EULAR recommendations for the use of imaging in the diagnosis and management of spondyloarthritis in clinical practice

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ABSTRACT
A taskforce comprised of an expert group of 21 rheumatologists, radiologists and methodologists from 11 countries developed evidence-based recommendations on the use of imaging in the clinical management of both axial and peripheral spondyloarthritis (SpA). Twelve key questions on the role of imaging in SpA were generated using a process of discussion and consensus. Imaging modalities included conventional radiography, ultrasound, magnetic resonance imaging, computed tomography (CT), positron emission tomography, single photon emission CT, dual-emission x-ray absorptiometry and scintigraphy. Experts applied research evidence obtained from systematic literature reviews using MEDLINE and EMBASE to develop a set of 10 recommendations. The strength of recommendations (SOR) was assessed by taskforce members using a visual analogue scale. A total of 7550 references were identified in the search process, from which 158 studies were included in the systematic review. Ten recommendations were produced using research-based evidence and expert opinion encompassing the role of imaging in making a diagnosis of axial SpA or peripheral SpA, monitoring inflammation and damage, predicting outcome, response to treatment, and detecting spinal fractures and osteoporosis. The SOR for each recommendation was generally very high (range 8.9–9.5). These are the first recommendations which encompass the entire spectrum of SpA and evaluate the full role of all commonly used imaging modalities. We aimed to produce recommendations that are practical and valuable in daily practice for rheumatologists, radiologists and general practitioners.

The group of spondyloarthritides comprises a number of closely related rheumatic diseases with common clinical features, including ankylosing spondylitis (AS), psoriatic arthritis (PsA), arthritis/psoriatic arthritis related to inflammatory bowel disease and reactive arthritis (ReA). Imaging is a key component of classification criteria for SpA, primarily due to the lack of specific clinical symptoms as well as varying disease activity over time. For example, radiographic sacroiliitis is an essential part of the internationally accepted modified New York criteria for AS. Significant advances have been made within the field of imaging in SpA over the past decade. Several imaging modalities are now available that may aid in the diagnosis and monitoring of both axSpA and pSpA as well as in predicting structural damage and treatment response. However, conventional radiography (radiography) only visualises the late structural consequences of the inflammatory process, while the early inflammatory changes can be detected by MRI, often several years before the appearance of sacroiliitis on radiography.

Accordingly, MRI was incorporated in the ASAS classification criteria for axSpA as well as pSpA.

Reflecting the perceived need for developing evidence-based recommendations on the use of musculoskeletal imaging in the clinical management of SpA, a European League Against Rheumatism (EULAR) taskforce was convened to develop evidence-based recommendations on the use of musculoskeletal imaging in the clinical management of SpA, for rheumatologists, radiologists and general practitioners.

METHODS
An expert group of 21 rheumatologists, radiologists and methodologists representing 11 countries formed the taskforce. The objectives were to formulate key clinical questions relating to the role of imaging in SpA, to identify and critically appraise the available evidence, and to generate recommendations based on both evidence and expert opinion.

At the initial taskforce meeting, members proposed clinically relevant questions related to key aspects of the use of imaging in SpA. Twelve final research questions (Q1–12) were formulated and agreed upon by consensus, encompassing the full spectrum of the role of imaging in diagnosing axSpA or pSpA, monitoring inflammation and damage, predicting outcome and response to treatment, as well as detecting spinal fractures and...
osteoporosis (see online supplementary material S1: research questions).

Three systematic literature searches were performed using MEDLINE and EMBASE databases. The first search summarised research questions 1–10 (Q1–10) (questions on the diagnostic, monitoring and predictive role of imaging), while the research question on the detection of spinal fractures (Q11) and that on the detection of osteoporosis (Q12) were covered by independent searches. Specific medical subject headings and additional keywords were used to identify all relevant studies (see online supplementary material S2: search strategy). In addition, abstract archives of relevant international rheumatology and radiology meetings (2011, 2012) as well as the bibliographies of included papers were hand searched for evidence of other studies for inclusion. Titles and abstracts of all citations identified were screened, and potentially relevant articles were reviewed in full text using predetermined inclusion and exclusion criteria.

Studies published in English up to January 2013, on the use of imaging in adults (≥18 years) with a suspected or established clinical diagnosis of SpA (including inflammatory and low back pain for the research question on the diagnostic role of imaging in axSpA), axSpA or pSpA (and suspicion of spinal (vertebral) fracture with regard to Q11), were included. Imaging modalities included radiography, ultrasound (US), MRI, CT, positron emission tomography, single-photon emission CT (SPECT), quantitative sacroiliac (SI) joint scintigraphy (QSS) and dual-energy X-ray absorptiometry (DXA). Study types included randomised controlled trials (RCTs), systematic reviews, controlled clinical trials, cohort, case-control and diagnostic studies.

Studies not in English language, those including patients ≤18 years of age and those reporting data acquired from <20 patients with suspected or established disease (and/or <20 control patients for questions 1–2 on the diagnostic role of imaging) were excluded. Quality assessment of all included studies was done using the QUADAS-2 tool and presented at the second taskforce meeting according to study expertise. Recommendation 1: diagnosing axial SpA

A. In general, conventional radiography of the SI joints is recommended as the first imaging method to diagnose sacroiliitis as part of axial SpA. In certain cases, such as young patients and those with short symptom duration, MRI of the SI joints is an alternative first imaging method.

B. If the diagnosis of axial SpA cannot be established based on clinical features and conventional radiography, and axial SpA is still suspected, MRI of the SI joints is recommended. On MRI, both active inflammatory lesions (primarily bone marrow edema (BME)) and structural lesions (such as bone erosion, new bone formation, sclerosis and fat infiltration) should be considered. MRI of the spine is not generally recommended to diagnose axial SpA.

C. Imaging modalities other than conventional radiography and MRI are not generally recommended in the diagnosis of axial SpA.

* CT may provide additional information on structural damage if conventional radiography is negative and MRI cannot be performed. Scintigraphy and US are not recommended for diagnosis of sacroiliitis as part of axial SpA.

Strength of recommendation: 9.5 (95% CI 9.2 to 9.8).

