The value of MRI for detecting subclinical joint inflammation in clinically suspect arthralgia

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REVIEW

The value of MRI for detecting subclinical joint inflammation in clinically suspect arthralgia

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ABSTRACT

In the last decade, much research has focused on the development of rheumatoid arthritis (RA) and the symptomatic phase preceding the onset of clinical arthritis. Observational studies on imaging have revealed that subclinical joint inflammation in patients with arthralgia at risk for RA precedes and predicts the onset of clinically apparent arthritis. Moreover, the results of two placebo-controlled randomised proof-of-concept trials in patients with arthralgia and MRI-detected subclinical inflammation studies will soon be available. The initial results are encouraging and suggest a beneficial effect of DMARD treatment on subclinical inflammation. Since this may increase the necessity to detect subclinical joint inflammation in persons with arthralgia that are at risk for RA, we will here review what has been learnt about subclinical inflammation in at-risk individuals by means of imaging. We will focus on MRI as this method has the best sensitivity and reproducibility. We evaluate the prognostic value of MRI-detected subclinical inflammation and assess the lessons learnt from MRIs about the tissues that are inflamed early on and are associated with the clinical phenotype in arthralgia at risk for RA, for example, subclinical tenosynovitis underlying pain and impaired hand function. Finally, because long scan times and the need for intravenous-contrast agent contribute to high costs and limited feasibility of current MRI protocols, we discuss progress that is being made in the field of MRI and that can result in a future-proof way of imaging that is useful for assessment of joint inflammation on a large scale, also in a society with social distancing due to COVID-19 restrictions.

KEY MESSAGES

⇒ Imaging studies in arthralgia at risk for rheumatoid arthritis (RA) have furthered our understanding of the processes underlying key symptoms and signs.
⇒ Combination of imaging features provide high negative predictive values or high positive predictive values for RA development in subgroups of patients with clinically suspect arthralgia.
⇒ High costs, invasiveness and low accessibility hamper widespread use of MRI to detect subclinical inflammation in daily outpatient clinical practice.
⇒ Promising future developments on short MRI sequences, without contrast agent, short acquisition times and automated scoring using artificial intelligence could make implementation of MRI feasible and cost-effective.

INTRODUCTION

In the last decade, much research has been focused on the development of rheumatoid arthritis (RA), with the underlying premise that a better understanding of the processes involved in the development of RA may ultimately provide clues to address these processes and hinder disease development. The development of RA consists of an asymptomatic phase in which autoimmunity develops, which is followed by a symptomatic phase with symptoms. The pattern of symptoms that is considered characteristic for imminent RA (eg, pain, morning stiffness, functional limitations) while clinical arthritis is yet absent has been called clinically suspect arthralgia (CSA). This is also described by an EULAR definition of CSA.[1] In other settings the symptoms are less defined and the combination of arthralgia and the presence of anticyclic citrullinated peptide antibodies (ACPAs) is a slightly different population that is at risk for progression to RA.[2 3] Only part of patients with CSA or ACPA-positive arthralgia indeed develop RA. This suggests that other biomarkers are required on top of this. Observational studies have revealed that imaging detected subclinical joint inflammation is one of the most potent predictors. Interestingly however, still only ~50% of patients with arthralgia, ACPA and subclinical synovitis develop RA. This suggests that disease chronicity has not yet developed at this symptomatic at-risk stage and that this stage may be a time period where permanent disease modification can still take place. Several proof-of-concept trials in arthralgia are ongoing.[4] Initial results of two

