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ORIGINAL ARTICLE

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Two localization patterns of vascularity demonstrated by power Doppler sonography at the suprapatellar recess in knee joints of patients with rheumatoid arthritis: intracapsular and supracortical

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Abstract Intraarticular vascularization in 54 knee joints of 27 patients with rheumatoid arthritis was examined by power Doppler sonography. Localization of the vascularity at the suprapatellar recess was classified into two patterns: intracapsular and supracortical. The patients with supracortical vascularization showed a tendency to higher grades of synovitis and higher levels of inflammatory laboratory indices than those with intracapsular vascularization.

Key words Intracapsular vascularity · Knee joint synovitis · Power Doppler sonography (PDS) · Rheumatoid arthritis (RA) · Supracortical vascularity

Introduction

Intraarticular vascularization in joints of patients with rheumatoid arthritis (RA) can be demonstrated by color Doppler and power Doppler sonography (PDS).[1–5] It has been shown that this vascularization is closely associated with clinical activity in the joints and laboratory inflammation data.[6,7] However, the localization of vascularity and its clinical significance in the knee joints as demonstrated by PDS have not been clearly determined. In this study, we classified the localization of intraarticular vascularity detected by PDS at the suprapatellar recess into two patterns: intracapsular and supracortical. Here, we discuss the clinical significance of classifying intraarticular vascularity into these two localization patterns.

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Patients and methods

Patients

We examined 54 knee joints in 27 patients (23 women and 4 men) with rheumatoid arthritis (RA). Their mean age was 61 years (range 33–84 years), and the mean disease duration was 6.9 years (range 0.5–25 years). The diagnosis of RA was based on the American College of Rheumatology (ACR) 1987 revised criteria.[8] Using Thompson's modified indices of synovitis activity,[9] the clinical activity of the joint inflammation was classified as active (swollen, warm, and tender; grade 2), moderately active (swollen and tender; grade 1), or inactive (only swollen or neither swollen, warm, nor tender; grade 0). C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and rheumatoid factor (RF) were evaluated as inflammatory markers during a period from 2 weeks before PDS examination to 2 weeks after.

Gray-scale sonography and power Doppler sonography

Gray-scale sonography and power Doppler sonography were performed using a Toshiba Aplio-80 system. A multidimensional linear scanner (PLT-704 AT) was used as the transducer at 11–5 MHz. The B-mode frequency was 11.0 MHz, and the color-mode frequency was 5.3 MHz. The suprapatellar region of the knee was scanned longitudinally and transversely. The intensity of synovial effusion and synovial proliferation were evaluated semiquantitatively by gray-scale sonography using the grades established by Rubaltelli et al.[10]: grade 0, thickness of $\leq$1 mm; grade 1, thickness of 2–4 mm; grade 2, thickness of 5–7 mm; grade 3, thickness of $\geq$8 mm. Vascularization was defined as the color-flow signals in the intraarticular soft tissue between the highly echogenic cortical surface of the femur and the moderately echogenic articular capsule. Standard machine settings (transmit power, $<500\,mW/cm^2$; low-pass wall filter No. 3; medium persistence) were used, and remained fixed throughout the study. These settings were chosen to maxi-

Table 1. Comparison of clinico-laboratory findings between RA patients with intracapsular vascularization and supracortical vascularization demonstrated by PDS at the suprapatellar recess of the knee joints

Localization pattern of vascularity	No. of patients	Mean duration of disease (years)	Grade of clinical activity (mean ± SD)	Grade of synovial effusion (mean ± SD)	Grade of synovial proliferation (mean ± SD)	Grade of vascularization (mean ± SD)	Mean values of		
							CRP mg/dl	ESR mm/h	RF IU/l
Intracapsular (No. available)	17	6.3 ± 5.8 (17) ns	1.1 ± 0.6 (17) ns	1.0 ± 0.6 (17) ns	1.2 ± 0.4 (17) ns	1.2 ± 0.6 (17) ns	3.4 ± 2.6 (17) *	59.9 ± 34.1 (15) ns	202.6 ± 304.7 (13) ns
Supracortical	10	7.9 ± 5.6 (10)	1.2 ± 0.8 (10)	1.2 ± 0.9 (10)	1.3 ± 0.4 (10)	1.2 ± 0.5 (10)	5.7 ± 3.4 (10)	69.9 ± 38.5 (9)	1312 ± 1914 (7)

CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; PDS, power Doppler sonography; RA, rheumatoid arthritis; RF, rheumatoid factor; ns, not significant
* $P < 0.05$

mize the sensitivity to low-velocity and low-volume blood flow. The power Doppler gain was optimized by increasing the gain until noise appeared, and then reducing gain just enough to suppress the noise (usually ~60% to 70% gain). Standard power Doppler settings were used, with a pulse repetition frequency (PRF) of 11.7–12.2 KHz. The window (color region of interest) was restricted in the vascular area studied. After visualization of the color-flow signals, pulsed-wave spectral Doppler imaging was performed to confirm true arterial or venous flow using the lowest filter setting (125 Hz) and the smallest scale available that would display the Doppler waveforms as large as possible without aliasing.

The intensity of vascularization in the intraarticular space was evaluated using a modified version of Klauser's method[6] to count color-flow signals in the chosen area (window), as follows: grade 0, no intraarticular color-flow signals; grade 1, 1–4 signals (1–5 in Klauser's method); grade 2, 5–8 signals (6–10 in Klauser's method); grade 3, 9 or more signals (11 or more in Klauser's method). The results of PDS were evaluated independently by two examiners (YY and AT) who were not aware of the clinical findings of the patients.

Statistical analysis

Statistical analysis was performed using the FREE JSTAT for Windows. Differences between groups were tested by Student's unpaired *t*-test. *P* values less than 0.05 were considered to indicate significance.

Results

Localization of the intraarticular color-flow signals was classified mainly into two patterns, intracapsular and supracortical, based on the predominant locations of the numbers and intensity of color-flow signals. The intracapsular pattern comprises vasucularization in the area of the articular capsule (moderately echogenic figure), including proliferated synovia. The supracortical pattern comprises vascularization in the area above the femoral cortex (highly echogenic figure), including proliferated synovia. Color-flow signals located between these two areas were classified as intracapsular or supracortical based on which area they were closer to. The color-flow signal localization pattern of each patient was classified as intracapsular or supracapsular based on which pattern was predominant when putting together the PDS images of the right and left knee joints.

Representative PDS images of intracapsular vascularization are shown in Fig. 1a (grade 3 vascularization) and Fig. 1b (grade 1 vascularization). Representative PDS images of supracortical vascularization are shown in Fig. 2a (grade 2 vascularization) and Fig. 2b (grade 1 vascularization). We classified 17 patients as having intracapsular vascularization, and 10 patients as having supracortical vascularization. Clinico-laboratory findings were compared between these two groups in order to assess the correlation with disease duration, clinical activity of the joints, synovial effusion, synovial proliferation, synovial vascularization, CRP, ESR, and RF. The results obtained are summarized in Table 1. The group with supracortical vascularization showed higher grades of clinical activity, synovial effusion, and synovial proliferation than the group with intracapsular vascularization, although the differences were not significant in all indices. In addition, the supracortical vascularization group showed higher levels of CRP, ESR, and RF than the intracapsular vascularization group, with a significant difference in CRP (5.7 ± 3.4 vs. 3.4 ± 2.6, $P < 0.05$), but not in ESR and RF.

