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# Imaging in peripheral and axial psoriatic arthritis: contributions to diagnosis, follow-up, prognosis and knowledge of pathogenesis

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## ABSTRACT

*Imaging in psoriatic arthritis (PsA) is rapidly evolving, and the use of sensitive modalities both in clinical research and routine care is increasing. This article provides an overview of current knowledge of different imaging methods in PsA, including current and possible future use in diagnosis, prognosis and clinical management, value in understanding pathogenesis, and latest activities to establish responsive imaging outcome measures. Much research remains to be performed concerning imaging in PsA, particularly on its optimal use in routine clinical care, the clinical consequences of imaging-detected subclinical disease, and specific and sensitive PsA imaging outcome measures.*

## Introduction

Psoriatic arthritis (PsA) is an inflammatory joint disease, which is part of the wider entity 'psoriatic disease', a chronic systemic disease involving both skin and joints, as well as related extra-articular manifestations and comorbidities. PsA can manifest itself as peripheral arthritis and/or axial spondyloarthritis (SpA) with or without enthesitis, tenosynovitis and dactylitis. The main differential diagnoses include rheumatoid arthritis (RA), other SpA diseases including ankylosing spondylitis (AS), osteoarthritis (OA), gout and fibromyalgia.

PsA often is a progressive disease, which may cause erosions early in the disease course, and diagnostic delay is associated with poor clinical and structural outcomes (1-5). New effective treatments may halt this progression (6-11) and consequently treatment goals have evolved from simple reduction of pain to achieving full remission or minimal disease activity (12). These advances emphasise a need for early diagnosis and a treat-to-target (T2T) strategy (12); sensitive imaging techniques

may be of value in this process (13, 14). Various imaging methods are used in PsA, with different advantages and limitations. Structural damage is routinely identified using conventional radiography, as in all inflammatory joint diseases, but can be visualised with higher sensitivity and accuracy using computed tomography (CT) and magnetic resonance imaging (MRI). For soft tissue pathologies, ultrasound (US) and MRI are the most sensitive options.

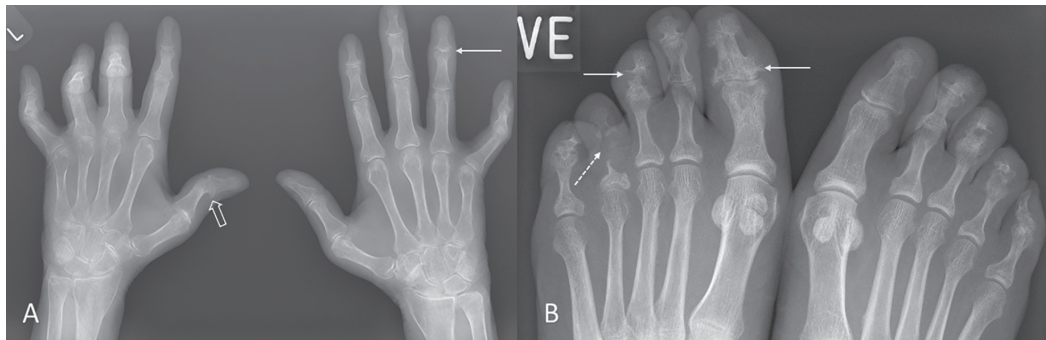
In this review, we describe use of these different imaging modalities in PsA, their value as imaging biomarkers in diagnosis, prognosis and monitoring, and also as outcome measures in clinical research.

## Peripheral PsA

Joint involvement in peripheral PsA is highly variable, and often changes over time (15). It can involve the small joints of hands and feet, as well as larger weight bearing joints. The pattern in the hands can be that of symmetrical (RA-like) polyarthritis, but more frequently asymmetrical poly- or oligoarthritis. The latter may be in a ray-pattern, meaning that all joints in one digit are affected and potentially also the wrist. PsA is unusual for inflammatory arthritis with a predilection for the distal interphalangeal joint, and sparing of the metacarpophalangeal joint. Another frequent joint pattern is that of oligoarthritis affecting mainly large joints. Enthesitis and dactylitis also are commonly seen, and can accompany any of the other manifestations (15).

## Radiography

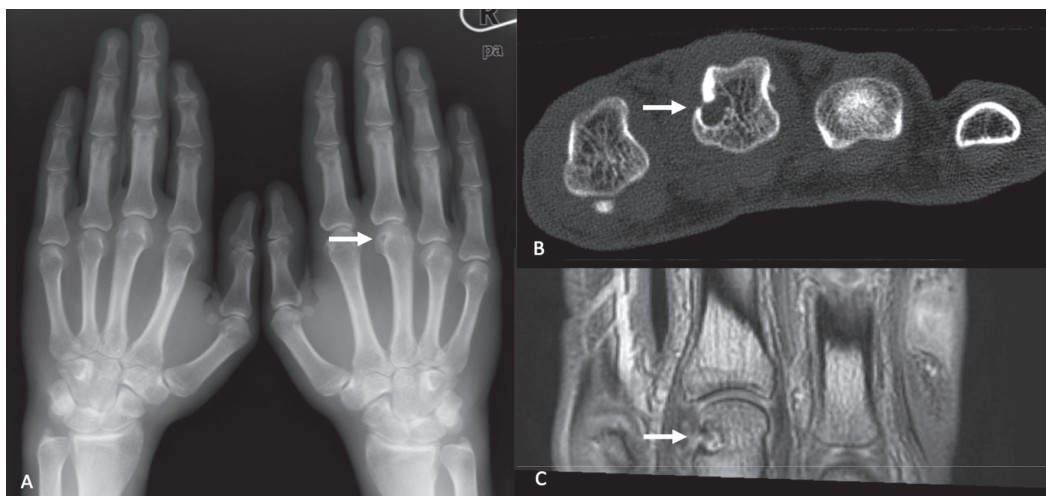
Conventional radiography remains the most common imaging modality in PsA. It visualises skeletal structures with a high resolution and shows cumulative joint damage (16). The advantages of radiography are that it is fast, accessible, relatively inexpensive and



