

**MRI Lesions in the Sacroiliac Joints of Patients with Spondyloarthritis: Update of  
Definitions and Validation by the ASAS MRI Working Group**

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## **ABSTRACT**

**Objectives.** The Assessment of SpondyloArthritis international Society (ASAS) MRI working group (WG) was convened to generate a consensus update on standardized definitions for MRI lesions in the sacroiliac joint (SIJ) of patients with spondyloarthritis (SpA), and to conduct preliminary validation.

**Methods.** The literature pertaining to these MRI lesion definitions was discussed at 3 meetings of the group. 25 investigators (20 rheumatologists, 5 radiologists) determined which definitions should be retained or required revision, and which required a new definition. Lesion definitions were assessed in a multi-reader validation exercise using 278 MRI scans from the ASAS classification cohort by global assessment (lesion present/absent) and detailed scoring (inflammation and structural). Reliability of detection of lesions was analyzed using kappa statistics and the intraclass correlation coefficient (ICC).

**Results.** No revisions were made to the current ASAS definition of a positive SIJ MRI or definitions for subchondral inflammation and sclerosis. The following definitions were revised: capsulitis, enthesitis, fat lesion, erosion. New definitions were developed for joint space

enhancement, joint space fluid, fat metaplasia in an erosion cavity, ankylosis, and bone bud. The most frequently detected structural lesion, erosion, was detected almost as reliably as subchondral inflammation ( $\kappa$ /ICC:0.61/0.54 and 0.60/0.83) . Fat metaplasia in an erosion cavity and ankylosis were also reliably detected despite their low frequency ( $\kappa$ /ICC:0.50/0.37 and 0.58/0.97).

**Conclusion.** The ASAS-MRI WG concluded that several definitions required revision and some new definitions were necessary. Multi-reader validation demonstrated substantial reliability for the most frequently detected lesions and comparable reliability between active and structural lesions.

**Key Words.** Spondyloarthritis, magnetic resonance imaging, sacroiliac joint, lesions, definitions, reliability

## INTRODUCTION

MRI is now an established tool in the assessment of the SIJ in patients with SpA, especially in early disease<sup>1</sup>. Both active and structural lesions may be observed prior to the appearance of radiographic findings<sup>2</sup> and SIJ MRI is being used for studies of disease pathogenesis and as a quantitative measure for assessment of therapeutics. It is therefore essential that there is widespread understanding of each lesion based on a standardized descriptive terminology generated by international consensus. Moreover, comprehension of these definitions should be validated in reading exercises.

It has been a decade since the first international consensus culminated in published definitions for MRI lesions in the SIJ<sup>3</sup>. This described active and structural lesion definitions but did not include any reading exercises. In addition, this group also formulated a provisional definition of an MRI that could be considered positive for SpA for the purposes of disease

classification, which was based on the clear presence of bone marrow edema (BME)/osteitis in subchondral bone marrow. A recent consensus from ASAS further elaborated the descriptive terminology of this definition emphasizing the importance of contextual interpretation of both active and structural lesions to enhance confidence in interpretation<sup>4</sup>. However, this exercise also did not include any readings of MRI scans.

Over the past decade our understanding of MRI lesions in the SIJ has increased substantially and there have been further descriptions of structural lesions, which have been assessed longitudinally to understand their origin and association with active lesions. This progress led to the decision by ASAS to convene the ASAS-MRI WG to discuss progress in the field, review existing definitions, determine the necessity for updated or new lesion definitions, and conduct a multi-reader exercise by expert readers from the ASAS-MRI WG to examine the performance of all lesion definitions in the SIJ.

## **METHODS**

### **Consensus exercises**

Rheumatologists (n =20) and radiologists (n =5) of the ASAS-MRI WG were invited to participate in the consensus exercises and an initiative to validate lesion definitions using the available MRI scans from patients recruited to the ASAS classification cohort<sup>5</sup>. Published definitions for active and structural MRI lesions in the SIJ were reviewed at two face-to-face meetings in 2016, in Gent, Belgium and Leiden, the Netherlands. A summary of these deliberations was presented at the annual meeting of ASAS on January 20, 2017. Feedback from ASAS members was taken into consideration during a webex on March 21, 2017 where the ASAS MRI WG finalized consensus wording of these definitions and agreed on a set of reference images that depict each lesion<sup>6</sup>. The group also agreed on a study design, the ASAS MRImagine

study, for multi-reader assessment of lesion definitions and a study-specific interactive electronic case report form (eCRF).

### **ASAS eCRF for evaluation of MRI lesions in the SIJ**

The online-available<sup>6</sup> CRF comprised two sections: A. Data was first entered onto a global scoring page where readers recorded the presence/absence of each lesion in iliac and sacral portions of each SIJ and whether the scan met the ASAS definition for a positive MRI<sup>3,4</sup>. B. After global assessment, data was entered onto a granular scoring web-based interface where inflammatory and structural lesions were recorded in each SIJ quadrant on consecutive semicoronal slices<sup>6</sup>. All slices with a minimum 1cm vertical height of visible SIJ were scored and SIJ quadrants were defined according to established rules<sup>7</sup>. Structural lesions were recorded in either SIJ quadrants (erosion, fat, sclerosis) or upper and lower SIJ halves (fat metaplasia in an erosion cavity, ankylosis) as previously defined<sup>8</sup>.

