Magnetic Resonance Imaging of the Wrist and Finger Joints in Patients with Inflammatory Joint Diseases

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ABSTRACT. ***Objective.*** To study magnetic resonance imaging (MRI) features in the wrist and metacarpophalangeal (MCP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints in 4 patient groups: early rheumatoid arthritis (RA) (< 3 yrs); established RA (> 3 yrs); other arthritis; arthralgia.

Methods. MRI was obtained before and after contrast (gadodiamide) injection of the wrist and finger joints in 103 patients and 7 controls. The study included: (1) 28 patients with disease duration < 3 yrs who fulfilled the American College of Rheumatology (ACR) criteria for RA; (2) 25 patients with RA disease duration > 3 yrs who fulfilled the ACR criteria; (3) 25 patients with reactive arthritis, psoriatic arthritis, or mixed connective tissue disease; and (4) 25 patients with arthralgia. The following MRI variables were assessed: number of joints with enhancement after contrast injection, number of joints with joint fluid, and number of bones with edema in the wrist and fingers. The volume of the enhancing synovial membrane after contrast injection in the MCP, PIP, and DIP joints was manually outlined. MR images were scored independently under blinded conditions.

Results. Bone marrow edema was found in 68% of the patients with established RA, and the number of bones with edema was significantly higher in patients with established RA compared to patients with early RA, other arthritis, and arthralgia (Mann-Whitney $p < 0.04$). Bone edema was not found in patients with arthralgia. There was marked overlap within and between the patient groups. No differences in MRI features were found between patients with early RA and patients with other arthritis. The volumes of the synovial membrane in the MCP, PIP, and DIP joints were significantly higher in patients with arthritis compared to patients with arthralgia.

Conclusion. Although there was marked overlap between the arthritis patient groups, MRI determined bone marrow edema and synovial membrane volumes provided additional information about disease activity and may be used as a marker of it. Bone marrow edema appeared with the highest percentage in patients with long duration of RA (> 3 yrs) and is probably secondary to changes in inflammatory activity. (J Rheumatol 2001;28:2193–200)

Key Indexing Terms:
RHEUMATOID ARTHRITIS ARTHRITIS MAGNETIC RESONANCE IMAGING
ACUTE PHASE PROTEINS BONE EDEMA GADOLINIUM

Magnetic resonance imaging (MRI) allows direct visualization of inflammatory soft tissue and cartilage and bone changes in rheumatoid arthritis (RA), a "whole organ assessment"[1]. MRI has the potential to assess both the inflammatory process and the resulting structural damage of surrounding tissue and thus may provide quantitative information about the severity and activity of the synovial inflammation.

MRI studies in RA have mainly evaluated the knee, the wrist, or the metacarpophalangeal (MCP) joints[2,3]. MRI is more sensitive as well in the detection of inflammatory changes (synovitis) and bone changes (erosions) than the clinical examination and radiography[4].

The volume of the synovial membrane after contrast can be estimated by different methods[5]. This volume has been found to be correlated with histologic findings and to some extent with clinical variables[6-9]. Thus, synovial

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volumes have been found to be greater in clinically active knee, wrist, and MCP arthritic joints compared with inactive joints[10,11]. Manually outlining synovial volumes is a time consuming process and therefore not useful in clinical practice — other MRI features such as bone erosions and bone edema might be more useful in daily practice.

Although studies have suggested the importance of quantitative assessments of the synovial membrane as a marker of disease activity, large volume variations within clinically uniform groups and considerable overlap between clinically active and inactive arthritic joints have been found[10,12].

Preliminary findings suggest that MRI changes (synovitis, bone edema, and bone erosions) may be useful to predict joint damage[13,14]. Other studies indicate that the localization of inflammatory changes may be used to differentiate between RA and spondyloarthropathy[15-17]. Bone marrow edema may be useful in differentiating patients with poor prognosis from those with good prognosis[18].

However, it is uncertain which MRI techniques and features are the most useful in patients with different kinds of arthritis. We compared MRI features such as synovial membrane volumes, number of joints with synovial membrane made more visible by contrast enhancement, number of bones with marrow edema, and number of joints with effusion in patients with different varieties of arthritis.

