American College of Radiology
ACR Appropriateness Criteria®
Inflammatory Back Pain: Known or Suspected Axial Spondyloarthritis

Variant 1: **Inflammatory back pain. Suspected axial spondyloarthritis. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography sacroiliac joints and spine area of interest	Usually Appropriate	☢☢☢
Radiography sacroiliac joints	Usually Appropriate	☢☢
US sacroiliac joints	Usually Not Appropriate	O
US spine area of interest	Usually Not Appropriate	O
MRI sacroiliac joints without and with IV contrast	Usually Not Appropriate	O
MRI sacroiliac joints without IV contrast	Usually Not Appropriate	O
MRI spine area of interest without and with IV contrast	Usually Not Appropriate	O
MRI spine area of interest without IV contrast	Usually Not Appropriate	O
Bone scan with SPECT or SPECT/CT sacroiliac joints	Usually Not Appropriate	☢☢☢
Bone scan with SPECT or SPECT/CT spine area of interest	Usually Not Appropriate	☢☢☢
CT sacroiliac joints with IV contrast	Usually Not Appropriate	☢☢☢
CT sacroiliac joints without IV contrast	Usually Not Appropriate	☢☢☢
CT sacroiliac joints without and with IV contrast	Usually Not Appropriate	☢☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without IV contrast	Usually Not Appropriate	Varies

Variant 2: **Inflammatory back pain. Suspected axial spondyloarthritis. Additional imaging following radiographs. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI sacroiliac joints and spine area of interest without and with IV contrast	Usually Appropriate	O
MRI sacroiliac joints and spine area of interest without IV contrast	Usually Appropriate	O
MRI sacroiliac joints without and with IV contrast	Usually Appropriate	O
MRI sacroiliac joints without IV contrast	Usually Appropriate	O
CT sacroiliac joints without IV contrast	May Be Appropriate	☢☢☢
CT sacroiliac joints and spine area of interest without IV contrast	May Be Appropriate	Varies
US sacroiliac joints	Usually Not Appropriate	O
US sacroiliac joints and spine area of interest	Usually Not Appropriate	O
Bone scan with SPECT or SPECT/CT sacroiliac joints	Usually Not Appropriate	☢☢☢
Bone scan with SPECT or SPECT/CT sacroiliac joints and spine area of interest	Usually Not Appropriate	☢☢☢
CT sacroiliac joints with IV contrast	Usually Not Appropriate	☢☢☢
CT sacroiliac joints without and with IV contrast	Usually Not Appropriate	☢☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
CT sacroiliac joints and spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT sacroiliac joints and spine area of interest without and with IV contrast	Usually Not Appropriate	Varies

Variant 3: **Inflammatory back pain. Suspected axial spondyloarthritis. Negative radiographs and negative MRI of the sacroiliac joints. Next imaging study.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography spine area of interest	Usually Appropriate	Varies
MRI spine area of interest without and with IV contrast	Usually Appropriate	O
MRI spine area of interest without IV contrast	Usually Appropriate	O
CT spine area of interest without IV contrast	Usually Appropriate	Varies
US spine area of interest	Usually Not Appropriate	O
Bone scan with SPECT or SPECT/CT spine area of interest	Usually Not Appropriate	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies

Variant 4: **Known axial spondyloarthritis. Follow-up for treatment response or disease progression.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography sacroiliac joints and spine area of interest	Usually Appropriate	☢☢☢
Radiography sacroiliac joints	Usually Appropriate	☢☢
MRI sacroiliac joints and spine area of interest without and with IV contrast	May Be Appropriate	O
MRI sacroiliac joints and spine area of interest without IV contrast	May Be Appropriate	O
MRI sacroiliac joints without and with IV contrast	May Be Appropriate	O
MRI sacroiliac joints without IV contrast	May Be Appropriate	O
US sacroiliac joints	Usually Not Appropriate	O
US sacroiliac joints and spine area of interest	Usually Not Appropriate	O
Bone scan with SPECT or SPECT/CT sacroiliac joints	Usually Not Appropriate	☢☢☢
Bone scan with SPECT or SPECT/CT sacroiliac joints and spine area of interest	Usually Not Appropriate	☢☢☢
CT sacroiliac joints with IV contrast	Usually Not Appropriate	☢☢☢
CT sacroiliac joints without IV contrast	Usually Not Appropriate	☢☢☢
CT sacroiliac joints without and with IV contrast	Usually Not Appropriate	☢☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
CT sacroiliac joints and spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT sacroiliac joints and spine area of interest without and with IV contrast	Usually Not Appropriate	Varies
CT sacroiliac joints and spine area of interest without IV contrast	Usually Not Appropriate	Varies

Variant 5: **Axial spondyloarthritis with spine ankylosis. Suspected fracture. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography spine area of interest	Usually Appropriate	Varies
MRI spine area of interest without IV contrast	Usually Appropriate	O
CT spine area of interest without IV contrast	Usually Appropriate	Varies
US spine area of interest	Usually Not Appropriate	O
MRI spine area of interest without and with IV contrast	Usually Not Appropriate	O
Bone scan with SPECT or SPECT/CT spine area of interest	Usually Not Appropriate	☢☢☢
Fluoride PET/CT skull base to mid-thigh	Usually Not Appropriate	☢☢☢☢
CT spine area of interest with IV contrast	Usually Not Appropriate	Varies
CT spine area of interest without and with IV contrast	Usually Not Appropriate	Varies

INFLAMMATORY BACK PAIN: KNOWN OR SUSPECTED AXIAL SPONDYLOARTHRITIS

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Summary of Literature Review

Introduction/Background

Axial spondyloarthritis or axial spondyloarthropathy (axSpA) describes a heterogeneous group of inflammatory disorders affecting the axial skeleton that were historically classified separately as ankylosing spondylitis (AS), reactive arthritis, psoriatic spondyloarthritis, enteropathic spondyloarthritis, juvenile spondyloarthritis, and undifferentiated spondyloarthritis [1]. The prevalence of axSpA is estimated to be between 0.9% to 1.4% in the United States adult population [2]. There is a genetic component to axSpA, including a strong association with HLA-B27, which is positive in 74% to 89% of patients [1]. Patients with axSpA often present before age 45 with chronic back pain and stiffness and may have elevated inflammatory markers [3]. A clinical hallmark is the presence of inflammatory back pain, which is present in 70% to 80% of patients [4]. There are varying definitions for inflammatory back pain, although characteristically this pain includes the following features: insidious onset, improvement with exercise, no improvement with rest, occurring at night, and age of onset <40 years of age [4]. Inflammatory back pain symptoms, depending on the criteria used, have been reportedly been present in 5% to 6% of the general adult population [5], and in up to 15% of patients in the primary care setting [6]. Although recognition of axSpA is improving, a mean delay of 4.9 years from onset of symptoms to diagnosis was recently reported, highlighting the challenge of establishing this diagnosis early in the disease course [7].

Patients with axSpA suffer from an inflammatory arthropathy of the axial skeleton that classically involves the sacroiliac joints initially [3]. There is some heterogeneity in disease distribution within axSpA subtypes. Patients with AS typically develop bilateral sacroiliitis, whereas patients with other subtypes, such as psoriatic spondyloarthritis, develop either unilateral or bilateral sacroiliitis [8]. Classically, axSpA after first involving the sacroiliac joints and then may progress to involve the spine. However, the pattern of disease can be variable with a minority of patients having isolated spine involvement [3]. The thoracic spine and thoracolumbar junction are the most common sites of spinal involvement [9-13]. The inflammatory changes of enthesitis, synovitis, and osteitis in axSpA results in bone erosion, sclerosis, bone formation, and potentially ankylosis at sites of involvement [1]. Approximately 30% to 50% of patients with axSpA have associated peripheral arthritis or enthesitis [3]. The approach to peripheral spondyloarthritis is discussed in the ACR Appropriateness Criteria® topic on "Chronic Extremity Joint Pain-Suspected Inflammatory Arthritis" [14].

Imaging plays a critical role in the diagnosis of axSpA. Historically, imaging diagnosis was based on radiographs using the modified New York criteria [15]; however, the radiographic changes of axSpA were subsequently found to evolve slowly over the course of years [16,17]. Additionally, some patients with symptomatic AS did not have radiographic evidence of axSpA [18], driving the search for additional imaging biomarkers of early disease. As evolving literature accumulated on the utility of MRI in axSpA, the Assessment of SpondyloArthritis international Society (ASAS) established diagnostic criteria in 2009 for axSpA that included MRI in the diagnostic algorithm, promoting the diagnosis of both patients with radiographically evident axSpA (radiographic-axSpA or classic AS) as well as patients with negative radiographs who may have inflammatory changes demonstrated on MRI (nonradiographic-axSpA) [17,19]. It was later shown that a portion of patients with nonradiographic-axSpA will

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progress to radiographic-axSpA over the course of years [20], although it is uncertain if radiographic-axSpA and nonradiographic-axSpA represent a continuum of the same entity or if they are truly separate disease subsets. This is the topic of some debate [1,21-23]. The development of the ASAS criteria facilitated diagnosis of patients at an earlier stage of disease and allowed more patients with axSpA to be considered for biologic therapy [17,19,22]. However, care should be taken to acknowledge that the ASAS criteria are designed for use in clinical research, not for definitive clinical diagnosis.

Treatment algorithms focus on controlling disease activity and improving quality of life. Multiple studies have shown that axSpA patients report decreases in quality of life measures and that high levels of disease activity are associated with more profound decreases [24-26]. In AS specifically, it has been shown that worsening functional impairment over time correlates with worsened structural changes and disease activity [27-29]. In patients with active disease despite nonsteroidal anti-inflammatory drugs, treatment with biologic agents such as tumor necrosis factor (TNF)-α antagonists has become standard of care with 24 randomized controlled trials demonstrating their efficacy in improving patient's self-reported outcomes, decreasing clinical disease activity, and decreasing inflammatory changes on MRI upon follow-up [30]. Recommendations for treating radiographic-axSpA and nonradiographic-axSpA are similar [30].

Beyond the important roles of imaging in early diagnosis and treatment in axSpA patients, those with advanced axSpA resulting in ankylosis are a subset of patients that warrants further discussion. These patients, classically considered to have AS, develop spinal rigidity combined with osteoporosis resulting in a risk of fracture even with low energy trauma or no apparent trauma [1,31-33]. These fractures are often unstable and involve all 3 spinal columns [31,34]. The cervical spine is most frequently involved [32,33,35]. Associated neurologic deficits have been reported in 21% to 100% of patients, and other complications reported in 84% of patients [32]. The diagnosis can be delayed in 15% to 41% of cases, and therefore, clinical suspicion for fracture must be elevated in the appropriate setting given the severity of these injuries. Many patients undergo surgical fixation of these injuries, although unfavorable outcomes with relatively high morbidity and mortality are reported [32,35]. Early use of advanced imaging modalities is crucial in these patients to facilitate a timely diagnosis.

Initial Imaging Definition

Imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care)

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient's care).

Discussion of Procedures by Variant

Variant 1: Inflammatory back pain. Suspected axial spondyloarthritis. Initial imaging.

The body regions covered in this clinical scenario are the sacroiliac joints, cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information.

Bone Scan with SPECT or SPECT/CT Sacroiliac Joints

Bone scintigraphy with single-photon emission computed tomography (SPECT) or SPECT/CT is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting its use in this setting.

