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The value of diffusion-weighted imaging in the diagnosis of active sacroiliitis

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ABSTRACT

The aim of this study was to evaluate the effectiveness of diffusion-weighted imaging (DWI) in the diagnosis of active sacroiliitis.
In this prospective study, 66 patients with clinical prediagnosis of active sacroiliitis were evaluated. Four patients who were not suitable for MRI examination were excluded. Twenty subjects with no complaint of low back pain constituted the control group. All of the patients underwent sacroiliac MRI examination performed with a 1.5 Tesla unit using phase array body coil. Before DWI, oblique axial and coronal T1 and T2-weighted TSE followed by STIR sequences were obtained. DWI examinations were obtained on SS-SE EPI sequence through chemical shifting selective fat suppression technique. 'b' value was chosen as 50, 400 and 800 mm^2/sec and total scanning time was 114 seconds. ADC calculations were made from the ADC maps by placing ROI on the active inflammatory regions in case group and on sacrum and iliac bones in control group.
Of the 62 cases, 42 had a radiologic diagnosis of active sacroiliitis, and 20 were regarded as normal. Mean ADC values in 42 patients with active sacroiliitis were significantly higher than control group. The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy rate of DWI in the diagnosis of active sacroiliitis were found to be 100 % for all. The cut-off ADC value was 0.94×10^{-3} mm^2/sec for right sacroiliitis and 0.89×10^{-3} mm^2/sec for left sacroiliitis.
We believe that DWI and ADC quantification can be used successfully for the early diagnosis and follow-up of active sacroiliitis.

Key Words: Apparent diffusion coefficient, Diffusion-weighted imaging, inflammation, MRI, sacroiliitis

Introduction

Diffusion-weighted magnetic resonance imaging (DWI) is based on the tissue-dependent signal attenuation caused by incoherent thermal motion of water molecules (1). The apparent diffusion coefficient (ADC), a quantitative parameter is calculated from DWI (2).

Sacroilitis is the inflammation of sacroiliac joints which causes hipache and backache as main symptoms. It can be detected in association with rheumatical diseases (SAPHO syndrome, Rheumatoid Arthritis, Systemic Lupus Erythematosus), metabolic disorders, various infections (Tuberculosis, Brucellosis, Typhoid fever) and rarely malignancies (3,4).

Conventional radiology fails for the early diagnosis of sacroiliitis. In present, conventional MRI and clinical findings are evaluated for the early diagnosis of sacroiliitis. However, conventional MRI requires longer examination time and contrast medium administration. Thus the contribution of DWI for early diagnosis of sacroiliitis will be useful which can be performed in a short time and without contrast medium administration.

The aim of this study was to evaluate the effectiveness of DWI and quantitative measurement of ADC values in the diagnosis of active sacroiliitis cases, with the correlation of STIR sequence, clinical and laboratory findings.

Material and Methods

In this prospective study, 66 patients (age range: 14-71 years) with a clinical prediagnosis of active sacroiliitis were evaluated. Four patients who were not suitable for MRI examination (prosthesis, cardiac pace-maker) were excluded.

Patients were examined with 1.5 Tesla MRI unit using body coil. All patients were evaluated with DWI by means of echoplanar imaging (EPI) sequence in addition to routine MRI protocol. Before DWI

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Table 1. Demonstrative statistics and comparison results for characteristics of each group

	Control				Mechanical pain				Sacroiliitis				
	Mean	St. dev.	Min.	Max.	Mean	St. dev.	Min.	Max.	Ort.	St. dev.	Min.	Max.	p
Age	30	7,98	15,00	56,00	30	12,64	19,00	71,00	27	9,87	14,00	55,00	0.347
Right Iliac ADC	0,50	0,06	0,36	0,63	0,51	0,08	0,26	0,63	1,52	0,16	1,21	1,91	0.001
Right Sacrum ADC	0,50	0,06	0,38	0,62	0,52	0,06	0,41	0,62	1,53	0,18	1,15	1,95	0.001
Left Iliac ADC	0,46	0,10	0,26	0,66	0,48	0,09	0,33	0,66	1,52	0,18	1,16	1,89	0.001
Left Sacrum ADC	0,48	0,09	0,37	0,69	0,49	0,10	0,26	0,64	1,52	0,19	1,16	1,89	0.001
Right mean ADC	0,50	0,06	0,37	0,63	0,52	0,06	0,35	0,63	1,52	0,15	1,25	1,93	0.001
Left mean ADC	0,47	0,08	0,35	0,63	0,48	0,08	0,30	0,63	1,52	0,17	1,16	1,89	0.001

