

MRI-based CT-like Sequence vs. Conventional CT for the Assessment of Structural Lesions in Patients with Suspected Sacroiliitis

Yiftach Barash MD and Iris Eshed MD

Department of Diagnostic Imaging, Sheba Medical Center, Tel Hashomer, affiliated with Gray Faculty of Medical and Health Sciences, Tel Aviv University, Tel Aviv, Israel

ABSTRACT **Background:** Ultra-short-echo magnetic resonance imaging (MRI) sequences improve visualization of bone cortex and enable the generation of an MRI-based computed tomography (CT)-like (CT-l) images.

Objectives: To compare the agreement between CT-l images derived from merged fast-field echo (MFFE) sequence with conventional CT (cCT) for detecting sacroiliitis-associated structural lesions.

Methods: Consecutive MRI and conventional CT examinations (maximum one-year interval) of the sacroiliac joints (SIJs) of patients with suspected sacroiliitis, performed between 2022 and 2023 were retrospectively evaluated by a musculoskeletal radiologist and a third-year resident who evaluated half of the study's images for the presence of erosions, sclerosis, and ankylosis on semicoronal CT-l and cCT-SIJ images. Cohen's kappa was used to compare the results between the two modalities. The diagnostic performance of the CT-l was analyzed using cCT as the reference standard. Inter-reader reliability was assessed using intraclass correlation coefficients (ICCs) between the two readers.

Results: Sacroiliitis was detected in 11 patients (21%). Erosions, sclerosis, and ankylosis were detected in 44%/31%, 48%/42%, 4%/4% on CT-l/cCT, respectively. Statistical analysis regarding ankylosis was not feasible due to its low prevalence. Cohen's kappa agreement between modalities was substantial for erosions (0.68) and almost perfect for sclerosis (0.92). Sensitivity and specificity of CT-l were 0.90 and 0.69 for erosions and 0.72 and 0.91 for sclerosis, respectively. The ICC on CT-l/cCT for detecting erosions was 0.72/0.68 and 0.84/0.91 for sclerosis.

Conclusions: CT-l MRI sequence is a promising, radiation-free alternative to conventional CT for detecting structural lesions in SIJs, with high diagnostic performance and inter-reader agreement.

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KEY WORDS: CT-like MRI images, magnetic resonance imaging (MRI), computed tomography (CT), sacroiliac joints, sacroiliitis

Axial spondyloarthritis (axSpA) is a group of chronic inflammatory diseases predominantly affecting the axial spine [1]. Inflammatory involvement of the sacroiliac joints (SIJs), which is the hallmark of axSpA, is best detected on magnetic resonance imaging (MRI) [2]. MRI is highly sensitive to early, active inflammatory changes, which are not evident on radiographs or computed tomography (CT), on which only structural lesions are evident [3].

Periarticular bone marrow edema in the SIJs, a key indicator for diagnosing sacroiliitis, has limited sensitivity and specificity (65% and 75%, respectively) [4], while the presence of SIJs erosions on MRI markedly increases the specificity of sacroiliitis detection to 95% [4].

For many years, CT was considered superior to MRI for the detection of SIJ erosions [4]; however, the development of advanced cortical-sensitive sequences improved dramatically the ability to detect erosions on MRI [5]. Ultra-short echo time (UTE) sequences have revolutionized the ability of MRIs to visualize structures with short T2 relaxation times, such as the cortical bone, which previously presented challenges due to rapid signal decay in conventional MRI with longer echo times [5]. UTE sequences utilize echo times of 1 millisecond or less, allowing for enhanced contrast and detailed visualization of bone edges and pathologies, including SIJ erosions and sclerosis [6].

One such UTE sequence is the merged fast-field echo (MFFE), which is a spoiled T2*-weighted sequence in which several individual gradient echoes are generated at different TEs. The individual echoes are magnitude reconstructed and then combined into a single image. Inversion of these images generates images resembling bone window CT, providing a CT-like, (CT-l) high-resolution, bone structure images but without the radiation exposure entailed with conventional CT (cCT) [7]. Diagnostic performance of several such CT-l sequences

was shown to be superior to regular T1 sequence in the detection of structural SIJ lesions and to cCT [8-10] but to the best of our knowledge no studies evaluated the performance of this MRI MFFE sequence.

