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Original Article

Is there a role for DWI in the diagnosis of sacroiliitis based on ASAS criteria?

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Abstract: Purpose: Sacroiliitis based on MRI is one of the main diagnostic criteria of axial spondyloarthritis (SpA). Our purpose was to assess (a) whether apparent diffusion coefficient (ADC) values on diffusion-weighted imaging (DWI) differ between regions of bone marrow edema (BME) and subchondral normal-appearing bone marrow (NABM) in active sacroiliitis, (b) whether ADC values can differentiate early SpA and chronic SpA, both in the active and inactive phase, and (c) whether ADC values are related to laboratory findings. Materials and methods: 47 patients (24 female, 23 male, mean age: 38.53 years) with the diagnosis of SpA were included in this retrospective study. 20 age- and sex-matched subjects without SpA constituted the control group. ADC measurements were taken from all lesions and NABM of each sacroiliac joint. Results: A total number of 120 subchondral BME lesions (acute: 17, chronic active: 103) were noted. The mean ADC values of the BME lesions ($1.30 \pm 0.18 \times 10^{-3}$ mm^2/s) were significantly higher than the ADC values in the NABM regions ($0.55 \pm 0.08 \times 10^{-3}$ mm^2/s) as well as in both the control group ($0.56 \pm 0.05 \times 10^{-3}$ mm^2/s) and the chronic inactive group ($0.54 \pm 0.03 \times 10^{-3}$ mm^2/s). There were more BME regions in patients with chronic active sacroiliitis than early SpA patients. Correlation was found between the CRP values and ADC values. Conclusion: DWI with ADC values may be complementary to FS T2-weighted or STIR MR images for accurately diagnosing inflammatory sacroiliitis. The value of DWI versus dynamic contrast-enhanced imaging in the follow-up needs to be clarified.

Keywords: Active sacroiliitis, apparent diffusion coefficient, bone marrow edema, spondyloarthritis

Introduction

Axial spondyloarthritis (SpA) comprises a heterogeneous group of chronic inflammatory diseases, including ankylosing spondylitis (the main representative), psoriatic arthritis, enteropathic arthritis, reactive arthritis, and undifferentiated spondyloarthritis [1, 2]. These diseases mainly affect the synovial and fibrous joints in the spine with similar clinicopathological features and genetic predisposition, notably an association with the human lymphocyte antigen (HLA)-B27.

The diagnosis of axial SpA is primarily based on the specific clinical features associated with or without imaging and laboratory data [1, 3]. Sacroiliitis is one of the main diagnostic criteria of axial SpA, because the sacroiliac joints (SIJ) are predominantly affected and the first manifestation is commonly sacroiliitis. Conventional radiography can only reveal structural or chronic changes and thus result in a diagnostic delay; however, magnetic resonance imaging (MRI) can demonstrate active (acute) inflammation in pre-radiographic sacroiliitis for early diagnosis in addition to structural signs of sacroiliitis [3-9]. Therefore, evidence of sacroiliitis based on MRI was incorporated into the new criteria defined by the Assessment in SpondyloArthritis International Society (ASAS) in 2009 as one of the two arms for the classification of axial SpA to facilitate early diagnosis [3]. Osteitis, an inflammatory bone marrow edema (BME) typically located periarticularly, is the essential pathologic lesion for the diagnosis of active

sacroiliitis among the four well-described MRI findings (osteitis/BME, enthesitis, capsulitis, and synovitis). MRI diagnostic findings have the same significance as the other arm of the ASAS criteria, HLA-B27 positivity.

In patients with axial SpA, it is difficult to assess inflammatory intensity and progression particularly due to the difficulty in the visualization and quantitation of inflammatory lesions. Accurate measures that will not suffer from the drawback of subjectivity are crucial for the assessment of disease activity and disease progression in planning and evaluating treatment. Although there have been efforts to show the role of MRI in detecting inflammatory sacroiliitis, advanced imaging methods providing quantitative measures, such as diffusion-weighted MRI, are still limited.

