Added value of T2 Mapping of the Articular Cartilage to the routine MRI of the Sacroiliac Joint in Assessment of Patients with Axial Spondyloarthritis

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Abstract

Background: Diagnosing axial spondyloarthritis (Axial SpA) early is clinically difficult, with conventional MRI frequently missing subtle sacroiliac joint abnormalities.

Objectives: To assess the added value of T2 mapping of the sacroiliac joint cartilage to routine MRI in the evaluation of patients with axial SpA.

Patients and methods: This study was conducted on 30 axial SpA patients naive to biologic therapy, 16 male (53.3%)& 14 female (46.7%) and 30 healthy age- and sex-matched controls , 13 male (46.7%) & 17 female (53.3%) between February and May 2025. The mean age was 33.5 ± 8.7 years in the Axial SpA group and 30.1 ± 7.6 years in the control group; without notable difference ($p = 0.074$). MRI assessments were done using a 1.5 T GE scanner, including conventional sequences and T2 mapping. T2 relaxation times were quantitatively analyzed, and sacroiliitis was assessed using the SPARCC MRI index.

Results: Axial SpA patients had higher T2 values than controls (57.15 vs. 44.13 ms; $p < 0.001$). ROC analysis indicated strong diagnostic value (AUC = 0.973) with 93.3% sensitivity and 96.7% specificity at 48.72 ms. T2 values did not correlate with clinical or demographic variables.

Conclusion: T2 mapping provides a significant added value to routine MRI in differentiating axial SpA patients from healthy individuals by detecting early cartilage changes, even in the absence of clinical disease activity correlations.

Keywords: T2 mapping-MRI; SIJ; ASpa

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Introduction

Axial spondyloarthritis (Axial SpA) is chronic inflammatory condition of the sacroiliac joints and spine that can severely impact quality of life. Early and accurate disease assessment is vital to prevent irreversible structural damage **(Cao *et al.*, 2023)**. Although conventional MRI reliably detects bone marrow edema (BME), structural lesions, and synovitis, it may fail to identify early cartilage degeneration or subtle biochemical alterations **(Diekhoff et al., 2022)**.

T2 mapping is an advanced MRI technique that quantifies the relaxation time of protons within tissues. This technique provides detailed information on the biochemical composition of tissues, including cartilage **(Zimba et al., 2024)**. T2 mapping has shown promise in assessing cartilage degeneration and inflammation in various musculoskeletal disorders **(Kiil et al., 2022)**.

The limitations of conventional MRI in detecting early-stage cartilage changes in axSpA were reported **(Jurik et al., 2023)**. The complex anatomy of the sacroiliac joints , including the fibrocartilage and hyaline cartilage layers, poses additional challenges for accurate imaging interpretation. **(Drosos et al., 2023)**.

T2 mapping, with its sensitivity to cartilage structure and composition, may offer a potential solution to this problem **(Peuna et al., 2022)**. By quantifying the T2 values, this technique can highlight subtle changes in the cartilage that are not visible with routine MRI. According to several studies T2 mapping can identify early cartilage degenerative changes before obvious structural damage manifests. **(Bordner et al., 2023)**.

This study intended to investigate the potential benefits of adding T2 mapping to routine MRI in the assessment of the early cartilage changes of the sacroiliac joint in patients with axial spondyloarthritis

Patients and methods

A total of 30 axial SpA patients and 30 age- and sex-matched healthy controls were included in this prospective case-control study. All participants were referred to the MRI Unit of the Radiodiagnosis Department at Tanta University Hospitals during the period from February 2025 to May 2025. The study adhered to ethical standards, with approval from the institutional ethical committee (approval code : 36264PR1063/1/25) informed consent obtained from all participants, data anonymized, and any unexpected risks or adverse events communicated to both participants and the ethical committee.

Inclusion criteria

- Patients with confirmed diagnosis of axial SpA as determined by SpondyloArthritis International Society (ASAS) criteria **(Venerito et al., 2024)**.
- Disease onset before age 45 .
- No previously received biologic therapy.
- The Controls were asymptomatic adults aged 18 or older, without a history of back pain or trauma.

