Sacroiliitis Associated with Axial Spondyloarthropathy: New Concepts and Latest Trends

Maria Navallas, MD • Jesús Ares, MD • Brigitte Beltrán, MD • María Pilar Lisbona, MD • Joan Maymó, MD • Albert Solano, MD

The sacroiliac joints are involved in most cases of axial spondyloarthropathy, the first manifestation usually being sacroiliitis. A finding of sacroiliitis at radiography is the classic diagnostic hallmark of axial spondyloarthropathy. However, radiographic changes reflect structural damage rather than active inflammation, which may delay the diagnosis by several years. In the past decade, the field of spondyloarthropathy has undergone major changes, largely driven by the development of new drugs for the treatment of ankylosing spondylitis. In recent years, the Assessment of SpondyloArthritis international Society has focused on the reassessment of existing classification criteria and the development and validation of diagnostic tools to facilitate early diagnosis and assessment of treatment response. Magnetic resonance (MR) imaging is the most recent innovation and the important change with respect to the previously established classification criteria. This modality has become an integral part of managing patients with sacroiliitis. MR imaging can serve as a biomarker of disease activity, allows monitoring, and can provide guidance for the treatment of affected patients, and it will likely become even more central to the care of these patients. Familiarity with the anatomy, anatomic variants, and physiologic changes of the sacroiliac joints is important for correctly interpreting findings and avoiding misdiagnosis.

©RSNA, 2013 • radiographics.rsna.org
Introduction

Spondyloarthropathy comprises a group of chronic inflammatory rheumatic diseases, including ankylosing spondylitis, reactive arthritis (Reiter syndrome), arthritis or spondylitis associated with inflammatory bowel disease, and psoriatic arthritis, as well as undifferentiated spondyloarthritis (1). These afflictions predominantly affect the axial skeleton, causing pain and stiffness (2); are seronegative for rheumatoid factor; and are often associated with the presence of human lymphocyte antigen (HLA)–B27 (3). They are largely differentiated on the basis of clinical information and the distribution of radiographic abnormalities (4).

The sacroiliac joints are involved in most cases of axial spondyloarthropathy, with sacroiliitis usually being the first manifestation (5,6).

In the past decade, the field of spondyloarthropathies has undergone major changes, largely driven by the development of new drugs for the treatment of ankylosing spondylitis (7), such as tumor necrosis factor (TNF)–α inhibitors (anti-TNF). The lack of valid biochemical markers for disease activity and the low sensitivity of radiography have necessitated the use of other diagnostic methods to support clinical assessment.

The new Assessment of SpondyloArthritis international Society (ASAS) criteria, which include magnetic resonance (MR) imaging findings, facilitate early diagnosis and assessment of treatment response because of the capacity of MR imaging to help detect active inflammation.

In this article, we provide a comprehensive review and update of the most relevant aspects of assessment for spondyloarthritis, with an emphasis on sacroiliitis. In addition, we discuss classification criteria, anatomy, and imaging techniques, as well as the findings used for diagnosis and follow-up. We also discuss MR imaging, the most recent innovation and most important change with respect to the previously established classification criteria, in terms of imaging protocol, common acute and chronic findings, and the definition of a positive MR imaging study. Furthermore, we describe different methods of monitoring disease activity, including diffusion-weighted imaging and dynamic contrast material–enhanced imaging.

Classification Criteria

Making a prompt and correct diagnosis of spondyloarthropathy has always been a challenge. The established classification criteria, such as the 1984 modified New York criteria for ankylosing spondylitis (8), the Amor criteria proposed in 1990–1991 (9), and the European Spondyloarthritis Study Group criteria (10), rely on the combination of clinical symptoms and a definite radiographic finding of sacroiliitis. However, conventional radiographs are usually normal at the onset of symptoms, and the diagnosis is commonly delayed by 8–11 years (11).

To date, appropriate criteria for diagnosing or classifying cases of axial spondyloarthropathy without radiographic changes, referred to as nonradiographic axial spondyloarthropathy, have been lacking (12). Consequently, the ASAS has developed new classification criteria for axial spondyloarthropathies. For the first time, these criteria include the use of MR imaging for early diagnosis and objective outcome measurement for clinical trials. Thus, the use of MR imaging is the most current breakthrough and the most important change with respect to the previously established criteria. With MR imaging, spondyloarthropathy can be diagnosed and treated in its early stages before structural damage occurs. This is important because patients with “preradiographic” disease have as much inflammatory activity and pain as patients with established spondyloarthropathy and respond well to treatment with anti-TNF (13). Furthermore, the use of MR imaging as a biomarker for disease activity and as a guide for the treatment of sacroiliitis (14) has revolutionized the care of these patients.

The ASAS criteria apply to patients with at least a 3-month history of back pain who are less than 45 years old at the onset of pain. Spondyloarthropathy is diagnosed radiologically in patients with sacroiliitis and is defined as (a) acute inflammation at MR imaging with bone marrow edema or osteitis, or (b) definite radiographic changes according to the modified New York criteria (7,15), plus (c) at least one clinical feature of spondyloarthropathy (Table 1). Spondyloarthropathy can also be diagnosed on the basis of the presence of HLA-B27 and at least two other clinical features of spondyloarthropathy (Table 1).

The sensitivity and specificity of the new classification criteria for axial spondyloarthropathy were 82.9% and 84.4%, respectively, and for the
Figure 1. (a) Coronal oblique fat-suppressed T1-weighted MR image of the normal sacroiliac joint in a 51-year-old man shows the smooth and parallel margins of the cartilaginous lower ventral portion (arrows). (b) Coronal oblique fat-suppressed T1-weighted MR image obtained more posteriorly shows the irregular edges of the fibrous or ligamentous upper dorsal portion (arrowheads). MR imaging makes it possible to distinguish between the compartments of the sacroiliac joint.