Twenty-five studies evaluated the diagnostic utility of various imaging modalities in axSpA. They demonstrated varying sensitivity (SE) and specificity (SP) of radiography in diagnosing sacroiliitis in inflammatory back pain (IBP) suspicion of SpA, while one observational study reported an SE of 0.84 and an SP of 0.75 in diagnosing sacroiliitis in AS. A single study reported only fair agreement between radiography and CT in suspected sacroiliitis and many false positive results using radiography. Two studies reported higher SE for CT than radiography for diagnosing sacroiliitis (1 in AS, 1 in suspected SpA).

Thirteen studies evaluated the diagnostic utility of MRI demonstrating varying SE and overall higher SP in patients with IBP or those with suspicion of SpA (table 2). Three studies reported SE (0.73–0.9) and SP (0.9–0.97) for SI joint BME on MRI in established AS. Finally, two studies found MRI of the SI joint superior to QSS or radiography for diagnosing sacroiliitis in IBP and SpA.

With regard to MRI of the spine, three studies reported SE of and SP for corner fat lesions and corner inflammatory lesions (CILs) in patients suspected for axSpA while two studies reported SE and SP in established AS. Finally, Weber et al have demonstrated that spinal MRI adds little incremental value in establishing the diagnosis of axial SpA.
Table 1  EULAR recommendations for the use of imaging in the diagnosis and management of spondyloarthritis in clinical practice

<table>
<thead>
<tr>
<th>SOR</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Axial SpA: diagnosis</td>
<td>9.5 (9.2–9.8) III</td>
</tr>
<tr>
<td>A. In general, conventional radiography of the SI joints is recommended as the first imaging method to diagnose sacroilitis as part of axial SpA. In certain cases, such as young patients and those with short symptom duration, MRI of the SI joints is an alternative first imaging method. B. If the diagnosis of axial SpA cannot be established based on clinical features and conventional radiography, and axial SpA is still suspected, MRI of the SI joints is recommended. On MRI, both active inflammatory lesions (primarily bone marrow oedema) and structural lesions (such as bone erosion, new bone formation, sclerosis and fat infiltration) should be considered. MRI of the spine is not generally recommended to diagnose axial SpA. C. Imaging modalities, other than conventional radiography and MRI are generally not recommended in the diagnosis of axial SpA.</td>
<td></td>
</tr>
<tr>
<td>2 Peripheral SpA: diagnosis</td>
<td>9.4 (9.0–9.8) III</td>
</tr>
<tr>
<td>When peripheral SpA is suspected, US or MRI may be used to detect peripheral enthesitis, which may support the diagnosis of axial SpA. Furthermore, US or MRI might be used to detect peripheral arthritis, tenosynovitis and bursitis.</td>
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</tr>
<tr>
<td>3 Axial SpA: monitoring activity</td>
<td>9.2 (8.8–9.6) Ib</td>
</tr>
<tr>
<td>MRI of the SI joints and/or the spine may be used to assess and monitor disease activity in axial SpA, providing additional information on top of clinical and biochemical assessments. The decision on when to repeat MRI depends on the clinical circumstances. In general, STIR sequences are sufficient to detect inflammation and the use of contrast medium is not needed.</td>
<td></td>
</tr>
<tr>
<td>4 Axial SpA: monitoring structural changes</td>
<td>9.3 (8.8–9.8) Ib</td>
</tr>
<tr>
<td>Conventional radiography of the SI joints and/or spine may be used for long-term monitoring of structural damage, particularly new bone formation, in axial SpA. If performed, it should not be repeated more frequently than every second year. MRI may provide additional information.</td>
<td></td>
</tr>
<tr>
<td>5 Peripheral SpA: monitoring activity</td>
<td>9.3 (8.9–9.7) Ib</td>
</tr>
<tr>
<td>US and MRI may be used to monitor disease activity (particularly synovitis and enthesitis) in peripheral SpA, providing additional information on top of clinical and biochemical assessments. The decision on when to repeat US/MRI depends on the clinical circumstances. US with high-frequency colour or power Doppler is sufficient to detect inflammation and the use of US contrast medium is not needed.</td>
<td></td>
</tr>
<tr>
<td>6 Peripheral SpA: monitoring structural changes</td>
<td>8.9 (8.4–9.4) III</td>
</tr>
<tr>
<td>In peripheral SpA, if the clinical scenario requires monitoring of structural damage, then conventional radiography is recommended. MRI and/or US might provide additional information.</td>
<td></td>
</tr>
<tr>
<td>7 Axial SpA: predicting outcome/erosivity</td>
<td>9.0 (8.5–9.5) Ib</td>
</tr>
<tr>
<td>In patients with ankylosing spondylitis (not non-radiographic axial SpA), initial conventional radiography of the lumbar and cervical spine is recommended to detect syndesmophytes, which are predictive of development of new syndesmophytes. MRI (vertebral corner inflammatory or fatty lesions) may also be used to predict development of new radiographic syndesmophytes.</td>
<td></td>
</tr>
<tr>
<td>8 Axial SpA: predicting treatment effect</td>
<td>8.9 (8.3–9.5) Ib</td>
</tr>
<tr>
<td>Extensive MRI inflammatory activity (bone marrow oedema), particularly in the spine in patients with ankylosing spondylitis, might be used as a predictor of good clinical response to anti-TNF-alpha treatment in axial SpA. Thus, MRI might aid in the decision of initiating anti-TNF-alpha therapy, in addition to clinical examination and CRP.</td>
<td></td>
</tr>
<tr>
<td>9 Spinal fracture</td>
<td>9.3 (8.9–9.7) IV</td>
</tr>
<tr>
<td>When spinal fracture in axial SpA is suspected, conventional radiography is the recommended initial imaging method. If conventional radiography is negative, CT should be performed. MRI is an additional imaging method to CT, which can also provide information on soft tissue lesions.</td>
<td></td>
</tr>
<tr>
<td>10 Osteoporosis</td>
<td>9.4 (9.0–9.8) III</td>
</tr>
<tr>
<td>In patients with axial SpA without syndesmophytes in the lumbar spine on conventional radiography, osteoporosis should be assessed by hip DXA and AP-spine DXA. In patients with syndesmophytes in the lumbar spine on conventional radiography, osteoporosis should be assessed by hip DXA, supplemented by either spine DXA in lateral projection or possibly QCT of the spine.</td>
<td></td>
</tr>
</tbody>
</table>

*CT may provide additional information on structural damage if conventional radiography is negative and MRI cannot be performed. Scintigraphy and US are not recommended for diagnosis of sacroilitis as part of axial SpA. ¶That is, radiographic axial spondyloarthritis.

