How much different is the semi-quantification of synovitis according to the ultrasound system and the blood flow detection technology?

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Abstract

Aim: To compare synovial blood flow scoring between different technologies and ultrasound (US) systems in active and inactive rheumatoid arthritis (RA). Material and methods. Fifty-nine RA patients underwent B-mode, power Doppler (PD), colour Doppler (CD), B-Flow and High-Resolution (High-Res) PDI assessments of 6 joints with two US systems at two European centres. Each joint was semi-quantitatively scored for all ultrasound parameters. PD, CD and High-Res PDI synovial signal was also quantitatively scored. Results. Correlations between the total score of SH with system 1 and 2 were very high (≥ 0.90, p<0.0001). Baseline correlations between systems for PD and CD total scores were moderate to very high (0.44-0.96, p<0.05). At baseline, there were no significant differences between ultrasound systems for PD or CD semiquantitative-based total scores in active or inactive patients (p>0.05). B-Flow and High-Res total scores were significantly lower than PD or CD total scores (p<0.05). Conclusion. A high-end and an entry-level US system were interchangeable for scoring SH and showed similar sensitivity and responsiveness in scoring synovial blood flow by PD and CD but not interchangeability. B-Flow and High-Res PDI were responsive, but they showed different sensitivity to detect synovial blood flow compared to conventional Doppler.

Keywords: ultrasound; Doppler; rheumatoid arthritis; synovitis; scoring

Introduction

Rheumatoid arthritis (RA) is a systemic autoimmune disease characterized by prominent expression in the synovial tissues. The management of RA has evolved dramatically in recent decades, with achieving clinical remission now a realistic goal [1]. In this context, musculoskeletal ultrasound (US) provides valuable support to clinicians at every stage of RA management, from diagnosis to disease activity monitoring and outcome prediction [2,3]. The ability of US to visualize intra- and extra-articular changes and the higher sensitivity for the detection of articular inflammation compared to clinical examination justify the fact that RA is the inflammatory condition most frequently studied by US [4].

Doppler techniques enable the detection of synovial blood flow and have become crucial for evaluating inflammatory activity in RA and chronic arthritis [5]. The persistence of highly perfused synovial tissue (defined as active synovitis), is considered a predictor of joint damage, particularly in the early phases of RA disease [6-8]. Furthermore, the evidence of subclinical active synovitis in RA patients in clinical remission may explain the apparent discrepancy between clinical improvement and progression of articular damage in some of RA patients, and in the same way may explain the flares of the disease [9,10]. The detection and quantification of the synovial
vascularization is therefore of particular importance in the assessment of RA patients.

Colour (CD) and power Doppler (PD) are the two classic and most commonly used Doppler modes in inflammatory arthritis [11,12]. More recently, new modalities have been developed to assess blood flow. B-Flow is an ultrasound technology that displays the blood flow signals in B-mode imaging throughout the entire field of view. This modality does not suffer from blooming or wall overwriting of the vessel wall as conventional Doppler modes, so it potentially offers a higher spatial resolution for vessel anatomy and a more realistic blood flow imaging. So far, B-Flow has mainly been used in the liver [13] and peripheral vascular diseases [14]. High-Resolution (High-Res) PDI is based on B-Flow technology but is processed and made by the Colour Flow processor and therefore has both the advantages of B-Flow and Colour Flow. The new methods for assessing blood flow are very promising, but currently, the available data in the literature are limited, typically presented in the form of case reports or in a small number of patients, and there are no studies on patients affected by inflammatory joint disease.

The objectives of this study, conducted in patients with active and inactive RA, were as follows: i) to compare semiquantitative and quantitative scoring of synovial blood flow using different technologies and two different ultrasound systems; and ii) to compare the responsiveness of semiquantitative and quantitative scoring of synovial blood flow using different technologies in two different ultrasound systems in active RA patients.

Material and methods

Consecutive patients diagnosed with RA fulfilling the 2010 ACR/EULAR RA classification criteria [15] were recruited from two academic rheumatological centres. Among centers, the patients had to be equally distributed in clinically active RA (i.e. Disease Activity Score in 28 joints (DAS28) >3.2 starting a new course of treatment, i.e. start or increase or change treatment for active disease) and clinically inactive (i.e. remission) RA (i.e. DAS28 <2.6). The patient could not have received corticosteroid injections in any examined joint during the previous 1 month before enrolment. Ethical committee approval was obtained at the involved centers (Hospital Universitario Fundación Jiménez Díaz, Madrid, Spain, and Academic Rheumatology Centre, University of Turin, Italy). All the patients gave written informed consent according to the Declaration of Helsinki.