**Fig. 1.** Conventional radiographs of hands (A) and feet (B) in a patient with psoriatic arthritis mutilans.

**A:** Severe changes in several joints, with a combination of destruction and new bone formation (arrows). Ankylosis is seen in the left 1<sup>st</sup> IP-joint (open arrow).

**B:** Total destruction of the head of the left 4<sup>th</sup> intermediate phalanx of the foot (dashed arrow) is also seen.



**Fig. 2.** Bone erosion of the right 3<sup>rd</sup> metacarpal head, shown on

**A.** conventional radiography  
**B.** axial computed tomography (CT) and

**C.** coronal contrast enhanced T1-weighted MRI. Images by courtesy from Dr René Poggenborg.

reliable. It has the limitation of being a 2-dimensional method, which may lead to projectional superimposition when visualising 3-dimensional structures, especially in complex joints. Radiography is of little value in evaluation of soft tissues and cannot detect early/small erosions (17). It also has the disadvantage of ionising radiation, although the dose for peripheral joint examination is small.

Radiographs of hands and feet are routinely used when peripheral PsA is suspected, especially for differential diagnosis and as a baseline for structural damage. The key radiographic feature of PsA is the combination of osteodestructive and osteoproliferative changes (Fig. 1), in contrast to RA, which is primarily a osteodestructive disease (16). The proliferative changes in PsA are seen as ill-defined ossifications around the joint or 'juxta articular new bone formation'. This finding is considered pathognomonic for PsA and is an important part of the Classification criteria for Psoriatic Arthritis (CASPAR-criteria) (18). Other radiographic features include joint space narrowing (as a measure of

cartilage loss) and "pencil-in-cup" deformities, as well as joint subluxations or interphalangeal ankylosis (19).

Radiography has a prognostic value, as joint damage on radiographs is an independent variable in the prognosis of further radiographic progression (10). Although used for long-term monitoring of joint damage, it is less sensitive to detect erosions than CT, MRI and US (17, 20). (Fig. 2)

Despite lack of sensitivity, cumulative joint damage on radiographs is a well-established outcome in clinical trials, which can be evaluated using different scoring methods (19). Most frequently used is the Sharp-van der Heijde modified method for PsA, based on the method developed for RA (21). With this method, bone erosion and joint space narrowing in hands and feet are scored separately, taking gross osteolysis and pencil-in-cup into account. Other methods are the PsA Ratingen score (22), in which joint destruction and bone proliferation are scored separately, and the modified Steinbrocker (23) method which scores erosions, joint space narrowing and lysis and/or ankylosis as one.

#### Computed tomography

CT can visualise calcified tissue with high resolution, and therefore provides an optimal depiction of bone structures, as the standard reference to recognise structural damage in inflammatory arthritides (17, 24). Its use is limited by ionising radiation and poor capacity to detect inflammation, and therefore has no role in routine clinical practice. For research studies, the characteristics of structural damage in peripheral PsA have been investigated using high-resolution CT and micro-CT. Studies comparing micro CT-scans of metacarpophalangeal joint in PsA and RA indicated erosions in PsA patients to be  $\Omega$ -shaped compared to U-shaped in RA patients (25). Micro CT-scans have also identified new bone formation at entheses in patients with psoriasis and patients with PsA, that were not seen in OA patients (26, 27).

One new experimental method involving CT is dual-energy CT iodine mapping (28), which allows for visualisation of inflammation on CT. Another new method is high-resolution Positron Emission Tomography PET/CT imaging, which can provide information

concerning the distribution of inflammation, as well as the extent of the inflammation burden (29). At this time, these techniques are used in rheumatology only for research.

#### *Ultrasonography*

Musculoskeletal US can visualise inflammatory changes in soft tissues such as synovium, tendons and entheses, and structural changes in the bone surface (erosions) with high resolution. No contrast agent is required, and no ionising radiation is involved. Furthermore, ultrasound may be used to guide invasive procedures. Evaluation of several joint areas can be accomplished in one session, limited only by the time needed for the examination.

The major limitation of US is that it cannot penetrate bone. This results in a lower sensitivity for detecting erosions than CT and MRI (30), due to limited access to some joint areas, and lacking capacity to diagnose osteitis. Image acquisition may be operator dependent and some intermachine variability exists, especially for the evaluation of perfusion (31). A European League Against Rheumatism (EULAR) task force has developed standardised procedures for US image acquisition in rheumatology to overcome some operator variability (32).

Examinations are performed using B-mode, which evaluate morphological changes, combined with colour or power Doppler. Doppler is a modality that superimposes colour information on the grey-scale image, derived by the US reflection of moving erythrocytes in the tissue, and gives information on vascularisation (33). The choice of Doppler modality may vary, dependent on the US equipment (31). If the Doppler sensitivity on the machine is poor, an US contrast agent in the form of microbubbles may be used, which amplifies the Doppler signal by enhancing the scattering reflections of the erythrocytes, thereby increasing sensitivity to slow flow (34).

