Spinal Changes in Patients with Spondyloarthritis: Comparison of MR Imaging and Radiographic Appearances

Since the advent of highly effective TNF-α inhibitors for treating spondyloarthritides, referring rheumatologists have been requesting the sensitive visualization of inflammatory changes not only of the sacroiliac joints but of the entire spine. Given that changes in spondyloarthritis may be very subtle, their visualization by means of magnetic resonance (MR) imaging relies critically on selecting the proper imaging protocol. Spinal changes associated with spondyloarthritis are florid anterior spondylitis (or Romanus lesion), florid diskitis (or Andersson lesion), ankylosis, insufficiency fractures of the ankylosed spine, syndesmophytes, arthritis of the apophyseal and costovertebral joints, and enthesis of the interspinal ligaments. A comparison of MR imaging findings with those of conventional radiography in individual patients reveals strengths and weaknesses of both modalities. Results of this comparison suggest that syndesmophytes are depicted better with radiography; ankylosis, equally well with both imaging techniques; and all other lesions, better with MR imaging. Classification of the different findings based on the typical signal-intensity changes seen on MR images enables standardized reporting, and scoring the lesions may be helpful in clinical trials.

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Abbreviations: STIR = short inversion time inversion recovery, TNF = tumor necrosis factor

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See the commentary by Manaster following this article.

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Introduction

Seronegative spondyloarthritis is a general term for a group of joint conditions that are not associated with rheumatoid factors or rheumatic nodules. Five subgroups of spondyloarthritis are distinguished: ankylosing spondylitis (1), reactive arthritis (eg, Reiter syndrome), psoriatic arthritis, arthritis associated with inflammatory bowel disease (eg, Crohn disease or ulcerative colitis), and undifferentiated spondyloarthritis (2). These conditions may have overlapping symptoms. The subtypes of spondyloarthritis are usually distinguished on the basis of the patient’s history and clinical findings (eg, history of urogenital tract infection in reactive arthritis, psoriatic skin lesions in psoriatic arthritis). Extraaxial involvement such as uveitis, calcaneal enthesis, or peripheral arthritis occurs in all five subtypes but with different frequencies. Imaging does not play a major role in differentiating between the subtypes of spondyloarthritis because their imaging features are comparable, especially in early disease. One exception is undifferentiated spondyloarthritis, which is diagnosed in cases with no definite radiologic signs of sacroiliitis (2). Another exception is psoriatic arthritis, which is known to produce parasyndesmophytes, a form of bony outgrowth distinct from syndesmophytes (3,4). Also, spondylitis with bone marrow edema of the entire vertebra occurs more frequently in psoriatic arthritis. All forms of spondyloarthritis may ultimately develop into ankylosing spondylitis in patients with longstanding disease.

The prevalence of the whole group of spondyloarthritides has been estimated to be between 0.5% and 1.9% (5,6). The lower prevalence value was determined by means of phone interviews in France. The higher value was estimated in a population-based study of blood donors in Berlin, Germany, by Braun et al (6) on the basis of HLA-B27 testing, questionnaires by mail, physical examinations, and magnetic resonance (MR) imaging examinations of the sacroiliac joints. In the latter study, ankylosing spondylitis was the most frequently diagnosed type of spondyloarthritis, with a prevalence of 0.86%; lower prevalences were found for undifferentiated spondyloarthritis (0.67%) and psoriatic arthritis (0.29%). Spondyloarthritis is closely associated with histocompatibility antigen HLA-B27 (7): Individuals with the HLA-B27 antigen have a 20-fold greater risk of developing spondyloarthritis (6).

The treatment options available for patients suffering from the more severe forms of spondyloarthritis have been limited in the past (8). Nonsteroidal anti-inflammatory drugs are widely used to ameliorate spinal pain (9), and intensive physical therapy plays a major role in maintaining spinal mobility (10,11). Recently, highly effective tumor necrosis factor (TNF)-α inhibitors were introduced for treating spondyloarthritis and have since been used with success (12–15). Thus, rheumatologists now have at their disposal a more effective therapy to influence the course of spondyloarthritis. As with other rheumatic conditions, early diagnosis and treatment are essential for avoiding structural damage and functional impairment. Hence, rheumatologists referring patients for radiologic evaluation are requesting detailed visualization of inflammatory changes in not only the sacroiliac joints but also the entire vertebral column.