Bone Scan with SPECT or SPECT/CT Spine Area of Interest

Bone scintigraphy with SPECT or SPECT/CT is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting its use in this setting.

CT Sacroiliac Joints

CT is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting its use in this setting.

CT Spine Area of Interest
CT is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting its use in this setting.

Fluoride PET/CT Skull Base to Mid-Thigh
F-18-fluoride PET/CT is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting its use in this setting.

MRI Sacroiliac Joints
MRI is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA; however, it is known that the inflammatory changes of sacroiliitis on MRI can precede radiographic structural findings of sacroiliitis by three to seven years [36,37], resulting in a low sensitivity of radiographs for detection of early disease [16,17]. In cases of those with a short duration of symptoms, MRI of the sacroiliac joints could be considered as the initial imaging modality [22].

MRI Spine Area of Interest
MRI is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting MRI of the spine in this setting.

Radiography Sacroiliac Joints
Radiographs of the pelvis have long been used as the first-line imaging modality for evaluation of patients with suspected axSpA [3,15,22]. The ASAS recommends radiographs of the whole pelvis to evaluate the sacroiliac joints as well as the hips, which can also be involved in axSpA [38]. There has been close agreement shown between anteroposterior and oblique sacroiliac joint radiographs with no benefit of adding oblique views [39]. Comparison of the anteroposterior and Ferguson views has shown general agreement with no superiority of one view over the other [40]. Radiographs demonstrate chronic erosions, sclerotic changes, and ankylosis as the sequela of inflammatory sacroiliitis, although radiographs are unable to demonstrate active inflammation [38]. As a result, there is a low sensitivity of radiographs for detection of early disease [16,17]. There is wide variability in reported sensitivity (19%–72%) and specificity (47%–84.5%) of radiographs for assessment of sacroiliitis [41-43]. One retrospective study on 910 patients reported that 41.3% of radiography reports gave an incorrect diagnosis using CT as the diagnostic reference standard [44]. A more recent study on 110 patients showed that radiography missed more than half of patients with structural changes of axSpA using low-dose CT as the reference standard [45]. Additionally, interobserver agreement for radiographic findings of sacroiliitis is fair to moderate [46-48]. Although radiographic evaluation of the sacroiliac joints is useful in the initial evaluation of suspected axSpA, its limitations must be acknowledged.

Radiography Sacroiliac Joints and Spine Area of Interest
The inflammatory changes of axSpA most often begin in the sacroiliac joints, although if symptoms are referable to the spine, spine radiographs can be obtained in addition to sacroiliac joint radiographs to assess for structural changes of syndesmophytes, erosions, shiny corners, vertebral body squaring, and ankylosis [38]. At least radiographs of the cervical and lumbar spine should be performed [22,38,49]. Thoracic spine radiographs are not broadly useful for the diagnosis of axSpA because of the difficulty in assessment related to overlying structures [38,49], although they can be obtained in the setting of referable symptoms to ensure identification of clinically important causes of the patient's symptoms. Spine radiographs are considered useful both in the diagnosis of axSpA and for evaluating the extent of fusion in patients with AS [30].

US Sacroiliac Joints
Ultrasound (US) is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting its use in this setting.

US Spine Area of Interest
US is not routinely obtained as the initial imaging modality in the evaluation of suspected axSpA, and there is no relevant literature supporting its use in this setting.

Variant 2: Inflammatory back pain. Suspected axial spondyloarthritis. Additional imaging following radiographs. Next imaging study.

The body regions covered in this clinical scenario are the sacroiliac joints, cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information.

Bone Scan with SPECT or SPECT/CT Sacroiliac Joints
Bone scintigraphy is not routinely suggested in the evaluation of patients with suspected axSpA [22]. Conventional bone scintigraphy has low to moderate sensitivity and variable specificity for the diagnosis of axSpA [41,42,50]. If bone scintigraphy is used, SPECT should be performed during the examination because of the complexity of the sacroiliac joint anatomy [51]. Although bone scintigraphy is not typically performed during the evaluation of suspected axSpA because of its limited diagnostic utility, there is recent data that hybrid SPECT/CT has higher sensitivity than conventional bone scintigraphy in the detection of sacroiliitis [52,53]. However, there is not enough evidence currently to support its routine use for evaluation of the sacroiliac joints and spine.

Bone Scan with SPECT or SPECT/CT Sacroiliac Joints and Spine Area of Interest
Bone scintigraphy is not routinely suggested in the evaluation of patients with suspected axSpA [22]. Conventional bone scintigraphy has low to moderate sensitivity and variable specificity for the diagnosis of axSpA [41,42,50]. If bone scintigraphy is used, because of the complexity of the sacroiliac joint anatomy, the use of SPECT should be performed during the examination [51]. Although bone scintigraphy is not typically performed during the evaluation of suspected axSpA because of its limited diagnostic utility, there is recent data that hybrid SPECT/CT has higher sensitivity than conventional bone scintigraphy in the detection of sacroiliitis [52,53]. However, there is not enough evidence currently to support its routine use for evaluation of the sacroiliac joints and spine.

CT Sacroiliac Joints
CT demonstrates the structural changes of sacroiliitis in patients with axSpA that may not be apparent on radiographs [22]. These structural changes, including erosions, sclerosis, bone formation, and ankylosis, are best demonstrated on sacroiliac protocol examinations that include obliquely oriented reformatted images prescribed parallel and perpendicular to the long axis of the sacrum [54]. Several studies have shown CT to have higher sensitivity for detection of sacroiliitis than radiography [43,44,47,55]. Low-dose CT is increasingly being performed and can demonstrate the fine structural changes of axSpA better than radiography [45]. Additionally, the interreader reliability has shown to be excellent for grading sacroiliitis on CT, higher than for radiography, because of the increased level of structural detail demonstrated by CT [47]. Although conventional CT has the ability to demonstrate the chronic structural changes of sacroiliitis, it cannot demonstrate active inflammation, and therefore MRI remains the technique of choice for the diagnosis of axSpA [1,3,19,22]. There is evolving literature on the use of dual-energy CT (DECT) in the evaluation of sacroiliitis in axSpA, with early studies showing the ability of DECT to demonstrate bone marrow edema in patients with axSpA in addition to the inherent ability of CT to demonstrate the chronic structural changes of sacroiliitis [56,57]. One study shows that DECT has a sensitivity of 87% to 93% and specificity of 91% to 94% for detection of bone marrow edema using MRI as the reference standard, but more data are needed to support the diagnostic utility of DECT in the evaluation of axSpA [56].

There is no role for intravenous (IV) contrast in CT evaluation of axSpA.

CT Sacroiliac Joints and Spine Area of Interest
CT demonstrates structural changes in the sacroiliac joints and spine in patients with axSpA that may not be apparent on radiographs [22]. These structural changes include erosions, sclerosis, bone formation, syndesmophytes, and ankylosis [49,54]. In addition to its diagnostic utility in assessment of the sacroiliac joints, CT of the spine has the ability to demonstrate syndesmophytes with higher sensitivity than radiographs, and low-dose protocols can be utilized [58]. CT is especially helpful for evaluation of the thoracic spine and facet joints, which can be challenging to evaluate on radiography [49]. There is not a consistently established convention to guide the clinician on whether to image only the sacroiliac joints or both the sacroiliac joints and spine in patients with suspected axSpA. However, spinal involvement is common, and numerous studies have shown that axSpA involvement can be isolated to the spine, isolated to the sacroiliac joints, or can involve both the sacroiliac joints and spine [19,59-63]. Therefore, if CT is performed, imaging the spine in addition to the sacroiliac joints is beneficial in the setting of symptoms referable to the spine.

There is no role for IV contrast in the CT evaluation of axSpA.

Fluoride PET/CT Skull Base to Mid-Thigh
There is not enough data to support the routine use of F-18-fluoride PET/CT in the evaluation of patients with suspected axSpA. F-18-fluoride has been shown to be a potentially useful tracer in identifying sites of osteoblastic activity in axSpA patients [64], with uptake corresponding to sites of active bone formation on histology [65]. Uptake on PET/CT has also been shown to correlate with clinical disease activity in patients with axSpA [66,67]; however, there is conflicting evidence regarding the extent to which tracer uptake correlates with specific

inflammatory and structural lesions seen on CT and MRI resulting in uncertainty about its diagnostic utility [64,67-72]. In one study, the interreader reliability of diagnosing sacroiliitis on PET/CT was poor and substantially lower than that for MRI or CT [67]. In a small study using radiographs as the reference standard, F-18-fluoride PET/CT had a sensitivity of 80% and specificity of 77% for the detection of sacroiliitis in AS, although there are inherent limitations in the use of radiographs as the reference standard for diagnosing axSpA [73]. Given the available data, the utility of PET/CT in the diagnosis of axSpA is uncertain at this time.

MRI Sacroiliac Joints

After radiography is performed, MRI of the sacroiliac joints is the next imaging technique of choice in the evaluation of patients with suspected axSpA [1,3,19,22]. MRI of the sacroiliac joints is widely recognized as an important tool in the evaluation of patients with suspected axSpA, resulting in improved diagnostic confidence and yielding findings that stimulate changes in both diagnosis and treatment plans for patients [1,3,19,22,74]. Additionally, MRI findings have been shown to be predictive of both subsequent radiographic disease progression and the likelihood of response to therapy [36,63,75,76].

MRI, utilizing short tau inversion recovery (STIR) and T1-weighted images, can identify both active inflammatory lesions of the sacroiliac joints (bone marrow edema, capsulitis, synovitis, and enthesitis) and chronic structural lesions (sclerosis, erosions, fat deposition, and ankylosis) that are typical for sacroiliitis [38,77]. MRI demonstrates active sacroiliitis with higher sensitivity and earlier than radiography because of its ability to detect inflammatory lesions of axSpA [13,36,37,78]. The inflammatory changes of sacroiliitis on MRI have been shown to precede structural radiographic findings by three to seven years [36,37]. MRI can also detect the chronic structural lesions of the sacroiliac joints with higher accuracy than radiographs [45].

It is important to recognize that the sensitivity and specificity of MRI for axSpA depends on the imaging criteria used, patient population, and reference standard for diagnosis. Early literature showed 95% sensitivity and 100% specificity of MRI for sacroiliitis, substantially higher than radiographs or bone scintigraphy, although that study included a small number of patients, and most subsequent studies demonstrate smaller yields [41]. The ASAS criteria developed in 2009 utilize the presence of bone marrow edema to define a positive MRI of the sacroiliac joints in axSpA [79]. Using solely the imaging arm of the ASAS algorithm (which includes positive radiographs or positive MRI with one clinical axSpA feature), the ASAS criteria were initially shown to have a sensitivity of 66.2% and specificity of 97.3%, although by combining both imaging and clinical arms of the algorithm the sensitivity was 82.9% and specificity was 84.4% for axSpA [19]. Subsequently, in an inception cohort followed for 8 years, the ASAS definition of a positive MRI demonstrated a sensitivity of 79% and a specificity of 89% for the diagnosis of axSpA [80]. Although the presence of bone marrow edema provides a sensitive evaluation for inflammatory changes in axSpA, bone marrow edema can also be seen in noninflammatory conditions such as in age-related degenerative changes, postpartum patients, patients with chronic back pain, athletes, and in up to 30% of healthy controls [81-85]. As a result, the ASAS MRI criteria have been criticized for decreased specificity of bone marrow edema as the sole MRI diagnostic criterion [82]. Importantly, although bone marrow edema may be nonspecific in some cases, one study found that the presence of a deep bone marrow edema lesion which extends at least 1 cm deep to the articular surface is more specific and found almost exclusively in axSpA [86]. Structural changes of axSpA including erosions, sclerosis, fatty deposition, and ankylosis are not accounted for in the ASAS definition of a positive MRI, although they are important findings in axSpA and should be identified in clinical practice [38]. Two related studies on a group of 187 patients demonstrated high sensitivity of 90% to 92% and specificity of 94% to 97% for the diagnosis of AS by using global assessment of both inflammatory and structural lesions [83,87], and subsequently this group of authors showed that identifying erosions and/or bone marrow edema increases sensitivity for axSpA compared with bone marrow edema alone, without decreasing specificity [85]. They also showed that identifying erosions and/or bone marrow edema on MRI increased both sensitivity and specificity for axSpA compared with the diagnostic criterion of solely bone marrow edema [88]. Subchondral fatty deposition, another chronic finding of structural marrow remodeling, is an additional helpful and highly specific finding in axSpA with reported specificities up to 95% to 98% [89,90]. Finally, intra-articular signal changes including increased T1 signal, T2 hyperintense joint fluid, and ankylosis are highly specific findings for axSpA, and when found together with bone marrow edema can increase the positive predictive value for a diagnosis of axSpA compared with bone marrow edema alone [91,92]. Overall, it is clear that interrogation of sacroiliac joint MRI using both STIR and T1-weighted images is critical to identify both the inflammatory and structural changes of axSpA in clinical practice.