Ultrasound assessment

The ultrasound assessment was performed by two rheumatologists (AI, EN), one for each centre, with more than 25 years of experience in musculoskeletal ultrasonography. The ultrasound examination was performed at baseline, and at 3 months in the active RA patients and at baseline in the inactive RA patients. The sonographers were blinded to clinical laboratory and radiographic data.

In each centre, the ultrasound examinations were performed with two real-time systems (LOGIQ E9, i.e, ultrasound system 1, and LOGIQ E, i.e. ultrasound system 2; GE Medical Systems Ultrasound and Primary Care Diagnostics, LLC, Wauwatosa, WI, USA) equipped with multifrequency linear matrix array transducers. The probes used during the assessment were as follows: i) ML6-15 (Logiq E9), for the knee and wrist and L8-18i (Logiq E9), for the metacarpophalangeal joints (MCP); ii) 12L (Logiq E), for the knee and wrist and L8-18i (Logiq E), for the MCP.

The patients underwent B-mode, PD, and CD assessment with the two ultrasound systems consecutively in a time frame of less than 30 minutes. B-Flow assessment with ultrasound system 1 and High-Res PDI assessments with ultrasound system 2 of 6 target joint areas. These joint areas comprised bilateral wrist (including radiocarpal, midcarpal, and distal radioulnar joints and dorsal recesses), bilateral second MCP joint (i.e. dorsal recess), and bilateral knee (i.e. anterior and parapatellar recesses). The use of a 6-joint ultrasound assessment for evaluating joint inflammation in RA was based on its validity, sensitivity-to-change and feasibility [16]. B-mode, PD, CD, B-Flow and High-Res PDI settings were optimized for the different assessed joints before the study and standardized for the whole study. The settings for CD and PD were adjusted to obtain the highest sensitivity without noise artefacts [17,18].

All images were recorded in the ultrasound systems. After completing all patient visits, the images were evaluated in a random fashion by the researchers blinded to the patient and the visit date.

Each joint was evaluated for the presence of B-mode synovial hypertrophy (SH). SH was defined according to the Outcome Measures in Rheumatology Clinical Trials (OMERACT) as the presence of abnormal hypoechoic (relative to subdermal fat) intraarticular tissue that is non displaceable and poorly compressible [19]. Joints with SH were scored semi-quantitatively (0-3) for SH (0, absent; 1, mild; 2, moderate; 3, marked) and synovial PD, CD, B-Flow and High-Res PDI signal (0, no synovial signal; 1, ≤3 signals within the SH; 2, >3 signals in less than half of the SH area; 3, signals in more than half of the SH area) according to the OMERACT synovitis scoring system [20] (fig 1-3). Joints with presence of PD, CD or High-Res PDI signal within SH were also quantitatively scored using a software for counting the colour fraction.
incorporated into the ultrasound machines (Q-Analysis, GE Healthcare). For this quantitative score, the sonographers recorded a 4-s video sequence at the area with more colour signals detected during the scanning of each joint. After manually delimiting the synovial area, the maximum measure of colour fraction (0–1) over the entire video sequence acquisition was showed and taken for analysis as quantitative score.

A total score for semiquantitative SH, PD, CD, B-Flow and High-Res PDI and for quantitative PD, CD and High-Res PDI was calculated for all patients at baseline and for active patients at three months by adding each score, respectively, obtained for each evaluated joint. Total scores were taken for analysis.

**Clinical assessment**

Patients underwent evaluation by a local experienced rheumatologist at baseline. Data on clinical examination, laboratory tests, hand-feet X-rays, and treatments were collected according to the study protocol. Additionally, clinical and laboratory assessments were conducted at 3 months following the initiation, escalation, or modification of treatment (therapy starting/increase/change) in the active RA group.

**Statistical analysis**

Descriptive results were summarized as mean, standard deviation (SD), minimum and maximum for quantitative variables and as absolute and relative frequencies for qualitative variables. Comparison between the distribution of variables were evaluated using the McNemar test. Correlation between total scores for PD, CD, B-Flow and High-Res PDI were estimated by the Pearson’s correlation coefficient. Pearson’s r values were interpreted as follows: 0-0.20 very low, 0.21-0.40 low, 0.41-0.60 moderate, 0.61-0.80 high and 0.81-1 very high. The Wilcoxon signed rank test for paired data was used to compare total scores for PD and CD between ultrasound systems and total scores for B-Flow and High-Res PDI with total scores of PD and CD from their corresponding ultrasound systems. Statistical significance was set as a p value <0.05. Statistical analysis was performed using SPSS version 21.0 and R statistical Software 3.3 version.

