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ORIGINAL ARTICLE

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Comparison in values of color flow signals and vascular resistance of synovial vascularity demonstrated by Doppler sonography between knee and metacarpophalangeal joints of patients with rheumatoid arthritis

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Abstract Synovial vascularity of 12 patients with rheumatoid arthritis (RA) was examined by Doppler sonography for color flow signals and vascular resistance on knee joints and metacarpophalangeal (MCP) joints, and the results were compared with each other and with C-reactive protein (CRP) levels of the patients. A significant correlation was observed between knee resistance index (RI) and MCP-RI ($P = 0.0140$), but not between knee color flow signals and MCP color flow signals ($P = 0.1029$). A significant correlation was also observed between knee color flow signals and knee RI ($P = 0.0107$), and knee pulsatility index (PI) ($P = 0.0146$). On the other hand, no correlation was observed between MCP color flow signals and MCP-RI ($P = 0.828$), and MCP-PI ($P = 0.434$). There was no significant correlation between CRP levels and grades of color flow signals, RI, and PI for both knee and MCP joints. Doppler sonographic evaluation of RI, especially knee RI, could be a useful marker for estimating synovial inflammation in RA patients.

Key words Color flow signals · C-reactive protein (CRP) · Knee joints · Metacarpophalangeal (MCP) joints · Resistance index (RI)

Introduction

Synovial vascularity in the joints of patients with rheumatoid arthritis (RA) has been clearly demonstrated by Doppler sonography.[1–5] A wide variety of joints have been scanned in studies of sonographic evaluation of RA, including knees,[1,5–7] wrists,[8,9] metacarpophalangeal (MCP) joints,[3,9,10] and proximal interphalangeal (PIP) joints.[8,9] In previous studies of sonographic evaluation of synovial vascularity and vascular resistance, we scanned knee joints.[5,11,12] Metacarpophalangeal and PIP joints are the joints that have been most often scanned in studies of sonographic evaluation of synovitis in RA patients.[3,8–10] However, there have been no significant comparisons of informativeness of Doppler sonographic findings between knee joints and MCP or PIP joints in the same RA patients. In the present study, knee and MCP joints of 12 RA patients were examined simultaneously for color flow signals and vascular resistance of synovial vascularity. The results for the knee and MCP joints of each patient were compared with each other and with the C-reactive protein (CRP) level of the patient. We attempted to find the most valuable Doppler sonographic finding which properly estimates the synovial inflammation in RA patients.

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Materials and methods

Patients and joints examined

Twelve patients with RA were enrolled in the present study. The subjects were 10 women and 2 men with an average age of 58.3 years (range, 39–78 years) and a mean disease duration of 2.48 years (range, 0.6–5.3 years). All patients satisfied the American College of Rheumatology 1987 revised criteria for RA.[13]

With each patient, both knee joints and the 2nd and 3rd MCP joints of both hands were scanned by Doppler sonography. The 2nd and 3rd MCP joints were selected because those two fingers are more frequently affected by RA than the other three fingers.

Doppler sonography

Color flow signals[5] and vascular resistance (resistance index [RI] and pulsatility index [PI])[11] were evaluated using methods described elsewhere. Briefly, a Toshiba Aplio 80 system

