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/ spondylitis 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 and pSpA. 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.

There were 158 selected articles for the systematic reviews, of which 118 were searched in MEDLINE (see online supplementary material S1: research questions). The combined searches included a total of 322 articles for review. All additional articles identified by experts were included. The following evidence was reported from the reviews: 

**Recommendation 1: diagnosing axial SpA**

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 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 sacroilitis 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 axial SpA.14–38 Five studies reported on the diagnostic utility of radiography.14–18 They demonstrated varying sensitivity (SE) and specificity (SP) of radiography in diagnosing sacroilitis in inflammatory back pain (IBP)/suspicions of SpA, while one observational study reported an SE of 0.84 and an SP of 0.75 in diagnosing sacroilitis in AS.14–18 A single study reported only fair agreement between radiography and CT in suspected sacroilitis and many false positive results using radiography.18 Two studies reported higher SE for CT than radiography for diagnosing sacroilitis (1 in AS, 1 in suspected SpA).15 17

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).19–31 Three studies reported SE (0.73–0.9) and SP (0.9–0.97) for SI joint BME on MRI in established AS.22 23 25 Wick et al36 reported an SE of 0.11 and an SP of 0.93 for MRI SI joint erosions for diagnosis of AS, while Weber et al22 reported that the combined features of SI joint erosion and/or BME increased SE to 0.98–0.96 compared with BME alone (0.91–0.83) without reducing SP and the area under the curve for diagnosis of AS. Heuft-Dorenborsch et al found that initial assessment of structural changes by radiography followed by MRI assessment of inflammation with negative radiography gives the highest returns for detecting involvement of the SI joint in patients with recent IBP.27 Finally, two studies found MRI of the SI joint superior to QSS or radiography for diagnosing sacroilitis in IBP and SpA.14 33

With regard to MRI of the spine, three studies reported SE of and SP for corner fat lesions and corner inflammatory lesions (CLIs) in patients suspected for axSpA.29 30 31 while two studies reported SE and SP in established AS.31 32 Finally, Weber et al22 have demonstrated that spinal MRI adds little incremental value
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 sacroiliitis in patients with IBP. Klauser et al. reported that contrast-enhanced US is a sensitive and specific tool for diagnosing active sacroiliitis in patients with IBP. One study reported that pulsatile monophasic colour Doppler US detects sacroiliitis 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.

**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>9.5 (9.2–9.8)</td>
<td>III</td>
</tr>
<tr>
<td>9.4 (9.0–9.8)</td>
<td>III</td>
</tr>
<tr>
<td>9.2 (8.8–9.6)</td>
<td>Ib</td>
</tr>
<tr>
<td>9.3 (8.8–9.8)</td>
<td>Ib</td>
</tr>
<tr>
<td>9.3 (8.9–9.7)</td>
<td>Ib</td>
</tr>
<tr>
<td>8.9 (8.4–9.4)</td>
<td>III</td>
</tr>
<tr>
<td>9.0 (8.5–9.5)</td>
<td>Ib</td>
</tr>
<tr>
<td>8.9 (8.3–9.5)</td>
<td>Ib</td>
</tr>
<tr>
<td>9.3 (8.9–9.7)</td>
<td>IV</td>
</tr>
<tr>
<td>9.4 (9.0–9.8)</td>
<td>III</td>
</tr>
</tbody>
</table>
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 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)

Thirty-four studies evaluated the utility of MRI in monitoring disease activity in axial SpA.20 21 48–79 Table 3 summarises and presents the results of longitudinal20 21 22 23 24–27 51 59 60 70 79 as well as cross-sectional51 59 60 70 79 studies evaluating correlation with accepted disease activity parameters (Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), Ankylosing Spondylitis Disease Activity Score (ASDAS)), C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) or pain.

