

Colour Doppler ultrasonography to detect pannus in knee joint synovitis

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Abstract

Objective

To determine if colour Doppler ultrasonography can characterise the nature of intraarticular echogenic structures and synovial villi more precisely than conventional ultrasonography.

Methods

This is a prospective study on 20 patients - 10 with rheumatoid arthritis and 10 with osteoarthritis. Colour Doppler ultrasonography of the knee joints was performed prior to total prosthetic replacement. Two independent, trained physician ultrasonographers examined the knee to be replaced with different ultrasound equipment using colour Doppler and power Doppler ultrasonography. The existence and extent of pannus were then assessed surgically and histologically.

Results

All 9 patients with histologically detected pannus had perfused, echogenic, intraarticular structures (ultrasonographer 2; ultrasonographer 1: 8 out of 9 patients). Sparse perfusion was detected in 1 patient (investigator 1) and in 5 patients (investigator 2) with extensive non-destructive synovial proliferation. Colour Doppler and power Doppler ultrasonography were equivalent in detecting small intraarticular vessels.

Conclusion

Colour Doppler ultrasonography improves the differentiation of intraarticular structures compared to conventional ultrasonography.

Key words

Ultrasonography, color Doppler ultrasonography, power Doppler ultrasonography, rheumatoid arthritis, osteoarthritis, knee joint, knee surgery, synovitis, pannus.

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Introduction

Pannus is responsible for the destruction of cartilage and bone in inflammatory rheumatic diseases. Management of these diseases aims at diminishing the extent of cartilage and bone destruction of the joints by using drugs (systemically or locally), radiosynoviorthesis, or synovectomy. Therefore it is important for the rheumatologist to obtain information about the extent and activity of pannus in a joint. Can ultrasonography give answers to this question? Grey scale ultrasonography can visualise synovitis. Fluid is anechoic in the ultrasound image. Echogenic structures seen in synovitis (Figs. 1 and 2) may be due to either tissue debris, blood clots, fibrinous deposits, non-destructive synovial proliferation, or pannus. Grey scale ultrasound cannot differentiate between these features. The aim of this study is to answer the question if colour Doppler and power Doppler ultrasonography can characterise more precisely the nature of echogenic structures in synovitis: Are they pannus or not pannus? This is currently achieved histologically.

Pannus is typical for rheumatoid arthritis (RA). It is characterised histologically by its invasive destruction of cartilage and bone. Other non-destructive synovial proliferation is found in osteoarthritis (OA).

Colour Doppler ultrasonography can sensitively visualise blood flow. It combines the imaging capabilities of B-mode ultrasonography with the flow-velocity determinations of Doppler ultrasonography and permits accurate assessment of both the anatomy and the flow characteristics of the vessels at specific sites. Technical improvements allow the visualisation of very small vessels. Power Doppler ultrasonography is an additional technical development that displays the total integrated Doppler power in colour. It visualises the blood flow independently from its direction and displays background noise in a way that increases the usable dynamic range. This should increase the instrument's sensitivity (1).

Patients and methods

In this prospective study we examined patients who were scheduled for total prosthetic knee joint replacement. We

compared the results of colour Doppler ultrasonography carried out by 2 independent investigators with the intraoperative findings and the results of histological examination of synovial, osseous, and cartilaginous tissue from probes taken during surgery.

Patients

We investigated 20 patients (16 female, 4 male) with a mean age of 64 years (range 35 to 86). Ten patients had RA (9 women) with a mean age of 56 years (range 35 to 74), and 10 patients had OA (7 women) with a mean age of 72 years (range 56 to 86). The diagnosis of RA and OA was confirmed by an independent rheumatologist. All patients fulfilled the classification criteria of the American College of Rheumatology (formerly, the American Rheumatism Association) for RA (2) and OA (3) respectively. All patients were scheduled for total prosthetic knee joint replacement.