Diffusion-weighted imaging (DWI) is based on the random diffusion of water molecules within cellular and extracellular tissue compartments and provides both quantitative and qualitative functional information [10-12]. The apparent diffusion coefficient (ADC), a quantitative parameter calculated from diffusion-weighted images, is the net diffusion of water molecules and reflects the effects of water diffusion and capillary perfusion in the extravascular extracellular space. DWI has been proven to be an effective diagnostic method in the evaluation of active inflammation with a change in the ratio of intracellular water (with high DWI signal) to extracellular water (with low DWI signal) [13]. Recently, this technique has been used to detect the early signs of sacroiliitis. However, scarce information exists on the utility and feasibility of DWI applications in axial SpA.

In this study, the possible role of DW imaging in the measurement of inflammation by ADC values for evaluating sacroiliitis in early SpA diagnosis and in SpA patients with established disease, both in the active and inactive phase, was considered. We aimed to assess (a) whether ADC values differ between regions of BME and subchondral normal-appearing bone marrow (NABM) in active sacroiliitis, (b) whether ADC values can differentiate early SpA patients and SpA patients with established disease, both in the active and inactive phase, and (c) whether ADC values are related to laboratory findings such as ESR, CRP, and HLA-B27.

Materials and methods

Patient population

This study was approved by the Institutional Research Ethics Committee, and all patients (or their relatives) were provided with written informed consent. A total of 47 patients (24 female, 23 male) with mean age of 38.53 ± 9.41 years (range 23-59) fulfilling the ASAS criteria for the diagnosis of axial SpA with mean disease duration of 45 ± 46.9 months (range: 3-264) were included in this retrospective study. 7 patients were excluded due to an incomplete MR examination and/or image distortion or artifacts on DWI.

Of the 47 patients with SpA, 22 patients had ankylosing spondylitis, 2 patients had enteropathic arthritis, 3 patients had psoriatic arthritis, and 20 patients were diagnosed as undifferentiated SpA.

Patients were divided into three groups according to clinical findings and MRI: acute sacroiliitis (early diagnosis of SpA), chronic active sacroiliitis, or chronic inactive sacroiliitis.

The patients with chronic sacroiliitis were under treatment with one or a combination of nonsteroidal anti-inflammatory drugs (NSAIs), corticosteroids, sulfasalazine, methotrexate (MTX) or tumor necrosis factor-α (TNF-α) inhibitor, predominantly with NSAI alone (n = 12) and a combination of NSAI and SS (n = 27).

A fourth group, the control population, consisted of 4 patients with psoriasis referred from a dermatology clinic and 16 patients referred from physical medicine and rehabilitation clinics with mechanical back pain (4 men, 16 women; mean age 39.45; range: 18-66 years). The control population had no inflammatory back pain or suspicious physical examination for SpA and laboratory findings (e.g., ESR, CRP) and MRI were within normal limits.

Clinical assessment

The diagnostic algorithm described by the ASAS group was used for the diagnosis of axial SpA [3].

Routine laboratory tests (renal and liver function tests, full blood count, ESR, CRP, and electrolyte levels) were evaluated before MRI exam-

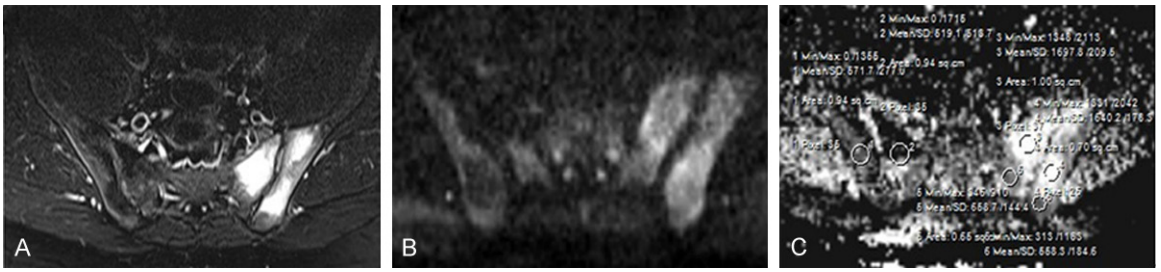

Figure 1. Chronic active sacroiliitis. FS T2W image (A) and DWI (B) show extensive bone marrow edema in the left sacral and iliac bones. On ADC map (C), active lesions demonstrate significantly higher ADC values than the adjacent and right sacroiliac joint normal appearing bone marrow.

