Research Article / Araştırma Makalesi

The Role of Diffusion Weighted MRI in Diagnosis of Sacroiliitis

Difüzyon Ağırlıklı MRG'nin Sakroiliit Tanısındaki Rolü

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Abstract

Background: The main aim of this study is to investigate the effectiveness of Apparent Diffusion Coefficient (ADC) and Diffusion Weighted Imaging (DWI) in identifying and detecting active sacroiliitis. The study seeks to evaluate the potential of these imaging techniques as diagnostic tools for this particular condition.
Materials and Methods: A total of 79 people underwent MRI examination for low back pain. Thirty-four of these individuals did not show any pathology in the sacroiliac joints and were included in the control group. 45 people diagnosed with sacroiliitis formed the patient group. All participants underwent spin echo, planar echo, diffusion-weighted MR imaging at a b=1000 s/mm². ADC values were determined by assessing the subchondral regions adjacent to both sacroiliac joints. Relative ADC values were obtained for both the patient and control groups.
Results: The study found a significant difference ($p<0.05$) in mean ADC values between the patient group (1202.4±268.2 mm²/s) and the control group (423.9±71.9 mm²/s). These results indicate distinct diffusion patterns between the two groups. Additionally, the relative ADC values were significantly different ($p<0.05$) with 0.434 in the patient group and 0.153 in the control group, further supporting the observed disparities in diffusion characteristics.
Conclusions: Diffusion-weighted imaging has similar diagnostic efficacy to other MRI methods in detecting active sacroiliitis. In addition, it is thought that the relative ADC values may contribute more to the diagnosis of sacroiliitis.

Key Words: Sacroiliitis, DWI, Ankylosing spondylitis

Öz

Amaç: Bu çalışmanın temel amacı, Görünür Difüzyon Katsayısı (ADC) ve Difüzyon Ağırlıklı Görüntüleme'nin (DAG) aktif sakroiliitin tanımlanması ve saptanmasında etkinliğini araştırmaktır. Çalışma, bu görüntüleme tekniklerinin bu özel durum için teşhis aracı olarak potansiyelini değerlendirmeyi amaçlamaktadır.
Materyal ve Metod: Toplam 79 kişiye bel ağrısı nedeniyle MR incelemesi yapıldı. Bu bireylerden 34'ü sakroiliak eklemlerde herhangi bir patoloji göstermeyerek kontrol grubuna dahil edildi. Hasta grubunu sakroileit tanısı alan 45 kişi oluşturdu. Tüm katılımcılara b=1000 s/mm²'de spin eko, düzlemsel eko, difüzyon ağırlıklı MR görüntüleme uygulandı. ADC değerleri her iki sakroiliak ekleme komşu subkondral bölgeler değerlendirilerek belirlendi. Hem hasta hem de kontrol grubu için rölatif ADC değerleri elde edildi.
Bulgular: Çalışmada hasta grubu (1202,4±268,2 mm²/s) ile kontrol grubu (423,9±71,9 mm²/s) arasında ortalama ADC değerleri açısından anlamlı bir fark ($p<0,05$) bulundu. Bu sonuçlar iki grup arasındaki farklı difüzyon modellerini göstermektedir. Ek olarak, göreceli ADC değerleri hasta grubunda 0,434 ve kontrol grubunda 0,153 ile anlamlı derecede farklıydı ($p<0,05$), bu da difüzyon özelliklerinde gözlenen eşitsizlikleri desteklemektedir.
Sonuç: Difüzyon ağırlıklı görüntülemenin aktif sakroiliitin saptanmasında diğer MRG yöntemleriyle benzer tanısal etkinliği vardır. Ayrıca göreceli ADC değerlerinin sakroileit tanısına daha fazla katkı sağlayabileceği düşünülmektedir.