**Results**

**Demographics and RA data**

We included 59 RA patients. Table 1 presents the demographics, RA characteristics, and baseline clinical and laboratory data of all patients. There were no sig-
significant differences between active patients and those in remission, except for a notably higher percentage of active patients taking nonsteroidal anti-inflammatory drugs (NSAIDs), and a significantly higher percentage of women in the active group.

At baseline, the mean (SD) DAS28 was 4.8 (0.8) for active patients and 2.4 (0.3) for inactive patients. At 3 months, the mean (SD) DAS28 of active patients decreased to 3.5 (1.0). At baseline, 18 (60%) patients of the active group were treated with conventional synthetic (cs) disease-modifying antirheumatic drugs (DMARDs), 1 (3.3%) with biologic (b) DMARDs, 2 (6.7%) with cs and bDMARDs, and 9 (30%) only with corticosteroids or NSAIDs. Baseline therapy change in the active group consisted of starting or increasing the dose of csDMARDs in 14 (46.7%) patients, adding a second csDMARD in 2 (6.7%) patients, adding a bDMARD in 6 (20%) patients, adding a targeted sDMARD in 1 (3.3%) patient, and increasing the dose of corticosteroids or NSAIDs in 7 (23.3%) patients. In the remission group, twenty-one (72.4%) patients were treated with csDMARDs, 1 (3.4%) with cs and bDMARDs, 4 (13.8%) with cs and bDMARDs, and 3 (10.3%) only with low-dose corticosteroids.

**Ultrasound qualitative findings**

At baseline, SH was detected in 100% of active and inactive patients with both ultrasound systems 1 and 2. At three-months follow-up, SH was found in 25 (83.3%) active patients with both ultrasound systems.

At baseline, in the active group, we detected synovial blood flow in 28 (93.3%) patients with PD and CD modes of ultrasound system 1 and in 29 (96.7%) and 28 (93.3%) with PD and CD, respectively, of ultrasound system 2. Synovial blood flow was found in 15 (50%) patients with B-Flow of ultrasound system 1 [B-Flow versus PD and CD of ultrasound system 1, p=0.008]. At three months, we found synovial blood flow in 18 (60%) patients with PD and CD modes of ultrasound system 1 and in 19 (63.3%) with PD, CD and High-Res PDI of ultrasound system 2. However, synovial blood flow was detected in only 7 (23.3%) patients with B-Flow of ultrasound system 1 [B-Flow versus PD and CD of ultrasound system 1, p=0.008].

In the remission group, we detected synovial blood flow in 17 (58.6%) patients with PD and CD modes of ultrasound system 1 and in 18 (62.1%) and 16 (55.2%) with PD and CD, respectively, of ultrasound system 2. Synovial blood flow was found in only 4 (13.8%) patients with B-Flow of ultrasound system 1 [B-Flow versus PD and CD of ultrasound system 1, p<0.001] and 10 (34.5%) patients with High-Res PDI of ultrasound system 2 [High-Res PDI versus PD and CD of ultrasound system 2, p=0.065 and p=0.186, respectively].

**Correlation between scores from ultrasound system 1 and 2**

Correlations (Pearson coefficient) between total score of SH obtained with ultrasound system 1 and 2 at baseline were very high: 0.95 [95% Confidence Interval (CI) 0.90-0.98, p<0.0001] for active patients, and 0.90 [95% CI 0.80-0.95, p<0.0001] for inactive patients. Table II shows correlations between semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 and 2 at baseline in active and inactive patients. Correlations between ultrasound systems for PD- and CD-based total scores were significantly moderate to very high, but in general they were better between semiquantitative-based scores, i.e. high or very high, than between quantitative-based scores. B-Flow and High-Res PDI-based total scores significantly correlated with a variable strength, from moderate to very high, with PD- and CD-based scores from their respective ultrasound systems.
There were no significant differences between mean baseline total scores of SH from ultrasound system 1 and 2 in active [mean (SD) 5.2 (3.2) for system 1; mean (SD) 5.1 (3.2); for system 2; p=0.899] or inactive patients [mean (SD) 2.7 (1.8) for system 1; mean (SD) 2.9 (2) for system 2; p=0.786].

