

Magnetic Resonance Imaging of the Sacroiliac Joints in Patients with Suspected Spondyloarthritis – Comparison of Turbo Spin-Echo and Gradient-Echo Sequences for the Detection of Structural Alterations

MRT-Bildgebung der Sakroiliakalgelenke bei Verdacht auf Spondyloarthritis – Vergleich von Turbospinecho- und Gradientenechosequenzen zum Nachweis struktureller Veränderungen

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Key words

- spondyloarthritis (SpA)
- sacroiliac joints (SIJ)
- magnetic resonance imaging (MRI)

Abstract



Purpose: Magnetic resonance imaging (MRI) is the method of choice for the evaluation of spondyloarthritis (SpA). According to the guidelines of the Assessment of Spondyloarthritis International Society (ASAS) and Outcome Measures in Rheumatology (OMERACT), MRI findings in SpA of the spine and the sacroiliac joints (SIJ) are classified as inflammatory and structural alterations. Modern gradient-echo sequences (GRE) are recommended for optimized detection of structural alterations of the SIJ. We assess the benefit of GRE in the detection of structural alterations of the SIJ in comparison to conventional turbo spin-echo sequences (TSE).

Material and Methods: Retrospective study of 114 patients who received MRI of the SIJ for the evaluation of SpA. Structural alterations of the SIJ were assessed by two blinded readers separately for T1 TSE and T2* GRE. The findings were classified according to a previously published chronicity score separately for both sides and sequences. Interobserver reliability was calculated with Cohen's Kappa, and the significance of findings was assessed with the Wilcoxon test. P-values <0.05 were required for statistical significance.

Results: 68 of 114 (60%) patients showed SpA-typical findings of the SIJ. The average chronicity score for GRE (score 3.3) was significantly higher than for TSE (score 2.6), $p=0.001$. The Kappa-values for the interobserver reliability were 0.86–0.90 without any statistically significant differences between both sides and sequences.

Conclusion: Both T1 TSE and T2* GRE showed a high interobserver reliability in the detection of structural alterations in patients with SpA. However, T2* GRE detected significantly more structural alterations than T1 TSE and

should be an integral part of a modern MRI protocol for the diagnostic workup of patients with suspected SpA.

Key points:

- ▶ T2* gradient-echo sequences are superior to T1 turbo spin-echo sequences in the detection of structural SI-joint alterations.

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Zusammenfassung



Hintergrund: Die Magnetresonanztomografie (MRT) ist das bildgebende Verfahren der Wahl zur Diagnose der Spondyloarthritis (SpA). Gemäß Empfehlungen der Assessment of Spondyloarthritis International Society (ASAS) und Outcome Measures in Rheumatology (OMERACT) werden die bei SpA zu beobachtenden MRT-Befunde in entzündliche und strukturelle Veränderungen unterteilt. Die Einteilung gilt für die Wirbelsäule und die Sakroiliakalgelenke (SIG). Zum Nachweis struktureller Veränderungen der SIG wie Erosionen und Knochenneubildungen empfiehlt die ASAS den Einsatz moderner Gradientenechosequenzen (GRE).

Ziel: Vergleich von konventionellen Turbospinechosequenzen (TSE) und modernen GRE-Sequenzen hinsichtlich der Nachweismöglichkeit struktureller Veränderungen der SIG bei Patienten mit Verdacht auf SpA.

Methodik: Retrospektive Studie an 114 Patienten mit MRT der SIG bei Verdacht auf SpA. Die MRT wurden verblindet von zwei Radiologen getrennt hinsichtlich struktureller Veränderungen ausge-

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wertet. In einer ersten Auswertung wurde nur eine axiale T1 TSE-Sequenz beurteilt, in einer zweiten Auswertung nur eine axiale T2* GRE-Sequenz. Die SIG wurden entsprechend eines Chronizitätscores getrennt für rechts und links von 0–4 klassifiziert und ein Summenscore gebildet (Maximalwert 8). Die Interobserverreliabilität wurde nach Cohens Kappa ermittelt, die Signifikanz der Unterschiede der Summenscores mit dem Wilcoxon-Test berechnet. P-Werte <0,05 wurden als signifikant gewertet.