Anahtar Kelimeler: Sakroileit, DWI, Ankilozan spondilit

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Introduction

The group of diseases known as seronegative spondyloarthropathies comprises ankylosing spondylitis, Reiter's syndrome, enteropathic arthritis, and psoriatic arthritis (1). It is important to note that there is no association between this disease group and the presence of rheumatoid factor. It has been shown that HLA-B27 increases the risk of developing the disease in this disease group (2,3). Primarily, the sacroiliac joints are involved and the presence of sacroiliitis is very important in the diagnosis (4). Although conventional radiography was used for the first time, its insufficiency in the early period delays the diagnosis. Therefore, more advanced imaging methods are needed for early diagnosis (4). In the active phase of the disease, dynamic contrast magnetic resonance imaging (MRI) or Diffusion-weighted MRI (DWMRI) helps the diagnosis before laboratory findings are positive.

Diffusion-weighted imaging (DWI) is a technique used to generate images by detecting and quantifying the random movement of water molecules within tissues. Contrast material is not used while the images are taken and the process is completed in a short time. Although DWMRI is mainly used in the central nervous system, it also plays an active role in the detection of other pathologies. It is used in the diagnosis of acute ischemic stroke, brain abscesses and tumors in the brain, in demonstrating normal brain myelination in newborns, and in the detection and characterization of tissue changes in multiple sclerosis (5,6). The diffusion properties of a particular tissue can be affected by several factors both in vivo and ex vivo. In vivo, factors like patient age and body temperature can influence the diffusion characteristics. Ex vivo factors, such as the specific MRI device used, the region of interest (ROI) selected, and the choice of b-value, can also introduce variations. To account for these variations, it is recommended to employ the normalized ADC, also referred to as the relative ADC (r-ADC).

The relative apparent diffusion coefficient (r-ADC) is determined by dividing the ADC measurement of the affected area by the ADC measurement obtained from a reference region (7). This normalization helps to standardize the ADC measurements and mitigate the impact of confounding factors, enabling more reliable and comparable results.

Based on this information, we aimed to evaluate the sensitivity and relative ADC values of DWMRI and ADC in the diagnosis of active sacroiliitis.

Materials and Methods

From June 2013 to December 2014, this study was carried out prospectively. Patients who underwent sacroiliac MRI in the radiology department of our hospital were included. On June 4, 2013, the study protocol was submitted to the Ethics Committee of our Harran University Faculty of Medicine for review and obtained approval under decision number 06 and session number 27.

The study included a total of 79 individuals with ages ranging from 14 to 51 years. Of these, 34 people without sacroiliac joint pathology were assigned to the control group. The patient group consisted of 45 people diagnosed with active sacroiliitis with MRI findings and clinical and laboratory data supporting the diagnosis. The sacroiliac joint was divided into upper and lower regions using an imaginary line passing through the S1 and S2 vertebral bodies. Then, measurements were taken from a total of 8 subchondral regions adjacent to the joint. The mean ADC value was determined by calculating the mean of the three highest values in the patient group, while the average of the measurements from all 8 locations in the control group was used. Subgroup analysis was performed by including non-lesion measurement regions of patients with sacroiliitis in the control group.

The MRI imaging was conducted using the Siemens 1.5 Tesla Magnetom Symphony A Tim System, located in Erlangen, Germany. Sequences containing oblique coronal and axial T2W Fatsat, T1W and T1A Fatsat were obtained before contrast application. Three series of single-shot spin echo planar (SS-SE-EP) arrays were obtained, sensitized with TR/TE/NEX/echo-planar values in the x, y, z directions, and enriched with values of 0, 500, and b. 1000 mm^2/s. Post-contrast axial and oblique coronal T1W Fatsat images were obtained after administration of gadolinium-based contrast medium.

Images were transferred to a clinical workstation for ADC measurements. ROI (Region of Interest) measurement area was set to approximately 0.5-1 cm^2 and ADC values were measured on the created ADC maps (Figure 1). ADC measurements were made over b=1000 values and measurements were made by a single radiologist.