(Toshiba Medical Systems, Tokyo, Japan) (transmit power, <5000 mW/cm^2; low pass wall filter No. 3; medium persistence) was used for Doppler sonography. A pulse repetition frequency of 11.7–12.2 kHz was used for power Doppler sonography (PDS), and the lowest filter setting (125 Hz) was used for spectral Doppler sonography (SDS). A multidimensional scanner (PLT-704 AT) (Toshiba Medical Systems) at a power setting of 5.3 MHz was used as the transducer. For scanning of MCP joints, a polyacrylamide gel pad (GE-Yokogawa Medical Systems, Tokyo, Japan) was placed on the joints. Both knees were scanned at the suprapatellar region longitudinally and transversely, and MCP joints were scanned longitudinally and transversely on the dorsal side of the joints. One of the color flow signals on the image panel produced from joint scans was selected, and that joint was scanned further with spectral Doppler sonography to draw a velocity wave. Intensity of the color flow signals obtained by PDS was graded using a modified version of Klauser's method[4,5]: grade 0, no color flow signals; grade 1, 1–4 color flow signals; grade 2, 5–8 color flow signals; grade 3, more than 9 color flow signals. Vascular resistance was assessed by measuring RI and PI, which were automatically calculated by tracing manually the margin of the velocity wave obtained from pulsed-wave SDS, using the following formula: RI = peak systolic (maximum) velocity–end diastolic (minimum) velocity/peak systolic (maximum) velocity; PI = peak systolic (maximum) velocity–end diastolic (minimum) velocity/mean velocity. RI and PI are two similar indicators to represent vascular resistance. Difference in meaning of RI and PI is not clearly elucidated. As will be taken from the formula, RI values are limited to 1.0 at maximum whenever the diastolic velocity is 0, whereas PI values may exceed 1.0. A reduced vascular resistance represents an increased perfusion (permeability) of blood flow or increased vascular beds.[2] Mean values of color flow signals were calculated as the mean grades of sonographic images with positive color flow signals, out of the total of four sonographic images (longitudinal and transverse) obtained for each pair of knees and the total of eight sonographic images (longitudinal and transverse) obtained for each set of four MCP joints. Mean RI and PI were calculated as the mean RI and PI values of sonographic images with positive velocity waves, out of the total of four sonographic images (longitudinal and transverse) obtained for each pair of knees and the total of eight sonographic images (longitudinal and transverse) obtained for each set of four MCP joints. We assessed the following types of correlation: between knee and MCP joints for grade of color flow signals, RI and PI; between mean grade of color flow signals and RI, and PI of knee and MCP joints; between CRP levels and grade of color flow signals, RI and PI of knee and MCP joints.

Blood samples used to measure CRP levels were drawn at the same time that the Doppler sonography was performed.

Statistical analysis was performed using the J-Stat software package for Windows. For two items including color flow signals, correlation between two values was assessed using Spearman's rank correlation coefficient. For two items excluding color flow signals, correlation between two values was assessed using the regression line coefficient. P values of less than 0.05 were considered to indicate significance.

Results

For the right knee joint of patient 1, PDS produced grade 2 color flow signals (Fig. 1a) and SDS produced a velocity wave with RI of 0.81 and PI of 1.91 (Fig. 1b). For the left 2nd MCP joint of patient 1, PDS produced grade 3 color flow signals (Fig. 1c) and SDS produced a velocity wave with RI of 0.82 and PI of 1.96 (Fig. 1d). Color flow signals were obtained for all 24 knee joints. In contrast, color flow signals were obtained for only 24 of the 48 (50%) MCP joints: 1 joint in four patients, 2 joints in six patients, and 4 joints in two patients (Table 1). Mean values of grade of color flow signals, RI, and PI for the knee and MCP joints and CRP levels are shown in Table 1. Mean values of color flow signals, RI, and PI of 12 patients were compared between knee and MCP joints. No significant correlation was observed in color flow signals between knee and MCP joints ($r = 0.5455$, $P = 0.1029$; Fig. 2a), whereas a significant correlation was observed in RI values between knee and MCP joints ($r = 0.6849$, $P = 0.0140$; Fig. 2b). A correlation of PI values between knee and MCP joints was not significant but close to significance ($r = 0.5694$, $P = 0.053$; Fig. 2c). Correlations of knee color flow signals (knee signals) with knee RI and knee PI were significant in both ($r = -0.7696$, $P = 0.0107$ and $r = -0.736$, $P = 0.0146$, respectively). On the other hand, no correlations of MCP-signals with MCP-RI and MCP-PI were observed ($r = 0.0656$, $P = 0.828$ and $r = 0.2356$, $P = 0.434$, respectively). There was no significant correlation between CRP levels and grade of color flow signals, RI, or PI for both knee and MCP joints.

