Evaluation of Inflammatory Disease Activity in the Sacroiliac Joints Using Magnetic Resonance Imaging: A Comparative Analysis of Short-Tau Inversion Recovery, Post-Contrast, and Diffusion-Weighted Imaging - Preliminary Study

Elif Hocaoglu[1], Sema Aksoy[2], Ercan Inci[3]

Bakirkoy Dr Sadi Konuk Research and Training Hospital, University of Health Sciences, Türkiye
Email: drelifhocaoglu@hotmail.com[1], semaaksoy2000@yahoo.com[2], ercan@inci.com[3]

Abstract

Introduction: It is essential to detect sacroiliitis earlier to decrease morbidity and unwanted complications such as ankylosing of sacroiliac joints. In recent studies, magnetic resonance imaging (MRI) serves as a key diagnostic tool for identifying sacroiliitis and is now included in the diagnostic criteria. We aim to detect the utility of diffusion-weighted imaging on the MRI in diagnosing sacroiliitis and measure ADC values for the response to treatment in future studies. Materials -methods: There were 39 patients (16 male, 20 female). A 1.5 Tesla MR device with a pelvic coil was used. The sequences were T1 (before and after intravenous contrast administration of gadolinium), T2-weighted fast field echo, short tau inversion recovery (STIR), diffusion-weighted (DW) images, and apparent diffusion coefficient (ADC) mapping. Sacroiliac joints were divided into four quadrants, and two radiologists interpreted all the sequences by giving scores from 0 to 3 depending on bone marrow edema from none to severe. The concordance of scores assigned to STIR, T1-weighted gadolinium-enhanced images, ADC mapping, and diffusion-weighted MR images was evaluated by calculating intraclass correlation coefficients. Results: A statistically significant positive correlation was observed between the activity scores derived from short tau inversion recovery (STIR) and other magnetic resonance (MR) sequences, namely T1-weighted gadolinium-enhanced images, apparent diffusion coefficient (ADC) mapping, and diffusion-weighted MR images. Conclusion: Active bone marrow abnormalities were identified with comparable efficacy using STIR imaging and other MR sequences (T1W-Gad, ADC mapping, DW-MR). In our study, we tried to emphasize the role of the diffusion-weighted images near the other sequences. Diffusion is a fast, easy-applied sequence. After increased experience in the diffusion-weighted images, routine application of this sequence will increase, and even becoming one of the diagnostic criteria will be inevitable. The difference in DWI from the other sequences is that it is measurable. The response to treatment may be followed up by ADC values.

Keywords: diffusion-weighted imaging, magnetic resonance, sacroiliitis.

1. Introduction

Spondyloarthropathies form the roof of a disease group different from inflammatory arthritis groups such as arthritis. The spondyloarthropathies are composed of ankylosing spondylitis, spondyloarthropathies in inflammatory bowel diseases, psoriatic arthritis, reactive arthritis, and undifferentiated spondyloarthropathy [1], [2]. Unilateral or bilateral sacroiliitis is very characteristic of spondyloarthropathies. The involvement is unilateral in the ankylosing spondylitis and inflammatory bowel disease and bilateral in psoriatic arthritis and reactive arthritis. Sacroiliitis usually leads to typical inflammatory lower back pain. Inflammatory back pain, sacroiliitis, asymmetric peripheral arthritis, spondylitis, enthesitis, dactylitis, and uveitis are the classification criteria of spondyloarthropathies [3], [4], [5], [6], [7]. Inflammatory back pain is back pain for over three months and has at least four properties of five based on Assessment in Ankylosing Spondylitis Working Group (ASAS) Criteria. These five properties include onset typically under 40 years of age, sudden onset, improvement with exercise, lack of relief with rest, and nighttime pain that diminishes upon getting up.