### **ASAS Classification Cohort MRI Resource.**

MRI scans of the SIJ were available from 278 cases recruited to the ASAS classification cohort. Of these, 175 cases were in standard DICOM format, 71 were in JPEG format, and in 32 cases images were derived from hard copy film. Global assessment for active lesions on a fat-suppressed scan was possible for all available cases (263 semi-coronal and 15 axial scans). Global assessment for structural lesions on a T1W scan was possible for 238 cases (189 semi-coronal and 49 axial scans). Granular assessment for active and structural lesions was conducted only in cases where a DICOM series was available in semi-coronal orientation (160 for fat-suppressed scans and 148 for T1W scans, respectively).

**Reading exercises.** Seven readers from the ASAS-MRI WG with over 10 years' experience evaluating SIJ lesions for SpA assessed the MRI scans. Validated calibration modules aimed at

standardization of slice selection and defining SIJ quadrants were provided online for review prior to the readings<sup>9,10</sup>.

**Statistics.** Frequencies of each SIJ lesion were assessed descriptively according to individual as well as majority reader ( $\geq 4/7$  readers) data. Reliability for presence/absence of each lesion was assessed using the kappa statistic. Reliability for the number of SIJ quadrants or halves with SIJ lesions was assessed by intra-class correlation coefficient (ICC 2.1 (two-way random effects, absolute agreement, single rater/measurement MedCalc v12.6)).

## **RESULTS**

### **Overarching Considerations**

The ASAS-MRI WG consensus emphasized several overarching recommendations pertaining to optimal interpretation of MRI lesions in the SIJ (Table 1). Definitions were categorized according to lesions indicating signs of activity and structural lesions.

### **Lesion definitions indicating signs of activity**

#### **Bone Marrow Edema (BME)**

The ASAS definition for subchondral BME in the SIJ indicative of SpA was not revised from the definition reported previously<sup>3,4</sup>.

#### **Capsulitis**

The wording of this definition was revised from the original description<sup>3</sup> to clarify its location (new reference image Figure 1A).

#### **Joint Space Enhancement**

This is a new definition to replace the original lesion definition named ‘synovitis’<sup>3</sup> and only applies to contrast-enhanced sequences (supplementary Figure). A new definition was considered necessary because of the observation that synovium is only present at the perimeter of the lower



third of the cartilaginous portion of the joint<sup>11</sup>. Concomitant enhancement of tissue at the perimeter of the joint is captured in the definition of capsulitis.

### **Inflammation at the site of erosion**

This is a new definition describing inflammation within an erosion (new reference image Figure 1B).

### **Enthesitis**

This definition has been revised from the original definition<sup>3</sup> to exclude the inter-osseous soft tissues in the ligamentary portion of the SIJ because this could be difficult to distinguish from vascular signal (new reference image Figure 1C).

### **Joint space fluid**

This is a new definition to describe bright signal in the joint space on a T2-weighted fat suppressed sequence (new reference image Figure 1D).

## **Lesion definitions indicating signs of structural change**

### **Erosion**

This definition was revised to include wording that not only describes a breach in cortical bone but also loss of adjacent marrow matrix (new reference images Figures 1A, 1B, 2). It was noted that erosions have variable signal intensity on water-sensitive sequences and the defect may be small (discrete erosion) or large (multiple confluent erosions along the iliac and/or sacral bone) causing pseudo-widening of the joint.

### **Fat lesion (also known as Fat Metaplasia)**

This definition was revised to include morphologic characteristics that indicate fat metaplasia after resolution of an inflammatory lesion, such as distinct border and location adjacent to

subchondral bone, rather than the fat infiltration that may be seen in healthy individuals (new reference image Figure 3A).

### **Fat metaplasia in an erosion cavity (also known as “backfill”)**

This is a new definition and was considered necessary to define a distinctive structural lesion that may develop following resolution of inflammation in an erosion cavity and is comprised of two components: A. Bright signal within the erosion cavity, signifying a reparative process previously termed backfill resembling the transformation of subchondral BME into fat metaplasia that occurs in bone marrow; B. An irregular band of dark signal reflecting sclerosis at the border of the original erosion. This composite lesion may be observed along the vertical height of the joint cavity on a semi-coronal scan after erosions have become confluent (new reference image Figure 3B).

### **Sclerosis**

This definition has not been revised from the previous ASAS definition (new reference image Figure 2)<sup>3</sup>.

### **Ankylosis**

A new definition was considered necessary to clearly indicate that ankylosis is considered present when there is continuity of bright bone marrow signal across the joint space (new reference image Figure 3C).

### **Non-bridging bone-bud**

This is a new definition to describe new bone formation in the SIJ that has not bridged the joint cavity (new reference image Figure 3C).