MRI has long been considered inferior to CT in demonstrating the structural changes of axSpA, although evolving literature demonstrates that a specific MRI sequence, volumetric interpolated breath-hold examination (VIBE), can

demonstrate erosions with higher sensitivity and similar specificity compared to conventional T1-weighted imaging, and may be comparable to CT [93,94], making it a promising technique for identifying structural lesions of axSpA on MRI.

Multiple studies have examined diffusion-weighted imaging and dynamic contrast-enhanced MRI to determine their diagnostic utility and performance as imaging biomarkers of inflammation. Although these studies show correlation between diffusion-weighted imaging, dynamic contrast-enhanced, and conventional sequences, there is no evidence that these MRI techniques provide additional diagnostic utility compared with conventional MRI sequences [95-106].

Contrast-enhanced MRI can demonstrate active inflammatory changes of the sacroiliac joints in axSpA, although multiple studies show that noncontrast and contrast-enhanced MRI have overall similar diagnostic utility for axSpA [107-111]. Contrast-enhanced MRI has been reported to increase the diagnostic confidence of MRI interpretation in 1 study [107].

MRI Sacroiliac Joints and Spine Area of Interest

After radiography is performed, MRI is the next imaging technique of choice in the evaluation of suspected axSpA [1,3,19,22]. MRI of the sacroiliac joints and spine is associated with improved diagnostic confidence in axSpA and yields findings that stimulate changes in both diagnosis and treatment plans for patients [74]. Although there is agreement in the literature and among experts that MRI should include the sacroiliac joints, there is not a consistently established convention to guide the clinician on whether to image only the sacroiliac joints or both the sacroiliac joints and the spine in patients with suspected axSpA [1,3,19,22]. Not unexpectedly, there is heterogeneity in clinical practice regarding the use of MRI to evaluate the sacroiliac joints and/or spine in these patients [112]. One study has shown that the majority of patients can be diagnosed with axSpA by obtaining MRI of the sacroiliac joints only [60]. Another study shows that the addition of spine MRI to sacroiliac joint MRI adds little incremental value in the diagnosis of nonradiographic axSpA [113]. However, axSpA often involves the axial skeleton proximal to the sacroiliac joints and may exhibit findings isolated to the spine. For example, in a study of whole-body MRI in active axSpA, 99% of patients were found to have active inflammatory lesions in the axial skeleton, with inflammatory changes isolated to the sacroiliac joints in 52% of patients, inflammatory changes isolated to the spine in 5% of patients, and with inflammatory changes at both the sacroiliac joints and spine in 41% of patients [59]. Other studies have shown widely varying degrees of isolated spinal involvement on MRI ranging from 1% to 49% [19,60-63,114,115]. In early axSpA, it has been shown that inflammation involving both the sacroiliac joints and spine can be seen in 28.3% of patients [116]. Therefore, it can be useful in some cases to image both the sacroiliac joints and the spine to help ensure MRI yields the highest diagnostic utility and establishes the extent of disease burden. The decision on whether to image the spine as well as the sacroiliac joints could be based on the site of symptoms. Although there is some disagreement about the extent to which inflammatory changes in the axial skeleton correspond with symptoms, imaging the spine in the clinical region of interest is beneficial in the setting of referable symptoms [62,117-119]. Multiple authors utilize whole-spine or whole-body MRI to identify the burden of disease throughout the spine rather than imaging specific segments because findings may potentially be found in any portion of the spine [10,59,63,89,114,120-122].

The spine MRI findings of axSpA include the active inflammatory changes of spondylitis and spondylodiscitis, inflammatory changes of the costovertebral joints, costotransverse joints, and facet joints, and areas of enthesitis along other vertebral ligamentous attachments [123]. The chronic structural changes of fatty deposition, erosions, and syndesmophytes are also characteristic findings [123]. One study showed that the presence of two or more corner inflammatory lesions had a sensitivity of 69% and specificity of 94% for AS and that lateral vertebral inflammatory lesions had high specificity of 97% [120]. The presence of multiple lesions in the spine has shown to be useful; specifically the presence of at least 5 inflammatory lesions or 5 fatty lesions in the spine has been shown to have a specificity of 95% for axSpA [89]. One study shows that the corner sign in the lumbar spine on T1-weighted or T2-weighted images without fat saturation has a sensitivity of 62% and specificity of 96% for AS [12]. Furthermore, it has been shown that the presence of multiple fatty corner lesions in the spine has a high specificity of 98% and can be useful in the absence of active inflammatory lesions [11]. The ASAS considers a spine MRI positive for axSpA if there are three or more sites of inflammatory spondylitis and considers fatty corner deposition at several sites suggestive of axSpA especially in younger adults [123]. A subsequent study confirmed that the presence of multiple corner lesions has high specificity for axSpA, although it showed a low diagnostic utility because of low sensitivity [121]. Importantly, the findings on spine MRI should be interpreted alongside sacroiliac joint MRI to ensure the highest diagnostic utility. Additionally, MRI findings should be interpreted with specific

attention to identify associated morphologic findings such as disc degeneration or osteophytes that favor degenerative changes rather than axSpA, because both inflammatory and fatty lesions can occur in degenerative changes [124].

Contrast-enhanced MRI can demonstrate active inflammatory changes of the sacroiliac joints and spine in axSpA, although multiple studies show that noncontrast and contrast-enhanced MRI have overall similar diagnostic utility for axSpA [9,107-111,125-129]. Contrast-enhanced MRI has been reported to increase the diagnostic confidence and reliability of MRI interpretation in 2 studies [9,107].

US Sacroiliac Joints

US is not suggested as a routine diagnostic modality for the evaluation of sacroiliitis in patients with suspected axSpA because of its lack of established diagnostic utility [22]. Importantly, US provides evaluation limited to the superficial posterior margins of the sacroiliac joints, and therefore many structural details are not demonstrated. Many of the available studies examine the utility of Doppler evaluation. It has been shown that patients with active sacroiliitis because of axSpA have lower Doppler US resistive indices than healthy controls or patients with osteoarthritis at the sacroiliac joints [130-132]. Using MRI as the reference standard in a study of 51 patients with AS, a pulsatile monophasic waveform was shown to have a sensitivity of 82% and specificity of 92% for active disease, although 18.5% of active AS patients, 70.8% of inactive AS patients, and 63.3% of normal patients had no Doppler flow identified, and the sensitivity for detection of AS patients overall was only 43% [133]. One study reported higher sensitivity of contrast-enhanced US compared with conventional US [134,135]. A recent systematic review of US of the sacroiliac joints in spondyloarthritis reported a median sensitivity of 90% and specificity of 89% in seven of those studies, although with variation in the method of evaluation and reference standard. The authors concluded that there is not enough evidence to support the use of US for the diagnosis of axSpA [136].

US Sacroiliac Joints and Spine Area of Interest

US is not suggested as a routine diagnostic modality for the evaluation of sacroiliitis in patients with suspected axSpA because of its lack of established diagnostic utility [22]. Importantly, US provides evaluation limited to the superficial posterior margins of the sacroiliac joints and spine, and therefore many structural details are not demonstrated. Many of the available studies examine the utility of Doppler evaluation. In addition to data showing decreased resistive indices at the sacroiliac joints in patients with active sacroiliitis joints [130-132], there is evidence that resistive indices of the thoracolumbar paraspinal areas are also decreased in patients with AS [132]. However, there is not enough evidence to support the use of US for the diagnosis of axSpA.

Variant 3: Inflammatory back pain. Suspected axial spondyloarthritis. Negative radiographs and negative MRI of the sacroiliac joints. Next imaging study.

The body regions covered in this clinical scenario are the sacroiliac joints, cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information.

Bone Scan with SPECT or SPECT/CT Spine Area of Interest

Bone scintigraphy is not routinely suggested in the evaluation of patients with suspected axSpA because of its lack of established diagnostic utility [22]. Conventional bone scintigraphy has low to moderate sensitivity and variable specificity for the diagnosis of axSpA [41,42,50]. If bone scintigraphy is used, because of the complexity of the spine anatomy, the use of SPECT should be performed during the examination [51]. Although bone scintigraphy is not typically performed during the evaluation of suspected axSpA because of its limited diagnostic utility, there is recent data that hybrid SPECT/CT has higher sensitivity than conventional bone scintigraphy in the detection of sacroiliitis [52,53], although there is not enough evidence at this time to support its routine use for evaluating the sacroiliac joints or spine.

CT Spine Area of Interest

CT demonstrates structural changes in the spine that may not be apparent on radiographs [22], including structural changes such as erosions, sclerosis, bone formation, syndesmophytes, and ankyloses [49,54]. CT has been shown to demonstrate syndesmophytes with higher sensitivity than radiographs and low-dose protocols can be utilized [58]. CT is especially helpful for evaluation of the thoracic spine and facet joints, which can be challenging to evaluate on radiography [49]. Although MRI remains the technique of choice for the diagnosis of axSpA [1,3,19,22], CT can be useful in patients in the setting of prior negative radiographic and negative CT evaluation of

the sacroiliac joints in order to identify patients with axSpA who have disease isolated to the spine, which has been shown to occur in a variable percentage of patients based on data from MRI studies [19,59-63].

There is no role for contrast-enhanced CT in the evaluation of axSpA.

Fluoride PET/CT Skull Base to Mid-Thigh

There is not enough data to support the routine use of PET/CT in the evaluation of patients with suspected axSpA. F-18-fluoride has been shown to be a potentially useful tracer in identifying sites of osteoblastic activity in axSpA patients [64,65]. Uptake on PET/CT has also been shown to correlate with clinical disease activity in patients with axSpA [66,67]; however, there is conflicting evidence regarding the extent to which tracer uptake correlates with specific inflammatory and structural lesions seen on CT and MRI resulting in uncertainty about its diagnostic utility [64,67-72]. In one study, the interreader reliability of diagnosing sacroiliitis on PET/CT was poor and substantially lower than that for MRI or CT [67]. In a small study using radiographs as the reference standard, F-18-fluoride PET/CT had a sensitivity of 80% and specificity of 77% for the detection of sacroiliitis in AS, although there are inherent limitations in the use of radiographs as the reference standard for diagnosing axSpA [73]. Given the available data, the utility of PET/CT in the diagnosis of axSpA, including its utility in assessment of the spine, is uncertain at this time.