MATERIALS AND METHODS

Subjects. Four groups of patients were studied — (1) 28 patients with early RA with disease duration < 3 years. All patients fulfilled the American College of Rheumatology (ACR) 1987 classification criteria for RA[19]. (2) 25 patients with RA with disease duration > 3 years by ACR criteria. (3) 25 patients who did not fulfil ACR criteria who had synovitis in the finger joints on clinical examination at the time of inclusion. By this definition this group consisted of different subgroups — patients with reactive arthritis (n = 16), psoriatic arthritis (n = 8), and mixed connective tissue disease (n = 1). (4) 25 patients with arthralgia but no clinical signs, past or present, of synovitis.

A total of 103 patients and 7 healthy controls (median age 41.4 yrs, range 31–49) were studied.

Three patients were excluded, one from Group 3 due to claustrophobia in the MRI unit, one each from Group 3 and Group 4 due to technical problems in relation to MR examination.

MRI process. MRI of the wrist and finger joints (MCP), proximal interphalangeal (PIP), and distal interphalangeal (DIP) joints in the most symptomatic hand was performed using a 1.5 T MR system (Gyroscan ACS-NT, Philips, Best, The Netherlands). Coronal short-tau inversion recovery (STIR) images (repetition time/echo time/inversion time 2000/90/160 ms) with 2.5 mm slice thickness and 0.2 mm inter-slice gap were obtained. Examination time was 8–12 min. 3-D coronal T1 weighted fast-field echo (FFE) images (repetition time/echo time/slice thickness 25–26/4.6 ms/1 mm) with flip angle 50° were obtained. Examination time was 6–8 min. Voxel size was $0.86 \times 0.86 \times 1$ mm. While the patient remained in the same position in the MR unit, the contrast agent gadodiamide (Gd-DTPA-BMA, Gd; Nycomed Amersham A/S, Denmark), 0.05 mmol/kg body weight, was injected intravenously through a cannula inserted prior to the examination. The T1 weighted 3-D FFE images were repeated. In all sequences matrix size was 256×256 and field of view (FOV) 220 mm. Patients were positioned prone with the hand above the head and with a circular surface receive-only coil placed over the hand. The position was maintained and movement avoided with the aid of sandbags. MRI of finger joints was started within 30 s after the contrast injection to minimize synovial fluid enhancement.

MRI evaluation. The 3-D data set of the wrist and finger joints was analyzed by multiplanar reconstruction using standard software within the unit.

The synovial membrane was identified by the increased signal intensity on postcontrast T1 weighted images. The areas of synovial membranes were outlined in all 100 patients (total of 1400 joints) on each transversal slice in the 1st–5th MCP, PIP, and DIP joints (14 joints). Outlining was done manually by visual analysis, and based on these the areas were calculated automatically. The synovial volumes were sums of volumes in the MCP, PIP, and DIP joints and were calculated by summation of slices: synovial membrane volume = $\sum(Ar_{syn,i} \times ST)$, where ST is slice thickness and $Ar_{syn,i}$ represents the areas of the synovial membrane in slice i. In addition to manual outlining of the synovial membrane, the number of joints with synovial enhancement after contrast was summed for the wrist, MCP, PIP, and DIP joints on the T1 weighted images.

Joint effusion was identified as high signal intensity on STIR images. The number of joints with effusion were summed for the wrist, MCP, PIP, and DIP joints.

The bone marrow edema pattern zone was hyperintense on STIR images. The number of bones with edema was summed for the wrist, MCP, PIP, and DIP joints. Results were calculated for the total bone and did not differentiate between presence of bone edema in the head or at the base of the bone. All measurements of MR data were conducted by an investigator blinded to the clinical data.

Clinical variables. Three skilled investigators blinded to MRI findings performed the clinical examination of each patient. Evaluation of the joints was performed by uniform criteria, although a study of observer variation was beyond the scope of this study. Subjective and semiobjective data included a joint count, where tenderness and swelling were assessed separately in each joint, including the DIP joints. Individual joints were scored on a 0–3 scale and joint scores were summarized for a total of 36 joints: shoulder, elbow, wrist, MCP, PIP, DIP, and knee joints. Physician and patient global assessments of disease activity on a 1–5 scale were collected, as well as patient's assessment of pain intensity on a 100 mm visual analog scale (VAS), a Health Assessment Questionnaire (HAQ), duration of morning stiffness (min), and duration of disease. Levels of erythrocyte sedimentation rate (ESR; reference level 0–15 mm/h), C-reactive protein (CRP; reference level < 10 mg/ml), and rheumatoid factor (RF; reference level < 8 IU/l) were assessed. Clinical variables were measured the same day as the MRI.

