EULAR-PReS points to consider for the use of imaging in the diagnosis and management of juvenile idiopathic arthritis in clinical practice

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ABSTRACT
To develop evidence based points to consider the use of imaging in the diagnosis and management of juvenile idiopathic arthritis (JIA) in clinical practice. The task force comprised a group of paediatric rheumatologists, rheumatologists experienced in imaging, radiologists, methodologists and patients from nine countries. Eleven questions on imaging in JIA were generated using a process of discussion and consensus. Research evidence was searched systematically for each question using MEDLINE, EMBASE and Cochrane CENTRAL. Imaging modalities included were conventional radiography, ultrasound, MRI, CT, scintigraphy and positron emission tomography. The experts used the evidence obtained from the relevant studies to develop a set of points to consider. The level of agreement with each point to consider was assessed using a numerical rating scale. A total of 13 277 references were identified from the search process, from which 204 studies were included in the systematic review. Nine points to consider were produced, taking into account the heterogeneity of JIA, the lack of normative data and consequent difficulty identifying pathology. These encompassed the role of imaging in making a diagnosis of JIA, detecting and identifying pathology. These encompassed the role of imaging in making a diagnosis of JIA, detecting and identifying pathology. The role of imaging in monitoring disease progression and remission (see online supplementary material S1). A detailed systematic search of the published literature was performed on studies involving the use of imaging in children with JIA. Imaging modalities included were X-ray described as conventional radiography (CR), ultrasound (US), MRI, CT, scintigraphy and positron emission tomography. Included studies were evaluated for risk of bias and applicability using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS)-2 tool. Following presentation of the literature review at a second meeting, experts produced points to consider (PTC) with final agreement by a process of discussion and consensus. The available evidence for each recommendation was scored according to the Oxford Centre for Evidence-Based Medicine level of evidence. The experts anonymously scored their level of agreement for each proposition using a 0–10 numerical rating scale (0=do not agree at all, 10=fully agree). Scores reflected research evidence and clinical expertise. An agenda for future research was also agreed upon following presentation of the literature review.

INTRODUCTION
Juvenile idiopathic arthritis (JIA) is a heterogeneous group of conditions with onset under the age of 16 years with unknown aetiology and persistence of symptoms for over 6 weeks. Imaging plays an important role in diagnosis and monitoring of patients with JIA, but until recently there were few studies in this area.

A European League against Rheumatism (EULAR)—Pediatric Rheumatology European Society (PReS) task force was convened to produce evidence and consensus-based recommendations on the use of imaging in the diagnosis and management of JIA in clinical practice for use by secondary care professionals caring for children with JIA, to help define standards of care for appropriate imaging.

RESULTS
The database search (November 2013) resulted in 13 277 records leaving 10 925 articles after
deduplication. Four hundred and thirty-three articles were included for detailed review once exclusions were made based on title or abstract. All full text articles written in English were retrieved for review, of which 244 articles were excluded leaving 189 articles for inclusion. The hand search identified 15 additional articles, resulting in a total of 204 articles for inclusion (see flow chart in the online supplementary figure S4). Articles that were relevant to multiple research questions were included in the review as necessary. The number of articles included per question is shown in the online supplementary table S5.

The task force produced nine PTC which are presented with level of evidence, grade of recommendation and level of agreement in table 1. The task force felt that the supporting data was not sufficient to produce ‘recommendations’ so they were categorised as ‘points to consider’. Scores for risk of bias and applicability of the included studies according to QUADAS-2, a full reference list for articles included in each recommendation, and feedback given at the Patient and Public Involvement meeting are given in the online supplementary text S6 S7 and S8.