Level of evidence (LOE): Ia, evidence for meta-analysis of randomised controlled trials; Ib, evidence from at least one randomised controlled trial; Iia, evidence from at least one controlled study without randomisation; Iib, evidence from at least one other type of quasi-experimental study; III, evidence from non-experimental descriptive studies, such as comparative studies, correlation studies and case–control studies; IV, evidence from expert committee reports or opinions or clinical experience of respected authorities, or both. AP, anterior–posterior; CRP, C-reactive protein; DXA, dual-energy X-ray absorptiometry; EULAR, European League Against Rheumatism; m-axSpA, non-radiographic axial spondyloarthritis; QCT, quantitative CT; SI, sacroiliac; SS, sacroiliac joints; SOR, strength of recommendation; SpA, spondyloarthritis; STR, short tau inversion recovery; TNF-alpha, tumour necrosis factor alpha; US, ultrasonography.

compared with MRI of the SI joint alone in terms of lesion detection and classification of patients with early SpA. Four studies reported that QSS has low SE for diagnosis of sacroilitis in patients with IBP. Krause et al reported that contrast-enhanced US is a sensitive and specific tool for diagnosing active sacroilitis in patients with IBP and AS. One study reported that pulsatil monocyclic Doppler US detects sacroilitis in patients with AS. Quality assessment is reported in online supplementary figure S6.1; of note risk of patient selection bias and applicability concerns with regard to patient selection were high in 52% and 36% of the included manuscripts, respectively.

Recommendation 2: diagnosing peripheral SpA

When peripheral SpA is suspected, US or MRI may be used to detect peripheral enthesitis, which may support the diagnosis of SpA. Furthermore, US or MRI might be used to detect peripheral arthritis, tenosynovitis and bursitis.

Strength of recommendation: 9.4 (95% CI 9.0 to 9.8)

Nine studies evaluated grey-scale and/or power Doppler US (GSUS/PDUS, respectively) for assessment of entheses in patients with established pSpA using clinical examination as gold standard. Eight studies evaluated multiple entheses, while one study evaluated only the Achilles tendon. One study reported that PDUS has an SE of 0.76 and an SP of 0.81 in suspected SpA, while four studies reported varying SE and overall higher SP in established PsA. Four studies reported an SE of 0.83–0.98 and an SP of 0.48–0.9 for PDUS assessment in established pSpA. Finally, Feydy et al reported that MRI of the heel had an SP of 0.94 but SE of 0.22 for discriminating between patients with SpA and controls.
Quality assessment is reported in online supplementary figure S6.2; of note risk of patient selection bias and applicability concerns with regard to the index test were high in 55% and 33% of included manuscripts, respectively.

Recommendation 3: monitoring disease activity in axial SpA

MRI of the SI joints and/or the spine may be used to assess and monitor disease activity in axial SpA, providing additional information on top of clinical and biochemical assessments. The decision on when to repeat MRI depends on the clinical circumstances. In general, short tau inversion recovery (STIR) sequences are sufficient to detect inflammation and the use of contrast medium is not needed.

Strength of recommendation: 9.2 (95% CI 8.8 to 9.6)

Table 2

<table>
<thead>
<tr>
<th>Studies</th>
<th>No.</th>
<th>Study population</th>
<th>Gold standard</th>
<th>SIJ/spine</th>
<th>MRI lesion</th>
<th>SE</th>
<th>SP</th>
<th>+LR</th>
<th>−LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal/RCT</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bennett et al</td>
<td>50</td>
<td>SpA</td>
<td>X-ray</td>
<td>SIJ</td>
<td>Grade 3 SI+HLAB27 27B27</td>
<td>0.62</td>
<td>0.92</td>
<td>7.7</td>
<td>0.41</td>
</tr>
<tr>
<td>Marzo-Ortega et al</td>
<td>76</td>
<td>IBP (NSBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ  Grade 1 SI</td>
<td>0.82</td>
<td>0.43</td>
<td>1.4</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SIJ</td>
<td>Grade 2 SI</td>
<td>0.73</td>
<td>1.0</td>
<td>∞</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SIJ</td>
<td>Grade ≥ 2 SI</td>
<td>0.85</td>
<td>0.47</td>
<td>1.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Cross-sectional/case-control</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Weber et al</td>
<td>187</td>
<td>AS, IBP (NSBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>BME (AS)</td>
<td>0.9</td>
<td>0.97</td>
<td>44.6</td>
<td>0.92</td>
</tr>
<tr>
<td>Weber et al</td>
<td>157</td>
<td>AS, IBP (NSBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>BME+ERO</td>
<td>0.81</td>
<td>0.97</td>
<td>27</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SIJ</td>
<td>BME</td>
<td>0.73</td>
<td>0.9</td>
<td>7.3</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SIJ</td>
<td>BME and/or ERO</td>
<td>0.82</td>
<td>0.9</td>
<td>8.2</td>
<td>0.2</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SIJ</td>
<td>Fl</td>
<td>0.21</td>
<td>0.97</td>
<td>8.3</td>
<td>0.81</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SIJ</td>
<td>Fl with BME or ERO</td>
<td>0.24</td>
<td>0.97</td>
<td>9.2</td>
<td>0.78</td>
</tr>
<tr>
<td>Heuft-Dorenbosch et al</td>
<td>68</td>
<td>IBP</td>
<td>X-ray</td>
<td>SIJ</td>
<td>chronic changes</td>
<td>0.49</td>
<td>0.97</td>
<td>16.3</td>
<td>0.52</td>
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<tr>
<td>Weber et al</td>
<td>95</td>
<td>AS, IBP, (HC)</td>
<td>Clinical diagnosis</td>
<td>Spine</td>
<td>&gt;2 CIL (AS)</td>
<td>0.69</td>
<td>0.94</td>
<td>12</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Spine</td>
<td>&gt;2 CIL (IBP)</td>
<td>0.32</td>
<td>0.96</td>
<td>8</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Spine</td>
<td>LIL</td>
<td>0.97</td>
<td>0.31</td>
<td>1.4</td>
<td>0.09</td>
</tr>
<tr>
<td>Retrospective</td>
<td>104</td>
<td>AS (HC)</td>
<td>Clinical diagnosis</td>
<td>Spine MRI corner sign</td>
<td>0.44</td>
<td>0.96</td>
<td>11</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Wick et al</td>
<td>179</td>
<td>AS (various)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>ERO</td>
<td>0.11</td>
<td>0.93</td>
<td>1.57</td>
<td>0.95</td>
</tr>
<tr>
<td>Bennett et al</td>
<td>185</td>
<td>SpA (DA, IBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ and spine</td>
<td>&gt;3 Rls</td>
<td>0.33</td>
<td>0.97</td>
<td>12.4</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SIJ and spine</td>
<td>≥5 FRLs</td>
<td>0.22</td>
<td>0.98</td>
<td>12.6</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Table 2: Recommendation 1: summary of studies on the use of MRI in diagnosing axial spondyloarthritis

The terms of the individual original publications have been used in the table.

