Which para-axial sequence should be included in the optimal MRI protocol of the sacroiliac joints in Spondylarthropathies

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Aims and objectives

The relevant role of MRI for the diagnosis of seronegative axial Spondylarthritis (SpA) is currently well established, especially since 2009, when ASAS designated MRI findings of active sacroiliitis among the criteria for axial SpA diagnosis. However, there is still a debate about the optimal protocol that should be time-efficient and of high diagnostic value at the same time [1-4].

Recent publications have suggested [5-8] that the complex anatomy of the sacroiliac joint (SIJ) requires a para-axial plane to precisely assess the anatomy of the anterior and posterior margins of the cartilaginous portion of the SIJ, reliably characterize the ligaments, carefully localize abnormalities, and reduce partial volume effects.

However, to date, studies recommending the appropriate para-axial sequence are still missing.

The aim of this study was to evaluate the diagnostic value of the para-axial T2-weighted TSE sequence (paT2) for detecting chronic findings and the fat-suppressed proton density (paPD-FS) sequence for investing both acute and chronic signs of SpA.

Methods and materials

106 patients with clinical findings suggestive of SpA, according to the 2009 criteria of the Assessment of Spondyloarthritis International Society (ASAS)[1], underwent a routine MRI protocol of the SIJ.

MRI protocol

MRI investigation of the SIJ was performed on a 3 Tesla MR (Philips Achieva; Philips Medical Systems, Best, the Netherlands) using a body array coil.

The protocol was established according to ASAS guidelines and included the following sequences: paracoronal T1-weighted Turbo Spin Echo (TSE) (pcT1); paracoronal STIR (pcSTIR); paracoronal and para-axial T1-weighted TSE with selective fat suppression after i.v. gadolinium (Gd, 0.1 mmol/kg body weight) (pcCE-T1-FS and paCE-T1-FS, respectively). Gd was not administered to five patients because of a previous history of contrast media allergy or termination of the examination due to claustrophobia, which was also the cause for the missing paT2 sequence in one case.
In addition, 105 of the 106 patients underwent a para-axial T2-weighted TSE sequence (paT2), and 41 subjects underwent a para-axial proton density-weighted fat-suppressed sequence (paPD-FS). The paPD-FS sequence was added to our regular MR protocol after 10 months.

All images were acquired with a slice thickness of 3 mm; the para-axial and para-coronal planes were, respectively, parallel and perpendicular to the upper endplate of the first sacral vertebral body.

Four acute (bone marrow edema (BME), enthesitis, capsulitis, synovitis) and two chronic criteria (erosions, ankylosis) were evaluated. Acute and chronic findings were assessed by paPD-FS and compared with the gold standard sequences (paCE-T1-FS and pcCE-T1-FS), whereas chronic signs (because of the lack of fat suppression) were evaluated on the paT2 and compared with the reference (pcT1).

**Images analyses**

**Anatomical subdivision**

The following anatomical subdivisions are represented in Figure 1.

**BME assessment:**

Each SIJ was subdivided into 12 quadrants to precisely investigate each area of inflammation, and therefore, accurately evaluate the diagnostic value of the applied sequences. Specifically, the iliac and sacral bones on each side were partitioned into the following regions: supero-anterior; supero-posterior; middle-anterior; middle-posterior; infero-anterior; and infero-posterior.

The boundary between the superior and middle region was traced at the level of the first sacral foramina, whereas the limit between the middle and the inferior portion was delineated at the level of the second sacral foramina. The boundary between the anterior and posterior part of each joint was established at the transition point between the cartilaginous and ligamentous portions of the SIJ [5-7].

**Capsulitis assessment:**

it was evaluated on four distinct areas of the capsule on each side: supero-anterior; supero-posterior; infero-anterior; infero-posterior.

**Enthesitis assessment:**

it was assessed on the anterior and posterior (posterior and interosseous) ligaments on both right and left SIJ [7,9].
Synovitis assessment:

It was evaluated on the inferior third of the SIJ, because the characteristics of a synovial joint are confined to the margins of the iliac joint facet in the inferior portion of the SIJ, as elegantly demonstrated by the anatomical studies of Puhakka et al. [7].

Erosions assessment:

They were separately assessed on the sacrum and ilium and the presence of ankylosis was distinctly evaluated on the right and left SIJ.

Scoring and images evaluation systems

The evaluations of BME, synovitis, and capsulitis were performed according to the previously described anatomical subdivision of the SIJ (Fig 1), and were based on the paPD-FS, pc and paCE-T1-FS sequences. The agreement between the pre- and post-contrast images was evaluated according to the acquisition plane (e.g., para-axial PD-FS versus para-axial CE-T1-FS). Postcontrast images were used as the gold standard sequence, and therefore, served as reference for all the acute findings.

Both the anterior and posterior ligaments were investigated on paPD-FS and then on paCE-T1-FS, considering the latter as the gold standard.

All comparisons between paPD-FS and paCE-T1-FS were feasible in only 39 of the 41 patients who underwent paPD-FS (Gd was not administered to two of the 41 patients because of a previous history of CM allergy).