<table>
<thead>
<tr>
<th>Point to consider</th>
<th>Level of evidence</th>
<th>Grade of recommendation</th>
<th>Level of agreement, mean NRS 0–10 (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 US and MRI are superior to clinical examination in the evaluation of joint inflammation; these techniques should be considered for more accurate detection of inflammation, in diagnosis and assessing extent of joint involvement.</td>
<td>3b</td>
<td>C</td>
<td>9.07 (6–10)</td>
</tr>
<tr>
<td>2 When there is clinical diagnostic doubt, CR, US or MRI can be used to improve the certainty of a diagnosis of JIA above clinical features alone.</td>
<td>3b</td>
<td>C</td>
<td>9.43 (9–10)</td>
</tr>
<tr>
<td>3 If detection of structural abnormalities or damage is required, CR can be used. However MRI or US may be used to detect damage at an earlier time point than CR.</td>
<td>3b</td>
<td>C</td>
<td>8.71 (5–10)</td>
</tr>
<tr>
<td>4 In JIA imaging may be of particular benefit over routine clinical evaluation when assessing certain joints, particularly the use of MRI in detecting inflammation of the TMJ and axial involvement.</td>
<td>3b</td>
<td>C</td>
<td>9.64 (8–10)</td>
</tr>
<tr>
<td>5 Imaging in JIA may be considered for use as a prognostic indicator. Damage on CR can be used for the prediction of further joint damage. Persistent inflammation on US or MRI may be predictive of subsequent joint damage.</td>
<td>4</td>
<td>C</td>
<td>9.07 (5–10)</td>
</tr>
<tr>
<td>6 In JIA, US and MRI can be useful in monitoring disease activity given their sensitivity over clinical examination and good responsiveness. MRI should be considered for monitoring axial disease and TMJ.</td>
<td>3b</td>
<td>C</td>
<td>9.07 (7–10)</td>
</tr>
<tr>
<td>7 The periodic evaluation of joint damage should be considered. The imaging modality used may be joint dependent.</td>
<td>3b</td>
<td>C</td>
<td>8.29 (5–10)</td>
</tr>
<tr>
<td>8 US can be used for accurate placement of intra-articular injections.</td>
<td>3b</td>
<td>C</td>
<td>9.64 (8–10)</td>
</tr>
<tr>
<td>9 US and MRI can detect inflammation when clinically inactive disease is present; this may have implications for monitoring.</td>
<td>3b</td>
<td>C</td>
<td>8.86 (5–10)</td>
</tr>
</tbody>
</table>

The level of evidence and grade of recommendation are based on the Oxford Centre for Evidence-Based Medicine system. CR, conventional radiography; JIA, juvenile idiopathic arthritis; TMJ, temporomandibular joint; US, ultrasound.

**Overarching principles**

The task force produced general statements that should be considered when interpreting the PTC. These principles cover the imaging needs of inflammatory arthritis is children and assume that other important differentials such as infection have been ruled out.

- **JIA** is an umbrella term for all forms of inflammatory arthritis that begins before the age of 16 years, persists for more than 6 weeks and is of unknown origin. This heterogeneous group of diseases is currently classified according to the International League of Associations for Rheumatology classification. There is a lack of information on imaging related to JIA categories at present.

- There is a paucity of data on the joint-specific imaging features present during growth and skeletal development in healthy children. Understanding normative data is essential for interpretation of imaging abnormalities. For example, some physiological features of recently ossified bones can be misinterpreted as cortical erosions, cartilage thickness may vary with skeletal maturation and vascularity of epiphyses will change with ageing.

- Joint inflammation at certain developmental time points may cause specific structural changes, further challenging imaging assessment.

- The appropriateness and feasibility of different imaging modalities differs with age, related to radiation exposure and requirement for sedation. Every effort should be made to avoid unnecessary radiation exposure. However, there is a long established experience with the use of CR to demonstrate damage.

- Patient experience with different imaging modalities is affected by their age and development. It is important to provide a ‘child friendly’ environment.

**Points to consider**

**Making a diagnosis of JIA**

**PTC 1:** US and MRI are superior to clinical examination in the evaluation of joint inflammation; these techniques should be considered for more accurate detection of inflammation, in diagnosis and assessing extent of joint involvement.

Sixty-five studies compared clinical examination with imaging in the detection of inflammation in various joints, 40 with US, 27 with MRI, 5 with CR and 1 with positron emission tomography (table 2). The data is represented according to detection rates; for example, how many times more (>one fold) or less (<one fold) does imaging detect inflammation over clinical examination; this has the potential to increase false positive results. In general, US and MRI were able to detect joint inflammation more frequently than clinical examination; for example.
<table>
<thead>
<tr>
<th>Ultrasound</th>
<th>MRI</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>US knees vs CE</td>
<td>MRI knees vs CE</td>
<td>CR knees vs CE</td>
</tr>
<tr>
<td>13 studies</td>
<td>13–15 36 72 84–87</td>
<td>3 studies</td>
</tr>
</tbody>
</table>

