High-resolution MRI of flexor tendon pulleys using a 16-channel hand coil: disease detection and differentiation of psoriatic and rheumatoid arthritis

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Abstract

Background: To evaluate the value of 3 Tesla (T) magnetic resonance imaging (MRI) changes of flexor tendon pulleys for the differentiation of psoriatic (PsA) and rheumatoid arthritis (RA), using a novel 16-channel high resolution hand coil.

Methods: Seventeen patients with active PsA, 20 patients with active RA and 16 healthy controls (HC) underwent high-resolution 3T MRI using the dedicated 16-channel hand coil. Images were analyzed by three independent readers for the degree of inflammatory changes, thickness of flexor tendon pulleys and comparison to the outcome measures for RA clinical trials (OMERACT) PsA MRI score (PsAMRIS) and to its sub-scores. For correlation analyses Spearman rho correlation was calculated.

Results: Flexor tendon pulleys were thicker in PsA than in RA patients (mean difference 0.16 mm, $p<0.001$) and HC (mean difference 0.2 mm, $p<0.001$) and showed a higher degree of associated inflammatory changes (mean difference from RA: 4.7, $p= 0.048$; mean difference from HC: 14.65, $p<0.001$). Additionally, there was a strong correlation of accessory pulley inflammation and PsAMRIS and its acute-inflammatory sub-scores, flexor tenosynovitis, synovitis and periarticular inflammation (for second digit: synovitis $\rho= 0.72$, flexor tenosynovitis $\rho= 0.7$, overall PsAMRIS $\rho= 0.72$, $p< 0.01$). Similar robust correlations were evident in digits 3-5. Weaker correlations were evident in RA (synovitis $\rho= 0.49$, flexor tenosynovitis $\rho= 0.49$, periarticular inflammation $\rho= 0.4$).

Conclusion: The assessment of MRI changes of flexor tendon pulleys is potentially beneficial for disease detection in PsA, as well as for its distinction from RA and HC.

C. Background

Psoriatic arthritis (PsA) is a very common chronic inflammatory disease that affects joints and ultimately leads to joint destruction and functional disabilities (1,2). Regarding its clinical presentation, PsA shares many similarities with rheumatoid arthritis (RA), which potentially complicates the distinction between both entities, especially in cases of symmetric and seronegative RA (3–5). However, PsA and RA differ in their pathophysiology: RA is considered to be a synovial disease that exhibits secondary spread to the adjacent bone; PsA on the other hand characteristically affects entheses, such as tendon and ligament insertion sites. These can be classified as fibrous and fibrocartilaginous and belong to the so-called synovio-entheseal complex (6–10). Additionally, tendons build so-called “functional entheses” with associated ligamentous structures, such as flexor tendon pulleys (11). These pulleys have a fibrocartilaginous component and discontinuously wrap around the flexor tendons preventing their bowstringing during flexion (12). Recent studies have shown that inflammation and thickening of flexor tendon pulleys are potentially due to mechanical stress (“deep Koebner response”) and may lead to the initial development of flexor tenosynovitis and dactylitis, that are major features of PsA (13–15).

As in RA, remission is the ultimate goal of disease-modifying therapy in PsA. Hence, early accurate diagnosis and treatment are pivotal for a favorable clinical outcome (16). Additionally, distinct pharmacological options and treat-to-target strategies exist for both diseases which underlines the importance of an unequivocal distinction (3,17,18). Even though not yet included in the Classification Criteria for PsA (CASPAR), magnetic resonance imaging (MRI) is becoming increasingly important and widely used for diagnosis and the monitoring of therapy for PsA (19–21). The Outcome Measures for Rheumatoid Arthritis Clinical Trials (OMERACT) working group has developed a semi-quantitative PsA MRI (sum-)score (PsAMRIS) that is highly sensitive for disease-related joint changes and is widely used for therapy monitoring (22–24). However, until most recently, enthesitis was not included in any MRI score, despite being a hallmark of PsA (25,26). Indeed, enthesitis is difficult to accurately evaluate in small joints using conventional MRI or with high resolution MRI surface coils that can only visualize a small area. We addressed this by developing using a dedicated 16-channel high resolution hand coil to permit a global evaluation of digits in PsA and RA. Herein, we describe our findings indicating that this technique has considerable potential to differentiate between RA and PsA hand involvement.

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D. Methods

1. *Patients*

17 patients (mean age 53.7 ± 11.6; minimum/maximum 26/72 years, male/female 9/8) fulfilling the CASPAR criteria with a mean disease duration of 4 ± 3.6 years and peripheral joint involvement and dactylitis were prospectively recruited for the “Analysis of the DActylic Melange” (ADAM) research initiative. All patients had failed methotrexate (MTX) monotherapy and were escalated to Etanercept (Enbrel® 50 mg s.c. fortnightly) after a baseline MRI scan.

Additionally, 20 therapy naïve patients (mean age 46 ± 15.7, minimum/maximum 19/67 years, male/female 9/11), fulfilling the ACR/EULAR 2010 criteria for RA with a mean disease duration < 6 months (mean duration 8 weeks, minimum/maximum 2/22 weeks) from the ‘Cartilage in early RA’ (CAR-ERA) study, were included. Patients were allowed a daily dose of oral prednisone at <10 mg. After a baseline scan, patients received either MTX monotherapy or a combination of MTX and adalimumab. Patients were blinded for their therapy regime.