Table 2. Demonstrative statistics and comparison results for etiologies* in sacroiliitis group

	Ankylosing spondylitis				Brucellosis				Idiopathic				
	Mean	St. dev	Min	Max	Mean	St. dev.	Min.	Max	Mean	St. dev	Min	Max	p
Age	28	9,46	14	46	23	7,05	14	35	29	13,10	14	55	0,316
Right Iliac ADC	1,52	0,19	1,21	1,91	1,47	0,11	1,33	1,63	1,53	0,16	1,25	1,86	0,709
Right SacrumADC	1,56	0,21	1,15	1,95	1,49	0,15	1,28	1,72	1,54	0,16	1,25	1,82	0,729
Left Iliac ADC	1,53	0,23	1,18	1,89	1,49	0,19	1,16	1,82	1,53	0,09	1,46	1,70	0,865
Left Sacrum ADC	1,56	0,19	1,22	1,89	1,51	0,26	1,16	1,89	1,49	0,08	1,39	1,61	0,776
Right mean ADC	1,54	0,18	1,29	1,93	1,48	0,09	1,35	1,59	1,53	0,15	1,25	1,84	0,671
Left mean ADC	1,54	0,20	1,20	1,89	1,50	0,20	1,16	1,76	1,51	0,07	1,44	1,64	0,857

*For the etiologies Ankylosing spondylitis, Brucellosis, and Idiopathic cases

examination, T1- and T2-weighted sequences with and without fat suppression, and STIR (TR 5640 sec; TE 70 sec; TI 150; Average 2; Flip Angle *150*°; Matrix 256x256; Slice number 18; Slice thickness 5mm; FOV 350; Slice gap 7mm) sequences were obtained on oblique and coronal planes. DWI examinations were obtained on SS-SE EPI sequence through chemical shifting selective fat suppression technique. 'b' value was chosen as 50, 400 and 800 mm^2/sec and total scanning time was 114 seconds. Intravenous contrast medium was not administered to any of the patients.

On STIR images which were accepted as gold standard, active sacroiliitis was diagnosed by means of detecting active inflammatory changes like subchondral-paraarticular bone marrow edema, intraartricular synovitis, surrounding enthesitis or capsullitis in sacroiliac joint, and clinical-laboratory findings which support sacroiliitis.

Case group was constituted by 42 patients (28 male, 14 female, mean age: 27±9,87, age range: 14-55 years) who were diagnosed as sacroiliitis on DWI. For control group 20 individuals (13 male, 7 female, mean

Table 3. The relation of sex and etiology in sacroiliitis group

Sex	Etiology						Total
	Ankylosing Spondylitis	Brucellosis	Idiopathic	Typhus	Reactive Spondyloarthropathy	Undifferentiated Spondyloarthropathy	
Male	10	11	5	1	1	0	28
Female	4	2	6	1	0	1	14
Total	14	13	11	2	1	1	42

Table 4. The relation of etiology and side of involvement in sacroiliitis group

	Etiology						Total
Side	Ankylosing Spondylitis	Brucellosis	Idiopathic	Typhus	Reactive Spondylo arthropathy	Undifferentiated Spondylo arthropathy	
Right Sacroiliitis	2	4	4	1	1	0	12
Left Sacroiliitis	0	6	1	1	0	0	8
Bilateral Sacroiliitis	12	3	6	0	0	1	22
Total	14	13	11	2	1	1	42

Chi square= 20.404, p = 0.026

Table 5. The relation of sex and side of involvement in sacroiliitis group

Side	Sex		Total
	Male	Female	
Right Sacroiliitis	9	3	12
Left Sacroiliitis	6	2	8
Bilateral Sacroiliitis	13	9	22
Total	28	14	42

Chi square= 1.193, p = 0.551

age 30±7.98 years, age range:15-56 years) who did not have any lumbal or sacroiliac pathology, were chosen.