In addition, seven studies compared the utility of different MRI sequences (contrast-enhanced T1-weighted (T1Gd) and STIR), for monitoring disease activity in axial SpA,50 51 52 55 56 57 65 77 78 80–86 six of which reported high levels of agreement or correlation between the two sequences.48 49 53 56 57 65 67 77 A single longitudinal and two cross-sectional studies reported higher SE of STIR,59 63 66 while a single longitudinal and two cross-sectional studies reported higher diagnostic confidence/reliability of the T1Gd-DPTA sequence.48 49 53

Regarding frequency of spinal MRI examination, two longitudinal studies reported significant changes detected already at 6 or 12 weeks50 72 with similar results for both STIR and T1Gd sequences.72 There is currently no evidence for how frequently MRI should be repeated for monitoring disease activity in axial SpA. Quality assessment is reported in online supplementary figure S6.3.

**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 should be repeated for monitoring disease activity in axial SpA–5 years with similar results for both STIR and T1Gd sequences.36 85 86

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

<table>
<thead>
<tr>
<th>Studies No.</th>
<th>Study population</th>
<th>Gold standard SIJ/spine MRI lesion</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>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bennett et al20</td>
<td>SpA</td>
<td>X-ray</td>
<td>SIJ</td>
<td>0.62</td>
<td>0.92</td>
<td>7.7</td>
<td>0.41</td>
</tr>
<tr>
<td>Marzo-Ortega et al20</td>
<td>IBP (NSBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>0.82</td>
<td>0.43</td>
<td>1.4</td>
<td>0.41</td>
</tr>
<tr>
<td>Oostveen et al21</td>
<td>IBP</td>
<td>X-ray</td>
<td>SIJ</td>
<td>0.73</td>
<td>1.0</td>
<td>∞</td>
<td>0.73</td>
</tr>
<tr>
<td>Cross-sectional/case-control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weber et al22–23</td>
<td>AS, IBP (NSBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>0.85</td>
<td>0.47</td>
<td>1.6</td>
<td>0.31</td>
</tr>
<tr>
<td>Weber et al24–25</td>
<td>AS, IBP (NSBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>0.9</td>
<td>0.97</td>
<td>44.6</td>
<td>0.92</td>
</tr>
<tr>
<td>Heuft-Dorenbosch et al27</td>
<td>IBP</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>0.82</td>
<td>0.9</td>
<td>8.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Weber et al28–29</td>
<td>AS, IBP, (HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>0.97</td>
<td>0.31</td>
<td>1.4</td>
<td>0.09</td>
</tr>
<tr>
<td>Kim et al29</td>
<td>AS (HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>0.87</td>
<td>0.9</td>
<td>8.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Retrospective</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Wick et al25</td>
<td>AS (various)</td>
<td>Clinical diagnosis</td>
<td>SIJ</td>
<td>0.11</td>
<td>0.93</td>
<td>1.6</td>
<td>0.31</td>
</tr>
<tr>
<td>Bennett et al28–29</td>
<td>SpA (DA, IBP, HC)</td>
<td>Clinical diagnosis</td>
<td>SIJ and spine</td>
<td>0.33</td>
<td>0.99</td>
<td>14.5</td>
<td>0.87</td>
</tr>
</tbody>
</table>

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.
Five studies reported correlation between changes over time in MRI and radiography and/or CT parameters of structural damage,\textsuperscript{19-21,37,55} while Puhakkala et al\textsuperscript{51} found MRI and CT are superior to radiography. A single study reported correlation between spinal MRI and metrological measures,\textsuperscript{70} while two reported no correlation.\textsuperscript{39,98} One study reported correlation between MRI changes and BASMI,\textsuperscript{88} whereas two studies reported no correlation with CRP and/or ESR.\textsuperscript{98,101} Two studies reported correlation with swollen or tender joint counts.\textsuperscript{80,102} Another study reported no correlation between PD and axial entheses.\textsuperscript{102} A single study reported correlation between PD and axial entheses, while Kiris et al\textsuperscript{102} reported no correlation between PD and axial entheses.\textsuperscript{102} Aydin et al\textsuperscript{100} reported correlation between grey-scale enthesal changes of the Achilles tendon and CRP while five studies reported no correlation with CRP and/or ESR.\textsuperscript{98,101-104} Hamdi et al\textsuperscript{99} reported correlation between pain and power Doppler enthesal changes of the lower limb entheses, while Kiris et al\textsuperscript{102} reported no correlation between PD and axial entheses.