Statistical analysis was performed using SPSS for Windows version 20.0. The normal distribution of the data was verified through the utilization of the Kolmogorov-Smirnov test. Therefore, parametric tests were preferred for further analysis. Chi-Square test was employed to assess discrepancies in categorical variables between the groups. The parametric data underwent analysis using the Student's t-test, with a statistical significance level set at $p<0.05$ for group comparisons. Receiver Operating Characteristic (ROC) analysis was performed to determine the predictive values of mean ADC and relative ADC values for sacroiliitis. The evaluation of ADC values in this analysis involved assessing diagnostic performance through the computation of sensitivity, specificity, and the area under the curve (AUC). In addition, Pearson correlation analysis was used to evaluate the relationships between measurable data in the patient group. This analysis contributes to the understanding of relationships by examining potential correlations between variables.

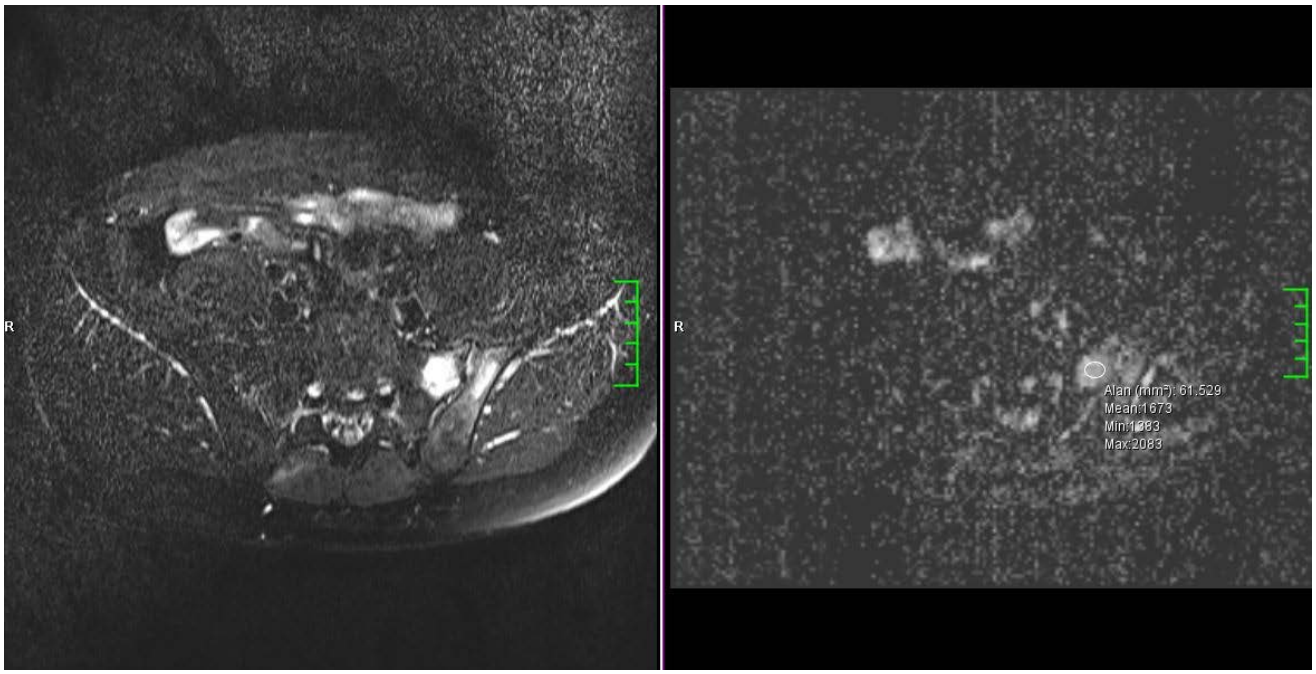

Figure 1. In a 30-year-old male patient, fat-suppressed T2A image of the sacral and iliac bone faces forming the left sacroiliac joint shows signal enhancement compatible with edema-inflammation reflecting active sacroiliitis. On single-shot, spin echo, echo planar (SS SE EP) DAG (b=1000), we measured a mean ADC of 1673 mm²/s on the left sacral side: 1673 mm²/s.