## **Frequency of SIJ MRI lesions in patients from the ASAS Classification Cohort**

Subchondral BME was the most frequent lesion detected according to majority reader agreement ( $\geq 4$  of 7) and was observed in 40.3% of the 278 cases (Table 2). However, only 31.3% of cases were deemed to have subchondral BME that would meet the ASAS definition of a positive MRI. Other inflammatory lesions were observed  $<10\%$  of cases. Descriptive data based on individual reader assessments was comparable to the majority reader data (supplementary Table 1).

Subchondral BME was also the most frequently detected MRI lesion on granular assessment (supplementary Table 2).

Erosion was the most frequent structural lesion in the SIJ being observed in 28.3% of cases (Table 2). Fat lesion and sclerosis were observed in 19.8% and 16.9% of cases, respectively, while fat metaplasia in an erosion cavity was observed in 7.6%. Ankylosis and bone bud were observed in  $<5\%$  of cases. Fat lesion was the most frequently scored structural lesion according to granular assessment, followed by erosion and sclerosis (supplementary Table 2).

### **Reliability of Detection of SIJ MRI lesions in patients from the ASAS Classification Cohort**

Reliability for detection of active and structural MRI lesions in the SIJ was broadly comparable when all available MRI scans were assessed (Table 3). In particular, reliability (mean kappa (95%CI)) for detection of erosion (0.55 (0.44-0.66)) and fat lesion (0.59 (0.47-0.71)) was almost at the same level as for subchondral BME (0.65 (0.56-0.74)) but less than the reliability for detection of an ASAS positive MRI (0.75 (0.66-0.83)). Reliability for detection of all structural lesions, with the exception of bone bud, was improved when images from the 175 cases with DICOM scans were assessed, which were judged to be better quality images. Reliability for detection of inflammatory lesions was also greater when these DICOM scans were assessed except for detection of subchondral BME and ASAS positive MRI. Acceptable reliability ( $\kappa \geq 0.50$ ) was attained for ASAS positive MRI, subchondral BME, capsulitis, erosion, fat lesion, fat

metaplasia in an erosion cavity, and ankylosis. Reliability (mean ICC (95%CI)) for granular assessment of lesions according to affected number of SIJ quadrants or halves per case was excellent for ankylosis (0.97(0.96-0.98)), very good for subchondral BME (0.83(0.78-0.88)), and acceptable ( $\geq 0.50$ ) for erosion, fat lesion, and sclerosis (supplementary Table 3).

## **DISCUSSION**

The primary objective of this ASAS initiative was to provide an updated international consensus for MRI lesion definitions in the SIJ of patients with SpA and to conduct a first validation exercise assessing the reliability of detection of these lesions in patients from the ASAS classification cohort. Structural lesions occurred almost as frequently as inflammatory lesions and were detected to a comparable degree of reliability as subchondral BME. Certain newly defined lesions were detected less reliably although all occurred at low frequency (<10%) in this cohort.

Reliable detection of subchondral BME meeting the ASAS definition of a positive MRI was comparable to a previous evaluation of MRI scans from cases with early SpA<sup>12</sup>. Subchondral BME was recorded in about 10% more cases than an ASAS positive MRI indicating that readers distinguished between BME indicative of SpA and BME unrelated to SpA. The definition for capsulitis was revised to include further details regarding its location and a new reference image was provided where this lesion is more clearly evident than in the prior publication<sup>3</sup>. Although reliability for its detection was poor when all available scans were evaluated, this was substantially greater when only DICOM images were assessed.

The definition for joint space enhancement generated considerable debate prior to attainment of consensus. Some considered that the only lesion reflecting increased signal in the

joint space on contrast-enhanced sequences is synovitis and argued for no revision to the original definition, which had been named ‘synovitis’, or a minor revision to ‘synovial enhancement’.

Others considered that the increased signal may reflect inflammation in other tissues e.g. cartilage, osteochondral interface or may even occur after trauma. Detailed post-mortem analysis of the healthy sacroiliac joint has shown that synovium is only present in the lower third of the joint and only at the periphery of the joint<sup>11</sup>. Since there is no synovium in the joint space in the interior of the joint, increased signal in the joint space on contrast-enhanced images without any concomitant peripheral enhancement cannot be considered as reflecting synovitis. Moreover, synovitis on contrast-enhanced sequences will usually only be visible as enhancement at the periphery of the joint in its lower one-third and not as enhancement of effusion because this often requires delayed imaging to fully capture gradual leakage of contrast material into joint fluid. These MRI appearances most likely reflect inflammation at the osteochondral interface as this would be consistent with our understanding of early sacroiliitis and histopathological data indicating that the primary lesion in early disease is subchondral inflammation<sup>13,14</sup>. High signal in the joint space on the STIR sequence is not synonymous with joint space enhancement on contrast MRI and a recent report described high STIR signal in the joint space of up to a third of healthy sports enthusiasts<sup>15</sup>.

