RHEUMATOLOGY

Rheumatology 2017;56:1312–1319
doi:10.1093/rheumatology/kex153
Advance Access publication 18 April 2017

Original article

Joint positions matter for ultrasound examination of RA patients—increased power Doppler signal in neutral versus flat position of hands

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Abstract

Objective. Position of joints might influence the result of US examination in patients with RA. The purpose of this work was to compare grey-scale (GS) and power Doppler (PWD) findings obtained in neutral *vs* flat position of hands.

Methods. A cross-sectional study of 42 RA patients with active disease. Two dimensional and 3D sonography of wrists and MCP joints were conducted in two different joint positions: neutral position, which is a slight flexion of the fingers with relaxed extensor muscles; and flat position, where all palm and volar sides of fingers touch the Table. Two dimensional GS synovitis (GSS) and PWD signals were scored semi-quantitatively (0–3). For 3D sonography, the percentage of PWD voxels within a region of interest was calculated. GSS was not quantified using 3D sonography.

Results. Compared with neutral position, 2D PWD signals disappeared in 28.3% of joints upon flattening. The median global 2D PWD score (sum of all PWD scores of an individual patient) decreased from 8 to 3 ($P < 0.001$), and the global 3D PWD voxel score from 3.8 to 0.9 ($P < 0.001$). The reduction of PWD scores was similar in all joints (2D: minus 50%, 3D: minus 66.4–80.1%). Inter- and intrareader agreement of PWD results was good (intraclass correlation coefficient: 0.75–0.82).

Conclusion. In RA, a neutral position of the hands is linked to a higher sensitivity of 2D and 3D sonography in detecting PWD signals at wrists and MCP joints, compared with a flat position. Standardization of the scanning procedure is essential for obtaining comparable US results in RA patients in trials and clinical routines.

Key words: rheumatoid arthritis, hand, diagnostic imaging, ultrasonography, wrist

CLINICAL SCIENCE

Rheumatology key messages

- Standardized ultrasound assessment of hands in RA patients is pivotal for producing reliable results.
- RA patients had a higher number of power Doppler positive joints in neutral versus flat position of hands.
- In RA patients, global 2D and 3D power Doppler scores decreased upon flattening of hands.

Introduction

US is increasingly used for the diagnosis and follow-up of patients with RA [1]. The new EULAR recommendations for the use of imaging in RA emphasized that sonography should be considered for a more accurate assessment of joint inflammation [2]. Previous studies demonstrated that power Doppler (PWD) signals may be detected in up to 60% of RA patients in clinical remission; conversely, sonographic signs of inflammation were absent in 20% of RA cases despite, increased DASs [3–7].

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Submitted 12 August 2016; revised version accepted 10 March 2017

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Although sonography is often criticized because of its operator dependence, most available studies in RA reported a good to excellent inter- and intra-observer reliability of US results [1]. In contrast, clinical joint counts are limited by a high inter-observer variance and unsatisfactory sensitivity and specificity for detecting joint inflammation [8, 9]. Moreover, US scores revealed a good sensitivity to change in follow-up studies of RA patients treated with CSs or biological agents [10–14].

A good reliability of US results, however, can only be obtained when guidelines on the conduction and interpretation of sonography exist, and when they are implemented with the standard operating procedures. In 2001, EULAR released recommendations on the standard US scans, and these are currently being updated [15]. Since then, several OMERACT projects and other initiatives have been conducted to better standardize sonography in RA, including definitions and scoring methods for grey scale synovitis (GSS) and PWD abnormalities [16–19].

In 2012, a study reported that the position of hands influenced PWD scores at wrists and MCP joints [20]. The authors demonstrated that a flat position of hands facilitated a more sensitive detection of PWD signals (thus resulting in higher PWD scores) compared with flexed or hyperextended positions. In a flat position of hands, however, extensor muscles (and tendons) are contracted, potentially leading to a compression of small vessels within the synovia of wrists and/or MCP joints. Whether US examination of hands in a neutral position (with relaxed extensors) is more sensitive than sonography in a flat position is unknown, and this was addressed by the present study using 2D and 3D US.