Ergebnisse: 68 von 114 (60%) Patienten zeigten in der MRT der SIG SpA-typische Befunde. Der durchschnittliche Summenscore für die strukturellen Veränderungen der SIG war für die GRE-Sequenzen (Score 3,3) signifikant höher als für die TSE-Sequenzen (Score 2,6), $p=0,001$. Die Übereinstimmungsgrade der Scores zwischen den beiden Auswertern betragen 93–95%, die Kappa-Werte betragen 0,86–0,90 ohne signifikanten Unterschied zwischen beiden Seiten und Sequenzen.

Schlussfolgerung: T1 TSE- und T2* GRE-Sequenzen weisen in der Beurteilung struktureller SIG-Veränderungen eine hohe Interobserverreliabilität auf. Mit der verwendeten T2* GRE-Sequenz lassen sich signifikant mehr strukturelle Veränderungen der SIG nachweisen als mit der T1 TSE-Sequenz. T2* GRE-Sequenzen sollten fester Bestandteil eines modernen Untersuchungsprotokolls der SIG bei Verdacht auf SpA sein.

Introduction

Spondyloarthritis (SpA) represents a heterogeneous group of chronic inflammatory diseases whose individual entities have numerous clinical, genetic, and immunological commonalities [1]. Ankylosing spondylitis (AS) is the most common type of SpA. Psoriatic arthritis (PsA), reactive SpA and SpA as part of a chronic inflammatory intestinal disease are further types. Involvement of the axial skeleton, in particular the sacroiliac joints, is characteristic but not obligatory for SpA [2]. Magnetic resonance imaging (MRI) has become established as the imaging method of choice for the diagnosis and monitoring of SpA [3]. Since changes in the axial skeleton visible on conventional radiological images are no longer required by the new classification criteria for the diagnosis of SpA, MRI plays an important role particularly in early diagnosis [4]. The strength of the method is the highly sensitive detection of acute inflammatory processes with high-resolution visualization of anatomical and chronic structural changes. A further advantage of MRI is the lack of radiation exposure since SpA typically clinically manifests in young adults and is increasingly used to monitor the course of the disease [5].

According to the guidelines of the Assessment of Spondyloarthritis International Society (ASAS) and the Outcome Measures in Rheumatology (OMERACT), the MRI-morphological changes observed in SpA are categorized as acute inflammatory and chronic structural changes [6]. This categorization applies to both the spine and the sacroiliac joints. The ASAS references the optional use of gradient echo sequences (GRE) in addition to turbo spin echo sequences (TSE) for the sacroiliac joints to potentially optimize the detection of structural lesions [6]. In addition to periarticular sclerosis and fat accumulations, intraarticular lesions such as erosions, bone bridges, and ankylosis, are characteristic, chronic structural sacroiliac joint changes accepted by the ASAS. However, a gain in diagnostic informa-

tion from GRE sequences compared to TSE sequences for these changes has only been scientifically proven by one publication [7]. The goal of this study is therefore to compare TSE and GRE sequences with respect to the ability to detect structural changes in the sacroiliac joints in patients with suspicion of SpA.

Method

The findings for 114 patients who underwent MRI of the sacroiliac joints in the case of suspicion of SpA in the period from 2/2012 to 12/2012 were analyzed in a retrospective study. All patients were examined with the following standardized examination protocol on a 1.5 T MRI unit (Philips Ingenia, Amsterdam, Netherlands):