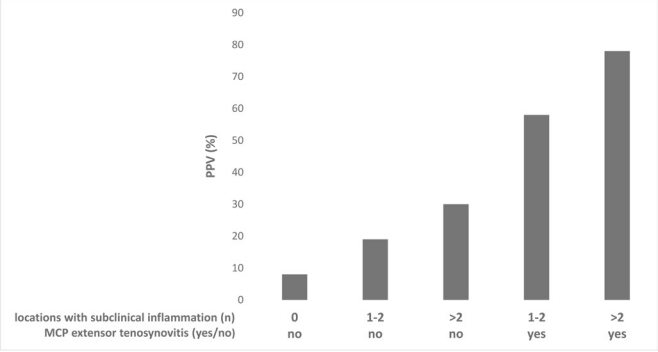

Figure 1 Positive predictive values for RA development in 2 years depending on different MRI features (adapted from Matthijssen *et al* (2019))[19]. Legend: 5 categories: 1: no locations with subclinical inflammation, no MCP extensor tenosynovitis, 2: 1–2 locations with subclinical inflammation, no MCP extensor tenosynovitis, 3: 3 or more locations with subclinical inflammation, no MCP extensor tenosynovitis, 4: 1–2 locations with subclinical inflammation and MCP extensor tenosynovitis, 5: 3 or more locations and MCP extensor tenosynovitis. RA, rheumatoid arthritis; MCP, metacarpophalangeal.

placebo-controlled randomised proof-of-concept trials in patients with arthralgia and MRI-detected subclinical inflammation studies are encouraging.[5 6] Although the full results are not yet published, a beneficial effect of Disease Modifying AntiRheumatic Drugs (DMARD) treatment on subclinical inflammation was suggested. As this further demonstrates the relevance of detecting subclinical joint inflammation in persons with arthralgia that are at risk for RA, in this narrative review we will evaluate what has been learnt using imaging about subclinical inflammation in individuals at risk for RA. We will mainly focus on MRI because of the high sensitivity and reproducibility of this modality, and include only studies with a field strength of >1.0 Tesla.

ACCURACY OF MRI FOR DETECTING SUBCLINICAL JOINT INFLAMMATION AND EROSIONS

Scoring methodology

Several studies have shown that subclinical joint inflammation precedes the occurrence of clinical arthritis and RA.[2 3 7–12] MRI has shown to be sensitive and predictive for RA development compared with other imaging modalities.[8 13] Most studies scanned unilateral wrist and metacarpophalangeal (MCP) joints, some studies evaluated Metatarsophalangeal (MTP) or Proximal Interphalangeal (PIP) joints as well.[7 14] No imaging studies in CSA scanned hands or feet at both sides. Subclinical inflammation and erosions are generally evaluated with the OMERACT (Outcome Measures in Rheumatology) rheumatoid arthritis magnetic resonance image scoring system (RAMRIS). Although this method was primarily developed for use in clinical trials, it is commonly used in observational longitudinal studies as well, as it is the only validated scoring method. In this scoring system bones, joints and tenosynovial sheaths are evaluated semiquantitively (mostly range 0–3) on bone marrow oedema (osteitis), synovitis, tenosynovitis and erosions.[15–17] It was developed for use in patients with classified RA. Since subclinical inflammation in at-risk stages is subtle, lesions with higher grades of scores are very rare and it can be questioned whether the RAMRIS is optimally sensitive to measure subtle lesions or to detect changes over time in the phase of arthralgia. For example, osteitis covering 15% or 30% of the bone will both be scored with one point, while the area has doubled. Although the RAMRIS method was not designed for observational studies in populations at risk to develop RA, this method was key to determine the predictive accuracy of MRI-detected inflammation and erosions.

Accuracy of subclinical joint inflammation

The presence of subclinical inflammation in patients with CSA has been associated with a risk of developing RA in the next year of up to 31%.[8] Evaluation of the individual inflamed tissues (synovitis, tenosynovitis, osteitis) revealed that, of these three features, tenosynovitis was the only independent predictor for progression to clinical arthritis.[8 18] Since MRI scans portray more information than only the presence versus absence of subclinical inflammation, Matthijssen *et al* studied whether information on the location and severity of subclinical inflammation, the number of inflamed joints/bones/tendon sheaths, and combinations of inflammatory features is valuable in differentiating patients with CSA that will and will not develop RA. This study showed that the number of locations with inflammation as well as the presence of tenosynovitis/peritenditinis at the extensor sides of MCP joints were independent predictors.[19 20] Interestingly, although tenosynovitis at the extensor side of MCP joints was infrequent, its occurrence had a high positive predictive value (PPV) for RA development. The presence of this feature conferred a risk of ~65% for RA, both in derivation and validation data sets. Including all information mentioned on inflammation as depicted by MRI resulted in subgroups of patients with CSA with a very low risk for RA (eg, <10%) and also groups of patients with high risks. Figure 1 presents PPVs for RA development in 2 years' time, based on this study.[19] Next steps are to incorporate subclinical joint inflammation in predictive models that also include other factors (eg, clinical characteristics, serology), such as done recently for MRI or ultrasound detected subclinical inflammation, and to generate a stratification method that is internationally validated.[21 22] This last step has not yet been implemented but is currently being examined by an EULAR task force.[23]