Results

Clinical and radiological findings of sacroiliitis were found in 45 (20 males, 25 females, age range 14-50 years, mean age 32.6±9.5 years) of 79 patients who underwent sacroiliac MRI and constituted the patient group. Thirty-four patients (13 males, 21 females, age range 17-51, mean age 29.3 ± 7.3 years) with normal sacroiliac MRI findings constituted the control group (Table 1).

There were no statistically significant differences in terms of age and gender between the patient and control groups (p>0.05).

In the patient group, 11 patients exhibited right-sided sacroiliitis, 16 patients had left-sided sacroiliitis, and 18 patients had bilateral sacroiliitis. There was no significant association between the site of joint involvement and gender in the patient group (p>0.05).

The mean ADC value measured from the lesion areas in the patient group was 1202.4±268.2 mm²/s. In the control group, the mean ADC value was 423.9±71.9 mm²/s. There was a statistically significant difference in mean ADC values between the two groups (p<0.05).

The mean cerebrospinal fluid (CSF) ADC values in the patient and control groups were 2766.5±240.7 mm²/s and 2765.6±170 mm²/s, respectively. The CSF ADC values did not show a statistically significant difference between the two groups (p>0.05).

Table 1. Demographic Data of the Patient and Control Group

	Patient	Control	p
Male/Female(n)	20/25	13/21	0,580[a]
Age Range (years)	14-50	17-51	
Average Age(years)	32,6 ± 9,5	29,3 ± 7,3	0,091[b]

N: count
[a] Chi square test
[b] Independent t test

Relative ADC values were calculated for all individuals by dividing the mean ADC values by the CSF ADC values. In the patient and control groups, the relative ADC values were 0.434 and 0.153, respectively. There was a statistically significant difference in relative ADC values between the patient and control groups (p<0.05) (Table 2). In the analysis of the ROC curve for the relative ADC value, an area under the curve of 1 was observed, with a relative ADC threshold value of 0.224 to distinguish active sacroiliitis from the normal sacroiliac joint. The sensitivity and specificity for this threshold value were both 100%.

The ROC curve analysis for the mean ADC value showed an area under the curve of 1, with an ADC cut-off value of 646.12 mm²/s to differentiate active sacroiliitis from the normal sacroiliac joint. The sensitivity and specificity for this cut-off value were both 100%.

Table 2. Relative ADC values in the patient and control groups

	Patient	Control	p
Mean ADC	1202,4±268,2	423,9±71,9	<0,001[a]
CSF ADC	2766,5±240,7	2765,6±170	0,986[a]
Relative ADC	0,434	0,153	<0,001[a]

[a] Independent t test; ADC: Apparent Diffusion Coefficient; CSF: Cerebrospinal fluid

Descriptive statistics and a comparison of ADC values obtained from lesion and non-lesion areas based on the localization of sacroiliitis involvement are presented in Table 3. Upon examining the table, it was found that lesions were identified in the upper right sacrum region of 13 patients, with a mean ADC value of 1200.3 ± 306.8 mm²/sec (minimum 659, maximum 1697). Conversely, no lesions were observed in the right upper sacrum among 66 patients, and the mean ADC value in this group with a normal superior right sacrum was 400.7 ± 78.6 mm²/sec (minimum 212, maximum 554). A statistically significant difference was found between the ADC values of patients with and without lesions in the upper right sacrum region (p<0.05).

Among the patients, lesions were detected in the right iliac inferior region in 18 cases, with a mean ADC value of 1183.2 ± 229.8 mm²/sec (minimum 709, maximum 1594). Conversely, no lesions were found in the right iliac inferior among 61 patients. The mean ADC value in the group with a normal right iliac inferior was 413.5 ± 93.4 mm²/sec (minimum 199, maximum 609). A statistically significant difference was observed in the ADC values between patients with and without lesions in the right iliac inferior (p<0.05).

Table 3. Descriptive statistics and comparison of ADC values obtained from sites with and without lesions according to the localization of sacroiliitis involvement.