In case group, ADC values were calculated from lesions at sacroiliac joint space, surrounding bone and adjacent bone marrow on ADC map. In control group ADC values were calculated from bilateral normal sacroiliac joint space, surrounding bone and adjacent bone marrow.

One way ANOVA test was used for analyzing any difference between the mean ADC values of the case and control groups. After variance analysis, Duncan comparison test was used for evaluating different groups. Also in both groups for searching the differences between these variables, Spearman correlation coefficient was used. Chi-square test was applied to indicate the relationship between cathegorical variables. ROC-curve analysis was used to analyze ADC cut-off value which was calculated on right and left iliac bones and sacrum for the differentiation of control and sacroiliitis groups. Statistically significance was accepted as 5% and analyses were made with SPSS 13.0 software programme.

Results

In 42 of the 62 patients, sacroiliitis was detected; so these 42 patients constituted the case group; in 20 of them sacroiliitis was not diagnosed and they were classified as mechanical originated backache group. For control group 20 healthy individuals were chosen who did not have any sacroiliac pathology or hip-backache. In these 42 patients (28 male,14 female) with sacroiliitis, the etiology was detected as Ankylosing spondilitis for 14, Brucellosis in 13, Typhoid fever in 2, Reactive Arthritis for 1 and Undifferentiated Spondyloarthropathy for 1 patient. In 11 patients no any etiology was detected.

In our study, according to ADC, average and standard deviation for the sacroiliitis group were 1.52±0.15 x 10^{-3} mm^2/sec on the right, and 1.52±0.17 x 10^{-3} mm^2/sec on the left. For control group mean ADC values were 0.50±0.06 x 10^{-3} mm^2/sec on the

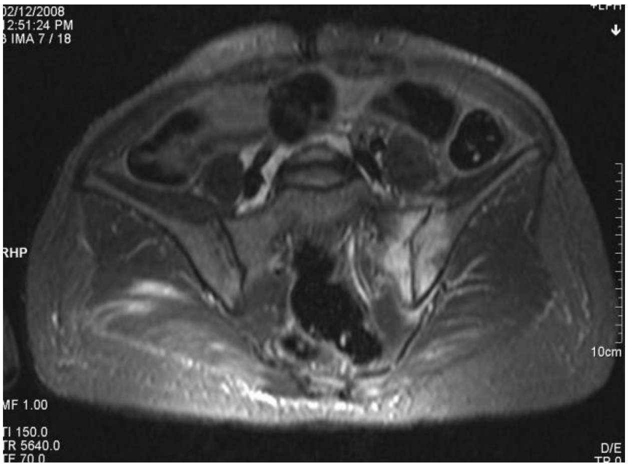
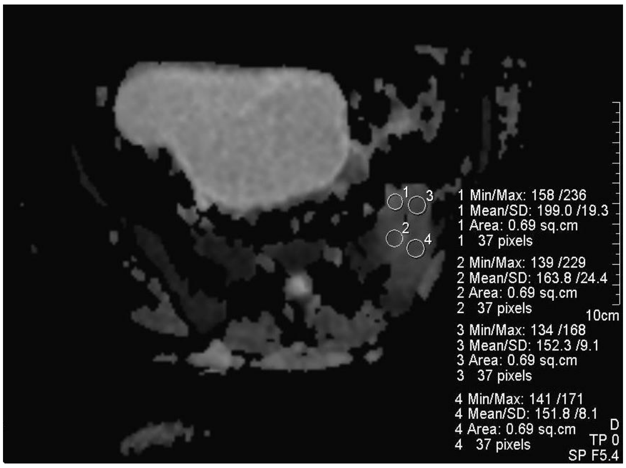


Fig.a.