MRI versus musculoskeletal ultrasound

Although this review focuses on MRI, ultrasound has some advantages that explain why musculoskeletal ultrasound (MSUS) is more commonly used in clinical practice. MSUS is more accessible, has lower cost, is easy to implement during consultation and is well tolerated (eg,

claustrophobia is not an issue). Disadvantages of MSUS are a higher machine and operator dependency, resulting in a lower reproducibility of MSUS.[24] Studies comparing MRI and MSUS in sensitivity of detecting inflammation in small joints showed that MSUS, compared with MRI, missed up to 50% of synovitis lesions and up to 80% of tenosynovitis lesions.[13 25] Intrinsic to the technical differences, osteitis cannot be detected by MSUS. Longitudinal studies in CSA comparing MSUS and MRI have not been performed. A recent systematic review on studies using MSUS in various arthralgia populations reported that the presence of MSUS detected subclinical inflammation (reflected by the presence of power Doppler) increased the prior risk of RA by on average 10%–15%.[26] Another recent study including MSUS and MRI, though applied in different ACPA-positive arthralgia populations, suggested somewhat lower PPVs for the presence of subclinical synovitis as assessed by MSUS.[27] However, to make this comparison fair, comparative studies are needed with both modalities in the same at-risk patients. This is a topic for future studies.

While most studies evaluated small joints, the difference in sensitivity between MSUS and MRI may be different when evaluating large joints. Interestingly, Abdelzaher *et al* demonstrated that ultrasound of the shoulder in RA is highly specific and sensitive with an excellent agreement with MRI.[28] A US study on shoulder involvement in CSA revealed no increased prevalence of subclinical inflammation in the shoulder.[29] This may fit with the notion that small joints are initially affected by inflammation in the trajectory of RA development and that large joints follow at a later stage.

Are all signs of inflammation on MRI abnormal?

Whereas a sensitive evaluation of inflammation in the earliest phases of RA development is key, the specificity is equally important. Especially when a test with a low specificity is applied at a large scale, this will result in false-positive test results. For the field of 'RA risk' it would result in persons who will not develop RA having a positive test. A review of studies in healthy people indicated that symptom-free persons can show areas of high intensity on MRI, which at first glance are indistinguishable from true subclinical joint inflammation.[30] A subsequent large MRI study among symptom-free persons without a rheumatological disorder showed the presence of subclinical inflammation, especially at higher age and at certain joint locations. Part of these findings may be degenerative in nature (eg, Carpometacarpal (CMC)-1 and Scaphotrapeziotrapezoid (STT) joints with grade 1 synovitis in persons aged >60 years) or related to mechanical forces (eg, bone marrow oedema in the lunate). Since these increased signal intensities occur in the general population without causing symptoms, these imaging findings are most likely unrelated to RA-related subclinical inflammation. From all features, tenosynovitis was the least present in persons from the general population, a finding that was also recently observed in an MSUS study among healthy persons.[31] In conclusion, especially when MRI results on subclinical inflammation would be incorporated in decision making in patients with arthralgia in clinical practice, a reference of normality should be considered to prevent false-positive findings. A recent study used a cut-off of a prevalence of <5% in age, MRI feature and location matched reference population, to define a positive MRI result and showed that this raised the specificity of MRI without lowering the sensitivity.[32]

Juxta-articular inflammation visualised by MRI in arthralgia

Tenosynovitis, inflammation of tendon sheaths that surround the tendons of wrist, MCP, PIP or MTP joints, has been mentioned above as an early and specific feature for imminent RA. Detailed MRI studies in early RA, palindromic rheumatism and CSA have revealed that there are also other features of extracapsular juxta-articular synovial inflammation.[33–35]

The intermetatarsal bursae in the forefeet have a synovial lining as well, and inflammation, resulting in intermetatarsal bursitis, occurs not only in patients with RA but also in CSA.[34 35] This feature often occurs together with synovitis and tenosynovitis. Moreover, interosseous tendinitis in the hands has also been described in RA and ACPA-positive arthralgia.[36] Although RA is traditionally considered as a disease of intra-articular synovitis, the results of these MRI studies in the last decade have revealed that juxta-articular synovium is present in hands and feet, is inflamed in RA, and can precede the occurrence of clinical arthritis.