Exclusion criteria (for both the patient and control groups)

- History of other rheumatic or autoimmune diseases.
- Any prior spine or pelvic trauma or surgery.
- Refusal to participate in the study .
- Any contraindications to MRI such as the presence of metallic

implants, artificial cardiac pacemakers, ferromagnetic cerebral aneurysm clips, cochlear implants, or claustrophobia. **(Taha et al., 2024)**

All participants underwent a comprehensive medical history review and clinical examination. The medical history included personal details, such as name, age, sex, address, occupation, and contact information, as well as the onset, course, and duration of any presenting symptoms. A past medical history was obtained to document any previous spine or pelvic trauma, surgeries, and systemic illness such as hypertension or diabetes. Additionally, any previous radiological exams, were also reviewed. Clinical examination was performed by specialists from the Rheumatology, Rehabilitation, and Physical Medicine Departments. Disease activity was assessed using the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI)**(Wiąk-Walerowicz et al .,2024).**

For MRI imaging, all examinations were conducted using a 1.5 T GE MRI scanner (General Electric, USA). No specific preparation was required, though participants were asked to remove any metallic objects, such as keys or dental prostheses, before entering the magnetic field. The MRI protocol included the following sequences: coronal oblique T1 weighted (T1WI) images (repetition time/echo time, 492/10 ms) , axial T1 weighted (T1WI) images (450/13ms) , axial T2 weighted (T2WI) images (3879/95 ms) , coronal oblique T2WI (3500/96 ms), axial T2WI with fat suppression (3495/54 ms) , coronal T2WI with fat suppression (4170/55 ms) , slice thickness= 4 mm and slice gap =0.4 mm. axial T2 mapping by using multi-echo spin-echo with a TR of about 1000 and eight TEs (8ms, 16 ms, 24ms, 32 ms, 40ms, 48 ms, 55 ms and 63 ms) . slice thickness=3 mm; slice gap=1 mm. The acquisition time for T2 mapping was about 6 minutes.

The T2 mapping data were transferred to a workstation for qualitative and quantitative analysis. The analysis was conducted using GE software, which generated T2 relaxation maps with color coding applied in the range of 25 ms to 75 ms. The color scale ranged from red to blue .

Sacroiliitis was diagnosed when subchondral bone marrow edema ≥1 cm in depth appeared on two consecutive slices or in multiple areas on one slice. STIR images were evaluated using the SPARCC MRI index (max score: 72), based on presence of edema, its intensity, and depth .**(Maksymowych et al.,2005).**

Statistical analysis

Data were analyzed using IBM SPSS (25th edition). Qualitative data were presented as frequencies and percentages, while quantitative data were expressed as means, standard deviations, and ranges for parametric distributions, and medians with interquartile ranges (IQR) for non-parametric distributions. Analytic statistics included the Chi-square test for associations between qualitative variables, the unpaired Student's t-test for comparisons of quantitative data between two groups, the Mann-Whitney test for non-parametric comparisons, Spearman’s correlation for assessing relationships between quantitative variables, and the ROC curve for evaluating sensitivity and specificity of diagnostic measures.

Results

A total of 60 participants were involved in this study, 30 patients diagnosed with Axial SpA and 30 healthy control subjects. The sex distribution in the Axial SpA group was 53.3% male and 46.7% female, compared to 46.7% male and 53.3% female in controls without notable difference (p = 0.438). The mean age was 33.5 ± 8.7 years in the Axial SpA group and 30.1 ± 7.6 years in the control group; without notable difference (p = 0.074). as in **(Table.1).**

Table 1. Demographic characteristics among the two groups

Variables		Axial SpA (N=30)		Controls (N=30)		p- value
		N	%	N	%	
Sex:	**Male**	16	53.3%	13	43.3%	0.438‡
	Female	14	46.7%	17	56.7%	
Age (years):	**Mean ±SD** **Range**	34.20 ±9.12 19- 50		30.50 ±6.38 19- 46		0.074#

p>0.05 is non-significant; p≤0.05 is significant. #Student T test, ‡ Chi-square test,

Among Axial SpA patients, the median disease duration was 40 weeks (IQR: 18–72 weeks), indicating considerable variability. According to ASAS criteria classification 63.3% of patients were ASAS-negative and 36.7% were ASAS-positive. The SPARCC MRI index had a median value of 2.5 (IQR: 0–10), with scores ranging from 0 to 17. Regarding HLA-B27 status, 30.0% of patients tested positive, while 70.0% were negative **(Table. 2).**

Table (2): Clinical and diagnostic data among Axial SpA group

Variables		Axial SpA (N=30)	
		N	%
Disease duration (weeks)	**Median (IQR)** **Range**	13.5 (7- 33) 2- 150	
BASDAI:	**Mean ±SD** **Range**	5.12 ±1.38 1.4- 7.6	
ASAS:	**Negative**	19	63.3%
	Positive	11	36.7%
SPARCC MRI index:	**Median (IQR)** **Range**	2.5 (0- 10) 0- 17	
HLA-B27	**Negative**	21	70.0%
	Positive	9	30.0%

T2 mapping values were significantly elevated in the Axial SpA group compared to controls. The median T2 value in the Axial SpA group was 57.15 ms (IQR: 52.58–59.12; range: 49.06–67.04), while the control group demonstrated a median of 44.13 ms (IQR: 42.17–46.01; range: 39.05–50.16) (p < 0.001) **(Table.3, Fig. 1,3).**