The local ethics committee approved the protocol and informed consent was obtained from all patients.

Statistical analysis. Nonparametric analyses were used with 5% level of significance. In analyses with more than 2 groups, the Kruskal-Wallis test (one way analysis of variance by ranks) was performed. In case of significance of the Kruskal-Wallis test ($p < 0.05$), the Mann-Whitney U test (2 sample rank-sum test) was used for pairwise comparison between groups. Statistical correlations were assessed by Spearman test (Rs) and Bonferroni correction was performed in each case.

RESULTS

The demographic data and measures of disease activity of the 4 patient groups are shown in Table 1.

Bone edema. The number of bones with edema differed significantly within the 4 groups ($p < 0.0001$, Kruskal-Wallis test). Bone edema was found more frequently in 17 of 25 patients (68%) with established RA (> 3 yrs) than in patients with early RA (< 3 yrs) or patients with other arthritis (Table 2, Figures 1–3). Bone edema was not found in patients with arthralgia or in the control group.

Table 1. Clinical and laboratory measures and manually outlined volume of the synovial membrane (Vsm) after contrast (Gd) in patients with RA, other arthritis, and arthralgia. Median values are given with the range in parentheses.

	RA, < 3 yrs	RA, > 3 yrs	Other Arthritis	Arthralgia
Age, yrs	51 (22–64)	41 (25–44)	46 (28–59)	43 (31–49)
Disease duration, mo	7 (1–32)	120 (24–624)	39 (1–240)	8 (1–336)
Physician's global assessment, 1–5	3 (1–4)	3 (1–4)	3 (2–4)	2 (1–4)
Patient global assessment, 1–5	3 (1–5)	3 (1–4)	3 (2–5)	4 (2–5)
Pain, VAS, mm	29.5 (0–92)	46 (0–98)	57 (9–100)	61 (4–100)
Morning stiffness, min	45 (0–1440)	90 (0–1440)	90 (0–1440)	150 (0–1440)
HAQ, 0–3 scale	0.5 (0–1.6)	0.6 (0–1.7)	0.3 (0–2.3)	0.8 (0–2)
ESR, mm/h	6 (1–39)	5 (0–58)	4 (1–30)	7 (1–39)
CRP, mg/ml	5 (5–71)	6 (5–136)	6 (5–39)	5 (5–41)
Rheumatoid factor, IU/l	0 (0–338)	61 (0–358)	0 (0–116)	0 (0–153)
Swollen joint count, 36 joints	6.5 (0–20)	13 (0–24)	9 (0–28)	0 (0–9)
Tender joint count, 36 joints	5 (0–31)	9 (0–28)	8 (0–33)	16 (0–34)
Vsm after Gd, ml	0.2 (0–6.0)	0.6 (0–15.8)	0 (0–4.3)	0 (0–0.9)

HAQ: Health Assessment Questionnaire, VAS: visual analog scale, ESR: erythrocyte sedimentation rate, CRP: C-reactive protein. The synovial volumes (Vsm) are given in ml.

Table 2. MRI of the wrist and finger joints in patients with inflammatory joint diseases. Data are percentage (%) of patients in which synovial enhancement (joint enhancement), joint effusion, and bone edema were calculated. The median number of joints (ranges) with enhancement after contrast and with effusion and the number of bones with edema in the wrist, MCP, PIP, and DIP joints are listed.

	RA, < 3 yrs		RA, > 3 yrs		Other Arthritis		Arthralgia	
	%	Median (range)	%	Median (range)	%	Median (range)	%	Median (range)
No. joints with synovial enhancement	75	2 (0–9)	76	4 (0–13)	56	1 (0–8)	16	0 (0–4)
No. joints with effusion	39	9 (0–6)	72	1 (014)	43	0 (0–11)	40	0 (0–3)
No. bones with bone marrow edema	39	0 (0–13)	68	3 (0–20)	17	0 (0–7)	0	—

Synovial membrane. MRI synovial volumes differed significantly within the patient groups (Table 1) ($p < 0.0001$, Kruskal-Wallis test). Total synovial volume was significantly higher in patients with RA and other arthritis compared to patients with arthralgia. A marked overlap existed between patients with RA and patients with other arthritis.