MRI-detected erosions

In clinical practice, the presence of erosions is generally investigated with radiographs. However, when MRI is being done to identify inflammation, erosions can also be detected. Matteo *et al* demonstrated that radiographic erosions are rare in ACPA +arthralgia and not associated with the development of inflammatory arthritis.[12] MRI studies in the general population found MRI erosions. These erosions occurred more often at increasing age. RA-specific erosions on MRI defined by Boeters *et al* are grade ≥2 erosions, MTP5 erosions and MTP1 erosions if aged <40 years.[37] A study on the value of MRI erosions in CSA observed that MRI-detected erosions were not predictive for RA development, neither when any MRI-detected erosion nor when the mentioned RA-specific erosions were assessed.[38] Although more studies may be needed for validation of these findings, this would indicate that MRIs in patients with arthralgia do not need to be evaluated for erosions when used for risk stratification. Similarly, if MRI findings were to be used in clinical practice, we should be careful not to overinterpret the value of MRI-detected erosions, as the prognostic accuracy of MRI-detected erosion in CSA presumably differs from that of radiographic erosions in RA. The higher sensitivity of MRI for identifying erosions and the fact that radiographic erosions are mostly absent in CSA may be basic to this difference.

Also ultrasound and CT are used to evaluate erosions in at-risk populations. In ACPA-positive arthralgia the presence of ultrasound-detected erosions associated with the risk of the development of clinical arthritis.[11 39] CT is also very sensitive in detecting erosions in arthralgia.[10] A study comparing CT-detected erosions with MRI-detected erosions revealed that CT-detected erosions were more specific.[40] More research in different validation cohorts and with different imaging modalities is needed to define which imaging detected erosions in CSA or ACPA-positive arthralgia are clinically relevant.

THE USE OF MRI TO UNDERSTAND SYMPTOMS AND SIGNS IN THE PHASE OF CSA

The presence of CSA is assessed by clinical expertise in daily practice and the accuracy of the clinical expertise has been described (OR of 55, differentiating CSA from unexplained arthralgia).[41] To ensure homogeneity in the clinical characterisation of CSA, EULAR recently developed a definition of arthralgia suspicious for progression to RA.[1] This definition was validated in the outpatients clinics of the experts included in the taskforce and subsequently also in independent validation studies.[1 42] The following symptoms and signs were identified by the taskforce as independently relevant clinical components of CSA: symptoms of recent onset, symptoms located in MCP joints, duration of morning stiffness ≥60 min, most severe symptoms present in the early morning, positive family relative, difficulty making a fist and a positive squeeze test of MCP joints. After this development, MRI studies that compared imaging and clinical finding shed light on the inflammatory structures that are basic to the clinical components of the EULAR definition (summarised in table 1).

Table 1 Involved inflamed tissues in symptom explanation in CSA

EULAR-defined characteristics describing arthralgia suspicious for progression to RA	Inflamed joint tissue related to symptom/sign
History taking	
► Joint symptoms of recent onset (duration <1 year)	NA
► Symptoms located in MCP joints	► Tenosynovitis ► Synovitis
► Morning stiffness ≥60 min	► Tenosynovitis ► Synovitis
► Most severe symptoms present in the early morning	NA
► Presence of a first-degree relative with RA	NA
Physical examination	
► Difficulty making a fist	► Tenosynovitis
► Positive squeeze test of MCP joints	► Synovitis

CSA, clinically suspect arthralgia; MCP, metacarpophalangeal joint ; NA, not applicable; RA, rheumatoid arthritis.