MRI Spine Area of Interest

Although MRI of the sacroiliac joints has high utility for the diagnosis of axSpA, some patients will not demonstrate imaging features of axSpA in the sacroiliac joints on MRI as indicated by sensitivities of all studies to varying degrees below 100% [22], and therefore some patients may need further imaging evaluation with MRI given that it is the imaging modality of choice for the diagnosis of axSpA [1,3,19,22]. Studies have shown widely varying degrees of isolated spinal involvement on MRI in axSpA ranging from 1% to 49% [19,59-63,114,115]. Therefore, imaging of the spine is beneficial for patients in whom there is suspicion for axSpA but imaging of the sacroiliac joints has been negative. Some authors have shown the utility of using whole-spine or whole-body MRI to identify the burden of disease rather than selecting specific areas of the spine to image because findings may be potentially isolated to any portion of the spine [10,59,63,89,114,120-122].

The spine MRI findings of axSpA include the active inflammatory changes of spondylitis and spondylodiscitis, the inflammatory changes of the costovertebral joints, costotransverse joints, and facet joints and areas of enthesitis along other vertebral ligamentous attachments [123]. The chronic structural changes of fatty deposition, erosions, and syndesmophytes are also characteristic findings [123]. One study showed that the presence of two or more corner inflammatory lesions had a sensitivity of 69% and specificity of 94% for AS and that lateral vertebral inflammatory lesions had high specificity of 97% [120]. The presence of multiple lesions in the spine has shown to be useful; specifically the presence of at least five inflammatory lesions or five fatty lesions in the spine has been shown to have a specificity of 95% for axSpA [89]. One study shows that the corner sign in the lumbar spine on T1-weighted or T2-weighted images without fat saturation has a sensitivity of 62% and specificity of 96% for AS [12]. Furthermore, it has been shown that the presence of multiple fatty corner lesions in the spine has a high specificity of 98% and can be useful in the absence of active inflammatory lesions [11]. The ASAS considers a spine MRI positive for axSpA if there are three or more sites of inflammatory spondylitis and considers fatty corner deposition at several sites suggestive of axSpA especially in younger adults [123]. A subsequent study confirmed that the presence of multiple corner lesions has a high specificity for axSpA, although it showed a low diagnostic utility because of low sensitivity [121]. Importantly, the findings on spine MRI should be interpreted alongside sacroiliac joint MRI to ensure the highest diagnostic utility. Additionally, MRI findings should be interpreted with specific attention to identify associated morphologic findings such as disc degeneration or osteophytes that favor degenerative changes rather than axSpA, because both inflammatory and fatty lesions can occur in degenerative changes [124].

Contrast-enhanced MRI can demonstrate active inflammatory changes of the spine in axSpA, although multiple studies show that noncontrast and contrast-enhanced MRI have overall similar diagnostic utility for axSpA [9,125-129]. Contrast-enhanced MRI has been reported to increase reliability of MRI interpretation in 1 study [9].

Radiography Spine Area of Interest

If radiographs and MRI of the sacroiliac joints have been negative, radiographic evaluation of the spine can be obtained to evaluate for the structural imaging findings of axSpA, including syndesmophytes, erosions, shiny corners, vertebral body squaring, and ankylosis [38]. Although radiographs show structural changes, they will not demonstrate the inflammatory changes or fatty infiltration that can be demonstrated on MRI.

US Spine Area of Interest
US is not beneficial as a diagnostic tool for the evaluation of sacroiliitis in patients with suspected axSpA because of its lack of established diagnostic utility [22]. Importantly, US provides limited evaluation of the superficial posterior margins of the spine, and therefore many structural details are not demonstrated. There is a paucity of evidence literature evaluating US in the spine in patients with axSpA. One study demonstrates that resistive indices of the thoracolumbar paraspinal areas are also decreased in patients with AS, similar to findings reported at the sacroiliac joints [132].

Variant 4: Known axial spondyloarthritis. Follow-up for treatment response or disease progression.

The body regions covered in this clinical scenario are the sacroiliac joints, cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information.

Bone Scan with SPECT or SPECT/CT Sacroiliac Joints
Bone scintigraphy is not routinely obtained to evaluate for treatment response or disease progression in axSpA patients, and there is no relevant literature supporting its use in this setting.

Bone Scan with SPECT or SPECT/CT Sacroiliac Joints and Spine Area of Interest
Bone scintigraphy is not routinely obtained to evaluate for treatment response or disease progression in axSpA patients, and there is no relevant literature supporting its use in this setting.

CT Sacroiliac Joints
CT demonstrates structural changes of the sacroiliac joints in axSpA that may not be apparent on radiographs [22]; however, it is not routinely used for follow-up or assessing disease progression.

CT Sacroiliac Joints and Spine Area of Interest
CT demonstrates structural changes of the sacroiliac joints in axSpA that may not be apparent on radiographs [22] and can better demonstrate spinal syndesmophyte growth than radiographs using low-dose techniques [49,58]. However, it is not routinely used for follow-up or assessing disease progression.

Fluoride PET/CT Skull Base to Mid-Thigh
F-18-fluoride PET/CT is not routinely obtained to evaluate for treatment response or disease progression in axSpA patients, and there is no relevant literature supporting its use in this setting.

MRI Sacroiliac Joints
There is no standard method of following patients with MRI to evaluate for treatment response or disease progression [22,30]. Although multiple studies demonstrate decreasing inflammation on MRI following treatment with TNF-inhibitors, including some long-term studies showing sustained reduction in inflammation, the degree to which MRI findings correlate with disease activity is variable [30]. The American College of Rheumatology and European League Against Rheumatism agree that the decision to repeat MRI to assess disease activity or monitor for disease response depends on the clinical circumstances [22,30]. Specifically, MRI of the sacroiliac joints may be helpful for cases in which the disease activity is unclear, available clinical or laboratory data are conflicting, or knowledge of MRI findings is expected to alter treatment [30]. MRI can also detect chronic structural changes on axSpA in the sacroiliac joints, although the clinical utility of follow-up for that purpose is not established [137]. Noncontrast and contrast-enhanced MRI have overall similar diagnostic utility for evaluation of the sacroiliac joints in axSpA [107-111]. The Spondyloarthritis Research Consortium of Canada method has been utilized as a scoring system for quantification and follow-up of lesions at the sacroiliac joints on MRI [138].

MRI Sacroiliac Joints and Spine Area of Interest
There is no standard method of following patients with MRI to evaluate for treatment response or disease progression [22,30]. Although multiple studies demonstrate decreasing inflammation on MRI following treatment with TNF-inhibitors, including some long-term studies showing sustained reduction in inflammation, the degree to which MRI findings correlate with disease activity is variable [30]. The American College of Rheumatology and European League Against Rheumatism agree that the decision to repeat MRI to assess disease activity or monitor for disease response depends on the clinical circumstances [22,30]. Specifically, MRI of the sacroiliac joints and spine may be helpful for cases in which the disease activity is unclear, available clinical or laboratory data are conflicting, or knowledge of MRI findings is expected to alter treatment [30]. MRI can also detect chronic structural changes on axSpA in the sacroiliac joints and spine, although the clinical utility of follow-up for that purpose is not

established [110,137]. Noncontrast and contrast-enhanced MRI have overall similar diagnostic utility for evaluation of the sacroiliac joints and spine in axSpA [9,107-111,125-129]. The Spondyloarthritis Research Consortium of Canada and Berlin methods have been used as scoring systems for quantification and follow-up of lesions in the sacroiliac joints and spine on MRI [138-140].

Radiography Sacroiliac Joints

There is no standard method of following patients with radiographs to evaluate for progression of structural changes [22], and the American College of Rheumatology recommends against routine radiographic follow-up given the lack of proven benefit [30]. Repeat radiographs can be obtained as necessary for counseling patients on the status and prognosis of their disease, although radiographs are more typically performed to evaluate the spine rather than the sacroiliac joints [30]. This is because of the low utility of sacroiliac joint radiographs for detecting disease progression based on the relatively poor intra- and interreader reliability of interpretation [141]. Radiographs can demonstrate evolving structural changes or bone formation, although these changes occur slowly over time at the sacroiliac joints, often requiring years to detect a change and prompting many authors to suggest a radiographic imaging interval of axSpA patients of no less than 2 years for assessment of disease progression [141-146]. There is evidence that patients on TNF-inhibitors may have slower progression of structural damage at the sacroiliac joints [147,148], although there is some disagreement in the literature [149]. Radiographic scoring systems, such as the Bath Ankylosing Spondylitis Radiology Index for the sacroiliac joints, have been utilized for quantification and follow-up of radiographic progression in patients over time [29,150].

Radiography Sacroiliac Joints and Spine Area of Interest

There is no standard method of following patients with radiographs to evaluate for progression of structural changes [22], and the American College of Rheumatology recommends against routine follow-up given the lack of proven benefit [30]. Repeat radiographs can be obtained for counseling patients on the status and prognosis of their disease, although radiographs are more typically performed to evaluate the spine rather than the sacroiliac joints [30]. This is because of the low utility of sacroiliac joint radiographs for detecting disease progression based on the relatively poor intra- and interreader reliability of interpretation [141]. Radiographic follow-up can demonstrate evolving structural changes or bone formation, although these changes occur slowly over time at the sacroiliac joints and spine, often requiring years to detect a change and prompting some authors to suggest a radiographic imaging interval of axSpA patients of no less than 2 years for assessment of disease progression [141,143-145,151-153]. There is evidence that patients on TNF-inhibitors may have slower progression of structural damage at the sacroiliac joints and spine [148,154-156], although there is some disagreement in the literature [149]. Radiographic scoring systems, such as the Bath Ankylosing Spondylitis Radiology Index for the sacroiliac joints and the modified Stoke Ankylosing Spondylitis Spine Score for the spine, have been utilized for quantification and follow-up of radiographic progression over time [29,150,157].

US Sacroiliac Joints

US of the sacroiliac joints is not utilized as a routine diagnostic tool in the assessment of treatment response or disease progression. Importantly, a US evaluation is limited to the superficial posterior margins of the sacroiliac joints and spine, and therefore many structural details are not demonstrated. Many of the available studies examine the utility of Doppler evaluation. There is evidence in small studies that Doppler resistive indices at the sacroiliac joints increase following treatment with TNF-inhibitors [132,158,159], although more data are necessary to justify the routine use of US in this setting.

US Sacroiliac Joints and Spine Area of Interest

US of the sacroiliac joints is not utilized as a routine diagnostic tool in the assessment of treatment response or disease progression. Importantly, an US evaluation is limited to the superficial posterior margins of the sacroiliac joints and spine, and therefore many structural details are not demonstrated. Many of the available studies examine the utility of Doppler evaluation. There is evidence in small studies that Doppler-resistive indices at the sacroiliac joints increase following treatment with TNF-inhibitors [132,158,159], and there is limited data showing potentially similar findings in thoracolumbar paraspinal spondylitis [132], although more data are necessary to justify routine use of US in this setting.

Variant 5: Axial spondyloarthritis with spine ankylosis. Suspected fracture. Initial imaging.

The body regions covered in this clinical scenario are the cervical, thoracic, and lumbar spine. These body regions might be evaluated separately or in combination as guided by physical examination findings, patient history, and other available information.