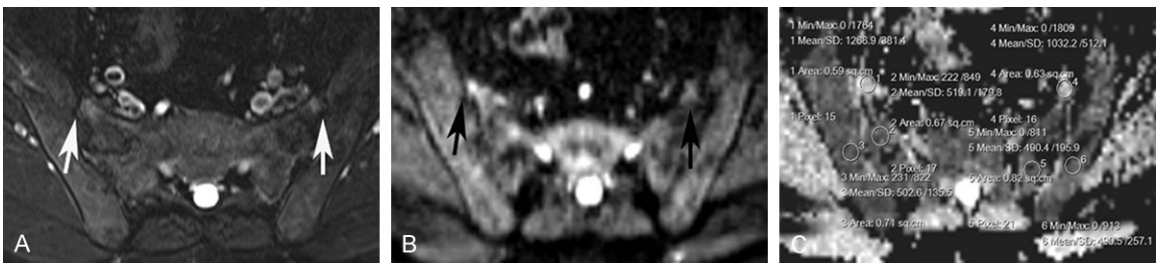

Figure 2. Early sacroiliitis. FS T2W image (A) shows small bone marrow edema regions in the right and left sacral bones (white arrows) which are more prominent on DWI (B, black arrows) and ADC map. On ADC map (C), active lesions demonstrate significantly higher ADC values than the adjacent and iliac normal appearing bone marrow.

ination. The acute-phase reactants were considered elevated if C-reactive protein (CRP) ≥ 0.5 mg/l and/or erythrocyte sedimentation rate (ESR) ≥ 20 mm/h.

MRI techniques and image acquisition

All MRI examinations were performed on a 1.5 T MR scanner (Magnetom Avanto, Siemens, Erlangen, Germany) using a 6-channel phased-array body matrix coil. Standard protocol for SIJ, including T1-weighted SE and fat-saturated (FS) T2-weighted SE in coronal oblique and axial planes and axial DWI, was performed. The following imaging series were used for image analysis: (1) FS T2-weighted fast SE images (TR/TE: 4200-4800/70-80 ms; matrix: 256 × 256; NEX: 2; slice thickness: 3 mm; intersection gap, 0 mm; and field of view: 20-25 cm). (2) DWI (single-shot spin-echo echo-planar imaging (EPI)) sequence with diffusion gradient b values of 0, 400 and 800 (TR/TE: 3900/76 ms; matrix: 192 × 192; NEX: 2; slice thickness: 4 mm; intersection gap: 0 mm; and field of view: 20-25 cm). ADC maps were automatically created by the MR system. ADC values are given in units of 10^{-3} mm^2/s.

MR image analysis

MR images were reviewed by two radiologists (--, --) with 11 and 19 years of experience, respectively, in musculoskeletal diseases. The radiologists were blinded to clinical and laboratory findings but were aware of the clinical suspicion of SpA.

Diagnostic criteria and image interpretation

All MRI examinations were reviewed at a commercial imaging workstation (Leonardo; Siemens Medical Solutions) for qualitative and quantitative evaluation.

MRI criteria for inflammatory sacroiliitis were based on the ASAS definition [3]. The criterion for the diagnosis of active sacroiliitis was the presence of osteitis (BME) that is visualized as periarticular focal or diffuse areas of high signal intensity on FS T2-weighted images.