Symptoms in MCP joints

Joint pain or tenderness in CSA is associated with the presence of subclinical inflammation. Both synovitis and tenosynovitis underline this symptom. Osteitis, in contrast, was not related to joint tenderness or pain.[43]

Morning stiffness

Morning stiffness is often defined by its presence of more than 60 min. Patients with morning stiffness more often have MRI-detected tenosynovitis and synovitis, but not osteitis. A dose-response relationship was also found; the longer the stiffness lasted, the more frequently subclinical inflammation occurred.[44] Although within clinical arthritis, and not CSA, similar findings were observed in a study that demonstrated morning stiffness was associated with synovitis and tenosynovitis and especially with the combined presence of these inflamed tissues.[45 46]

Difficulty making a fist

Although clinical arthritis is absent, patients with CSA can have difficulties with making a fist. Either fist closure is incomplete, meaning the top of the fingers do not touch the palm of the hand, or fist closure is complete but the strength reduced. Multivariate analyses, including the different inflamed tissues, revealed that tenosynovitis had the strongest relation with this clinical sign. Incomplete fist closure was mostly related with flexor tenosynovitis at the level of MCP joints and decreased fist strength with flexor tenosynovitis at the wrist level.[47]

Positive squeeze test of MCP joints

Studies in early arthritis had revealed that a positive squeeze test is associated with both swollen joints and MRI-detected joint inflammation.[48] Likewise, in CSA the presence of a positive squeeze test is associated with the presence of subclinical synovitis and tenosynovitis. Multivariable analyses revealed that only synovitis associated independently with a positive squeeze test. Hence a positive squeeze test at the level in MCP in patients with arthralgia might be a sign of synovitis. A positive squeeze test at the level of MTP is also a sign of subclinically present synovitis.[49] In addition, the presence of intermetatarsal bursitis was associated with a positive squeeze test in the forefeet.[50]

Other symptoms

Patients with CSA often report to have fatigue. This symptom was not included in the EULAR definition because it did not sufficiently distinguish arthralgia as a sign of impending RA from pain of different origin. A recent large MRI study performed in patients with RA showed MRI-detected joint inflammation was not helpful in explaining fatigue.[51] Similar comparisons were made in CSA. Although subclinical inflammation contributed more to fatigue in CSA than in the phase of classified RA the related variance was low,

Table 2 Advantages and disadvantages of different imaging modalities used to detect subclinical inflammation in CSA

	Ultrasound	Conventional MRI	Modified dixon MRI
Accuracy			
Sensitivity to detect			
Synovitis	✓	✓	✓
Tenosynovitis	✗✓	✓	✓
Osteitis	✗	✓	✓
Erosions	✓	✓	✓
Reproducibility—machine	✗	✓	✓
Reproducibility—operator	✗	✓	✓
Signal-to-noise ratio	NA	✓	✓
Patient friendliness			
No contrast agent	✓	✗	✓
Short acquisition time	✗ (40 min)	✗ (30–40 min)	✓ (6 min)
Possibility of social distancing	✗	✗	✓

CSA, clinically suspect arthralgia; NA, not applicable.

suggesting that fatigue might be more related to other causes (unpublished data).

Patients with CSA often have functional impairments.[52] These can be related to the symptoms and signs described above. Not surprisingly, also the presence and extent of functional limitations in CSA, measured with the Health Assessment Questionnaire, are associated with subclinical joint inflammation.

In conclusion, MRI studies have taught us that several key symptoms and signs in the stage of CSA can possibly be explained by subclinical tenosynovitis and/or synovitis. These associations are 'incomplete', meaning that the presence of these symptoms cannot replace an MRI for prognostic purposes while maintaining a similar accuracy. Nonetheless, better understanding of the processes related to the complaints of people with CSA is an important contribution of MRI research to the field.