In figure 4 the comparison between mean values of PD and CD, semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 versus ultrasound system 2 at baseline in active and inactive patients, respectively, are displayed.

### Table II. Correlation between semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 and 2 at baseline in active and inactive patients. Correlation between total scores for PD, CD, B-Flow and High-Res PDI were estimated by the Pearson’s correlation coefficient.

<table>
<thead>
<tr>
<th>Ultrasound scores</th>
<th>Active patients (n=30)</th>
<th>Inactive patients (n=29)</th>
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</thead>
<tbody>
<tr>
<td>SQ PD system 1 with SQ PD system 2</td>
<td>0.67 (0.41-0.83; &lt; 0.0001)</td>
<td>0.96 (0.92-0.98; &lt; 0.0001)</td>
</tr>
<tr>
<td>SQ CD system 1 with SQ CD system 2</td>
<td>0.72 (0.48-0.86; &lt; 0.0001)</td>
<td>0.87 (0.74-0.94; &lt; 0.0001)</td>
</tr>
<tr>
<td>Q PD system 1 with Q PD system 2</td>
<td>0.44 (0.08-0.70; 0.019)</td>
<td>0.73 (0.50-0.87; &lt; 0.0001)</td>
</tr>
<tr>
<td>Q CD system 1 with Q CD system 2</td>
<td>0.58 (0.27-0.790; 0.001)</td>
<td>0.55 (0.23-0.76; 0.002)</td>
</tr>
<tr>
<td>SQ PD with SQ B-Flow system 1</td>
<td>0.48 (0.14-0.72; 0.007)</td>
<td>0.74 (0.52-0.87; &lt; 0.0001)</td>
</tr>
<tr>
<td>SQ CD with SQ B-Flow system 1</td>
<td>0.46 (0.12-0.70; 0.011)</td>
<td>0.43 (0.07-0.69; 0.021)</td>
</tr>
<tr>
<td>SQ PD with SQ High-Res PDI system 2</td>
<td>0.54 (0.21-0.76; 0.003)</td>
<td>0.51 (0.18-0.74; 0.004)</td>
</tr>
<tr>
<td>SQ CD with SQ High-Res PDI system 2</td>
<td>0.60 (0.29-0.79; 0.001)</td>
<td>0.52 (0.18-0.74; 0.004)</td>
</tr>
<tr>
<td>Q PD with Q High-Res PDI system 2</td>
<td>0.85 (0.70-0.93; &lt; 0.0001)</td>
<td>0.33 (-0.046-0.62; 0.084)</td>
</tr>
<tr>
<td>Q CD with Q High-Res PDI from system 2</td>
<td>0.75 (0.52-0.88; &lt; 0.0001)</td>
<td>0.50 (0.17-0.73; 0.005)</td>
</tr>
</tbody>
</table>

Pearson’s r values were expressed as value (95% CI; p). SQ, semiquantitative; Q, quantitative; PD, Power Doppler; CD, colour Doppler; CI, confidence Interval.

**Comparison of scores from ultrasound system 1 and 2**

While there were no significant differences between these parameters in patients in remission, both PD and CD quantitative-based total scores were significantly higher for the ultrasound system 1 than for ultrasound system 2 in active patients. There were no significant differences between ultrasound system 1 and 2 for PD or CD semiquantitative-based total scores in active patients.

Mean semiquantitative B-Flow-based total score in active and inactive patients [mean (SD) 1.2 (1.7) and 0.3 (0.7), respectively] was significantly lower than semiquantitative PD- or CD-based total scores from ultrasound system 1 (p<0.001 for PD and CD in active patients; p=0.001 for PD and CD in inactive patients). Likewise,

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Fig 4. Comparison between PD and CD semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 versus ultrasound system 2 at baseline in active patients; b) Comparison between PD and CD semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 versus ultrasound system 2 at baseline in inactive patients; c) Comparison between mean values of baseline-three months change in PD and CD semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 versus ultrasound system 2 in active patients; PD, power Doppler; CD, colour Doppler; SQ, semiquantitative; Q, quantitative.
total scores based on semiquantitative [mean (SD) 1.3 (1.5) in active patients; 0.6 (0.9) in inactive patients] and quantitative [mean (SD) 0.1 (0.1) in active patients; 0 (0.1) in inactive patients]. High-Res PDI were significantly lower as compared to semiquantitative and quantitative, respectively, PD- or CD-based total scores from ultrasound system 2 in both active and inactive patients (p<0.001 for all comparisons in active patients; p=0.003 and p=0.015 for semiquantitative PD and CD, respectively, in inactive patients; p=0.001 and p=0.002 for quantitative PD and CD, respectively, in inactive patients).