Imaging arm alone they were 66.2% and 97.3%, respectively (16). The specificity of the new criteria was much better than that of the European Spondylarthropathy Study Group criteria modified for MR imaging (sensitivity, 85.1%; specificity, 65.1%) and somewhat better than that of the modified Amor criteria (sensitivity, 82.9%; specificity, 77.5%) (16).

**Anatomic Considerations**

**Normal Anatomy**
The sacroiliac joint is a very complex structure that undergoes many physiologic changes over a lifetime and has many anatomic variants. Imaging tests provide good support for the diagnosis of the etiology of back pain. However, it is necessary to know the anatomic variants and the normal changes in this joint to correctly interpret the imaging findings and avoid misdiagnosis of disease.

The sacroiliac joint has two well-differentiated parts. The first is a lower ventral part with (a) anatomic characteristics of a cartilaginous articulation consistent with a symphysis (15), (b) hyaline cartilage firmly attached to the adjacent bone by fibrous tissue (17), and (c) smooth and parallel margins (18). There is also an upper dorsal part, a syndesmosis (ie, a fibrous joint in which the bone surfaces are united by interosseous ligaments) (17) with very irregular edges (Figs 1, 2) (18). In the

| Table 1: ASAS Criteria for the Classification of Axial Spondyloarthropathy |
|-----------------------------|---------------------------------------------------------------|
| Criteria | Clinical Features of Spondyloarthropathy                      |
| Acute inflammation at MR imaging with bone marrow edema or osteitis, or definite radiographic changes according to the modified New York criteria, plus at least one clinical feature of spondylarthropathy | Inflammatory back pain, arthritis, enthesitis (heel), uveitis, dactylitis, psoriasis, Crohn disease/colitis, good response to NSAIDs, family history of spondyloarthropathy, HLA-B27, elevated CRP level |
| Presence of HLA-B27 and at least two other clinical features of spondylarthropathy |                                                                 |

**Note.**—Criteria apply to patients with at least a 3-month history of back pain who are less than 45 years old at the onset of pain. CRP = C-reactive protein, NSAID = nonsteroidal anti-inflammatory drug.
distal one-third of the joint, the margins of the iliac joint facet resemble those of a synovial joint and include an inner capsule with synovial cells (15). Keep in mind that the hyaline cartilage in the anterior joint is thicker on the sacral side than along the iliac margin, which is why structural changes are initiated and are more profuse on the iliac facet (19).

There are significant age- and sex-related differences in the normal MR imaging morphology of pediatric sacroiliac joints, which demonstrate cartilaginous connections to the intervertebral foramina at the level of the rudimentary intervertebral disks of the sacrum. These segmental apophyses of the sacral wings become progressively ossified from age 9 to 16 years, earlier in girls than in boys. Furthermore, the lateral apophyses of the sacral wings manifest as marginal cartilaginous rims adjacent to the sacroiliac joints and show progressive ossification from age 9 to 17 years (again, earlier in girls than in boys) (Fig 3) (20).

The ligaments that contribute to joint stability include the interosseous, ventral and dorsal sacroiliac, sacrospinous and sacrotuberous, and iliolumbar ligaments.

**Anatomic Variants**

Many anatomic variants, some of which may be symptomatic, can occur in the sacroiliac joints. Awareness of these variants is paramount for avoiding diagnostic errors because they may simulate joint abnormalities associated with sacroiliitis (15). An accessory sacroiliac joint is the most common variant. It is located at the posterosuperior portion of the joint and may develop degenerative changes, thereby causing low back pain (Fig 4a). An iliosacral complex is formed by an iliac projection inserted into a complementary sacral recess and is usually located at the transitional zone between the synovial and ligamentous portions of the joint. A bipartite iliac bone plate is located at the posteroinferior portion of the joint (Fig 4b). Other anatomic variants such as a crescentic iliac articular surface (usually at the posterosuperior portion of the joint),
Figure 3. Normal anatomy of the sacroiliac joint in a 12-year-old girl. Coronal oblique fatsuppressed T1-weighted MR image shows the hyperintense joint cartilage (white arrow) and the cartilaginous segmental apophyses of the sacral wings (arrowhead). Mildly hyperintense rims are seen in the lateral apophyses of the sacral wings between the sacroiliac joints and the sacral bone marrow (black arrow). The junctions between the sacroiliac joints and the segmental apophyses are depicted as rhomboid cartilaginous extensions (*).

Figure 4. Anatomic variants of the sacroiliac joints. (a) Axial computed tomographic (CT) image obtained in a 65-year-old woman shows bilateral accessory sacroiliac joints with flat, irregular, and mildly sclerotic articular facets (arrows). (b) Axial CT image obtained in a 58-year-old woman shows bilateral bipartite iliac bone plates (arrowheads).

Physiologic Changes

Age-related changes in the sacroiliac joint begin in puberty and continue throughout life (21). Some kind of degeneration can be found in all joints after the age of 50 years. These changes are more profuse in females than in males of the same age and progress faster in multiparous than in nulliparous women (22). As a consequence, differentiating between sacroiliitis and degenerative changes can be difficult. One of the most common changes is loss of joint space (normal width = approximately 2.49 mm ± 0.66 in people under 40 years of age and 1.47 mm ± 0.21 in older people) (23). Vogler et al (24) used CT to study the sacroiliac joints of 45 asymptomatic subjects and found the joints to be symmetric in people under the age of 30 years and asymmetric in older people. In addition, they found that nonuniform iliac sclerosis, focal joint space narrowing in patients over 30 years of age, and ill-defined areas of subchondral sclerosis, particularly on the iliac side, occur frequently in the asymptomatic population and are, therefore, poor indicators of sacroiliitis (24). On the other hand, sacral subchondral sclerosis (in young people), uniform joint space narrowing, erosions, and intraarticular ankylosis are rarely found in asymptomatic patients and consequently may represent good indicators of sacroiliitis (24). Finally, osteophytes, pneumocysts, and the “articular vacuum sign” are characteristic of osteoarthritis, although the latter can also be detected in patients with sacroiliitis without active inflammation (22).
Imaging Techniques