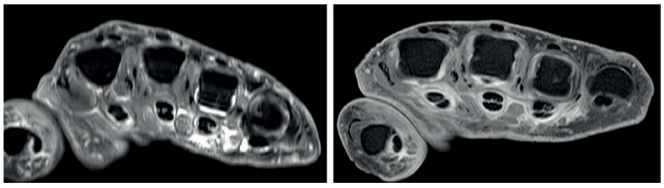

Figure 2 Example of synovitis and tenosynovitis in the MCP joints and flexor tendons depicted with a modified Dixon sequence and conventional sequence on a 1.5 T extremity MRI scanner of one patient. Legend: left; water-only axial reconstruction of a modified Dixon sequence. Right; axial T2 weighted image of a 1.5 T extremity MRI scanner with contrast agent. Images are made in the same patient. MCP 3 and 4 are scored for synovitis. Tenosynovitis is scored in the flexor tendons of fingers 2, 3 and 4. MCP, metacarpophalangeal.

ARTHRALGIA VERSUS PALINDROMIC RHEUMATISM

So far results from studies performed in patients with CSA and ACPA-positive arthralgia (but without clinical arthritis) have been discussed. Palindromic rheumatism is another RA-related entity. The definition of this entity may vary, while some consider clinical arthritis identified at joint examination (that remits spontaneously) characteristic, others feel that self-reported joint swelling is sufficient to diagnose palindromic arthritis. In the latter setting palindromic rheumatism may be a prearthritis phase as well. An interesting and large MRI study in palindromic rheumatism recently revealed the importance of extracapsular inflammation in these patients.[33] Subsequent imaging studies are required for validation and to learn the course of this extracapsular inflammation during progression to RA.

HOW TO IMPLEMENT MRI FOR PATIENTS WITH ARTHRALGIA IN DAILY PRACTICE

Current challenges for implementation

Although MRI has been shown valuable for risk stratification in CSA, several characteristics hamper its widespread use in daily practice. First, the tolerability of MRI is difficult in some persons (eg, with claustrophobia). Whether or not the head is in or nearly outside the scanner while scanning the hands may depend on the body length. Second, the recommended MRI protocol

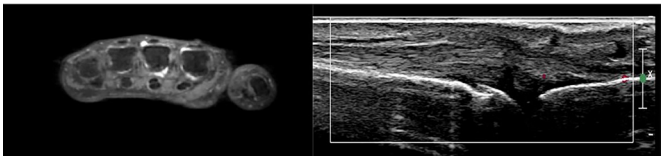

Figure 3 Example of synovitis in the metacarpophalangeal joint in a modified Dixon MRI sequence and ultrasound image of one patient on the same day. Legend: Left; water-only axial reconstruction of a modified Dixon sequence. Synovitis is depicted in MCP 2 and 3. Right; ultrasound image of the right MCP3, scored for grayscale and PD. MCP, metacarpophalangeal; PD, power Doppler.

(which is actually designed for scientific studies and not for diagnostic purposes in clinical practice) consists of T1-weighted precontrast and postcontrast and T2-weighted fat suppressed sequences.[53] Drawbacks of this protocol are long acquisition times and the need for contrast agent administration. Both have important restrictions for accessibility. In addition, as the costs for MRI are directly related to the long scan times and the contrast agent (~€100 per dose of gadolinium chelate), these characteristics also create high costs, that further hamper the feasibility of MRI.[54 55] The ideal imaging modality is affordable, patient-friendly and feasible. Ultrasound has these advantages, but as described above, this comes at the cost of a lower sensitivity and reproducibility. Dedicated extremity MRI scanners have also been used for this purpose; these have the disadvantage of a small field of view. Consequently wrist and MCP joints cannot be scanned in one acquisition but only successively, which prolongs acquisition times.[56 57] Table 2 summarises advantages and disadvantages of MRI and shows that the optimal imaging modality to screen for

Research Agenda
Accuracy of MRI in secondary care
• Comparison of ultrasound and MRI in the same at-risk arthralgia population • Difference in prognostic accuracy of radiographic and MRI detected erosions • Integration of MRI detected subclinical inflammation with other biomarkers • Validation of risk stratification in independent cohort
Understanding symptoms and signs in the phase of CSA
• Prevalence of symmetrical subclinical inflammation in CSA • Time order of subclinical inflammation during progression to clinical arthritis, with respect to MRI features, locations and symmetry
Towards implementation of MRI in daily practice

• Quick and sensitive MRI sequence, mDixon
  ○ Determination of accuracy in CSA
  ○ Validation in CSA and early arthritis
  ○ Reference of normality in healthy controls
  ○ Cost-effectiveness
• Time-effective reading of MRI
  ○ Simple visual scoring/staging method
  ○ Development of automated scoring method using AI
  ○ Validation of simple visual and automated scoring methodology

Figure 4 Research agenda for the implementation of MRI in patients with CSA. CSA, clinically suspect arthralgia; mDixon, modified Dixon; AI, artificial intelligence.

subclinical joint inflammation in CSA is not yet widely available.