Furthermore, 16 patients (mean age 39 ± 16.1, minimum/maximum 17/78 years, male/female 9/7) with no history of arthritis were retrospectively recruited as healthy controls (HC). MRI studies were performed due to clinical reasons (e.g. suspected carpal ganglion) in our daily routine. At the time of retrospective recruitment, all subjects of HC were over 18 years of age. The study was approved by the local ethics committee (MO-LKP-719, 4962R). Written and informed consent was obtained from all patients before initiation of the study.

2. *MR imaging*

For MR imaging, a 3T MRI scanner (Magnetom Skyra, Siemens Healthineers, Erlangen, Germany) and a purpose built dedicated 16-channel hand coil (figure 1; 3T Tim Coil, Siemens Healthineers, Erlangen, Germany) were used, allowing for a high-resolution imaging over a wide area.. PsA patients received a baseline (T0) and a follow-up (T1) scan with an approximately 6.2 ± 0.85 month (minimum/maximum: 5/8 months) interval in between. A baseline (T0) and two follow-up (T1 and T2) scans were performed in the RA population with approximately 2.8 ± 0.1 months (minimum/maximum 2.6/3 months) between T0 and T1 and 5.6 ± 0.1 months (minimum/maximum 5.4/5.8 months) between T0 and T2. For HC only a single scan was performed.

The imaging protocol followed the recommendations of the OMERACT working group for PsA and RA (21, (27). In PsA patients this included pre- and post-contrast ($DOTA^-$, Dotarem, Guerbet, Villepinte, France; intravenous-injection of 0.4 ml/kg bodyweight) T1-weighted turbo spin echo (TSE) and non-contrast enhanced fat-saturated T2-weighted TSE or short tau inversion recovery (STIR) sequences in two different orthogonal planes. The field of view covered MCP, PIP and DIP of digits 2-5. In RA patients the protocol included the following sequences: pre- and post-contrast ($DOTA^-$, Dotarem, Guerbet, Villepinte, France intravenous-injection of 0.4 ml/kg bodyweight) coronal T1-weighted TSE and transversal fat-saturated T1-weighted spin echo (SE) after contrast agent application as well as a coronal STIR. The field of view covered MCP 2-5, carpometacarpal, carpal, radiocarpal and distal radioulnar joints.

In control patients our in-house standard protocol was used, which included the same sequences as detailed for the RA patients above. In addition, a transversal fat-saturated proton-density weighted sequence was acquired. The field of view differed according to the clinical region of interest.

The sequence parameters were as follows:

PsA: coronal T1 TSE (TR/TE in ms, PsA: 862/27, RA: 862/27; flip angle in °, PsA: 150, RA: 150; slice thickness in mm, PsA: 2.5, RA: 2.5; field of view in mm, PsA: 140, RA: 130; pixel size: PsA: 0.3 x 0.3 mm, RA: 0.3 x 0.3; acquisition matrix: 512 x 512), coronal STIR (TR/TE in ms, PsA: 5560/31, RA: 5560/31; flip angle in °, PsA: 120, RA: 120; slice thickness in mm, PsA: 2.5, RA: 2.5; field of view in mm, PsA: 140, RA: 130; pixel size: PsA: 0.3 x 0.3 mm, RA: 0.3 x 0.3 mm; acquisition matrix: 448 x 314), sagittal PD TSE fat-saturated (only PsA: TR/TE in ms 3150/47, flip angle 150°, slice thickness 2.5 mm, field of view 150 mm; pixel size: 0.3 x 0.3 mm; acquisition matrix: 448 x 182), transversal T2 TSE fat-saturated (only PsA: TR/TE in ms: 5693.8/89, flip angle 180°, slice thickness 3.0 mm, field of view: 160 mm; pixel size: 0.3 x 0.3 mm; acquisition matrix: 512 x 358), transversal T1 SE fat-saturated after iv contrast (TR/TE in ms, PsA: 807/16, RA: 702/16; flip angle in °, PsA: 90, RA: 90; slice thickness in mm, PsA: 3.0, RA 2.5; field of view in mm, PsA:130, RA: 120; pixel size: PsA: 0.3 x 0.3 mm, RA: 0.3 x 0.3 mm; acquisition matrix: 384 x 288) and coronal T1 TSE after iv contrast (TR/TE in ms, PsA: 862/27, RA: 862/27; flip angle in °, PsA: 150, RA; 150; slice thickness in mm, PsA: 2.5, RA: 2.5; field of view in mm, PsA; 140, RA: 140; pixel size: PsA: 0.3 x 0.3 mm, RA: 0.3 x 0.3 mm; acquisition matrix: 512 x 512).