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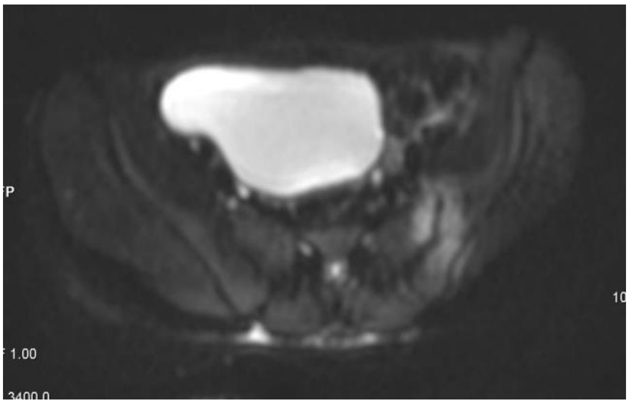

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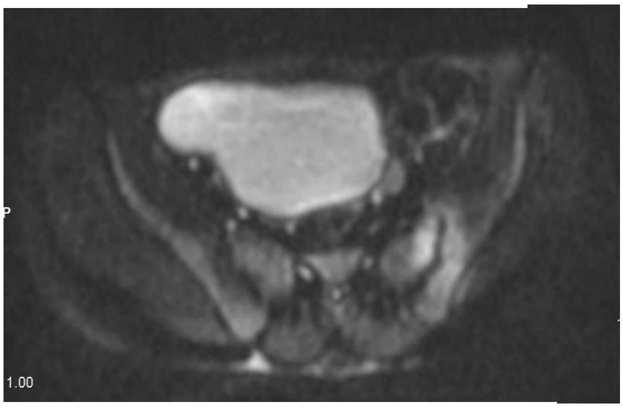

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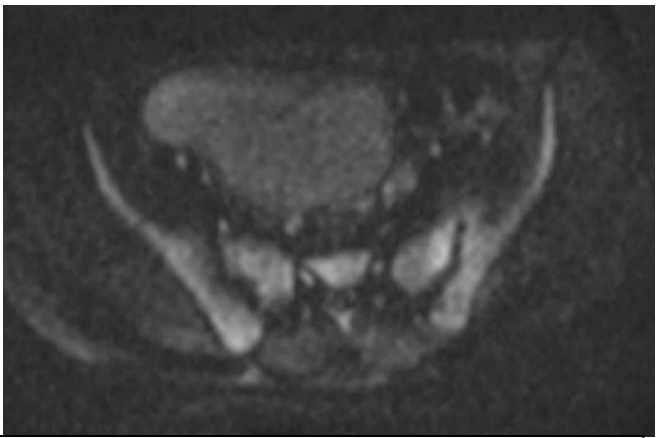


Fig.e.

Fig. 1a-e. 18 year old female patient's STIR (a), ADC (b) and DWI examination with b:50 (c), 400 (d), 800 (e) x10^{-3}mm^2/sec, revealed signal changes compatible with active sacroiliitis (edema-inflammation) on left sacroiliac joint and iliac-sacral bones adjacent to sacroiliac joint. The mean ADC values of signal changes were 1.78x10^{-3} mm^2/sec on left sacral side and 1.51x10^{-3} mm^2/sec on left iliac side. The etiology was accepted as typhoid fever after clinical and laboratory evaluation.

right sacroiliac, and 0.47±0.08 x 10^{-3} mm^2/sec on the left sacroiliac joint. For mechanical originated backache group mean ADC values were 0.52±0.06 x 10^{-3} mm^2/sec on the right and 0.48±0.08 x 10^{-3} mm^2/sec on the left. According to these values; there was statistically significant difference between sacroiliitis group and both mechanical originated backache group and control group. The ADC values were significantly increased in sacroiliitis group when compared with mechanical originated backache group and control group (p<.001). There was no statistically significant difference between mechanical originated