Inflammation at the site of erosion is a newly defined lesion and a well-known feature of SpA on MRI. Its inclusion as a distinct entity reflects recent work demonstrating that the appearance of erosive lesions on both STIR and T1W sequences changes as the inflammation resolves (*vide infra*). Its contribution to sensitivity and specificity for SpA is unknown and it is possible that even a small erosion with a focus of inflammation in the erosion cavity may be specific for SpA. It is unclear why this lesion was not reliably detected and it may reflect the

complexity of detecting both an erosion on the T1W scan as well as unequivocally bright signal within the erosion cavity on the STIR scan, which could resemble blood vessel if small.

It is now well-established that resolution of subchondral BME in the SIJ may be associated with the appearance of bright tissue on a T1W scan indicating the expression of fatty acids although the histopathology of this tissue is unknown<sup>16-18</sup>. While the appearance of fat in the bone marrow may also be physiological<sup>19,20</sup>, previous reports have shown that the appearance of post-inflammatory fat metaplasia has characteristic features defined by a distinct border, homogeneous increase in T1W signal, and proximity to subchondral bone<sup>21</sup>. This lesion has previously been shown to be reliably detected and to be highly specific for SpA<sup>21,22</sup> although questionable to what degree it enhances diagnosis because of the concomitant presence of lesions such as BME and erosion. The presence of this lesion in the SIJ has been associated with a worse prognostic phenotype characterized by an increased propensity to new bone formation in both the SIJ and spine<sup>23-25</sup>.

It has been shown that resolution of inflammatory lesions in erosions is also associated with the appearance of bright tissue on a T1W scan at the site of erosion<sup>8,17,18</sup>. Since erosions in the SIJ often extend along the vertical height of the iliac and/or sacral joint surface this leads to the appearance of bright signal in the joint space. A band of tissue that is dark on all MRI sequences may be seen at the border of an erosion and is thought to reflect reactive new bone formation. The variable appearance of erosions on T1W scans was first recognized almost a decade ago following assessment of scans from a cross-sectional cohort<sup>26</sup> and a clearer understanding of the evolution of these MRI appearances was then determined in a prospective cohort analysis of patients with SpA<sup>18</sup>. The characteristic appearance of bright signal in the erosion cavity on T1W MRI with a dark irregular band lateral to it was termed backfill to denote

the “filling-in” of the erosion cavity with reparative tissue resembling fat metaplasia<sup>26</sup>. In the ASAS-MRI WG it was decided to name this “fat metaplasia in an erosion cavity”, rather than backfill, to emphasize the descriptive character of the definition, as its histopathological correlate is not fully known. This lesion has also been associated with the development of ankylosis in the SIJ and may therefore have prognostic significance<sup>18</sup>. Reliable detection is challenging because this requires agreement that there is both unequivocally bright signal in the joint space and an adjacent irregular dark band on the T1W scan. However, acceptable reliability was attainable when DICOM images were available despite a low frequency of only 8% in this cohort. Reliability can likely be enhanced with more intensive calibration using web-based DICOM images that provide examples of lesions at the threshold of detection<sup>9,10,27</sup>.

Reliability for detection of erosion has varied widely and this may reflect both the complexity of the lesion as well as the application of different lesion definitions<sup>8,26-29</sup>. Reliability is enhanced when readers are calibrated with a validated online DICOM-based calibration module similar to the one available for readers of the ASAS MRI-WG<sup>9,10,27</sup>. The degree to which readers used this calibration module prior to the scoring exercise was not documented although reliability was greater when DICOM images were available.

The new definition for ankylosis stresses the importance of continuity of bright marrow signal across the joint space on a T1W scan as a defining feature. Reliability was comparatively high when taken in the context of the low frequency of this lesion in this cohort and comparable to a previous report<sup>8</sup>. Reliability for detection of bone bud and enthesitis was low though this may reflect their very low frequency ( $\leq 5\%$ ) in this cohort.

In conclusion, the ASAS MRI-WG provides a consensus-based update of MRI lesion definitions in the SIJ of patients with SpA. Testing of these definitions in scans from the ASAS

classification cohort for agreement among 7 expert readers demonstrated acceptable reliability for most inflammatory and structural lesions even among some lesions that occurred at a frequency of <10%. Validation of these lesions for diagnostic, classification, and prognostic utility is warranted.

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### **Patient and Public Involvement**

This consensus-based initiative was done without patient involvement. Patients were not invited to comment on the study design of the MRI reading exercise and were not consulted to interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

### **Competing Interests**

The authors declare no competing interests

### **Contributorship**

All authors contributed to the design of the study, review of study data, drafting of the final manuscript, and agreed to the final version of the manuscript.

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**Ethical approval**

The study did not require ethical approval.

**Data sharing statement**

The MRI scans and data from the readings reported in this study can be made available after submission of a study proposal to the ASAS MRI-WG.