Many different inflammatory lesions may occur in spondyloarthritis of the vertebral column because of its anatomic complexity. Arthritic lesions may affect the vertebrae and intervertebral disks, the synovial joints of the vertebral column, and the tendon and ligament attachments (entheses). Several vertebral lesions may ultimately lead to chronic abnormalities such as syndesmophytes or ankylosis. Selection of a suitable imaging protocol is therefore crucial for identifying all types of lesions. Spinal changes associated with spondyloarthritis discussed in this article are florid anterior spondylitis (or Romanus lesion), florid diskitis (or Andersson lesion), ankylosis, insufficiency fractures of the ankylosed spine, syndesmophytes, arthritis of the apophyseal and costovertebral joints, and enthesitis of the interspinal ligaments.

Various rheumatic and nonrheumatic disorders of the spine, including rheumatoid arthritis, degenerative disk disease, diffuse idiopathic skeletal hyperostosis, pyogenic spondylodiskitis, vertebral fracture, and Paget disease, can damage the integrity of the periosteum, cortical bone, spongyosa, bone marrow, intervertebral disks, joints, capsular structures, and ligaments (16). All of these conditions produce a fairly uniform range of anatomic changes in the diskovertebral unit of the affected spinal segment (a diskovertebral unit consists of an intervertebral disk and the adjacent halves of the superior and inferior vertebrae). These entities can be differentiated from the subtypes of spondyloarthritis by means of the patient’s history, clinical findings, and radiographic and magnetic resonance (MR) imaging features. However, a discussion of this differential diagno-
sis is beyond the scope of the present article and has already been described elsewhere (17,18). In this article, we present an overview of the MR imaging findings in spondyloarthritis, which may be very subtle, and discuss the appropriateness of using this imaging modality, compared with conventional radiography, for this clinical application.

**MR Imaging Protocol**

An MR imaging protocol that has proved useful for evaluating the spinal column comprises a sagittal T1-weighted turbo spin-echo sequence and a sagittal short inversion time inversion-recovery (STIR) sequence with an image matrix of 512 pixels acquired at 1.5 T. Administration of a paramagnetic contrast medium such as gadopentetate dimeglumine is required in spinal MR imaging only in specific cases. In our experience, enthesitis is better visualized on contrast material–enhanced MR images. If a patient’s history suggests septic spondylodiskitis or abscess formation, contrast medium administration is recommended to distinguish between florid infection and necrotic tissue, to assess the extent of the soft-tissue mass, and to show disk enhancement (19,20). When a contrast medium is given, images should be acquired with a fat-suppressed, T1-weighted turbo spin-echo sequence. Depending on the findings and their location, a supplementary transverse STIR sequence may be useful, particularly to visualize the costovertebral junctions.

**Anterior and Posterior Spondylitis**

The initial structural abnormalities described by Romanus and Yden (21) are the earliest changes of spondylitis depicted on conventional radiographs. These changes consist of irregularities and erosions involving the anterior and posterior edges of the vertebral endplates and are also known as Romanus lesions. The underlying anatomic structure is the epiphyseal ring in juvenile patients; in adults, it is fused with the vertebral body. Later in the course of the disease, sclerotic changes of the edges of the vertebral endplates appear, findings referred to as “shiny corners.”

MR imaging allows for the detection of Romanus lesions in both early and late spondyloarthritiis. In active disease, these lesions are depicted as reduced signal intensity of the rim of the endplate on T1-weighted MR images and as increased signal intensity on STIR images (Fig 1) and represent bone marrow edema or osteitis (22). The condition is designated anterior spondylitis when the changes involve only the anterior vertebral edge, posterior spondylitis when they involve the posterior edge, and marginal spondylitis when combined changes are seen. The changes described occur exactly at the site of attachment of...
the anulus fibrosus to the vertebral endplate. Because such a junction of bone and ligamentous structure is an enthesis by definition, anterior or posterior spondylitis can be regarded as an enthesis.

Later in the disease course, the epiphyseal ring can appear hyperintense on T1-weighted images (Fig 2b). Such hyperintense lesions represent circumscribed areas of postinflammatory, fatty bone marrow degeneration (24). Only at this stage are shiny corners depicted by conventional radiography (Fig 2a)—that is, long after inflammation has run its course.

**Figure 2.** Spondylitis (inactive Romanus lesions) in a 39-year-old patient with ankylosing spondylitis. (a) Lateral radiograph of the lumbar region shows syndesmophytes (arrows) at L3 through S1 and a shiny corner at the superior endplate of L5. (b) On the corresponding T1-weighted fast spin-echo image, the syndesmophyte at L5 (lower long arrow) is barely visible. Postinflammatory fatty bone marrow degeneration of the anterior vertebral edges is seen (short arrows), findings compatible with inactive Romanus lesions. (Fig 2a and 2b reprinted, with permission, from reference 23.)