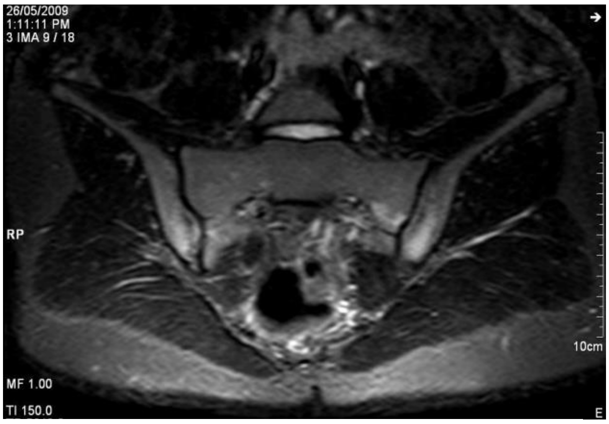


Fig.a.

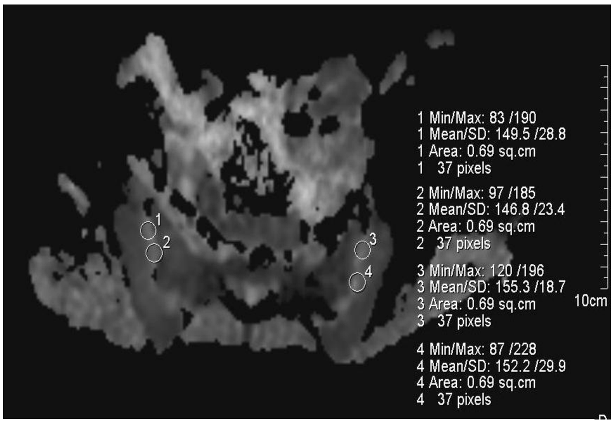


Fig.b.

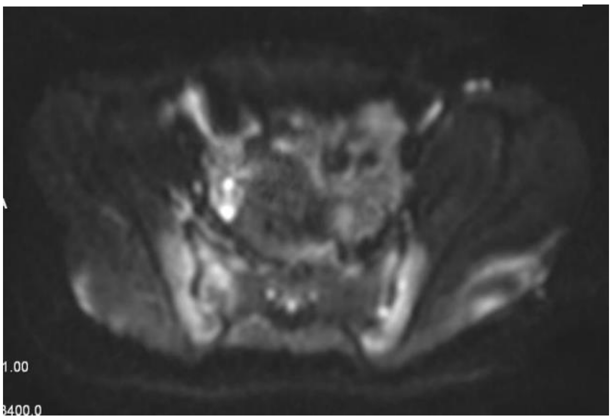
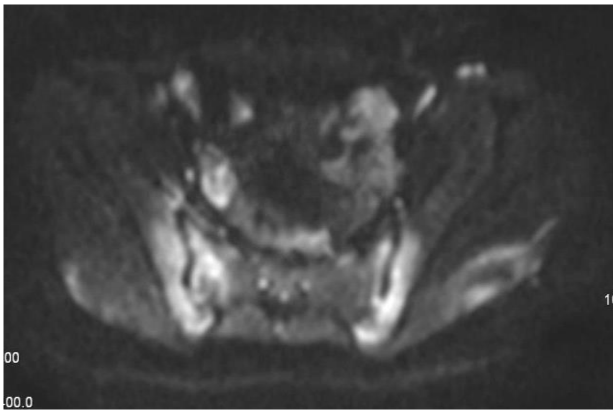


Fig.c



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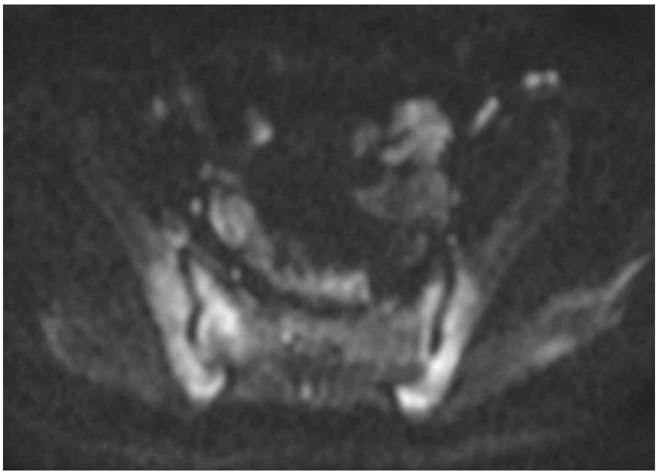