Bone Scan with SPECT or SPECT/CT Spine Area of Interest
Bone scintigraphy is not routinely obtained to evaluate for suspected fracture in axSpA patients with spine ankylosis, and there is no relevant literature supporting its use in this setting.

CT Spine Area of Interest
CT and MRI are the imaging techniques of choice for definitive evaluation of the patient with ankylosis and suspected fracture [22,32]. CT can be performed rapidly in trauma patients and excellently depicts the complex structures of each vertebral column that can injured in this setting [31] and therefore is typically the preferred modality [22]. The sensitivities of CT and MRI for fracture detection are similar in the available small case series, notably with some fractures better detected on CT and some better detected on MRI, suggesting these modalities have a degree of complementary diagnostic utility [34,160,161]. CT, similar to MRI, has higher sensitivity for detection of fracture in the setting of ankylosis than radiographs [31,32,34,161]. The cervical spine is most frequently involved in a fracture [32,33,35]. The presence of two or more fractures is common [160], and therefore, the entire spine should be imaged to both ensure detection of the potential fracture(s) and to detect multilevel involvement [32].

Fluoride PET/CT Skull Base to Mid-Thigh
F-18-fluoride PET/CT is not routinely obtained to evaluate for suspected fracture in axSpA patients with spine ankylosis, and there is no relevant literature supporting its use in this setting.

MRI Spine Area of Interest
CT and MRI are the imaging techniques of choice for definitive evaluation of the patient with ankylosis and suspected fracture [22,32]. Technical difficulties can be encountered during an MRI of some patients with spine ankylosis in the acute posttraumatic setting, including inability of patients to remain immobile during the examination, difficulty with coil selection, and motion artifact. These factors combined with varying degrees of spinal deformity and occasional lack of associated bone marrow edema at fracture sites can result in challenging interpretation [160]. Therefore, CT is typically the preferred modality in this setting [22]. The sensitivities of CT and MRI for fracture detection are similar in the available small case series, notably with some fractures better detected on CT and some better detected on MRI, suggesting these modalities have a degree of complementary diagnostic utility [34,160,161]. MRI, similar to CT, has higher sensitivity for detection of fracture in the setting of ankylosis than radiographs [32,34,161]. MRI can detect both osseous fractures as well as soft tissue injuries such as ligamentous disruption or spinal cord injury [31,34,160]. In the setting of neurologic deficit, MRI should be performed, either as the sole cross-sectional imaging modality or in addition to CT [22,162]. The cervical spine is most frequently involved by fracture [32,33,35]. The presence of two or more fractures is common [160], and therefore the entire spine should be imaged to both ensure detection of the potential fracture(s) and to detect multilevel involvement [32].

Radiography Spine Area of Interest
Radiography of the spine can be considered as an initial imaging modality in patients with axSpA and suspected fracture [22], although fractures can be difficult to detect on radiographs in axSpA patients, especially in the setting of structural abnormalities and osteopenia, contributing further to an already inherent lower sensitivity of radiography for fracture detection compared with CT or MRI [31,32,34,160,161]. Negative radiographs in these patients should be followed by cross-sectional imaging. If obtained, radiographs should cover the entire spine in patients with ankylosis and suspected fracture because of the potential for multilevel fractures [32,160].

Additionally, it is possible that the presence or extent of ankylosis in trauma patients, who may have diagnosed or undiagnosed axSpA, may not be established at the time of presentation following trauma and therefore initial radiographs may be crucial to identify this group of patients at risk for severe traumatic spinal injuries.

US Spine Area of Interest
US is not routinely obtained to evaluate for suspected fracture in axSpA patients with spine ankylosis, and there is no relevant literature supporting its use in this setting.

Summary of Recommendations

- **Variant 1**: Radiography sacroiliac joints or radiography sacroiliac joints and spine area of interest is usually appropriate as the initial imaging of suspected axSpA. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

- **Variant 2**: After radiography is performed, MRI sacroiliac joints and spine area of interest without and with IV contrast or MRI sacroiliac joints and spine area of interest without IV contrast or MRI sacroiliac joints without and with IV contrast or MRI sacroiliac joints without IV contrast is usually appropriate as the next imaging study of suspected axSpA. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 3**: If radiographs and MRI of the sacroiliac joints have been negative, radiography spine area of interest or MRI spine area of interest without and with IV contrast or MRI spine area of interest without IV contrast or CT spine area of interest without IV contrast is usually appropriate as the next imaging study of suspected axSpA. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 4**: Radiography sacroiliac joints and spine area of interest or radiography sacroiliac joints is usually appropriate as the follow-up imaging for treatment response or disease progression in axSpA. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).
- **Variant 5**: Radiography spine area of interest or MRI spine area of interest without IV contrast or CT spine area of interest without IV contrast is usually appropriate as the initial imaging for suspected fracture in axSpA with spine ankylosis. These procedures are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging

examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [163].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

References

1. Taurog JD, Chhabra A, Colbert RA. Ankylosing Spondylitis and Axial Spondyloarthritis. N Engl J Med 2016;374:2563-74.
2. Reveille JD, Witter JP, Weisman MH. Prevalence of axial spondylarthritis in the United States: estimates from a cross-sectional survey. Arthritis Care Res (Hoboken) 2012;64:905-10.
3. Sieper J, Poddubnyy D. Axial spondyloarthritis. Lancet 2017;390:73-84.
4. Sieper J, van der Heijde D, Landewe R, et al. New criteria for inflammatory back pain in patients with chronic back pain: a real patient exercise by experts from the Assessment of SpondyloArthritis international Society (ASAS). Ann Rheum Dis 2009;68:784-8.
5. Weisman MH, Witter JP, Reveille JD. The prevalence of inflammatory back pain: population-based estimates from the US National Health and Nutrition Examination Survey, 2009-10. Ann Rheum Dis 2013;72:369-73.
6. Underwood MR, Dawes P. Inflammatory back pain in primary care. Br J Rheumatol 1995;34:1074-7.
7. Masson Behar V, Dougados M, Etcheto A, et al. Diagnostic delay in axial spondyloarthritis: A cross-sectional study of 432 patients. Joint Bone Spine 2017;84:467-71.
8. Jadon DR, Sengupta R, Nightingale A, et al. Axial Disease in Psoriatic Arthritis study: defining the clinical and radiographic phenotype of psoriatic spondyloarthritis. Ann Rheum Dis 2017;76:701-07.
9. Baraliakos X, Hermann KG, Landewe R, et al. Assessment of acute spinal inflammation in patients with ankylosing spondylitis by magnetic resonance imaging: a comparison between contrast enhanced T1 and short tau inversion recovery (STIR) sequences. Ann Rheum Dis 2005;64:1141-4.
10. Bennett AN, Rehman A, Hensor EM, Marzo-Ortega H, Emery P, McGonagle D. Evaluation of the diagnostic utility of spinal magnetic resonance imaging in axial spondylarthritis. Arthritis Rheum 2009;60:1331-41.
11. Bennett AN, Rehman A, Hensor EM, Marzo-Ortega H, Emery P, McGonagle D. The fatty Romanus lesion: a non-inflammatory spinal MRI lesion specific for axial spondyloarthropathy. Ann Rheum Dis 2010;69:891-4.
12. Kim NR, Choi JY, Hong SH, et al. "MR corner sign": value for predicting presence of ankylosing spondylitis. AJR Am J Roentgenol 2008;191:124-8.
13. Weber U, Hodler J, Jurik AG, et al. Assessment of active spinal inflammatory changes in patients with axial spondyloarthritis: validation of whole body MRI against conventional MRI. Ann Rheum Dis 2010;69:648-53.

14. Jacobson JA, Roberts CC, Bencardino JT, et al. ACR Appropriateness Criteria® Chronic Extremity Joint Pain-Suspected Inflammatory Arthritis. J Am Coll Radiol 2017;14:S81-S89.
15. van der Linden S, Valkenburg HA, Cats A. Evaluation of diagnostic criteria for ankylosing spondylitis. A proposal for modification of the New York criteria. Arthritis Rheum 1984;27:361-8.
16. Mau W, Zeidler H, Mau R, et al. Clinical features and prognosis of patients with possible ankylosing spondylitis. Results of a 10-year followup. J Rheumatol 1988;15:1109-14.
17. Rudwaleit M, Landewe R, van der Heijde D, et al. The development of Assessment of SpondyloArthritis international Society classification criteria for axial spondyloarthritis (part I): classification of paper patients by expert opinion including uncertainty appraisal. Ann Rheum Dis 2009;68:770-6.
18. Khan MA, van der Linden SM, Kushner I, Valkenburg HA, Cats A. Spondylitic disease without radiologic evidence of sacroiliitis in relatives of HLA-B27 positive ankylosing spondylitis patients. Arthritis Rheum 1985;28:40-3.
19. Rudwaleit M, van der Heijde D, Landewe R, et al. The development of Assessment of SpondyloArthritis international Society classification criteria for axial spondyloarthritis (part II): validation and final selection. Ann Rheum Dis 2009;68:777-83.
20. Costantino F, Zeboulon N, Said-Nahal R, Breban M. Radiographic sacroiliitis develops predictably over time in a cohort of familial spondyloarthritis followed longitudinally. Rheumatology (Oxford) 2017;56:811-17.
21. Ghosh N, Ruderman EM. Nonradiographic axial spondyloarthritis: clinical and therapeutic relevance. Arthritis Res Ther 2017;19:286.
22. Mandl P, Navarro-Compan V, Terslev L, et al. EULAR recommendations for the use of imaging in the diagnosis and management of spondyloarthritis in clinical practice. Ann Rheum Dis 2015;74:1327-39.
23. Poddubnyy D, Sieper J. Similarities and differences between nonradiographic and radiographic axial spondyloarthritis: a clinical, epidemiological and therapeutic assessment. Curr Opin Rheumatol 2014;26:377-83.
24. Law L, Beckman Rehnman J, Deminger A, Klingberg E, Jacobsson LTH, Forsblad-d'Elia H. Factors related to health-related quality of life in ankylosing spondylitis, overall and stratified by sex. Arthritis Res Ther 2018;20:284.
25. Lopez-Medina C, Garrido-Castro JL, Castro-Jimenez J, et al. Evaluation of quality of life in patients with axial spondyloarthritis and its association with disease activity, functionality, mobility, and structural damage. Clin Rheumatol 2018;37:1581-88.
26. van Lunteren M, Ez-Zaitouni Z, de Koning A, et al. In Early Axial Spondyloarthritis, Increasing Disease Activity Is Associated with Worsening of Health-related Quality of Life over Time. J Rheumatol 2018;45:779-84.
27. Landewe R, Dougados M, Mielants H, van der Tempel H, van der Heijde D. Physical function in ankylosing spondylitis is independently determined by both disease activity and radiographic damage of the spine. Ann Rheum Dis 2009;68:863-7.
28. Ramiro S, van der Heijde D, van Tubergen A, et al. Higher disease activity leads to more structural damage in the spine in ankylosing spondylitis: 12-year longitudinal data from the OASIS cohort. Ann Rheum Dis 2014;73:1455-61.
29. van der Heijde D, Braun J, Deodhar A, et al. Modified stoke ankylosing spondylitis spinal score as an outcome measure to assess the impact of treatment on structural progression in ankylosing spondylitis. Rheumatology (Oxford) 2019;58:388-400.
30. Ward MM, Deodhar A, Gensler LS, et al. 2019 Update of the American College of Rheumatology/Spondylitis Association of America/Spondyloarthritis Research and Treatment Network Recommendations for the Treatment of Ankylosing Spondylitis and Nonradiographic Axial Spondyloarthritis. Arthritis Care Res (Hoboken) 2019;71:1285-99.
31. Campagna R, Pessis E, Feydy A, et al. Fractures of the ankylosed spine: MDCT and MRI with emphasis on individual anatomic spinal structures. AJR Am J Roentgenol 2009;192:987-95.
32. Rustagi T, Drazin D, Oner C, et al. Fractures in Spinal Ankylosing Disorders: A Narrative Review of Disease and Injury Types, Treatment Techniques, and Outcomes. J Orthop Trauma 2017;31 Suppl 4:S57-S74.
33. Westerveld LA, Verlaan JJ, Oner FC. Spinal fractures in patients with ankylosing spinal disorders: a systematic review of the literature on treatment, neurological status and complications. Eur Spine J 2009;18:145-56.