In the current study, we evaluated the reliability and agreement of this CT-I sequence compared with SIJ cCT in detecting structural SIJ lesions.

PATIENTS AND METHODS

STUDY DESIGN AND PARTICIPANTS

The MRI protocol for evaluating the SIJs at our institution, a tertiary medical center, includes semicoronal T1-W and T2-W fat-saturated (T2-W-FS) sequences as well as an MFFE MRI sequence that was integrated into the protocol a year before the study initiation.

The institution's picture archive system was searched for patients who underwent an SIJ MRI examination for suspected sacroiliitis between 2022 and 2023 as well as a cCT examination including the entirety of the SIJs (i.e., pelvic, abdominal, or spinal CT) performed for any indication.

Included in the study were patients with a maximum time interval of 1 year between the MRI and the cCT examinations.

Patients younger than 18 years of age, patients who did not undergo a CT examination, patients with orthopedic hardware, or patients who underwent a CT that was performed in a time interval larger than 1 year from the MRI, were excluded.

Approval from the institutional review board was obtained (9916-22-SMC), and in keeping with the policies for a retrospective review, informed consent was not required.

MAGNETIC RESONANCE IMAGING

All MRI examinations were conducted on a 3.0T unit (Inginia, Philips healthcare, Amsterdam, Netherlands) with a phased-array 16-element coil. The examination was performed in the semicoronal orientation (along the long axis of the sacrum and perpendicular to the S2 vertebral body) using T1-W (without fat suppression) and T2-W-FS as well as MFFE sequences. The CT-I scans were obtained using the following parameters: TR 53ms, TE 2.3ms, FA 15, FOV 200 × 200 × 76, matrix 224 × 224, voxel 0.9 × 0.9 × (0.6–2.5) mm. Slice thickness variability reflected routine clinical protocol optimization balancing spatial resolution, signal-to-noise ratio, and anatomical coverage, while maintaining a consistently

high in-plane resolution of 0.9 × 0.9 mm across all examinations. The multiple individual MFFE echoes were magnitude-reconstructed and then combined and inverted generating CT-I images.

CT IMAGING

All CT examinations were conducted on two 64-slices CT scanners (ICT 956, Brilliance, Philips Medical Systems, Eindhoven, Netherlands or VCT LightSpeed, GE Healthcare, Milwaukee, WI, USA). All CT examinations were performed with slice thickness of 0.6 mm, were reformatted in the semicoronal plane from the raw data and were evaluated in a bone window.

SACROILIAC JOINTS IMAGING EVALUATION

A musculoskeletal radiologist (20 years of experience in musculoskeletal imaging) separately evaluated the CT-I images and the cCT images for the presence (score=1) or absence (score=0) of erosions, sclerosis, and ankylosis across 12 distinct regions of each joint; four quadrants and three positions (anterior, middle, posterior) as was previously described [9]. The sum of each lesion was calculated for quadrant, for the iliac and sacral aspects of each joint, for each joint side (right and left), and for both SIJs combined (per patient). In addition, the reader also evaluated the images for a global impression to determine whether the imaging findings were suggestive of sacroiliitis. This decision was subjective and based on the reader's clinical judgment, relying on the presence or absence of structural lesions highly suggestive of sacroiliitis [11], without a strict predefined diagnostic definition.

Each modality was assessed separately with a minimum of a 2-week interval between the two assessments.

In a separate reading session, a radiologic diagnosis was determined, when possible, for each patient by the two readers based on all available imaging data from both MRI (excluding the CT-I sequence) and CT. The diagnosis included sacroiliitis (according to the presence of characteristic active and structural lesions) or an alternative MRI diagnosis, such as normal findings, degenerative joint disease, osteitis condensans ilii, degenerative spine disease, or an unknown diagnosis.