#### • *Diagnosis*

US can detect inflammation both intra-articularly (synovitis, erosions) and extra-articularly (enthesitis, tendinitis, tenosynovitis) in PsA with higher sensi-

tivity than clinical examination (20, 35-39). No reported study has evaluated quantitatively the overall performance of US in addition to clinical findings for the diagnosis of PsA.

The appearance of joint inflammation (synovitis) on US in PsA is nonspecific, so its role in diagnosis is the mere detection of joint involvement. The pattern of involved joints can be useful in differential diagnosis, as previously described. A scoring system for evaluation of the degree of US synovitis in the joint, has been developed by the Outcome Measures in Rheumatology (OMERACT)-US working group (40). Enthesitis is a frequent finding in PsA (Fig. 3). One study comparing US findings in PsA and RA found no difference in synovitis or tenosynovitis, but PsA patients had more extrasynovial inflammation, including enthesitis and soft tissue, compared to RA patients, which may help in differential diagnosis (41). A consensus-based agreement has been reached on the definition of US enthesitis in SpA, to enable greater consistency in clinical studies (42). The elementary lesions included in this definition are thickening of the enthesis, hyperechogenicity/loss of fibrillary structure, erosions, calcifications, enthesophytes and Doppler activity at the enthesis. The OMERACT US working group has developed a consensus-based scoring system for enthesitis (43), which is currently being tested in clinical trials.

Long-term changes of the entheses such as the presence of erosions and enthesophytes are nonspecific and can be seen in weight-bearing entheses due to mechanical stress (39). By contrast, Doppler activity at the cortical bone insertion is specific for SpA (44, 45), and erosions in this area also indicate SpA (46). Dactylitis is a characteristic feature of PsA and US studies have provided insights into which structures are involved. The main finding is tenosynovitis (47, 48), but other abnormalities such as synovitis of the joints, subcutaneous oedema and swelling, as well as enthesitis of the flexor and extensor tendon entheses, may also be seen (47, 49) (Fig. 4). The OMERACT US group is in the process of reaching a consensus on the elementary lesions in dactylitis (50).

#### • *Prognosis*

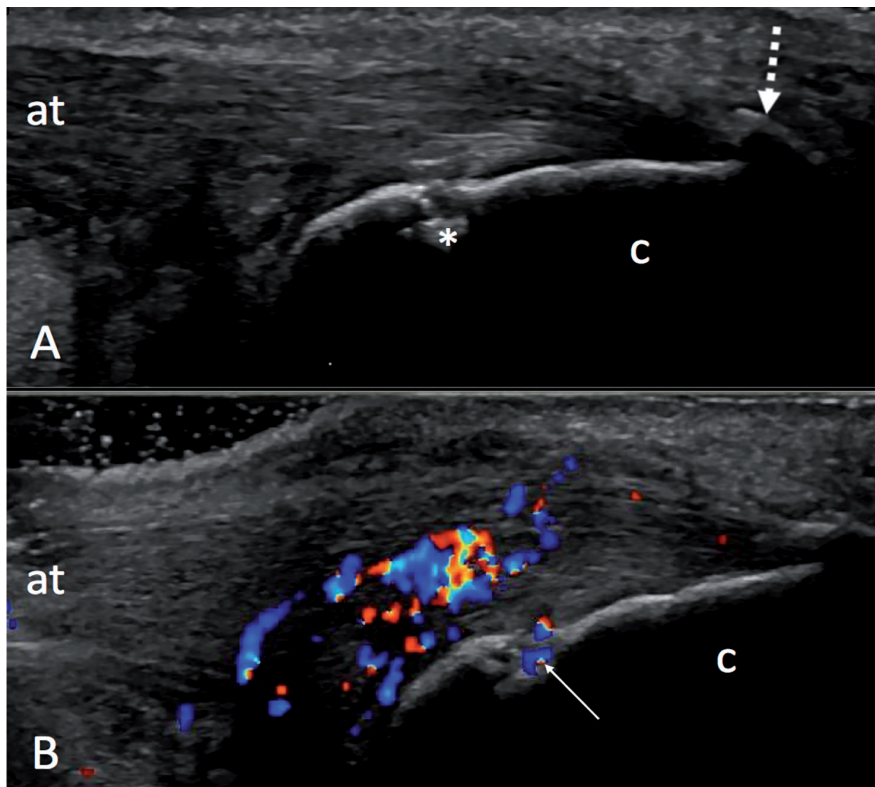
Prediction of development of PsA in patients with psoriasis and the identification of biomarkers for the prognosis of poorer outcome in PsA is of great interest. US-detected subclinical synovitis and enthesitis are frequent in patients with psoriasis (39, 51-55), and it appears that enthesal involvement may be a predictor of PsA (52), but larger studies are needed. In established PsA, high scores for synovitis and active enthesitis on US at baseline, as well as persistent US synovitis and enthesitis at follow-up, may be risk factors for poor prognosis (56).

Clinical psoriatic nail changes such as pitting, onycholysis, subungual hyperkeratosis and discolouration, are much more frequent in PsA patients than in psoriasis patients who do not have arthritis (57-59), and provide an independent predictor of later development of PsA (60). High frequency probes for both GS and Doppler can detect small changes with high resolution and sensitivity, and have been used in investigation of nails and skin in PsA (61, 62). US features of nail changes include loss of definition of the nail plate, hyperechoic spots in the nail plate, thickening of the nail bed, increased Doppler signal in the nail matrix/nail bed (62) and possibly enthesopathy of the extensor enthesis (63). An index for evaluating nail changes has recently been proposed (64). US features of psoriatic plaques include thickening of epidermis and dermis, hypoechoic band in upper dermis, and increased Doppler signal (62).