Ultrasonographic evaluation

Ultrasonography was performed by two independent, experienced physician ultrasonographers. Investigator 1 used an ATL Ultramark 9 HDI (Advanced Technology Laboratories, Bothell, Wash., USA) from 1993 with a 10.5 MHz (38 mm) scanner. Investigator 2 used a Siemens Sonoline Elegra acquired in 1997 (Siemens, Issaquah, WA, USA) with a 9.5 MHz (38 mm) scanner. The equipment was adjusted to a maximum of sensitivity for the colour signal just below the disappearance of colour noise. Investigator 1 used conventional colour Doppler ultrasonography. Investigator 2 additionally performed power Doppler ultrasonography.

The knee joint was first investigated with conventional grey scale ultrasonography starting at the lateral joint space, continuing to the lateral, central, and medial suprapatellar recess, and finally to the medial joint space. It was done in a longitudinal and transverse plane. Additionally the dorsal and the infrapatellar regions of the knee joints were examined. The following parameters were measured independently by both investigators:

- Existence of an effusion.
- Extent of an effusion, assessed by

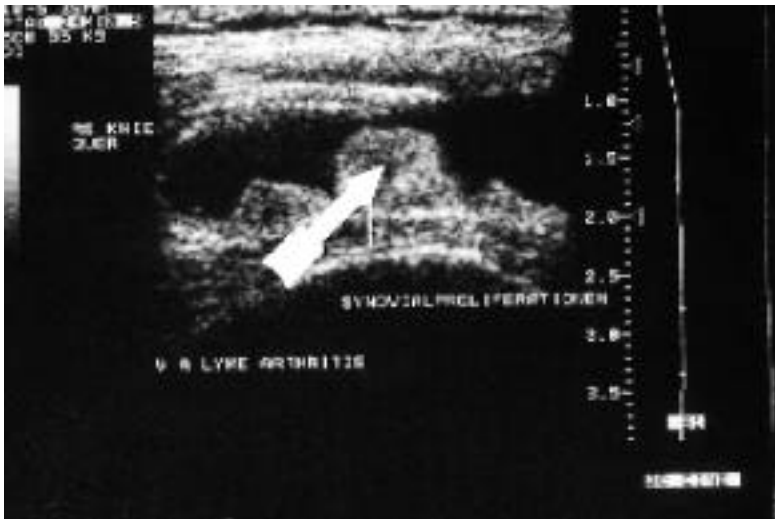


Fig. 1. Grey scale ultrasound image of synovial villi (arrow). They may be pannus or non-destructive synovial proliferation. The anechoic area is representative of synovial fluid. The scale represents centimetres below the skin surface.

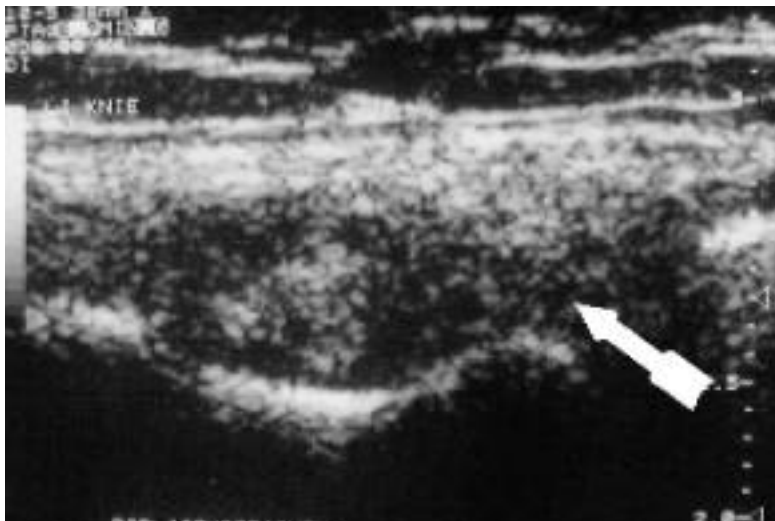


Fig. 2. Grey scale ultrasound image of echogenic structures close to the lateral knee joint space (arrow). This may be tissue debris, fibrin, blood clots, synovial proliferation, or pannus. The scale represents centimetres below the skin surface.

cess. In Figure 1 the maximum sagittal diameter of the villi was about 7 mm. Other echogenic structures could be demonstrated and measured at the medial and lateral joint spaces (Fig. 2; the diameter is about 5 mm at the arrow). The thickness was graded on the same scale used in other studies (5): 0: < 2 mm; 1: 2 to 5 mm; 2: 6 to 8 mm; 3: > 8 mm.