Detection rate, mean (range)

<table>
<thead>
<tr>
<th>US vs CE</th>
<th>MRI vs CE</th>
<th>CR vs CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synovitis/effusion (12 studies)</td>
<td>Synovitis vs clinical swelling (3 studies)</td>
<td>Joint distension vs swelling (3 studies)</td>
</tr>
<tr>
<td>1.19-fold (0.14–3.67-fold)</td>
<td>1.02-fold (0.96–1.12-fold)</td>
<td>0.69-fold (0.45–1.0-fold)</td>
</tr>
</tbody>
</table>

Effusion (1 study)

Agreement k=0.54
CE missed a significant no. of effusions

PD vascularity (2 studies)

Synovial volume vs CRP (1 study)

n=0.51–0.80
p=0.000–0.036
r=n.68–0.74

Joint distension vs pain (1 study)

1.57-fold

US hip vs CE

Synovitis/effusion (5 studies)

MRI vs CE

5 studies

CR hip vs CE

1 study

Synovitis/effusion vs pain (1 study)

Association k=0.006

MRI inflammation (4 studies)

0.88-fold (0.50–1.78-fold)

Joint distension vs clinical effusion (1 study)

0.80-fold

US hands/wrists vs CE

Synovitis/effusion (3 studies)

MRI vs CE

2 studies

CR hands/wrists vs CE

1 study

PO vascularity (2 studies)

Synovitis volume vs total hand swelling score (1 study)

r=0.52–0.72
p<0.05

Synovitis volume vs LOM (1 study)

r=0.76
p<0.05

Joint distension vs clinical effusion 

0.63-fold

Flexor/extensor tenosynovitis (1 study)

Significant association with clinical disease activity

Synovitis score vs wrist swelling score (1 study)

MRI score significantly higher with higher swelling score

p<0.0001

US ankles/feet vs CE

Synovitis/effusion (3 studies)

MRI ankles/feet vs CE

1 study

PD vascularity (1 study)

Synovitis/effusion (3 studies)

Tibiotalar synovitis (1 study)

1.00-fold

Subtalar synovitis (1 study)

3.33-fold

US TMJ vs CE studies

Synovitis/effusion (2 studies)

MRI TMJ vs CE

8 studies

Synovitis (6 studies)

2.46-fold (1.10–5.91-fold)

Significantly correlated

Reduced MIO best predictor of active MRI changes

Acute changes (1 study)

71% asymptomatic

63% normal CE

Continued
Table 2  Continued

<table>
<thead>
<tr>
<th>US enthesitis vs CE 3 studies</th>
<th>MRI enthesitis vs CE 1 study</th>
</tr>
</thead>
<tbody>
<tr>
<td>US enthesitis vs CE 3 studies</td>
<td>MRI enthesitis vs CE 1 study</td>
</tr>
<tr>
<td>Enthesitis (3 studies) 107–109</td>
<td>0.79-fold (0.53–1.09-fold)</td>
</tr>
<tr>
<td>Enthesitis (1 study) 110</td>
<td>0.50-fold</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>US VARIOUS MULTIPLE JOINTS vs CE 9 studies</th>
<th>MRI VARIOUS MULTIPLE JOINTS vs CE 1 study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synovitis/effusion (6 studies) 111–114</td>
<td>Synovitis/effusion (1 study) 110</td>
</tr>
<tr>
<td>Association US changes vs swelling (1 study)</td>
<td>1.85-fold (1.00–3.33-fold)</td>
</tr>
<tr>
<td>Swelling: r=0.63 Effusion: r=0.66 PD: r=0.50</td>
<td></td>
</tr>
<tr>
<td>Association synovitis vs CE (2 studies) 117</td>
<td>1.08-fold</td>
</tr>
<tr>
<td>Swelling: r=0.50 LOM: r=0.40 Pain: r=0.21</td>
<td></td>
</tr>
<tr>
<td>CE missed inflammation in 25.2% joints</td>
<td></td>
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</tbody>
</table>

| Synovitis/SH (1 study) 20 | 4.25-fold |
| MRI SIJ vs. CE 2 studies 23 | 0.93-fold |
| Sacroiliitis (2 studies) 23 | 0.99-fold |
| CE was normal in 22.9% patients with MRI sacroiliitis |

CE, clinical examination; CR, conventional radiography; CRP, C reactive protein; GS, grey scale; LOM, limitation of movement; MIO, maximal incisinal opening; PD, power Doppler; SIJ, sacroiliac joint; SH, synovial hypertrophy; TMJ, temporomandibular joint; US, ultrasound.
the mean (range) detection rate for synovitis and effusion at the knee was 1.19-fold (0.14–3.67-fold) for US and 1.02-fold (0.96–1.12-fold) for MRI knee synovitis.