34. Wang YF, Teng MM, Chang CY, Wu HT, Wang ST. Imaging manifestations of spinal fractures in ankylosing spondylitis. AJNR Am J Neuroradiol 2005;26:2067-76.
35. Caron T, Bransford R, Nguyen Q, Agel J, Chapman J, Bellabarba C. Spine fractures in patients with ankylosing spinal disorders. Spine (Phila Pa 1976) 2010;35:E458-64.
36. Bennett AN, McGonagle D, O'Connor P, et al. Severity of baseline magnetic resonance imaging-evident sacroiliitis and HLA-B27 status in early inflammatory back pain predict radiographically evident ankylosing spondylitis at eight years. Arthritis Rheum 2008;58:3413-8.
37. Oostveen J, Prevo R, den Boer J, van de Laar M. Early detection of sacroiliitis on magnetic resonance imaging and subsequent development of sacroiliitis on plain radiography. A prospective, longitudinal study. J Rheumatol 1999;26:1953-8.
38. Sieper J, Rudwaleit M, Baraliakos X, et al. The Assessment of SpondyloArthritis international Society (ASAS) handbook: a guide to assess spondyloarthritis. Ann Rheum Dis 2009;68 Suppl 2:ii1-44.
39. Battistone MJ, Manaster BJ, Reda DJ, Clegg DO. Radiographic diagnosis of sacroiliitis--are sacroiliac views really better? J Rheumatol 1998;25:2395-401.
40. Omar A, Sari I, Bedaiwi M, Salonen D, Haroon N, Inman RD. Analysis of dedicated sacroiliac views to improve reliability of conventional pelvic radiographs. Rheumatology (Oxford) 2017;56:1740-45.
41. Blum U, Buitrago-Tellez C, Mundinger A, et al. Magnetic resonance imaging (MRI) for detection of active sacroiliitis--a prospective study comparing conventional radiography, scintigraphy, and contrast enhanced MRI. J Rheumatol 1996;23:2107-15.
42. Inanc N, Atagunduz P, Sen F, Biren T, Turoglu HT, Direskeneli H. The investigation of sacroiliitis with different imaging techniques in spondyloarthropathies. Rheumatol Int 2005;25:591-4.
43. van Tubergen A, Heuft-Dorenbosch L, Schulpen G, et al. Radiographic assessment of sacroiliitis by radiologists and rheumatologists: does training improve quality? Ann Rheum Dis 2003;62:519-25.
44. Geijer M, Gothlin GG, Gothlin JH. The clinical utility of computed tomography compared to conventional radiography in diagnosing sacroiliitis. A retrospective study on 910 patients and literature review. J Rheumatol 2007;34:1561-5.
45. Diekhoff T, Hermann KG, Greese J, et al. Comparison of MRI with radiography for detecting structural lesions of the sacroiliac joint using CT as standard of reference: results from the SIMACT study. Ann Rheum Dis 2017;76:1502-08.
46. Christiansen AA, Hendricks O, Kuettel D, et al. Limited Reliability of Radiographic Assessment of Sacroiliac Joints in Patients with Suspected Early Spondyloarthritis. J Rheumatol 2017;44:70-77.
47. Devauchelle-Pensec V, D'Agostino MA, Marion J, et al. Computed tomography scanning facilitates the diagnosis of sacroiliitis in patients with suspected spondylarthritis: results of a prospective multicenter French cohort study. Arthritis Rheum 2012;64:1412-9.
48. van den Berg R, Lenczner G, Feydy A, et al. Agreement between clinical practice and trained central reading in reading of sacroiliac joints on plain pelvic radiographs. Results from the DESIR cohort. Arthritis Rheumatol 2014;66:2403-11.
49. Tan S, Ward MM. Computed tomography in axial spondyloarthritis. Curr Opin Rheumatol 2018;30:334-39.
50. Song IH, Brandt H, Rudwaleit M, Sieper J. Limited diagnostic value of unilateral sacroiliitis in scintigraphy in assessing axial spondyloarthritis. J Rheumatol 2010;37:1200-2.
51. Jacobsson H, Larsson SA, Vesterskold L, Lindvall N. The application of single photon emission computed tomography to the diagnosis of ankylosing spondylitis of the spine. Br J Radiol 1984;57:133-40.
52. Kim YI, Suh M, Kim YK, Lee HY, Shin K. The usefulness of bone SPECT/CT imaging with volume of interest analysis in early axial spondyloarthritis. BMC Musculoskelet Disord 2015;16:9.
53. Parghane RV, Singh B, Sharma A, Singh H, Singh P, Bhattacharya A. Role of (99m)Tc-Methylene Diphosphonate SPECT/CT in the Detection of Sacroiliitis in Patients with Spondyloarthropathy: Comparison with Clinical Markers and MRI. J Nucl Med Technol 2017;45:280-84.
54. Navallas M, Ares J, Beltran B, Lisbona MP, Maymo J, Solano A. Sacroiliitis associated with axial spondyloarthropathy: new concepts and latest trends. Radiographics 2013;33:933-56.
55. Lee YH, Hwang JY, Lee SW, Lee J. The clinical usefulness of multidetector computed tomography of the sacroiliac joint for evaluating spondyloarthropathies. Korean J Intern Med 2007;22:171-7.
56. Wu H, Zhang G, Shi L, et al. Axial Spondyloarthritis: Dual-Energy Virtual Noncalcium CT in the Detection of Bone Marrow Edema in the Sacroiliac Joints. Radiology 2019;290:157-64.

57. Zhang P, Yu KH, Guo RM, et al. Comparing the diagnostic utility of sacroiliac spectral CT and MRI in axial spondyloarthritis. Br J Radiol 2016;89:20150196.
58. de Koning A, de Bruin F, van den Berg R, et al. Low-dose CT detects more progression of bone formation in comparison to conventional radiography in patients with ankylosing spondylitis: results from the SIAS cohort. Ann Rheum Dis 2018;77:293-99.
59. Althoff CE, Sieper J, Song IH, et al. Active inflammation and structural change in early active axial spondyloarthritis as detected by whole-body MRI. Ann Rheum Dis 2013;72:967-73.
60. Ez-Zaitouni Z, Bakker PA, van Lunteren M, et al. The yield of a positive MRI of the spine as imaging criterion in the ASAS classification criteria for axial spondyloarthritis: results from the SPACE and DESIR cohorts. Ann Rheum Dis 2017;76:1731-36.
61. Larbi A, Fourneret B, Lukas C, et al. Prevalence and topographic distribution of spinal inflammation on MR imaging in patients recently diagnosed with axial spondyloarthritis. Diagn Interv Imaging 2017;98:347-53.
62. Lorenzin M, Ortolan A, Frallonardo P, et al. Spine and sacroiliac joints on magnetic resonance imaging in patients with early axial spondyloarthritis: prevalence of lesions and association with clinical and disease activity indices from the Italian group of the SPACE study. Reumatismo 2016;68:72-82.
63. Rudwaleit M, Schwarzlose S, Hilgert ES, Listing J, Braun J, Sieper J. MRI in predicting a major clinical response to anti-tumour necrosis factor treatment in ankylosing spondylitis. Ann Rheum Dis 2008;67:1276-81.
64. Bruijnen ST, van der Weijden MA, Klein JP, et al. Bone formation rather than inflammation reflects ankylosing spondylitis activity on PET-CT: a pilot study. Arthritis Res Ther 2012;14:R71.
65. Bruijnen STG, Verweij NJF, van Duivenvoorde LM, et al. Bone formation in ankylosing spondylitis during anti-tumour necrosis factor therapy imaged by 18F-fluoride positron emission tomography. Rheumatology (Oxford) 2018;57:631-38.
66. Idolazzi L, Salgarello M, Gatti D, et al. 18F-fluoride PET/CT for detection of axial involvement in ankylosing spondylitis: correlation with disease activity. Ann Nucl Med 2016;30:430-4.
67. Raynal M, Bouderraoui F, Ouichka R, et al. Performance of (18)F-sodium fluoride positron emission tomography with computed tomography to assess inflammatory and structural sacroiliitis on magnetic resonance imaging and computed tomography, respectively, in axial spondyloarthritis. Arthritis Res Ther 2019;21:119.
68. Buchbender C, Ostendorf B, Ruhlmann V, et al. Hybrid 18F-labeled Fluoride Positron Emission Tomography/Magnetic Resonance (MR) Imaging of the Sacroiliac Joints and the Spine in Patients with Axial Spondyloarthritis: A Pilot Study Exploring the Link of MR Bone Pathologies and Increased Osteoblastic Activity. J Rheumatol 2015;42:1631-7.
69. Fischer DR, Pfirrmann CW, Zubler V, et al. High bone turnover assessed by 18F-fluoride PET/CT in the spine and sacroiliac joints of patients with ankylosing spondylitis: comparison with inflammatory lesions detected by whole body MRI. EJNMMI Res 2012;2:38.
70. Ouichka R, Bouderraoui F, Raynal M, et al. Performance of 18F-sodium fluoride positron emission tomography with computed tomography to assess inflammatory and structural sacroiliitis on magnetic resonance imaging in axial spondyloarthritis. Clin Exp Rheumatol 2019;37:19-25.
71. Sawicki LM, Lutje S, Baraliakos X, et al. Dual-phase hybrid (18) F-Fluoride Positron emission tomography/MRI in ankylosing spondylitis: Investigating the link between MRI bone changes, regional hyperaemia and increased osteoblastic activity. J Med Imaging Radiat Oncol 2018;62:313-19.
72. Toussirot E, Caoduro C, Ungureanu C, Michel F, Runge M, Boulahdour H. 18F- fluoride PET/CT assessment in patients fulfilling the clinical arm of the ASAS criteria for axial spondyloarthritis. A comparative study with ankylosing spondylitis. Clin Exp Rheumatol 2015;33:588.
73. Strobel K, Fischer DR, Tamborrini G, et al. 18F-fluoride PET/CT for detection of sacroiliitis in ankylosing spondylitis. Eur J Nucl Med Mol Imaging 2010;37:1760-5.
74. Carmona R, Harish S, Linda DD, Ioannidis G, Matsos M, Khalidi NA. MR imaging of the spine and sacroiliac joints for spondyloarthritis: influence on clinical diagnostic confidence and patient management. Radiology 2013;269:208-15.
75. Maksymowych WP, Chiowchanwisawakit P, Clare T, Pedersen SJ, Ostergaard M, Lambert RG. Inflammatory lesions of the spine on magnetic resonance imaging predict the development of new syndesmophytes in ankylosing spondylitis: evidence of a relationship between inflammation and new bone formation. Arthritis Rheum 2009;60:93-102.