Fig. 2a-e. 18 year old female patient's STIR (a), ADC (b) and DWI examination with b:50 (c), 400 (d), 800 (e) $x10^{-3}mm^2/sec$, revealed signal changes compatible with active sacroiliitis (edema-inflammation) on bilateral sacroiliac joint and iliac-sacral bones adjacent to sacroiliac joint. The mean ADC values of signal changes were $1.48x10^{-3}$ mm^2/sec on right iliac side, $1.39x10^{-3}$ mm^2/sec on right sacral side, $1.49x10^{-3}$ mm^2/sec on left sacral side and $1.54x10^{-3}$ mm^2/sec on left iliac side. The etiology was accepted as brucellosis after clinical and laboratory evaluation.

backache group and control group. In sacroiliitis group the difference between the averages of right and left sides was not significant. (Table 1)

As a result of ROC-curve analysis which was used to demonstrate the sacroiliitis group and control group according to ADC values, the cut-off ADC value was 0.94 x 10^{-3} mm^2/sec for the right sacroiliitis and 0.89 x 10^{-3} mm^2/sec for the left sacroiliitis, both with a sensitivity and specificity of 100%.

According to calculated average ADC values the differences among the affected localizations (right iliac, right sacrum, left iliac, left sacrum/right

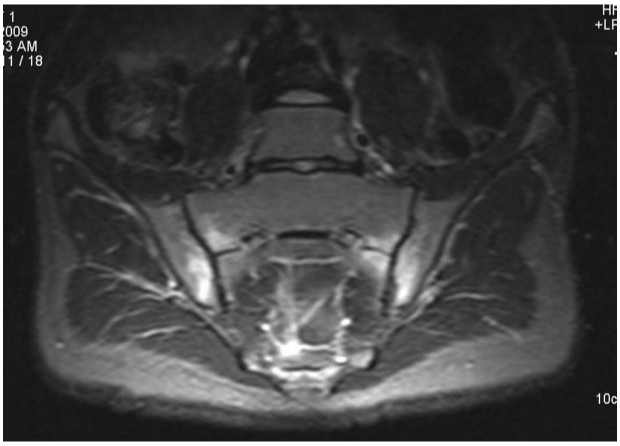

Fig.a.

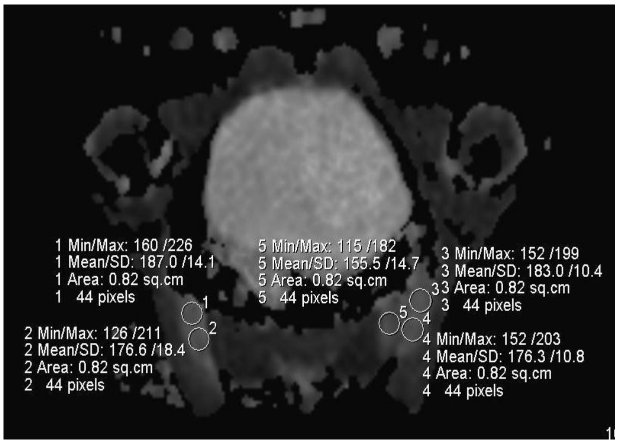

Fig.b.

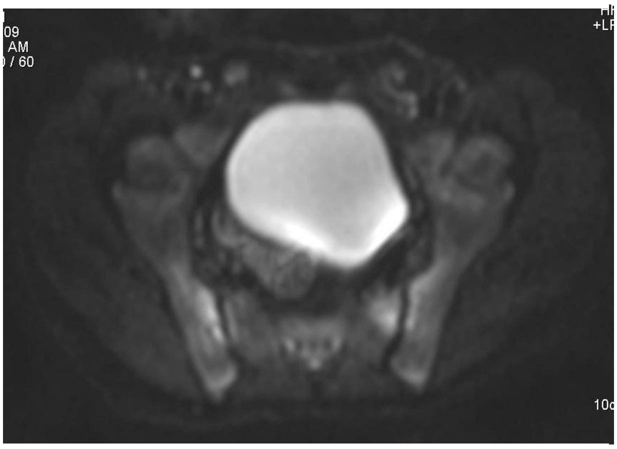

Fig.c.

