Axial spondyloarthritis: synthetic magnetic resonance imaging in the detection of sacroiliac joint lesions

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To the Editor: Axial spondyloarthritis (axSpA) is characterized by sacroiliac joint inflammation, spine inflammation, bone destruction, and osteogenesis. Ankylosis of the spine and/or hip joints may occur later, significantly affecting the patient's quality of life. As the earliest and most common imaging finding of axSpA, sacroiliitis can be divided into early active and late structural lesions. Magnetic resonance imaging (MRI) not only detects active inflammatory changes that cannot be found in computed tomography (CT) or X-rays but also has a similar sensitivity to CT in detecting structural lesions.[1] However, conventional MRI only provides the qualitative diagnosis of sacroiliac joint lesions but does not provide quantitative information. Objective, accurate, and repeatable quantitative assessment, especially for bone marrow edema (BME) and fat metaplasia, which are associated with disease prognosis, offers potential imaging methods to evaluate the state of illness and therapy efficacy. Synthetic MRI, as a new imaging technique, provides both qualitative and quantitative information based on the same scan. In the present study, we aimed to verify whether synthetic MRI provides the similar qualitative diagnostic value of sacroiliac joint lesions in patients with axSpA compared with conventional MRI and to assess the quantitative diagnostic performance of quantitative maps generated by synthetic MRI in the detection of BME and fat metaplasia in the sacroiliac joint. To our knowledge, this study is the first to investigate the potential practicality of synthetic MRI for assessing sacroiliac joint lesions in participants with axSpA.

Synthetic MRI sequence using the quantification of relaxation times and proton density using multi-echo acquisition of saturation recovery with turbo-spin-echo readout technique, which uses a single saturation recovery turbo spin echo, is a multislice sequence with a long repetition time among subsequent acquisitions. This method is used to estimate inherent tissue properties by MRI parameters, such as longitudinal T1 relaxation, transverse T2 relaxation, and proton density (PD).[2]

This prospective study was approved by the Institutional Research Ethics Board of the Fifth Affiliated Hospital, Sun Yat-sen University (No. [2021] K14–1), and written informed consent was obtained from all participants before the study. A total of 105 consecutive participants diagnosed with axSpA based on the 2009 Assessment of Spondylo Arthritis international Society (ASAS) classification criteria were recruited between October 2019 and October 2020.[3] Conventional and synthetic MRI were performed using a 3T system (Signa Pioneer, GE Healthcare, Milwaukee, WI, USA) with a 16-channel abdomen and spine coil in the same scan. All participants were placed in the supine position. The head entered first, and the middle of the anterior superior iliac spine was placed at the center of the coil. Conventional MRI included routine oblique coronal fast spin-echo T1-weighted (T1-FSE) and short inversion time inversion-recovery (STIR) sequences. Oblique coronal images of the sacroiliac joint parallel to the long axis of the sacrum were obtained. Synthetic MRI included morphological images corresponding to conventional MRI, and multiple quantitative maps (T1 mapping, T2 mapping, and PD mapping) were generated by a GE AW 4.6 Workstation (GE Healthcare).

A visual analysis of sacroiliac joint lesions in conventional and synthetic images was performed 2 weeks apart by two readers independently in a random order. Disagreements of assessments reached a final consensus after communication. The readers were blinded to the clinical information and trained according to the 2019 ASAS update of definitions of MRI lesions in the sacroiliac joint with spondyloarthritis.[4] Lesions requiring a qualitative analysis include active lesions (BME, capsulitis, enthesitis, and

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joint space fluid) and structural changes (erosion, fat metaplasia, sclerosis, and ankylosis). All images were analyzed using the available PACS workstation (Vue version 12.1.0.2041; Carestream Health, Rochester, NY, USA). The readers depicted the region of interest of fat metaplasia and BME to obtain the T1, T2, and PD values. Fat metaplasia shows a brighter signal than the normal bone marrow observed on a T1-FSE sequence and meets the homogeneously bright requirements, and it is located in the subchondral bone and sharp borders. BME manifests as a hyperintense signal on the STIR sequence and is located in the subchondral bone. The mean measured values of readers 1 and 2 were used for further quantitative diagnostic performance analysis.

Data were analyzed by SPSS (version 26.0; IBM, Armonk, NY, USA). The interreader and intermethod agreements for ranked data were determined using the weighted Cohen kappa test and Cohen kappa test without weights for the binary variable. The intraclass correlation coefficient (ICC) was used to assess the interreader consistency of the T1, T2, and PD values. *A priori* Wilcoxon signed-rank test was used to compare the continuous variables. The receiver-operating characteristic (ROC) curve analysis was used for quantitative diagnostic analysis. P values < 0.001 were considered statistically significant.

A total of 105 participants (aged 18.0–57.0 years; mean age = 33.8 years), including 74 men (aged 18.0−57.0 years; mean age = 33.4 years) and 31 women (aged 19.0−53.0 years; mean age = 34.7 years), were enrolled in this study. The interreader agreements of conventional MRI and synthetic MRI for visual analysis of sacroiliac joint lesions were good to almost perfect (conventional MRI kappa = 0.731−0.828; synthetic MRI kappa = 0.610−0.855). The intermethod agreements of reader 1 and reader 2 were good to almost perfect (reader 1 kappa = 0.762−0.924; reader 2 kappa = 0.750−0.897). The intermethod agreements of the consensus results were also good to almost perfect (kappa = 0.655−0.872).