Two radiologists independently assessed the MR images for the presence of active inflammatory lesions on the right and left SIJs. Each SI joint was divided into 4 quadrants (sacral upper, sacral lower, iliac upper, and iliac lower

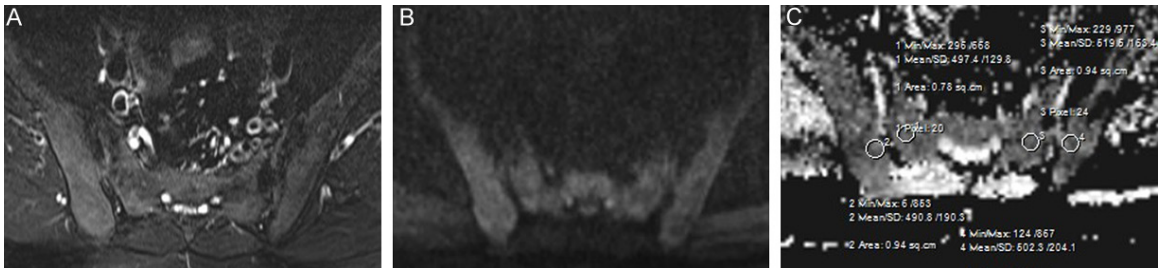

Figure 3. Chronic inactive sacroiliitis. FS T2W image (A) and DWI (B) show no signs of activity. Fat deposition and irregularity on both sides of the sacroiliac joints are consistent with chronic sacroiliitis. On ADC map (C), ADC values obtained from normal appearing bone marrow of both sacroiliac joints are similar to ADC values obtained from normal appearing bone marrow of control group and patients with active lesions.

quadrants), and each quadrant was analyzed for activity.

On DWI ADC maps, a circular region of interest (ROI) with an area of 70-90 mm^2 was placed in the subarticular surface of NABM in all four quadrants of each SIJ in all of the patients and the control group (**Figures 1**-**3**). In patients with BME, ADC measurements were taken from all apparent lesions as well (**Figures 1** and **2**).

Statistical analysis

Both SIJs were considered as a single unit for each patient in the statistical analysis. Differences in ADC values between the active inflammatory lesions and adjacent NABM were assessed using the paired t-test. Mann-Whitney U test was used to assess differences between the active inflammatory lesions in SpA patients and control group. Differences in ADC values and other variables between the 3 diagnostic groups were assessed using the one-way ANOVA test. Spearman's Rho correlation test was used to determine associations between ADC values in the NABM and BME regions and explanatory variables (e.g., age, sex, type of SpA, disease duration, HLA-27, CRP, ESR).

All *P* values were two-sided and $P < .05$ was considered as a statistically significant level. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 17.0.

Results

Clinical and laboratory findings

According to ASAS criteria [3], 35 patients had active disease.

The mean CRP level was 1.07 mg/dL (range: 0.0-6 mg/dL) and mean ESR level was 15.43 mm/h (range: 2-45 mg/dL) for patients with active sacroiliitis. HLA-B27 was positive in 15 (40%) of the 38 patients with axial SpA and HLA-B27 was unknown for 9 patients.

Patients were categorized into three subgroups according to the clinical and MRI findings. 10 (21%) patients who were not diagnosed before were grouped as early active sacroiliitis. The remaining 37 patients with a diagnosis of SpA were assigned to either the chronic SpA with active inflammation (25 patients, 53%) or the chronic SpA without active inflammation group (12 patients, 26%).

The mean duration for the early diagnosis of SpA was 3.79 months (range: 3-5 months), for chronic active sacroiliitis 60.72 months (range: 12-264 months), and for chronic inactive sacroiliitis 47.17 years (range: 5-120 months).

All of the groups were homogeneous; there was no statistical difference in the gender and age distribution.

Table 1 summarizes the demographics, laboratory findings, and the mean ADC values of the patients.

DWI findings

A total number of 120 subchondral BME lesions (acute: 17, chronic active: 103) that were hyperintense on FS T2W sequences were noted. All of these lesions were bright on DW images at a b value of 800 and intermediate (lesser than cerebrospinal fluid intensity) to slightly low signal intensity on ADC maps.