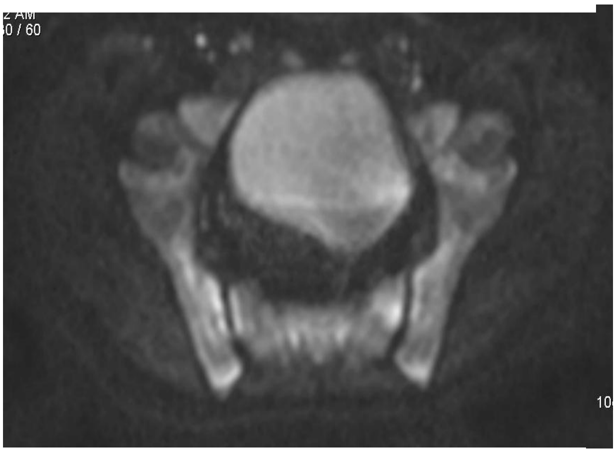

Fig.d.

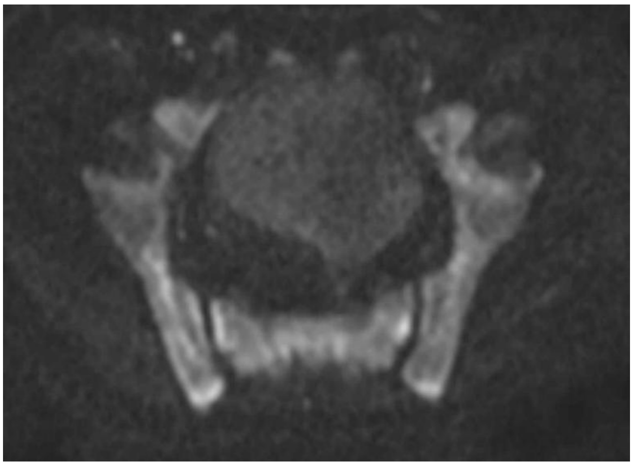

Fig. 3a-e. 15 year old male patient's STIR (a), ADC (b) and DWI examination with b:50 (c), 400 (d), 800 (e) $x10^{-3}mm^2/sec$, revealed signal changes compatible with active sacroiliitis (edema-inflammation) on bilateral sacroiliac joint and iliac-sacral bones adjacent to sacroiliac joint. The mean ADC values of signal changes were $1.67x10^{-3}$ mm^2/sec on right iliac side, $1.78x10^{-3}$ mm^2/sec on right sacral side, $1.69x10^{-3}$ mm^2/sec on left sacral side and $1.55x10^{-3}$ mm^2/sec on left iliac side. The etiology was accepted as Ankylosing spondilitis after clinical and laboratory evaluation.

sacroiliac, left sacroiliac) or etiologies (Ankylosing spondilitis, Brucellosis and idiopathic) were not statistically significant (Table 2). Sex-etiology, etiology-side of involvement, and sex-side of involvement parameters are demonstrated in tables 3-5.

In all the 42 patients with sacroiliitis at the detected lesion areas, both DWI and ADC maps showed increased signal intensity compared to normal sacral and iliac bones (Figure 1-3). These sequences showed increased signal intensity in none of the patients with mechanical originated backache group and control group.

In our study, DWI had a sensitivity, specificity, positive predictive value, negative predictive value, and accuracy rate of 100% for the diagnosis of active sacroiliitis.

Discussion

Active sacroiliitis could be diagnosed by increased signal on DWI and ADC map, with increased ADC values compared with normal sacroiliac joint. The early diagnosis and the management of efficient treatment protocol for sacroilitis can decrease morbidity at the later period by suppressing the severity of the disorder's course (5). Clinic evaluation and the anamnesis give only limited results for the early diagnosis of sacroiliitis. For this reason at the diagnostic period, often reliable imaging findings are required (6).