Imaging is an important tool in the diagnostic evaluation of the sacroiliac joint. The decision as to which imaging technique to perform should be based on disease duration, suspicion for inflammatory activity or infectious disease, and the patient’s age. A common algorithm proposed for investigating the sacroiliac joint consists of radiography performed as the first imaging method after evaluation of clinical and laboratory findings. The unequivocal presence at radiography of sacroiliitis in a patient with inflammatory back pain is sufficient to establish the diagnosis (8). However, when the radiographic findings do not support the clinical diagnosis, additional imaging may provide more information (25). Thus, if radiographic findings are negative, a diagnosis of axial spondyloarthritis can still be made based on the presence of active inflammation at MR imaging (16).

At our institution, once the diagnosis has been established, conventional radiography is usually performed every 2–3 years as a monitoring measure. However, this is changing because of the key role that MR imaging has begun to play in the follow-up of patients with spondyloarthritis. MR imaging has become the new biomarker of disease activity because of its capacity to help detect inflammatory changes, even in advanced stages in which ankylosis of the sacroiliac joint has emerged (26). More important, MR imaging is able to help quantify inflammatory activity, which makes it ideal for monitoring disease activity and for guiding treatment of sacroiliitis.

CT is performed only in equivocal cases to confirm the presence of incipient erosions or intraarticular ankylosis.

Radiography

Radiography is the most widely accepted imaging method for diagnosing sacroiliitis (27) because it is relatively inexpensive, readily available, and, when it yields positive findings, very helpful (28). However, radiography can help detect only chronic bone changes, which usually require several years to become evident, clearly causing a delay in diagnosis (5,29). Furthermore, radiographs are difficult to interpret (30–33), intra- and interobserver correlation is low (34,35), and active inflammation cannot be assessed.

With respect to protocol, the ASAS recommends performing radiography of the whole pelvis to assess the hip joints as well as the sacroiliac joints (Fig 5) (27). In most circumstances, anteroposterior radiography of the pelvis will yield a diagnosis of sacroiliitis, without the additional radiation exposure and expense involved in radiography of specific sacroiliac joints (36). In addition, it is important to visualize the hip joints, since they are affected in 25% of patients with spondyloarthritis (27).

According to the modified New York criteria, five grades—from 0 (normal) to 4 (ankylosis) can be differentiated (8). Grade 0 denotes normal sacroiliac joints with well-defined margins; grade 1, suspicious changes with incipient sclerosis and decreased focal thickness of the articular space; grade 2, minimal abnormality with loss of definition of the articular margins, subchondral osteoporosis, and areas of reactive sclerosis; grade 3, unequivocal abnormality with subchondral sclerosis of both sacral and iliac articular margins (predominantly on the iliac side), erosions, reduced articular space, widening of the joint space, and incipient ankylosis; and grade 4, complete ankylosis with residual sclerosis, which tends to decrease over time. On the basis of the modified New York criteria, bilateral changes corresponding to grade 2 or higher, or unilateral changes corresponding to grade 3 or higher, must be detected to diagnose sacroiliitis radiographically.
Computed Tomography

CT is more sensitive than conventional radiography for the detection of structural changes; therefore, it allows a more detailed assessment of the sacroiliac joints (40–42). In addition, there is less interobserver variability in the interpretation of CT findings (41,43), and, unlike MR imaging, CT allows good evaluation of bone proliferation in the ligamentous portion of the joint (44). Drawbacks of CT include radiation exposure and the inability to assess for the presence of active inflammation.

To accurately interpret a CT scan of the sacroiliac joints, coronal and axial oblique multiplanar reformation must be performed parallel and perpendicular to the long axis of the sacrum, with a high-resolution algorithm.

The CT findings of sacroiliitis are similar to those seen at radiography and include erosions, sclerosis, and, eventually (if the disease progresses), ankylosis (Figs 6, 7) (45). A 2003 workshop on sacroiliitis proposed a grading system for CT findings in which grade IA denotes a sacroiliac joint articular space greater than 4 mm; IB, a sacroiliac joint space less than 2 mm; IIA, contour irregularities; IIB, erosions (appearing early in
the iliac aspect and later on the sacral side); IIIA, significant subchondral sclerosis; IIIB, spur formation; IVA, transarticular bone bridges; and IVB, total ankylosis (27).

**MR Imaging**

MR imaging is now one of the cardinal tools for diagnosing sacroiliitis associated with axial spondyloarthropathy because it allows assessment of acute inflammatory changes (42, 46). This means that MR imaging can show incipient changes in the cartilage and acute inflammatory activity in the subchondral bone, ligaments, synovium, and capsular region. Of these findings, bone marrow edema is the first to appear (47). In addition, MR imaging has a similar sensitivity to CT in detecting early structural changes and a better sensitivity for assessing fatty deposits (46), and, unlike CT, it involves no radiation exposure. Drawbacks of MR imaging are mostly related to ferromagnetic implants, cardiac pacemakers, and claustrophobia.

**Protocol.**—At most institutions, coronal oblique imaging parallel to the long axis of the sacrum is standard MR imaging procedure. However, to achieve optimum sensitivity to changes in the ligamentous portion, imaging in two perpendicular (coronal and axial oblique) planes is required (44). The entire sacral bone should be imaged from its anterior to its posterior border, which usually requires at least 10–12 sections.