Mean ADC values obtained from the axial SpA patients and the control group are shown in **Table 3**. The mean ADC values were 1.26 ±

Table 1. Demographics, laboratory findings and the mean ADC values of early sacroiliitis, chronic active, and chronic inactive patients

	Early sacroiliitis mean ± SD (range) (n = 10)	Chronic active sacroiliitis mean ± SD (range) (n = 25)	Chronic inactive sacroiliitis mean ± SD (range) (n = 12)
Age (years)	39.30 ± 9.20 (25-50)	38.28 ± 9.08 (23-59)	38.42 ± 10.98 (24-58)
Symptom duration (months)	3.10 ± 0.88 (3-5)	60.72 ± 52.43 (12-264)	47.17 ± 32.63 (5-120)
CRP (mg/dL)	0.78 ± 1.27 (0.00-4.17)	1.35 ± 1.36 (0.06-6.00)	0.54 ± 0.79 (0.06-2.85)
ESR (mm/h)	13.30 ± 12.73 (2-43)	17.56 ± 11.98(2-45)	12.50 ± 11.64(2-40)
ADC (NABM)			
RUS	0.51 ± 0.05 (0.46-0.58)	0.56 ± 0.07 (0.45-0.71)	0.55 ± 0.03 (0.49-0.58)
RLS	0.55 ± 0.04 (0.50-0.61)	0.56 ± 0.09 (0.44-0.83)	0.55 ± 0.04 (0.46-0.61)
RUI	0.53 ± 0.08 (0.43-0.67)	0.57 ± 0.06 (0.48-0.73)	0.55 ± 0.04 (0.48-0.62)
RLI	0.55 ± 0.07 (0.50-0.72)	0.57 ± 0.08 (0.40-0.75)	0.53 ± 0.06 (0.38-0.62)
LUS	0.53 ± 0.09 (0.39-0.65)	0.55 ± 0.09 (0.38-0.84)	0.53 ± 0.04 (0.46-0.58)
LLS	0.55 ± 0.05 (0.50-0.63)	0.55 ± 0.09 (0.38-0.75)	0.53 ± 0.05 (0.46-0.61)
LUI	0.53 ± 0.09 (0.40-0.65)	0.54 ± 0.08 (0.34-0.73)	0.55 ± 0.06 (0.50-0.69)
LLI	0.53 ± 0.07 (0.40-0.64)	0.56 ± 0.09 (0.39-0.91)	0.55 ± 0.05 (0.47-0.65)
ADC (lesion)			
RUS	1.25 ± 0.28 (0.98-1.54)	1.21 ± 0.19 (0.89-1.58)	
RLS	1.25 ± 0.14 (1.14-1.41)	1.37 ± 0.29 (0.65-1.66)	
RUI		1.18 ± 0.21 (0.95-1.39)	
RLI	1.40 ± 0.16 (1.22-1.58)	1.33 ± 0.26 (0.79-1.66)	
LUS	1.26 ± 0.41 (0.97-1.56)	1.40 ± 0.30 (0.69-1.70)	
LLS	1.30 ± 0.33 (1.11-1.68)	1.41 ± 0.24 (0.99-1.76)	
LUI	1.12	1.34 ± 0.27 (0.74-1.61)	
LLI	1.49	1.38 ± 0.28 (0.81-1.68)	

CRP = C-reactive protein; ESR = Erythrocyte sedimentation rate; RUS = right upper sacral; RLS = right lower sacral; RUI = right upper iliac; RLI = right lower iliac; LUS = left upper sacral; LLS = left lower sacral; LUI = left upper iliac; LLI = left lower iliac.