1. Coronal: Short Tau Inversion Recovery sequence (STIR)
TR 2857s; TE 40s; matrix 400 × 400; acquisition time 4:05 min.; FoV RL: 250 mm, FH: 83 mm, AP: 250 mm; pixel size (reconstructed) 0.71 × 0.71 × 4.0 mm; bandwidth 297.8 Hz
2. Coronal: Contrast-enhanced fat-saturated T1-weighted turbo spin echo sequence (T1 TSE fs contrast agent)
TR 532s; TE 8s; matrix 400 × 400; acquisition time 3:40 AM min.; FoV RL: 200 mm, FH: 200 mm, AP: 105 mm; pixel size (reconstructed) 0.50 × 0.50 × 4.0 mm; bandwidth 201.6 Hz
3. Axial: Unenhanced T1-weighted turbo spin echo sequence (T1 TSE)
TR 683s; TE 10s; matrix 432 × 434; acquisition time 3:46 AM min.; FoV RL: 200 mm, FH: 105 mm, AP: 200 mm; pixel size (reconstructed) 0.46 × 0.46 × 4.0 mm; bandwidth 260.4 Hz
4. Axial: Unenhanced T2*-weighted steady state gradient echo sequence (T2* GRE)
TR 671s; TE 9s; matrix 384 × 384; flip angle 35°; acquisition time 4:33 min.; FoV RL: 200 mm, FH: 105 mm, AP: 200 mm; pixel size (reconstructed) 0.52 × 0.52 × 4.0 mm; bandwidth 359.4 Hz

The coronal plane was parallel to the longitudinal axis of the sacroiliac joints and the axial plane was perpendicular to the longitudinal axis. All sequences were acquired with a slice thickness of 4 mm. The examinations were performed in a supine position using a digital surface coil with 32 coil elements with an integrated analog-digital converter. Gadoteric acid (Dotarem, Guerbet GmbH, Sulzbach/Taunus, Germany) in a dose of 0.1 ml/kg body weight was applied intravenously as the contrast agent. Injection was performed with a high-pressure injector (Medtronic AG, Saarbrücken, Germany) with a flow rate of 1 ml/s followed by a bolus injection of 20 ml of a physiological saline solution.

In the retrospective analysis, the MRI examinations were evaluated with respect to structural changes separately by two blinded radiologists on a digital workstation with two high-resolution monitors (Barco GmbH, Karlsruhe, Germany). Both evaluators had substantial rheumatological MRI experience.

Only the axial T1-TSE sequence was evaluated in the first analysis (◉ Fig. 1a), and only the axial T2* GRE sequence was then evaluated in a second analysis 4 weeks later (◉ Fig. 1b). The MRI findings for the sacroiliac joints were given a score between 0 and 4 according to the chronicity score of Her-

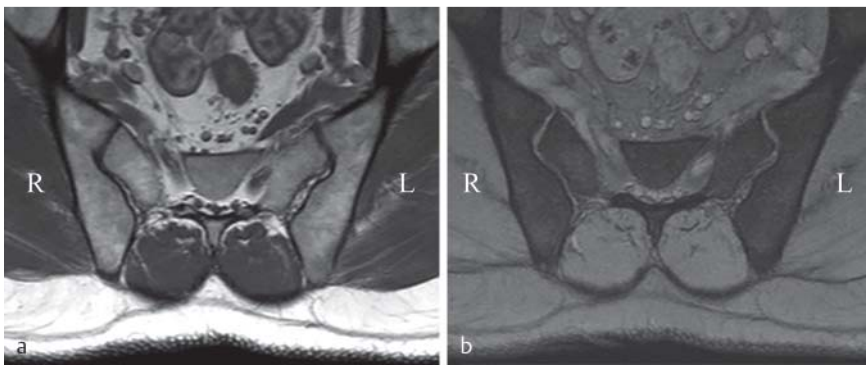


Fig. 1 Normal finding of sacroiliac joints. **a** axial T1 TSE sequence. **b** axial T2* GRE sequence.

Table 1 Grading of chronic sacroiliac joint changes (chronicity score) according to Hermann et al. [8].

grade	morphological features
0	no chronic inflammatory joint changes
1	mild subchondral sclerosis with smooth joint contours normal joint cavity width maximum of 2 erosions per layer
2	moderate subchondral sclerosis more than 2 erosions per layer without confluence normal joint cavity width
3	significant periarticular sclerosis confluent erosions with pseudodilation of the joint cavity transarticular bone bridges
4	ankylosis of the joint cavity > 1/4 of the joint cavity

Table 2 Grading of inflammatory sacroiliac joint changes (activity score) according to Hermann et al. [8].