The basic protocol consists of coronal and axial oblique fast spin-echo T1-weighted sequences to detect structural changes, and coronal and axial oblique short inversion time inversion-recovery (STIR) or fat-saturated fast spin-echo T2-weighted sequences to detect acute inflammatory changes. For the latter purpose, STIR images provide more information than T2-weighted images (15) but about the same amount of information as fat-saturated T2-weighted images (7, 26). STIR and fat-saturated T2-weighted sequences are comparable in terms of image contrast and spatial resolution, depicting active inflammatory lesions in sacroiliitis as increased signal intensity due to the presence of increased amounts of free water and their T2 effects (48). Therefore, we recommend using the highest-quality fluid-sensitive sequence that can be performed on the available MR imager. In addition, active inflammatory changes in the sacroiliac joints can be demonstrated with fat-saturated fast spin-echo T1-weighted sequences after the administration of gadolinium-based contrast material. These sequences depict areas of increased vascularization due to increased diffusion of gadolinium into the interstitial space and its T1-shortening effect (48). Regarding the use of paramagnetic contrast medium, it has traditionally been thought that STIR and fat-saturated T2-weighted sequences are slightly less sensitive than contrast-enhanced T1-weighted sequences for determining the extent of acute inflammatory changes (26, 27, 44).

In a recent study, inflammatory changes in the bone marrow were detected with almost equal frequency on STIR and contrast-enhanced fat-saturated T1-weighted images in patients with spondyloarthropathy. STIR imaging was more sensitive in the periphery of areas with fatty infiltration, whereas contrast-enhanced fat-saturated T1-weighted imaging was more sensitive in detecting small subchondral lesions, mainly because of its higher spatial resolution (49). Furthermore, the intravenous administration of gadolinium-based contrast material helps detect subtle osteitis or bone marrow edema and other imaging findings that are sometimes difficult to see without contrast material administration (eg, enthesitis and capsulitis) (50). Moreover, administration of a paramagnetic contrast agent is required to differentiate synovitis from joint effusion. Thus, contrast-enhanced images ensure maximum diagnostic reliability in patients with early-stage sacroiliitis (48). Furthermore, such images allow inflammatory changes to be quantified and monitored (48), a capability that really sets contrast-enhanced imaging apart from other MR sequences and imaging techniques, and that is changing the paradigm for the care of patients with spondyloarthropathies. Imaging can now be used to initiate and guide therapy. On the other hand, if a contrast agent is used, the subtraction technique may be useful in the early detection of active sacroiliitis because it makes inflammatory changes more conspicuous (51).

In addition to the aforementioned sequences, inclusion of a fat-saturated T1-weighted or gradient-echo T2-weighted sequence provides good contrast between cartilage and subchondral bone and is very sensitive for the detection of erosions (Fig 8) (12, 44). A recent report evaluated the effi-
Coronal oblique T1-weighted MR images obtained without (a) and with (b) fat suppression in a 33-year-old man with ankylosing spondylitis show periarticular fatty deposits (white arrowheads) and subchondral iliac sclerosis (arrow) in the right sacroiliac joint. Note how the joint space (black arrowhead) is better depicted after fat suppression.

Figure 8. Coronal oblique T1-weighted MR images obtained without (a) and with (b) fat suppression in a 33-year-old man with ankylosing spondylitis show periarticular fatty deposits (white arrowheads) and subchondral iliac sclerosis (arrow) in the right sacroiliac joint. Note how the joint space (black arrowhead) is better depicted after fat suppression.

cacy of fat-saturated spin-echo T1-weighted, three-dimensional fast low-angle shot (3D FLASH), and 3D double excitation in the steady state (DESS) sequences for the assessment of the morphology of sacroiliac joint bone cortex and cartilage in patients with clinically suspected active sacroiliitis (52). The authors found 3D FLASH to be the most useful sequence for the detection of cartilaginous and cortical bone abnormalities (52). Other sequences that should also be performed include dynamic contrast-enhanced and diffusion-weighted sequences (discussed later).

All of our patients were examined with a 3.0-T MR imager (Intera Achieva Quasar Dual X series; Philips, Best, the Netherlands). Imaging was performed using a 15-element phased-array SENSE spinal coil with the patient in the supine position. The following sequences were used:

1. Coronal and axial oblique fast spin-echo T1-weighted sequences (repetition time [TR] msec/echo time [TE] msec = 530/8, 172 × 122 and 172 × 124 matrixes, respectively).

2. Coronal oblique turbo spin-echo T2 spectral presaturation with inversion recovery (SPIR) sequence (TR/TE = 2280/80, 172 × 119 matrix).

3. Coronal oblique fast spin-echo T1-weighted SPIR sequence (TR/TE = 415/8, 172 × 122 matrix).


5. Single-shot spin-echo echoplanar sequences with diffusion gradient b values of 0, 600, and 1000 sec/mm² or 0, 400, and 800 sec/mm². The following diffusion-weighted imaging parameters were used: TR/TE = 4621/57, 18 × 18-cm field of view, four signals acquired, 80 × 71 matrix, 3-mm section thickness, and 1-mm intersection gap.

6. Three-dimensional fast-field-echo fat-suppressed T1-weighted sequence. Images were acquired dynamically in 40 consecutive sections every 12.5 seconds in 14 time frames. Between the first and second measurements, a bolus of 0.1 mmol of gadopentetate dimeglumine per kilogram of body weight was injected intravenously.

7. Coronal and axial oblique fast spin-echo T1-weighted SPIR sequences (performed after dynamic contrast-enhanced imaging and, therefore, after the administration of contrast medium) (TR/TE = 415/8, 172 × 122 and 172 × 124 matrixes, respectively).

All sequences except the diffusion-weighted and dynamic contrast-enhanced sequences were performed with the following parameters: field of view = 17 × 17; section thickness = 3 mm (coronal oblique) or 4 mm (axial oblique); intersection gap = 1.5 mm, except for STIR imaging (1-mm gap); and number of signals acquired = two.
Figure 9. Coronal oblique fat-suppressed T2-weighted MR image of the sacroiliac joints in a 32-year-old man with ankylosing spondylitis shows bilateral periarticular bone marrow edema (arrows).