PTC 2: When there is clinical diagnostic doubt, CR, US or MRI can be used to improve the certainty of a diagnosis of JIA above clinical features alone.

The diagnosis of JIA is mainly based on clinical features and the exclusion of other causes of chronic arthritis. However this point illustrates the role of imaging when there is diagnostic doubt; no specific imaging signatures for JIA have been described yet, but imaging is helpful to narrow the differential diagnosis. Four studies compared imaging features in suspected/proven JIA with either controls or other disease entities, including infectious arthritis, acute lymphoblastic leukaemia and haemophilia.\textsuperscript{7–10} US detected more joint inflammation than clinical examination; two studies specifically described US improving the diagnostic certainty in subjects with suspected JIA.\textsuperscript{11 12}

Detecting damage

PTC 3: If detection of structural abnormalities or damage is required, CR can be used. However MRI or US may be used to detect damage at an earlier time point than CR.

Thirty-seven studies compared joint damage (erosions, joint space narrowing (JSN), deformity) detected by imaging with clinical findings suggestive of underlying damage, such as tenderness, limitation of movement and crepitus. In general, all imaging modalities appeared to detect less joint damage than suggested by clinical examination; for example the mean (range) detection rate for cartilage loss at the knee was 0.32-fold for US, 0.63-fold (0.20–1.0-fold) for MRI and 0.46-fold (0.23–0.71-fold) for CR when compared with pain.\textsuperscript{11–15} This reflects the poor sensitivity of pain as an indicator of underlying damage.

When the imaging modalities are directly compared MRI and US detected more joint damage than CR, particularly at the hip (MRI vs CR detection rate, mean (range) 1.54-fold (1.08–2.0-fold); US vs CR detection rate, mean 2.29-fold), and at the wrist (MRI vs CR detection rate, 1.36-fold (1.0–2.0-fold)).\textsuperscript{13 15–19}

Imaging specific joints

PTC 4: In JIA imaging may be of particular benefit over routine clinical evaluation when assessing certain joints, particularly the use of MRI in detecting inflammation of the temporomandibular joint (TMJ) and axial involvement.

Cervical spine MRI appears better at detecting inflammation than clinical examination; one study showed 20% of patients had pain and/or limitation of movement whereas 85% had MRI inflammatory changes suggesting that cervical spine involvement in JIA is often clinically silent.\textsuperscript{20} MRI and CR have shown better detection rates than clinical examination for structural changes in the cervical spine (4.5-fold and mean, range 2.29 (1.58–3.0-fold), respectively.\textsuperscript{21 22} Abnormal sacroiliac joint (SIJ) imaging is also demonstrated despite a high rate of normal examination; for example, normal SIJ examination in 42.9% and 22.9%, in patients with CR and MRI sacroilitis, respectively.\textsuperscript{23 24}

Muller et al\textsuperscript{25} compared TMJ clinical examination and US with MRI changes, and found that examination correctly identified 58% patients with active MRI TMJ arthritis compared with 33% for US, and missed inflammation in 42% and 67%, respectively. They described reduced maximal incisal opening to be the best predictor of active MRI changes.\textsuperscript{26} Full data comparing the various imaging modalities with clinical examination of the TMJ is given in the online supplementary text S9.

Prognosis

PTC 5: Imaging in JIA may be considered for use as a prognostic indicator. Damage on CR can be used for the prediction of further joint damage. Persistent inflammation on US or MRI may be predictive of subsequent joint damage.