The MRI of sacroiliac joints is sensitive for demonstrating sacroiliitis. For detecting inflammation, STIR, fat suppressed T2 and contrast enhanced T1 sequences are used. In several studies the effectiveness of these sequences have been evaluated.

In some studies, it was suggested that STIR sequence can detect inflammatory changes as well as dynamic contrast enhanced MRI (7, 8). Muche B. et al. (9) reported that STIR sequence was nearly equal to contrast enhanced MRI for detailed evaluation of sacroiliitis. In a study of Madsen KB et al. (10) they compared STIR and fat suppressed contrast enhanced T1 MRI sequence for evaluating the degree of severity of the inflammatory changes at sacroiliac joints in the patients with spondyloarthropathy and they found significant positive correlation between them. They suggested that STIR and fat suppressed contrast enhanced T1 sequences were nearly equal for detecting the active bone marrow changes in patients with spondyloarthropathy.

With the results of previous studies we also used STIR sequence as the gold standard for the diagnosis of active sacroiliitis. Active sacroiliitis diagnosis was made by detecting the active inflammatory changes like subchondral and paraarticular bone marrow edema, intraarticular synovitis and surrounding enthezitis or capsulitis areas and with clinical and laboratuary findings which supports sacroiliitis.

Recently DWI has been used increasingly on the musculosceletal disorders. Ward et al. (12) analyzed normal and post-traumatic bone marrow diffusion characteristics and they suggested that ADC values of traumatic bone marrow are elevated when compared with normal bone tissue. Chan et al.(13) reported mean ADC values of normal bone marrow, benign vertebral fractures and vertebral fractures duo to neoplasia as 0.23, 1.94, and 0.82 x 10^{-3} mm^2/sec respectively. Dietrich et al. (14) reported normal vertebral bone marrow mean ADC value as 0.3 x 10^{-3} mm^2/sec similar to the previous study.

In a study of Bozgeyik et al (15), they calculated mean ADC values in the patients with back pain of mechanical origin with a b:1000 mm^2/sec, on right iliac and sacral, left iliac and sacral bones as 0.53, 0.56, 0.53 and 0.56 x 10^{-3} mm^2/sec, respectively. Similar to this study, in our study in back pain of mechanical origin group we calculated mean ADC values on right iliac, right sacrum, left iliac and left sacrum as 0.51, 0.52, 0.48, 0.49 x 10^{-3} mm^2/sec, respectively. The mean ADC values calculated in sacroiliitis group were markedly increased when compared with back pain of mechanical origin and control groups.

Gaspersic et al. (15) evaluated the affects of different treatments for enthesitis in anchylosing spondylitis and bone inflammation by using DWI and dynamic contrast enhanced MRI. They suggested that DWI and dynamic contrast enhanced MRI were effective in detecting inflammatory changes during treatment of ankylosing spondylitis and could evaluate the effectiveness of the treatment.

Bozgeyik et al. (16) searched the value of DWI in 42 patients with spondyloarthropathy or early ankylosing spondylitis who had active inflammatory changes at their sacroiliac joints. They found that ADC values of the patients with sacroiliitis (11) were markedly increased when compared with the patient who had back pain of mechanical origin. They also suggested that DWI could detect acute lesions in sacroiliitis as well as Gadolinium enhanced T1WI.

In our study we found that the mean ADC values were markedly increased in the sacroiliitis group when compared with those in back pain of mechanical origin and control groups. The difference in the mean ADC values of sacroiliitis group and both back pain of mechanical origin and control groups was statistically significant ($p<0,001$). The difference in the mean ADC values of back pain of mechanical origin group and control group was not significant (Table 1).

In conclusion, being a non-invasive and fast imaging technique, free from contrast medium administration and ionizing radiation, we believe that DWI can be used successfully for the early diagnosis and follow-up of active sacroiliitis.

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