3. *Image analysis*

MR images were read and analyzed in consensus by two radiologists (one attending physician [CS], one resident physician [DBA]) and one rheumatologist (attending physician [PS]), with long-term experience in musculoskeletal imaging of > 8 years (CS and PS) and all trained in RAMRIS and PsAMRIS-Scoring according to the OMERACT guidelines [15, 16]. Readers were blinded to the diagnosis of the patients. Flexor tendon pulleys A1 and A2 were analyzed in digits 2 to 5. Each pulley was evaluated regarding its thickness in mm and its intrinsic and/or surrounding signal intensity at the radial, ulnar and volar aspect of each pulley (see figure 2 and 3 for typical changes). The PsAMRIS was adapted due to the clear visualization of the pulleys with abnormalities being scored as 0-3 as per PsAMRIS scoring at other sites such as synovium and tenosynovium (21). Consequently, the score reflected the degree of enhancing and/or hyperintense signals within the pulley complex and scores 0, - 3 indicated the absence of any abnormality (score 0), the involvement of < 50 % of the pulley thickness (score 1), of ≥ 50 % (score 2), and of its entire thickness (score 3). For each pulley we took the sum of the radial, ulnar and volar grading regarding the sourrounding and/or intrinsic inflammatory changes and the mean of the radial and ulnar thickness of the pulley itself in mm. Additionally, PsA patients were evaluated according to PsAMRIS at MCP, PIP and DIP joint level of digits 2-5 for synovitis (score 0-3), flexor tenosynovitis (score 0-3), bone edema (score 0-3), erosion (score 0-10), proliferation (score 0 or 1) and periarticular inflammation (score 0 or 1) (21). In case of different findings, the analysts reached a common consensus.

4. *Statistical analysis*

All statistical analyses were performed using SPSS software (IBM, version 22, Armonk, NY, USA). For descriptive analysis, the mean, standard deviation, minimum and maximum are presented. Mean values were compared with a one-way analysis of variance (ANOVA) and a post-hoc Scheffé test. For correlation analyses, Spearman rho correlation coefficient (ρ) was used. Correlation strength was graded as suggested by Cohen (28): small (< 0.3), moderate (0.3 - 0.5) and large (> 0.5).

Due to the large number of comparisons between PsA patients, RA patients, and healthy controls, Bonferroni correction was applied, and the level of significance was set to $p \leq 0.05 / 3 = 0.0167$. Three patient cohorts were comparatively evaluated and therefore may be considered as separate experiments. In a stricter statistical sense, correction of all 66 sub-experiments (i.e. three cohorts, two assessed MRI characteristics, and 11 anatomical flexor tendon pulley levels) ought to be performed; however, the increased risk of producing false negatives secondary to overly conservative statistical analyses rendered this option impractical. Accordingly, we decided to use (design-adapted) Bonferroni correction and look for consistent and significant changes of the pulleys as a function of disease entity instead of relying on statistical formalism. Inter- and intra-rater reliability for pulley thickness and pulley inflammatory changes was calculated by two-way mixed intraclass correlation coefficients (single-measure ICC (sICC) for intra-rater and average-measure ICC (aICC) for inter-rater reliability).

E. Results

1. *PsAMRIS (subscores) at MCP, PIP and DIP joint level in PsA and RA patients*

Descriptive analysis of inflammation sub-scores according to PsAMRIS are illustrated in table 1 for PsA and in table 2 for RA patients. Synovitis, flexor tenosynovitis and periarticular inflammation (extracapsular changes) were commonly found in all PsA and RA patients. Bone edema and bone erosions, on the other hand, were less frequently seen, whereas bone proliferations were rarely detected. Periarticular inflammation (extracapsular changes) and bone erosions were significantly more frequently detected in PsA than in RA patients ($p = 0.003$ and $p < 0.001$) as originally described in hand joints (29). Regarding all other sub-scores no significant differences could be detected.

Inflammation parameter	MCP	PIP	DIP	Overall
Overall	23.41 ±4.89	22.94 ±7.2	21.12 ±9.71	67.47 ±18
Synovitis	9.18 ±2.1	7.41 ±2.32	5.53 ±2.43	22.12 ±5.67
Flexor tenosynovitis	4.76 ±1.44	2.94 ±1.82	2.76 ±2.31	10.47 ±4.99
Periarticular inflammation	6.47 ±1.66	6.88 ±1.58	6.41 ±1.66	19.76 ±3.95
Bone edema	0.6 ±1.18	2.59 ±2.24	3.41 ±4.11	6.59 ±5.47
Bone erosion	2.29 ±1.49	2.53 ±2.83	2.65 ±2.94	7.47 ±5.46
Bone proliferation	0.12 ±0.33	0.59 ±0.87	0.35 ±0.49	1.06 ±1.39

Table 1 PsAMRIS values at MCP, PIP and DIP joint level. PsAMRIS: Psoriatic Arthritis Magnetic Resonance Imaging Score. For each item mean ±standard deviation are presented.

Inflammation parameter							
	Synovitis	Flexor tenosynovitis	Periarticular inflammation	Bone edema	Bone erosion	Bone proliferation	Overall
MCP Joint	10.35 ±1.87	5.05 ±1.61	4.15 ±2.24	0.4 ±1.27	0.5 ±0.76	0 ±0	20.45 ±4.17
p-value	0.084	0.572	**0.003**	0.643	**<0.001**	0.163	0.071

Table 2 Mean PsAMRIS values ± standard deviation for each inflammation parameter at MCP joint level in RA patients. P-values for the comparison of means between RA patients (this table) and PsA patients (Table 1). After (adapted) Bonferroni correction p-values <0.01 were considered significant and are printed in bold type.

2. *Inflammatory changes and thickness of the flexor tendon pulleys*

Mean values of inflammatory changes and thickness of the A1 and A2 flexor tendon pulleys in PsA and RA patients and in HC are summarized in Tables 3 and 4. Visualization of flexor pulley changes in figures 2 and 3.