Methods

Patients

We performed a cross-sectional study on 42 consecutive RA patients with clinically active disease as defined by $\geqslant 1$ tender (TJ) and/or $\geqslant 1$ swollen joint (SJ) at wrists and/or MCP joints. All patients fulfilled the 2010 ACR-EULAR classification criteria for RA [21]. The institutional review board of the Medical University Graz approved the present study and written informed consent was obtained from each patient.

Patients underwent complete history as well as clinical assessment by one of two rheumatologists (M.S., J.H.) unaware of US results. The following parameters were recorded: number of TJs and SJs (68 articular index), the patient's global assessment of disease activity, the patient's pain assessment as well as the evaluator's global assessment of disease activity determined on visual analogue scales (range 0–100 mm; 100 = worst). Blood samples were routinely tested for ESR, normal range 0–10 mm/first hour) and CRP (normal range 0–5 mg/l) levels. The Simple Disease Activity Index (SDAI), the Clinical Disease Activity Index and the DAS-28 were calculated as previously described [22].

US protocol

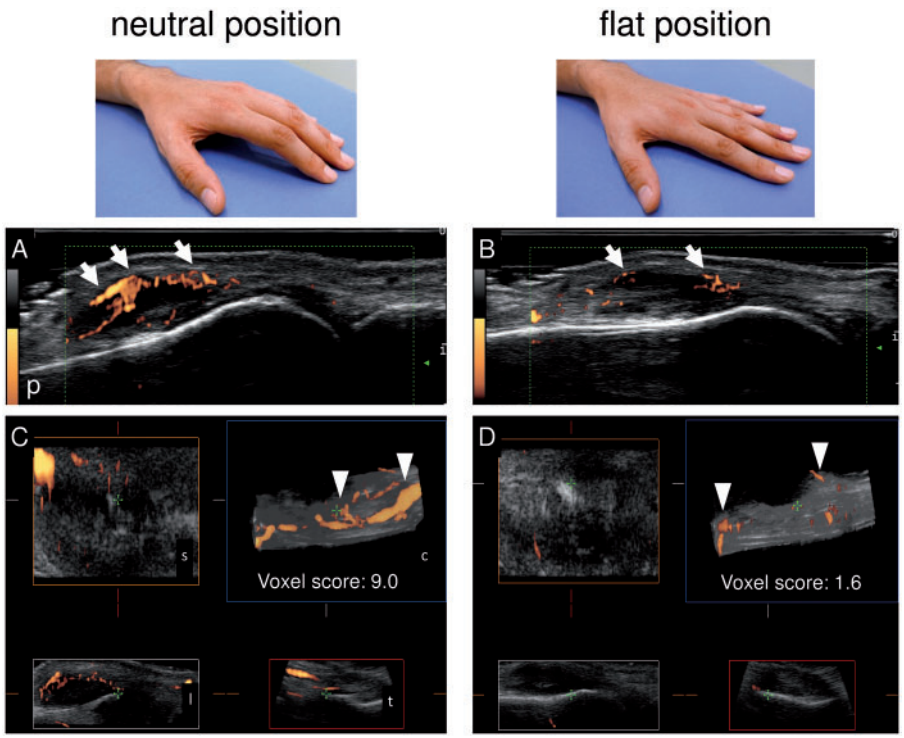
Technical settings

US was performed by one rheumatologist (R.H.) who was blinded to the clinical investigation performed on the same day. A 2D as well as a 3D volumetric probe was used. Grey scale (GS) and PWD scans were performed within the same session at dorsal sites of wrists and MCP joints 2–5 bilaterally. Examinations were conducted in a darkened room in which the temperature was held constant at 20 °C. Patients were not allowed to smoke before the examination. Each examination took 15–20 min. We used a MyLab Twice US device (Esaote, Genova, Italy) with a 2D multifrequency linear transducer (6–18 MHz) and a 3D multifrequency linear transducer (4–13 MHz). For GS scans, we used a frequency of 18.0 MHz (2D) or 13.0 MHz (3D). Imaging parameters were adjusted to maximize the contrast between examined structures. PWD settings were standardized accordingly: 2D PWD: frequency 9.1 MHz, pulse repetition frequency 750 Hz and medium persistence; 3D PWD: frequency 6.3 MHz, pulse repetition frequency 1000 Hz and medium persistence. The PWD gain was optimized (2D, 3D) by increasing the gain until noise appeared and then reducing it just enough to suppress the noise.