AS, ankylosing spondylitis; BME, bone marrow oedema; CIL, corner inflammatory lesion; DA, degenerative arthropathy; ERO, erosion; Fl, fatty infiltration; FRL, fatty Romanus’ lesion; HC, healthy control; HLA27, human leucocyte antigen B27; IBP, inflammatory back pain; LIL, lateral segment inflammatory lesion; +LR, positive likelihood ratio; −LR, negative likelihood ratio; No., number of individuals included in the study; NSBP, non-specific back pain; RCT, randomised controlled trial; RL, ‘Romanus’ lesion; SE, sensitivity; SP, specificity; SI, sacroiliitis; SIJ, sacroiliac joints; SpA, spondyloarthritis.

Recommendation 4: monitoring structural changes in axial SpA

Conventional radiography of the SI joints and/or spine may be used for long-term monitoring of structural damage, particularly new bone formation, in axial SpA. If performed, it should not be repeated more frequently than every second year. MRI may provide additional information.

Strength of recommendation: 9.3 (95% CI 8.8 to 9.8)

Twenty-three studies evaluated the utility of various imaging modalities in monitoring structural damage in axSpA. 

Quality assessment is reported in online supplementary figure S6.3.

Of 13 radiography studies, 10 reported correlation between radiographic changes and accepted measures of function (Bath Ankylosing Spondylitis Functional Index (BASFI), Bath Ankylosing Spondylitis Metrology Index (BASMII), metrological measures (chest expansion, occiput-to-wall distance, finger-to-floor distance, tragus-wall distance, Schober’s test, spinal flexion, cervical rotation)) (table 4).63 81 83 85–87 93 94 96

Six studies compared various spine radiography scoring methods (Bath Ankylosing Spondylitis Radiology Index (BASRI), Stoke Ankylosing Spondylitis Spinal Score (SASSS), modified Stoke Ankylosing Spondylitis Spinal Score (mSASSS), Berlin X-ray score, Radiographic Ankylosing Spondylitis Spinal Score (RASSS)),82 83 84 87 93 96 of which two reported mSASSS being superior to BASRI and SASSS.83 85

Baraliakos et al58 reported the RASSS method, which includes the thoracic segment, superior to mSASSs, while Ramiro et al42 reported no advantage of RASSS over mSASSs. Taylor et al41 reported correlation between CT changes and QSS in the SI joint.
Five studies reported correlation between changes over time in MRI and radiography and/or CT parameters of structural damage, while Puhakka et al. found MRI and CT are superior to radiography. A single study reported correlation between spinal MRI and metrological measures, while two studies reported no correlation with BASFI. Akgul et al. reported that fatty infiltration of the paraspinal muscles on MRI correlates with metrological measures. Regarding the frequency of MRI examinations for the monitoring of structural changes under treatment, a study investigating GSUS/PDUS for the assessment of entheses (8 on multiple entheses, 2 on the Achilles tendon) reported correlation between pain and power Doppler US measurements. The decision on when to repeat US/MRI depends on the clinical circumstances.

### Table 3: Summary of studies on the use of MRI in monitoring disease activity in axial spondyloarthritis

<table>
<thead>
<tr>
<th>Studies</th>
<th>No.</th>
<th>Region</th>
<th>MRI scoring method</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal/RCT</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Marzo-Ortega et al.</td>
<td>76</td>
<td>Spine</td>
<td>LEEDS</td>
<td>–</td>
</tr>
<tr>
<td>Oostveen et al.</td>
<td>25</td>
<td>SJ</td>
<td>mNY</td>
<td>–</td>
</tr>
<tr>
<td>Baraliakos et al.</td>
<td>40</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>–</td>
</tr>
<tr>
<td>Bonel et al.</td>
<td>28</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>–</td>
</tr>
<tr>
<td>Braun et al.</td>
<td>20</td>
<td>Spine</td>
<td>AsspiMRI-a/c</td>
<td>0.35</td>
</tr>
<tr>
<td>Braun et al.</td>
<td>98</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>0.35</td>
</tr>
<tr>
<td>Lambert 2007</td>
<td>82</td>
<td>Spine/SJ</td>
<td>SPARCC</td>
<td>–</td>
</tr>
<tr>
<td>Machado et al.</td>
<td>221</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>0.14</td>
</tr>
<tr>
<td>Machado et al.</td>
<td>221</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>0.23</td>
</tr>
<tr>
<td>Maksymowych et al.</td>
<td>36</td>
<td>Spine</td>
<td>SPARCC</td>
<td>–</td>
</tr>
<tr>
<td>Maksymowych et al.</td>
<td>42</td>
<td>Spine/SJ</td>
<td>LEEDS</td>
<td>–</td>
</tr>
<tr>
<td>Pedersen et al.</td>
<td>82</td>
<td>Spine/SJ</td>
<td>Berlin</td>
<td>0.46/0.31</td>
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<tr>
<td>Puhakka et al.</td>
<td>34</td>
<td>SJ</td>
<td>BME</td>
<td>–</td>
</tr>
<tr>
<td>Rudwaleit et al.</td>
<td>62</td>
<td>Spine/SJ</td>
<td>Berlin</td>
<td>–</td>
</tr>
<tr>
<td>Steper et al.</td>
<td>20</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>0.5</td>
</tr>
<tr>
<td>Song et al.</td>
<td>76</td>
<td>Spine/SJ</td>
<td>AsspiMRI-a/berlin</td>
<td>p=0.04</td>
</tr>
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<td>Vissanathan et al.</td>
<td>279</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>–</td>
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<td>Cross-sectional/case-control</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blachier 2013</td>
<td>648</td>
<td>Spine/SJ</td>
<td>Dichotomous</td>
<td>–</td>
</tr>
<tr>
<td>Goh et al.</td>
<td>34</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>–</td>
</tr>
<tr>
<td>Kitz et al.</td>
<td>100</td>
<td>Spine/SJ</td>
<td>Berlin</td>
<td>NS</td>
</tr>
<tr>
<td>Konca et al.</td>
<td>50</td>
<td>Spine</td>
<td>AsspiMRI-a</td>
<td>0.37</td>
</tr>
<tr>
<td>Puhakka et al.</td>
<td>41</td>
<td>SJ</td>
<td>BME enhancement</td>
<td>–</td>
</tr>
<tr>
<td>Weber et al.</td>
<td>197</td>
<td>ACW</td>
<td>Dichotomous</td>
<td>–</td>
</tr>
</tbody>
</table>