- Based on the perfusion of the above mentioned structures, the investigator had to provide his conclusions as to the existence of pannus.

Surgical evaluation

A surgical evaluation was made after a median of 2 days (range 1-7 days) after ultrasonography had been conducted. The knee joints were evaluated during prosthetic knee joint replacement by an orthopaedic surgeon who was blinded to the results of ultrasonography. He assessed following parameters:

- Existence and extent of an effusion.
- Existence and maximum diameter of synovial villi.
- Estimation of the thickness of synovial proliferation or pannus in the medial and lateral joint spaces, and in the medial, lateral, and central suprapatellar recesses.

Histologic evaluation

All of the synovium that had been removed surgically was sent for histologic evaluation. It was assessed for the following parameters by a pathologist who was blinded to the clinical, surgical, and ultrasonography findings:

- Existence of pannus (pannus was defined as synovial proliferation with invasive destruction of cartilage and bone in contrast to other types of synovial proliferation).
- Number of vessels in the pannus per 0.95 mm².
- Number of vessels in the synovium per 0.95 mm².
- Existence of fibrinous exudation.

Statistical analysis

The SPSS statistical package was used for the statistical analysis. The Mann-Whitney U test was used to compare the results between groups.

- measuring the maximum anterior-posterior diameter of the suprapatellar recess in a supine position with the knee joint extended and the biceps femoris muscle contracted, as described in previous studies (4, 5).
- The echogenicity of an effusion was subjectively analysed and graded on a scale of 0 to 3 (0: no echoes in the effusion; 1 to 3: increasing degrees of echogenicity in the effusion).
- The intensity of perfusion was subjectively analysed by colour Doppler ultrasonography and/or power Doppler ultrasonography, and graded on a scale of 0 to 3 (0, no perfusion; 1 to 3, in-

creasing degrees of perfusion). Figure 3 gives examples of the intensity of perfusion. It was measured at the medial and lateral joint spaces as well as the medial, lateral, and central suprapatellar recesses. The flow had to be demonstrated in two planes; in case of doubt it was additionally measured by pulsed-wave Doppler ultrasonography to exclude artefacts.

- An estimation of the thickness of echogenic intraarticular structures, such as pannus, synovial proliferation, or synovial villi was made at the 5 sites described above. Synovial villi could be measured in the suprapatellar re-