Figure 10. Inflammatory sacroiliitis and spondylodiskitis in a 39-year-old man with ankylosing spondylitis. Coronal oblique fat-suppressed T1-weighted MR images obtained before (a) and after (b) the administration of paramagnetic contrast medium show marked irregularity and several erosions of both sacroiliac joints (arrows in a, white arrows in b), as well as a large erosion on the superior S1 endplate (arrowhead). Note the enhancement of the synovial portion of both joints (black arrows in b), a finding that is consistent with synovitis, and the enhancement of the S1 endplate erosion, a finding that is consistent with inflammatory spondylodiskitis (Andersson lesion).

Imaging Findings.—Active inflammatory lesions (ie, bone marrow edema, synovitis, capsulitis, and enthesitis) can be visualized on STIR, fat-suppressed T2-weighted, and contrast-enhanced fat-suppressed T1-weighted images. Bone marrow edema manifests with increased signal intensity on fat-saturated fast spin-echo T2-weighted or STIR images, and with enhancement on gadolinium-enhanced fat-saturated fast spin-echo T1-weighted images. It is located periarticularly and may be associated with structural changes such as erosions (Fig 9). Sacral interforaminal bone marrow signal is the standard of reference for normal bone marrow signal. Synovitis can be differentiated from joint fluid only after the administration of paramagnetic contrast medium and manifests as enhancement in the synovial part of the joint (Figs 10, 11). Capsulitis may involve the anterior and posterior capsule, and it is sometimes easier to detect on contrast-enhanced fat-suppressed T1-weighted images than on STIR or fat-suppressed T2-weighted images (Fig 12). Finally, enthesitis

Figure 12. (a, b) Capsulitis and enthesitis in a 33-year-old man with ankylosing spondylitis. Coronal oblique (a) and axial oblique (b) contrast-enhanced fat-suppressed T1-weighted MR images show enhancement of both anterior capsules (arrowheads), a finding that is consistent with anterior capsulitis; enhancement of the ligamentous aspect of both sacroiliac joints (arrows in a), a finding that is consistent with enthesitis, along with enhancement of the right zygoapophyseal facet joint (white arrow in b); and endplate erosions (black arrow in b). (c, d) Capsulitis and enthesitis in a 49-year-old woman with ankylosing spondylitis. Coronal oblique fat-suppressed T1-weighted MR images obtained before (c) and after (d) the administration of paramagnetic contrast medium show postcontrast enhancement of the posterior capsule, especially on the right side (white arrowheads in d), a finding that is consistent with posterior capsulitis; adjacent bone marrow edema (black arrowhead in d); and left-sided enthesitis (arrow in d).
Figure 11. Bone marrow edema and synovitis in a 32-year-old man with ankylosing spondylitis. Coronal oblique fat-suppressed T2-weighted (a) and contrast-enhanced fat-suppressed T1-weighted (b) MR images show bilateral hyperintense sacral and iliac areas consistent with bone marrow edema (arrows), along with enhancing foci in both sacroiliac joints (arrowheads in b) consistent with synovitis. Note that synovitis can be confirmed only after the administration of paramagnetic contrast medium.
Figure 13. Enthesitis in a 37-year-old man with undifferentiated spondyloarthropathy. Coronal oblique contrast-enhanced fat-suppressed T1-weighted MR image shows marked enhancement of the ligamentous aspect of the left sacroiliac joint (arrow), a finding that is consistent with enthesitis. Intravenous administration of gadolinium-based contrast material helps detect enthesitis and ensures maximum diagnostic reliability, since it has been shown that a nonnegligible percentage of healthy individuals and patients with nonspecific low back pain have a degree of bone marrow edema that meets the proposed criteria for a positive MR imaging examination.

Chronic or structural lesions are usually well depicted on T1-weighted images and include subchondral sclerosis, erosions, periarticular fat deposits, and ankylosis. With all sequences, subchondral sclerosis manifests as low-signal-intensity bands that typically extend at least 5 mm from the sacroiliac joint space, since small areas of periarticular sclerosis may represent physiologic or degenerative changes (Fig 8). Erosions are bone defects at the joint margin of the cartilaginous compartment and appear as hypointense foci on T1-weighted images and (if active) as hyperintense foci on STIR images, often being better depicted on gradient-echo T2-weighted or fat-suppressed T1-weighted images (Fig 14). Erosions are usually more prominent

Figure 14. Coronal oblique T1-weighted MR images obtained without (a) and with (b) fat suppression in a 44-year-old man with ankylosing spondylitis show bilateral hyperintense sacral areas that become hypointense after fat suppression (arrows), findings that are consistent with fat deposits, as well as irregular margins of both sacroiliac joints. Note that the iliac and sacral bone erosions on the right sacroiliac joint (arrowhead) are difficult to distinguish without fat suppression.
Figure 15. Coronal oblique T1-weighted MR image obtained in a 61-year-old man with ankylosing spondylitis shows complete fusion of both sacroiliac joints (arrows).

Figure 16. Septic sacroiliitis in a 14-year-old boy. Axial contrast-enhanced fat-suppressed T1-weighted MR image shows articular effusion (black arrow), bone marrow edema (arrowheads), intramuscular abscesses, and inflammatory soft-tissue changes (white arrow) on the right side.

anteroinferiorly and on the iliac side of the joint, where cartilage is thinner and subchondral bone is less protected (43). The confluence of erosions may cause apparent widening of the joint. Fat deposits, which appear hyperintense on non-fat-suppressed T1-weighted images, are a nonspecific finding that probably indicates areas of previous inflammation (Fig 14). Bone bridges or ankylosis typically result from the fusion of bone buds that have formed during the course of inflammation and face each other, and may cause the joint cavity to have a blurred appearance (Fig 15) (12).