76. Sepriano A, Ramiro S, Landewe R, Dougados M, van der Heijde D, Rudwaleit M. Is active sacroiliitis on MRI associated with radiographic damage in axial spondyloarthritis? Real-life data from the ASAS and DESIR cohorts. Rheumatology (Oxford) 2019;58:798-802.
77. Maksymowych WP, Lambert RG, Ostergaard M, et al. MRI lesions in the sacroiliac joints of patients with spondyloarthritis: an update of definitions and validation by the ASAS MRI working group. Ann Rheum Dis 2019;78:1550-58.
78. Puhakka KB, Jurik AG, Egund N, et al. Imaging of sacroiliitis in early seronegative spondylarthropathy. Assessment of abnormalities by MR in comparison with radiography and CT. Acta Radiol 2003;44:218-29.
79. Rudwaleit M, Jurik AG, Hermann KG, et al. Defining active sacroiliitis on magnetic resonance imaging (MRI) for classification of axial spondyloarthritis: a consensual approach by the ASAS/OMERACT MRI group. Ann Rheum Dis 2009;68:1520-7.
80. Aydin SZ, Maksymowych WP, Bennett AN, McGonagle D, Emery P, Marzo-Ortega H. Validation of the ASAS criteria and definition of a positive MRI of the sacroiliac joint in an inception cohort of axial spondyloarthritis followed up for 8 years. Ann Rheum Dis 2012;71:56-60.
81. Agten CA, Zubler V, Zanetti M, et al. Postpartum Bone Marrow Edema at the Sacroiliac Joints May Mimic Sacroiliitis of Axial Spondyloarthritis on MRI. AJR Am J Roentgenol 2018;211:1306-12.
82. Arnbak B, Grethe Jurik A, Horslev-Petersen K, et al. Associations Between Spondyloarthritis Features and Magnetic Resonance Imaging Findings: A Cross-Sectional Analysis of 1,020 Patients With Persistent Low Back Pain. Arthritis Rheumatol 2016;68:892-900.
83. Weber U, Lambert RG, Ostergaard M, Hodler J, Pedersen SJ, Maksymowych WP. The diagnostic utility of magnetic resonance imaging in spondylarthritis: an international multicenter evaluation of one hundred eighty-seven subjects. Arthritis Rheum 2010;62:3048-58.
84. Weber U, Jurik AG, Zejden A, et al. Frequency and Anatomic Distribution of Magnetic Resonance Imaging Features in the Sacroiliac Joints of Young Athletes: Exploring "Background Noise" Toward a Data-Driven Definition of Sacroiliitis in Early Spondyloarthritis. Arthritis Rheumatol 2018;70:736-45.
85. Weber U, Zubler V, Pedersen SJ, et al. Development and validation of a magnetic resonance imaging reference criterion for defining a positive sacroiliac joint magnetic resonance imaging finding in spondyloarthritis. Arthritis Care Res (Hoboken) 2013;65:977-85.
86. de Winter J, de Hooge M, van de Sande M, et al. Magnetic Resonance Imaging of the Sacroiliac Joints Indicating Sacroiliitis According to the Assessment of SpondyloArthritis international Society Definition in Healthy Individuals, Runners, and Women With Postpartum Back Pain. Arthritis Rheumatol 2018;70:1042-48.
87. Weber U, Lambert RG, Pedersen SJ, Hodler J, Ostergaard M, Maksymowych WP. Assessment of structural lesions in sacroiliac joints enhances diagnostic utility of magnetic resonance imaging in early spondylarthritis. Arthritis Care Res (Hoboken) 2010;62:1763-71.
88. Weber U, Ostergaard M, Lambert RG, et al. Candidate lesion-based criteria for defining a positive sacroiliac joint MRI in two cohorts of patients with axial spondyloarthritis. Ann Rheum Dis 2015;74:1976-82.
89. de Hooge M, van den Berg R, Navarro-Compan V, et al. Patients with chronic back pain of short duration from the SPACE cohort: which MRI structural lesions in the sacroiliac joints and inflammatory and structural lesions in the spine are most specific for axial spondyloarthritis? Ann Rheum Dis 2016;75:1308-14.
90. Hu Z, Wang X, Qi J, Kong Q, Zhao M, Gu J. Backfill is a specific sign of axial spondyloarthritis seen on MRI. Joint Bone Spine 2016;83:179-83.
91. Laloo F, Herregods N, Jaremko JL, Verstraete K, Jans L. MRI of the sacroiliac joints in spondyloarthritis: the added value of intra-articular signal changes for a 'positive MRI'. Skeletal Radiol 2018;47:683-93.
92. Laloo F, Herregods N, Varkas G, et al. MR signal in the sacroiliac joint space in spondyloarthritis: a new sign. Eur Radiol 2017;27:2024-30.
93. Baraliakos X, Hoffmann F, Deng X, Wang YY, Huang F, Braun J. Detection of Erosions in Sacroiliac Joints of Patients with Axial Spondyloarthritis Using the Magnetic Resonance Imaging Volumetric Interpolated Breath-hold Examination. J Rheumatol 2019;46:1445-49.
94. Diekhoff T, Greese J, Sieper J, Poddubnyy D, Hamm B, Hermann KA. Improved detection of erosions in the sacroiliac joints on MRI with volumetric interpolated breath-hold examination (VIBE): results from the SIMACT study. Ann Rheum Dis 2018;77:1585-89.

95. Beltran LS, Samim M, Gyftopoulos S, Bruno MT, Petchprapa CN. Does the Addition of DWI to Fluid-Sensitive Conventional MRI of the Sacroiliac Joints Improve the Diagnosis of Sacroiliitis? AJR Am J Roentgenol 2018;210:1309-16.
96. Boy FN, Kayhan A, Karakas HM, Unlu-Ozkan F, Silte D, Aktas I. The role of multi-parametric MR imaging in the detection of early inflammatory sacroiliitis according to ASAS criteria. Eur J Radiol 2014;83:989-96.
97. Bozgeyik Z, Ozgocmen S, Kocakoc E. Role of diffusion-weighted MRI in the detection of early active sacroiliitis. AJR Am J Roentgenol 2008;191:980-6.
98. Bradbury LA, Hollis KA, Gautier B, et al. Diffusion-weighted Imaging Is a Sensitive and Specific Magnetic Resonance Sequence in the Diagnosis of Ankylosing Spondylitis. J Rheumatol 2018;45:771-78.
99. Bray TJP, Vendhan K, Ambrose N, et al. Diffusion-weighted imaging is a sensitive biomarker of response to biologic therapy in enthesitis-related arthritis. Rheumatology (Oxford) 2017;56:399-407.
100. Chan CWS, Tsang HHL, Li PH, et al. Diffusion-weighted imaging versus short tau inversion recovery sequence: Usefulness in detection of active sacroiliitis and early diagnosis of axial spondyloarthritis. PLoS One 2018;13:e0201040.
101. Chung HY, Xu X, Lau VW, et al. Comparing diffusion weighted imaging with clinical and blood parameters, and with short tau inversion recovery sequence in detecting spinal and sacroiliac joint inflammation in axial spondyloarthritis. Clin Exp Rheumatol 2017;35:262-69.
102. Gaspersic N, Sersa I, Jevtic V, Tomsic M, Praprotnik S. Monitoring ankylosing spondylitis therapy by dynamic contrast-enhanced and diffusion-weighted magnetic resonance imaging. Skeletal Radiol 2008;37:123-31.
103. Gezmis E, Donmez FY, Agildere M. Diagnosis of early sacroiliitis in seronegative spondyloarthropathies by DWI and correlation of clinical and laboratory findings with ADC values. Eur J Radiol 2013;82:2316-21.
104. Kucybala I, Ciuk S, Urbanik A, Wojciechowski W. The usefulness of diffusion-weighted imaging (DWI) and dynamic contrast-enhanced (DCE) sequences visual assessment in the early diagnosis of axial spondyloarthritis. Rheumatol Int 2019;39:1559-65.
105. Shi Z, Han J, Qin J, Zhang Y. Clinical application of diffusion-weighted imaging and dynamic contrast-enhanced MRI in assessing the clinical curative effect of early ankylosing spondylitis. Medicine (Baltimore) 2019;98:e15227.
106. Zhang M, Zhou L, Huang N, Zeng H, Liu S, Liu L. Assessment of active and inactive sacroiliitis in patients with ankylosing spondylitis using quantitative dynamic contrast-enhanced MRI. J Magn Reson Imaging 2017;46:71-78.
107. Althoff CE, Feist E, Burova E, et al. Magnetic resonance imaging of active sacroiliitis: do we really need gadolinium? Eur J Radiol 2009;71:232-6.
108. de Hooge M, van den Berg R, Navarro-Compan V, et al. Magnetic resonance imaging of the sacroiliac joints in the early detection of spondyloarthritis: no added value of gadolinium compared with short tau inversion recovery sequence. Rheumatology (Oxford) 2013;52:1220-4.
109. Giraudo C, Weber M, Puchner A, Grisar J, Kainberger F, Schueller-Weidekamm C. Which MR sequences should we use for the reliable detection and localization of bone marrow edema in spondyloarthritis? Radiol Med 2017;122:752-60.
110. Madsen KB, Egund N, Jurik AG. Grading of inflammatory disease activity in the sacroiliac joints with magnetic resonance imaging: comparison between short-tau inversion recovery and gadolinium contrast-enhanced sequences. J Rheumatol 2010;37:393-400.
111. Sung S, Kim HS, Kwon JW. MRI assessment of sacroiliitis for the diagnosis of axial spondyloarthropathy: comparison of fat-saturated T2, STIR and contrast-enhanced sequences. Br J Radiol 2017;90:20170090.
112. Bennett AN, Marzo-Ortega H, Kaur-Papadakis D, Rehman A, BritspA. The Use of Magnetic Resonance Imaging in Axial Spondyloarthritis: Time to Bridge the Gap Between Radiologists and Rheumatologists. J Rheumatol 2017;44:780-85.
113. Weber U, Zubler V, Zhao Z, et al. Does spinal MRI add incremental diagnostic value to MRI of the sacroiliac joints alone in patients with non-radiographic axial spondyloarthritis? Ann Rheum Dis 2015;74:985-92.
114. Chung HY, Yiu RSW, Chan SCW, Lee KH, Lau CS. Fatty corner lesions in T1-weighted magnetic resonance imaging as an alternative to sacroiliitis for diagnosis of axial spondyloarthritis. BMC Rheumatol 2019;3:17.