Synovial volume was weakly correlated to swollen joint count on a 0–3 scale ($Rs = 0.36$, $p < 0.01$), but not with other clinical or laboratory measures of disease activity after Bonferroni correction.

Synovial membrane enhanced after contrast was found in all 4 patient groups, but not in controls (Table 2). The number of joints with synovial enhancement was higher in patients with established RA (> 3 yrs) compared to patients with early RA (< 3 yrs) and those with other arthritis or with arthralgia, but again there was marked overlap between patient groups with arthritis (Table 2).

On MRI, a linear trend was found in the proportion of joints with enhancement in relation to swollen joint count in 16 of 18 joints in the hand (chi-squared test for linear trend, $p < 0.05$), while no similar relation was found for the tender joint count.

Joint effusion. Joint effusion was seen in all 4 patient groups, most frequently (72%) in patients with established RA (> 3 yrs) and in 2 healthy controls (Table 2).

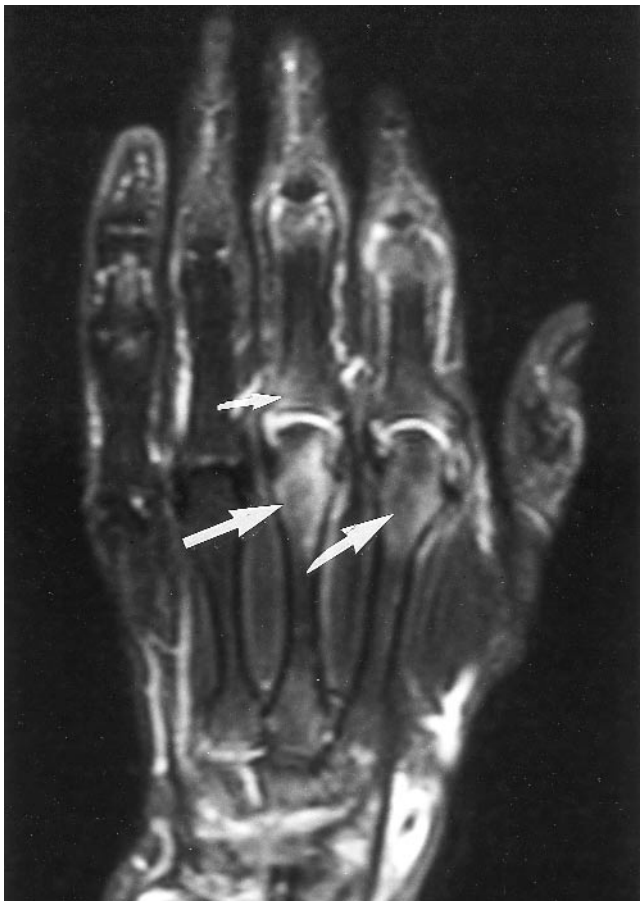
DISCUSSION

The volume of the synovial membrane could be used as an outcome measure. As outlining manually is a time consuming process, not useful in clinical practice, less time consuming MR features are needed to predict joint damage.

MRI measurements of variables such as synovial membrane volumes, bone marrow edema, and joint effusion have been evaluated in relatively small, clinically uniform, patient groups[12,13]. To our knowledge, no one has previously investigated 103 patients divided into 4 categories in one study.

Preliminary data suggest that synovitis, bone edema, and MRI determined bone erosions may predict later joint damage[13,14].

The fat suppression MRI technique STIR can be used to



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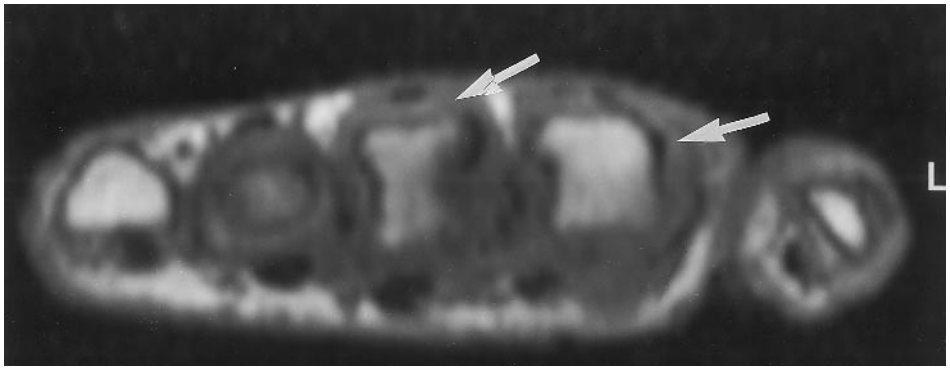