grade	morphological features
0	no pathological signal increase
1	signal increase $\geq 10\%$ of the quadrant surface
2	signal increase 11 – 33 % of the quadrant surface
3	signal increase 34 – 66 % of the quadrant surface
4	signal increase > 66 % of the quadrant surface

mann et al. [8] separately for the right and left side (Table 1) and a total score was calculated (maximum value 8). The interobserver reliability of the chronicity scores was determined according to Cohen's Kappa and the significance of the differences of the total scores was determined with the Wilcoxon test. P-values of less than 0.05 were considered significant. The statistics program WinSTAT for Microsoft Excel (R. Fitch Software, Bad Krozingen, Germany) was used. A consensus evaluation of the entire MRI protocol was then performed by both evaluators. Inflammatory lesions were classified according to the activity score of Hermann et al. [8] (Table 2, Fig. 2) and it was determined whether a characteristic SpA manifestation of the sacroiliac joints was present. The HLA-B27 status, CRP value, and the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI) of all patients were determined to evaluate the disease activity at the time of MRI examination. For this purpose patients rated their pain, fatigue, and morning stiffness on a scale of 0–10 in six individual evaluations. The index value is the arithmetic mean of the six individual values and the maximum value is thus 10.

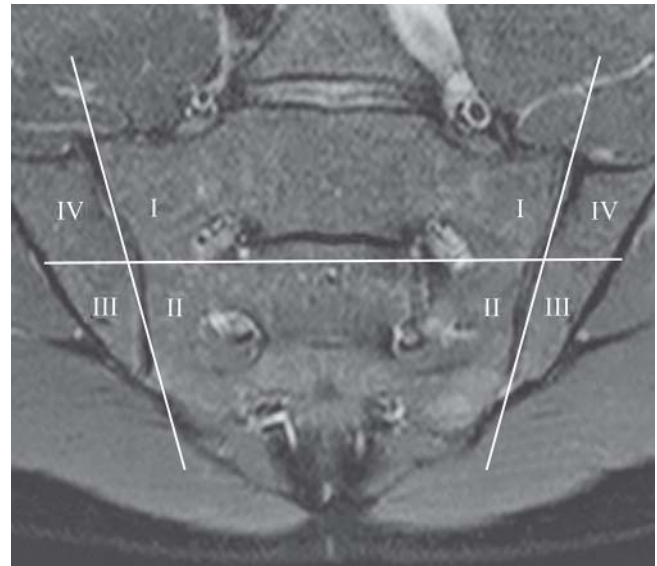


Fig. 2 Division of the sacroiliac joints into four quadrants according to Hermann et al. [8].

Results

114 patients (66 (58%) female and 48 (42%) male) were evaluated. The median age was 43 years (range: 20–82 years), and 70 patients (61.4%) were HLA-B27 positive. The average CRP value of the collective was 6.83 mg/l (minimum 0.11; maximum 52.3; median 3.3; SA 10.7; 95% CI 5.0–9.2), and the average BASDAI was 3.9 (median 4.2; SA 2.6; 95% CI 3.4–4.4). The patients had the following diseases: 27 (23.7%) ankylosing spondylitis (AS), 24 (21.0%) psoriatic arthritis (PsA), 14 (12.3%) undifferentiated SpA, 5 (4.4%), enteropathic SpA and 2 (1.8%) polymyalgia rheumatica (PMR). 42 patients (36.8%) did not have a rheumatological disease. The degree of agreement of the scores for chronic sacroiliac joint changes was 93–95% between the two evaluators, and the Kappa values were 0.86–0.90 without a significant difference between the two sides and sequences. The average total score for the sacroiliac joints of 3.1 for the GRE sequences (median 2; SA 1.9; 95% CI 2.7–3.4) was significantly higher ($p=0.01$) than the score of 2.4 for the TSE sequences (median 2; SA 1.5; 95% CI 2.1–2.7). All scores for the GRE sequences were either equal to or higher than the scores for the corresponding TSE sequences (Table 3, Fig. 3, 4).