Fifty-two participants (85 sacroiliac joints) who were BME-positive and 64 participants (111 sacroiliac joints) who were fat metaplasia-positive on both conventional and synthetic MRI were analyzed quantitatively. The T1, T2, and PD values of the normal marrow, BME, and fat metaplasia had ICCs of 0.842 (95% confidence interval [CI] = 0.753, 0.901) −0.959 (95% CI = 0.934, 0.975). T1 and T2 values of BME, and T1, T2, and PD values of fat metaplasia showed significant differences from normal marrow ($P < 0.001$). The ROC quantitative analysis of the T1 and T2 values in the evaluation of BME revealed area under the ROC curve (AUC) values of 0.99 (95% CI = 0.99, 1; $P < 0.001$) and 0.74 (95% CI = 0.65, 0.84; $P < 0.001$), respectively. The cutoff value of 798.25 ms for the T1 value of BME yielded a sensitivity of 100% (64 of 64), a specificity of 98.4% (63 of 64), and an accuracy of 99.2% (127 of 128). The cutoff value of 92.65 ms for the T2 value of BME yielded a sensitivity of 84.4% (54 of 64),a specificity of 57.8% (37 of 64), and an accuracy of 71.1% (97 of 128). The T1, T2, and PD values in the evaluation of fat metaplasia revealed AUC values of 0.91 (95% CI = 0.85, 0.96; $P < 0.001$), 0.86 (95% CI = 0.80,0.92; $P < 0.001$), and 0.87 (95% CI = 0.80, 0.93; $P < 0.001$), respectively. The cutoff value of 505.9 ms for the T1 value of fat metaplasia yielded a sensitivity of 89.1% (57 of 64), a specificity of 87.5% (56 of 64), and an accuracy of 88.3% (113 of 128). The cutoff value of 129 ms for the T2 value of fat metaplasia yielded a sensitivity of 57.8% (37 of 64), a specificity of 98.4% (63 of 64), and an accuracy of 78.1% (100 of 128). The cutoff value of 91.2 pu for the PD value of fat metaplasia yielded a sensitivity of 89.1% (57 of 64), a specificity of 76.6% (49 of 64), and an accuracy of 82.8% (106 of 128) [Figure 1, Supplementary Figures 1–5, Supplementary Tables 1–4, http://links.lww.com/CM9/A935].

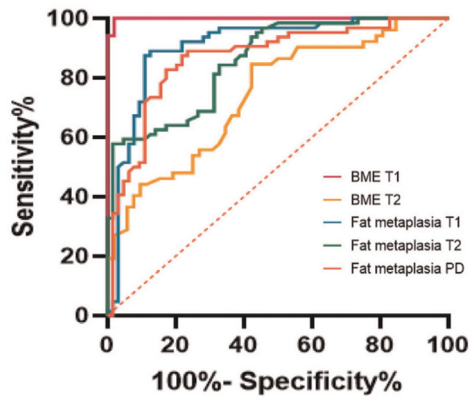

Figure 1: The graph shows the receiver-operating characteristic curves calculated from T1, T2, and PD values measured on T1 mapping, T2 mapping, and PD mapping synthesized by MAGiC in differentiating BME and fat metaplasia from the normal marrow of the sacroiliac joint. BME: Bone marrow edema; MAGiC: Magnetic resonance image compilation; PD: Proton density.

In our study, interreader and intermethod agreements of sacroiliac joint lesions were good to almost perfect. However, we observed that the signals of sclerosis and erosion on synthetic T1-FSE images were lower than those on conventional T1-FSE, and fat metaplasia was hyperintense on synthetic T1-FSE compared with conventional T1-FSE. The BME signal intensity on synthetic STIR was higher than that on conventional STIR. The BME signal intensity of synthetic MRI is greater in fat suppression than conventional MRI in the knee joint; this is partly due to B1 inhomogeneity correction, which may also account for BME being particularly hypointense on synthetic T1-FSE images.[5] In the quantitative analysis, our preliminary results showed that the T1 and T2 values of BME were all significantly higher than the corresponding values of normal marrow, especially the T1 value, which may be caused by increased inflammatory exudation in BME, and the movement of water molecules also led to increased T1 and T2 values. The PD value was of little significance in identifying the edema in our study, which may be due to the sample size or insensitivity to BME. For fat metaplasia, except for the T1 value, which was significantly lower than that of normal marrow, the T2 and PD values were significantly higher than those of normal marrow and higher than the T2 and PD values of BME. The T1 value had the best performance for differentiating both BME and fat metaplasia. In most cases, higher BME signals on STIR resulted in higher T1 and T2 values on the quantitative maps. Together, these findings suggested that the T1, T2,

and PD values are more objective, accurate, individualized, and repeatable observations of sacroiliac joint lesions than subjective STIR or T1-FSE signals. Thus, there is a potential capacity of synthetic MRI to reflect the degree and change of axSpA as an imaging index in future clinical work in an objective, visual, repeatable, and quantitative manner.

There were some limitations in our work. First, the parameters of synthetic MRI need to be optimized to present imaging that is closer to or even better than conventional MRI in the future. Second, the present study did not correlate quantitative values or quantitative dynamics with clinical indicators of disease severity to better reflect its clinical significance. Finally, there was no intrareader reliability.

In conclusion, synthetic MRI achieves a similar qualitative diagnostic value of sacroiliac joint lesions in participants with axSpA compared with conventional MRI. Furthermore, synthetic MRI quantitative maps, especially T1 mapping, accurately distinguish BME and fat metaplasia from the normal marrow.

Conflicts of interest

None.

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