Methods to arrive at an affordable, quick and patient-friendly MRI protocol

Although many studies imaged hand and foot joints, the question is whether imaging both extremities is needed. Scanning only one of these may substantially diminish scan times. Studies have revealed that the feet can be omitted from the scan protocol without reducing the accuracy. This has not only been shown in CSA but also in UA and is caused by the finding that subclinical inflammation in the forefeet without concomitant inflammation in the hands almost did not occur. Thus, also when patients have symptomology of the forefeet, scanning the hands only was sufficient.[58 59] These findings still require validation in other at-risk cohorts; the implication could be time sparing.

Second, there are technical advances that may allow to arrive at a short (and therefore cheaper) MRI protocol. Different techniques are used to generate homogeneous fat suppression to improve visibility of osteitis, optimise signal-to-noise ratio and better define lesions after contrast agent administration. Dixon technique uses differences in resonance in water and hydrogen protons to generate fat suppression. This technique has other advantages such as the possibilities to reconstruct images with variable fat and water weighting, and independency to field strength.[60–65] A study that compared different fat-suppression techniques in patients with suspected RA concluded that Dixon sequences yielded more effective fat suppression and more reproducible RAMRIS scoring.[63]

Although general 2D and 3D Dixon techniques have long acquisition times, recently a 'modified' or optimised isotropic Dixon technique was developed that had a short scan time. Thanks to the possibility of multiplanar reconstructions, axial reconstructions can be made without the use of an additional sequence.[66] This resulted in a short scan time of 6 min for the entire protocol. This Dixon technique can be applied on generally used 3T scanners. In contrast to conventional MRI, contrast administration is not required to visualise synovitis and tenosynovitis. This short Dixon-based MRI protocol was evaluated with the conventional contrast-enhanced MRI protocol as reference; a high reliability was observed.[67] An example of this modified Dixon MRI in comparison with other imaging modalities are depicted in figures 2 and 3. Further studies on this MRI technique are required. If larger studies show a maintenance of high accuracy, this technique with a scan time of 5–6 min has all the features that are important for a fast and easy MRI protocol that can be widely used. Then this technique combines the advantage of high sensitivity, for example, for osteitis, tenosynovitis (similar to conventional MRI) and the high feasibility and patient friendliness (similar to MSUS).

Another step or possibility to reduce cost and time is the use of artificial intelligence in automatic reading of MRIs.

Performing ultrasound is labour-intensive for rheumatologists (especially when all small hand and foot joints are systemically evaluated); reading MRIs needs to be done by radiologists or rheumatologists and requires time and experience as well. Deep-learning techniques are currently being used to develop automated MRI reading methodology. MRIs of patients can be compared with a digital reference of normality and signs of pathology automatically indicated. This is work in progress and requires time for algorithm training and validation. Deep learning techniques may not only reduce the workload of physicians, but computerised pattern recognition may eventually also be helpful because of a higher precision compared with evaluation by eye. Presumably artificial intelligence will not fully replace the interpretation by physicians but will facilitate their work.[68]

In short, continued efforts could make it possible to create a short MRI scan for patients with CSA with a rapid and automated scoring method that is feasible and affordable for widespread use, and also fits in a society of social distancing due to the COVID-19 pandemic.

CONCLUSION

Upcoming results of intervention studies in patients with arthralgia at risk for RA and subclinical inflammation may increase the growing desire to apply MRI in clinical practice to accurately identify patients at high risk for RA. However, a number of questions still need to be answered, as summarised in the research agenda in figure 4. One of these is the development of an accurate, short and inexpensive MRI protocol with an automated fast result. Although this is not yet possible, efforts are being made to get there and look promising. Ultimately, this could be an ideal way to implement MRI cost-effectively in daily practice for patients with CSA.

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