Verified SpA was present in 70 patients. Of these cases, inflammatory and/or structural SpA-typical changes of the sacroiliac joints were detected in 68 cases. The total score for the chronic sacroiliac joint findings for TSE was 2.6 (median 2; SA 1.5; 95% CI 2.2 – 2.7) compared to 3.3 (median 4; SA 1.8; 95% CI 2.9 – 3.7) for GRE ($p=0.001$). The average activity score for these 68 positive sacroiliac joint examinations was 2.3 (median 0; SA 4.1; 95% CI 1.3 – 3.3) (Table 4). Of the 68 cases with verified sacroiliitis, 42 patients (62%) only had chronic changes and 4 patients (6%) only had inflammatory changes. In total, 58 patients (83%) were HLA-B27 positive in the group with confirmed SpA. The average CRP value was 9.93 mg/l (median 4.0; SA 11.8; 95% CI 7.1 – 12.8), and the average BASDAI was 4.34 (median 4.6; SA 3.0; 95% CI 3.8 – 5.0).

Discussion

Enthesitis is the characteristic inflammatory manifestation of spondyloarthritis. The sacroiliac joints are the largest entheses of the human body. Their morphological changes have therefore been particularly well described and documented. Typical X-ray signs clearly reflect the pathophysiological processes of enthesitis. Dihlmann used the conventional radiological term "colorful picture" for the sacroiliac joints based on the simultaneous occurrence of osteodes-

tructive and osteoproliferative processes [9]. This aspect was taken into account in 1984 in the modified New York criteria in that a grading system from 0 – 4 was formulated for projection radiography. While these chronic structural findings can be effectively visualized with a suitable acquisition technique in conventional radiography because of the high spatial resolution, acute inflammatory changes of the entheses cannot be visualized with conventional radiography. Inflammatory lesions can only be reliably detected by MRI, making it particularly important for early diagnosis [4]. Periarticular subchondral osteitis and an edema-equivalent bone marrow signal are important morphological features of acute sacroiliitis. These features provide positive verification of sacroiliitis in accordance with current modified classification criteria [6]. Fat-saturated T2-weighted sequences and contrast-enhanced T1-weighted sequences visualize inflammatory SpA-typical changes of the axial skeleton with the same reliability making the use of contrast agent seem unnecessary [10, 11].

The ASAS encourages the use of unenhanced T1-weighted and optionally also T2*-weighted GRE sequences for imaging structural changes. GRE sequences provide high-contrast visualization of the joint cavity due to the signal-intensive cartilage imaging. Erosions and transarticular bone bridges may consequently be able to be better visualized (Fig. 3, 4). To our knowledge, the diagnostic benefit of GRE sequences in the diagnosis of sacroiliac joints in patients with suspected SpA with respect to these structural changes has only been scientifically examined in one study [7]. The composition of our patient collective regarding age, gender distribution, and HLA-B27 status is comparable with other SpA studies [10 – 12].

Our results show significantly better visualization of erosions and ankylosis by GRE imaging. In the recently published study by Krohn et al., more erosions could be detected with GRE sequences than with TSE sequences. However, the authors do not make any statements regarding the level

Table 3 Chronicity score of the sacroiliac joints of 114 patients.

MRI sequence	T1 TSE		T2* GRE	
	R	L	R	L
individual score (± SD)	1.1 (± 0.7)	1.3 (± 0.7)	1.5 (± 0.8)	1.6 (± 0.9)
total score (± SD)	2.4 (± 1.5)		3.1 (± 1.8)	
	p = 0.01			

score	chronicity				activity	
	T1 TSE		T2* GRE		STIR/T1 TSE fs contrast agent	
MRI sequence	R	L	R	L	R	L
individual score (± SD)	1.1 (± 0.7)	1.3 (± 0.7)	1.5 (± 0.8)	1.6 (± 0.9)	1.5 (± 2.9)	0.8 (± 2.1)
total score (± SD)	2.6 (± 1.5)		3.3 (± 1.8)		2.3 (± 4.1)	
	p = 0.001					

Table 4 Chronicity and activity score of 68 patients with SpA manifestation of the sacroiliac joints.