Thirteen observational studies examined the relationship between baseline imaging and subsequent radiographic and clinical outcome; 11 with CR and 2 with MRI at baseline. The statement on US inflammation is therefore based on expert opinion; the findings are given in full in table 3. In general, CR damage in the 1st year has a moderate correlation with functional deterioration according to Steinbocker class, Childhood Health Assessment Questionnaire and physician/parent disability scores at 3 years, as well as with CR progression at 5 years.\textsuperscript{26–29} A baseline CR wrist adapted Sharp van der Heijde score >1 was shown to be predictive of CR progression at 5 years (OR, 8.2), and patients with erosions and/or JSN in the first 6 months of the study spent more time with clinically active disease and were less likely to achieve clinical remission on medication.\textsuperscript{30 31} Just one study described the correlation of baseline MRI wrist synovial volume with MRI erosive progression at 1 year; this found a moderate correlation, and all patients with high synovial volume at baseline had erosive progression.\textsuperscript{32}

Monitoring inflammation

PTC 6: In JIA, US and MRI can be useful in monitoring disease activity given their sensitivity over clinical examination and good responsiveness. MRI should be considered for monitoring axial disease and TMJ.

Data comparing imaging with clinical examination in detecting joint inflammation is discussed in PTC 1, and specific information on imaging the TMJ and for axial involvement is summarised in PTC 4. This section will consider the comparison of the ability of imaging to detect inflammation, responsiveness of imaging to change in inflammation, and which joints should be assessed.

Comparison of the ability of imaging to detect inflammation

Several studies compared US with MRI in the detection of inflammation, particularly at the knee.\textsuperscript{13 14 33 34} These studies have shown MRI to be better in detecting knee inflammation than US (mean detection rate 1.20-fold, range 0.63–1.56-fold) and in particular MRI was better than US in differentiating pannus from effusion.\textsuperscript{13} Knee MRI with contrast enhancement was more reliable at localising and differentiating synovial hypertrophy from synovial fluid particularly when there was <5 mm of synovial hypertrophy, but the addition of contrast did not provide additional information in the assessment of inflammatory bone marrow lesions.\textsuperscript{35–37} Comparison of power Doppler with grey-scale wrist US has resulted in conflicting results, whereas the use of contrast significantly increased knee US synovial pixel intensity in those with symptomatic disease (p=0.004) and asymptomatic disease (p=0.0001), but not in those in clinical remission.\textsuperscript{38–40}

Studies comparing TMJ US with MRI have shown a poor correlation between these modalities, with US missing 67–75% of TMJ MRI inflammation.\textsuperscript{24 41} The use of MRI contrast enhancement improved the detection of MRI TMJ inflammation from 35.7% to 86.7%.\textsuperscript{42} One study examined the CR findings in patients with TMJ MRI synovitis and found significant correlation with abnormal condyle morphology and accentuated antegonial notchling on CR, and joints with both of these changes
Table 3  Point to consider 5: Summary of included studies describing the prognostic value of the imaging modalities