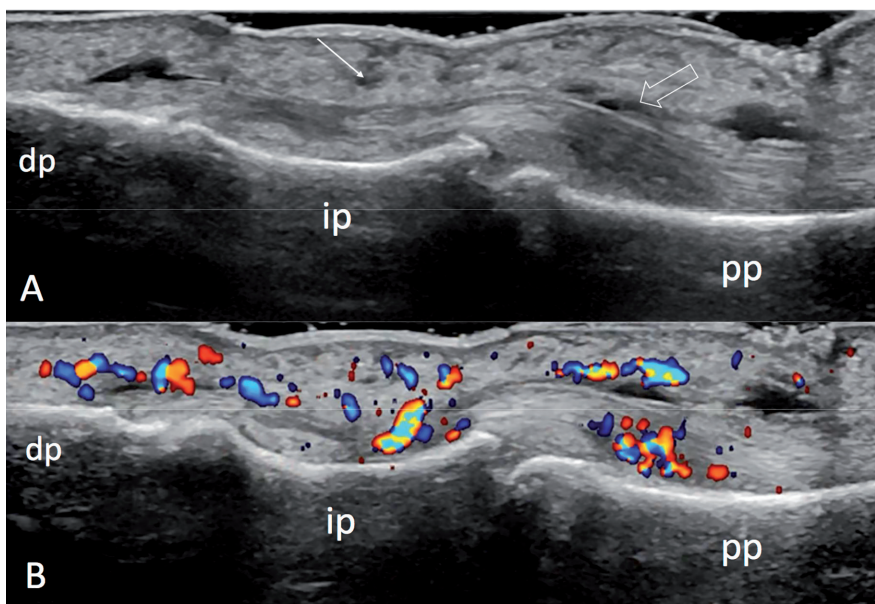
#### • *Monitoring*

US changes such as synovitis, tenosynovitis, erosions and enthesal abnormalities, morphologic as well as Doppler signal, have been shown to be sensitive to change with treatment in PsA (65-67). Several scoring systems have been proposed for monitoring PsA with US (38, 67-69), including different reduced joint sets and combination of structures, one also including skin and nails (69). Although the different systems show good feasibility and sensitivity, there is no consensus on a preferred system (35). Subclinical synovitis is frequent in PsA patients (39) and may lead to structural





**Fig. 3.** US image of enthesitis in the Achilles enthesis. **A:** B-mode. Enthesophyte (dashed arrow), bone erosion (asterix). **B:** Colour Doppler. Doppler activity in the tendon and enthesis (colour dots) and Doppler activity in the erosion (arrow). at: Achilles tendon; c: calcaneus.



**Fig. 4.** US image of finger with dactylitis. **A:** B-mode. Subcutaneous oedema (arrow) and tenosynovitis (open arrow). **B:** Colour Doppler. Doppler activity in the synovial sheath and subcutaneous tissue (colour dots). pp: proximal phalanx; ip: Intermediate phalanx; dp: Distal phalanx.

progression (56), as it has also been shown for RA (70). Criteria for US remission, defined as no Doppler activity, have been proposed (71, 72) and studies report discrepancies between remission on US and clinical- and com-

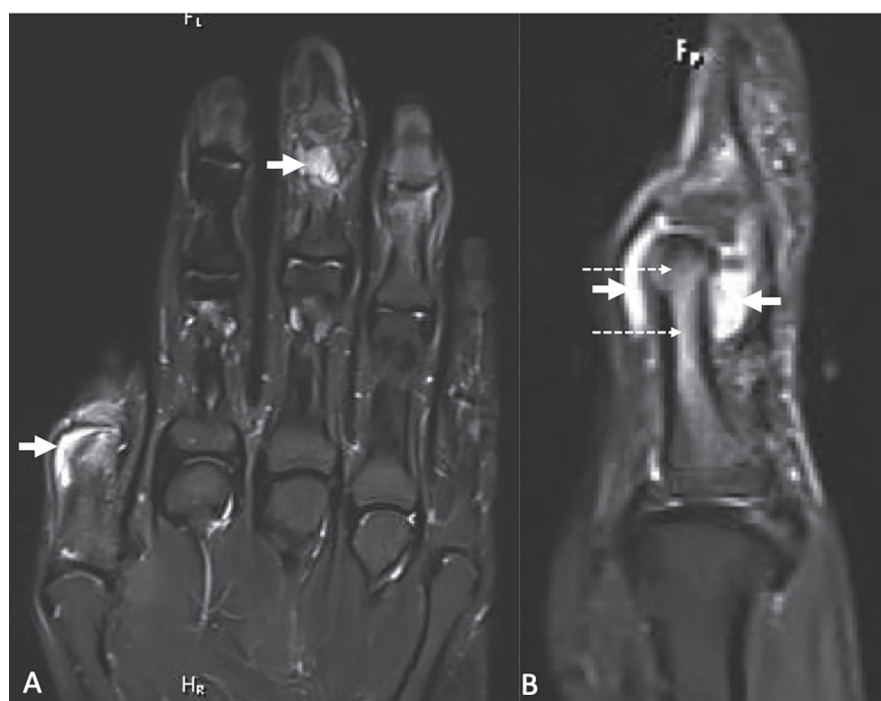
posite score-remission, with remaining subclinical activity observed by US (71, 72). A T2T strategy, using US remission as the treatment goal may potentially give added value to current clinical T2T strategies (73).