Two studies reported correlation with swollen or tender joint count,\textsuperscript{39,104} while a single study reported no correlation.\textsuperscript{40} Hamdi et al\textsuperscript{99} reported correlation with clinical enthesitis indices (Maastricht Ankylosing Spondylitis Score, Spondyloarthritis Research Consortium of Canada (SPARC) Enthesitis Index), while two studies reported no correlation.\textsuperscript{39,98} Two studies reported discrepancies in abnormal entheses detected by US versus clinical examination.\textsuperscript{40,105}

\begin{table}[h]
\centering
\begin{tabular}{|l|l|l|l|l|l|l|l|l|}
\hline
\textbf{Study} & \textbf{No.} & \textbf{Region} & \textbf{MRI scoring method} & \textbf{BASDAI} & \textbf{BASMI} & \textbf{CRP} & \textbf{ESR} & \textbf{Pain} \\
\hline
Marzo-Ortega et al\textsuperscript{20} & 76 & Spine & LEEDS & – & NS & NS & – & NS \\
Oostveen et al\textsuperscript{21} & 25 & SJ & mNY & – & NS & OR 2.1 & OR 2.1 & OR 1.2 \\
Baraliakos et al\textsuperscript{40} & 40 & Spine & ASspiMRI-a & – & NS & NS & – & – \\
Bonel et al\textsuperscript{32} & 28 & Spine & ASspiMRI-a & – & 0.41 & – & – & – \\
Braun et al\textsuperscript{53} & 20 & Spine & ASspiMRI-a/c & – & 0.49–0.6 & – & – & – \\
Braun et al\textsuperscript{54} & 98 & Spine & ASspiMRI-a & 0.35 & NS & 0.4 & – & NS \\
Lambert 2007\textsuperscript{41} & 82 & Spine/SJ & SPARCC & – & NS & p=0.018 & – & NS \\
Machado et al\textsuperscript{53} & 221 & Spine & ASspiMRI-a & 0.14 & NS & – & – & – \\
Machado et al\textsuperscript{54} & 221 & Spine & ASspiMRI-a & 0.23 & NS & 0.32 & – & – \\
Maksymowych et al\textsuperscript{66} & 68 & Spine & SPARCC & – & NS & 0.65–0.68 & – & NS \\
Maksymowych et al\textsuperscript{67} & 36 & Spine & SPARCC & – & NS & 0.45 & 0.44 & – \\
Marzo-Ortega et al\textsuperscript{68} & 42 & Spine/SJ & LEEDS & – & p=0.04 & – & – & – \\
Pedersen et al\textsuperscript{74} & 82 & Spine/SJ & Berlin & 0.46/0.31 & –0.41/–0.31 & NS & – & – \\
Puhakkala et al\textsuperscript{31} & 34 & SJ & BM & – & NS & – & – & – \\
Rudwaleit et al\textsuperscript{73} & 62 & Spine/SJ & Berlin & – & NS & NS & NS & NS \\
Sieper et al\textsuperscript{74} & 20 & Spine & ASspiMRI-a & – & 0.5 & NS & NS & – \\
Song et al\textsuperscript{86} & 76 & Spine/SJ & ASspiMRI-a/SPARCC & p=0.04 & – & NS & – & – \\
Visvanathan et al\textsuperscript{77} & 279 & Spine & ASspiMRI-a & – & p<0.001 & – & – & – \\
Blachier 2013\textsuperscript{35} & 648 & Spine/SJ & Dichotomous & – & – & – & – & aOR 1.71–2.86 \\
Goh et al\textsuperscript{85} & 34 & Spine & ASspiMRI-a & – & NS & NS & NS & – \\
Kiltz et al\textsuperscript{87} & 100 & Spine/SJ & Berlin & NS & NS & 0.22 & – & – \\
Konica et al\textsuperscript{60} & 50 & Spine & ASspiMRI-a & 0.37 & NS & 0.33 & 0.39 & – \\
Puhakkala et al\textsuperscript{27} & 49 & SJ & BM enhancement & – & NS & – & – & – \\
Weber et al\textsuperscript{79} & 197 & ACW & Dichotomous & – & – & – & – & \kappa 0.21–0.33 \\