According to the new ASAS criteria for axial spondyloarthropathy, the presence of subchondral or periarticular bone marrow edema is mandatory for the definition of sacroiliitis at MR imaging. If there is only one lesion, it should be present on at least two sections; if there is more than one lesion on a single section, that section is sufficient for making the diagnosis. The presence of synovitis, capsulitis, or enthesitis is consistent with but not sufficient for making the diagnosis of active sacroiliitis. Structural lesions such as fat deposits, sclerosis, erosions, and bone ankylosis are likely to reflect previous inflammation, but they do not suffice for the definition of a positive MR imaging examination (12).

Differential Diagnosis and Pitfalls.—Many conditions, such as osteoarthritis, septic sacroiliitis (Fig 16), insufficiency sacral fractures, osteitis condensans ili, and bone tumors, may mimic the inflammatory lesions seen in spondyloarthropathies. However, sacroiliac joint inflammation in spondyloarthropathies is usually limited to the bone and sacroiliac joint space and does not cross anatomic borders. With osteoarthritis, it is not uncommon to see anterior osteophytes surrounding the sacroiliac joints. Osteitis condensans ili is typically seen in middle-aged women, in whom it manifests as sclerotic areas, mainly in the iliac bone, with relatively normal joint spaces.
In addition, ligaments surrounded by blood vessels may appear to be, and may erroneously be interpreted as being, actively inflamed on STIR images (12), and clefts, ligaments, and cysts can also be confused with structural lesions (7). Furthermore, inadequate fat suppression may cause normal anatomic structures to appear hyperintense, especially in the posterior part of the sacrum. In addition, the so-called coil effect may result in brighter signal closer to the coil-body interface. Similar effects on the adjacent soft tissue help distinguish these conditions from real alterations (50).

Utility of MR Imaging.—An international multicenter MR imaging study by the MORPHO International MR imaging Group involving 187 patients with spondyloarthropathy and age- and sex-matched control subjects demonstrated the high diagnostic utility of MR imaging (53). The study revealed that structural changes occur sooner than previously thought and are evident in patients with less than a 2-year history of symptoms, and that they can be detected earlier with MR imaging than with conventional radiography. In addition, bone marrow edema and fat infiltration are relatively nonspecific findings and may occur even in healthy, asymptomatic individuals. In fact, bone marrow edema meeting the proposed ASAS criteria for a positive MR imaging examination was recorded concordantly in 23% of patients with nonspecific back pain and 7% of healthy control subjects. The clinical implication is that low-grade acute lesions of the sacroiliac joint that are visible at MR imaging should be interpreted with caution to avoid misclassifying young people with back pain as having spondyloarthropathy. Compared with bone marrow edema-like lesions and fat infiltration, erosions were observed much less frequently in both control groups and may contribute most to improved sensitivity (53–55). According to our experience, it is likely that the visualization of synovitis, capsulitis, and enthesitis, facilitated by the administration of a paramagnetic contrast agent, may also contribute to the early and correct diagnosis of spondyloarthropathy.

Finally, another study tested the predictive value of both arms of the ASAS criteria by applying it retrospectively in patients with early inflammatory back pain who were followed up for 8 years (56). The study found that the imaging arm was more sensitive (83% versus 62%), which suggested that MR imaging plays an important role in making the diagnosis. The second aim of this study was to determine to what extent baseline MR imaging findings that are considered positive according to the ASAS definition correctly help predict the development of “radiographic” sacroiliitis at long-term follow-up. In this analysis, neither the ASAS classification criteria nor the ASAS definition of a positive MR imaging examination appeared to have prognostic value. Although up to 35% of patients appeared to have some disease progression during radiographic follow-up, this was not sufficient to meet the modified New York Criteria, which require bilateral structural abnormalities to be at least grade 2 and unilateral abnormalities to be at least grade 3. The reasons for this are multifactorial, although the available follow-up time, which may be insufficient, could be an important contributing factor (56).

Monitoring

Sensitive and reliable tools for monitoring disease activity and damage and for prognosis are essential for providing optimal treatment in daily clinical practice and for discriminating between different effective treatments in clinical trials (57). MR imaging, besides having become a mainstay in the diagnostic criteria for axial spondyloarthropathies, has also come to play a key role in the follow-up of these patients. Because of its ability to help detect and quantify inflammatory activity, MR imaging can serve as a biomarker for disease activity and as a guide for the treatment of sacroiliitis (14). To
achieve this goal, several quantitative and semi-quantitative methods have been proposed.

**Quantitative Methods**

The development of new MR sequences has revolutionized the interaction between MR imaging and treatment. A recent study has shown that diffusion-weighted and dynamic contrast-enhanced imaging may be effective in quantifying inflammatory changes at involved skeletal sites and, thus, useful for assessing treatment efficacy in ankylosing spondylitis (14).

Diffusion-weighted imaging is a noninvasive fast sequence that involves neither ionizing radiation nor contrast material, making it a good and cost-effective alternative for imaging the sacroiliac joints. Diffusion-weighted imaging is based on the tissue-dependent signal attenuation caused by the incoherent thermal motion of water molecules (58). The apparent diffusion coefficient (ADC), a quantitative parameter calculated from diffusion-weighted images, combines the effects of capillary perfusion and water diffusion in the extracellular extravascular space (59) and offers the possibility of quantifying inflammatory lesions. Bozgeyik et al (60) found higher ADC values in the affected areas in patients with axial spondyloarthritis compared with the iliac and sacral areas in patients with mechanical low back pain. Higher ADC values reflect elevated diffusion compared with that of normal bone because of the increased water content in the extracellular space, where water is less restricted (61). Because diffusion-weighted imaging includes both T2-weighted and diffusion-weighted components, the combined cell infiltration and vasogenic edema due to inflammation may appear as hypo-, iso-, or slightly
Figure 18. Bilateral sacroiliitis in a 28-year-old man with ankylosing spondylitis. (a) Coronal oblique fat-suppressed T2-weighted MR image shows severe bone marrow edema (arrowheads). (b) ADC map shows a hyperintense area in the right sacral subchondral bone with a high ADC value of $1.179 \times 10^{-3}$ mm$^2$/sec, a finding that represents increased diffusion. (c) Coronal oblique fat-suppressed T2-weighted MR image obtained after 3 months of treatment with anti-TNF shows that the bone marrow edema has almost disappeared (arrowheads). (d) ADC map shows that the ADC value in the right sacroiliac joint ($0.323 \times 10^{-3}$ mm$^2$/sec) has also decreased significantly.