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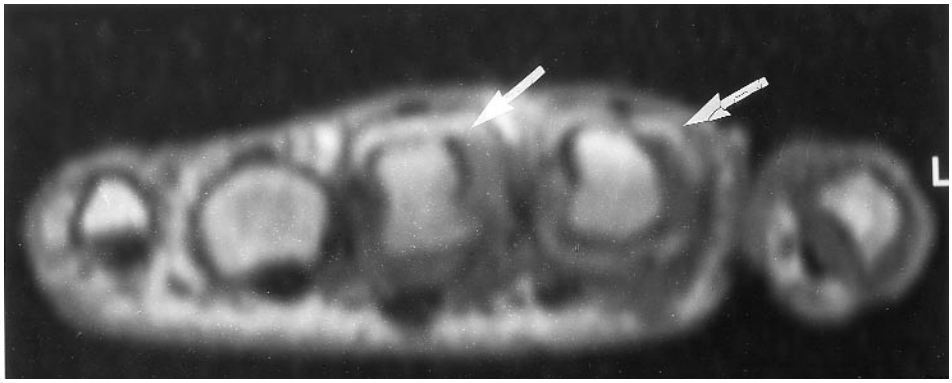

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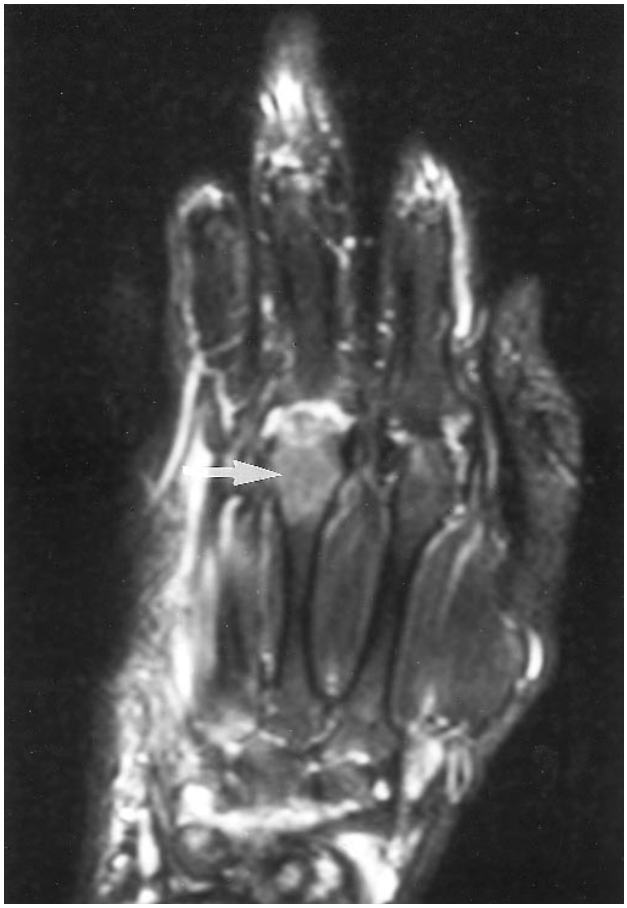
detect water accumulation, i.e., bone edema, edematous synovial tissue (synovitis), and joint effusion that appear with a bright high signal intensity on MR images[20].

Bone marrow edema was found in a higher percentage (68%) of patients with established RA (> 3 yrs) compared to patients with early RA (< 3 yrs) (39%) and patients with other arthritis (17%). The median number of bones with edema in the hand was higher in patients with established RA (> 3 yrs), but we found large variations within the arthritis patient groups as well as overlap between the groups. The MRI findings of bone edema in patients with established RA (> 3 yrs) are in accord with a study[21] that found bone edema in 68% of patients with RA. Bone edema was only found in patients with arthritis, and not in patients with arthralgia or in the control group. Further, the number of bones with edema was correlated with clinical signs of disease activity, ESR, HAQ, and patient global disease activity assessment. Thus, MRI determinations of bone marrow edema provided additional information about

Figure 1. A. Coronal STIR MR image in a 49-year-old woman (12 months' duration of RA). ESR and CRP are normal, but RF is increased. Swollen joint score = 2 for both 2nd and 3rd MCP joints. Bone edema in the 2nd and 3rd metacarpals (arrows) and proximal phalanges. Joint fluid within distal radius ulna joint, 2nd and 3rd MCP and PIP joints. B. In the same patient, transverse T1 weighted MR image through the MCP joints before contrast. Increased area of synovial membrane in the 2nd and 3rd MCP joints. C. After contrast, the increased synovial membrane is enhanced markedly in the 2nd and 3rd MCP (arrows).