Table 2. Mean ADC values of the control group and axial SpA patients

	Control group mean ± SD (range) (n = 20)	Patients NABM mean ± SD (range) (n = 47)	Patients Lesion mean ± SD (range) (n = 47)
RUS	0.56 ± 0.06 (0.45-0.73)	0.55 ± 0.06 (0.45-0.71)	1.21 ± 0.19 (0.89-1.58)
RLS	0.56 ± 0.06 (0.45-0.64)	0.55 ± 0.07 (0.44-0.83)	1.35 ± 0.27 (0.65-1.66)
RUI	0.57 ± 0.06 (0.46-0.71)	0.56 ± 0.06 (0.43-0.73)	1.18 ± 0.22 (0.77-1.46)
RLI	0.54 ± 0.05 (0.46-0.66)	0.56 ± 0.07 (0.38-0.75)	1.35 ± 0.24 (0.79-1.66)
LUS	0.57 ± 0.07 (0.45-0.74)	0.54 ± 0.08 (0.38-0.84)	1.38 ± 0.30 (0.69-1.70)
LLS	0.55 ± 0.06 (0.46-0.64)	0.54 ± 0.07 (0.38-0.75)	1.39 ± 0.25 (0.99-1.76)
LUI	0.58 ± 0.08 (0.46-0.83)	0.54 ± 0.08 (0.34-0.73)	1.32 ± 0.27 (0.74-1.61)
LLI	0.55 ± 0.06 (0.46-0.66)	0.55 ± 0.08 (0.39-0.91)	1.39 ± 0.27 (0.81-1.68)

NABM = normal-appearing bone marrow; RUS = right upper sacral; RLS = right lower sacral; RUI = right upper iliac; RLI = right lower iliac; LUS = left upper sacral; LLS = left lower sacral; LUI = left upper iliac; LLI = left lower iliac.

0.18 × 10^{-3} mm^2/s (range: 0.98 to 1.58 × 10^{-3} mm^2/s) and 1.32 ± 0.18 × 10^{-3} mm^2/s (range: 0.85 to 1.56 × 10^{-3} mm^2/s) for the subchondral BME lesions in early axial SpA and chronic active SpA, respectively. ADC values in the NABM for these groups were 0.54 ± 0.06 × 10^{-3} mm^2/s (range: 0.46 to 0.62 × 10^{-3} mm^2/s) and 0.56 ± 0.06 × 10^{-3} mm^2/s (range: 0.46 to 0.78 × 10^{-3} mm^2/s), respectively. The mean ADC value for the group with chronic inactive SpA was 0.54 ± 0.03 × 10^{-3} mm^2/s (range: 0.50 to 0.59 × 10^{-3} mm^2/s) and 0.56 ± 0.05 × 10^{-3} mm^2/s (range: 0.48 to 0.70 × 10^{-3} mm^2/s) for the control group. The mean ADC values of the

Table 3. The frequencies and distribution of active lesions in early and chronic active sacroiliitis

	RUS	RLS	RUI	RLI	LUS	LLS	LUI	LLI	Total
Early sacroiliitis	3	3	0	4	2	3	1	1	17
Chronic active sacroiliitis	15	14	9	15	11	18	9	12	103

bone marrow lesions were significantly higher than the ADC values in the NABM regions as well as in both the control group and the chronic inactive group. However, the ADC values in the BME regions in early active sacroiliitis showed no difference when compared to chronic active SpA. No statistically significant difference was noted between the ADC values of the control group and those of patients with chronic inactive SpA. Likewise, ADC values in the NABM region in both early and chronic active SpA patients showed no significant difference from normal SIJs or SIJs of patients with only chronic changes. No significant differences in mean ADC values of the sacral and iliac sides of the joints were observed, either.

Laboratory parameters in the diagnosis of SpA, such as ESR, CRP, and HLA-B27, were also evaluated. ESR was found to be high in 16 patients and CRP was higher than normal in 21 patients.

In the comparison of 2 groups with active inflammatory lesions; i.e., acute sacroiliitis and chronic active sacroiliitis, there were more BME regions with larger areas in patients with chronic active sacroiliitis (**Table 2**), but no statistically significant difference was noted between the ADC values. Also, there was no difference in variables between the 3 diagnostic groups; rather, the difference was in disease duration.

The correlation between ESR and HLA-B27 positivity and ADC values was not found to be significant. However, correlation was found between the CRP values and ADC values. Otherwise, there was no association between ADC values, the severity of disease in the NABM and BME regions, and explanatory variables.

Discussion

In this study, the diagnostic performance of quantitative DW imaging (ADC values) was retrospectively evaluated in the determination of BME associated with sacroiliitis in patients with early SpA and chronic SpA diagnosis. The mean ADC values of the bone marrow edema lesions in early SpA and chronic active SpA were significantly higher than ADC values in the NABM regions, as well as in the chronic inactive SpA and control groups.