**Table 1.** Assessments in SpondyloArthritis international Society MRI Working Group Consensus Definitions for MRI Lesions in the Sacroiliac Joint of Patients with Spondyloarthritis

<b>A. OVERARCHING PRINCIPLES</b>
<p>1. When interpreting medical studies of the SIJ in SpA for diagnostic or classification purposes, all available images for that modality should be reviewed at the same time as different slice orientations or sequences may provide additional information that is important for the correct interpretation of the findings. MR images that illustrate different features of sacroiliitis compatible with (or highly suggestive of) SpA, such as active disease and structural damage, should be simultaneously reviewed and interpreted in the context of all findings.</p>
<p>2. Many artifacts occur on MRI of the SIJ and when a feature of uncertain significance is seen in one orientation then, if possible, the feature should be verified on a second orientation. This may be more important for imaging studies used for diagnostic or classification purposes.</p>
<p>3. The SIJ lesion(s) must be clearly present, located in a typical anatomical location, and its appearance must be highly suggestive of SpA. The presence of any small solitary lesion should be interpreted with caution. It is rare for a lesion to be “clearly present” if small and solitary and it is expected that relevant lesions will be either multiple or seen on multiple images (slices, sequences, orientation). If a lesion appears to be present but it is hard to determine whether the lesion is “highly suggestive of SpA”, then the decision may be influenced by the presence of other concomitant lesions<sup>4</sup>.</p>
<p>4. The visual interpretation of an MRI scan of the SIJ should be performed objectively. In the research setting the interpretation will usually be done in the absence of patient data.</p>

But the clinician should interpret the MRI report in the total context of the demographic, clinical, and laboratory information from the patient and although the MRI of the SIJ may be reported as suggestive of SpA the final decision can still be that the patient has no SpA. Other conditions of the SIJ such as fracture, osteoarthritis, sepsis, trauma, neoplasia, and artefacts may resemble lesions observed on MRI in patients with SpA.

## **B. MRI SIJ LESION DEFINITIONS INDICATING SIGNS OF ACTIVITY**

These observations are made on MRI sequences that are sensitive for the detection of disease activity such as T2-weighted (T2W) sequences with fat suppression (FS) that are sensitive for free water (e.g. short tau inversion recovery (STIR)), or T1W sequences with fat suppression that are sensitive for contrast enhancement such as T1WFS post-gadolinium (Gd).

**1. ASAS definition of positive MRI for the classification of SpA** (Figures 1A, B, D, and 2)<sup>3,4</sup>: MRI evidence of bone marrow inflammation must be present and the features required for the definition of active sacroiliitis on MRI are:

A. Bone marrow edema (BME) on a T2W sequence sensitive for free water (e.g. STIR, T2FS) or bone marrow contrast enhancement on a T1W sequence (e.g. T1FS post-Gd).

BME is depicted as a hyperintense signal on STIR images and usually as a hypointense signal on T1 images. A hyperintense signal on contrast-enhanced, T1-weighted, fat-saturated images (T1 post-Gd) reflects increased vascularization and is referred to as osteitis. The sacral interforaminal bone marrow signal forms the reference for assignment of normal signal in the bone marrow<sup>7</sup>.

B. Inflammation must be clearly present and located in a typical anatomical area (subchondral bone).

<p>C. MRI appearance must be highly suggestive of SpA.</p>
<p><b>2. Capsulitis</b> (Figure 1A): Increased signal on STIR and/or T1FS post-Gd, which is observed at the perimeter of the joint (anterior or posterior on axial images, cranial or caudal on semicoronal images).</p>
<p><b>3. Joint Space Enhancement</b> (supplementary figure): Increased signal on contrast-enhanced images in the joint space of the cartilaginous portion of the SIJ.</p>
<p><b>4. Inflammation at the site of erosion</b> (Figures 1B): Increased signal on STIR and/or T1FS post-Gd at the site of erosion.</p>
<p><b>5. Enthesitis</b> (Figure 1C): Increased signal in bone marrow and/or soft tissue on STIR and/or T1FS post-Gd at sites where ligaments and tendons attach to bone, but not including the inter-osseous ligaments of the sacroiliac joint.</p>
<p><b>6. Joint space fluid</b> (Figures 1D): Bright signal in the joint space on STIR images equivalent to cerebrospinal fluid.</p>
<p><b>C. MRI SIJ LESION DEFINITIONS INDICATING SIGNS OF STRUCTURAL CHANGE</b></p> <p>These observations are made on MRI sequences that are sensitive for the detection of structural change. Most of the observations can only be seen clearly on sequences sensitive for fat signal, specifically T1W spin echo without fat suppression.</p>
<p><b>1. Erosion</b> (Figures 1A, 1B, and 2): A defect in subchondral bone associated with full-thickness loss of the dark appearance of the subchondral cortex at its expected location, with loss of signal on a T1W non-fat-suppressed sequence compared to the normal bright appearance of adjacent bone marrow.</p>



**2. Fat Lesion (also known as Fat Metaplasia)** (Figure 3A): Bright signal seen on a T1W non-fat-suppressed sequence that is brighter than normal bone marrow, which meets the following requirements:

- a. Homogeneously bright.
- b. Located in a typical anatomical area (subchondral bone).
- c. Sharply defined along its non-articular border with normal bone marrow.