**Spondylodiskitis**

Inflammatory involvement of the intervertebral disks by spondyloarthritis is known as spondylodiskitis or Andersson lesion, according to Andersson, who first described this condition in 1937 (25). Rheumatic spondylodiskitis is a noninfec-

tious condition that occurs in about 8% of patients with ankylosing spondylitis as detected at radiography (26). At MR imaging, these lesions are depicted as disk-related signal-intensity abnormalities of one or both vertebral halves of a diskovertebral unit; they appear hyperintense on STIR images and hypointense on T1-weighted images, where they are often hemispherically shaped (Fig 3b, 3c). Lines of increased signal intensity may be seen at the interface between the anulus fibrosus and nucleus pulposus or within the latter in early disease.

Just as MR imaging is better than conventional radiography in its depiction of anterior spondylitis (or Romanus lesions), MR imaging also provides a superior view of spondylodiskitis (27,28), since the edematous changes in early disease are not radiographically visualized. Radiography depicts irregularities and erosions of the vertebral endplates that are not related to the anterior or posterior edge but rather to the central portion (Fig 3a); such findings are now known to be late features of spondyloarthritis.
Insufficiency Fracture

The inflammatory type of Andersson lesion is distinguished from a noninflammatory type lesion, as described by Dihlmann and Delling (29). The noninflammatory lesion corresponds to an insufficiency fracture in the ankylosed spine (29). This lesion occurs either spontaneously or after minimal trauma, often on the basis of prior osteoporotic damage of the spine associated with ankylosing spondylitis (30). Insufficiency fractures occur as fatigue fractures at the level of the disk (transdiskal) or at the level of the vertebral body (transvertebral). They are typically diagnosed with conventional radiography (Fig 4a). Older insufficiency fractures appear hyperintense on T1-weighted images, whereas fresh fractures

Figure 3. Spondylodiskitis (inflammatory Andersson lesions) in a 24-year-old patient with ankylosing spondylitis. (a) Lateral radiograph of the lumbar spine shows height reduction of intervertebral disk space, sclerosis of the endplates at L4–5, erosion (arrow) of the superior endplate of L5 (Andersson lesion), and a syndesmophyte at L4 (arrowhead). (b) Sagittal T1-weighted fast spin-echo image reveals erosive defects of the inferior endplate (arrow) of L4 and superior endplate of L5, as well as signal loss in the surrounding bone marrow. (c) Corresponding STIR image shows increased signal intensity (arrowheads) adjacent to the intervertebral disk (florid Andersson lesion). (d) Sagittal T1-weighted image obtained 26 weeks after treatment with TNF-α inhibitor shows increased signal intensity in the former low-signal-intensity areas, findings indicative of postinflammatory fatty bone marrow degeneration. (e) Corresponding STIR image shows complete regression of the former high-signal-intensity changes.
have low signal intensity (Fig 4b). When such fractures heal and form a false joint, their MR imaging appearance can mimic that of erosive osteochondrosis.

**Arthritis of the Synovial Joints of the Vertebral Column**

Arthritis of the zygapophyseal joints (facet joints), costovertebral joints, and costotransverse joints is comparable to arthritis of peripheral joints in terms of imaging features as well as progression of abnormal changes. These abnormalities may escape detection when only sagittal MR images are acquired. Acquisition of additional transverse MR images is therefore recommended. Arthritis involving the above-mentioned joints is characterized by joint effusion, synovitis, erosions, and bone marrow edema (Fig 5b–5d). Affected joints may undergo ankylosis at late stages and thus impair chest excursion. On conventional radiographs, arthritis of the facet joints is characterized by blurring of the joint clefts, whereas in ankylosis the joint is no longer delineated. However, these changes are depicted radiographically only when they affect the cervical spine and lumbar spine: The radiographic evaluation of the thoracic vertebrae is severely impaired by overlying ribs and lung structures (Fig 5a) (31).

