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A Study on the Diagnostic Ability of MRI for Modic Changes and Endplate Sclerosis in the Lumbar Spine

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Abstract: *Objective*: To investigate the diagnostic value of magnetic resonance imaging (MRI) in patients with Modic changes and endplate sclerosis of the lumbar spine. *Methods*: A total of 66 patients with lumbar spine diseases who underwent MRI and CT diagnostic examinations at the hospital from May 2024 to April 2025 were included in this study. The MRI findings of Modic changes were compared between Type I and Type II patients, and the presence or absence of endplate sclerosis signals and the HU value ratio on CT were analyzed. The pathological characteristics of Modic changes in Type I and Type II patients were observed. The imaging features of Modic changes in patients with lumbar spine diseases were analyzed. *Results*: Modic changes were present in 34 patients, with a total of 204 endplates evaluated, of which 74 were affected. MRI classification showed: Type I in 8 cases (10.81%), Type I/II mixed in 10 cases (13.51%), Type II in 51 cases (68.92%), and Type II/III mixed in 5 cases (6.76%). In CT reconstruction images, 26 endplates with Modic changes on MRI showed sclerosis in the vertebral body, presenting high-density sclerotic features. These sclerotic areas did not exhibit distinct signal characteristics on MRI but pathologically demonstrated Type II Modic changes concurrently with fatty degeneration and sclerosis; In patients with Modic changes of Type I and Type II, regardless of the presence or absence of endplate sclerosis, the sagittal T1/T2 signal intensity ratio showed no statistically significant difference ($P > 0.05$). However, the HU value ratio in Type II changes with sclerotic regions (2.74 ± 0.61) was significantly higher than that in regions without sclerosis (1.16 ± 0.23), with a statistically significant difference ($P < 0.05$). *Conclusion*: CT reconstruction images of patients with lumbar Modic changes clearly demonstrate endplate sclerosis, a phenomenon closely associated with the bone marrow repair process. MRI has limited sensitivity for detecting sclerosis, potentially due to the following factors: first, differences in the radiographic characterization of endplate mineral content; second, the specific influence of different Modic types on signal intensity. This suggests that MRI classification should be combined with CT features for comprehensive interpretation.

Keywords: Magnetic resonance imaging; CT; Lumbar spine; Modic changes; Endplate sclerosis; Diagnostic value

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1. Introduction

Endplate changes are primarily caused by bone marrow and endplate damage. Existing studies have shown a significant association between endplate changes and intervertebral disc degeneration [1]. With advances in imaging technology, MRI has become the primary diagnostic method for assessing Modic changes and endplate sclerosis in the lumbar spine. It can sensitively detect abnormal bone marrow signals in the adjacent endplate region and clearly show signal characteristic changes in the endplate and subendplate bone in patients with disc herniation, providing important imaging evidence for clinical decision-making [2]. According to international classification standards, Modic changes are categorized into Type I (oedematous stage), Type II (lipid-rich stage), and Type III (osteosclerotic stage) based on MRI signal characteristics and histopathological changes [3] . Given the low clinical incidence of Type III changes, this study focuses on patients with Type I and Type II changes. A total of 66 patients with lumbar spine diseases admitted between May 2024 and April 2025 were selected as the study subjects, systematically analyze the diagnostic efficacy of MRI in identifying Modic Type I and Type II endplate sclerosis, explore the imaging characteristics of different subtypes, particularly the visualization of endplate sclerosis, and clarify the sensitivity of MRI in distinguishing mineralization from fat infiltration during bone marrow repair. The specific details are as follows.

2. Materials and methods

2.1. General data

The study included 66 patients with lumbar spine disorders admitted to the hospital from May 2024 to April 2025. Among them, 39 were male and 27 were female, with ages ranging from 30 to 72 years, and an average age of (47.14 ± 8.65) years. The study was approved by the Ethics Committee of our hospital and conducted in accordance with medical ethical standards.

2.1.1. Inclusion criteria

(1) Persistent lower back pain symptoms

(2) Complete clinical records

2.1.2. Exclusion criteria

(1) Localized structural abnormalities of the lumbar spine

(2) Post-spinal fusion surgery or MRI examination results were unsatisfactory

(3) Failure to sign the informed consent form. 1.2 Methods All enrolled patients underwent MRI and CT examinations.

2.2. Methods

2.2.1. MRI examination

Imaging was performed using a 1.5T MRI scanner and a phase-array spinal coil. Sagittal T1-weighted images were acquired using a fast spin-echo sequence with the following parameters: repetition time (TR) 420 ms, echo time (TE) 9.4 ms, echo train length 3, number of echoes 4, matrix 320 × 192, field of view (FOV) 35 × 35 cm, slice thickness 4 mm, and slice spacing 1 mm. Sagittal T2-weighted images were acquired using a fast reverse recovery sequence combined with fast spin-echo technology, with the following parameters: TR 3000 ms, TE 117 ms, echo sequence length 25, number of echoes 4, matrix 320 × 224, and FOV and slice thickness settings

identical to the T1 sequence. Fat suppression scanning uses chemical shift selective saturation, implemented on the basis of the fast spin echo inversion recovery sequence, with scanning parameters identical to those of the sagittal T2 sequence. All image data are transmitted to the ADW4.4 workstation for post-processing, and signal intensity values of the endplates and bone marrow regions are measured using specialized software.