Table 3. Mean T2 values among the two groups

Variables		Axial SpA (N=30)		Controls (N=30)		p-value
		N	%	N	%	
Mean T2 values (ms)	**Median (IQR) Range**	**57.15 (52.58-59.12) 49.06- 67.04**		**44.13 (42.17-46.01) 39.05- 50.16**		**<0.001***

p>0.05 is non-significant; p≤0.05 is significant. *Mann-Whitney U test

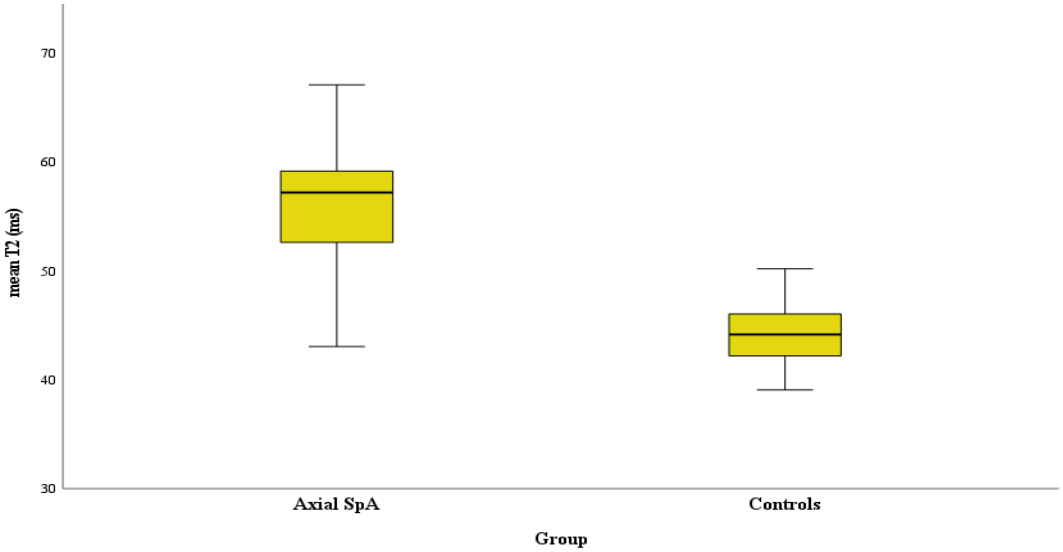

Fig.1. Comparison between the two groups regarding mean T2 values.

No notable correlations were found between T2 values and clinical or demographic variables. Specifically, there was no significant association between mean T2 values and age (r = –0.12, p = 0.312), BASDAI scores (r = 0.07, p = 0.491), or the SPARCC MRI index (r = 0.09, p = 0.418) **(Table.4).**

Table 4. Spearman's correlation between mean T2 values with different numeric parameters

Variables	Mean T2 values	
	Spearman's rho	P-value
Age	**0.171**	**0.193**
Disease duration in months	**-0.336**	**0.069**
BASDAI	**0.200**	**0.288**
SPARCC MRI index	**-0.293**	**0.116**

p>0.05 is non-significant; p≤0.05 is significant.

Analysis of categorical subgroups showed no notable differences in T2 values based on sex (p = 0.433). T2 values also did not differ significantly between HLA-B27-positive (median: 57.15 ms; IQR: 53.44–57.87) and HLA-B27-negative patients (median: 57.15 ms; IQR: 52.58–59.12) (p = 0.894). Similarly, there were no notable differences in T2 values between

ASAS-positive (median: 57.15 ms; IQR: 52.58–59.03) and ASAS-negative (median: 57.15 ms; IQR: 52.58–59.40) patients (p = 0.830) **(Table.5).**

Table 5. Relation between mean T2 values with different categorical parameters

Variables		Mean T2 values (ms)					P-value
		Median	IQR		Range		
Sex	**Male**	51.16	44.09	57.87	41.03	64.19	0.433
	Female	47.16	43.68	54.35	39.05	67.04	
ASAS	**Negative**	57.15	52.58	59.40	47.87	67.04	0.830
	Positive	57.15	52.58	59.03	43.03	64.19	
HLA-B27	**Negative**	57.15	52.58	59.12	43.03	67.04	0.894
	Positive	57.15	53.44	57.87	51.16	64.19	

p>0.05 is non-significant; p≤0.05 is significant. *Mann-Whitney U test

Receiver Operating Characteristic (ROC) curve analysis demonstrated excellent diagnostic performance for T2 mapping in differentiating Axial SpA patients from controls. Using a mean T2 cutoff value of 48.72 ms, T2 mapping achieved a sensitivity of 93.3% and a specificity of 96.7%. The area under the curve (AUC) was 0.973 (p < 0.001), indicating excellent discriminatory ability **(Table. 6, Fig. 2).**