Discussion

One disadvantage of sonography for examination of joints is the inability to scan many joints in a short time, because sonography is time consuming. The following joints have been scanned in studies of sonography: both knees,[1,5–7] the second MCP joint of the right hand,[3] the first MCP joint and 5 PIP joints,[9] 1 MCP joint and 1 PIP joint,[8] and all 10 MCP joints.[10] Selections of sites and numbers of joints to be scanned seem to be made without having any evidence of sonographic findings. In our previous studies of sonographic evaluation of synovial vascularity and vascular resistance, we have scanned knee joints.[5,11,12] Other investigators prefer to use the finger joints for studies of sonography,[3,8–10] presumably based on the assumption that small joints are more often affected by arthritis in RA patients. The present findings indicate that the Doppler sonographic scans of knee joints can clearly illustrate synovitis (especially synovial vascularity) in RA patients. All 24 of the knee joints in the present study had color flow signals, whereas only half (24/48) of the MCP joints had color flow signals. This differ-

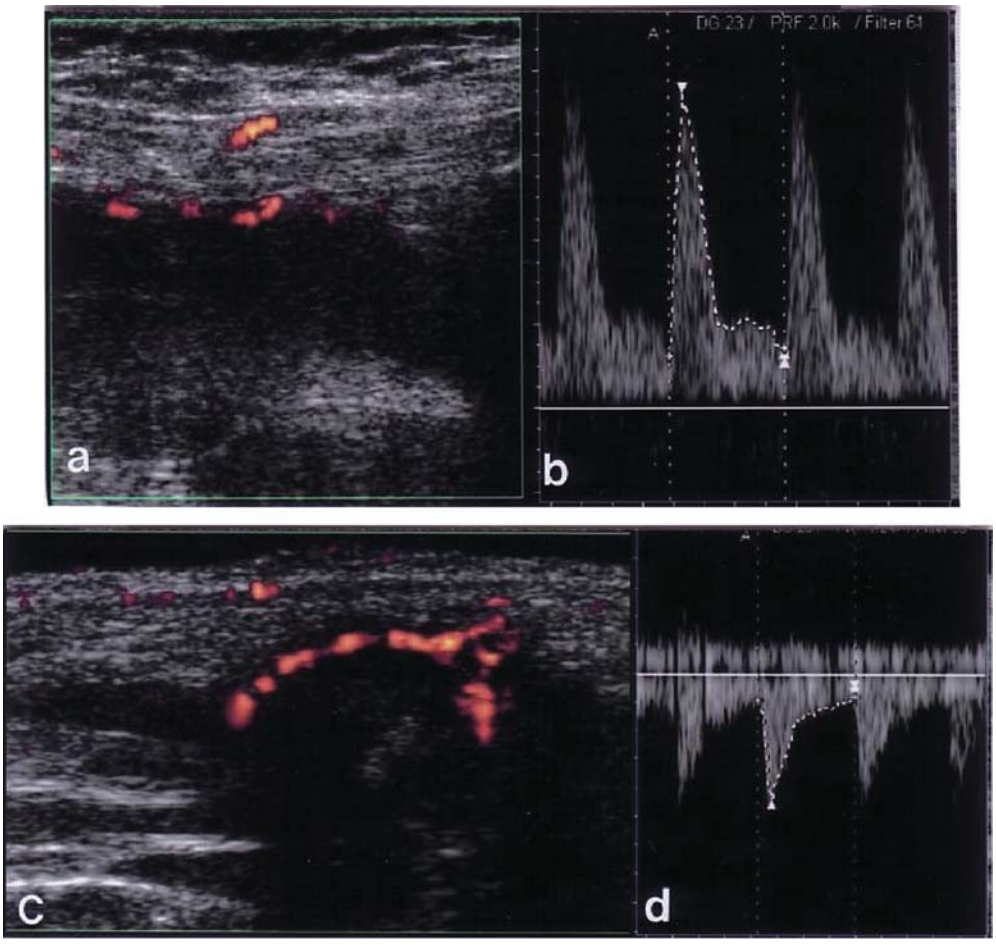

Fig. 1. Power Doppler sonograms (**a,c**) and spectral Doppler sonograms (**b,d**) of the right knee joint (**a,b**) and left 2nd metacarpophalangeal joint (**c,d**) of patient 1. **a** Grade 2 color flow signals were observed on the suprapatellar longitudinal image of the right knee. **b** resistance index (RI) (0.81) and pulsatility index (PI) (1.91) of the same view of the right knee. **c** Grade 3 color flow signals were observed on the dorsal longitudinal image of the left 2nd metacarpophalangeal joint. **d** RI (0.82) and PI (1.96) of the same view of the left 2nd metacarpophalangeal joint