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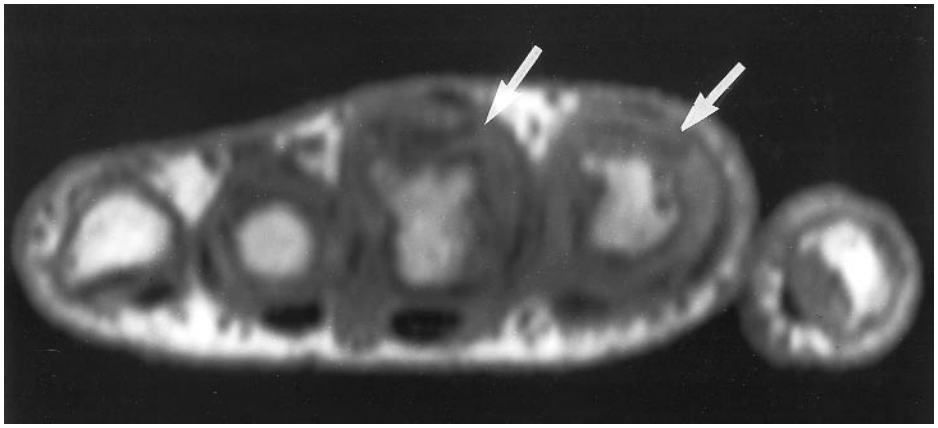

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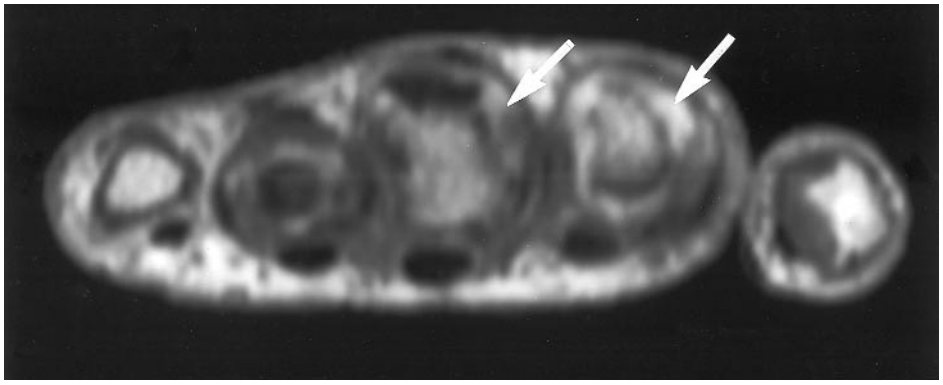