	Patient					Control				
	n	**Mean ADC**	**SD**	**Min**	**Max**	**n**	**Mean ADC**	**SD**	**Min**	**Max**
RS Superior	13	1200,3	306,8	659	1697	66	400,7	78,6	212	554
RS Inferior	14	1295.1	292,4	702	1826	65	434,8	87,4	246	584
RI Superior	9	1018,3	191,6	758	1411	70	407,8	88,8	196	644
RI Inferior	18	1183,2	229,8	709	1594	61	413,5	93,4	199	609
LS Superior	11	1232,8	239,8	877	1673	68	423,4	77,1	212	570
LS Inferior	18	1074,8	247,3	653	1505	61	433,1	81,2	256	596
LI Superior	8	1200,0	241,5	857	1482	71	421,2	75,3	237	592
LI Inferior	25	1230,5	228,5	740	1538	54	418,7	83,1	223	596

N: count, ADC: Apparent Diffusion Coefficient, RS: Right sacrum, RI: Right iliac, LS: Left sacrum, LI: Left iliac

Lesions were identified in the upper left sacrum region in 11 patients, showing a mean ADC value of 1232.8 ± 239.8 mm²/sec (minimum 877, maximum 1673) (Figure 1). Additionally, 68 patients had no lesions in the superior left sacrum. The mean ADC value in the group with a normal superior left sacrum was 423.4 ± 77.1 mm²/sec (minimum 212, maximum 570). A significant statistical distinction was observed in the ADC values between patients who exhibited superior left sacrum lesions and those without such lesions (p<0.05).

Among the patients, lesions were detected in the lower left sacrum region in 18 cases, with a mean ADC value of 1074.8 ± 247.3 mm²/sec (minimum 653, maximum 1505). Conversely, no lesions were found in the lower left sacrum among 61 patients. The mean ADC value in the group with a normal lower left sacrum was 433.1 ± 81.2 mm²/sec (minimum 256, maximum 596). A significant statistical distinction was observed in the ADC values between patients who exhibited lower left sacrum lesions and those without such lesions (p<0.05).

Lesions were detected in the left iliac superior region in 8 patients, with a mean ADC value of 1200.0 ± 241.5 mm²/sec (minimum 857, maximum 1482) (Figure 2). Conversely, no lesions were found in the left iliac superior among 71 patients. The mean ADC value in the group with a normal left iliac superior was 421.2 ± 75.3 mm²/sec (minimum 237, maximum 592).

A significant statistical distinction was observed in the ADC values between patients who exhibited superior left iliac lesions and those without such lesions ($p<0.05$).

Lesions were detected in the left iliac inferior region in 25 patients, showing a mean ADC value of 1230.5 ± 228.5 mm²/sec (minimum 740, maximum 1538). Conversely, no lesions were found in the left iliac inferior among 54 patients. The mean ADC value in the group with a normal left iliac inferior was 418.7 ± 83.1 mm²/sec (minimum 223, maximum 596). There was a statistically significant difference in the ADC values between patients with and without lesions in the left iliac inferior ($p<0.05$).

Discussion

Evaluation of patients with suspected sacroiliitis is extremely important in order to prevent delays and to make rapid diagnosis and treatment planning (8). History and physical examination have a limited role in the early diagnosis of sacroiliitis and highlight the need for reliable imaging modalities. MRI has long been used as the primary imaging technique for peripheral joints, but its use in assessments of the sacroiliac joint is a more recent development (9). MRI provides superior soft tissue contrast in evaluating ligament and synovium components in the sacroiliac joint (9,10). It also provides valuable information about changes in bone marrow, joint capsule, synovium and cartilage, as well as detecting common bone lesions such as erosion and sclerosis, these features are superior to other imaging methods (11).

Melchior et al. and Tasar et al. studies showed that MRI has similar diagnostic sensitivity to CT in the diagnosis of sacroiliitis. However, MRI outperforms other modalities by imaging sacroiliitis-related changes in the subchondral bone and periarticular bone marrow (12,13). In recent years, the use of fat suppressed sequences (such as STIR and T2AFS) in sacroiliac joint examinations has gained importance. These sequences increase oil-water contrast by suppressing oil signals, thereby increasing the sensitivity of detecting inflammatory changes (14).