In summary, a value of US in the management of PsA has been established but implementation in routine care remains to be clarified, and further studies are needed.

#### *Magnetic resonance imaging*

MRI is a very sensitive method for visualisation of all structures involved in inflammatory arthritides. Much knowledge is derived from studies in RA or broader SpA populations, as fewer studies are reported in PsA patients (74). MRI has the important advantage of capacity to see through and inside bone, thereby providing complete assessment of even complex joints and inflammation inside the bone (bone marrow oedema or osteitis). Limitations of MRI include a need for long examination times, only a single anatomical area per examination (except for whole-body MRI, see below), potential adverse events of intravenous contrast agent administration, and exclusion of certain patients with claustrophobia or certain metallic implants.

In peripheral arthritides, synovitis, tenosynovitis, periarticular inflammation, bone marrow oedema, erosions and bone proliferations can be visualised on MRI (Fig. 5) (74, 75). Consensus MRI definitions of these pathologies, and which sequences to be obtained for their visualisation, have been published by the OMERACT MRI in Arthritis Working group (75). For inflammation and structural changes, T1-weighted sequences in 2 planes is performed (signal mainly reflecting fat content and contrast agent), supplemented with a T2-weighted, fat-suppressed sequence or short tau inversion recovery (STIR) sequence (signal mainly reflecting water content) (Fig. 6) (16, 75). Acquisition of additional T1-weighted sequences after intravenous gadolinium-containing contrast agent, with or without fat suppression, can assist in evaluation of tissue inflammation in peripheral joints. Use of intravenous contrast is needed for optimal assessment of synovitis and tenosynovitis, but not for evaluation of erosions, bony proliferation and bone marrow oedema (75). Enthesitis also can be assessed using MRI (Fig. 7), and the OMERACT MRI group is currently



**Fig. 5.** Coronal MRI of the hand in patient with PsA. **A:** Coronal STIR image, showing synovitis in the 1<sup>st</sup> IP joint and, in a less optimal slice, the 3<sup>rd</sup> DIP joint. **B:** Closer look of the same 1<sup>st</sup> IP shows synovitis (thick solid arrow) and bone marrow oedema (dashed arrow).

developing consensus definitions and a scoring system for MRI enthesitis (76).

#### • Pathogenesis

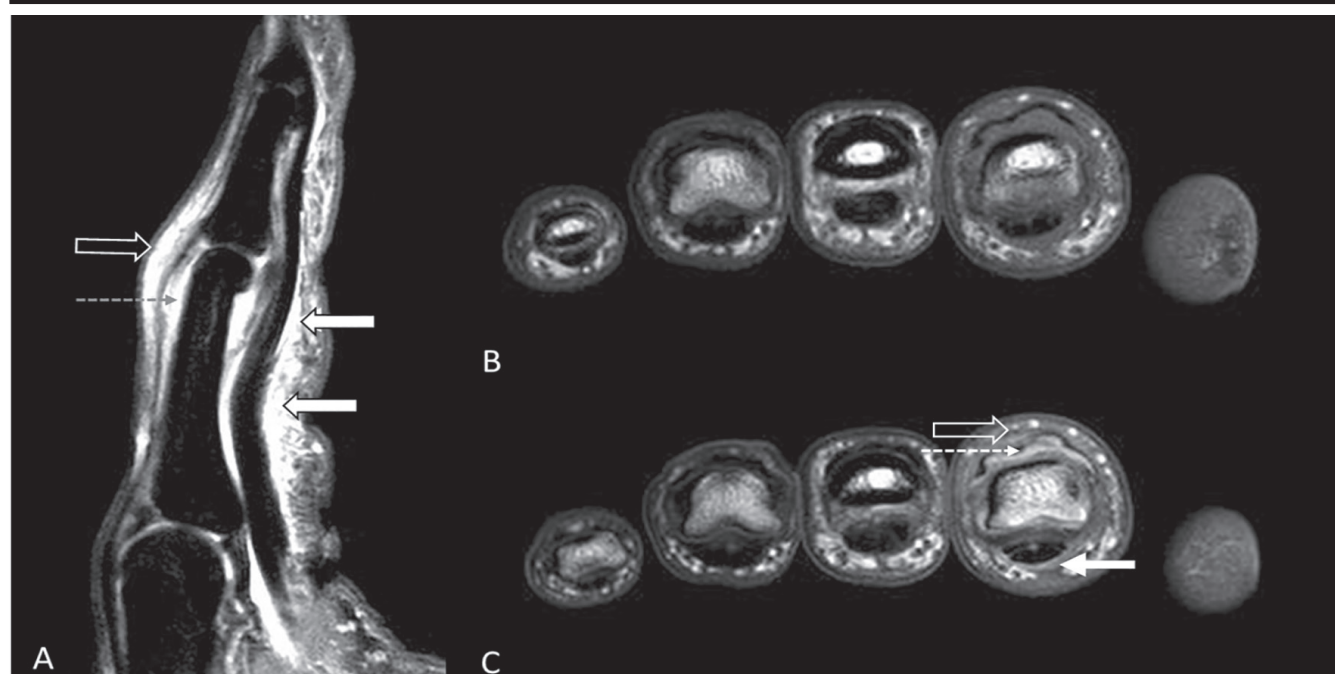
Imaging studies have contributed to

understanding of pathogenesis in PsA. Enthesitis is no longer perceived as a focal lesion, but as inflammation of a wider 'entheses organ' or 'synovio-enthesal complex' (77, 78). This concept