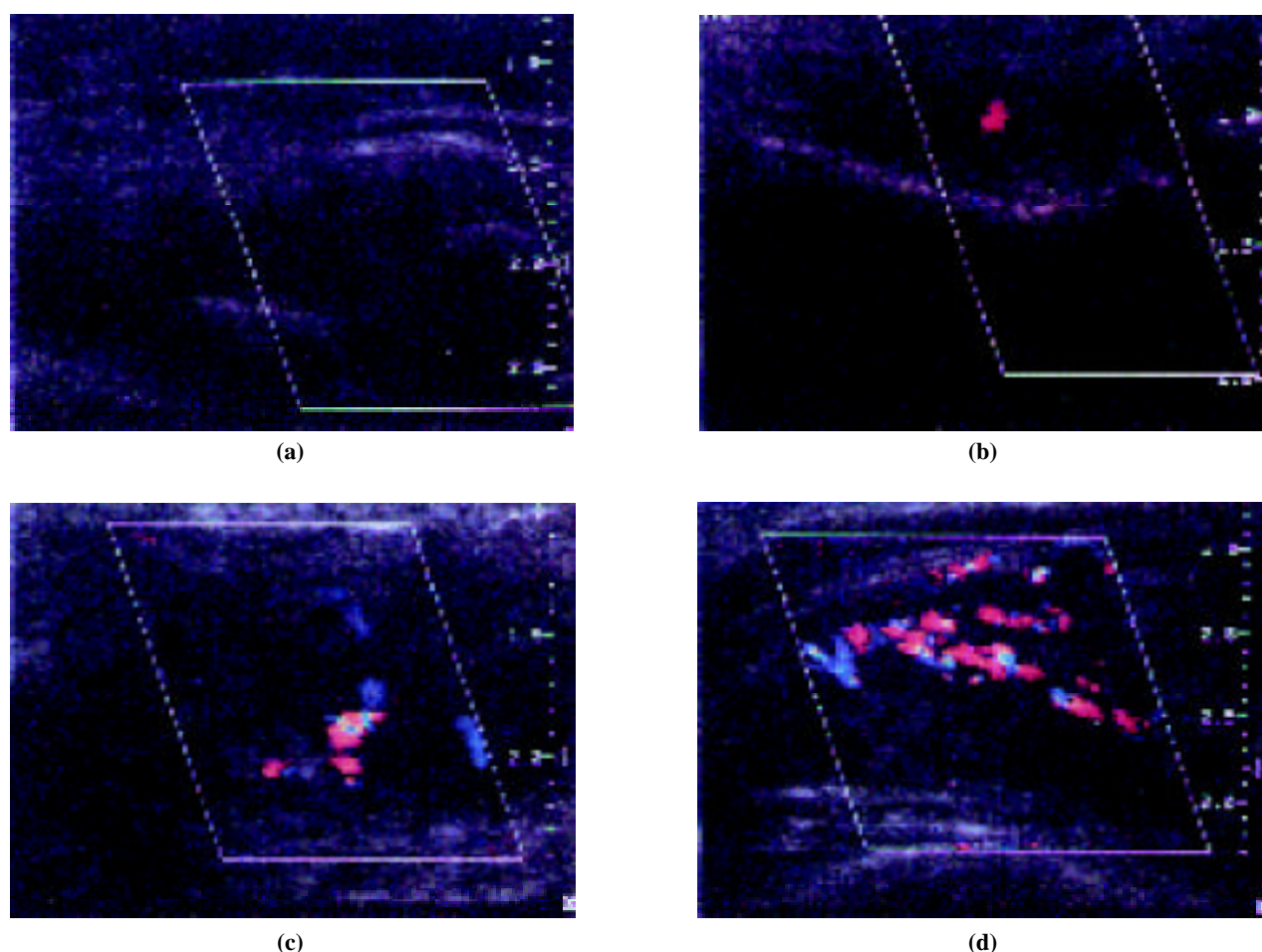


Fig. 3. (a) Colour Doppler ultrasound image showing no perfusion of knee joint synovium (grade 0); (b) colour Doppler ultrasound image showing mild perfusion of knee joint synovium (grade 1); (c) colour Doppler ultrasound image showing moderate perfusion of knee joint synovium (grade 2); (d) colour Doppler ultrasound image showing intense perfusion of knee-joint synovium (grade 3).

Table I. Intensity of perfusion of intra-articular structures correlated to the histologic finding of pannus (concerning maximum perfusion detected by each ultrasonographer; grade 0 = no perfusion; grade 1 = mild perfusion; grade 2 = moderate perfusion; grade 3 = intense perfusion).

Patients with the histological finding of pannus			Patients without the histological finding of pannus		
Patient no.	Investigator 1 Grade of perfusion	Investigator 2 Grade of perfusion	Patient no.	Investigator 1 Grade of perfusion	Investigator 2 Grade of perfusion
1	3	3	1	2	1
2	3	3	2	0	2
3	3	2	3	0	1
4	2	3	4	0	1
5	2	2	5	0	1
6	2	2	6	0	0
7	2	2	7	0	0
8	2	1	8	0	0
9	0	2	9	0	0
			10	0	0
			11	0	0

Results

Colour Doppler ultrasonography

In 9 patients pannus was found histologically. In all of these patients perfusion of echogenic structures in the joint cavity could be detected by investigator 2. Investigator 1, who used less modern equipment, found perfusion in 8 of these 9 patients. Eight patients with pannus had a clinical diagnosis of RA, and one was diagnosed as OA. In the patients without a histological diagnosis of pannus ultrasonographer 1 detected perfusion once, ultrasonographer 2 five times. Table I shows the maximum grade of intensity of intraarticular perfusion seen by each sonographer correlated to the histologic finding of pannus. In most of the patients with pannus the perfusion was intense or moderate. If perfusion was found in patients without pannus it was mild or moderate. The average grade of perfusion on a scale of 0 to 3 (0 = no

Table II. Intensity of perfusion of intra-articular structures at 5 sites of the knee joint correlated to the histologic finding of pannus (grade 0: no perfusion; grade 1 to 3: increasing intensity of perfusion).