2.2.2. CT examination

During CT sagittal image reconstruction, a 64-slice spiral scanning system with a matching detector was used for axial scanning. The original data reconstruction slice thickness was set to 0.625 mm, and sagittal images were obtained using multi-planar reconstruction (MPR) technology, with the reconstruction slice thickness adjusted to 4 mm. All image data are uploaded to the ADW4.4 workstation for quantitative analysis, thereby obtaining high-resolution sagittal reconstruction images, which provide the technical foundation for measuring CT values of endplate sclerosis.

2.3. Observation indicators

Compare the CT manifestations of endplate sclerosis between patients with Modic Type I and Type II changes, measure the MRI signal intensity ratio of the affected endplates and the CT HU value ratio, and systematically analyze the imaging characteristics of patients with Modic Type I and Type II changes.

2.4. Statistical methods

Data analysis was performed using SPSS 18.0. Quantitative data were expressed as mean ± standard deviation ($\bar{x} \pm s$) and analyzed using t-tests; categorical data were expressed as percentages (%) and analyzed using χ^2 tests. $P < 0.05$ indicated statistically significant differences.

3. Results

3.1. Comparison of endplate sclerosis signal intensity on CT between Type I and Type II MRI-involved endplates

Among 66 patients, 34 (51.52%) exhibited Modic changes, involving a total of 74 endplates, accounting for 36.27% of the total assessed endplates. The MRI classification distribution was as follows: Type I: 8 (10.81%), Type I/II mixed: 10 (13.51%), Type II: 51 (68.92%), Type II/III mixed: 5 (6.76%). CT reconstruction revealed high-density sclerosis signs in 26 endplates, with Type II changes simultaneously exhibiting both fatty degeneration and sclerosis features. Comparative analysis revealed: Regardless of the presence or absence of endplate sclerosis, there was no statistically significant difference in the T1/T2 signal intensity ratio in the sagittal plane between Type I and Type II Modic changes ($P > 0.05$), as shown in **Table 1**.

Table 1. Comparison of signal intensity between MRI-involved endplates with and without endplate sclerosis in CT scans for Modic Type I and Type II lesions ($\bar{x} \pm s$)

Subtype	Number	Sagittal T1 signal intensity ratio		Sagittal T2 signal intensity ratio	
		Sclerosis present	No sclerosis	Hardening present	No sclerosis
Modic change type I	8	0.53 ± 0.12	0.57 ± 0.21*	0.32 ± 0.04	0.37 ± 0.14*
Modic change type II	51	1.50 ± 0.51	1.53 ± 0.51*	0.49 ± 0.13	0.54 ± 0.21*

Note: Compared with the same subtype with sclerosis, *$P > 0.05$

3.2. Comparison of HU value ratios of CT-detected endplate sclerosis in Type I and Type II MRI-involved endplates

In Modic Type I changes, the CT value ratios for endplates with and without sclerosis were (1.91 ± 0.50) and (1.76 ± 0.14), respectively, with no statistically significant difference ($P > 0.05$). In Modic Type II changes, the CT value ratio of endplates with sclerosis was (2.74 ± 0.61), significantly higher than that of the group without sclerosis (1.16 ± 0.23), with a statistically significant difference ($P < 0.05$).

3.3. Modic changes in patients with Type I and Type II lesions

In Modic Type I patients, the endplate and subendplate bone appear as low signal intensity on T1-weighted images (T1WI) and high signal intensity on T2-weighted images (T2WI). The edges of the endplate are blurred with thin abnormal signal intensity, and there is no swelling or mass in the surrounding soft tissues. In Modic Type II patients, the endplate and subendplate bone appear as high signal intensity on T1WI and isointense or slightly hyperintense on T2WI. Adjacent vertebral bone marrow shows signs of fat infiltration. Both types of changes exhibit abnormal endplate structure, but there are significant differences in signal characteristics and pathological changes.

4. Discussion

Modic changes (MC) of the endplates and subendplate bone in the lumbar spine are important MRI markers of intervertebral disc degeneration and are significantly associated with chronic low back pain. According to the Modic classification, Type I (low signal on T1/high signal on T2) represents bone marrow oedema and fibrosis, Type II (high signal on T1/equal or high signal on T2) represents fat replacement, while Type III changes (low signal on both T1 and T2) clearly correspond to sclerosis of the endplates and subchondral bone [4]. However, conventional MRI sequences (e.g., T1WI, T2WI) have inherent limitations in detecting bone sclerosis, with significantly poorer ability to visualize cortical bone and micro-sclerotic lesions compared to CT. Although Type III Modic changes are defined on MRI as low signal intensity on both T1 and T2, distinguishing them from focal calcification of the degenerative endplate and partial volume effect artifacts in actual clinical readings is often challenging, leading to reduced diagnostic consistency and potential misdiagnosis [5]. Therefore, a systematic evaluation of conventional and advanced MRI sequences (such as gradient echo sequences and ultra-short echo time sequences) for detecting Modic Type III sclerosis changes, characterizing their features with high accuracy, and distinguishing their diagnostic value has become an urgent need to improve the precise imaging assessment of vertebral endplate degeneration [6]. This study aims to investigate the diagnostic efficacy of different MRI sequences (including conventional and optimized sequences) in identifying Modic Type III endplate sclerosis changes in the lumbar spine through rigorous imaging-histology or CT gold standard comparison designs.