Today, as a routine practice in many centers, the initial imaging method is conventional radiography to diagnose sacroiliitis. The diagnosis of radiographic sacroiliitis can be made after 1 to 9 years with the onset of the symptoms of inflammatory back pain, which is a long time. As a result of the late diagnosis of spondyloarthropathies, often severe morbidity occurs [8], [9]. "Modified New York criteria" are used to classify sacroiliitis radiographically [7]. Radiographic findings in sacroiliitis due to spondylarthropathies are the same. They are erosions, periostitis, new bone formation at the enthesis, and abnormal bone mineralization [10]. The earliest sign seen on radiographs is erosions on the face of the iliac crest of the sacroiliac joint. The reason for this is that cartilage is thinner in this region. As a result of the progression of erosive joint changes, a widening of joint space and sclerosis of the articular surface is seen. Joint space narrowing and ankylosis are seen at the end stages [7], [10]. [11]. On plain radiographs, at least "grade 2" in double-sided or " grade 3-4" in single-sided radiographic detection of lesions is used in the diagnosis of sacroileitis [12]. Although ‘modified New York criteria’ are used for only diagnosing ankylosing spondylitis, Amor and ESSG (European Spondyloarthropathy Study Group) criteria are used for all the spondyloarthropathy group of the disease. Amor criteria were defined for the spondyloarthropathies, including 12 variables. Amor criteria are better than ESSG in the early diagnosis of spondyloarthropathies [13], [14]. Sacroiliitis is detectable on conventional radiography in destructive periods only by chronic changes like articular surface sclerosis, erosion, and ankylosing. Changes in the early stages, such as bone marrow edema in the neighboring bones, synovitis, capsulitis, and enthesitis findings of the predestructive period of the disease can only be shown by MRI [15]. Assessment in Ankylosing Spondylitis Working Group (ASAS) defined criteria include MRI for diagnosing spa. According to these criteria for patients under 45 with lower back pain for at least three months, clinical and radiological diagnoses of properties are sorted into two main headings. Spondyloarthropathy can be diagnosed by radiological diagnostic criteria of sacroiliitis and at least one clinical feature [12]. New York criteria were previously used for radiological diagnosis.

Unilateral grade 3-4 or bilateral grade 2 sacroiliitis is required for the diagnosis [7]. The ASAS working group realizes that radiographs are essential in diagnosing and treating spondyloarthropathies, but more is needed for early-stage diagnosis of spondyloarthropathy. Thus, MRI was added to the diagnostic criteria of sacroiliitis as a new modality [12], [16]. Early detection of the disease and starting the treatment before the development of morbidity will make it possible to have a better quality of life. By the use of inhibitors of TNF-α, the disease progression is slowed [17]. According to studies by the ASAS group, in the diagnosis of active sacroiliitis, the presence of adjacent bone marrow edema at the side of insertion is sufficient alone for the diagnosis of sacroiliitis. MRI is the only modality that could identify this edema. Chronic changes in MRI can also be monitored, but this is insufficient for diagnosing sacroiliitis. According to ASAS criteria, periarticular or subchondral bone marrow edema on short tau inversion recovery (STIR) images or contrast enhancement on T1 contrast-enhanced images (osteitis) are essential for diagnosing active sacroileitis. Early findings such as synovitis, enthesitis, and capsulitis and late-stage findings like sclerosis, erosion, and ankylosing do not allow the diagnosis of sacroiliitis on MRI without bone marrow edema or osteitis. For the diagnosis of bone marrow edema or osteitis on MRI, the lesion should be seen in two consecutive sections, or there must be multiple lesions in one section [12], [16].

2. Materıal and Method:

Referred to our department for sacroiliac MRI by the physical therapy and rehabilitation service, this retrospective study included 36 patients (16 male and 20 female; mean age: 34 years) with a history of spondyloarthropathies of less than two years and a clinical suspicion of a new attack of sacroiliitis. The local ethics committee approved the study.