Discussion

Synovial vascularization in RA patients is generally considered to be accompanied by synovial proliferation in synovitis. In a previous study,[11] we found that the intensity of intraarticular vascularization, as demonstrated by PDS at

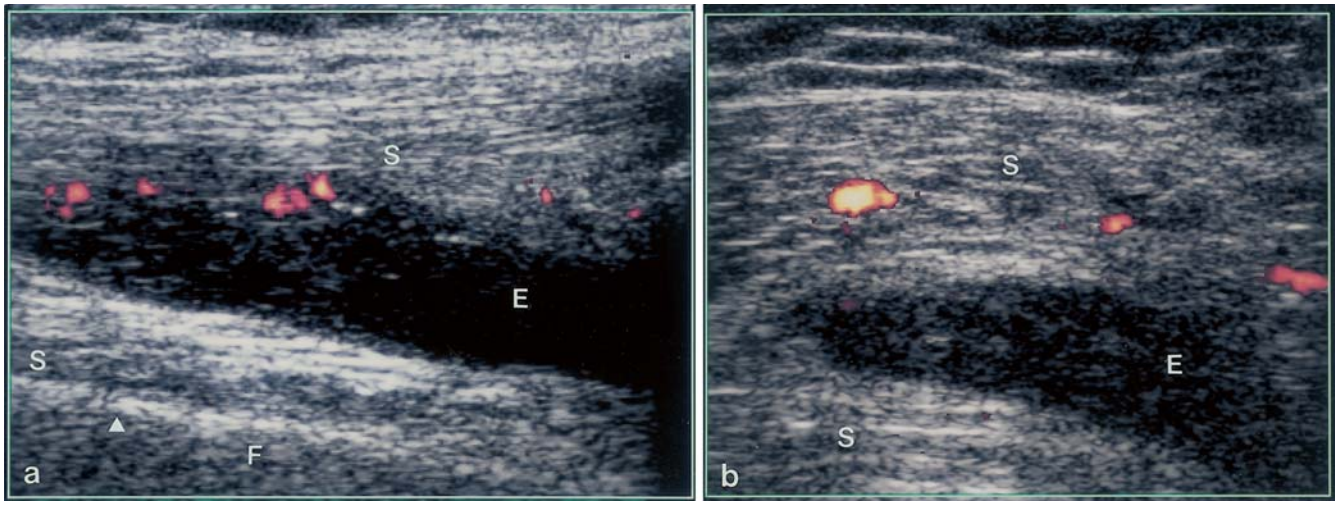

Fig. 1. Power Doppler sonographs. **a** Intracapsular vascularization with grade 3 intensity observed on a longitudinal scan at the suprapatellar aspect of the right knee of a 73-year-old female patient with CRP at 9.4 mg/dl. **b** Intracapsular vascularization with grade 1 intensity observed on a transverse scan at the suprapatellar aspect of the left knee of a 37-year-old female patient with CRP at 0.8 mg/dl. *E*, synovial effusion; *F*, femur; *s*, synovial proliferation; △, bone cortex