All 2D US scans were performed in longitudinal and transverse view in accordance with current guidelines and publications [2, 14]. GSS was identified by GS imaging in each joint as abnormal hypoechoic poorly compressible (synovial proliferation) and/or anechoic compressible intraarticular material (effusion) [15, 16]. 2D GSS was subjectively graded from 0 to 3 (0 represented no GSS, 1 = minimal, 2 = moderate and 3 = extensive GSS) as defined previously [16–18]. 2D PWD signals were also semi-quantitatively scored on a scale from 0 to 3 (0 = no PWD signal, 1 = up to three single or two confluent vessels, 2 = less than half of the synovia and 3 = half or more of the synovia covered by PWD signals) [16–18]. The 2D GSS and 2D PWD scores were rated in the longitudinal view; however, transverse scans were used to confirm the findings. For 3D sonography, the probe was placed at the wrist in a longitudinal position over the lunate bone and at MCPs, and in a longitudinal position over the extensor tendon and the joint space. Then, a total of 100 slides (over a transversal distance of 8.5 mm) were acquired by an automated sweep of the probe. Image acquisition was set at 10 s per sweep in order to decrease the possible variability of PWD signals caused by the different phases of the heart rhythm. For the assessment of PWD signals, a region of interest (ROI) was set manually along the borders of the synovial membrane using the stored image series. The percentage of PWD voxels within the ROI (= voxel score) was calculated by the integrated 3D software. GSS could not be quantified with 3D sonography because the software did not support the calculation of volumes in GS.

Scoring of GSS and PWD with 2D US was performed during the scan, whereas 3D images were stored and analysed at a later time-point. Sum scores (global scores) were calculated for 2D GSS (range 0–30), 2D

Fig. 1 Illustrations and US image examples of hands in neutral and flat positions



(**A**) and (**B**) depict 2D US images of a longitudinal dorsal scan of a MCP joint in neutral (**A**) and flat (**B**) hand position. Both images reveal a grey-scale synovitis grade 3 and a power Doppler (PWD) score of 2, albeit the level of PWD signals (arrows) is reduced upon flattening of the hand. (**C**) and (**D**) depict the reconstructions of 3D scans of the same joint (see Materials and Methods section for details on image acquisition) in neutral (**C**) and flat (**D**) hand position. The sagittal (s), longitudinal (l), transversal (t) and 3D cube (c) reconstructions, as well as the PWD voxel-score (Voxel-score), are shown. Arrowheads indicate intrasynovial PWD signals in the 3D reconstruction. P: proximal.

PWD (0–30) and 3D PWD voxels, adding the values obtained at each joint (range 0–1000).

Positioning of patients and hands

Patients were seated at the opposite site of the examination table with hands positioned on a cushion that was placed on the examination table. Wrist and MCP joints were then scanned in the following positions (see Fig. 1 for representative examples): neutral position, which is a slight flexion of the fingers in order that extensor muscles are relaxed, and that only the wrist and the finger tips touch the cushion; flat position, where all palm and volar site of fingers touch the cushion. Scans were always conducted within the same visit and in the same order: 2D sonography in neutral position; 2D sonography in extended position; 3D sonography in neutral position; and 3D sonography in extended position.

Reliability exercise

To test the interobserver reliability of 2D PWD and 3D PWD US findings, four patients were scanned at the same visit by a second rheumatologist (C.D.) blinded to the assessments of the first reader (R.H.). For intraobserver variability, saved video loops were assessed >1 week apart by one investigator (R.H.).

Statistical analysis

Statistical analysis was performed using SPSS (version 23.0). Descriptive statistics were used to summarize the data. For continuous non-parametric data, we show the median and range, whereas for parametric data, the means (S.D.) are depicted. Comparisons of paired data were analysed with the Wilcoxon test due to non-parametric distribution of data. Paired categorical data were analysed with the Chi-squared test. Inter-rater reliability was determined using the intraclass correlation coefficient (ICC).