The results revealed that although Type II changes exhibit histological features of fat infiltration, CT reconstruction images clearly demonstrated that 35.14% of the affected endplates (26/74) simultaneously exhibited high-density sclerosis signs, confirming that Type II changes actually coexist with both fatty degeneration and sclerosis [7]. This study also found that regardless of whether endplate sclerosis was detected by CT, there was no statistically significant difference in the sagittal T1/T2 signal intensity ratio between Modic Type I and Type II changes ($P > 0.05$), further confirming that MRI signal ratios lack sensitivity for endplate sclerosis. The mechanism may be related to the following factors: (1) The interference effect of mineral deposits in the sclerotic area on MR signals is limited; (2) The presence of fatty tissue signals weakens the imaging characteristics of sclerosis; (3) The complexity of tissue composition at different repair stages leads to signal variability [8].

The MRI imaging capability of endplate sclerosis in lumbar Modic changes is directly correlated with bone marrow mineral content. Studies on osteoblastomas have shown that reactive bone sclerosis exhibits low signal intensity in sagittal T1/T2 fast spin-echo sequences. Pathological findings confirm that endplate sclerosis is essentially caused by abnormal calcium deposition in the interstitial tissue. Notably, reactive sclerosis accompanied by bone oedema exhibits a characteristic signal pattern, which is particularly typical in the progression of arthritis: during the acute phase, the anterior margin of the intervertebral joint shows non-sclerotic T1 low/T2 high signal intensity, which transitions to non-sclerotic T1 high/T2 high signal intensity in the chronic phase [9].

Pathology defines osteophytosis as an abnormal increase in bone mass per unit volume of bone. Endplate sclerosis can present two mineralization states: complete mineralization with dense calcium deposition, and partial mineralization with significantly reduced calcium deposition [10]. This difference in mineralization directly determines the sensitivity of MRI to detect sclerosis—partially mineralized areas with insufficient calcium deposition exhibit reduced magnetic susceptibility, leading to insufficient signal attenuation in T1/T2 sequences, explaining why Modic Type II, despite histological sclerosis, did not show statistically significant MRI signal ratios in this study. In terms of MRI features of Modic Type I changes, the subendplate bone marrow exhibits well-defined, homogeneous patchy signals, with some cases showing low-signal bands surrounding the lesions; T2WI primarily shows homogeneous high signals, but multiple lesions often present with blurred borders. Modic Type II lesions exhibit abnormal fat deposition within the vertebral body, with typical features including irregular punctate or scattered patchy signal patterns, whose distribution characteristics show no clear association with the anatomical orientation of the endplates. CT and X-ray studies confirm that the endplate sclerosis observed in Modic Type II patients reflects pathological changes in the microenvironment of the vertebral trabeculae within the lumbar vertebrae.

However, this study found that the sclerosis lesions observed in CT images of both Modic Types I and II may correspond to the regenerative state of newly formed bone during the bone marrow repair process. This mechanism establishes an intrinsic link between the progression of intervertebral disc degeneration in patients with low back pain and Modic changes, providing a new pathophysiological perspective for clinical research. It is worth noting that MRI imaging of endplate sclerosis is constrained by two factors: on the one hand, it depends on the mineral content within the bone marrow—completely mineralized regions form typical low signals due to dense calcium deposits, while partially mineralized regions exhibit minimal signal attenuation due to insufficient calcium deposition; on the other hand, it is closely related to Modic classification: in Type II changes, the high T1 signal of fatty tissue masks accompanying sclerosis signs, explaining why the CT value ratio (2.74 ± 0.61) was significantly higher in the Type II sclerosis group in this study, but the MRI signal ratio showed no statistical difference; High-density sclerosis lesions detected by CT can be regarded as biomarkers of the bone marrow repair process, while MRI classification primarily reflects the qualitative changes in bone marrow components. Therefore, comprehensive imaging assessment is crucial—when patients with Modic Type II changes present with persistent lower back pain, CT-confirmed endplate sclerosis may indicate active bone remodelling, providing imaging evidence for targeted treatment.

5. Conclusion

In summary, CT reconstruction images of lumbar Modic changes effectively demonstrate endplate sclerosis, a feature closely associated with the bone marrow repair process. MRI has limited sensitivity in visualizing sclerosis, with mechanisms involving two factors: first, endplate mineral content influences signal attenuation; second, different Modic classifications (especially Type II with fat infiltration) introduce specific interference in image contrast.

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Disclosure statement

The authors declare no conflict of interest.

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