According to a study carried out by Celikay et al., they measured the mean ADC values as 0.22±0.05 x 10^{-3} mm²/s and 1.06±0.22 x 10^{-3} mm²/s in normal and pathological vertebrae, respectively. In the conducted study, a statistically significant difference was identified between the mean ADC values observed in normal vertebrae and pathological vertebrae. Additionally, the researchers discovered that both ADC values and ADC ratios were significantly elevated in the group with spondylodiscitis and Modic type 1 degeneration when compared to the group with metastatic infiltration. Furthermore, they reported a statistically significant difference in both ADC rates and values when comparing the benign and malignant groups (15).

Overall, accurate and timely diagnosis of sacroiliitis is crucial and, in combination with techniques such as MRI, fat suppressed sequences and DWMRI, plays an important role in achieving this goal and assessing the extent of inflammatory changes (16). Gezmiş et al. conducted a study in which they measured ADC values in the sacroiliac joints (2). They found 0.23 × 10^{-3} mm²/sec ADC values on both surfaces of both sacroiliac joints in the control group. They observed a statistically significant increase in the mean ADC value (0.48 × 10^{-3} mm²/sec) due to medullary edema in the group of patients with early sacroiliitis, indicating an increased diffusion ($p<0.001$). They also identified a slight correlation between CRP levels and ADC values, suggesting an association between disease activity and active inflammation.

In a cohort comprising patients with active sacroiliitis (n=39) and individuals with low back pain (n=17). Significantly higher mean ADC and r-ADC ratio values were observed in the lesion areas compared to the normal-appearing bone marrow regions. This indicates that there is a notable increase in these values in the presence of the lesions, suggesting a potential association with active sacroiliitis (17). The study found that the r-ADC ratio, which takes into account the ADC of inflammatory lesions relative to the ADC of lumbar vertebra, was identified as a highly sensitive metric for detecting active sacroiliitis. This suggests that the r-ADC ratio has the potential to be a valuable tool in accurately identifying and diagnosing cases of active sacroiliitis. It has been proposed as an alternative approach to conventional ADC measures for assessing inflammation. To achieve more objective and predictive data, this study aimed to utilize the cerebrospinal fluid (CSF) ADC value and relative ADC value in the denominator, instead of using the ADC value of lumbar vertebra. Consistent with previous studies in the literature, The study demonstrated a substantial increase in both mean ADC and relative ADC values within the patient group in comparison to the control group.

Akdeniz et al. conducted a study to evaluate the diagnostic reliability of diffusion-weighted MRI (DWMRI) in patients suspected of having sacroiliitis (4). They discovered that the ADC value in the sacroiliitis group (n=42) was significantly elevated compared to both the group with low back pain (n=20) and the control group (n=20). However, the study did not identify a statistically significant difference in ADC values between the group with low back pain and the control group. This indicates that there was no significant discrepancy in ADC values between these two groups.

The higher ADC values observed in patients with active sacroiliitis can be attributed to increased water movement and local diffusion caused by bone marrow edema in the affected areas. This causes an increase in ADC values.

It is crucial to recognize and address the limitation of this study. This limitation includes the lack of a specific aetiological determination within the patient cohort. These factors should be taken into account when interpreting the results and generalising the findings.

In conclusion, Diffusion Weighted MRI (DWMRI) is a diagnostic imaging modality that exhibits comparable efficacy to conventional MRI sequences in diagnosing sacroiliitis. It

offers advantages such as fast uptake time and no need for contrast material, making it a viable alternative in routine practice. In addition, the study suggests that the use of relative ADC values may provide more objective results in the detection of sacroiliitis.

Ethical Approval: *. On June 4, 2013, the study protocol was submitted to the Ethics Committee of Harran University Faculty of Medicine for review and obtained approval under decision number 06 and session number 27.*

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