For an inter-reader reliability assessment, a random subset of half of the cases was read by a 2nd reader (3rd year resident). This random selection was stratified to maintain a representative distribution of patient demographics, disease severity, and imaging findings across the cohort.

Lesions were defined as follows:

- Erosion: a focal, ill-defined lucency of the subchondral bone with a clear interruption of the cortical bone in the cartilaginous compartment.
- Sclerosis: a hyperdense subchondral bone with a minimum of 5 mm thickness.
- Ankylosis: a dense lesion within the joint space consistent with the bone and bridging between the two adjacent bones.

Assessments were conducted randomly, with no pre-determined order in the evaluation of cCTs or MRIs. Readers were blind to the T2-W-FS and T1-W sequence findings as well as to the patient’s clinical information and to the scoring of the other modality.

To ensure a uniform and reliable score, a calibration exercise with a set of 10 test cases was performed by the readers prior to the main assessment.

STATISTICAL ANALYSIS

The two readers scores were evaluated for inter-reader reliability using the intraclass correlation coefficient (ICCs) analysis calculated by two-way mixed analysis for consistency agreement. The agreement between the CT-I MRI sequence and cCT (continuous scores) was also assessed using the ICCs analysis calculated by two-way mixed analysis for consistency agreement. Analyses were performed per patient (both right and left sacroiliac joints combined), per joint (right or left), and per joint aspect (iliac or sacral side of the right or left SIJ). Reader’s decision on the presence of sacroiliitis (binary: yes/no) was compared for CT-I and cCT using Cohen’s kappa coefficient and also compared with the radiologic diagnosis.

ICC values were interpreted according to Landis and Koch [12]: < 0.00 = poor; 0.00–0.20 = slight; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = substantial; and 0.81–1.00 = almost perfect agreement.

Sensitivity and specificity for the detection of structural lesions on a patient level (positive defined as any score > 1) were calculated using cCT as the reference standard. A P-value of < 0.001 was chosen.

Statistical analyses were performed using IBM Statistical Package for the Social Sciences statistics software, version 27 (SPSS, IBM Corp, Armonk, NY, USA).

During the preparation of this work the authors used Chat GPT (OpenAI, San Francisco, CA, USA) for English language editing and to improve readability. After using this tool, the authors reviewed and edited the content as needed. They take full responsibility for the content of the published article.

COMPLIANCE WITH ETHICS STANDARDS

All procedures performed in studies involving human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

RESULTS

Overall, 52 patients were included in the study: 30 females and 22 males, mean age 46 years ± 11 years. A summary of participant characteristics is shown in Table 1.

Table 1. Characteristics of the study’s participants (n=52)

Characteristic	Value
Age (years)	46 ± 11 (19–77)
Female	30
Male	22
Time between MRI and CT (months)	5.3 ± 4.1
Final MRI diagnosis	
Sacroiliitis	11 (21%)
Degenerative SIJ disease	16 (31%)
Osteitis condensans ilii	7 (13%)
Tumor	2 (4%)
Degenerative spine disease	13 (25%)
Unknown	3 (6%)

CT = computed tomography, MRI = magnetic resonance imaging, SIJ = sacroiliac joints

The final MRI diagnosis of the evaluated patients was: sacroiliitis (n=11), degenerative joint disease (n=16), osteitis condensans ilii (n=7), tumor (n=2), degenerative spine disease (n=13) and unknown (n=3).

Erosions were identified in 16 (31%) patients on cCT and in 23 (44%) patients on CT-I. Sclerosis was detected in 22 (42%) patients on cCT and in 25 (48%) patients on CT-I and ankylosis in 2 (4%) patients both on CT-I- and on cCT.

A summary of sum lesions scoring according to joint’s quadrants in CT-I and cCT is presented on Table 2.