The Spearman test for rank correlation is used for test of correlation, values are correlation coefficients (rho), if not otherwise indicated. p Values indicate the level of statistical significance.

**Recommendation 5:** Monitoring disease activity in peripheral SpA

US and MRI may be used to monitor disease activity (particularly synovitis and enthesis) in peripheral SpA, providing additional information on top of clinical and biochemical assessments. The decision on when to repeat US/MRI depends on the clinical circumstances. US with high-sensitivity colour or power Doppler is sufficient to detect inflammation and the use of US contrast medium is not needed.

**Strength of recommendation:** 9.3 (95% CI 8.9 to 9.7)

Fifteen studies evaluated the utility of various imaging modalities in monitoring disease activity in pSpA, of which 10 investigated GSUS/PDUS for the assessment of entheses (8 on multiple entheses, 2 on the Achilles tendon). Out of the 10 studies investigating GSUS/PDUS, only a single study was longitudinal, while the remaining 9 were cross-sectional. A single study reported correlation with BASDAI, while four reported no correlation. Aydin et al. reported correlation between grey-scale entheseal changes of the Achilles tendon and CRP while five studies reported no correlation with CRP and/or ESR. Hamdi et al. reported correlation between pain and power Doppler entheseal changes of the lower limb entheses, while Kiris et al. reported no correlation between PD and axial entheses.

Two studies reported correlation with swollen or tender joint count, while a single study reported no correlation. Hamdi et al. reported correlation with clinical enthesis indices (Maastricht Ankylosing Spondylitis Score, Spondyloarthritis Research Consortium of Canada (SPARCC) Enthesitis Index), while two studies reported no correlation. Two studies reported discrepancies in abnormal entheses detected by US versus clinical examination.
Four longitudinal\textsuperscript{106-109} and a single cross-sectional\textsuperscript{110} study evaluated the utility of MRI in monitoring disease activity in pSpA with three longitudinal studies reporting the psoriatic arthritis MRI score (PsAMRIS) and rheumatoid arthritis MRI score performing well regarding SE to change.\textsuperscript{106-108} Tan \textit{et al} found no correlation between BME (as scored by PsAMRIS) and clinical disease activity measures in a cross-sectional study.\textsuperscript{110} There is currently no evidence whether and if so how frequently US and/or MRI should be repeated for the monitoring of disease activity in peripheral SpA. Quality assessment is reported in online supplementary figure S6.5; of note patient selection bias was high in 47% of included manuscripts.

**Recommendation 6: monitoring structural changes in peripheral SpA**

In peripheral SpA, if the clinical scenario requires monitoring of structural damage, then conventional radiography is recommended. MRI and/or US might provide additional information.

**Strength of recommendation:** 8.9 (95\% CI 8.4 to 9.4)

Seven studies evaluated the utility of conventional radiography (CR) to monitor structural changes in pSpA,\textsuperscript{111-115} with one study also evaluating PDUS\textsuperscript{116} and an additional study evaluating MRI.\textsuperscript{117} Among the studies assessing the utility of radiography, two reported correlation with the functional indices Health Assessment Questionnaire and/or Arthritis Impact Measurement Scales.\textsuperscript{114,115} A longitudinal study on 74 patients with PsA reported correlation between clinical joint deformity, typical radiographic changes in PsA and the PsA-modified Sharp score.\textsuperscript{114} A case–control study on 98 patients with ReA reported correlation between radiographic condylar erosions of the temporomandibular joint and patient-reported outcomes.\textsuperscript{112} A cross-sectional study on 60 patients with AS reported correlation between BASFI and both radiographic and sonographic signs of enthesitis.\textsuperscript{112} while a cross-sectional study on 44 patients with SpA reported correlation between the SpA tarsal radiographic index and the Glasgow Ultrasound Enthesitis Score, but no correlation between the radiographic index and BASMI or BASRI.\textsuperscript{119} Finally, Tan \textit{et al}\textsuperscript{110} reported correlation between MRI erosions/BME and CR erosions/joint space narrowing in 28 patients with PsA. Quality assessment is reported in online supplementary figure S6.6; of note risk of patient selection bias was high in 50% of included manuscripts. There is currently no evidence whether and if so how frequently US and/or MRI should be repeated for the monitoring of structural changes in peripheral SpA.

**Recommendation 7: predicting outcome/severity in axial SpA**

In patients with AS\textsuperscript{*} (not non-radiographic axial SpA), initial conventional radiography of the lumbar and cervical spine is recommended to detect syndesmophytes, which are predictive of development of new syndesmophytes. MRI (vertebral corner development of new radiographic syndesmophytes).\textsuperscript{118} That is, radiographic axial spondyloarthritis.

**Strength of recommendation:** 9.0 (95\% CI 8.5 to 9.5)

Seventeen publications were included.\textsuperscript{119 81 92 116-129} All studies evaluating radiography reported that baseline radiographic change (syndesmophytes) predicts radiographic progression in AS.\textsuperscript{118 116 118 122 126 129} Baraliakos \textit{et al} reported that syndesmophytes/ankylosis, rather than erosion or sclerosis, were the features most frequently showing progression in AS.\textsuperscript{116} Maksymowycz \textit{et al}\textsuperscript{122} found that high baseline mSASSS (cut-off of 10 units; OR 18.6) was an independent predictor of 2-year progression in AS.