The paT2 sequence was applied only for the evaluation of chronic findings, because the lack of fat suppression would not have allowed a reliable detection of the above-mentioned acute criteria (e.g., unreliable distinction between the bright signal of fat replacement and edema in the bone marrow). Para-coronal T1 without fat suppression is still considered the gold standard for structural changes, such as erosions or ankylosis [9]. For this reason, comparisons of the diagnostic value of paT2w and paPD-FS could be performed only for erosions and ankylosis using the pcT1 as the gold standard.

Statistical analysis

Absolute frequencies and percentages are presented for categorical data.

To determine the diagnostic value of paPD-FS and paT2 for all the other categorical variables (BME, enthesitis, capsulitis, synovitis, erosions, and ankylosis), sensitivity (Se) and specificity (Sp), as well as their 95% confidence intervals, were calculated.
Fig. 1: Drawing of the sacroiliac joint representing the anatomical subdivisions used for the evaluation of the pathologic findings. SIJ: S=superior region; M=middle region; I=inferior region; A=anterior region; P=posterior region. The boundary between the upper and middle region was traced at the level of the first sacral foramina, whereas the limit between the middle and the inferior portion was delineated at the level of the second sacral foramina. The boundary between the anterior and posterior part of each joint was established at the transition point between the cartilaginous and ligamentous portions of the SIJ. Blue lines= posterior ligament; green lines= anterior ligament assessed at the level of the mid portion of the joint; gray figure= cartilaginous portion of the SIJ; purple figure= synovial membrane of the SIJ; red dotted line= capsule (the antero-superior, postero-superior, infero-anterior, and infero-posterior portions of the joint capsule can be easily distinguished in the axial plane).
Results

The results of all the performed analyses are reported in Table 1. paPD-FS demonstrated high sensitivity (98.9%) and specificity (99.1%) for BME [Fig 2]: of the 959 examined areas, eight were positive on paPD-FS and negative on paCE-T1-FS, one area of BME was detected only on the post-contrast images. Sensitivity and specificity for both, synovitis [Fig 3] and enthesitis [Fig 4], were 100%.

Two cases of capsulitis were missed on paPD-FS (paPD-FS: n capsulitis=12; Se=85.7%); however, none was misinterpreted as false-positive (Sp=100%).

No differences emerged about the evaluation of BME, synovitis, or capsulitis between postcontrast axial and coronal images (paCE-T1-FS and pcCE-T1-FS)[Fig 3, 4]. Furthermore, all the areas of BME detected on the post-contrast images were also visible on pcSTIR.

paPD-FS and paT2 showed good results in the detection of chronic findings [Fig 5-7]. All erosions detected on paPD-FS (n=49) and paT2 (n=139) were correctly interpreted, resulting in a specificity of 100%. Sensitivity was 98% for paPD-FS and 85.3% for paT2.

The statistical analysis revealed 100% sensitivity (paT2: n ankylosis=30; paPD-FS: n ankylosis=2) and 100% specificity for both sequences in the diagnosis of ankylosis.

Images for this section:
**Fig. 1:** Drawing of the sacroiliac joint representing the anatomical subdivisions used for the evaluation of the pathologic findings. SIJ: S=superior region; M=middle region; I=inferior region; A=anterior region; P=posterior region. The boundary between the upper and middle region was traced at the level of the first sacral foramina, whereas the limit between the middle and the inferior portion was delineated at the level of the second sacral foramina. The boundary between the anterior and posterior part of each joint was established at the transition point between the cartilaginous and ligamentous portions of the SIJ. Blue lines= posterior ligament; green lines= anterior ligament assessed at the level of the mid portion of the joint; gray figure= cartilaginous portion of the SIJ; purple figure= synovial membrane of the SIJ; red dotted line= capsule (the antero-superior, postero-superior, infero-anterior, and infero-posterior portions of the joint capsule can be easily distinguished in the axial plane).
### Table 1: Analysis of acute and chronic findings by paPD-FS and paT2.

<table>
<thead>
<tr>
<th></th>
<th>paCE-T1-FS (n=39 patients*)</th>
<th>paPD-FS (n=39 patients*)</th>
<th>paT2 (n=41 patients*)</th>
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<tbody>
<tr>
<td></td>
<td>N+</td>
<td>N-</td>
<td>N examined areas</td>
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<td></td>
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<tr>
<td><strong>BME</strong></td>
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<td></td>
<td>92*</td>
<td>867</td>
<td>959</td>
</tr>
<tr>
<td>synovitis</td>
<td>13</td>
<td>65</td>
<td>78</td>
</tr>
<tr>
<td>enthesitis</td>
<td>13</td>
<td>65</td>
<td>78</td>
</tr>
<tr>
<td>capsulitis</td>
<td>14</td>
<td>298</td>
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</table>