Hyperintense signal on diffusion-weighted images but always as hyperintense signal on ADC maps (Fig 17) (14). Gaspersic et al (14) evaluated the effects of different therapies in patients with active ankylosing spondylitis and found that the more effective the treatment according to clinical and laboratory parameters, the more pronounced the decrease in diffusion (Fig 18). Consequently, diffusion-weighted imaging represents a new and useful alternative tool for detecting and quantifying inflammatory lesions in patients with spondyloarthropathy.

Dynamic contrast-enhanced imaging quantifies the distribution profile of paramagnetic con-
Contrast agent in microvessels and in the interstitial space of the tissues investigated, allowing quantitative measurements of inflammation (14). Consequently, it allows noninvasive assessment of blood perfusion in vivo and provides some insight into the microvascular structure of the tissue observed (14). Serial images are obtained after the intravenous administration of a bolus of gadolinium-based contrast material. After a circular region of interest (ROI) has been placed in the joint cartilage or periarticular bone tissue, a signal intensity–time curve is acquired. The ROI is usually retrospectively chosen and placed in the region of maximal enhancement. The curve obtained may be either flat, medium, or very steep and correlates with the patient’s degree of pain (62). It also allows patients to be classified as having either no sacroiliitis, latent sacroiliitis, or acute sacroiliitis (Fig 19) (63). In addition, from the resulting signal intensity–time curve obtained at dynamic imaging, the enhancement factor $F_{enh}$ (expressed as a percentage) can be calculated as $(SI_{max} - SI_{0}) \times 100/\text{SI}_{0}$, where $SI_{0}$ is the precontrast signal intensity and $SI_{max}$ is the postcontrast signal intensity at the highest point on the curve before the plateau phase. The enhancement gradient $G_{enh}$ (expressed as percentage per minute) can be calculated as $\left[(SI_{max} - SI_{0}) \times 100\right]/\text{SI}_{0} \times T_{max}$, where $T_{max}$ is the time to maximum signal. These parameters permit a more exact classification of patients and also make it possible to quantify inflammatory changes (63,64). Braun et al (63) showed that dynamic contrast-enhanced imag-
lar inflamed skeletal region, and can be used to monitor inflammatory activity during treatment, providing a quantitative assessment of treatment efficacy. Thus, dynamic contrast-enhanced imaging findings correlated quite well with clinical history, degree of inflammatory back pain, and physical examination findings in patients with acute sacroiliitis. Bollow et al (65) demonstrated that there is a correlation between the degree of uptake detected at MR imaging and the inflammatory cellularity in spondyloarthritis, making dynamic MR imaging helpful in monitoring pharmacologic treatment of patients with inflammatory arthropathies. Therefore, even though dynamic contrast-enhanced imaging has already been reported to be valuable in detecting early- and late-stage inflammation in the sacroiliac joints of patients with spondylarthropathy, the main difference between it and the usual MR sequences—and what really makes the difference in the way that patients with spondyloarthropathies can now be managed—is that it can provide additional quantitative information about inflammatory activity in a particular inflamed skeletal region, and can be used to monitor inflammatory activity during treatment, providing a quantitative assessment of treatment efficacy.
Figure 21. Bilateral sacroiliitis in the same patient as in Figure 20. (a) Screen shot (top left) shows values for ROIs placed in the left sacroiliac joint (ROI A) and in an iliac vessel to maintain the same scale as in Figure 20 (ROI B). Dynamic contrast-enhanced MR image (bottom left) and color map from computer-assisted diagnostic analysis of dynamic contrast-enhanced MR imaging data (bottom right) obtained after 3 months of treatment with anti-TNF show no areas of increased contrast material uptake. On a graph of signal intensity versus time (top right), the curve derived from ROI A indicates no inflammation (red line). The curve derived from ROI B is shown in blue. (b) ADC map shows a significant decrease in the ADC value of the synovial portion of the left sacroiliac joint \(0.584 \times 10^{-3} \text{mm}^2/\text{sec}\).

Semiquantitative Methods

Several scoring systems have been proposed for the assessment of disease activity in the sacroiliac joints (Table 2). Coronal oblique STIR or contrast-enhanced fat-suppressed T1-weighted images are usually used to depict the amount of bone marrow edema or osteitis in the sacrum and ilium. This amount is measured per quadrant, per area (cartilaginous and ligamentous portions of the sacroiliac joint), or per joint. Some methods also score inflammation in the joint space or in the ligamentous portion of the joint (44,49,66–69). The ASAS/OMERACT MR imaging working group evaluated the comparative reliability and sensitivity to change of different scoring methods for the assessment of acute lesions. They concluded that the comprehensive Spondyloarthritis Research Consortium of Canada (SPARCC) scoring system was somewhat better than the more condensed systems in these respects (69).
Several scoring systems for the assessment of damage in the sacroiliac joints have been described that score bone erosions, ankylosis, sclerosis, and fat deposition on T1-weighted images (Table 3) (44,49,67). However, the validation of these methods is limited, and their clinical value over that of radiography has not yet been established (57).

Finally, there is a new grading system for the assessment of both acute and chronic inflammatory changes. With this method, the cartilaginous and ligamentous portions of the joint are evaluated on coronal and axial oblique MR images, with STIR and contrast-enhanced images being scored separately. A significant correlation was found between erosions seen on MR images and changes seen on conventional radiographs scored in accordance with the modified New York criteria. This correlation may imply that MR imaging can be used in place of radiography (49).