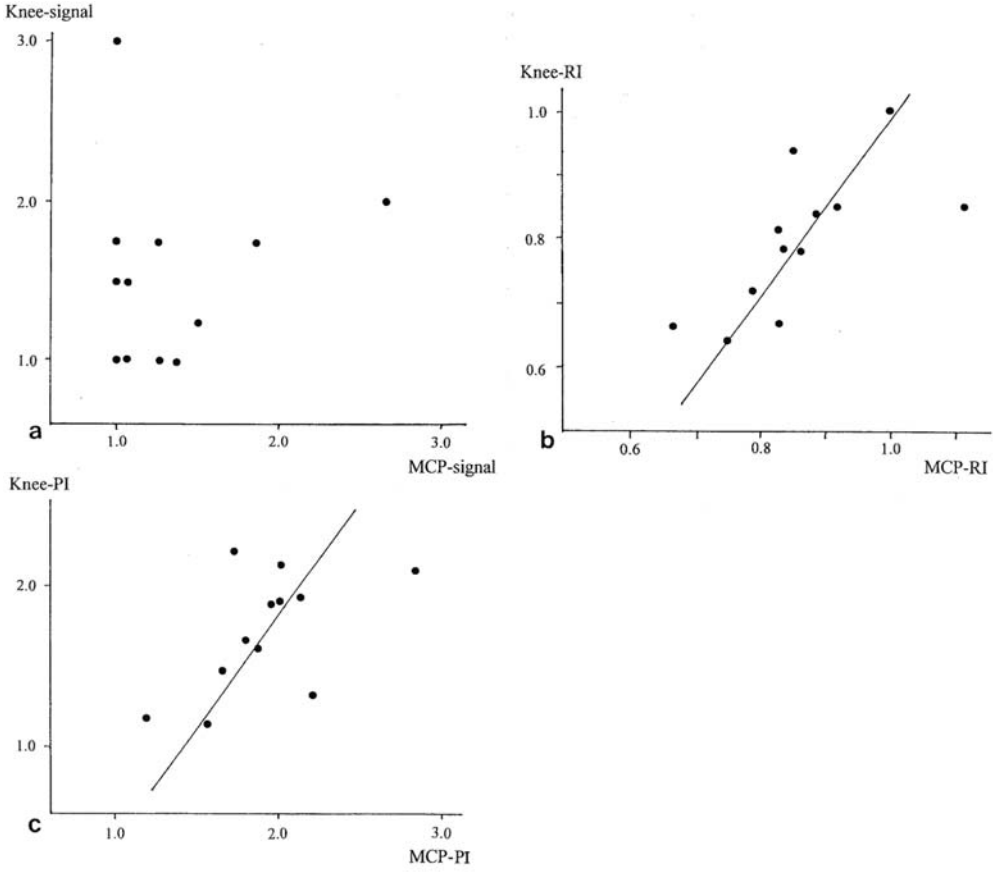

Fig. 2a–c. Results of analysis of correlation between knee and metacarpophalangeal (MCP) joints in Doppler sonographic findings. **a** There was no significant correlation between grades of color flow signals of knee joints (*Knee-signal*) and those of MCP joints (*MCP-signal*). $r = 0.5455$, $P = 0.1029$ (Spearman's rank correlation coefficient). **b** There was significant correlation between resistance index of knee joints (*Knee-RI*) and RI of MCP joints (*MCP-RI*). $r = 0.6849$, $P = 0.0140$ (regression line coefficient). **c** There was no significant correlation between pulsatility index of knee joints (*Knee-PI*) and PI of MCP joints (*MCP-PI*). $r = 0.5694$, $P = 0.053$ (regression line coefficient)

Table 1. Clinical and Doppler sonographic findings of 12 patients with rheumatoid arthritis: comparison in values between knee and metacarpophalangeal joints

No. of patients	Age (years)/ sex	Duration of disease (years)	CRP (mg/dl)	No. of joints with color flow signals		Grade of color flow signals (mean)		RI (mean)		PI (mean)	
				Knee	MCP	Knee	MCP	Knee	MCP	Knee	MCP
1	44/F	4.5	4.17	2	2	2.0	2.66	0.81	0.83	1.61	1.88
2	39/M	5.3	1.75	2	1	1.0	1.0	1.0	1.0	2.15	2.0
3	54/F	2.5	3.18	2	2	1.75	1.25	0.66	0.67	1.18	1.19
4	48/F	2.4	0.88	2	2	1.50	1.0	0.78	0.86	1.65	1.80
5	77/F	1.7	0.84	2	1	1.0	1.0	0.85	0.92	1.89	1.96
6	65/M	3.8	2.53	2	4	1.0	1.38	0.85	1.13	2.21	1.73
7	72/F	2.4	1.70	2	2	1.25	1.5	0.78	0.84	1.90	2.03
8	65/M	1.5	5.30	2	1	1.75	1.0	0.67	0.83	1.34	2.21
9	46/M	1.8	2.70	2	2	3.0	1.0	0.64	0.75	1.13	1.57
10	58/M	2.1	3.94	2	1	1.5	1.0	0.72	0.79	1.47	1.65
11	78/M	1.2	0.78	2	4	1.75	1.88	0.84	0.89	2.11	2.84
12	63/M	0.6	4.60	2	2	1.0	1.25	0.94	0.85	1.92	2.16