	No. of joints w/ histologic/ surgical finding of pannus	Sonographer 1 Average degree of perfusion if pannus +	Sonographer 2 Average degree of perfusion if pannus +	Sonographer 1 Average degree of perfusion if pannus -	Sonographer 2 Average degree of perfusion if pannus -	Significance Sonographer 1	Significance Sonographer 2
Medial joint space	9	1.7	1.4	0.1	0.2	< 0.01	< 0.05
Lateral joint space	9	1.8	1.4	0.2	0.2	< 0.01	< 0.01
Medial suprapatellar recess	9	1.0	1.2	0.0	0.4	< 0.01	< 0.05
Central suprapatellar recess	8	0.6	0.9	0.0	0.1	< 0.05	< 0.01
Lateral suprapatellar recess	9	1.3	1.4	0.0	0.4	< 0.01	0.05

perfusion and 3 = intensive perfusion) was 0.36 in the patients without pannus and 2.17 in those with pannus (significant < 0.001). Figure 3 gives examples of the grade of perfusion of the knee joint synovium. Table II shows the correlation of perfusion and the detection of pannus in the various regions of the knee joint. The 4 patients with mild or moderate perfusion detected by ultrasonographer 2 alone despite negative histologic findings of pannus, had extensive synovial proliferation (between 5 and 20 mm measured surgically). These patients had an effusion of 10 to 40 ml as a sign of active inflammation, and the amount of synovial vessels found histologically was above average (36/0.95 mm² versus 25/0.95 mm²). Nevertheless, one patient with OA had mild to moderate perfusion seen by both ultrasonographers despite the negative histologic finding of pannus, mild synovial proliferation, and only 6 synovial vessels/0.95 mm².

Altogether there was no correlation between the amount of vessels seen histologically in the pannus and either the extent of synovial proliferation or the intensity of perfusion seen on ultrasonography. There was also no correlation between the degree of perfusion seen on ultrasonography and the extent of knee joint effusion. Power Doppler ultrasonography did not detect more joints with perfusion than conventional colour Doppler ultrasonography, although the colour was sometimes more intense using power Doppler ultrasonography.

Grey scale ultrasonography

Twelve of 13 surgically confirmed effu-

sions were seen by the ultrasonographers. Fibrin was found histologically in 8 of 10 RA patients, but in none of the OA patients. Grey scale ultrasonography found intraarticular echogenic structures in 7 of 8 patients with the histological finding of fibrin, but also in 6 patients without the histologic detection of fibrin. Synovial villi were detected in 5 patients with RA by ultrasonographer 1, in 6 patients with RA by ultrasonographer 2, and in 4 patients with OA respectively by both ultrasonographers. Surgically synovial villi were found in 5 patients with RA, and in 3 patients with OA. The rate of agreement concerning the existence of villi was only 80% between the two ultrasonographers, 85% between ultrasonographer 1 and the surgeon, and 80% between ultrasonographer 2 and the surgeon. Of the 6 patients in whom synovial villi were detected both by the 2 ultrasonographers and the surgeon, 4 patients had RA with the histological finding of pannus, and 2 patients had OA without pannus in their histology. Three patients with histologically detected pannus had no villi found by ultrasonography or surgery.

Clinically the 2 patients with RA and negative histologic findings of pannus did not differ from the other RA patients. All of the investigated knees showed either primary osteoarthritis or osteoarthritis secondary to RA. There was no correlation between the results of the clinical examination of the knee and grey scale ultrasonography data on the amount of effusion, echogenicity, and diameter of intraarticular structures on the one hand, and the surgical or histologic findings of

pannus on the other hand.