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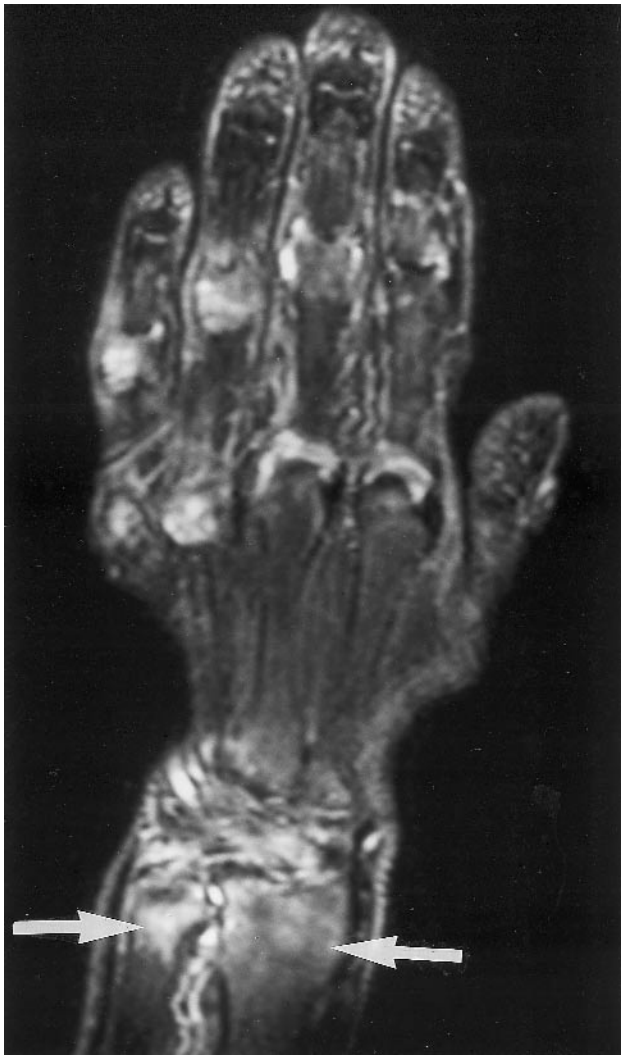
Figure 2. A. Coronal STIR MR image in a 30-year-old man (72 months' duration of seronegative psoriatic arthritis). ESR and CRP are increased. Swollen joint score: 2nd MCP = 3, 3rd MCP = 2. Bone edema within the 2nd and 3rd metacarpals (arrows). Joint fluid in 2nd and 3rd MCP joints. B. The same patient: transverse T1 weighted fast field echo image before contrast. Increased area of synovial membrane in 2nd and 3rd MCP joints (arrows). C. After contrast, the increased synovial membrane is enhanced markedly in 2nd and 3rd MCP joints (arrows).

disease activity in patients with arthritis and may be a possible marker of disease activity.

Alternatively, studies have shown that evaluation of bone marrow edema by disease sites may help to differentiate early RA from other inflammatory arthritis, particularly entheseal disease sites or those that are primarily intrasynovial, as in RA[17,22].

The synovial volumes were significantly greater in patients with arthritis compared to those with arthralgia. However, large volume variations within the arthritis patient groups were found. This may indicate that the measured volumes are disease related, but it seems there is a marked overlap between the groups. Synovial volumes were weakly correlated with swollen joints on a 0–3 scale in the MCP, PIP, and DIP joints. Thus, the clinical presentation of a joint did not unequivocally reflect the amount of inflamed synovial membrane. The synovial membrane determinations were not correlated to the clinical or laboratory measures of disease activity, probably because they are



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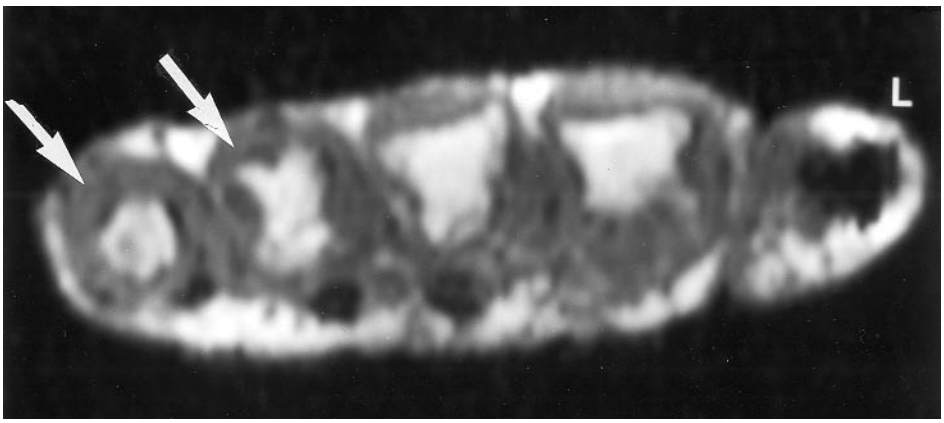
measures of global disease activity, which are not reflected in a few small joints such as the MCP, PIP, and DIP. The large volume variations within the same patient groups may reflect important differences in disease activity/severity. As suggested[10,23], a high synovial membrane volume in a clinically uninflamed and inactive joint may indicate the presence of some subclinical inflammatory activity and a higher risk of progressive joint destruction than in a joint with low synovial membrane volume.