<table>
<thead>
<tr>
<th>Reference</th>
<th>No. of subjects</th>
<th>Duration of follow-up (months)</th>
<th>Radiological or clinical assessment</th>
<th>Outcome assessed</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline CR predictive factors</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Susic et al[20]</td>
<td>87</td>
<td>48</td>
<td>Wrist involvement</td>
<td>CHAQ-DI</td>
<td>Significant correlation p&lt;0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hip involvement</td>
<td>Significant correlation p&lt;0.001</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>JADI-A</td>
<td>Significant correlation p&lt;0.01</td>
</tr>
<tr>
<td>Ravelli et al[29]</td>
<td>96</td>
<td>min. 60</td>
<td>CR wrist changes at: baseline in 1st year in 1st 5 years</td>
<td>No. of joints with LOM</td>
<td>Baseline: low r=0.16 1st year: low r=0.35 1st 5 years: moderate r=0.59</td>
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<tr>
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<td></td>
<td>1st year: moderate r=0.53 1st 5 years: moderate r=0.60</td>
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<td></td>
<td>Steinbocker functional class 1st year: moderate r=0.48 1st 5 years: moderate r=0.55</td>
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<tr>
<td></td>
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<td></td>
<td>CR progression at 5 years Baseline: low r=0.38 1st year: moderate r=0.61 1st 5 years: high r=0.89</td>
</tr>
<tr>
<td>Pederzoli et al[30]</td>
<td>130</td>
<td>min. 60</td>
<td>CR wrist a SH score &gt; 1</td>
<td>CR progression at 5 years</td>
<td>Significant predictor OR 8.2</td>
</tr>
<tr>
<td>Magni-Manzoni et al[28]</td>
<td>94</td>
<td>54</td>
<td>Baseline Poznanski score</td>
<td>Yearly CR progression</td>
<td>Baseline Poznanski score r=0.88 p=0.47</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CR wrist progression in 1st year</td>
<td>Final Poznanski score</td>
<td>OR 14.32, p&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CHAQ</td>
<td>r=0.58, p&lt;0.0001</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>r=0.59, p&lt;0.0001</td>
</tr>
<tr>
<td>Bertamino et al[23]</td>
<td>148</td>
<td>max. 132</td>
<td>CR hip progression in 1st year</td>
<td>CHAQ</td>
<td>r=0.24, p=0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SJC</td>
<td>r=0.03, p=0.86</td>
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<td></td>
<td>TJC</td>
<td>r=0.06, p=0.65</td>
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<td></td>
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<td></td>
<td>No. of joints with LOM</td>
<td>r=0.46, p=0.0005</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Steinbocker functional class</td>
<td>r=0.50, p=0.005</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>JADI-A</td>
<td>r=0.45, p=0.01</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Physician disability score</td>
<td>r=0.40, p=0.05</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Parent disability score</td>
<td>r=0.53, p=0.007</td>
</tr>
<tr>
<td>Oen et al[21]</td>
<td>136</td>
<td>min. 60</td>
<td>Early (&lt;2 years) erosions/JSN</td>
<td>CHAQ</td>
<td>No correlation</td>
</tr>
<tr>
<td>Selvaag et al[22]</td>
<td>197</td>
<td>36</td>
<td>Baseline swelling/osteopenia</td>
<td>CR erosive progression</td>
<td>OR 7.95, p&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td>Less patients with CR progression had CHAQ of 0, p=0.045</td>
</tr>
</tbody>
</table>

Continued
<table>
<thead>
<tr>
<th>Reference</th>
<th>No. of subjects</th>
<th>Duration of follow-up (months)</th>
<th>Radiological or clinical assessment</th>
<th>Outcome assessed</th>
<th>Correlation</th>
</tr>
</thead>
</table>
| Ringold et al     | 104            | 29.9                           | Early (<6 months) erosions/JSN vs normal | Time with active disease CRM | More time with active disease p<0.001  Less chance of CRM, RR=0.34, p<0.001  
|                   |                |                                | RF +ve vs −ve                      |                  | More time with active disease p=0.07                                       |
| Oen et al         | 88             | Early (<2 years) Late (1–20.8 years) | Late vs early JSN Joint pain | CHAQ            | Significant correlation Explains 17.7% of variation in CHAQ Explains 32.4% of variation in CHAQ p=0.07 |
| Habib et al       | 68             | –                              | ACPA                               | CR erosions      | Significant correlation p=0.004                                              |
| Arvidsson et al   | 103            | 324                            | Baseline/early TMJ involvement     | Micrognathia     | 66.7% patients with micrognathia had baseline TMJ involvement; 33.3% had CR TMJ involvement within 2 years |

**Baseline MRI predictive factors**

<table>
<thead>
<tr>
<th>Reference</th>
<th>No. of subjects</th>
<th>Duration of follow-up (months)</th>
<th>MRI erosive progression</th>
<th>Correlation</th>
</tr>
</thead>
</table>
| Malattia et al    | 58             | 12                             | Baseline wrist synovial volume | Correlation r=0.42  p<0.02  
|                   |                |                                | Baseline CRP           |              |
| Gardner-Medwin et al | 10            | 12                             | Baseline synovial hypertrophy in a clinically normal joint Disease extension from monoarthritis | 100% patients developed clinical arthritis in other joints |

ACPA, anticyclic citrullinated peptide antibody; aSH, adapted Sharp van der Heijde score; CHAQ-DI, Childhood Health Assessment Questionnaire disability index; CR, conventional radiography; CRM, clinical remission on medication; CRP, C reactive protein; JADI-A, Juvenile Arthritis Damage Index for articular damage; JSN, joint space narrowing; LOM, limitation of movement; RF, rheumatoid factor; +ve, positive; −ve, negative; RR, relative risk; SJC, swollen joint count; TJC, tender joint count; TMJ, temporomandibular joint.
on CR were 7.5 times more likely to have MRI synovitis (OR 7.55, 95% CI 1.66 to 34.4, p=0.009). 43