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**Table 4**

<table>
<thead>
<tr>
<th>Studies</th>
<th>No.</th>
<th>Region</th>
<th>X-ray scoring method</th>
<th>BASFI</th>
<th>BASMI</th>
<th>Metrological measures</th>
<th>CT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machado \textit{et al}\textsuperscript{13}</td>
<td>214</td>
<td>Spine</td>
<td>mSASSS</td>
<td>0.18; p=0.008</td>
<td>0.59; p&lt;0.001</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Avens \textit{et al}\textsuperscript{31}</td>
<td>53</td>
<td>Spine</td>
<td>SASSS</td>
<td>–</td>
<td>–</td>
<td>–0.396; p&lt;0.01 (CE)</td>
<td>–</td>
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<td></td>
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<td></td>
<td></td>
<td>0.503; p&lt;0.001 (OWD)</td>
<td>–</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.351; p&lt;0.02 (FFD)</td>
<td>–</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>–0.690; p&lt;0.0001 (Schober)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–0.717; p&lt;0.0001 (total spinal movement)</td>
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</tr>
<tr>
<td>Baraliakos \textit{et al}\textsuperscript{132}</td>
<td>82</td>
<td>Spine</td>
<td>mSASSS</td>
<td>NS</td>
<td>0.49–0.59; p=0.01</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Baraliakos \textit{et al}\textsuperscript{133}</td>
<td>80</td>
<td>Spine</td>
<td>mSASSS</td>
<td>–</td>
<td>0.49</td>
<td>NS</td>
<td>–</td>
</tr>
<tr>
<td>Creemers \textit{et al}\textsuperscript{136}</td>
<td>50</td>
<td>Spine</td>
<td>mSASSS</td>
<td>–</td>
<td>–</td>
<td>p=0.05–0.005 (CE, OWD, SF)</td>
<td>–</td>
</tr>
<tr>
<td>Salaffi \textit{et al}\textsuperscript{139}</td>
<td>95</td>
<td>Spine</td>
<td>mSASSS</td>
<td>p=0.02</td>
<td>p=0.01</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Taylor \textit{et al}\textsuperscript{134}</td>
<td>70</td>
<td>Spine/SIJ</td>
<td>Semi-quantitative</td>
<td>–</td>
<td>–</td>
<td>–0.40; p&lt;0.05 (SF)</td>
<td>0.52; p&lt;0.01 (spine) 0.75; p&lt;0.001 (SIJ)</td>
</tr>
<tr>
<td>Wanders \textit{et al}\textsuperscript{136}</td>
<td>133</td>
<td>Spine/SIJ</td>
<td>mSASSS</td>
<td>0.41</td>
<td>–</td>
<td>–0.77 (SF)</td>
<td>0.65 (OWD)</td>
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<td></td>
<td></td>
<td></td>
<td>SASSS</td>
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<td></td>
<td>–0.76 (mSchober)</td>
<td>–</td>
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<tr>
<td>Cross-sectional/control</td>
<td>Lee \textit{et al}\textsuperscript{136}</td>
<td>39</td>
<td>Spine</td>
<td>BASRI</td>
<td>–</td>
<td>–</td>
<td>0.53–0.73 (p&lt;0.001)</td>
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<td>Lubrano \textit{et al}\textsuperscript{137}</td>
<td>77</td>
<td>Spine</td>
<td>BASRI</td>
<td>NS</td>
<td>0.47; p&lt;0.001</td>
<td>0.49, p&lt;0.001 (CR)</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mSASSS</td>
<td></td>
<td></td>
<td>0.34, p=0.01 (TWD)</td>
<td>–</td>
</tr>
<tr>
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<td></td>
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<td>0.49, p&lt;0.001 (OWD)</td>
<td>–</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–0.24, p&lt;0.05 (mSchober)</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.37, p=0.01 (FFD)</td>
<td>–</td>
</tr>
</tbody>
</table>

The Spearman test for rank correlation is used for test of correlation, values are correlation coefficients (rho), if not otherwise indicated. p Values indicate the level of statistical significance.

BASFI, Bath Ankylosing Spondylitis Functional Index; BASMI, Bath Ankylosing Spondylitis Metrology Index; BASRI, Bath Ankylosing Spondylitis Functional Radiology Index; CE, chest expansion; CR, cervical rotation; FFD, finger-to-floor distance; mSASSS, modified Stoke Ankylosing Spondylitis Score; mSchober, modified Schober’s test; No., number of individuals included in the study; NS, not statistically significant; OWD, occiput-wall distance; RCT, randomised controlled trial; SASSS, Stoke Ankylosing Spondylitis Score; SF, spinal flexion; SIJ, sacroiliac joints; TWD, tragus-to-wall distance; –, not done.
Six studies reported correlation between CILs or vertebral edge inflammation on MRI and subsequent radiographic syndesmophyte formation in patients with AS.\textsuperscript{117, 119, 120, 123, 124, 128} Madsen \textit{et al.}\textsuperscript{21} reported correlation of baseline inflammation and subchondral fatty marrow deposition on MRI with radiographic progression in the SI joint of patients with AS.

In a 2-year longitudinal study, Pedersen \textit{et al.}\textsuperscript{124} found that new syndesmophytes develop more frequently from vertebral corners where a CIL had completely resolved on follow-up, and that no single vertebral corner evolved into a new syndesmophyte where a CIL was persistently observed on both baseline and follow-up MRI. Along the same line, a 2-year longitudinal study of patients with axSpA/AS revealed an association between decreasing inflammation in the SI joint and the concomitant development of new syndesmophytes (OR 12.48).\textsuperscript{126} In a 1-year longitudinal study, Song \textit{et al.}\textsuperscript{127} presented a significant relationship between the disappearance of inflammation and the appearance of fatty lesions in the spine of patients with axSpA. Moreover, Baraliakos \textit{et al.}\textsuperscript{119} showed that both spinal inflammation and fatty degeneration were associated with later syndesmophyte development but fatty degeneration showed the highest risk in AS. In contrast, a retrospective analysis of 100 patients with AS, inflammation (OR 5.8) emerged as a more significant predictor of new syndesmophytes than did fat infiltration (OR 1.9).\textsuperscript{120} Finally, Bennett \textit{et al.}\textsuperscript{19} reported no association between baseline BME on lumbar spine MRI and mSASSS progression after 8 years in patients with AS.