Table 6. Diagnostic Value of T2 Mapping in Routine MRI for Sacroiliac Joint Evaluation in Axial Spondyloarthritis

Variables	Best cut off	Sensitivity	Specificity	PPV	NPV	AUC	P-value
T2 values	**48.72**	**93.3%**	**96.7%**	**96.6%**	**93.5%**	**0.973**	**<0.001**

AUC: Area Under a Curve; p value: Probability value; NPV: Negative predictive value ; PPV: Positive predictive value ; *: Statistically significant at p ≤ 0.05

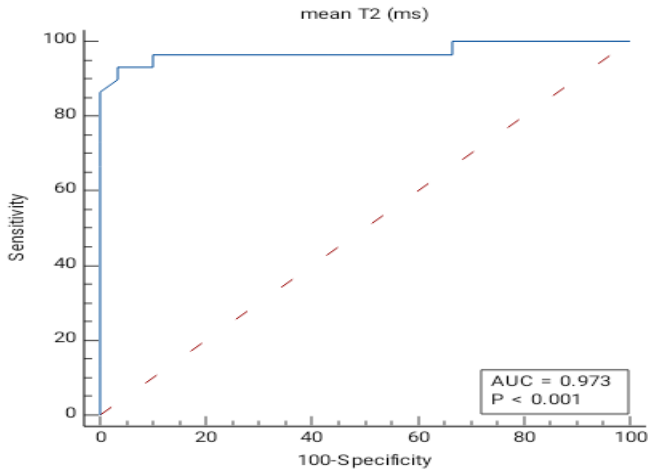

Fig.2. ROC curve of mean T2 values evaluation of sacroiliac joint in patients diagnosed with axial spondyloarthritis (SpA).

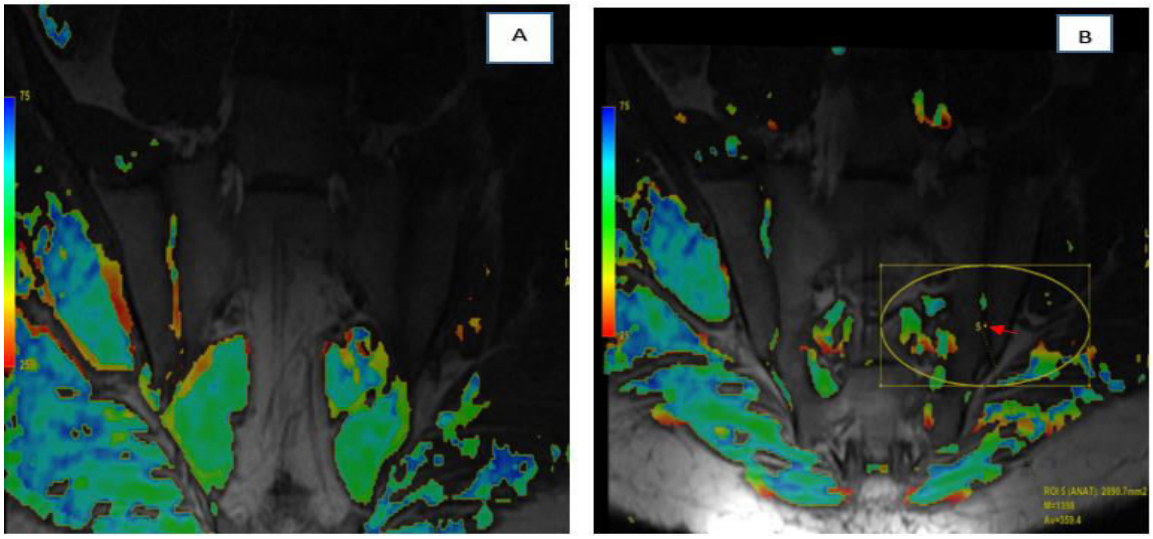

Fig.3. Male patient age 28 years old , not suffering from any medical condition (control patient): Two consecutive images with the color map on the right sacrolilac joint (A), towards the red color mainly , B) measurement of the T2 value on the left side ,the red arrow points at the small yellow dot (ROI) that measured the T2 value of the articular cartilage in the left sacroiliac joint =35.9ms.