For the sacroiliac examination of the patients, a 1.5 Tesla MRI (Siemens, Magnetom, Symphony, Germany) device with the pelvic coil was used. The sequences were coronal T1-weighted turbo spin-echo (T1W-TSE) (TR: 400 ms, TE 11 ms, exposure time: 4.20 min.), T2-weighted fast field echo (T2W-FFE) (TR: 4000 ms, TE: 70 ms, FA: 25°, shooting time: 3.51 min.) and fat-saturated STIR (TR: 2500 ms, TE: 10 ms, IR: 170 ms exposure time: 5.30 min.). Also, following IV administration of gadolinium-gradient echo, T1-weighted (T1W-Gad) axial and coronal images were obtained. Diffusion-weighted (DW) imaging was made using b = 0, 500, and 1000 s/mm2, and ADC maps were created. The slice thickness was 4 mm for all sequences.

Loss of sacroiliac joint distance was defined as sacroiliac joint ankylosing on the T1W-TSE, T2W-FFE, and STIR images, and the focal increased signal was defined as erosion on T2-images. The region of bone near the cartilage was defined as subchondral bone. Each sacroiliac joint was divided into four quadrants to evaluate bone marrow edema (1, upper iliac quadrant; 2, upper sacral quadrant; 3, lower sacral quadrant; 4, lower iliac quadrant). Leeds scoring system detects edema in sacroiliac joints and the spine. The Leeds scoring system graded bone marrow edema as mild, moderate, and severe. If there is no bone marrow edema, we call it grade 0. If > 25% of the one quadrant, bone marrow edema has been kept grade 1 (mild), between 25-75% of the one quadrant, grade 2 (moderate), > 75% of the one quadrant was scored as grade 3 (severe) edema. This system was used previously in some studies (18, 19). All images

independently were evaluated in two separate sessions by two experienced radiologists. STIR, T1W-Gad, DW, and ADC mapping sequences were evaluated separately. For each quadrant (total 8 for each patient), bone marrow edema was diagnosed within at least one sequence of at least one scoring. If there was no bone marrow edema in all sequences, the score was 0. STIR sequence is used as the most reliable sequence. The study calculated the correlation between detecting bone marrow edema and determining its extent across each imaging sequence. Accordingly, the sequences were compared with the STIR sequence. The total score for each patient in 8 quadrants was calculated separately for each sequence, compared to the STIR sequence regarding the probability of edema detection. Two separate measurements of both radiologists were interpreted by comparing the intra-and interobserver agreement (Fig. 1, 2).