PsA patients had significantly thicker A1 and A2 flexor tendon pulleys in most fingers as compared to RA and HC (overall mean difference compared to RA: 0.19 mm, p< 0.001; overall mean difference compared to HC: 0.16 mm, p< 0.001).

Additionally, PsA patients showed significantly more inflammatory changes (higher sum-scores) at A1 and A2 flexor tendon pulleys in all fingers as compared to HC (mean difference 14.65, p< 0.001). Furthermore, inflammatory changes of all flexor tendon pulleys were higher in PsA than in RA patients (mean difference 4.17; p= 0.048). Compared to HC, RA patients had a similar thickness, but more intense inflammatory changes of pulleys (mean difference 9.95, p< 0.001). sICC was 0.88 and aICC 0.93.

Finger + pulley	PsA	RA	HC	PsA vs RA	PsA vs HC	RA vs HC
	Inflammatory changes			p-values		
D2 A1	2.82 ±1.25	2.55 ±1.43	0.94 ±1.14	0.82	**0.001**	**<0.003**
D2 A2	2.06 ±1.08	1.75 ±1.55	0.75 ±1.03	0.77	**0.02**	0.08
D3 A1	3.24 ±1.59	2.6 ±1.16	0.69 ±0.98	0.35	**<0.001**	**<0.001**
D3 A2	3.28 ±1.62	1.85 ±1.56	0.94 ±1.03	0.02	**<0.001**	0.2
D4 A1	2.65 ±1.37	2.05 ±1.24	0.5 ±0.79	0.33	**<0.001**	**0.002**
D4 A2	2.5 ±1.12	1.7 ±1.05	1.13 ±1.11	0.1	**0.002**	0.32
D5 A1	2.18 ±1.15	1.5 ±1.57	0.38 ±0.70	0.27	**0.001**	**0.036**
D5 A2	2.22 ±1.27	1.95 ±1.53	0.69 ±0.98	0.82	**0.007**	**0.03**
D2-5 A1	10.88 ±4.30	8.7 ±3.15	2.5 ±2.87	0.194	**<0.001**	**<0.001**
D2-5 A2	10.06 ±3.11	7.25 ±3.65	3.5 ±3.51	0.031	**<0.001**	**0.004**
D2-5 A1+2	20.65 ±6.57	15.95 ±7.01	6 ±6.3	0.048	**<0.001**	**<0.001**

Table 3 Mean values ±standard deviation and intergroup comparisons of flexor tendon pulley inflammatory changes in PsA, RA and HC patients. After (adapted) Bonferroni correction p-values <0.01 were considered significant and are printed in bold type.

Finger + pulley	PsA	RA	HC	PsA vs RA	PsA vs HC	RA vs HC
	Pulley thickness in mm			p-value		
D2 A1	0.86 ±0.14	0.63 ±0.10	0.62 ±0.16	**<0.001**	**<0.001**	0.99
D2 A2	0.79 ±0.13	0.54 ±0.09	0.6 ±0.11	**<0.001**	**<0.001**	0.45
D3 A1	0.82 ±0.19	0.6 ±0.09	0.64 ±0.11	**<0.001**	**0.002**	0.76
D3 A2	0.83 ±0.11	0.58 ±0.12	0.66 ±0.18	**<0.001**	**0.006**	0.269
D4 A1	0.71 ±0.16	0.6 ±0.09	0.61 ±0.09	0.03	0.09	0.94
D4 A2	0.79 ±0.12	0.58 ±0.12	0.63 ±0.13	**<0.001**	**0.008**	0.54
D5 A1	0.76 ±0.21	0.58 ±0.08	0.64 ±0.13	**0.005**	0.1	0.56
D5 A2	0.71 ±0.21	0.61 ±0.08	0.61 ±0.12	0.13	0.15	1
D2-5 A1	0.79 ±0.18	0.6 ±0.09	0.63 ±0.13	**<0.001**	**<0.001**	0.74
D2-5 A2	0.78 ±0.15	0.58 ±0.22	0.63 ±0.14	**<0.001**	**<0.001**	0.21
D2-5 A1+2	0.79 ±0.17	0.59 ±0.19	0.63 ±0.13	**<0.001**	**<0.001**	0.35

Table 4 Mean values ±standard deviation and intergroup comparisons of flexor tendon pulley thickness in PsA, RA and HC patients. After (adapted) Bonferroni correction p-values <0.01 were considered significant and are printed in bold type.

3. *Correlation of flexor tendon pulley inflammation and pulley thickness and PsAMRIS (-subscores)*

Values for Spearman rho correlation coefficients of flexor tendon pulley inflammation and pulley thickness and PsAMRIS (-sub-scores) for PsA and RA patients are displayed in Table 5.

In PsA patients there was a strong correlation between pulley inflammation and overall PsAMRIS as well as inflammatory PsAMRIS sub-scores (synovitis, periarticular inflammation and flexor tenosynovitis) at most fingers. A heterogeneous (low to high) correlation was found for pulley inflammation and bone erosion and edema, whereas the correlation of pulley inflammation and bone proliferation was mostly weak. Furthermore, pulley inflammation and thickness showed a weak correlation.

In RA patients we also found a significant, but weaker correlation between pulley inflammation and overall PsAMRIS as well as inflammatory PsAMRIS sub-scores as compared to PsA. Correlation coefficients for bone erosion and bone edema were low to intermediate.