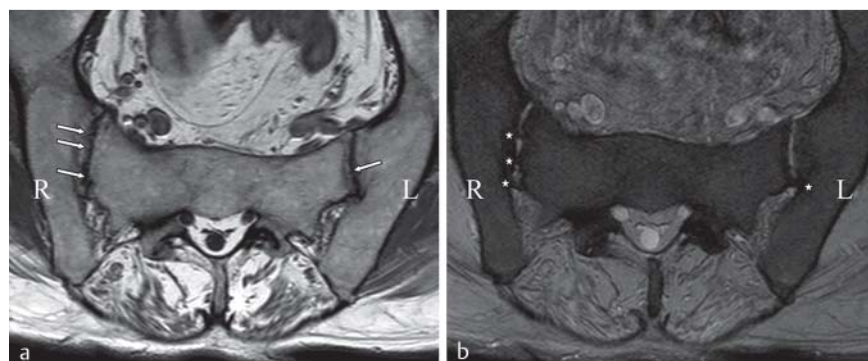


Fig. 3 Chronic sacroiliitis on both sides. **a** axial T1 TSE sequence: Chronicity score on the right 2 with moderate subchondral sclerosis and more than 2 erosions per layer without confluence (arrows), chronicity score on the left 1 with mild subchondral sclerosis and a maximum of 2 erosions per layer (arrow). **b** axial T2* GRE sequence: Chronicity score on both sides 3 with significant periarticular sclerosis, confluent erosions and transarticular bone bridges (stars).

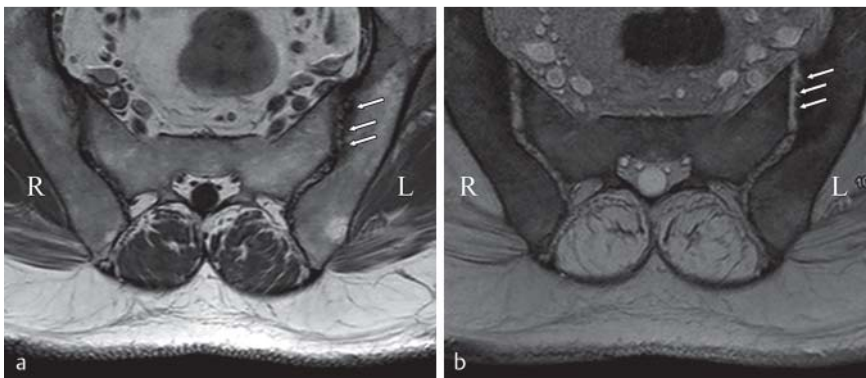


Fig. 4 Chronic sacroiliitis on both sides. **a** axial T1 TSE sequence: Chronicity score on the right 1 with mild subchondral sclerosis and a maximum of 2 erosions per layer, chronicity score on the left 2 with moderate subchondral sclerosis and more than 2 erosions per layer without confluence (arrows). **b** axial T2* GRE sequence: Chronicity score on the right 1 with mild subchondral sclerosis and a maximum of 2 erosions per layer, chronicity score on the left 2 with moderate subchondral sclerosis and more than 2 erosions per layer without confluence (arrows).

of significance [7]. The diagnostic significance of these structural changes is highlighted by the overall low activity score in our patient collective. As a result, over 60% of patients with radiologically characteristic sacroiliac joint involvement have only structural but no inflammatory changes. This may also explain the low CRP values and the comparably low BASDAI values of the examined patient collective. Conversely, characteristic structural changes were able to be detected in over 90% of patients with inflammatory sacroiliac joint changes. Patients with SpA often undergo MRI with a long diagnostic latency period so that purely inflammatory sacroiliac joint changes are typically the exception. The period from the start of symptoms to the definitive diagnosis of up to 10 years is particularly long, especially in the case of ankylosing spondylitis, the most common type of SpA [12]. Although we were able to show significantly higher grading of chronic changes by GRE sequences, we could not identify a case in our collective in which the diagnosis of axial SpA would not have been possible without these sequences. An explanation for this could be the size of the patient collective. Therefore, the direct clinical benefit of GRE imaging seems questionable. However, it must be taken into consideration that MRI not only plays an important role in the primary diagnosis of SpA but is also often used for follow-up. Our results could be clinically relevant in this context since progression of structural changes can indicate insufficient treatment. Our results do not allow such a conclusion for methodological reasons. There is also no repeated differentiation between TSE and GRE in the current study by Krohn et al. [7].