includes apart from the enthesis also the adjacent tendons, periosteum, fibrocartilage, synovium and bone at the attachment site (77, 79). Enthesitis of the digital extensor tendon has been proposed as the possible link between DIP joint inflammation and nail disease, based on high resolution (hr) MRI studies showing inflammation of the fibers extending from the dorsal DIP joint capsular entheses to the nail bed (80). In dactylitis, tenosynovitis has been perceived as the primary feature. However, recently, hrMRI studies have demonstrated poly-enthesitis in dactylitic digits, including flexor tendon pulleys and fibrous sheaths, offering a new explanation for the association between enthesitis and flexor tenosynovitis (81). It is possible that enthesitis, the hallmark of SpA diseases, may be the primary lesion in PsA, with secondary involvement of other tissues including synovium, tendons, subcutis, nails and bone (82). Further research is needed (83).

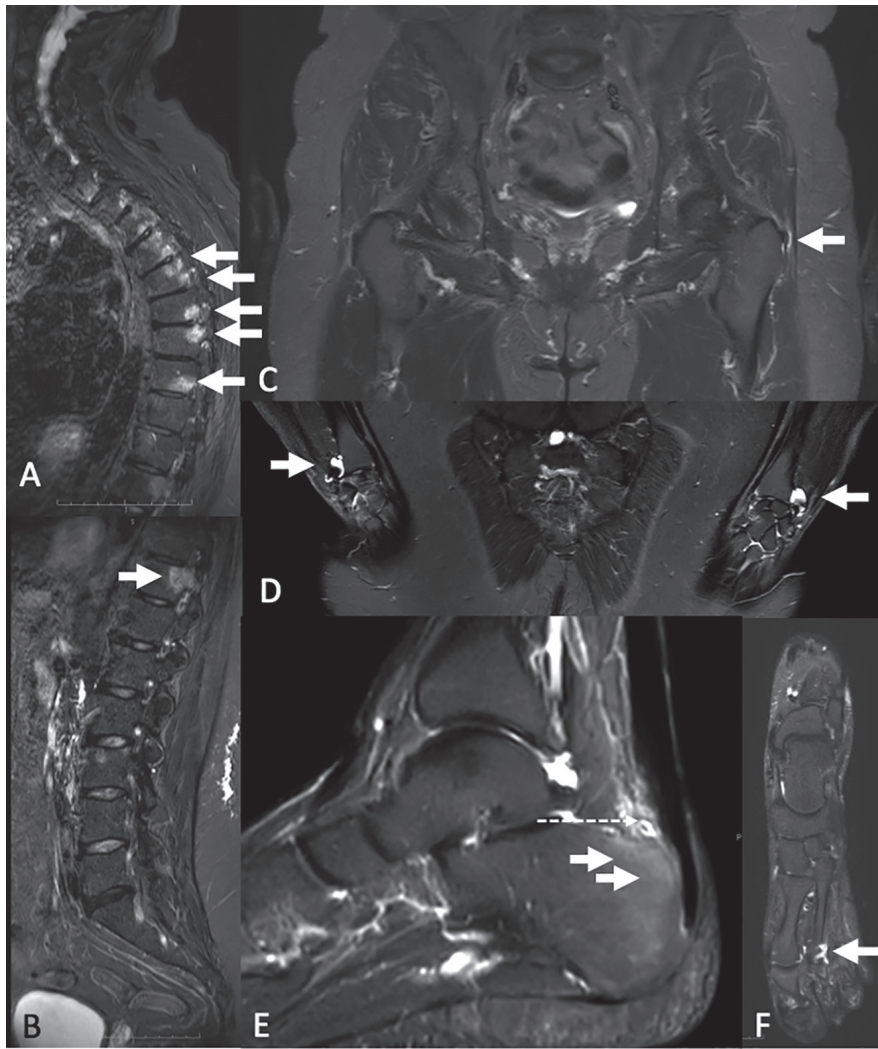
#### • Diagnosis

MRI findings of synovitis, enthesitis, tenosynovitis and bone marrow oedema are frequent in PsA, but are not disease specific (20, 74, 84, 85). Some MRI



**Fig. 6.** MRI of fingers of patient med PsA. **A:** Sagittal STIR-image of 2. finger, showing dactylitis with synovitis/effusion (dashed arrow) in the PIP-joint, flexor tenosynovitis (thick arrows) and thickening and increased signal of soft tissues (periarticular inflammation, open arrow). **B-C:** Axial T1 weighted images before (**B**) and after (**C**) intravenous contrast injection through 1<sup>st</sup>-5<sup>th</sup> finger (thumb right) showing contrast enhancement in the 2<sup>nd</sup> PIP joint (synovitis, dashed arrow), the flexor tendon sheath (tenosynovitis, thick arrow) and in the soft tissues around the joint (periarticular inflammation, open arrow).