	D2		D3		D4		D5	
	PsA	RA	PsA	RA	PsA	RA	PsA	RA
Synovitis	**0.72**	0.49	0.48	0.36	0.4	0.2	**0.83**	0.11
Flexor tenosynovitis	**0.7**	0.49	**0.91**	0.46	**0.7**	0.48	**0.76**	0.41
Periarticular inflammation	0.49	0.49	**0.62**	0.32	**0.77**	0.49	0.6	0.53
Bone erosion	0.37	0.16	0.43	0.31	0.13	na	0.62	0.28
Bone edema	0.52	-0.34	**0.66**	0.39	0.36	na	0.28	na
Bone proliferation	-0.03	na	-0.05	na	-0.44	na	0.05	na
PsAMRIS	**0.72**	0.46	**0.81**	0.47	0.45	**0.63**	**0.80**	0.46
Pulley thickness	0.23		0.11		0.22		0.07	

Table 5 Spearman rho correlation coefficient (ρ) for the score of inflammatory changes of flexor tendon pulleys (A1 and A2) and PsAMRIS subscores, total PsAMRIS and flexor tendon pulley thickness at D2-5 in PsA and RA patients. After (adapted) Bonferroni correction p-values <0.01 were considered significant and are printed in bold type.

F Discussion

Psoriatic arthritis has a prominent entheseal disease component manifesting at the so-called “synovio-entheseal complex”, that includes flexor tendon pulleys (9). In this study we evaluated the value of high-resolution 3T MRI changes of flexor tendon pulleys in PsA patients for disease detection as well as distinction from RA and HC using a dedicated 16-channel hand coil.

According to our results, PsA patients had significantly thicker A1 and A2 flexor tendon pulleys than RA patients or HC. Between the latter, on the other hand, there were no significant differences of pulley thickness. These findings of pulley thickening in PsA patients confirm the prior ultrasound studies of Tinazzi et al., who evaluated a small population of patients with PsA, RA, non-arthritic psoriasis (Pso) and healthy individuals (14). They hypothesized that the distinctive thickening of flexor tendon pulleys in PsA could be due to ‘deep Koebnerization’, an adaptation of entheses to mechanical stress, according to dermal hyperplasia and thickening in Pso, commonly known as ‘Koebner phenomena’ (14). Even more recently Furlan et al. also found thickened A1 pulleys in PsA patients using ultrasound and concluded that pulley thickness could potentially be used to differentiate PsA from other forms of arthritis (30). In addition, Graceffa et al. also demonstrated entheseal thickening in larger entheses in PsA and Pso patients and assumed that these distinct changes were triggered by inflammation (31). Along with our findings, this contributes to the concept of ‘enthesitis being a hallmark of PsA’ (25). Our high resolution MRI study is the first to demonstrate these distinct PsA features using an alternative imaging method to sonography.

In addition, this study demonstrated that flexor tendon pulleys of PsA patients were not only thicker than those of HC and RA patients, but also showed more frequent and intense inflammatory changes in their course and at their insertion sites. In 2015, Tan et al. had already demonstrated that MRI inflammatory changes of finger entheses were more frequent and severe in PsA patients than in HC, but they only evaluated fingers with acute dactylitis and did not use a dedicated 16-channel hand coil as we did in this study (13). In particular when assessing small soft tissue structures as the A1 and A2 pulleys whose mean thickness we determined as 0.63 mm in healthy individuals (Table 4), MRI technique needs to be optimized regarding sequence parameter settings and coil and scanner configurations enable true high-resolution imaging. Consequently, we achieved in plane pixel dimensions of 0.3 x 0.3 mm^2.

Our findings show inflammation of pulleys at both dactylitic and non-dactylitic fingers and, therefore, expand the value of pulley involvement beyond the scope of dactylitis. Potentially this is partly due to a higher image resolution using a 16-channel hand coil in the present study and suggests that the non dactylitic tenosynovitis in PsA is also linked to pulley inflammation.

Furthermore, despite similar findings regarding pulley thickness, our data also showed more pulley-associated inflammation in RA patients than in HC. Considering that RA is primarily a synovial disease that is known to secondarily affect adjacent structures, such as flexor tendons, the involvement of entheses, and hence pulleys, seems evident. However, previous studies have shown that RA, despite involving the synovio-entheseal complex, primarily affects its synovial aspect; PsA on the other hand shows a stronger affection of its entheseal component (32). Along with our findings of more intense and

more frequent involvement of pulleys in PsA than in RA, this supports the idea of PsA being more predominantly an entheseal and extracapsular disease and contributes to the distinction of the two entities. Since early diagnosis and treatment is pivotal for a better outcome in both entities and treatment options are increasingly diverging due to the development of biological and targeted synthesized disease modifying antirheumatic drugs (bDMARD and tsDMARD), an early distinction between the two would be highly beneficial.