Responsiveness of imaging to change in inflammation
US and MRI have been shown to have good responsiveness to change in inflammation, as measured by standardised response means (SRM, ≥0.20 small change, ≥0.50 moderate, ≥0.80 good). The mean (range) SRM for MRI wrist synovitis was good at 1.27 (0.51 to 1.69) and demonstrated ability to discriminate between different levels of clinical responder categories, whereas the SRM for MRI wrist bone marrow oedema was small at 0.22. 19 32 44 45 Similar levels of SRM have been described for MRI knee synovial hypertrophy (0.68–0.70) and bone marrow oedema (0.15). 45 46 A comparison of MRI wrist synovitis score with US showed higher MRI responsiveness (1.61) when compared with US grey-scale (0.87) and US power Doppler (0.71). 47

Which joints to assess
Studies describing the frequency of US joint inflammation in JIA have shown changes to be most common in the knee (∼30%) and wrist (∼20%), then ankle, proximal interphalangeal joint and metatarsophalangeal joint (∼10%) each. 48 49 US power Doppler activity was most common in the wrist (∼35%). 48 49 One study examined the frequency of US peripheral synovitis and found changes more commonly in the metatarsophalangeal joint (61.9%) than in the metacarpophalangeal joint (39%), with the first metatarsophalangeal and second metatarsophalangeal joint most frequently affected (20% and 13%, respectively). 50

Monitoring damage
PTC 7: The periodic evaluation of joint damage should be considered. The imaging modality used may be joint dependent.

As for PTC 6, this section will consider the comparison of the ability of imaging to detect damage, responsiveness of imaging to change in damage, and which joints should be assessed. Data comparing imaging with clinical examination in detecting joint damage and comparing CR with MRI and US in detecting damage is discussed in part in PTC 3.

Comparison of the ability of imaging to detect damage
El-Miedany et al 44 examined the role of MRI, US and CR in the detection of knee JSN and described a 3.14-fold detection rate of MRI compared with US, 4.40-fold for MRI compared with CR and 1.4-fold for US compared with CR. The addition of contrast to MRI enhanced the appreciation of depth of cartilage involvement by 1.42-fold. Data describing the detection of wrist erosive changes have shown a detection rate for MRI compared with US of 1.92-fold, MRI compared with CR of 1.36-fold and US compared with CR of 1.0-fold. 17 19 40

In terms of detecting damage of the TMJ, Muller et al 25 showed that MRI condylar damage was detected in 25% of their cohort, whereas US detected only 17% (1.47-fold). Weiss et al 21 also described a poor correlation between these modalities, with only 50% agreement (detection rate 2.44-fold).

Responsiveness of imaging to change in damage
Several studies examined the responsiveness of imaging to detect change in damage at the wrist, particularly with CR and MRI. The rate of change in CR score (Larsen, Sharp, Poznanski) appears to be greatest in the 1st year, which is mainly due to progression in JSN. 28 51 This seems to slow after the 1st year, whereas the rate of erosive change is steady from baseline to year 3; the rate of progression overall slows after 3rd third year. In general, the rate of JSN exceeds that of erosions and total score. 29 When compared with CR, Malattia et al 44 described the relative efficacy of MRI compared with CR erosion score to be <1 at year 1; that is, MRI was less responsive than CR in detecting erosive progression; the fact that cartilage assessment was not included in the MRI scoring systems might explain this result. A study of TMJ condylar changes showed that MRI identified significantly more changes than CR (p≤0.003), and MRI was superior to CR in following condylar changes over time: MRI condylar changes at baseline were found in 58.6% compared with 80% at year 2; CR condylar changes were stable at baseline and year 2 at 30%. 52

Which joints to assess
Studies describing the distribution of CR changes in ‘early’ (within 2 years of disease onset) and ‘late’ (up to 20.8 years of follow-up) disease have shown JSN to be most common in early disease in the wrist (20%), hips (16%), cervical spine (5%), ankles (4%) and knees (3%) compared with 34%, 25%, 38%, 15% and 6%, respectively in late disease. 13 44 Rostom et al 25 observed CR hip disease to start after 4 years of disease, whereas 80% had developed hip disease at 6 years, and 100% after 14 years. Other studies describing radiological features of JIA found most CR changes in the hands (57%), knees (47%), ankles (27%) and feet (36%), with erosions mainly in hands (18%) and feet (25%). 38 The hands and feet were the area most likely to show CR damage progression at 6 months and 5 years. 37 58

Guided treatment
PTC 8: US can be used for accurate placement of intra-articular injections.