115. van der Heijde D, Sieper J, Maksymowych WP, et al. Spinal inflammation in the absence of sacroiliac joint inflammation on magnetic resonance imaging in patients with active nonradiographic axial spondyloarthritis. Arthritis Rheumatol 2014;66:667-73.
116. Marzo-Ortega H, McGonagle D, O'Connor P, et al. Baseline and 1-year magnetic resonance imaging of the sacroiliac joint and lumbar spine in very early inflammatory back pain. Relationship between symptoms, HLA-B27 and disease extent and persistence. Ann Rheum Dis 2009;68:1721-7.
117. Blachier M, Coutanceau B, Dougados M, et al. Does the site of magnetic resonance imaging abnormalities match the site of recent-onset inflammatory back pain? The DESIR cohort. Ann Rheum Dis 2013;72:979-85.
118. Bochkova AG, Levshakova AV, Bunchuk NV, Braun J. Spinal inflammation lesions as detected by magnetic resonance imaging in patients with early ankylosing spondylitis are more often observed in posterior structures of the spine. Rheumatology (Oxford) 2010;49:749-55.
119. de Hooge M, de Bruin F, de Beer L, et al. Is the Site of Back Pain Related to the Location of Magnetic Resonance Imaging Lesions in Patients With Chronic Back Pain? Results From the Spondyloarthritis Caught Early Cohort. Arthritis Care Res (Hoboken) 2017;69:717-23.
120. Weber U, Hodler J, Kubik RA, et al. Sensitivity and specificity of spinal inflammatory lesions assessed by whole-body magnetic resonance imaging in patients with ankylosing spondylitis or recent-onset inflammatory back pain. Arthritis Rheum 2009;61:900-8.
121. Weber U, Zhao Z, Rufibach K, et al. Diagnostic utility of candidate definitions for demonstrating axial spondyloarthritis on magnetic resonance imaging of the spine. Arthritis Rheumatol 2015;67:924-33.
122. Weiss BG, Bachmann LM, Pfirrmann CW, Kissling RO, Zubler V. Whole Body Magnetic Resonance Imaging Features in Diffuse Idiopathic Skeletal Hyperostosis in Conjunction with Clinical Variables to Whole Body MRI and Clinical Variables in Ankylosing Spondylitis. J Rheumatol 2016;43:335-42.
123. Hermann KG, Baraliakos X, van der Heijde DM, et al. Descriptions of spinal MRI lesions and definition of a positive MRI of the spine in axial spondyloarthritis: a consensual approach by the ASAS/OMERACT MRI study group. Ann Rheum Dis 2012;71:1278-88.
124. de Bruin F, ter Horst S, Bloem HL, et al. Prevalence of degenerative changes of the spine on magnetic resonance images and radiographs in patients aged 16-45 years with chronic back pain of short duration in the Spondyloarthritis Caught Early (SPACE) cohort. Rheumatology (Oxford) 2016;55:56-65.
125. Baraliakos X, Landewe R, Hermann KG, et al. Inflammation in ankylosing spondylitis: a systematic description of the extent and frequency of acute spinal changes using magnetic resonance imaging. Ann Rheum Dis 2005;64:730-4.
126. Braun J, Baraliakos X, Golder W, et al. Magnetic resonance imaging examinations of the spine in patients with ankylosing spondylitis, before and after successful therapy with infliximab: evaluation of a new scoring system. Arthritis Rheum 2003;48:1126-36.
127. Hermann KG, Landewe RB, Braun J, van der Heijde DM. Magnetic resonance imaging of inflammatory lesions in the spine in ankylosing spondylitis clinical trials: is paramagnetic contrast medium necessary? J Rheumatol 2005;32:2056-60.
128. Rudwaleit M, Baraliakos X, Listing J, Brandt J, Sieper J, Braun J. Magnetic resonance imaging of the spine and the sacroiliac joints in ankylosing spondylitis and undifferentiated spondyloarthritis during treatment with etanercept. Ann Rheum Dis 2005;64:1305-10.
129. Wang YX, Griffith JF, Deng M, et al. Vertebral body corner oedema vs gadolinium enhancement as biomarkers of active spinal inflammation in ankylosing spondylitis. Br J Radiol 2012;85:e702-8.
130. Arslan H, Sakarya ME, Adak B, Unal O, Sayarlioglu M. Duplex and color Doppler sonographic findings in active sacroiliitis. AJR Am J Roentgenol 1999;173:677-80.
131. Ghosh A, Mondal S, Sinha D, Nag A, Chakraborty S. Ultrasonography as a useful modality for documenting sacroiliitis in radiographically negative inflammatory back pain: a comparative evaluation with MRI. Rheumatology (Oxford) 2014;53:2030-4.
132. Unlu E, Pamuk ON, Cakir N. Color and duplex Doppler sonography to detect sacroiliitis and spinal inflammation in ankylosing spondylitis. Can this method reveal response to anti-tumor necrosis factor therapy? J Rheumatol 2007;34:110-6.
133. Mohammadi A, Ghasemi-rad M, Aghdashi M, Mladkova N, Baradaransafa P. Evaluation of disease activity in ankylosing spondylitis; diagnostic value of color Doppler ultrasonography. Skeletal Radiol 2013;42:219-24.

134. Klauser A, Halpern EJ, Frauscher F, et al. Inflammatory low back pain: high negative predictive value of contrast-enhanced color Doppler ultrasound in the detection of inflamed sacroiliac joints. Arthritis Rheum 2005;53:440-4.
135. Klauser AS, De Zordo T, Bellmann-Weiler R, et al. Feasibility of second-generation ultrasound contrast media in the detection of active sacroiliitis. Arthritis Rheum 2009;61:909-16.
136. Gutierrez M, Rodriguez S, Soto-Fajardo C, et al. Ultrasound of sacroiliac joints in spondyloarthritis: a systematic review. Rheumatol Int 2018;38:1791-805.
137. Madsen KB, Jurik AG. Magnetic resonance imaging grading system for active and chronic spondylarthritis changes in the sacroiliac joint. Arthritis Care Res (Hoboken) 2010;62:11-8.
138. Maksymowych WP, Inman RD, Salonen D, et al. Spondyloarthritis research Consortium of Canada magnetic resonance imaging index for assessment of sacroiliac joint inflammation in ankylosing spondylitis. Arthritis Rheum 2005;53:703-9.
139. Lukas C, Braun J, van der Heijde D, et al. Scoring inflammatory activity of the spine by magnetic resonance imaging in ankylosing spondylitis: a multireader experiment. J Rheumatol 2007;34:862-70.
140. Maksymowych WP, Inman RD, Salonen D, et al. Spondyloarthritis Research Consortium of Canada magnetic resonance imaging index for assessment of spinal inflammation in ankylosing spondylitis. Arthritis Rheum 2005;53:502-9.
141. Dougados M, Demattei C, van den Berg R, et al. Rate and Predisposing Factors for Sacroiliac Joint Radiographic Progression After a Two-Year Follow-up Period in Recent-Onset Spondyloarthritis. Arthritis Rheumatol 2016;68:1904-13.
142. Dougados M, Sepriano A, Molto A, et al. Sacroiliac radiographic progression in recent onset axial spondyloarthritis: the 5-year data of the DESIR cohort. Ann Rheum Dis 2017;76:1823-28.
143. Ibrahim A, Gladman DD, Thavaneswaran A, et al. Sensitivity and Specificity of Radiographic Scoring Instruments for Detecting Change in Axial Psoriatic Arthritis. Arthritis Care Res (Hoboken) 2017;69:1700-05.
144. Poddubnyy D, Rudwaleit M, Haibel H, et al. Rates and predictors of radiographic sacroiliitis progression over 2 years in patients with axial spondyloarthritis. Ann Rheum Dis 2011;70:1369-74.
145. Sepriano A, Rudwaleit M, Sieper J, van den Berg R, Landewe R, van der Heijde D. Five-year follow-up of radiographic sacroiliitis: progression as well as improvement? Ann Rheum Dis 2016;75:1262-3.
146. Wang R, Gabriel SE, Ward MM. Progression of Nonradiographic Axial Spondyloarthritis to Ankylosing Spondylitis: A Population-Based Cohort Study. Arthritis Rheumatol 2016;68:1415-21.
147. Dougados M, Maksymowych WP, Landewe RBM, et al. Evaluation of the change in structural radiographic sacroiliac joint damage after 2 years of etanercept therapy (EMBARK trial) in comparison to a contemporary control cohort (DESIR cohort) in recent onset axial spondyloarthritis. Ann Rheum Dis 2018;77:221-27.
148. Rios Rodriguez V, Hermann KG, Weiss A, et al. Progression of Structural Damage in the Sacroiliac Joints in Patients With Early Axial Spondyloarthritis During Long-Term Anti-Tumor Necrosis Factor Treatment: Six-Year Results of Continuous Treatment With Etanercept. Arthritis Rheumatol 2019;71:722-28.
149. Zong HX, Xu SQ, Tong H, Wang XR, Pan MJ, Teng YZ. Effect of anti-tumor necrosis factor alpha treatment on radiographic progression in patient with ankylosing spondylitis: A systematic review and meta-analysis. Mod Rheumatol 2019;29:503-09.
150. MacKay K, Mack C, Brophy S, Calin A. The Bath Ankylosing Spondylitis Radiology Index (BASRI): a new, validated approach to disease assessment. Arthritis Rheum 1998;41:2263-70.
151. Maas F, Arends S, Brouwer E, et al. Reduction in Spinal Radiographic Progression in Ankylosing Spondylitis Patients Receiving Prolonged Treatment With Tumor Necrosis Factor Inhibitors. Arthritis Care Res (Hoboken) 2017;69:1011-19.
152. Poddubnyy D, Haibel H, Listing J, et al. Baseline radiographic damage, elevated acute-phase reactant levels, and cigarette smoking status predict spinal radiographic progression in early axial spondylarthritis. Arthritis Rheum 2012;64:1388-98.
153. Ramiro S, Stolwijk C, van Tubergen A, et al. Evolution of radiographic damage in ankylosing spondylitis: a 12 year prospective follow-up of the OASIS study. Ann Rheum Dis 2015;74:52-9.
154. Jeong H, Eun YH, Kim IY, et al. Effect of tumor necrosis factor alpha inhibitors on spinal radiographic progression in patients with ankylosing spondylitis. Int J Rheum Dis 2018;21:1098-105.

155. Molnar C, Scherer A, Baraliakos X, et al. TNF blockers inhibit spinal radiographic progression in ankylosing spondylitis by reducing disease activity: results from the Swiss Clinical Quality Management cohort. Ann Rheum Dis 2018;77:63-69.
156. Park JW, Kim MJ, Lee JS, et al. Impact of Tumor Necrosis Factor Inhibitor Versus Nonsteroidal Antiinflammatory Drug Treatment on Radiographic Progression in Early Ankylosing Spondylitis: Its Relationship to Inflammation Control During Treatment. Arthritis Rheumatol 2019;71:82-90.
157. Creemers MC, Franssen MJ, van't Hof MA, Gribnau FW, van de Putte LB, van Riel PL. Assessment of outcome in ankylosing spondylitis: an extended radiographic scoring system. Ann Rheum Dis 2005;64:127-9.
158. Hu Z, Xu M, Wang Q, Qi J, Lv Q, Gu J. Colour Doppler ultrasonography can be used to detect the changes of sacroiliitis and peripheral enthesitis in patients with ankylosing spondylitis during adalimumab treatment. Clin Exp Rheumatol 2015;33:844-50.
159. Jiang Y, Chen L, Zhu J, et al. Power Doppler ultrasonography in the evaluation of infliximab treatment for sacroiliitis in patients with ankylosing spondylitis. Rheumatol Int 2013;33:2025-9.
160. Koivikko MP, Koskinen SK. MRI of cervical spine injuries complicating ankylosing spondylitis. Skeletal Radiol 2008;37:813-9.
161. Nakstad PH, Server A, Josefsen R. Traumatic cervical injuries in ankylosing spondylitis. Acta Radiol 2004;45:222-6.
162. Beckmann NM, West OC, Nunez D, Jr., et al. ACR Appropriateness Criteria® Suspected Spine Trauma. J Am Coll Radiol 2019;16:S264-S85.
163. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf. Accessed March 26, 2021.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.