Erosions were observed most frequently in the right and left upper iliac and sacral regions. Sclerosis was somewhat more prevalent than erosions in certain quadrants, particularly the right upper iliac and left upper sacral quadrants. Ankylosis was rare, detected only in a few quadrants and often in single cases. Overall, the distribution and frequency of findings reflect the well-re-

Table 2. Sum lesion scoring per quadrant on CT-like MFFE MRI sequence and conventional CT

Quadrant/Modality	Erosion		Sclerosis		Ankylosis	
	CT-l	cCT	CT-l	cCT	CT-l	cCT
Right upper ileum	6	9	19	18	2	1
Right lower ileum	6	0	10	6	8	0
Right upper sacrum	3	1	4	2	1	0
Right lower sacrum	2	1	0	0	2	0
Left upper ileum	2	0	3	2	1	0
Left lower ileum	3	0	0	0	0	0
Left upper sacrum	6	5	13	14	4	0
Left lower sacrum	7	3	9	5	4	1

CT-l = CT-like sequence, cCT = conventional CT

ported observation that erosions are less common in the evaluated sacroiliac joints than subchondral sclerosis [13,14].

The mean total erosion scores for CT-l and cCT were 0.7 (SD = 5.5) and 0.4 (SD = 3.6), respectively ($P > 0.05$). The corresponding sclerosis scores were 0.4 (SD = 3.0) and 0.6 (SD = 5.0) ($P > 0.05$), and the ankylosis scores were 0.1 (SD = 1.1) and 0.02 (SD = 0.2), respectively.

Examples of erosions and sclerosis on CT-l and cCT are displayed in Figure 1.

The reader diagnosed sacroiliitis in 13 patients based on the CT-l images (10 true positive cases according to the final radiographic diagnosis) and in 10 patients based on the cCT images (8 true positive cases).

Given the low prevalence of ankylosis in the cohort, statistical analysis of this feature was not feasible.

ICC between the two readers was substantial for the detection of erosions on both modalities; CT-l = 0.72 (95% confident interval [95%CI] 0.38–0.87), cCT = 0.68 (95%CI 0.29–0.85) and almost perfect for the detection of sclerosis; CT-l = 0.84 (CI: 0.64–0.93), cCT = 0.93 (95%CI 0.84–0.97), $P < 0.001$ for all.

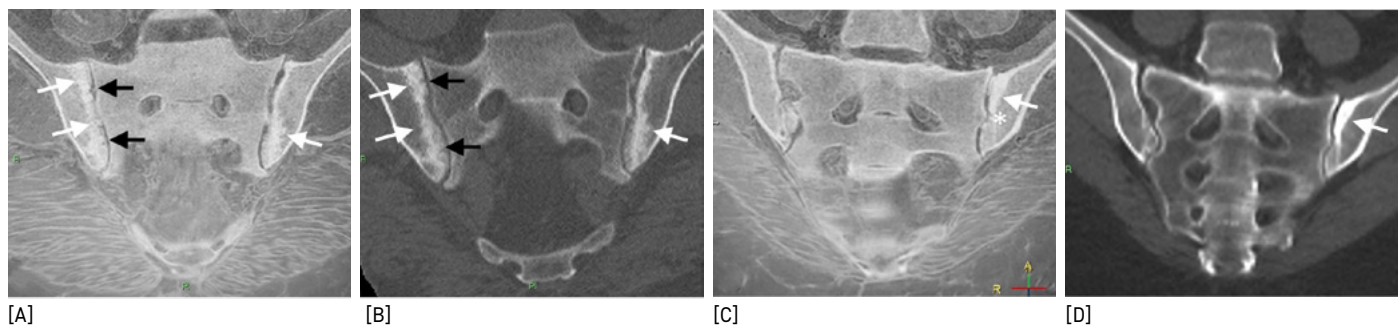
COMPARISON BETWEEN CCT AND CT-L IN IDENTIFICATION OF EROSIONS AND SCLEROSIS

ICC was substantial for the detection of erosions on a patient level (0.69, $P < 0.001$, 95%CI 0.18–0.93 and almost perfect for sclerosis 0.92, $P < 0.001$, 95%CI 0.62–0.98). Agreement was substantial to almost perfect on a joint's side level for erosions (right 0.69, 95%CI 0.68–0.89, left 0.79, 95%CI 0.12–0.98; $P < 0.001$) and almost perfect for sclerosis (right 0.92, 95%CI 0.67–0.99, left 0.92, 95%CI 0.35–0.99; $P < 0.001$).