In the detection of active sacroiliitis, MRI has a high specificity (83-100%) but varying sensitivity (20.6-94%) [8]. According to the ASAS protocol for MRI diagnosis, a FS T2-weighted turbo spin-echo or a STIR sequence is required for the detection of active inflammatory changes, alternatively with the administration of a paramagnetic contrast medium [3]. Previous studies emphasized that contrast-enhanced MRI improved the sensitivity for diagnosing acute inflammatory lesions by reflecting the vascularity and the perfusion characteristics of the disease when compared to proposed STIR and FS T2-weighted images [6, 13-15]. On the other hand, STIR sequences have been found to be comparable to FS T2-weighted sequences and thus sufficient in the assessment of active sacroiliitis by other investigators [8, 9].

According to the ASAS criteria for axial SpA, the presence of periarticular or subchondral BME (one lesion on at least two sections or more than one lesion on a single section) is essential for the diagnosis of active sacroiliitis via MRI [3]. The presence of synovitis, capsulitis, or enthesitis is not sufficient for the diagnosis of active sacroiliitis.

Accurate and sensitive tools are essential for monitoring disease activity to provide optimal treatment for prognosis in axial SpA [1, 4]. Several investigators used contrast-enhanced images to quantify and monitor inflammatory changes [1, 9, 13].

In this study, fast DWI sequencing without requiring the use of contrast media was assessed in the diagnosis of sacroiliitis as an alternative to conventional MRI sequences and contrast-enhanced imaging. To the best of our knowledge the current study is the first to compare the quantitative assessment of DW imaging of early sacroiliitis, advanced-active, and advanced-inactive disease stages based on conventional MRI and clinical findings.

DWI sequencing enables the assessment of changes associated with tissue organizational

features, mainly cellularity. In sacroiliitis, the areas with inflammatory cells will demonstrate diffusion restriction and result in increased signal intensity on b-value images. Furthermore, quantitative analysis of DW-MR images may improve the sensitivity of MRI in detecting and monitoring the inflammatory activity in SpA.

Bozgeyik et al. [5] found higher ADC values in patients with early sacroiliitis than in patients with mechanical low back pain and concluded that DWI may be used in the early diagnosis and follow-up of the acute early inflammatory lesions of the SIJs. Although it has been reported that DW-MR images have limited spatial resolution when compared with FS T2-weighted imaging, all BME regions on FS T2-weighted images could be identified on DWI and significantly higher ADC values were obtained from all these edema regions when compared to NABM. It was easy to diagnose widespread and strongly hyperintense BM lesions on MRI; however in cases with small lesions, DWI images were more clear to make a confident diagnosis of osteitis with the advantage of quantifying ADC values.

In patients with chronic active sacroiliitis, BME was revealed in more focus with larger areas than in patients with acute sacroiliitis. However, no difference was observed between the ADC values of these 2 groups. On the other hand, a recent study has shown that DWI may be effective in assessing treatment efficacy by quantifying inflammatory activity at involved sites and, thus, useful for follow-up in ankylosing spondylitis [13]. In our study, we did not assess DWI images and ADC values after treatment. The combined information provided by the number and the expansion of BME regions with ADC values might be helpful for the activity staging of the disease to determine the severity of the disease, optimal treatment choice, and clinical follow-up.

Recently, DWI has been used in the assessment of musculoskeletal diseases, including differentiation between malignant and benign vertebral compression fractures, bone marrow abnormalities (e.g., trauma, infection, and hematological malignancies), and post-treatment follow-up of vertebral tumors [5, 7, 8, 12]. The diagnostic feasibility and efficacy of DWI in the evaluation of sacroiliitis has also been studied in recent years.