**3. Fat metaplasia in an erosion cavity (also known as “backfill”)** (Figure 3B): Bright signal on a T1-weighted sequence in a typical location for an erosion or confluent erosions, with signal intensity greater than normal bone marrow, which meets the following requirements:

- a. Associated with complete loss of the dark appearance of the subchondral cortex at its expected location.
- b. Clearly demarcated from adjacent bone marrow by an irregular band of dark signal reflecting sclerosis at the border of the original erosion.

**4. Sclerosis** (Figure 2): Very low signal on all sequences located in a typical anatomical area (subchondral bone).

**5. Ankylosis** (Figure 3C): Abnormal bright signal on a T1W non-fat-suppressed sequence with similar signal intensity to bone marrow, which is in the expected location of the sacroiliac joint space and bridges the joint so that there is continuity of bone marrow signal between the ilium and sacrum. It is associated with full-thickness loss of the dark appearance of the subchondral cortex on both sides of the joint.

**6. Bone bud** (Figure 3C): Abnormal bright signal on a T1W non-fat-suppressed sequence with similar signal intensity to bone marrow, which is in the expected location of the sacroiliac joint space but does not bridge the joint so that it is continuous with the subchondral bone of either the ilium or the sacrum but not both. It is associated with full-thickness loss of the dark appearance of the subchondral cortex on the corresponding side of the joint, at its expected location.

**Table 2.** Descriptive data for global evaluation of active and structural MRI lesions in the SIJ generated by the majority ( $\geq 4$ ) of 7 readers from the ASAS MRI group who assessed 278 scans from the ASAS Classification cohort.\*

<b>Variable</b>	<b>Number (%) of cases</b>
Subchondral BME and meets ASAS definition for positive MRI	87 (31.3%)
Subchondral bone marrow edema	112 (40.3%)
Inflammation at site of erosion	20 (7.2%)
Capsulitis	8 (2.9%)
Joint fluid	18 (6.5%)
Enthesitis	14 (5.0%)
Subchondral sclerosis	40 (16.9%)
Erosion	67 (28.3%)
Fat lesion	47 (19.8%)
Bone bud	1 (0.4%)
Fat metaplasia in an erosion cavity	18 (7.6%)
Ankylosis	6 (2.5%)

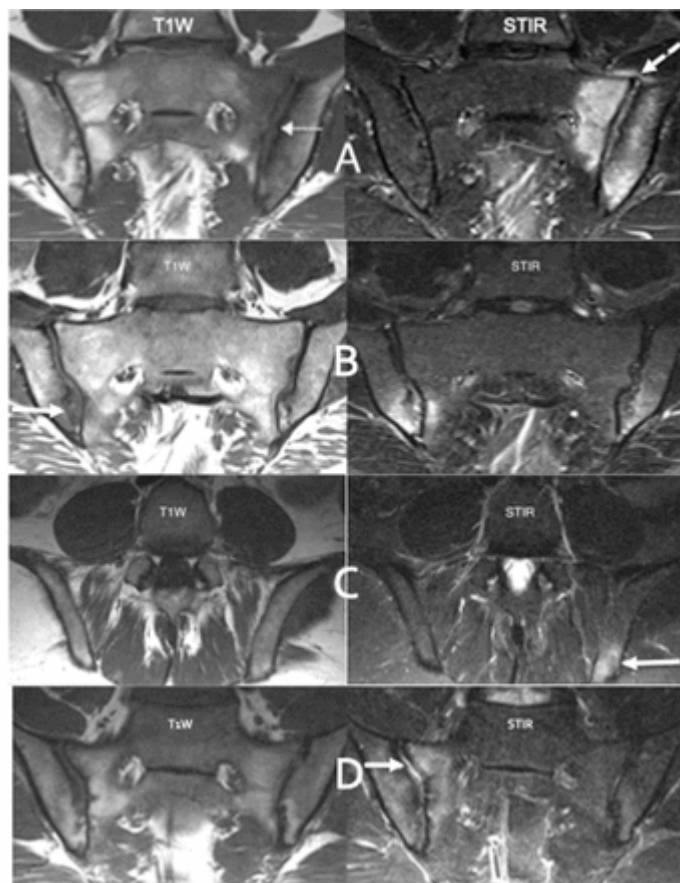
\*Data for structural lesions available from 238 scans

**Table 3.** Reliability ( $\kappa$  values) for detection of active and structural MRI lesions in the SIJ by 7 readers from the ASAS MRI group who assessed MRI scans from the ASAS Classification cohort.