\hline
\end{tabular}
\caption{Summary of studies on the use of MRI in monitoring disease activity in axial spondyloarthritis.}
\end{table}
Table 4 | Recommendation 4: summary of studies on the use of radiography in monitoring structural changes in axial spondyloarthritis

<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>
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<tr>
<td>Longitudinal/RCT</td>
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<td></td>
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</tr>
<tr>
<td>Machado et al</td>
<td>214</td>
<td>Spine</td>
<td>mSASSS</td>
<td>0.18; p=0.008</td>
<td>0.79; p=0.001</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Baraliakos et al</td>
<td>82</td>
<td>Spine</td>
<td>mSASSS</td>
<td>NS</td>
<td>0.49–0.59; p=0.01 (NS)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Baraliakos et al</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 et al</td>
<td>50</td>
<td>Spine</td>
<td>mSASSS</td>
<td>–</td>
<td>–</td>
<td>p=0.05–0.0005 (CE, OWD, SF)</td>
<td>–</td>
</tr>
<tr>
<td>Salaffi et al</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 et al</td>
<td>70</td>
<td>Spine/SU</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 (SIU)</td>
</tr>
<tr>
<td>Cross-sectional/case–control</td>
<td></td>
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<td></td>
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<tr>
<td>Lee et al</td>
<td>39</td>
<td>Spine</td>
<td>BASRI</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Lubrano et al</td>
<td>77</td>
<td>Spine</td>
<td>mSASSS</td>
<td>NS</td>
<td>0.47; p=0.001</td>
<td>–</td>
<td>0.53–0.73 (p=0.001)</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.

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, with one study also evaluating PDUS and an additional study evaluating MRI. Among the studies assessing the utility of radiography, two reported correlation with the functional indices Health Assessment Questionnaire and/or Arthritis Impact Measurement Scales. 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. A case–control study on 98 patients with ReA reported correlation between radiographic condylar erosions of the temporomandibular joint and patient-reported outcomes. A cross-sectional study on 60 patients with AS reported correlation between BASFI and both radiographic and sonographic signs of enthesis, 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. Finally, Tan et al 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* (not non-radiographic axial SpA), conventional radiography of the lumbar and cervical spine is recommended to detect syndesmophytes, which are predictive of development of new syndesmophytes. MRI (vertebral corner syndesmophytes/ankylosis, rather than erosion or sclerosis, were the features most frequently showing progression in AS. Basal syndesmophytes/ankylotic changes with or without inflammatory or fatty lesions may also be used to predict development of new radiographic syndesmophytes.

*That is, radiographic axial spondyloarthritis.

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

Seventeen publications were included. All studies evaluating radiography reported that baseline radiographic change (syndesmophytes) predicts radiographic progression in AS. Baraliakos et al reported that syndesmophytes/ankylosis, rather than erosion or sclerosis, were the features most frequently showing progression in AS. Maksymowych et al found that high baseline mSASSS (cut-off of 10 units; OR 18.6) was an independent predictor of 2-year progression in AS.
Six studies reported correlation between CILs or vertebral edge inflammation on MRI and subsequent radiographic syndesmophyte formation in patients with AS.\(^{117, 119, 120, 123, 124, 128}\) Madsen et al.\(^{121}\) 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 et al.\(^{124}\) 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 \(\text{(OR} \ 12.48)\).\(^{125}\) In a 1-year longitudinal study, Song et al.\(^{126}\) presented a significant relationship between the disappearance of inflammation and the appearance of fatty lesions in the spine of patients with axSpA. Moreover, Baraliakos et al.\(^{115}\) 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 \(\text{(OR} \ 5.8)\) emerged as a more significant predictor of new syndesmophytes than did fat infiltration \(\text{(OR} \ 1.9)\).\(^{120}\) Finally, Bennett et al.\(^{19}\) reported no association between baseline BME on lumbar spine MRI and mSASSS progression after 8 years in patients with AS.