In summary, grey scale ultrasonography, when used to analyse the villi in the suprapatellar recess, showed technical limitations in its ability to provide exact information about the existence and extent of pannus in the knee joint. Colour Doppler ultrasonography provided a much higher correlation between pathologic findings and the detection of pannus by histology than conventional grey scale ultrasonography.

Discussion

Grey scale ultrasonography fails to differentiate pannus from non-destructive synovial proliferation and intraarticular debris. Colour Doppler ultrasonography provides additional information about the existence and extent of pannus. Up to now there have been no surgically or histologically controlled studies investigating this question. Increased soft tissue perfusion depicting peritendinous and peribursal vessels in patients with various musculoskeletal inflammatory diseases has been reported (6). This perfusion was detected around inflamed tendons (7) and in the soft tissue around joint effusions (8). There are preliminary observations regarding synovial perfusion; Newman *et al.* observed a decrease in synovial perfusion after the intraarticular administration of corticosteroids in 7 patients (9). Magnetic resonance tomography with the use of gadolinium-diethylenetriamine pentaacetic acid may also identify synovial proliferation and can provide some information about vascularity as well (10, 11).

The intensity of perfusion depends on the

grade of inflammatory activity (6-9). In our study the detection of intraarticular blood flow did not correlate with the amount of vessels. Therefore, we state that the existing blood vessels are more intensively perfused in the inflammatory process; thus they can be detected by colour Doppler ultrasonography.

Evaluation of the grade of perfusion is rather subjective. It depends on the ultrasound equipment, its setting, the investigator, and the patient. A thick subcutaneous layer of fat may reduce the detectability of perfusion. Therefore a study with one ultrasonographer and video documentation read by one or two physicians may result in bias. For this reason we chose to compare the evaluations of two physician ultrasonographers using different equipment.

In our study intraarticular perfusion detected by ultrasound correlated with the existence of pannus. Due to the study design we only investigated RA and OA patients scheduled for prosthetic knee joint replacement. Thus, the detection of intraarticular perfusion does not exclude the involvement of structures other than pannus. For example, we have observed intense intraarticular perfusion also in patients with pigmented villonodular synovitis, intraarticular amyloidosis, and septic arthritis in RA.

Comparing power Doppler ultrasonography with conventional duplex ultrasonography we expected to find more joints with detectable perfusion using the power Doppler mode as described by other authors (12). Surprisingly there was no higher sensitivity of power Doppler sonography in our study. This subject was investigated only by ultrasonographer 2, but the findings could be confirmed by investigator 1 using power Doppler equipment from ATL in other patients after the end of the study. Investigations were carried out with one of the first commercially available Siemens Elegra machines and an upgraded ATL Ultramark 9 HDI. Our findings may be due to a higher quality of the conventional colour Doppler mode compared to the power Doppler mode in the instru-

ments used by us. They do not exclude that power Doppler may be superior to conventional colour Doppler ultrasonography using another technique.

This study shows that in patients with end-stage OA and RA of the knee joints, perfusion of intraarticular structures significantly differs depending upon the existence of pannus. In end-stage disease of a joint it is important to know whether the symptoms are primarily related to destruction or inflammation. Colour Doppler ultrasonography can aid in the differentiation between these two features. In end-stage RA the size of the blood vessels may be expected to be larger than in patients with early disease. On the other hand, it has been shown that perfusion of the intraarticular structures is closely related to disease activity (9), which correlates with our own experience outside of this study. Thus, further studies should investigate whether perfusion may be related to the stage and activity of the disease, and if the data can be reproduced in early disease using arthroscopic validation and arthroscopic collection of specimens for histological examination. Colour Doppler and power Doppler ultrasonography are superior to conventional grey scale ultrasonography in characterising the nature of intraarticular echogenic structures. The new technique non-invasively provides information regarding the existence and extent of pannus. This information is helpful to accurately assess joint diseases. Thus colour Doppler ultrasonography might substantiate the indication for synovectomy and radiosynoviorthesis. With better equipment the detection of intraarticular vascularisation may increase. The use of a microbubble ultrasound contrast agent, and the combination of a contrast agent with second harmonic imaging (13, 14) might further increase the possibility of detecting minor perfusion.

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