Results

Clinical characteristics

Patients' characteristics are summarized in Table 1. Nine patients (21.4%) had a disease duration of $\leqslant 2$ years, and 5 (11.9%) were newly diagnosed with RA on the day of the study visit. Five (11.9%), 23 (54.8%) and 14 (33.3%) patients had low, median and high disease activity according to the SDAI, respectively; none was in remission. RF was present in 25 (59.5%) and ACPAs in 24 (57.1%) patients. Twelve patients (28.6%) received NSAIDs regularly or on

Table 1 Clinical characteristics of RA patients ($n = 42$)

Age at inclusion, mean (S.D.), years	59.1 (16.8)
Female, *n* (%)	28 (66.7)
BMI, mean (S.D.), kg/m^2	25.2 (4.05)
Disease duration, mean (S.D.), years	11.6 (9.02)
ESR, median (range), mm/1st h	20.0 (1–75)
CRP, median (range), mg/l	9.25 (0.3–60.7)
TJC, 68 joint count, median (range)	8.0 (0–45)
SJC, 66 joint count, median (range)	5.5 (0–23)
PGA, median (range), mm	50.0 (0–90)
Ptpain, mean (S.D.), mm	49.4 (23.4)
EGA, median (range), mm	41.8 (10–70)
SDAI, median (range)	22.0 (5.1–48.3)
CDAI, median (range)	20.8 (5.0–48)
DAS-28, mean (S.D.)	3.9 (1.05)
Smokers, *n* (%)	
Current	12 (28.6)
DMARDs, *n* (%)	
csDMARDs	20 (47.6)
bDMARDs	5 (11.9)
csDMARD + bDMARDs	12 (28.6)
No therapy[a]	5 (11.9)
RF positive, *n* (%)	25 (59.5)
aCCP positive, *n* (%)	24 (57.1)
NSAID, *n* (%)	
Regular	4 (9.5)
On demand	8 (19.0)
Glucocorticoids, *n* (%)	
Regular low dose ($\leqslant$7.5 mg/day)	10 (23.8)
Flare treatment (>7.5 mg/day)	2 (4.8)

EGA, PGA and Ptpain were measured on a visual analogue scale (range 0–100 mm) and are expressed in mm. [a]Diagnosis was established on the day of study visit. bDMARD: biologic DMARD; CDAI: clinical disease activity index; CRP (normal values 0–5 mg/l); csDMARD, conventional synthetic DMARDs; EGA: evaluator's global assessment of disease activity; ESR (normal values 1–10 mm/1st h); PGA: patient's global assessment of disease activity; Ptpain: patient's pain assessment; SDAI: Simple Disease Activity Index; SJC: swollen joint count; TJC: tender joint count.

demand, and 10 patients (23.8%) were treated with low-dose glucocorticoids.

Influence of hand position on US findings

Using 2D US, we observed in neutral position a positive GSS and/or PWD result in 225/420 (53.5%) and 215/420 (51.2%) joints, respectively. A GSS score of 1, 2 and 3 was observed in 46 (20.4%), 110 (48.9%) and 69 (30.7%) joints, respectively. Details concerning individual PWD scores are depicted in Table 2. The median global GSS score was 10.5 (range 1–23), and the median global PWD score was 8 (1–21).

Using 3D US, the number of joints with a positive PWD finding was lower ($n = 192$, 45.7%), reflecting a lower sensitivity of the 3D volumetric compared with the 2D probe (89.3% using 2D sonography as reference). Analyses focusing on 2D PWD scores included therefore all 215 PWD-positive joints, whereas for 3D PWD assessments we used only those 192 joints positive in both modalities. The median global 3D PWD voxel score was 3.7 (0.5–16.1), and the mean voxel score per joint was 0.9 (0.1–7.4) (calculated as the global voxel score/number of joints with any detectable pixel).