	<b>Mean <math>\kappa</math> of all reader pairs (95% CI)</b>	<b>Median <math>\kappa</math> of all reader pairs</b>	<b>Range of <math>\kappa</math> for all reader pairs</b>
<b>All Available MRI Scans (n=278)</b> (Data for structural lesions available from 238 scans)			
<b>ASAS positive MRI</b>	0.75 (0.66-0.83)	0.75	0.64-0.86
<b>Subchondral bone marrow edema</b>	0.65 (0.56-0.74)	0.65	0.53-0.75
<b>Inflammation at the site of erosion</b>	0.30 (0.13-0.47)	0.30	0.15-0.53
<b>Capsulitis</b>	0.40 (0.14-0.66)	0.42	0.19-0.72
<b>Joint fluid</b>	0.36 (0.21-0.50)	0.36	0.18-0.53
<b>Enthesitis</b>	0.21 (0.05-0.37)	0.17	0.03-0.56
<b>Sclerosis</b>	0.43 (0.30-0.55)	0.42	0.20-0.62
<b>Erosion</b>	0.55 (0.44-0.66)	0.53	0.40-0.69
<b>Fat lesion</b>	0.59 (0.47-0.71)	0.58	0.41-0.72
<b>Fat metaplasia in an erosion cavity</b>	0.46 (0.27-0.66)	0.47	0.22-0.65
<b>Bone bud</b>	0.13 (-0.05-0.30)	0.12	-0.04-0.56
<b>Ankylosis</b>	0.53 (0.21-0.83)	0.49	0.28-0.91
<b>MRI scans with consecutive DICOM Images</b> (Data for active and structural lesions available from 160 and 148 scans, respectively)			
<b>ASAS positive MRI</b>	0.73 (0.61-0.84)	0.73	0.60-0.86
<b>Subchondral bone marrow edema</b>	0.60 (0.49-0.72)	0.60	0.47-0.69
<b>Inflammation at site of erosion</b>	0.37 (0.15-0.58)	0.37	0.18-0.73

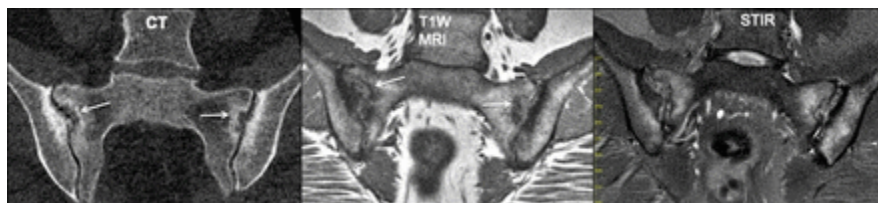
<b>Capsulitis</b>	0.55 (0.18-0.90)	0.56	0.29-0.80
<b>Joint fluid</b>	0.41 (0.23-0.59)	0.41	0.27-0.57
<b>Enthesitis</b>	0.23 (0.03-0.45)	0.20	-0.04-0.66
<b>Sclerosis</b>	0.48 (0.33-0.63)	0.52	0.25-0.68
<b>Erosion</b>	0.61 (0.47-0.75)	0.64	0.41-0.74
<b>Fat lesion</b>	0.61 (0.46-0.76)	0.61	0.32-0.78
<b>Fat metaplasia in an erosion cavity</b>	0.50 (0.26-0.74)	0.47	0.25-0.71
<b>Bone bud</b>	0.11 (-0.06- 0.29)	0.06	-0.06-0.60
<b>Ankylosis</b>	0.58 (0.25-0.89)	0.59	0.32-0.91

## Figure Legends



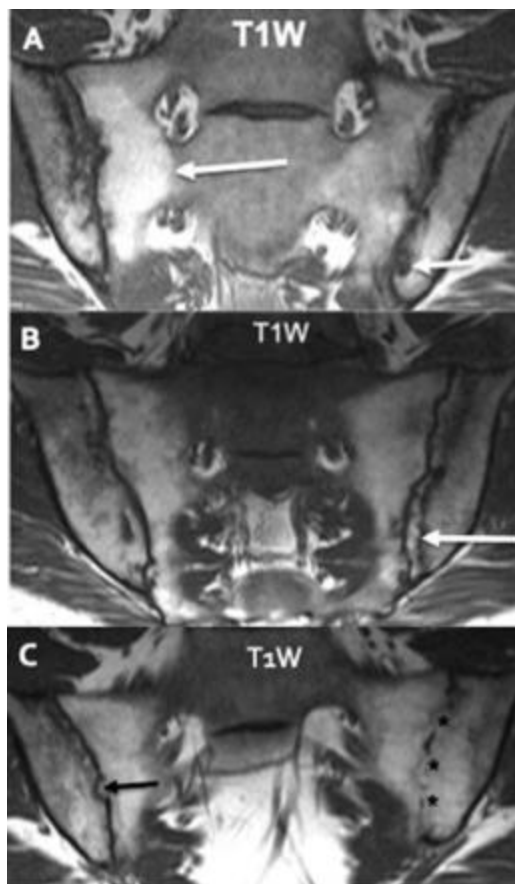
1. **ASAS consensus reference images for active MRI lesions in the sacroiliac joints of patients with spondyloarthritis.** All images have been acquired in the semicoronal orientation. **A.** MRI scans of a 42-year-old male with a one-year history of inflammatory back pain, a single episode of acute anterior uveitis, HLA-B27 positivity, and C-reactive protein level of 67.5 mg/L. Extensive bone marrow edema in the left iliac and sacral subchondral bone marrow is depicted as bright signal on the STIR MRI scan meeting the ASAS definition of a positive MRI. There is loss of the bone marrow fat signal in the corresponding location on the T1W scan and erosion of the entire vertical height of the