**Enthesitis**

The vertebral column is stabilized by numerous ligaments that may be involved in the inflammatory process in spondyloarthritis. Involvement is
most prominently seen when the interspinal ligaments—those that extend between the spinous processes—and the supraspinal ligaments are affected. Ligamentous involvement is characterized by an increased signal intensity on either STIR images or contrast-enhanced T1-weighted fatsaturated images (Fig 6b). It may be associated with osteitis of adjacent bone marrow in the spinous processes, which also has high signal intensity on STIR images. T1-weighted images frequently show thickening of these ligamentous structures (Fig 6a). Conventional radiography may show erosions and spurs (32), but usually these changes escape detection.
Syndesmophytes and Ankylosis

The syndesmophytes typically associated with ankylosing spondylitis are difficult to detect with MR imaging (Figs 2b, 7b, 7c). They occur in about 15% of the vertebrae in each patient (31). Conventional radiography with its rather high spatial resolution appears to be superior to MR imaging in the depiction of syndesmophytes (Figs 2a, 7a). On MR images, as on radiographs, syndesmophytes are seen as bony outgrowths of the anterior vertebral edges (Fig 2b); they have lower or higher signal intensity on STIR images, depending on the floridity of the patient’s ankylosing spondylitis. MR imaging has its role in depicting florid anterior spondylitis (Figs 1b, 7c), which is the stage preceding the development of syndesmophytes.

Ankylosis involves the vertebral edges or center, with bony extension through the disk. The former is thought to occur secondary to anterior or posterior spondylitis (21,33), whereas the latter is a sequel of an inflammatory Andersson lesion. The newly formed bone has the same signal intensity as normal bone on MR images (isointense relative to muscle on T1-weighted images, hypointense on STIR images). Vertebral ankylosis is clearly depicted by both conventional radiography and MR imaging.

Classification of Changes

The changes (eg, Romanus and Andersson lesions) seen in the diskovertebral unit have typical MR imaging appearances at different stages of spondyloarthritis. Three classes of lesions can be differentiated: acute inflammatory lesions, postinflammatory fatty bone marrow degeneration, and ankylosis (23). The typical MR imaging characteristics are summarized in the Table, which is provided as a guide to understanding the signal-intensity changes seen during the course of ankylosing spondylitis. This differentiation is based on the classification of degenerative disk disease proposed by Modic et al (34) and appears to be suitable to facilitate the description and reporting of spinal changes in ankylosing spondylitis, provided that a high intraobserver and interobserver agreement can be demonstrated. Moreover, scoring systems are being developed in which the progression of the disease is assessed separately for chronic and acute changes and which can be used as outcome measures in randomized clinical trials (35). Further development and evaluation of these scoring systems are being conducted by the
Outcome Measures in Rheumatology (OMERACT) working group that is studying use of MR imaging in ankylosing spondylitis (36).

Conclusions
Spondyloarthritis is characterized by typical MR imaging features. However, these findings are not specific and may be seen in degenerative or other spinal disorders as well (16). It is helpful to know that inflammatory changes of the vertebral column in spondyloarthritis rarely occur in isolation and frequently are associated with arthritis of the sacroiliac joints (37). For patients with a history of unspecific back pain who are presenting for an MR imaging evaluation, it is important to classify the findings correctly and to initiate additional diagnostic assessment of the sacroiliac joints as required. Follow-up imaging studies of inflammatory changes (Fig 3d, 3e) provide the rheumatologist with an objective measure of the effectiveness of therapy (eg, with TNF-α antagonists).

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Figure 7. Ankylosis and syndesmophytes in a 36-year-old patient with ankylosing spondylitis. (a) Lateral radiograph of the lumbar spine shows anterior syndesmophytes at L3–4 and L4–5 (arrows) and a defect of the epiphyseal ring at the anterior edge of L3 (arrowhead). Beginning ossification of intervertebral spaces L1–2 and L2–3 is evident. (b) On the T1-weighted turbo spin-echo image, syndesmophytes are not seen. (c) Sagittal contrast-enhanced fatsaturated T1-weighted turbo spin-echo image shows enhancement in the area of the epiphyseal rings at L4–5 (arrowheads), a finding representing a Romanus lesion. Subtle enhancement (arrow) of intervertebral disk L4–5 (an early Andersson lesion) is also seen.

### Classification of Changes in Spondyloarthritis of the Vertebral Column as Seen on MR Images

<table>
<thead>
<tr>
<th>Class</th>
<th>T1-weighted Image</th>
<th>T2-weighted or STIR Image</th>
<th>Interpretation</th>
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</thead>
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<td>0</td>
<td>Vertebra: intermediate SI</td>
<td>Vertebra: low SI</td>
<td>Normal findings</td>
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<td>Disk: low SI</td>
<td>Disk: high SI</td>
<td></td>
</tr>
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<td>Disk: low SI</td>
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<td></td>
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<td>Vertebra: low SI</td>
<td>Chronic postinflammatory fatty bone marrow degeneration</td>
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<td>Disk: low SI</td>
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<td>Vertebra: low SI</td>
<td>Partial or complete ankylosis</td>
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<td></td>
<td>Disk: intermediate SI</td>
<td>Disk: low SI</td>
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Note.—SI = signal intensity.
References


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