Avens et al.\(^{81}\) 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 \(\text{(BME)}\), particularly in the spine in patients with AS, might be used as a predictor of good clinical response to anti-TNF-alpha therapy 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 \(\text{(95\% CI 8.3 to 9.5)}\)

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.\(^{73}\) An RCT of 185 patients with non-radiographic axial SpA reported that a baseline SPARC MRI score \(\geq 2\) for either the SI joint or the spine was associated with better response after 12 weeks of adalimumab.\(^{75}\) 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.\(^{130}\) 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 \(\text{(95\% CI 8.9 to 9.7)}\)

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.\(^{131}\) 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 \(\text{(95\% CI 0.21 to 0.66)}\) and 0.48 \(\text{(95\% CI 0.30 to 0.65)}\), respectively. In contrast, weighted average SE to detect soft tissue injuries for MRI and radiography were 0.55 \(\text{(95\% CI 0.39 to 0.70)}\) and 0.07 \(\text{(95\% CI 0.02 to 0.13)}\), respectively.\(^{132}\) 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 \(\text{(95\% CI 9.0 to 9.8)}\)

A total of 42 studies were included,\(^{133–174}\) while one additional study that did not meet the inclusion criteria but provided some evidence was also shown to the taskforce.\(^{175}\) 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.\(^{133}\) Three studies reported no additional value of quantitative US compared with DXA\(^{134–136}\) 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\(^{137, 175}\) or the hip region.\(^ {138}\)

Moreover, 37 studies \(32 \text{ axSpA and 6 in PsA}\) provided data on the site for performing DXA.\(^ {139–173}\) 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,\(^ {136, 139–143}\) eight reported results in favour of the hip\(^ {135, 144–150}\) and one in favour of the spine.\(^ {151}\) 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.\(^ {143, 146, 149}\) Only four studies compared forearm DXA with other regions, all of them reporting data in favour of spine or hip\(^ {117, 142, 152, 153}\) 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 \(\text{(table 5)}\). Most of the studies found the hip region being less influenced by radiographic change than the AP/PA projection of the spine.\(^ {137, 138, 142, 143, 147, 148, 154, 155, 156}\) Two studies reported the lateral spine projection being less influenced by radiographic change than the AP/PA projection.\(^ {145, 157}\) 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

<table>
<thead>
<tr>
<th>Study</th>
<th>Radiographic damage</th>
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<tr>
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<td>(syndesmophytes/BASRI spine)</td>
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<td>Klingberg 2012157</td>
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<td>Donelly 1994146</td>
<td>87</td>
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<td>20</td>
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<thead>
<tr>
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<td>Jansen et al133</td>
<td>50</td>
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<td>66</td>
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<td></td>
<td>Taylor 2012146</td>
<td>55</td>
<td>r=0.30</td>
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<tr>
<td></td>
<td>van der Weijden 2011160</td>
<td>130</td>
<td>NS</td>
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<td>N=2</td>
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<td>Mermerci 2010146</td>
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<td>r=0.25</td>
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<tr>
<th>Study</th>
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<th>Correlation between BMD and disease activity parameters (ASDAS, BASDAI, CRP, ESR)</th>
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<td>N=1</td>
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<td></td>
<td>Mermerci 2010146</td>
<td>100</td>
<td>r=−0.24</td>
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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.

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) best predict the disease course (structural progression, pain, functional ability, health-related quality of life) and treatment response in SpA.
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.

SpA, spondyloarthropathies; US, ultrasound; 3D, three-dimensional; 4D, four-dimensional.
Finally, only four longitudinal studies assessed BMD over time to monitor osteoporosis in patients with SpA.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 figure 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.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.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 PAB. 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.

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