High-contrast visualization of the joint cavity by the GRE sequences can be explained by the high signal of the proteoglycans of the cartilaginous covering of the joint surfaces with simultaneous hypoechoic visualization of the bone, particularly the cortical bone. The sacral joint surface of the sacroiliac joints is comprised of hyaline cartilage and the iliac joint surface of fibrous cartilage which represents the particularly vulnerable enthesal joint side [13]. The GRE technique has become increasingly established in musculoskeletal MRI for dedicated cartilage visualization [14, 15]. However, unenhanced non-fat-saturated T1-weighted TSE sequences should also be part of the examination protocol for sacroiliac joints to rule out pathological bone marrow changes, e.g. tumor infiltrations or fractures. Moreover, periarticular fat accumulations caused by esterification of fatty acids in the bone marrow in the case of chronic inflammation can be detected by unenhanced T1-weighted ima-

ges. However, they are considered a non-specific chronic feature of sacroiliitis and are not taken into consideration in the chronicity score according to Hermann et al. [8]. A modification of the grading of structural changes, the so-called Berlin score, is presented in the study by Krohn et al. [7]. It is a separate classification of fatty lesions and erosions for the 8 quadrants of the sacroiliac joints (analogous to the activity score). We are of the opinion that the MRI score used by us and previously described by the same workgroup [8] is more suitable since it takes into consideration the important feature of new bone growth in the form of bridges and ankylosis. We feel that these features have a higher specificity than fatty lesions even though these are classified as structural lesions by the ASAS. However, this current study by the Berlin group [7] shows that these fatty lesions are potentially reversible which is not to be expected for the other structural lesions.

Periarticular fatty lesions were therefore not included in our analysis. Periarticular sclerosis can be reliably delimited both in TSE and GRE sequences as hypoechoic or anechoic subchondral and perichondral regions if fluid-sensitive sequences are included at the same time. However, it must be taken into consideration that sclerosis of the sacroiliac joints can also occur in the case of overstrain and degenerative processes. Dihlmann described the term hyperostosis triangularis ilii or osteitis condensans ilii in this context [17]. However, according to the ASAS definition, structural sacroiliac joint change alone is not sufficient for the diagnosis of sacroiliitis. Characteristic periarticular bone marrow edema is an essential criterion here as already mentioned. It must be multifocal or at least detectable on two adjacent layers. However, edema-equivalent bone marrow changes are some of the most commonly occurring findings in musculoskeletal MRI with a broad spectrum of differential diagnoses [18]. Therefore, it seems useful to include structural sacroiliac joint changes in the diagnostic evaluation of edema-equivalent bone marrow changes to increase specificity. A significant limitation of our study is the relatively low number of cases and the lack of a reference standard. Computed tomography (CT) can reliably detect structural sacroiliac joint changes due to its high spatial resolution and is therefore suitable for this purpose. However, due to the radiation exposure and the fact that patients are often young, CT is not the method of first choice in the evaluation of sacroiliitis. Despite the retrospective character of the study, the strengths of our study are the standardized examination

protocol and the use of clearly defined and established scoring methods for sacroiliac joint changes.

Conclusion

The used T1-weighted TSE sequence and the T2*-weighted GRE sequence both have high interobserver reliability in the evaluation of structural sacroiliac joint changes. The T2*-weighted GRE sequence used by us makes it possible to detect significantly more structural changes of the sacroiliac joint than with the T1-weighted TSE sequence. T2-weighted GRE sequences should therefore be used in addition to T1-weighted TSE sequences as an established part of examination protocols for sacroiliac joints in patients with suspected SpA to increase the specificity of inflammatory sacroiliac joint findings.

Clinical relevance of the study

T2*-weighted gradient echo sequences are superior to T1-weighted turbo spin echo sequences for the detection of structural changes in sacroiliac joints.

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