Studies summarising the role of imaging for guiding intra-articular steroid injections are given in online supplementary text S10, along with additional data on the use of imaging to assess and monitor efficacy of steroid injections. All studies used triamcinolone injections; doses and preparations varied according to the age of the patient and the joint being injected. Young et al 40 used US to assess the accuracy of needle placement for steroid injections at various sites (joints and tendon sheaths), and described that US allowed accurate visualisation of the injection point in all 1444 injections. A study by Parra et al 60 used CT to establish if US-guided TMJ injections had been accurately placed; needle placement was shown to be acceptable in 91% (75% required no needle adjustment, 16% required minor adjustment) and unacceptable in 9% where the needle required major readjustment. A study of the efficacy of TMJ injections used MRI to assess needle placement accuracy, according to the location (intra-articular or extra-articular) of the injected material on MRI acquired after injection; MRI confirmed that 65% of injections were accurately placed. 44 A similar study using postinjection MRI of the SIJ described technical success in 100%. 52

Remission
PTC 9: US and MRI can detect inflammation when clinically inactive disease is present; this may have implications for monitoring.

Several studies addressed the discrepancy between clinical remission and inflammation seen on US and MRI; these are summarised in the online supplementary text S11. Evidence of ongoing US synovitis has been described in 56.1–94.1% of patients with clinically inactive joints, and 32% of patients with
inactive disease showed US signs of synovial hypertrophy, effusion and power Doppler activity.\textsuperscript{63–65} In clinical remission, US grey-scale synovitis was seen in up to 84.1% of joints, and power Doppler activity in up to 48.6% of joints, with a non-significant trend to more US inflammation in clinical remission on medication compared with clinical remission off medication.\textsuperscript{39} \textsuperscript{66–71} MRI knee inflammation has been demonstrated in up to 50% of patients in clinical remission and bone marrow oedema in 33.3% patients with clinically inactive joints.\textsuperscript{72–74} Recent pilot studies have demonstrated that patients with subclinical US or MRI inflammation are more likely to develop active disease and disease progression, even within 6 months of follow-up.\textsuperscript{64} \textsuperscript{70} \textsuperscript{74} \textsuperscript{75}

### Research agenda

The group formulated a research agenda based on areas identified with a lack of currently available evidence, shown in box 1.

### DISCUSSION

These EULAR-PReS considerations for imaging provide important and novel advice for JIA in clinical practice. There is still significant research needed in this field, in particular consensus on understanding normative data to allow the interpretation of imaging abnormalities, agreement on appropriate MRI protocols and definitions of bone marrow oedema, synovitis and erosions, and suitability of the imaging modalities for detecting changes at specific joints. Our data is limited by the lack of specific information for each JIA disease subtype; this is reflected in the research agenda.

There are significant conceptual differences between imaging in adult and paediatric conditions, and consideration must be given to the appropriateness and feasibility of different imaging modalities which differs with age and developmental stage, as well as to economic issues such as the cost-effectiveness of the intervention. Repeated unnecessary exposure to radiation from imaging should also be considered. We appreciate that access to individual imaging modalities may be insufficient to allow full implementation of these PTC; however most of the points include the use of US which is generally readily available. An economic evaluation was not included in the process as the primary aim was to discuss the clinical implications of imaging; overall the cost of implementing the PTC should be low.

After dissemination of the PTC by means of publication and presentation at European meetings, we would propose to perform a survey of awareness and their use, for example:

- Are you have access to musculoskeletal US and MRI routinely?
- Are you aware of and implementing the EULAR-PReS JIA imaging PTC?
- Have the PTC changed your clinical practice?

The task force agreed that it was not appropriate to create audit or implementation tools as the strength of data was only sufficient to develop PTC rather than recommendations. In summary, we have developed nine PTC on the role of imaging in various clinical aspects in JIA. We would recommend that a similar rigorous process is followed to reassess the available data after an interval of 5 years.

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### Contributors

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