MRI determined synovial enhancement in the wrist and finger joints was nearly equal — 75% in patients with early RA (< 3 yrs) and 76% in patients with established RA (> 3 yrs). This indicates that synovial enhancement is a rather constant phenomenon in RA, independent of disease duration. Synovial enhancement of the wrist and finger joints was found to a lesser extent in patients with other arthritis and in only 16% of the patients with arthralgia. Some of these patients might later develop arthritis, although any predictive value of synovial enhancement remains to be clarified.

Consequently, this may indicate that bone edema is a later sign of inflammatory change than presence of synovial enhancement. A study in early inflammatory arthritis

Figure 3. A. Coronal STIR MR image in a 63-year-old man (336 months' duration of seronegative RA). ESR was increased, CRP normal. Swollen joint score: 2nd MCP = 1, 3rd MCP = 1, 4th MCP = 0, 5th MCP = 2. Bone edema in radius, ulna (arrows), carpals, metacarpals, and proximal phalanges. Joint fluid in 2–4 MCP and PIP joints. B. Transverse T1 weighted fast field echo images before contrast in the same patient. Increased area of the 4th and 5th joints (arrows). C (opposite). After contrast, the increased synovial membrane is enhanced markedly but heterogeneously in the 4th and 5th MCP joints, which probably represents both active pannus and inactive tissue (fibrosis).



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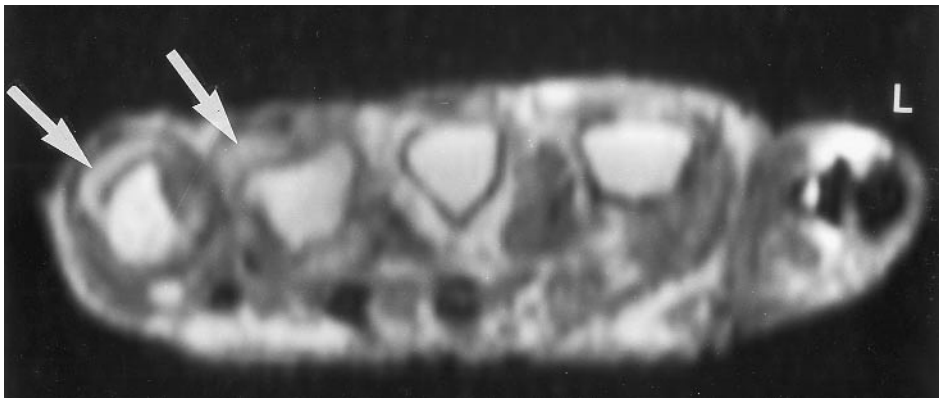

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suggested that synovitis may develop initially, and is often followed by bone marrow edema and finally by bony erosions, as seen on MRI scans[24].

The patient groups in our study reflect the diagnostic problems of the outpatient rheumatology clinic. Patients with arthralgia may consist of patients with pre-arthritis, but also a considerable number of patients with fibromyalgia. This may explain the large variation in tender joint count, HAQ results, and morning stiffness in this group.

None of the MRI findings were related to CRP. CRP has been found to be the best marker of disease activity[25-28] and for disease prognosis in RA, especially early in the disease[27,29], whereas rheumatoid factor is only a qualitative marker in early RA[27].

Although the finger joints represent a small fraction of joints involved in arthritis, the finger joints were chosen for the study because of their importance and frequency of involvement[30], as well as for feasibility of measurement, both clinically and by MRI. Laboratory variables such as ESR and CRP may be influenced by factors unrelated to the rheumatoid disease, and may be related to the effects from all joints. Scores for swollen and/or tender joints also vary considerably in clinical assessment of RA[31].

Synovitis and joint effusion were closely related and were found in 60% of our patients with established RA (> 3 yrs). However, joint effusion was also found in patients with arthralgia and in 2 controls. This indicates that joint effusion estimated by MRI is less specific than other MRI findings and cannot be used to distinguish arthritic joints from normal controls.

In summary, presence of bone marrow edema may be used as a marker of disease activity and is probably secondary to inflammatory changes. Although it seems to be closely correlated with clinical and laboratory disease measures, the importance of bone edema needs to be clarified in longitudinal studies. The synovial volume may be used as a disease marker, but cannot provide diagnostic distinction among patients with arthritis. Presence of synovial enhancement may reflect some severity of synovitis. Future longitudinal studies are needed to clarify the prognostic value of bone marrow edema in evaluating joint damage.

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