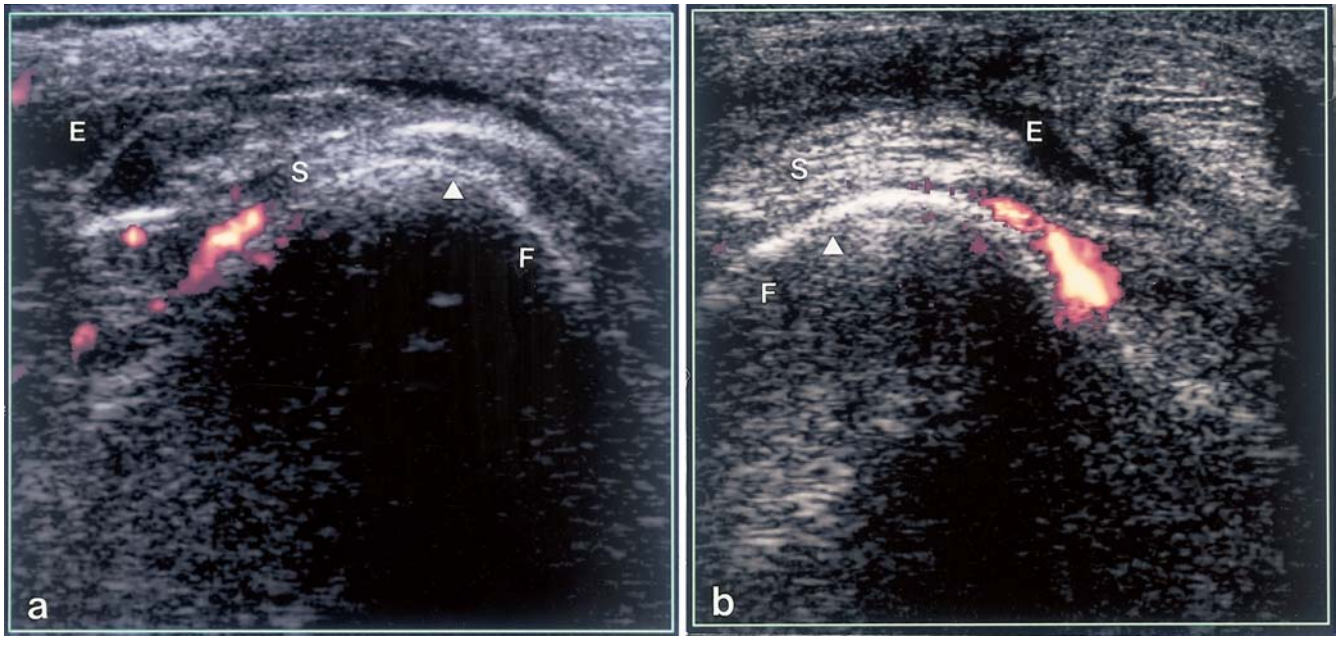

Fig. 2. Power Doppler sonographs. **a** Supracortical vascularization with grade 2 intensity observed on a transverse scan at the suprapatellar aspect of the right knee of a 33-year-old male patient with CRP at 8.0 mg/dl. **b** Supracortical vascularization with grade 1 intensity observed on a transverse scan at the suprapatellar aspect of the right knee of a 84-year-old female patient with CRP at 8.9 mg/dl

the suprapatellar recess of RA patients, correlated significantly with the intensity of synovial proliferation ($P < 0.05$) and synovial effusion ($P < 0.01$) demonstrated by gray-scale sonography. At the suprapatellar recess, synovial proliferation occurred in either the area of the articular capsule or in the femoral cortex. This suggests that the synovial vascularization demonstrated by PDS at the suprapatellar recess can be detected in both these areas. Although vascularization can occur anywhere in the intracapsular or supracortical areas, most of the color-flow signals were located in either the intracapsular or the supracortical area. A mixed pattern of color-flow signals (present in both intracapsular and supracortical areas) occurred in only a few cases. Therefore, in this study, we attempted to classify PDS color-flow signals into two localization patterns: intracapsular and supracortical. To our knowledge, such a classification of PDS localization patterns of vascularity has not previously been attempted. The

observed fact that the supracortical vascularization group showed a tendency toward higher levels of CRP, ESR, and RF than the intracapsular vascularization group is consistent with the fact that the supracortical vascularization was located closer to the cartilage and bone, and therefore damaged these tissues more than the intracapsular vascularization. However, we need a prospective study without differences in the numbers of CRP, ESR, and RF results in both groups to confirm the significance of CRP, ESR, or RF for the supracortical vascularization group compared with the intracapsular vascularization group. Schmidt et al.[2] found that vascularization detected by PDS in the knee joints of RA patients correlated with histological vascularity in the pannus. Similarly, Walther et al.[4] found that vascularity detected by PDS correlated with histological vascularity in knee joint pannus. To confirm that the supracortical vascularization detected by PDS in this study reliably indicates the presence of pannus and the destruction of cartilage and bone, further studies of the histology of bones removed by arthroscopy or surgery is needed. Based on the available evidence, we believe that a recognition of localization patterns of intraarticular vascularization can provide more information about the pathology of synovitis in RA patients, including the destruction of cartilage and bone.

In conclusion, we classified the localization of intraarticular vascularity detected by PDS at the suprapatellar recess of RA patients into two patterns: intracapsular and supracortical. The patients with supracortical vascularization showed a tendency toward a higher grade of synovitis and higher levels of inflammatory laboratory indices than those with intracapsular vascularization.

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