**Summary**

The sacroiliac joints are involved in most cases of axial spondyloarthritis, and sacroiliitis is usually the first manifestation. It is important to know the anatomy, anatomic variants, and physiologic changes of the sacroiliac joints to correctly interpret findings and avoid misdiagnosis.

Table 2

<table>
<thead>
<tr>
<th>Method*</th>
<th>MR Sequences</th>
<th>Parameters for Measurement</th>
<th>Features</th>
<th>Grades</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPARCC (66)</td>
<td>STIR</td>
<td>Quadrant (6 sections)</td>
<td>Bone marrow edema</td>
<td>0–1 per quadrant, +1 for depth ≥1 cm, +1 for high signal intensity</td>
<td>0–72</td>
</tr>
<tr>
<td>Aarhus–Puhakka (44)</td>
<td>STIR, FST1 + C</td>
<td>Area (n = 4) (cartilaginous and ligamentous portions)</td>
<td>Bone marrow edema</td>
<td>0–3 per joint</td>
<td>0–60</td>
</tr>
<tr>
<td>Berlin (67)</td>
<td>STIR, FST1 + C</td>
<td>Quadrant (1 section)</td>
<td>Synovitis</td>
<td>1</td>
<td>0–32</td>
</tr>
<tr>
<td>Leeds (68)</td>
<td>STIR</td>
<td>Quadrant</td>
<td>Bone marrow edema</td>
<td>0–3</td>
<td>0–24</td>
</tr>
<tr>
<td>Per joint (69)</td>
<td>STIR, FST1 + C</td>
<td>Joint</td>
<td>Bone marrow edema</td>
<td>0–3</td>
<td>0–6</td>
</tr>
<tr>
<td>Aarhus–Madsen (49)</td>
<td>STIR</td>
<td>Area (n = 4) (cartilaginous and ligamentous portions)</td>
<td>Bone marrow edema</td>
<td>0–3</td>
<td>0–40</td>
</tr>
</tbody>
</table>

Source.—Modified, with permission, from reference 57. FST1 + C = contrast-enhanced fat-suppressed T1-weighted, SPARCC = Spondyloarthritis Research Consortium of Canada.

*Numbers in parentheses indicate reference numbers.
Use of MR imaging is the most current breakthrough and the most important change with respect to the previously established diagnostic criteria. MR imaging is becoming the standard of reference for the imaging of sacroiliitis. It helps detect acute inflammatory changes and can reveal preradiographic disease, allowing early diagnosis and treatment of sacroiliitis. In addition, MR imaging can help quantify inflammatory activity and can be used as a biomarker for activity and as a guide for the treatment of sacroiliitis, as well as an objective measure for monitoring in clinical trials. Consequently, MR imaging has become an integral part of managing patients with sacroiliitis and will likely become even more central to the care of these patients. The basic protocol includes coronal and axial oblique T1-weighted sequences and STIR or fat-suppressed T2-weighted sequences. Use of paramagnetic contrast material increases diagnostic reliability, and dynamic contrast-enhanced imaging allows quantification of inflammatory activity. Furthermore, diffusion-weighted imaging represents a new and useful alternative tool for the detection and quantification of inflammatory lesions in patients with spondyloarthropathy. Therefore, both dynamic contrast-enhanced and diffusion-weighted imaging allow the monitoring of inflammatory activity throughout the treatment regimen and provide a quantitative assessment of treatment efficacy. Finally, fat-suppressed T1-weighted or T2-weighted gradient-echo sequences are very sensitive for detecting erosions.

The presence of subchondral or periarticular bone marrow edema is mandatory for the definition of sacroiliitis at MR imaging according to the new ASAS criteria for axial spondyloarthropathy. Optimal MR sequences and criteria for early diagnosis of spondyloarthropathy will need to be clarified in the future, and the value of diffusion-weighted imaging versus STIR and fat-suppressed T2-weighted imaging in the detection of inflammatory lesions will need to be assessed. In addition, it will be necessary to further develop techniques for monitoring inflammatory activity and documenting the value of systems for the evaluation of structural lesions at MR imaging versus conventional radiography. The investigation of alternative diagnostic techniques such as whole-body MR imaging will also be important.

Acknowledgment.—The authors thank Xavi García Puig for his assistance in establishing the MR imaging protocols, especially with regard to diffusion-weighted and dynamic contrast-enhanced MR imaging.

References


Sacroiliitis Associated with Axial Spondyloarthropathy: New Concepts and Latest Trends

María Navallas, MD • Jesús Ares, MD • Brigitte Beltrán, MD • María Pilar Lisbona, MD • Joan Maymó, MD • Albert Solano, MD

RadioGraphics 2013; 33:933–956 • Published online 10.1148/rg.334125025 • Content Codes: MK MR

Page 934
The new Assessment of SpondyloArthritis international Society (ASAS) criteria, which include magnetic resonance (MR) imaging findings, facilitate early diagnosis and assessment of treatment response because of the capacity of MR imaging to help detect active inflammation.

Page 940
Contrast-enhanced images ensure maximum diagnostic reliability in patients with early-stage sacroiliitis.

Page 940
Inclusion of a fat-saturated T1-weighted or gradient-echo T2-weighted sequence provides good contrast between cartilage and subchondral bone and is very sensitive for the detection of erosions.

Page 945
According to the new ASAS criteria for axial spondyloarthropathy, the presence of subchondral or periarticular bone marrow edema is mandatory for the definition of sacroiliitis at MR imaging.

Page 947
The development of new MR sequences has revolutionized the interaction between MR imaging and treatment. A recent study has shown that diffusion-weighted and dynamic contrast-enhanced imaging may be effective in quantifying inflammatory changes at involved skeletal sites and, thus, useful for assessing treatment efficacy in ankylosing spondylitis.