Substantial to almost perfect agreement between CT-l and cCT was observed for the iliac and sacral aspect scores of the joints (erosions 0.62–0.9, sclerosis 0.95–0.961, 95%CI for all 0.73–0.96; $P < 0.001$).

Figure 1. Examples of erosions and sclerosis on CT-l and cCT

CT = computed tomography, CT-l = computed tomography-like, cCT = conventional computed tomography, MRI = magnetic resonance imaging



Semicoronal CT-l MRI [A,C] and cCT [B,D] images of a 49 years old female [A,B] and a 45 years old male [C,D] with lower back pain and suspected sacroiliitis.

[A,B] Both on CT-l and on cCT, subchondral sclerosis (white arrows) and multiple confluent erosions (black arrows) are seen on the iliac sides of both right and left sacroiliac joints compatible with sacroiliitis.

[C,D] Both on CT-l and on cCT a triangular shaped subchondral sclerosis is seen on the anterior part of the left sacroiliac joint (white arrow), compatible with osteitis condensans ilii. However, there is some irregularity of the cortical bone falsely suggesting erosion seen on the CT-l adjacent to the sclerosis (asterisk) that is not seen on the cCT image.

An almost perfect agreement was also seen between the reader's decision on the presence of sacroiliitis based solely on the CT-I or the cCT images (0.891, $P < 0.001$).

Using cCT as the standard of reference, the sensitivity of CT-I in detecting erosions is 0.90 (95%CI 0.55–0.99), and the specificity was 0.69 (95%CI 0.58–0.86). For the detection of sclerosis, the sensitivity of CT-I was 0.72 (95%CI 0.46–0.90), and the specificity was 0.91 (95%CI 0.76–0.98).

DISCUSSION

In this study, we compare the agreement of CT-I derived from MFFE MRI sequences, with conventional CT in detecting erosions and sclerosis of the SIJs.

Inter-reader reliability calculated for the readings of the experienced radiologist and the radiology resident was good for both cCT and CT-I for the detection of erosions (0.68 and 0.72, respectively) and very good for the detection of sclerosis (0.93 and 0.84). These results, reported by others [9–11], reflect not only the known fact that the detection of erosions is more challenging than detecting sclerosis regardless of the modality [15,16] but also that using the CT-I sequence allows for reliable detection of erosions even by a less experienced reader.

Both erosions and sclerosis were more frequently detected on CT-I than on cCT. This finding was also reported in a study that used T1-GRE sequence as a CT-I [10] while in the study by Deppe and colleagues [8], both erosions and sclerosis were more frequently seen on cCT than on SWI CT-I. The differences probably stem from the different CT-I sequences but may indicate an over-reading of erosions on the MFFE sequence.

Our findings revealed a substantial to almost perfect level of agreement between CT-I and cCT in the detection of erosions (0.69) and of sclerosis (0.92) on a patient level with a sensitivity and specificity of 90% and 69% for the detection of erosions and 72% and 91%, respectively, for the detection of sclerosis. The results are similar to those reported by others [8,9] and indicate that advanced imaging techniques such as CT-I can offer a reliable evaluation parallel to cCT, enhancing the confidence in diagnostic imaging across various clinical settings.