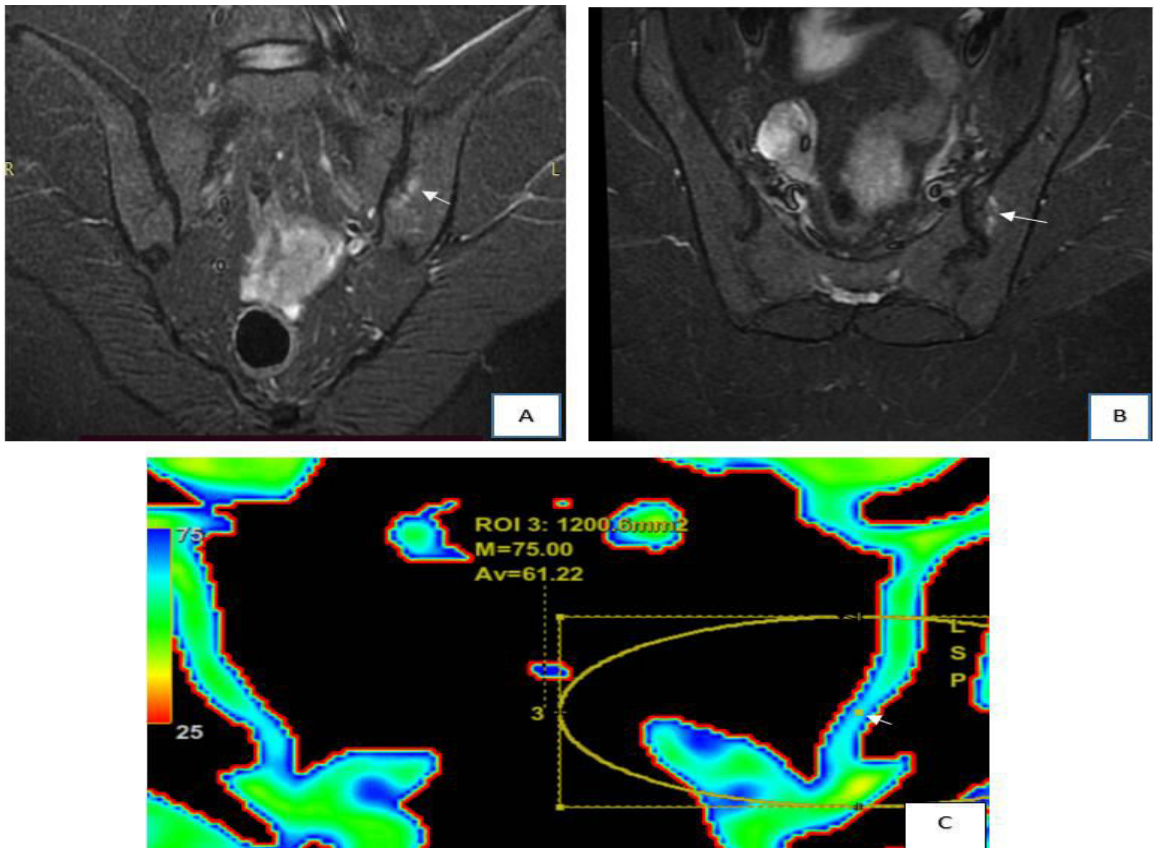

Fig.4. Male patient aged 38 years recently diagnosed with ankylosing spondylitis and did not receive any medical treatment A,) coronal , B) axial STIR

images , show focal subchondral edema at the anterior aspect of the left sacroiliac joint (white arrows) , C) the post processing T2 mapping images increased T2 value (at the area corresponding to the focal edema) =61.22 ms ,white arrow points at the ROI (the yellow dot).