The presented data shows only a weak correlation between inflammatory changes and thickness of A1 and A2 flexor tendon pulleys in PsA patients. This could be due to the patient population of non-early PsA patients that show side-by-side signs of acute inflammation and post-inflammatory changes in different joints/entheses. Thus, on the one hand, thickened pulleys could be associated with acute inflammation, while, on the other hand, being a result of previous inflammation. Baraliakos et al. also demonstrated that chronic changes of entheses can occur without inflammation present in patients with peripheral spondyloarthritis (33). Despite a weak correlation between pulley thickness and inflammation, we found a strong correlation between pulley inflammation and overall PsAMRIS, flexor tenosynovitis, periarticular inflammation and synovitis, and to a lesser extent with bone erosion and bone edema sub-score. PsAMRIS and its sub-scores are validated tools for the detection and monitoring of disease-related joint changes. Therefore, inflammatory changes of pulleys could also be appropriate for the evaluation of disease-driven joint involvement (24). In early 2019, Mathew et al. introduced a preliminary enthesitis-based MRI scoring system, named ‘Heel Enthesitis Scoring System’ (HEMRIS) that emphasizes the value of entheseal changes for the diagnosis and monitoring of PsA (26).

The following limitations to this study must be considered when interpreting its results: Our study has only a small sample size. Further investigations with larger patient populations are required. The mean disease duration of the PsA and RA study population differed by approximately 192 weeks (RA 8, PsA 200 weeks). Applying current definitions, we hence compare non-early PsA with early RA populations (early RA: disease duration < 12 months; early PsA: disease duration < 24 months) (34,35). Thus, the comparability of both populations is potentially limited; however, because PsA is a very heterogeneous disease, a distinct onset and, therefore, an early patient population, is difficult to establish. In addition, enthesitis is a sign of acute inflammation, and hence not limited to advanced disease stages. Since the evaluation of enthesitis, namely inflammatory changes of flexor tendon pulleys, was our main goal, we consider the divergent disease duration only a minor limitation.

MRI generally has a limited spatial resolution. Since flexor tendon pulleys frequently have a thickness of <1mm there is an increased risk of measuring inaccuracy due to partial volume effects, which may bring about substantial inter- and intra-rater variability. However, our findings show a good intra- and inter-rater reliability that is in coherence with previous studies regarding MRI measurements of pulleys and may also be the result of the optimized measurement setup that allows high-resolution imaging (36).

In conclusion, the assessment of high-resolution MRI changes of flexor tendon pulleys using a 16-channel hand coil could be used for disease detection in PsA and are potentially beneficial for the

distinction from RA and HC.

G Abbreviations

ACR: American College of Rheumatology

ADAM: Analysis of the DActylic Melange

aICC: average measure ICC

bDMARD: biological DMARD

CAR-ERA: Cartilage in early RA

CASPAR: classification criteria for psoriatic arthritis

DIP: Distal interphalangeal

DMARD: disease modifying drug

EULAR: European League Against Rheumatism

HC: healthy control

ICC: intraclass correlation coefficient

MCP: Metacarpophalangeal

MRI: Magnetic resonance imaging

Ms: milliseconds

MTX: methotrexate

OMERACT: Outcome measures in rheumatoid arthritis clinical trials

PD: proton density

PIP: Proximal interphalangeal

PsA: Psoriatic arthritis

PsAMRIS: Psoriatic arthritis magnetic resonance imaging score

RA: rheumatoid arthritis

RAMRIS: rheumatoid arthritis magnetic resonance imaging score

SE: spin echo

sICC: single measure ICC

STIR: short tau inverse recovery

T: Tesla

T2T: treat to target

TE: echo time

TR: relaxation time

tsDMARD: targeted synthetic DMARD

TSE: turbo spin echo

H Declarations

Ethics approval

The study was approved by the local ethics committee (MO-LKP-719, 4962R).

Consent for publication

Written and informed consent was obtained from all patients before the initiation of the study.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors’ contributions

All authors read and approved the final manuscript.

DBA: Acquisition, analysis and interpretation of data. Draft and design of the work.

CS: Conception and design of the study. Interpretation and analysis of data. Draft and design of the work. Revision of the work.