CRP, C-reactive protein; MCP, metacarpophalangeal; RI, resistance index; PI, pulsatility index

ence in the frequency of detection of color flow signals may be due to a difference between knee and MCP joints in the extent of the inflammation associated with synovitis.

In the present study, CRP levels did not correlate with any sonographic findings. Similarly, no correlation between CRP levels and color flow signals in the finger joints of RA patients was reported by Ribbens et al.[8] Interestingly, we observed a significant correlation between knee and MCP joints in RI values but not in grades of color flow signals. The reasons for these findings are unclear. They suggest that reduced vascular resistance, especially reduced RI, in inflamed synovium is part of a systemic vascular phenomenon of synovial inflammation in RA, and thus affects any joints. However, the intensity of color flow signals differed among joints depending on local arthritic activity. We also observed significant correlations between knee signals and knee RI, and knee PI which are consistent with the results of a previous study.[11] However, we observed no significant correlation between MCP-signals and MCP-RI, and MCP-PI possibly due to the lower prevalence of color flow signals in the MCP joints (50%), compared to knee joints, and the relatively low number of MCP joints (4 of 10) scanned in the present study.

In conclusion, we observed a significant correlation between knee RI and MCP-RI ($P < 0.05$) but not between knee signals and MCP signals. The RI value could be a useful Doppler sonographic finding for evaluating synovial inflammation, regardless of differences in the scanning joints.

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