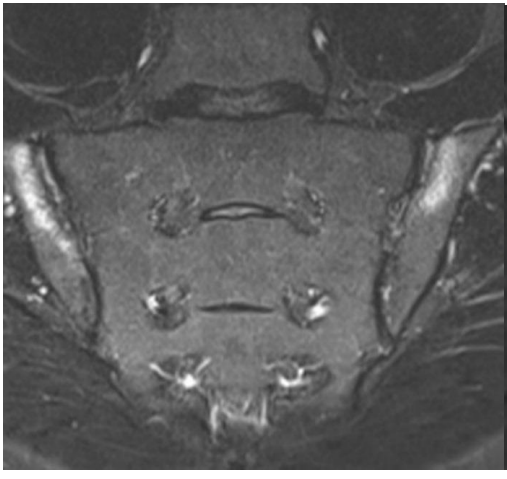


Fig. 1a

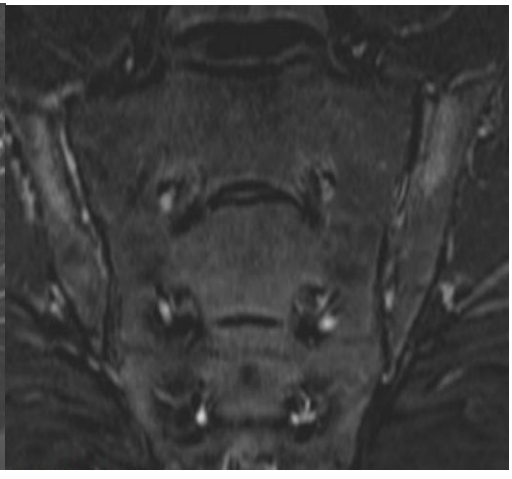


Fig. 1b

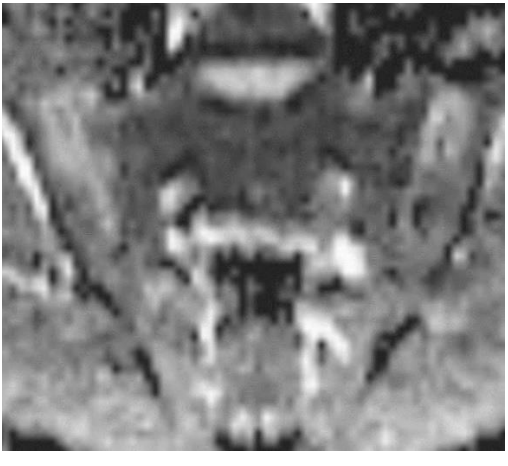


Fig. 1c

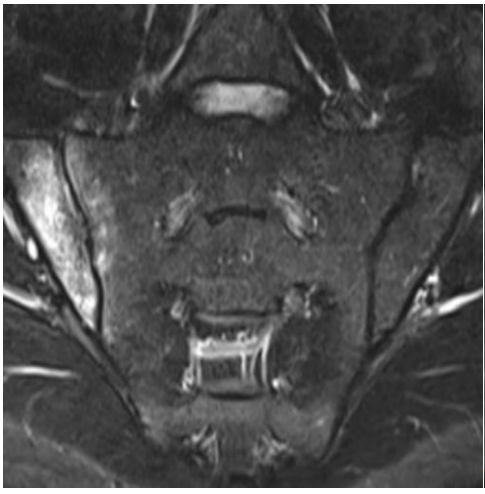


Fig.2a

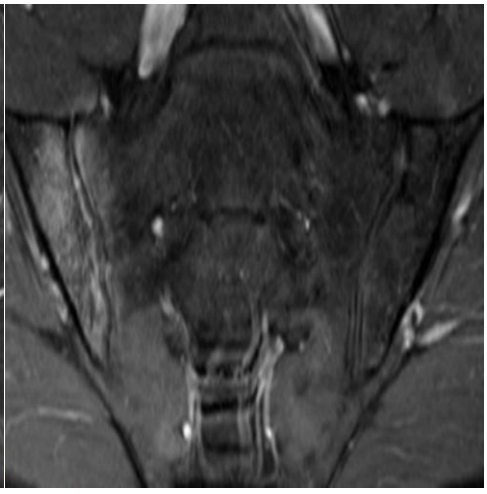


Fig.2b

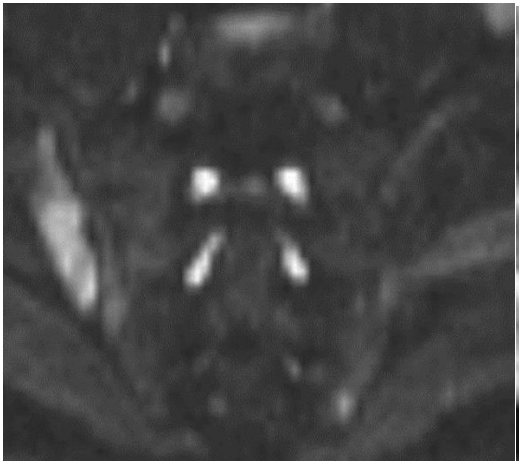


Fig. 2c

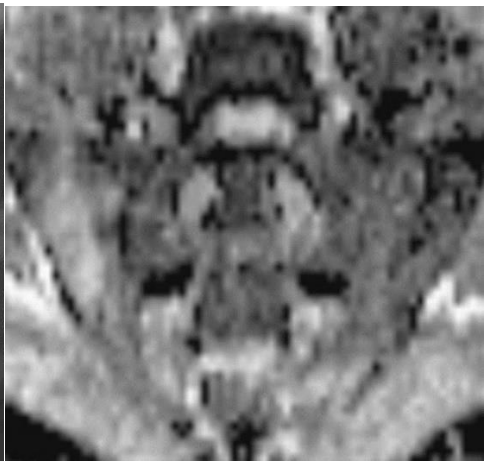


Fig. 2d

Statistically evaluation:

Statistical analyses were conducted utilizing NCSS statistical software (Number Cruncher Statistical System, 2007 Statistical Software, Utah, USA). The intraclass correlation coefficients were calculated to determine the agreement between scores assigned to STIR, T1W-Gad, ADC mapping, and DW-MR images for each quadrant and the total scores per joint. The diagnostic performance of MR sequences (T1W-Gad, ADC mapping, DW-MR) relative to the STIR sequence in four quadrants was estimated using the maximum likelihood of proper binormal receiver operating characteristic (ROC) curves. The area under the ROC curve (AUC) served as a summary performance index. Additionally, an intraclass correlation coefficient analysis was

conducted to evaluate the reliability of scoring in interreader agreement for STIR, T1W-Gad, ADC mapping, and DW-MR sequences between the two readers. Statistical significance was considered for p-values less than 0.05. The agreement between the two radiologists was assessed using Cohen's kappa (κ), with interpretations categorized as follows: poor agreement (0.00–0.20), fair agreement (0.21–0.40), moderate agreement (0.41–0.60), substantial agreement (0.61–0.80), and almost perfect agreement (0.81–1.00). All p-values were two-sided, and statistical significance was defined as $p < 0.05$.

3. Results:

For reviewing STIR, T1W-Gad, ADC mapping, and DW-MR images in the right sacroiliac joint, respectively, the K statistic characterizing agreement between the two radiologists was 0.99, 1, 1, and 0.98. The K statistics for agreement between the two radiologists were 0.90 for STIR images, 1 for T1W-Gad images, 0.99 for ADC mapping, and 0.98 for DW-MR images in the left sacroiliac joint. This indicates that inter-observer agreement was nearly perfect when interpreting all MR images.

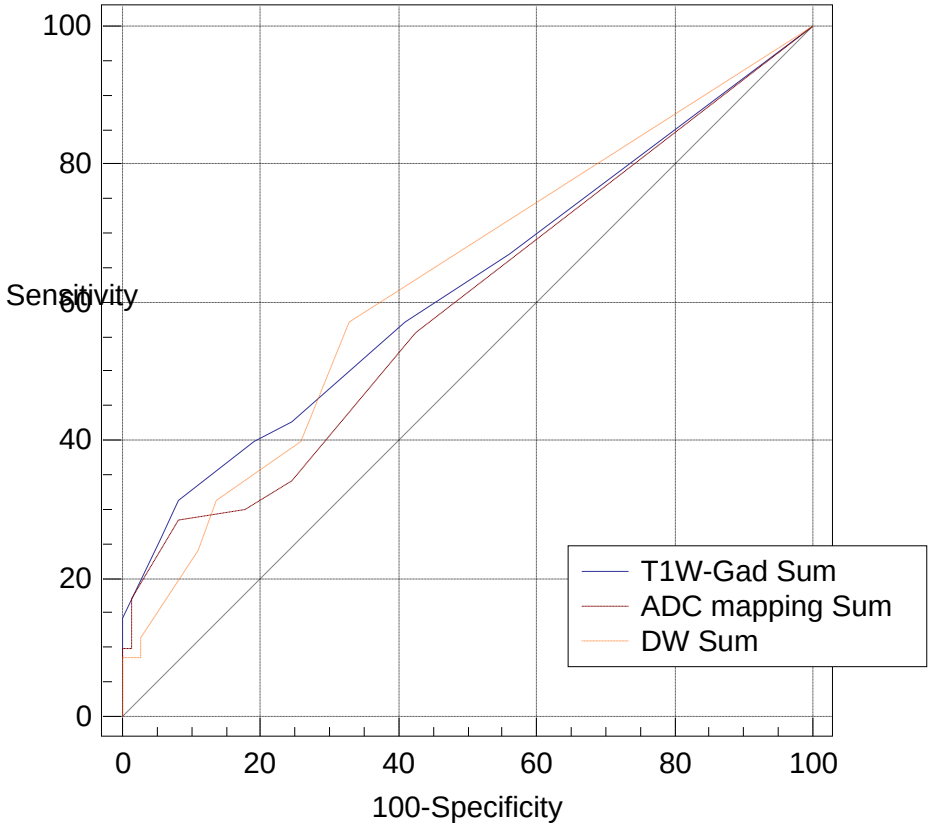
The intraclass correlation coefficients indicated strong agreement for the sum scores of the STIR and T1W-Gad sequences, measuring 0.82 for the right sacroiliac joint and 0.84 for the left sacroiliac joint. Similarly, high agreement was observed for the sum scores of the STIR and ADC mapping sequences, with values of 0.91 for the right sacroiliac joint and 0.84 for the left sacroiliac joint. Additionally, the intraclass correlation coefficients demonstrated strong agreement for the sum scores of the STIR and DW-MR sequences, measuring 0.84 for the right sacroiliac joint and 0.80 for the left sacroiliac joint (Table 1).