### Chronic findings

<table>
<thead>
<tr>
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<th>paT1 (n=105 patients*)</th>
<th>paPD-FS (n=41 patients*)</th>
<th>paT2 (n=105 patients*)</th>
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<tr>
<td></td>
<td>N+</td>
<td>N-</td>
<td>N examined areas</td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>erosions</td>
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<td>420</td>
</tr>
<tr>
<td>ankylosis</td>
<td>30</td>
<td>180</td>
<td>210</td>
</tr>
</tbody>
</table>

paCE-T1-FS—para-axial post-contrast fat suppressed (considered the gold standard for the evaluation of the acute findings); paPD-FS—para-axial proton density fat suppressed; paT1—para-axial T1-weighted sequence (considered the gold standard for the evaluation of the chronic findings); paT2—para-axial T2-weighted sequence; N+—number of positive areas; N—number of negative areas; N—total number of examined areas (according to the anatomical subdivision represented in Fig 1); Se—sensitivity; Sp—specificity; 95% CI—95% confidence interval.

*of the 959 examined areas, eight were positive on paPD-FS and negative on paCE-T1-FS, one area of BME was detected only on the post-contrast images.

* all the comparisons for acute findings, between paCE-T1-FS and paPD-FS, were performed on 39 patients (indeed only on 41 patients was performed a paPD-FS and Gd was not administered to two of them because of a previous history of contrast medium allergy)

and ** for the evaluation of the chronic findings were considered 105 patients for the comparisons between paT1 and paT2 and 41 patients for the comparisons between paT1 and paPD-FS.

**Fig. 2:** Focal area of BME (red arrow) well detectable on paPD-FS (A) and paCE-T1-FS (B).**
Fig. 3: paCE-T1-FS (A), and paPD-FS (B) demonstrating synovitis (white arrowhead) and postero-inferior capsulitis (yellow arrow) on the left SIJ. The para-axial plane allowed a more precise assessment of capsulitis than the paracoronal plane (C), enabling an accurate distinction between the anterior and posterior portion of the capsule.

Fig. 4: paCE-T1-FS (A), paPD-FS (B) demonstrating anterior (white circle) and posterior enthesitis (red arrow) on the mid portion of the left SIJ. On the coronal plane (C), the posterior enthesitis is easily assessed (red arrow), whereas, due to partial volume effects, the anterior ligament can hardly be appreciated at the mid portion of the SIJ (D). The yellow arrowhead points to the antero-superior capsulitis (not visible in A and B because of a different level of the joint).
**Fig. 5:** paPD-FS (A), pa T2 (B), and pcT1 (C) showing erosions (white arrow) on the left iliac bone.

**Fig. 6:** paT2 (A) and pcT1 (B) demonstrating bilateral signs of chronic SpA: ankylosis (red arrows) and erosions (yellow asterisks).

**Fig. 7:** paPD-FS (A), pa T2 (B), and pcT1 (C) demonstrating bilateral ankylosis of the SIJ (white arrows) and the presence of fat replacement (red asterisks).
Conclusion

Previous studies have highlighted [5-7,10] the benefits of the inclusion of a para-axial plane sequence to carefully assess the complex anatomy of the sacroiliac joint. Indeed, the anatomical studies of Puhakka et al., and subsequently, of Egund et al., demonstrated that para-axial images are highly recommended to precisely estimate sites such as the transition point between the cartilaginous and ligamentous portions of the SIJ, carefully localize abnormalities, and to reduce partial volume effects.

Even if the use of the para-axial plane is already strongly suggested by the Arthritis Subcommittee of the ESSR [11], to the best of our knowledge, up to now, there was a lack of scientific studies evaluating the different para-axial sequences in the SIJs of SpA patients. For many years, T2-TSE and PD-FS have played an important role in musculoskeletal imaging [12-15], but the diagnostic value of these sequences, especially of the latter, was never carefully assessed in SpA. The decision to include a PD-FS sequence to properly investigate acute and chronic findings affecting the SIJ was based on its properties, PD-FS is an extremely versatile and accurate fluid-sensitive sequence with a signal-to-noise ratio higher than that of other fat-suppression techniques, such as STIR. Although PD-FS was included in only 41 patients in the protocol, our preliminary results are highly promising.

T2 sequences without fat suppression are routinely applied to examine different joints (e.g., shoulder, knee), but, provide less information than fat-suppressed sequences for acute inflammatory findings because of the interference of the high signal of fat on T2 with the high signal of inflammatory edema [15-17]. For this reason, in our study, only chronic findings were assessed on paT2, and good results were obtained.

In conclusion, this study demonstrates that T2-TSE and PD-FS, applied in the para-axial plane, provided precious information that enabled an accurate interpretation not only of the complex anatomy of the SIJ, but also of the heterogeneous findings of SpA, which sometimes are not so easily assessed on the coronal plane.

According to our preliminary results and to the ability to detect both, acute and chronic findings, PD-FS carries a higher diagnostic value compared to T2, therefore it should be included in the SpA protocol. This is beneficial for obtaining accurate and specific information at the onset of symptoms as much as during the long-term follow-up that SpA requires.

Personal information
References