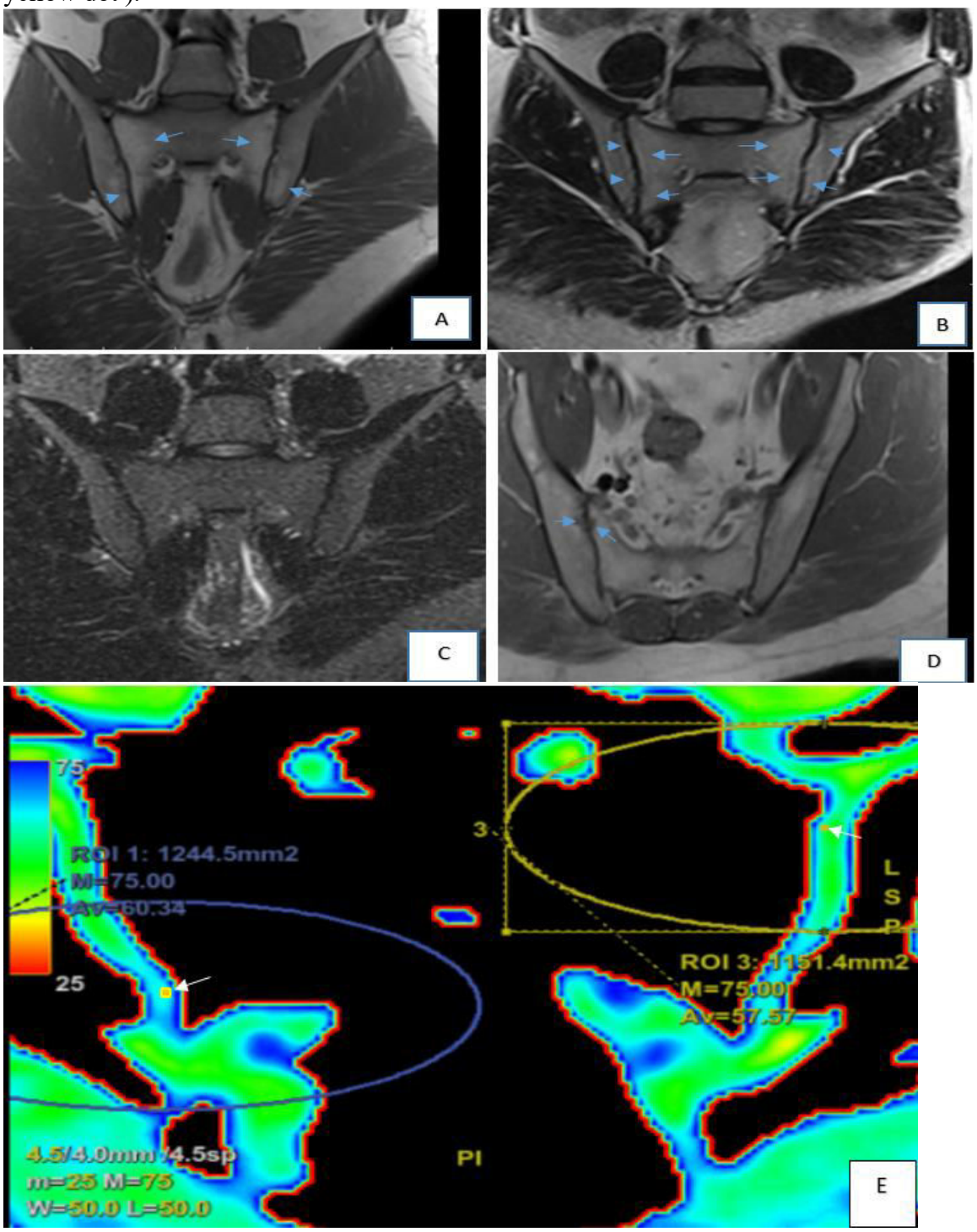

Fig.5. Male patient suffering form ankylosing spondylitis diagnosed since 1 year ago ,A)coronal T1WI , B) coronal T2WI , c) coronal STIR images revealed :

abnormal subchondral signal high in T1 (blue arrows) , with signal loss in fat suppressed image (c image) at both sacral and iliac sides denoting fatty metaplasia ,D) axial T1WI showed also subchondral fatty metaplasia and erosions on the right side (blue arrows),E) post processing T2 mapping images showed T2 values =60.3 & 57.57 ms measured at different point on both sacroiliac joints (white arrows on both sides and yellow dots mark the site of the ROI).