Averns \textit{et al.}\textsuperscript{81} reported correlation between baseline QSS values and radiographic progression in the spine at follow-up (median: 9 years) in patients with AS. Quality assessment is reported in online supplementary figure S6.7. **Recommendation 8:** predicting treatment effect in axial SpA

Extensive MRI inflammatory activity (BME), particularly in the spine in patients with AS, might be used as a predictor of good clinical response to anti-TNF-alpha treatment in axial SpA. Thus, MRI might aid in the decision of initiating anti-TNF-alpha therapy, in addition to clinical examination and CRP.

Strength of recommendation: 8.9 (95% CI 8.3 to 9.5).

A total of three studies were included. A longitudinal study of 62 patients with AS under treatment anti-TNF-alpha biologics reported a positive likelihood ratio of 6.7 for achieving BASDAI50 response in patients with a Berlin MRI spine score >11, while the absence of active inflammatory lesions in the spine was highly predictive of not achieving BASDAI50. Only a trend was found for the MRI SI joint score.\textsuperscript{73} An RCT of 185 patients with non-radiographic axial SpA reported that a baseline SPARCC MRI score ≥2 for either the SI joint or the spine was associated with better response after 12 weeks of adalimumab.\textsuperscript{72} An RCT including 40 human leucocyte antigen B27 (HLAB27)-positive patients with MRI sacroiliitis found no significant difference in BASDAI changes between patients with mild versus moderate/severe MRI SI joint BME at baseline.\textsuperscript{136} Quality assessment is reported in online supplementary figure S6.8; of note risk of patient selection bias, as well as of flow and timing and applicability concerns, was each high in 33% of included manuscripts.

**Recommendation 9:** spinal fracture

When spinal fracture in axial SpA is suspected, conventional radiography is the recommended initial imaging method. If conventional radiography is negative, CT should be performed. MRI is an additional imaging method to CT, which can also provide information on soft tissue lesions.

Strength of recommendation: 9.3 (95% CI 8.9 to 9.7)

Although no study met the inclusion criteria for this recommendation, two studies selected for full-text review were presented to the taskforce as they could provide some evidence (quality assessment however was not performed). The first study included 11 patients with AS and neurological symptoms after trauma to the neck region. CT and MRI detected all fractures while radiography detected 82% of them. Soft tissue injuries were detected in four patients, only by MRI.\textsuperscript{131} The second study included 199 patients from the general population with suspected cervical spine injury. Twenty-one acute fractures were detected in 14 patients. Weighted average SE to detect acute fractures for MRI and radiography were 0.43 (95% CI 0.21 to 0.66) and 0.48 (95% CI 0.30 to 0.65), respectively. In contrast, weighted average SE to detect soft tissue injuries for MRI and radiography were 0.55 (95% CI 0.39 to 0.70) and 0.07 (95% CI 0.02 to 0.13), respectively.\textsuperscript{132} In addition to its utility in imaging soft tissue, MRI allows the direct visualisation of the spinal cord and thus direct evaluation of spinal cord injuries.

**Recommendation 10:** osteoporosis

In patients with axial SpA without syndesmophytes in the lumbar spine on conventional radiography, osteoporosis should be assessed by hip DXA and anterior–posterior (AP)-spine DXA. In patients with syndesmophytes in the lumbar spine on conventional radiography, osteoporosis should be assessed by hip DXA, supplemented by either spine DXA in lateral projection or possibly quantitative CT (QCT) of the spine.

Strength of recommendation: 9.4 (95% CI 9.0 to 9.8).

A total of 42 studies were included,\textsuperscript{133–137} while one additional study that did not meet the inclusion criteria but provided some evidence was also shown to the taskforce.\textsuperscript{175} Only one study compared the diagnostic utility between two different techniques for detecting osteoporosis in SpA. This reported moderate SE (0.50–0.75) and SP (0.67–0.75) for quantitative US compared with DXA.\textsuperscript{133} Three studies reported no additional value of quantitative US compared with DXA\textsuperscript{134–136} while three studies compared QCT to DXA and reported that in patients with advanced AS osteoporosis is more frequently detected by QCT of the spine than using DXA of the spine\textsuperscript{137, 175} or the hip region.\textsuperscript{138}

Moreover, 37 studies (32 in axSpA and 6 in PsA) provided data on the site for performing DXA\textsuperscript{139–173} In axSpA, 20 studies compared DXA at different sites for distinguishing patients with AS and controls. Fifteen of these studies compared the AP/posterior–anterior (PA) projection at the spine versus the hip region but the results were inconsistent: six studies observed no differences,\textsuperscript{136, 139–143} eight reported results in favour of the hip\textsuperscript{135, 144–150} and one in favour of the spine.\textsuperscript{151} Three studies compared the AP/PA versus the lateral projection at the spine and all reported that the lateral projection differentiated better between AS and controls.\textsuperscript{145, 146, 149} Only four studies compared forearm DXA with other regions, all of them reporting data in favour of spine or hip\textsuperscript{137, 142, 152, 153} regions.

Furthermore, some studies also evaluated the possible influence of radiographic change, disease duration or disease activity in bone mineral density (BMD) determination at different regions (table 5). Most of the studies found the hip region being less influenced by radiographic change than the AP/PA projection of the spine.\textsuperscript{137, 139, 142, 145, 147, 148, 154, 155, 156} Two studies reported the lateral spine projection being less influenced by radiographic change than the AP/PA projection.\textsuperscript{145, 157} Moreover, the majority of the studies found a positive correlation between BMD and disease duration with AP/PA projection of the spine while no correlation was found with the lateral projection or at hip. However, most of the studies did not observe
Table 5  Recommendation 10: summary of studies evaluating different localisations to perform dual-energy X-ray absorptiometry in patients with axial spondyloarthritis

(A) Radiographic damage (syndesmophytes/BASRI spine) Results in favour of
Study N=11 N=12 AP/PA spine Hip AP/PA spine Hip

Devolgelaer et al.133 70 X X
Karberg 2005134 103 X X
Jun 2006135 68 ND ND
Mullaji 1994136 33 X X
Gilggi 2005137 20 X X
Muntean 2011138 44 X X
Taylan 2012139 55 X X
Vaisdev 2001140 80 ND ND
Baek 2005141 76 X X
Capaci 2003142 73 X X
Donelly 1994143 87 X X

