosis affects the MR signal intensity.

Modic Type II changes are observed as increased signal intensity on both T1WIs and T2WIs, portraying disruption of the end plates with increased formation of reactive bone and granulation tissue, as under certain conditions, matured osteoblasts and adipocytes can transform into one another and even to fibroblasts,²¹ haematopoietic elements in the vertebrae are also replaced by fat abundantly.¹ The sclerosis observed on CT images and plain film radiographs of Modic Type II change may also represent the mineralization of new reactive bone.

CONCLUSION

End plate oedema is present in a large proportion of mixed types, and Types I-II and Types II-I make up the majority of mixed types. This helps in patient selection and in pre-operative counseling of patients. End plate sclerosis exists in all types of Modic change which is better depicted on CT images and may also correlate with patients' clinical outcomes. End plate sclerosis reflects vertebral body mineralization rather than the change in the bone marrow. Hereby, we conclude that Modic change is a complex and pathological process.

Figure 6. A patient with a sclerotic Type II Modic change at the L5-S1 disc level. (a) T_1 weighted image, (b) T_2 weighted image (T2WI), (c) T2WI-fat saturation. Pure Modic II signal changes at the L5-S1 disc level. (d) Sagittal reconstructed CT images show sclerosis at the upper and lower end plate of L5-S1.

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