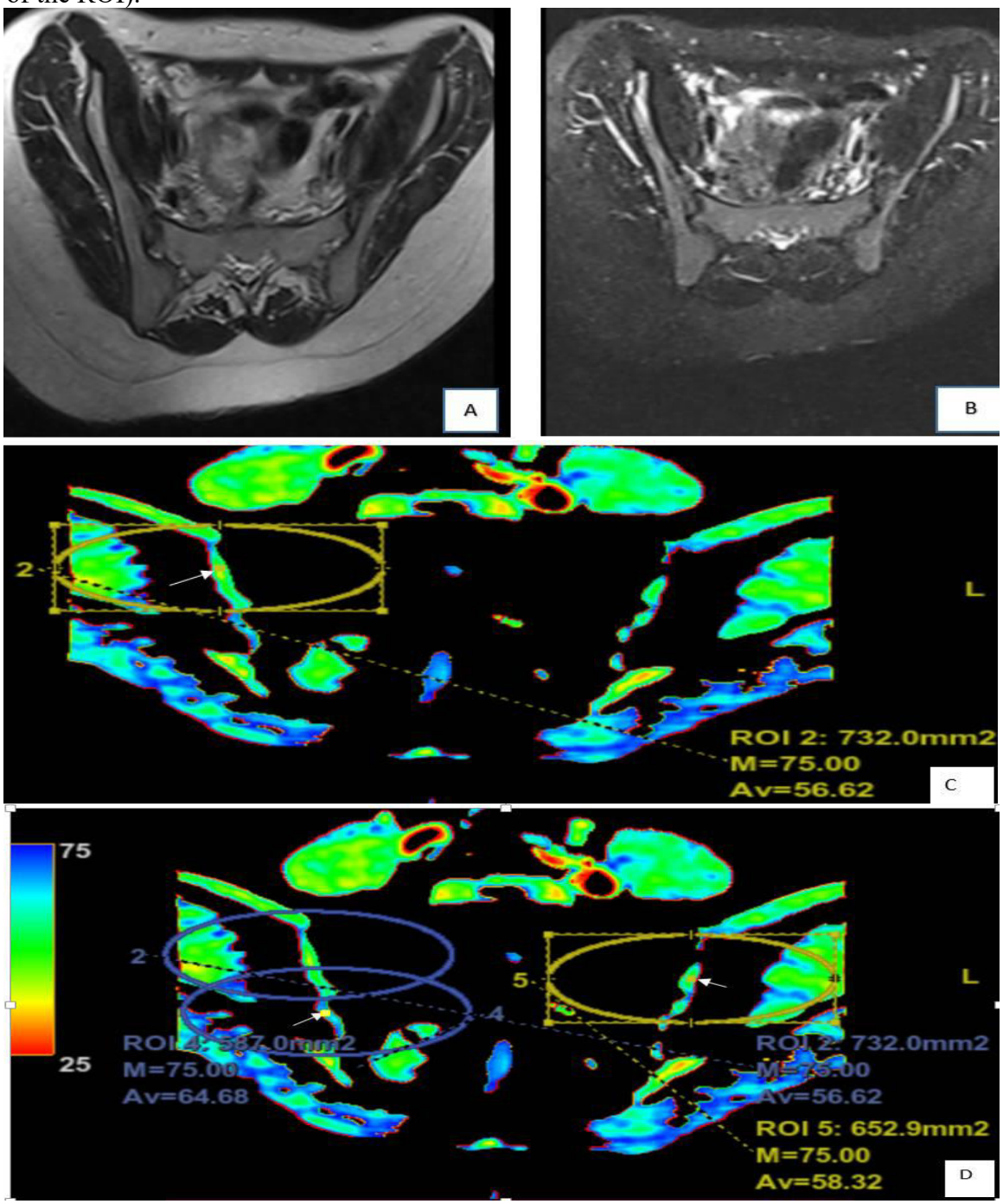

Fig .6. A)axial T2WI ,B) axial STIR in newly diagnosed case with still no structural changes detected on MRI (normal) . Post processing T2 mapping images (C &

D) showed increased T2 values =56.62 , 64.68 ms (on the right side) and 58.32 ms on the left side measured at different point on both sacroiliac joints (as marked by white arrows that points at the ROIs (yellow dots) .

Discussion

In this study, we assessed the added value of incorporating T2 mapping into the routine MR imaging protocols for evaluation of early cartilage changes in patients diagnosed with axial spondyloarthritis.

The primary finding of our study was the significantly higher mean T2 values in the Axial SpA group compared to the controls, with a median T2 value of 57.15 ms in the Axial SpA group versus 44.13 ms in the controls. Based on this significant difference, T2 mapping might be useful for distinguishing patients with Axial SpA from healthy controls, highlighting its potential use as a biomarker for assessing joint pathology in this patient group.

Our findings are in close agreement with those of **Albano et al. (2020)**, who similarly reported significantly higher mean T2 values among Axial SpA patients (58.5 ± 4.4 ms) compared to healthy individuals (44.1 ± 6.6 ms, $p < 0.001$).

Further supporting evidence is provided by **Kasar et al. (2022)**, who evaluated early biochemical alterations in the SIJ cartilage and subchondral bone using T2 mapping techniques. Even when there was no overt BME on traditional STIR or T2-weighted sequences, they showed that T2 values were much higher in Axial SpA patients. Thus, T2 mapping may detect subtle, early changes in tissue composition, such as increased water content, proteoglycan depletion, or collagen disorganization, before structural changes become apparent.

These findings also align with a study by **Abou Khadrah and Reda (2020)**, who also observed significantly higher T2 values in patients with osteoarthritis (OA) in the shoulder joint compared to controls. In their study, the median T2 values in the controls were 43.4 ms, while the OA group had median values of 59.2 ms for primary OA patients and 64.7 ms for secondary OA patients. The mean T2 values for the controls in their study were reported as 45.8 ± 8 ms in humeral cartilage, 45.2 ± 6.5 ms in the mid-zone, and 43.9 ± 7.1 ms in the glenoid cartilage. These values are in line with our findings and further reinforce the role of T2 mapping as a sensitive biomarker for joint degeneration. The elevated T2 values observed in OA patients reflect the cartilage degeneration and increased water content in the affected joint cartilage, a pattern that is consistent with the findings in both Axial SpA and OA studies.