left iliac cortical bone with loss of adjacent marrow matrix leading to an appearance of widening of the joint space (arrow). This meets the ASAS definition for erosion. The dashed arrow points to bright signal in the anterosuperior joint capsule on the STIR scan meeting the ASAS definition of capsulitis. **B.** MRI scans of a 35 year-old-male with a 5-year history of inflammatory back pain, lack of response to NSAID therapy, HLA-B27 positivity, and CRP level of 6.8 mg/L. The arrow on the T1W scan points to erosion of the right iliac bone. There is bright signal in the cavity of the erosion on the STIR scan, indicating that there is inflammation within the erosion cavity meeting the ASAS definition. There is also bright signal in the right iliac, left iliac, and right sacral subchondral bone marrow, indicating bone marrow edema meeting the ASAS definition for a positive MRI. **C.** MRI scan of same patient as in B. The arrow on the STIR scan points to bright signal in the bone marrow of the left iliac bone several slices posterior to the sacroiliac joint. This meets the ASAS definition of enthesitis. **D.** MRI scan from a 33-year-old male with a 2-year history of inflammatory back pain, HLA-B27 positive, and CRP level of 18.6 mg/L. The arrow on the STIR scan points to bright signal, with intensity comparable to vascular signal, in the right sacroiliac joint space. This meets the ASAS definition of joint fluid. There is also subchondral bone marrow edema in the right sacral and iliac bones meeting the ASAS definition of a positive MRI.



2. **ASAS consensus reference images for active and structural lesions in the sacroiliac joints of a patient with spondyloarthritis.** MRI scans and CT scan reconstructed in the semicoronal orientation from a 39 year-old-male with a four-year history of inflammatory back pain unresponsive to NSAID therapy, B27 positivity, and CRP level of 18.8mg/L. The arrows on the T1W scan point to large sacral erosions with loss of cortical bone and adjacent marrow matrix meeting the ASAS definition for erosion. This is clearly evident on the CT scan slice corresponding to the MRI slice. On the STIR scan, bone marrow edema is visible in all four bones meeting the ASAS definition of a positive MRI. There is dark signal in both iliac bones on both MRI sequences meeting the ASAS definition for bone sclerosis. This is also apparent on the CT scan.





3. **ASAS consensus reference images for structural MRI lesions in the sacroiliac joints of patients with spondyloarthritis.** All images have been acquired in the semicoronal orientation. **A.** MRI scan of a 32-year-old male with a three-year history of inflammatory back pain, Crohn's colitis controlled with TNF inhibitor therapy, HLA-B27 negativity, and CRP level of 3.5 mg/L. The arrow points to a region of homogeneously increased signal in the right sacral bone marrow on the T1W scan that has a distinct border and is adjacent to subchondral bone and erosion of the right sacral cortex. This appearance meets the ASAS definition for fat metaplasia related to SpA. There are smaller areas of fat metaplasia in both lower iliac bones adjacent to areas of erosion, especially the left iliac cortex (arrow). **B.** ASAS consensus reference image for fat metaplasia in an erosion cavity of the sacroiliac joint of a patient with spondyloarthritis. Semicoronal T1W MRI

scan of a 48-year-old male with a 14-year history of inflammatory back pain, symptoms controlled by NSAID therapy, HLA-B27 positivity, and CRP level of 5.7 mg/L. The arrow on the T1W scan points to a bright signal on the joint surface of the left iliac bone bordered laterally by a vertical irregular dark band. This meets the ASAS definition for fat metaplasia in an erosion cavity (backfill). **C.** ASAS consensus reference image for ankylosis and bone bud in a patient with spondyloarthritis. MRI scans of a 54-year-old female with a twenty three-year history of inflammatory back pain responsive to NSAID therapy, HLA-B27 positivity, and CRP level of 4.2 mg/L. The arrow on the T1W scan points to abnormal bright signal which protrudes into the sacroiliac joint space but does not bridge the joint. This meets the ASAS definition for bone bud. The asterisks on the T1W scan point to several regions of the left sacroiliac joint where there is continuity of bright marrow signal from ilium to sacrum across the joint space meeting the ASAS definition for ankylosis.

## **KEY MESSAGES**

### **What is already known?**

- Growing evidence demonstrates an increased spectrum of MRI lesions in the sacroiliac joint related to spondyloarthritis and more clearly defined associations between inflammatory and structural lesions over time but standardization of SIJ lesion definitions has not been updated for a decade.

### **What does this study add?**

- The Assessments in SpondyloArthritis international Society MRI Working Group reports a consensus-based update of standardized MRI SIJ lesion definitions relevant to SpA, which includes several new definitions for both inflammatory and structural lesions.
- These definitions were validated in a multi-reader exercise using 278 scans from the ASAS classification cohort which demonstrated acceptable reliability for most inflammatory and structural lesions, even for those occurring at low frequency.

### **How might this impact on clinical practice or future developments?**

- The updated definitions are aimed at enhancing educational and research initiatives towards improving early diagnosis, classification, and prognostic assessment.