N=2 AP/PA spine Lateral spine AP/PA spine Lateral spine
Gilggi 2005144 20 X X
Klingsberg 2012145 204 X X

(B) Disease duration Correlation between BMD and disease duration
Study N=12 N=12 AP/PA spine Hip AP/PA spine Hip

Arends 2011146 198 r=0.34 NS
El Magahroui 1999147 80 r=0.23 NS
Gilggi 2005148 20 r=0.52 NS
Grazio 2012149 80 r=0.05 r=−0.361
Jansen et al.150 50 No r=0.35
Meirrells 1999151 30 r=0.65 NS
Mermerci 2010152 100 r=0.25 r=−0.20
Muntean 2011153 44 NS NS
Speddon et al.154 66 NS NS
Taylan 2012155 55 r=0.30 NS
van der Weijden 2011156 130 NS NS
Vaisdev 2011157 80 NS NS

N=2 AP/PA spine Lateral spine AP/PA spine Lateral spine
Gilggi 2005158 20 r=0.52 NS
Mermerci 2010159 100 r=0.25 NS

(C) Disease activity Correlation between BMD and disease activity parameters (ASDAS, BASDAI, CRP, ESR)
Study N=9 N=9 AP/PA spine Hip AP/PA spine Hip

Frediani et al.160 186 NS NS
Grazio 2012161 80 r=−0.30 r=−0.22
Mermerci 2010162 100 r=−0.24 r=−0.24
Mullaji 1994163 33 NS ND
Muntean 2011164 44 NS NS
Park 2008165 35 NS r=−0.49
Taylan 2012166 55 NS NS
van der Weijden 2011167 130 NS NS
Vaisdev 2011168 80 NS NS

N=1 AP/PA spine Lateral spine AP/PA spine Lateral spine
Mermerci 2010169 100 r=−0.24 r=−0.30

The Pearson test for rank correlation is used for test of correlation, values are correlation coefficients (r).
AP, anterior–posterior; ASDAS, Ankylosing Spondylitis Disease Activity Score; BASDAI, Bath Ankylosing Spondylitis Disease Activity Score; BASRI, Bath Ankylosing Spondylitis Radiology Index; BMD, bone mineral density; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; ND, no statistically significant differences; NS, not statistically significant; PA, posterior–anterior.

In patients with PsA, published data are scarce. Three studies compared the ability of AP/PA DXA of the spine with DXA of the hip to distinguish between patients with PsA and controls but the results were not consistent.133 146 147 In patients with PsA, no correlation was observed between BMD detected by AP/PA DXA of the spine or the hip with disease duration134 148 or with disease activity.133 144

Box 1  Future research agenda

1. To further investigate which imaging findings (imaging modality, anatomical location and type of pathology) provides the best clinical utility for early and accurate diagnosis of SpA.
2. To further investigate which imaging findings (imaging modality, anatomical location and type of pathology) are best for monitoring peripheral and axial disease activity and structural damage in SpA in clinical practice.
3. To further investigate which imaging findings (imaging modality, anatomical location and type of pathology) best predict the disease course (structural progression, pain, functional ability, health-related quality of life) and treatment response in SpA.
4. To further investigate which imaging approaches best identify and monitor specific SpA-related features (such as enthesitis, dactylitis, synovitis and tenosynovitis, at different locations) in clinical practice.
5. To further investigate the spatial and temporal relation between different imaging findings (imaging modality, anatomical location and type of pathology) providing further insight into the disease process of SpA, which may inform future clinical management of SpA.
6. To investigate the importance of subclinical (detected only on imaging) axial and peripheral inflammation (including bone marrow oedema, synovitis, tenosynovitis and/or enthesitis), and if possible to identify thresholds to guide intervention. Subsequently to investigate the benefits (eg, on functional ability and quality of life) of incorporating such thresholds into treat-to-target strategies.
7. To investigate new and/or alternative technical options to existing imaging technologies (US: eg, 3D/4D-transducers, Doppler quantification, elastosonography; MRI: eg, whole-body MRI, diffusion-weighted MRI and dynamic contrast-enhanced MRI with automated reading) as well as new imaging modalities (eg, optical imaging, new nuclear medicine techniques) of potential use in SpA in clinical practice.
8. To further evaluate specific areas/joints to be assessed, timing of assessment(s) and the evaluation system to be employed in order to optimise the role of modern imaging modalities in the diagnosis, prognosis and outcome measurement of SpA.
9. To investigate which imaging approach provides the best clinical utility for diagnosing spinal fractures, and the consequences thereof.
10. To investigate which imaging approach provides the best clinical utility for diagnosis and monitoring of osteoporosis in SpA.
Finally, only four longitudinal studies assessed BMD over time to monitor osteoporosis in patients with SpA.\textsuperscript{165–168} In these studies, changes in BMD were observed after 1–2 years, especially in patients with active disease. Quality assessment is reported in online supplementary file S6.9; of note risk of index test and reference standard bias were high in 86% and 88% of included manuscripts, respectively.

**DISCUSSION**

These are the first recommendations produced by a EULAR taskforce on the use of imaging in SpA clinical practice. The group combined research-based evidence and expert opinion through a translational process among the experts from the presented literature-derived evidence to the final wording. Recommendations were primarily based on available research evidence with the exception of recommendation 9, which, lacking available data, was reliant on expert opinion. Finally, experts scored the SOR for each recommendation using data from the quality assessment.

We acknowledge that there is still a large amount of research required to optimise the use of imaging tools in the routine clinical practice of SpA.\textsuperscript{176} We have summarised the most important topics for future research according to currently available evidence and clinical practice in box 1. These recommendations will likely need to be revisited in the future when important new evidence becomes available.\textsuperscript{12}

In summary, we have developed 10 recommendations on various aspects of imaging in SpA. These are based on the best available evidence and clinical expertise supported by an international panel of experts. We aimed to produce recommendations that are practical and valuable in daily practice for rheumatologists, radiologists and general practitioners.

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**Contributors**

PM and VN-C performed the literature review with help from ST, PA and PB. PM and VN-C produced drafts of the manuscript with advice from OM and LT. All authors were involved in the conception of the study, in the analysis and interpretation of data, in the production of the recommendations and have reviewed the final manuscript.

**Competing interests**

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**REFERENCES**