In the literature, vertebral ADC values of normal vertebral bone marrow were reported to range between 0.15×10^{-3} mm^2/sn and 0.67×10^{-3} mm^2/sn [5, 6]. In this study, the mean ADC value of the NABM was calculated as 0.56×10^{-3} mm^2/sn for the control group. The mean ADC values obtained in the NABM in all diagnostic groups were within the limits reported in the literature, as shown in **Table 1**. The differences in ADC values can be assigned to different imaging parameters, b values, and the patients' ages. Gezmis et al. [6] obtained higher ADC values in normal-appearing subchondral areas adjacent to the SIJ in patients with axial SpA when compared to the control group. This is thought to be due to the increase in movement of the water molecules because of the BME. In contrast, the mean ADC values obtained from the NABM adjacent to the SIJ were not significantly different from those in the control group in this study, similar to Sanal et al [7]. We tried to include ROIs as far as possible from the edema regions that may explain these different findings.

The mean ADC value of 1.31×10^{-3} mm^2/sn obtained from the hyperintense BME areas in patients with axial SpA were significantly higher than the NABM areas in patients with axial SpA and the control group, consistent with the literature [5, 6]. The mean ADC values were approximately more than two times those in the NABM and can be helpful to accurate diagnosis. Bone marrow edema causes a local increase in water movement and thus results in increased local diffusion that is revealed by high ADC values in the lesions. The reported variability of ADC values in the literature may be related to study group differences, such as different phases of the disease, treatment, age, or female/male ratio.

In a study by Gaspersic et al. [13], both DWI and DCE-MRI were shown to be effective in quantifying inflammatory changes during the treatment of ankylosing spondylitis. In this study, active sacroiliitis based on conventional MRI and clinical findings was identified by DWI on qualitative analysis. Furthermore, DW imaging could differentiate active and inactive sacroiliitis by quantitative ADC measurements. Consequently, for detecting and quantifying inflammatory lesions in axial SpA, DWI may be a new and useful alternative method to contrast-enhanced MRI, which is generally more

time consuming and expensive with risks of adverse effects of contrast media. Further studies on the role of quantitative MRI analysis, as well as DWI correlated with DCE-MR and performed with advanced MR technologies using higher resolution, are required to validate and characterize these methods.

However, despite quantitative measurements, DWI has its own limitations [6, 7, 12]. Significant overlap has been noted for ADC values in differentiating benign and malignant fractures for evaluation of sclerotic bone metastases, soft tissue and bone tumors, and bone infection, thus limiting its clinical value. Furthermore, the EPI-based DWI is frequently affected by geometrical image distortions related to the long gradient echo train lengths that generate limitations, particularly in bone/soft tissue borders with significantly different susceptibilities. Another limitation is the relatively low spatial resolution of DWI, which requires further optimization of this technique.

Some studies reported that the increase in CRP and ESR (laboratory parameters of inflammation) may be used as a marker of disease activity [6]. In a study by Jee et al. [16], a correlation between ESR with CRP values and synovial contrast enhancement on MRI was reported. However, Puhakka et al. [17] found no abnormality in the CRP values in patients with sacroiliitis. In this study, CRP as a laboratory parameter was correlated with ADC as an imaging marker of the activity of the disease, consistent with the results of a recent study [6].

The limitations of this retrospective study include a relatively small and inhomogeneous patient population and no pathologic confirmation of the sample. In this study, we aimed to assess the MRI diagnosis of active sacroiliitis with DWI and used osteitis as the diagnostic criteria for disease activity. Therefore, the presence of the features of SpA (e.g., arthritis, enthesitis, uveitis, dactylitis, Crohn's disease or ulcerative colitis, urethritis, and family history of SpA) was not compared to the ADC values. In addition, the correlation between the ADC values and the degree of chronic changes (fatty marrow deposition, surface erosions, and sclerosis) were not obtained.

In conclusion, DWI is a sensitive, fast, cost-effective sequence for imaging SIJs without requiring a contrast agent. Our results suggest that DW imaging with ADC values may be complementary to FS T2-weighted or STIR MR images for accurately diagnosing osteitis that suggests inflammatory sacroiliitis. DWI may also be useful in the follow-up of acute inflammatory lesions as well as determination of prognosis. The value of DWI versus dynamic contrast-enhanced imaging in the follow-up of acute inflammatory lesions and determination of prognosis needs to be clarified.

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Disclosure of conflict of interest

None.

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