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Figures

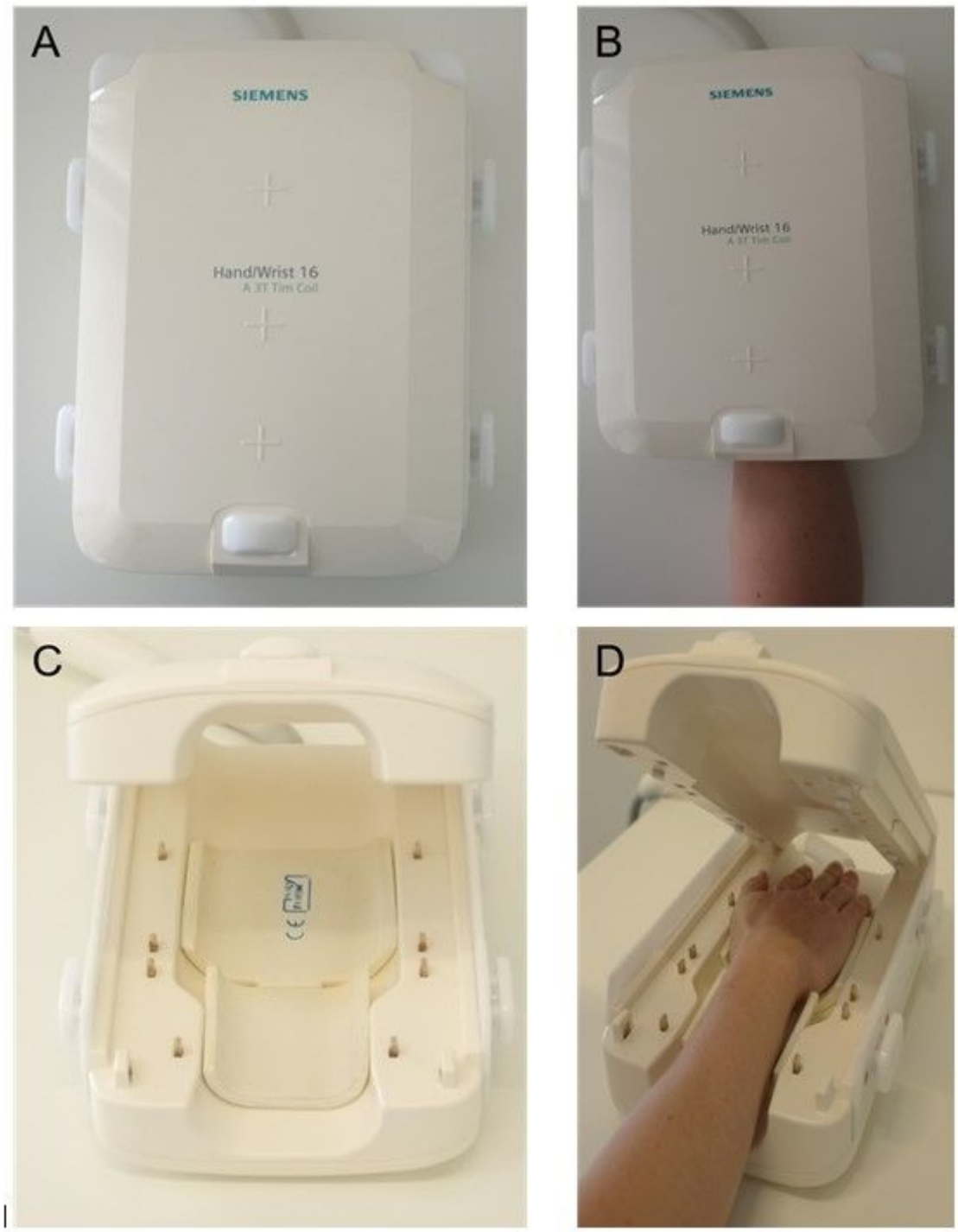

Figure 1

16-channel hand coil (3T Tim Coil, Siemens Healthineers, Erlangen, Germany). Top views of the closed (A, B) and open coil (C, D) without (A, C) and with a forearm contained within (B, D).