**Responsiveness of scores from ultrasound system 1 and 2**

In active patients, correlation between change in total score of B-mode SH from baseline to three-month follow-up obtained with ultrasound system 1 and 2 was 0.90 [95%CI 0.79-0.95, p<0.0001]. There was no significant difference between mean change in total score of SH at three months from ultrasound system 1 [mean (SD) 0.8 (3.5)] and ultrasound system 2 [mean (SD) 0.9 (3.4)] in active patients (p=0.874).

Table III displays the correlations between changes at three-month follow-up in semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 and 2 in active patients. Correlations were significantly low to moderate for PD and CD semiquantitative- and quantitative-based changes. B-Flow and High-Res PDI semiquantitative-based changes showed a significant moderate correlation with PD and CD-based changes from ultrasound system 1 and ultrasound system 2, respectively. High-Res PDI quantitative-based changes showed a variable correlation with PD and CD-based changes from ultrasound system 2.

![Figure 4 shows comparison between mean values of baseline-three months change in PD and CD semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 versus ultrasound system 2 in active patients. There were no significant differences between these variables. There were no significant differences in mean values of baseline-three months change in B-Flow-based total score [mean (SD) 0.7 (1.4)] as compared to semiquantitative PD- or CD-based scores from ultrasound system 1 (p=0.130 and p=0.134, respectively). Similarly, there were no significant differences in mean values of baseline-three months change in total scores based on semiquantitative [mean (SD) 0.1 (1.4)] and quantitative [mean (SD) 0.1 (0.1)] High-Res PDI as compared to semiquantitative PD- or CD-based scores (p=0.100 and p=0.07, respectively) and quantitative PD- or CD-based scores (p=0.125 and p=0.318 respectively), respectively, from ultrasound system 2.](image)

**Discussion**

B-mode and Doppler mode are common ultrasound techniques used to assess and monitor synovial inflammation in rheumatoid arthritis (RA) and other types of arthritis [4,5,8]. There are only a few studies that have compared different Doppler modalities (CD vs PD) different scoring systems (semiquantitative vs quantitative) or different ultrasound systems for Doppler-detected synovial blood flow [5,6,17,21].

In this study, we compared SH and the conventional Doppler modes, i.e. PD and CD, from a high-end ultrasound system and a portable ultrasound system (entry-level machine) in active and inactive RA patients.

Table III. Correlations between changes at three-month follow-up in semiquantitative- and quantitative-based total scores of synovial blood flow obtained with ultrasound system 1 and 2 in active patients. Correlation between total scores for PD, CD, B-Flow and High-Res PDI were estimated by the Pearson’s correlation coefficient.

<table>
<thead>
<tr>
<th>Change in ultrasound scores from baseline to three-month follow up</th>
<th>Active patients (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ PD system 1 with SQ PD system 2</td>
<td>0.41 (0.03-0.68; 0.035)</td>
</tr>
<tr>
<td>SQ CD system 1 with SQ CD system 2</td>
<td>0.39 (0.02-0.67; 0.042)</td>
</tr>
<tr>
<td>Q PD system 1 with Q PD system 2</td>
<td>0.29 (-0.13-0.62; 0.177)</td>
</tr>
<tr>
<td>Q CD system 1 with Q CD system 2</td>
<td>0.54 (0.18-0.78; 0.006)</td>
</tr>
<tr>
<td>SQ PD with SQ B-Flow system 1</td>
<td>0.55 (0.22-0.77; 0.003)</td>
</tr>
<tr>
<td>SQ CD with SQ B-Flow system 1</td>
<td>0.59 (0.27-0.79; 0.001)</td>
</tr>
<tr>
<td>SQ PD with SQ High-Res PDI system 2</td>
<td>0.45 (0.06-0.72; 0.025)</td>
</tr>
<tr>
<td>SQ CD with SQ High-Res PDI system 2</td>
<td>0.54 (0.19-0.77; 0.005)</td>
</tr>
<tr>
<td>Q PD with Q High-Res PDI system 2</td>
<td>0.79 (0.56-0.90; &lt;0.0005)</td>
</tr>
<tr>
<td>Q CD with Q High-Res PDI system 2</td>
<td>0.25 (-0.17-0.60; 0.232)</td>
</tr>
</tbody>
</table>

Pearson’s r values were expressed as value (95% CI; p). SQ, semiquantitative; Q, quantitative; PD, Power Doppler; CD, colour Doppler; r, Pearson correlation coefficient, CI, confidence interval.
Additionally, as an innovation, we compared B-Flow and High-Res PDI, two new blood flow detection modalities, with PD and CD modes.