Table I: The intraclass correlation coefficients showed high agreement for the sum scores of the STIR and T1W-Gad, ADC mapping, DW sequences.

	Intraclass Correlation Coefficients	%95 GA
STIR R / T1W-Gad R	0,821	0,714-0,888
STIR R / ADC mapping R	0,910	0,856-0,944
STIR R / DW R	0,848	0,757-0,905
STIR L / T1W-Gad L	0,840	0,744-0,900
STIR L / ADC mapping L	0,844	0,750-0,902
STIR L / DW L	0,801	0,682-0,875

The AUC values for diagnosis of sacroiliitis in quadrant III were 0.80 ± 0.03, 0.69 ± 0.04, and 0.69± 0.04 for reviewing T1W-Gad, ADC mapping, DW-MR images (Table 2).

Table II: The area under the ROC curve (AUC) values for diagnosis of sacroiliitis in quadrant III were 0.80 ± 0.03, 0.69 ± 0.04, 0.69± 0.04 for reviewing T1W-Gad, ADC mapping, DW-MR images.



Viewing T1W-Gad images significantly improved performance compared with ADC mapping and DW-MR images. No statistically significant difference was found between the AUC values in the other quadrants according to ROC analysis.

4. Dıscussıon:

Today, the standard sequences used in the sacroiliac joint MRI are T1W-TSE, T2W-FFE, and STIR sequence, suppressing fat tissue signal completely and providing high water/oil contrast. Due to the replacement of fat around the joint being accompanied by chronic sacroileitis, fat-suppressed MR imaging is required for the diagnosis [20], [21]. For this reason, STIR is the best sequence for the interpretation of edema. Our study took T1W-TSE, T2W-FFA, STIR T1W-Gad, and DW images. Inflammatory disease activity in the sacroiliac joint by using fat-suppressed imaging (STIR) and gadolinium-enhanced MR imaging has been evaluated in several studies [18], [19], [20], [21]. An increased signal in STIR imaging means edema or

inflammation, and enhancement after gadolinium corresponds to the inflammation. Muche et al. evaluated the diagnostic efficacy of STIR imaging versus contrast-enhanced T1-weighted imaging with gadolinium for diagnosing sacroiliitis and found the results to be comparable [10]. Subchondral bone edema in the pathogenesis of sacroileitis may be the primary cause, and there are different opinions about it. Some authors claim that subchondral bone edema is primarily responsible for the pathogenesis of sacroileitis [22]; some do not participate [23]. Yu et al. [23] showed that in their study of 24 patients with ankylosing spondylitis, all the patients with type 1 lesions on MRI imaging had chronic changes such as erosions and sclerosis in CT scans. Therefore, they concluded that bone marrow edema is not one of the earliest signs of sacroileitis. In their study on 45 patients, Boy, and his colleagues found that the specificity and positive predictive value of contrast-enhanced images were very high. Still, these images did not contribute to the diagnosis [21].

