Diffusion-weighted magnetic resonance imaging (MRI) of wrist and hands in patients with rheumatoid arthritis - reproducibility and correlation with conventional MRI

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Aims and objectives

Rheumatoid arthritis (RA) is a chronic, systemic inflammatory disease. It is primarily characterized by symmetric and erosive synovitis, which if uncontrolled, can lead to joint damage and disability (1). Appropriate therapy can prevent subsequent joint damage. MRI has been proven an important method for non-invasive, mainly qualitative evaluation of peripheral synovial joints in RA (2). Our hypothesis was a quantitative MRI method, diffusion-weighted imaging (DWI) may improve the qualitative evaluation of the disease. Quantitative MRI methods such as Dynamic contrast enhanced imaging (DCEI) and DWI may be used to quantify the synovial proliferation in patients with peripheral inflammatory arthritis (3) (4). DWI is a non-invasive non-contrast quantitative method that has gained an important role in diagnosis, staging and follow up of different musculoskeletal diseases (5) (6). This method is reported to be effective in quantifying bone inflammation during treatment of ankylosing spondylitis (7). The routinely used conventional MRI sequence for detection of bone marrow edema (BME) is short tau inversion recovery (STIR) MRI. The aim of this study was to investigate the performance of DWI in detecting high signal intensity areas (HSIA) as potential signs of bone inflammation, in wrist and metacarpophalangeal (MCP) joints of rheumatoid arthritis (RA) patients, in comparison with STIR MRI images.

Methods and materials

Patients: 26 patients (17 women and 9 men [mean age 62.7 years; age range 37-74 years]) were recruited. Permission from the ethics board and informed patients consents were obtained. All the patients, diagnosed with RA according to ACR (American College of Rheumatology)/EULAR (European League against Rheumatism) 2010 criteria, were known with bone erosions on conventional X-RAY imaging. Patients were in clinical remission phase without any joint swelling, and received Disease Modifying Anti-Rheumatic Drugs (DMARDs) but no biological therapy, without any change in treatment within last 6 weeks.

MRI protocol: MRI of patient's dominant hand were performed on a Philips Panorama 1T (Best, the Netherlands) scanner by using a three canal phased array coil to cover the wrist and hand. Scans covered wrist joints and 2nd to 5th MCP joints. All the patients underwent MRI including coronal DWI (b-values: 0, 267, 533, 800 s/mm²), from which apparent diffusion coefficient (ADC) maps were calculated, coronal T1-weighted (T1w) and coronal STIR images. 13 patients were rescanned after 4 months.
**Image analysis:** STIR scans were scored for BME according to Outcome Measures in Rheumatoid Arthritis Clinical Trials (OMERACT) Rheumatoid Arthritis Magnetic Resonance Imaging scoring system (RAMRIS) and DWI scans were scored for absence (0) or presence (1) of HSIA in the bone marrow. We used DWI with b-value 533 s/mm² to analyze HSIA. One reader reviewed STIR and DWI images separately without knowledge of patient's identity and while scoring STIR images DWI were not accessible and while scoring DWI images STIR images were not accessible. T1w images were used as anatomical reference with both STIR and DWI scoring. Mean ADC values were calculated in the wrist and MCP joints. For calculation of ADC, 21 regions of interest (ROIs) were drawn in each patient on all the bones of wrist joint and MCP joints, including distal radius, distal ulna, all carpal bones except pisiform, and basis and caput of 2nd to 5th metacarpal bones and at the basis of 2nd to 5th proximal phalanx. ROIs were placed by using following 2 methods.

1. **Method A:** This covered the maximal possible subcortical bone areas, including both areas with high and with normal signal, avoiding erosions if present. ROI must be within 1 cm of joint for long bones as radius, ulna, metacarpal and phalanx bones.

2. **Method B:** In DWI positive areas, ROIs were also placed within the HSIA.

![Fig. 1](image_url)
Statistical analysis: All statistical analyses were performed by using SPSS 19.0 software. ADC values were divided into 4 groups based on STIR and DWI scores and nonparametric tests were used to compare groups. The reproducibility of the scores was analyzed by kappa (k) values, intra-class correlation coefficient (ICC), and smallest detectable difference (SDD) and smallest detectable change (SDC).

Results

STIR showed more positive lesions (132 HSIA (=bone marrow edema)) than DWI (50 HSIA) (p<0.001 Fisher's exact test). The ADCs of 4 groups were compared by using one-way ANOVA (p<0.000 Kruskal-Wallis test) and Mann-Whitney U test as seen in the table below. Mean ADC of "STIR-only" (STIR+/DWI-) positive lesions (318±172x10-6 mm2/s) was significantly lower than lesions, where both STIR and DWI were positive (STIR+/DWI+; 894±486x10-6 mm2/s) (p<0.001; Mann-Whitney U test).
Fig. 2: Descriptives of ADC values of 4 groups which are stratified by STIR and DWI scoring and comparison between them shows that there is significant difference between ADC values of both positive areas (STIR+/DWI+) and only STIR positive areas (STIR+/DWI-). Descriptive of ADC values measured by method B. Descriptives of ADC values stratified by STIR scores; 0,1,2,3 according to RAMRIS system and comparison between them shows significant difference between them as ADC values increase with increasing STIR score.

References: Radiology Department, RigsHospital - Herlev/DK
Fig. 3: Boxplots and ADC values stratified by STIR and DWI scoring, showing higher ADC values of DWI positive areas.

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ADC values increased with increasing STIR scores (see table above and graph below).
Fig. 4: Boxplots and ADC values stratified by STIR scores: 0,1,2,3 by using RAMRIS system, showing higher ADC values with increasing STIR score.

**References:** Radiology Department, RigsHospital - Herlev/DK

The median ADC with method 1 (759.5x10-6 mm2/s) was slightly lower than the median ADC with method 2 (846x10-6 mm2/s) (p-value 0.048; Wilcoxon signed rank test) (see graph below).
Fig. 5: Boxplots and ADC values of DWI positive areas measured by 2 methods of ROI placement and there is slight difference between the 2 types of method.

References: Radiology Department, RigsHospital - Herlev/DK

There was no statistically significant difference between baseline and 4 months follow-up scans in any parameters (p=0.9, 0.8 and 0.2 for STIR, DWI and ADC respectively; Wilcoxon signed rank test).

The intraobserver agreement was good to excellent using STIR (k=0.80) and DWI (k=0.76), respectively (baseline). The intraobserver ICC of ADC measurements was 0.85. Intraobserver SDD of ADC at baseline was 60x10^-6 mm^2/s, whereas intraobserver SDC between baseline and 4 months follow up was 108x10^-6 mm^2/s.
Conclusion

DWI, including ADC measurements, in bones of patients with RA were highly reproducible and may partially reflect BME on STIR MRI. ADC values can quantify inflammation and high ADC values may represent more aggressive process of inflammation, which can provide additional help in predicting disease progression and monitoring of treatment response. Further studies are needed to investigate if the method is useful for monitoring treatment response and/or predicting disease progression.

Personal information

References