In our study, SH and synovial Doppler activity were detected in a very similar number of patients by B-mode and conventional Doppler modes, respectively, of both ultrasound systems in active patients at baseline, active patients after 3 months of therapy escalation and inactive patients. However, High-Res PDI mode of ultrasound system 2 was less sensitive in active patients and B-Flow mode of ultrasound system 1 was much less sensitive both in active and inactive patients in capturing patients with synovial blood flow compared to PD or CD of both ultrasound systems.

In terms of total scores based on the sum of individual scores from each assessed joint, both ultrasound systems were similar for SH scores and semiquantitative PD and CD score in the active and remission groups. However, the high-end ultrasound system resulted in higher scores for quantitative PD and CD scores in the active group but not in the remission group. A greater sensitivity to detect blood flow of this system, not enough to produce significant differences in the semi-quantitative score, could impact the quantitative score, particularly in active patients.

Clearly, B-Flow and High-Res PDI offered lower patient’s total scores than conventional Doppler modes of their respective ultrasound systems in both active and remission group. The point is whether B-Flow and High-Res PDI are less sensitive for slow blood flow present in inflamed synovial tissue or actually detect less artefacts produced by conventional PD or CD, especially when used with settings adjusted for maximal flow detection sensitivity [17]. Future validation studies comparing synovial blood flow detected by conventional Doppler modes, B-Flow and High-Res PDI with histology are needed to clarify this issue.

Both ultrasound systems highly correlated for patient’s total scores of B-mode SH and, in general, substantially for patient’s total scores of PD and CD-based synovial blood flow, particularly when scored semi-quantitatively. It was expected that the quantitative score would correlate less between the two ultrasound systems as it is subject to more potential variability in each scan. Small differences in the synovial area selected for video recording and in the manual drawing of the area of interest for color fraction quantification can result in a substantial difference in the score. Thus, semiquantitative scoring system for synovial blood flow seemed to be more consistent between ultrasound systems than quantitative scoring. In general, correlation of patient’s total scores for B-Flow and High-Res PDI with conventional Doppler modes of their respective ultrasound systems were variable but acceptable.

Regarding sensitivity to change, at the group level, B-mode SH and PD and CD modes of both ultrasound systems were similarly responsive. In the same way, responsiveness of B-Flow and High-Res PDI was comparable to that of PD or CD modes of their respective ultrasound systems. However, correlations between changes in conventional Doppler modes of both ultrasound systems and between changes in B-Flow and High-Res PDI and changes in conventional Doppler modes of their respective ultrasound systems were only modest.

Some limitations in our study should be noted. The population was relatively small. Additionally, we utilized ultrasound systems from a single manufacturer, indicating that our findings may not be directly generalizable to systems from other manufacturers. Further studies are necessary to validate the results obtained in this study.

Furthermore, two different sonographers participated in the ultrasound scanning and interpretation. However, both investigators were highly experienced in musculoskeletal ultrasound as well as highly trained and involved in the standardization process of scoring synovitis with ultrasound.

**Conclusion**

Our results support that the two ultrasound systems evaluated can be considered interchangeable for scoring SH on B-mode. Both ultrasound systems showed similar sensitivity and responsiveness and acceptable concordance in scoring synovial blood flow by PD and CD modes, particularly semi-quantitatively, but not interchangeability. Therefore, in transverse or longitudinal studies in which synovial blood flow is assessed, all patients must be scanned with the same ultrasound system transversally and throughout the study period. B-Flow and High-Res PDI modes were able to detect therapy response although they showed a remarkably different sensitivity to detect synovial blood flow, especially B-Flow mode, compared to conventional Doppler modes that should be further addressed in future validation studies.

**Conflict of interest:** none

**Acknowledgement:** The equipment used for this study was provided by GE Healthcare Systems, Wauwatosa, WI, USA. General Electric did not have any influence on the study protocol, the conduct of study and its results.
References