**Fig. 7.** Whole-body MRI in PsA. **A-B:** Sagittal STIR images of the upper (**A**) and lower (**B**) parts of spine, showing lateral inflammation (costovertebral inflammation on many levels, arrows). **C-D:** Coronal images of the hip region (**C**) and the hands (**D**, positioned behind the buttocks) showing mild enthesitis at the left major trochanter (arrow) and synovitis/effusion in both distal radioulnar joints (arrows). **E:** Sagittal STIR image of the heel, showing Achilles enthesitis with bone marrow oedema (solid arrows) and soft tissue inflammation, incl. bursitis (dashed arrow). **F:** axial STIR image of the foot, showing synovitis/effusion in the 2<sup>nd</sup> MTP-joint.

findings can be used to assist in differential diagnosis. Bone marrow oedema in PsA is often close to entheses, in contrast to synovial attachments in RA and primarily subchondral areas in OA (86). PsA is characterised by more prevalent diaphyseal bone marrow and/or enthesitis, soft tissue inflammation, extra-capsular inflammation and involvement of primarily flexor tendons, in contrast to extensor tendons in RA (87). Erosions in PsA often are located close to the collateral ligaments, while in OA they are mostly found centrally (88). A comparative study found erosions to be more frequent in RA, and periostitis more frequent in PsA (89). Studies on

psoriasis patients who do not have clinical arthritis have indicated subclinical inflammation on MRI in both joints and entheses (90-94). One of these studies found that patients with subclinical inflammation on MRI, in conjunction with arthralgia, had a high (55.5%) risk for later development of PsA, whereas patients without these had a low risk (15.3%) (94). Further investigation of this observation appears needed.

#### • Prognosis

A study of patients with arthritis mutilans found a close link between presence of bone marrow oedema and erosions, suggesting that bone marrow

oedema leads to erosions (95), as previously shown in RA (96, 97). Bone marrow oedema on MRI has been found to be related to subsequent development of later erosions detected by CT (24), but, again, more data are needed.

#### • Monitoring

The EULAR recommendations for the use of imaging in the diagnosis and management of SpA in clinical practice (98) support the use of MRI and/or US for monitoring both disease activity and structural changes in peripheral SpA, as they may add additional information to clinical and biochemical examinations and radiography, respectively. There is, however, no evidence for or consensus on if and how often examinations should be repeated in routine clinical practice (98).

In clinical trials, MRI has been used for several years for monitoring disease activity (99-101). The OMERACT MRI in Arthritis working group has developed and validated an MRI scoring system for the hand and forefoot (PsAMRIS) (75, 102-105), which includes scores for synovitis, erosions, bone oedema, tenosynovitis, periarticular inflammation and bone proliferations. The system has been shown to be sensitive to change, and far more data are available concerning validity than for any other scoring system in PsA (24, 102, 103, 106, 107). As training and calibration of readers are recommended, the OMERACT MRI in Arthritis working group has suggested development of a PsAMRIS atlas and possibly online training modules for improved utility of the tool (83). Monitoring enthesitis is another relevant area for use in clinical trials. Various methods have been suggested, but no consensus has been achieved (108, 109). Currently the OMERACT MRI in Arthritis working group has proposed consensus-based definitions of key pathologies based on a systematic literature review, and is developing a preliminary scoring system (76).

#### • New techniques

New MRI methods such as whole-body MRI (WB-MRI) and dynamic contrast enhanced MRI (DCE-MRI) are being used increasingly in research in PsA.

DCE-MRI allows for semiautomated quantification of inflammation, based on measurements of contrast enhancement patterns over time in the selected region of interest (110). Most studies using DCE-MRI have been performed in RA patients, in whom imaging data have been found correlated significantly with histology (111-113). A small study with PsA and RA patients did not find any difference in DCE-parameters between patients with PsA and RA, when matched for severity (110). A more recent report described possible differences in the pattern of enhancement of the synovial membrane between the two groups, with a higher volume of inflamed tissue in RA, but a higher degree of inflammation in PsA, as assessed by the DCE-MRI parameters maximum enhancement and initial rate of enhancement (114).

WB-MRI allows for MRI of the whole body in one scanning session, but with lower image resolution than conventional MRI (Fig. 7). It was used initially to screen for bone-marrow malignancies and systemic muscle diseases (115). One study investigated the feasibility of WB-MRI, and possible additional information compared to clinical examination in PsA. WB-MRI was well tolerated and subclinical inflammation was frequent, suggesting that the procedure could add incremental clinical value (116). Another report indicated moderate agreement between enthesitis on clinical scores and WB-MRI in patients with PsA, axial SpA and healthy subjects, with a higher frequency on MRI, also suggesting a value in detecting subclinical inflammation (117).

Another interesting possibility for WB-MRI is the evaluation of the total burden of inflammation in the entire body, including both axial and peripheral joints and entheses (118). The OMERACT MRI in Arthritis Working Group is in the process of developing an OMERACT WB-MRI scoring system for use in inflammatory arthritides. The group has selected inflammation in peripheral joints and entheses as the primary focus area, and have by consensus agreed on MRI definitions for key pathologies, the anatomical locations for assessment, a core set of MRI sequences and imaging

planes to be acquired and has proposed a preliminary scoring system (119).

### Axial PsA

PsA is part of the SpA disease spectrum, and patients with PsA may have axial involvement. Axial PsA includes inflammation of sacroiliac (SI) joints (sacroiliitis) and/or spine (spondylitis) (16). Most imaging knowledge is derived from research on wider SpA populations, as little research have been done specifically on axial PsA.