Maksymowicz and colleagues [24] showed that in their study on 35 patients, the contrast-enhanced images were helpful in the diagnosis of sacroileitis, especially in patients with minimal bone marrow edema. Still, unenhanced images for the diagnosis of active sacroileitis were enough. Bredella [25]. and Baraliakos [26] demonstrated that contrast-enhanced images outperformed fat-saturated T2 and STIR sequences in detecting acute inflammation in their studies. The contrast-enhanced sections must be taken, especially if you want to make a differential diagnosis of malignant and infectious sacroiliitis. In our study, we included contrast-enhanced images, which also had the effect of being one of the ASAS criteria; we believe these images will play a role in the early diagnosis of spondyloarthropathies.

In diagnosing subchondral bone marrow edema, STIR or fat-saturated T2 sequences were used in conjunction and compared to each other in various studies. In their study, boy and his colleagues [21] concluded that the most useful sequence in the diagnosis of sacroiliitis sequence was fat-saturated T2-weighted sequences. Bredella and his colleagues [25] found that STIR and fat-saturated T2-weighted sequences detected bone marrow edema at the same rate. STIR sequences have been widely used for many years to diagnose bone marrow-related diseases (multiple myeloma, metastasis, insufficiency fractures) [27], [28]. We also routinely use STIR sequence to diagnose sacroileitis as the most reliable sequence.

After the great benefits of diffusion-weighted images in neurological diseases, this sequence is widely used in oncological and abdominal diseases and, recently, in the musculoskeletal system [29], [30], [31]. Diffusion-weighted images of vertebral compression fractures are instrumental in discriminating between benign and malignant. In a study by Baur and his colleagues [32], acute benign vertebral fractures showed hypointense, and malignant vertebral fractures showed hyperintense signals in diffusion-weighted images. Del Vescovo and his colleagues [33] showed that detecting bone metastasis diffusion-weighted MR imaging was superior to scintigraphy and computed tomography. Bozgeyik and his colleagues [9] found that in their studies, diffusion-weighted imaging might be helpful in the diagnosis of sacroiliitis, and ADC values in iliac and sacral bones of the patients with sacroiliitis were significantly higher than ADC values of the patients with mechanical pain in their quantitative measurements. Gaspersic and his colleagues [34] showed that diffusion-weighted and contrast-enhanced sequences in their study on 30 patients effectively detected inflammatory changes while treating ankylosing spondylitis.

Sacroiliitis is a painful inflammatory disease [35], [36].

MRI is beneficial in diagnosing active sacroiliitis, especially the presence of adjacent bone marrow edema for the diagnosis of sacroiliitis. Our study detected Active bone marrow abnormalities nearly equally well with STIR and other MR sequences (T1W-Gad, ADC mapping, DW-MR). The roles of these sequences are increasing day by day. We tried to emphasize the role of diffusion-weighted images near the other sequences in the present study.

5. Conclusıon:

The place of radiology in diagnosing sacroileitis in recent years has increased considerably compared to the previous period. With the introduction of MRI as diagnostic criteria, MRI has been guiding for the early diagnosis and treatment of the disease. After increased experience in the diffusion-weighted images, routine application of this sequence increases, and even becoming one of the diagnostic criteria will be inevitable. Diffusion is a fast, easy-applied sequence. As well as in disease diagnosis, diffusion-weighted images might be helpful during follow-up and evaluation of the response to treatment. Further research on this issue will help us in the future. We aim to follow up on these patients and detect some threshold ADC values for the treatment according to clinical improvement. So, following up with the patients will be easier.

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