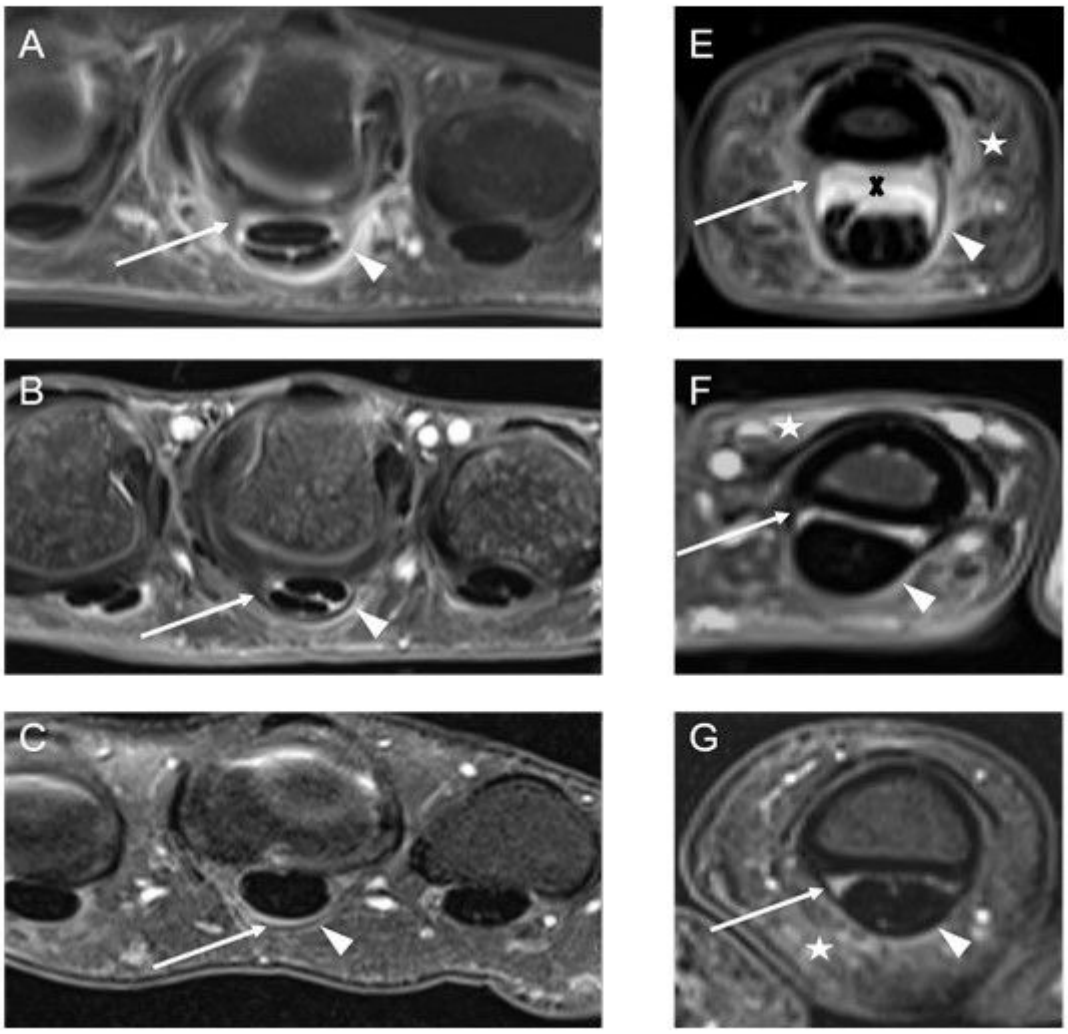

Figure 2

Transversal fat-saturated T1w images after iv contrast administration. A1 (A-C) and A2 (E-G) flexor tendon pulleys of D3 in PsA (A & E) and RA (B & F) patients and in HC (C & G). A & E: 25 year old male with PsA. Flexor tendon pulleys at A1 and A2 level (white arrows) with increased contrast enhancement surrounding each pulley in its course and at its attachment sites of the pulley (white arrowheads). White asterisk indicates periarticular inflammation within the soft tissue. Black X marks intense flexor tenosynovitis. B & F: 29 year old female with RA. A1 and A2 Flexor tendon pulleys appear thinner (white arrows) than in A & E, with only subtle contrast enhancement of the surrounding soft tissue (white arrowheads). There is also periarticular inflammation in the surrounding soft tissue (white asterisk). C & G: 37 year old healthy male. Flexor tendon pulleys (white arrows) appear thinner than in PsA. There is hardly any contrast enhancement surrounding each pulley (white arrowheads and asterisk).

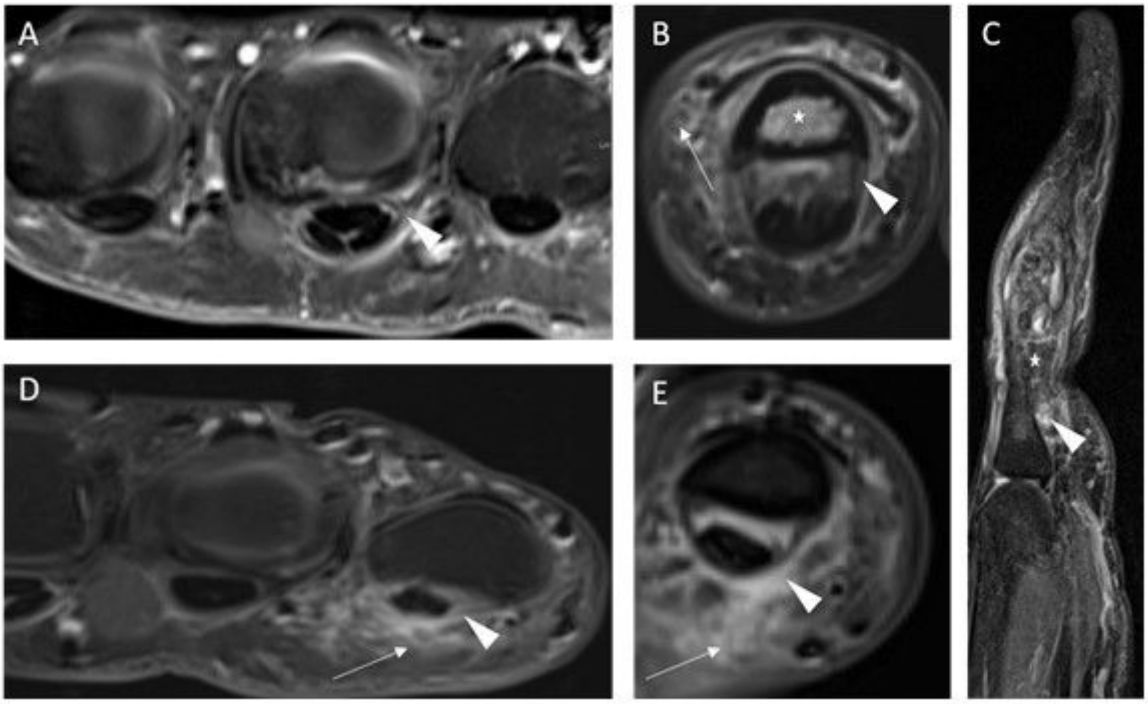

Figure 3

50 year old male with PsA. Transversal fat-saturated T1w images after iv contrast administration (A, B, D, E) and sagittal PDw image (C) depicting A1 and A2 flexor tendon pulleys. A: A1 flexor tendon pulley of D3 with increased surrounding and intrinsic contrast enhancement, especially at the radial aspect of ist course (arrowhead). B: A2 flexor tendon pulley of D3 with increased surrounding and intrinsic contrast enhancement (arrowhead). Additionally, bone marrow edema (asterisk) and extracapsular inflammatory changes (periarticular inflammation, arrow) are illustrated. C: Depiction of A2 flexor tendon pulley of D3 (asterisk) with increased signal intensity, especially in its proximal aspect (arrowhead). D & E: A1 and A2 flexor tendon pulley of D5 with increased surrounding contrast enhancement (arrowheads). Arrow indicates periarticular inflammation.