### Conventional radiography

Conventional radiography still plays a central role in axial PsA, being accessible, fast and relatively inexpensive. The doses of ionising radiation for examination of the axial skeleton are greater than for examining the peripheral joints, but not much more than one is exposed to in an airline flight. EULAR generally recommends conventional radiography of the SI-joints as first line modality for diagnosis of sacroiliitis as part of axial SpA, followed by MRI if radiography is negative/inconclusive. However, in young patients, and in patients with short disease duration, MRI of the SI-joints is the preferred initial imaging method (98). Conventional radiography of the spine can also be used for monitoring structural changes, particularly new bone formation, but should not be repeated more frequently than every second year, due to a limited sensitivity to change and the ionising radiation involved (98).

Axial PsA can have a slightly different pattern of radiographic features than AS, including asymmetrical sacroiliitis and nonmarginal and asymmetrical syndesmophytes (120). Assessment systems developed for AS often are applied in axial PsA. For sacroiliitis, diagnosis and grading hereof may be done according to the radiographic part of the modified New York 1984 criteria for AS (121). The modified Stoke AS spine score is the preferred method for recording structural damage in the spine (122). The Psoriatic Arthritis Spondylitis Radiology Index has been developed for axial PsA. It includes features of systems developed for AS, with addition of scores for the facet joints of the cervical and lumbar spine (123, 124).

A consensus on scoring systems to be used in axial PsA does not exist, and further research is warranted (125).

### Computed tomography

In SI-joints CT depicts bone erosion, sclerosis and joint space alterations, including ankylosis with very high resolution, and generally is considered the standard reference for assessment of structural damage (126). Despite this, it has little place in clinical practice, due to ionising radiation and the fact that MRI can detect SI-joint changes almost as well (126, 127). The use of CT is also very limited for the spine, but can be helpful in case of suspected vertebral fracture when radiography is negative. CT has a place in PsA only if radiography is negative/inconclusive and MRI is unavailable/contraindicated (98).

### Ultrasonography

The limitation of US to diagnose osteitis hampers its use in axial arthritis. It can however be used to guide SI-joint injections (128). Although contrast enhanced Doppler US studies have assessed SI joints, and reported that a lack of contrast enhancement has a high negative predictive value for sacroiliitis (129) and have been suggested to have capacity to differentiate active sacroiliitis from non-active SI-joints (130), US does not have a place in routine diagnosis of sacroiliitis in PsA patients.

### Magnetic resonance imaging

Inflammation in SI-joints and spine can be visualised by MRI. In the SI-joint, sacroiliitis is seen as bone marrow oedema and occasionally also soft tissue inflammation at insertions of the capsule and ligaments (enthesitis). In the spine, inflammatory changes include bone marrow oedema and/or soft tissue oedema at joints and entheses. Characteristically these changes are seen at the anterior and posterior corners of the vertebral bodies, and at the costovertebral, facet and costovertebral joints. Discovertebral lesion (Andersson lesion) may also be the first sign of PsA and is seen in approx. 6% of PsA and AS patients (131). There are few studies of axial PsA, and knowledge is therefore primarily derived

from studies of a broader group of axial SpA and AS patients, in whom MRI is proven to be the most sensitive method to detect and monitor both sacroiliitis and spondylitis. A recent comparison of MRI and conventional radiography with CT of the sacroiliac joints as gold standard reference of structural changes in axial SpA patients showed a sensitivity and specificity for of 0.85 and 0.92 for MRI *versus* only 0.48 and 0.88 for radiography, documenting than even for structural changes, MRI is more sensitive than radiography (126).

MRI image acquisition and MRI definitions and findings from the wider SpA group are also generally used for axial PsA (132, 133). No findings are specific for PsA, although the more asymmetrical pattern of findings in axial PsA compared to AS may also be seen by MRI and initial involvement of the spine compared to the SI-joints is less rare in PsA than axial SpA in general (120). MRI findings in axial PsA are often weakly associated with clinical findings (134, 135). In an outpatient rheumatology clinic, it was found that 38% (26/68) of PsA patients had sacroiliitis on MRI, and 38% (10/26) of these were without clinical features of the condition (135). One study found more severe axial inflammation on MRI to be related to HLA-B27 positivity in PsA (136).

An ASAS/OMERACT MRI group reached a consensus on MRI findings relevant for sacroiliitis and for use in the ASAS classification criteria for axial SpA (133, 137). For monitoring of inflammation in clinical trials and practice, measures developed for axial SpA, such as the SPARCC method (138, 139), the Berlin method (140) and/or the Canada-Denmark method (141) can be applied. The two former methods can be used to assess inflammation semiquantitatively in each discovertebral unit and add to provide a total score. The anatomy based Canada-Denmark system includes separate assessment of axial entheses and joints, which can provide knowledge concerning the course of inflammation and damage (fat lesions, erosions, and ankylosis) in individual parts of the spine, such as facet joints, costovertebral joints, vertebral corners, etc. (Fig. 7) (137, 141, 142).

## Conclusions

PsA is a complex disease, which may lead to a wide range of pathologic changes in peripheral and axial joints and entheses. The individual imaging methods have different strengths and limitations, but taken together, imaging can be of value for diagnosis and differential diagnosis, recognising the extent of the disease, monitoring inflammatory and structural changes, evaluating effects of treatment, predicting outcomes, and improving understanding of pathology and pathogenesis. However, many matters remain insufficiently clarified, such as the clinical significance of imaging-detected subclinical disease. Further research is needed to optimise the use of modern imaging in routine clinical practice and as an outcome measurement instrument in clinical trials.

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