Welsch et al. (2014), reported similar findings in patients with OA and inflammatory joint diseases, including Axial SpA. In their study of 120 patients with various types of arthritis, they found T2 values ranging from 50–60 ms for affected joints. In particular, the T2 values of sacroiliac joints in patients with inflammatory conditions were reported to range from 52–56 ms, which is consistent with the values observed in this study.

Additionally, **Guermazi et al. (2015)** demonstrated elevated T2 values in cases with joint spondyloarthritis, particularly in areas of cartilage with more pronounced degeneration. In their

study, OA patients exhibited T2 values ranging from 45–65 ms, depending on the grade of degeneration. This further supports our findings, suggesting that T2 values are elevated in diseased joints and offering more proof that the use of T2 mapping as a sensitive marker of joint pathology in inflammatory and degenerative conditions.

In our study, no notable correlations were found between T2 mapping values and major clinical or demographic variables. Specifically, mean T2 values did not significantly correlate with age, BASDAI scores, or the SPARCC MRI index. Similarly, subgroup analyses showed that T2 values were independent of sex, HLA-B27 status, and ASAS classification positivity.

These findings are consistent with **Weddell et al. (2024)**, who stated that MRI-detected inflammation in Axial SpA patients often influence the clinical decision-making independent of subjective disease activity scores like BASDAI. Similarly, they observed that nearly 57.8% of MRIs showed non-inflammatory pathologies unrelated to Axial SpA, further complicating the relationship between imaging findings and clinical metrics.

In the same line, **Albano et al. (2020)** found no correlation between T2 values and BASDAI scores ($r = –0.026$, $p = 0.827$), SPARCC scores ($r = –0.004$, $p = 0.981$), disease duration, or HLA-B27 status.

Furthermore, **Nardo et al. (2016)** examined the correlation between T2 values and disease activity markers such as BASDAI and CRP in patients with knee OA. Similar to our findings, they observed no significant correlation between T2 values and these markers, providing more evidence that T2 mapping primarily reflects cartilage structural changes rather than the degree of inflammation or disease severity. Their study reported T2 values ranging from 55–60 ms in moderate OA, which is consistent with the elevated T2 values observed in our study.

There is also an increasing interest in finding the correlation between HLA-B27 and T2 mapping values in the sacroiliac joint (SIJ). While some research indicates that there is no statistically significant relationship between T2 values and HLA-B27 status alone, as our study did, but according to a study by **Huang et al.(2025) ,** that involved 83 axSpA patients and 37 controls , T2 values were linked to disease activity and structural damage, which were frequently more noticeable in people who were HLA-B27 positive.

In line with our results, **Welsch et al. (2014)** and **Guermazi et al. (2015)** also reported weak correlations between T2 values and clinical disease markers. Their findings reinforce the concept that T2 mapping is particularly sensitive to structural cartilage changes, but may not always correlate with clinical markers of disease activity or severity.

Our results were also consistent with Zhang et al. (2024) in terms of independence from HLA-B27 status. They demonstrated that, even though HLA-B27 positivity was a powerful predictor when paired with MRI lesion characteristics for machine learning models, imaging features by themselves were still predictive of Axial SpA when HLA-B27 positivity was absent.

In a study conducted by **Kasar et al. (2022)**, highlighted that T2 values elevation correlated moderately with SPARCC scores, while in our results, no significant correlation was found

between T2 values and SPARCC or BASDAI scores

In contrast to the lack of significant correlations with clinical/demographic factors, our ROC analysis revealed outstanding diagnostic performance for T2 mapping. Using a cutoff value of 48.72 ms, T2 mapping achieved a sensitivity of 93.3%, specificity of 96.7%, and an AUC of 0.973 ($p < 0.001$). This in same line with **Albano et al. (2020)** study who reported that a T2 cutoff value of 52.51 ms achieved 100% sensitivity and 91.7% specificity for differentiating patients from controls.

Our AUC of 0.973 demonstrated the superior diagnostic potential of T2 mapping, especially that it is a non-radiative MRI technique, making it safer for repeated use in younger patient cohorts or in disease surveillance .

Limitations : Our study had several limitations including small sample size of the patients and control groups , its brief duration and the there is still no universally accepted T2 relaxation time cutoff value for diagnosing sacroiliitis or cartilage degeneration.

Conclusion

T2 mapping of the sacroiliac joint cartilage, which shows early structural changes not picked up by conventional MRI, helps differentiate patients with axial spondyloarthritis from healthy controls. Larger longitudinal studies are required to evaluate the relationship between T2 mapping values and disease activity markers, as well as the relationship between T2 values and response to treatment. The high sensitivity and specificity suggest that T2 mapping may be a useful imaging biomarker for enhancing the diagnostic assessment in Axial SpA.

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