In our study, the CT-I sequence demonstrated a higher apparent prevalence of erosions compared with cCT (44% vs. 31%), while specificity was modest (0.69). Indeed MRI-based techniques, including CT-I and gradient-echo sequences, have been shown to detect more erosions than cCT but with lower or variable specificity, probably reflecting differences in contrast mechanisms and bone depiction

[17]. Several sequence-related factors may contribute to this discrepancy. Susceptibility-related edge enhancement at the cortex–marrow interface, blooming adjacent to areas of sclerosis, and accentuation of physiologic or degenerative cortical irregularities can mimic small cortical defects and lead to overcalling [8,17]. In addition, differences in spatial resolution and partial volume effects, together with MRI-based contrast mechanisms, may exaggerate cortical discontinuities compared with cCT [18]. To mitigate overdiagnosis, readers should carefully assess suspected erosions in multiple planes and sequences, consider the presence of adjacent structural changes, and avoid over-interpretation of isolated shallow cortical irregularities without supportive features. The use of predefined morphological criteria and reader training may further improve specificity and reduce misclassification. Thresholds for reporting minor cortical irregularities may need adjustment when interpreting CT-I sequences.

Sclerosis was more prevalent than erosions in our cohort, likely reflecting the relatively high proportion of patients with degenerative SIJ changes and osteitis condensans ilii. Both conditions are characterized by subchondral bone sclerosis rather than erosions, which may be more easily and consistently detected across imaging modalities. This higher prevalence of sclerosis likely contributed to the higher agreement between CT-I and cCT, as sclerotic changes produce more uniform and conspicuous signal alterations on MRI-based CT-I sequences, whereas subtle erosions are more prone to variability in detection. In addition, sclerosis tends to be less affected by partial volume effects and MRI contrast differences, further enhancing inter-modality concordance.

The recommended SIJ MRI protocol for evaluating sacroiliitis, as outlined by radiological and rheumatological societies, includes an erosion-sensitive sequence but does not address CT-I sequences [19]. However, low dose CT has been shown to increase confidence and accuracy in the diagnosis of sacroiliitis on MRI [20]. Whether CT-I sequences can replace cCT for this purpose or should be added to the basic protocol to enhance diagnostic confidence for the sake of increasing the diagnostic confidence is yet to be studied and determined.

This study has several limitations. One of the primary constraints was the retrospective design, which might include selection bias. The sample size, while adequate for preliminary conclusions, is relatively small when considering the variability of SIJ pathologies, which may limit the generalizability of the findings. In addition, the interval of up to 1 year between CT and MRI may have

allowed interval changes, potentially introducing some inaccuracy. Another potential limitation is incorporation bias, as cCT was included in the consensus reference standard, which may have favored agreement when evaluating the diagnostic performance of CT-I. In addition, the study did not account for the potential influence of demographic variables such as age and disease duration on the imaging characteristics of SIJ pathologies. A further limitation is that the CT sequence was evaluated in isolation, whereas in clinical practice MRI diagnosis is based on integrated assessment of all sequences, including T1-weighted and fluid-sensitive images.

The study design was intentionally chosen to assess the standalone and additive value of the CT sequence but may have underestimated its performance in routine clinical interpretation. Furthermore, while CT-I appears to be a reliable modality for the assessment of SIJ erosions and sclerosis, its performance in the detection of ankylosis could not be determined due to data limitations. This limitation underscores the need for future research focusing on a broader spectrum of SIJ pathologies and incorporating larger, more diverse populations to validate our findings.

CONCLUSIONS

The CT-I sequence shows strong agreement with cCT for the detection of erosions and sclerosis and offers significant advantages in clinical practice. CT-I images provide improved visualization of bone structures in the sacroiliac joints, facilitating the identification of structural lesions characteristic of sacroiliitis. Our findings support the potential use of CT-I as a viable radiation-free alternative to cCT and suggest that it may reduce the need for CT in selected patients. Prospective studies with shorter imaging intervals, standardized diagnostic thresholds, and direct comparisons between different CT-I sequences are warranted to further validate its role in the evaluation of sacroiliac joint pathology.

Correspondence

Dr. I. Eshed

Dept. Diagnostic Imaging, Sheba Medical Center, Tel Hashomer 5265601, Israel

Phone: (972-3) 530-2498

Fax: (972-3) 530-2220

Email: irished@gmail.com

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