Three dimensional PWD findings correlated well with 2D results, with median voxel values being 0.4 (range 1.0–1.9), 1.1 (0.2–7.4) and 2.3 (0.3–7.2) in joints with 2D PWD-scores of 1, 2 and 3, respectively. Also, the global 2D PWD score and the global 3D voxel score correlated well ($corr_{coeff}$ 0.73, $P < 0.001$).

We found a weak to moderate correlation of the SJ count with the global 2D PWD score ($corr_{coeff}$ in neutral position 0.68, $P < 0.001$; $corr_{coeff}$ in flat position 0.61, $P < 0.001$) and the global 3D voxel score ($corr_{coeff}$ 0.41, $P < 0.05$ and $corr_{coeff}$ 0.38, $P < 0.05$, respectively). Neither 2D nor 3D scores correlated with the TJ count or ESR, whereas the 2D PWD score correlated weakly with CRP when hands were in the neutral position ($corr_{coeff}$ 0.35, $P < 0.05$).

Reduction of PWD scores in flat position of hands

With a flat position of hands as described in the Methods section, PWD signals were no longer detected in 61/215 joints (28.3%, $P < 0.001$) using 2D sonography. Figure 1 depicts representative 2D and 3D PWD US images. In 11 (26.2%) patients, $\geqslant$1 joint became PWD negative upon flattening of hands; these patients did not differ from the remaining in regard to SJs, TJs, DAS, disease duration or medication (data not shown).

Upon flattening of hands, the global 2D PWD score decreased from a median of 8 (range 1–21)–3 (0–16, $P < 0.001$), as detailed in Fig. 2. As outlined in Table 2, 2D PWD signals disappeared upon flattening of hands in 54.7% of joints with a PWD score of 1, in 18.6% with a PWD score of 2 and in 0% with a PWD score of 3 in neutral position. Joints with persisting PWD signals were more commonly swollen compared with those becoming PWD negative upon flattening (74.7% *vs* 45.9%, $P < 0.001$), whereas no difference was found in regard to tenderness.

For 3D US, the global PWD voxel score decreased from 3.8 (0.5–16.1) in neutral to 0.9 (0.1–5.4, $P < 0.001$) in flat position (Fig. 2). As detailed in Table 3, the reduction of the 3D PWD voxel scores was similar in joints with 2D PWD scores of 1, 2 or 3 (median reduction ranged from −71.7% to −75.5%). In two joints, the 3D voxel score increased upon flatting of hands: in one joint from 1.4 to 1.6 (corresponding to a change of +14.3%)—this joint yielded a 2D PWD score of 3 in neutral position. In the second joint, the 3D voxel score increased from 0.19 to 0.6 (+217.5%), and the 2D PWD score in neutral position was 2.

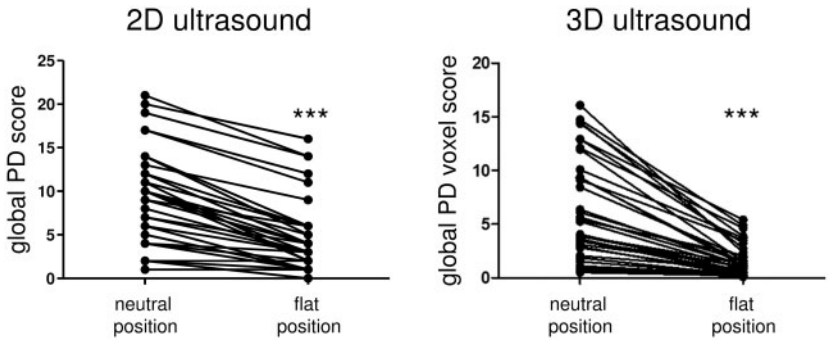
No difference was found with regard to GSS scores in neutral and flat positions, as investigated by 2D US (data not shown). Quantification of GSS with 3D sonography

Table 2 Prevalence of 2D US power Doppler scores in neutral and flat positions

Neutral position		Flat position			
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
		PWD = 0	PWD = 1	PWD = 2	PWD = 3
PWD = 0	205 (100)	205 (100)	0	0	0
PWD = 1	64 (29.8)	35 (54.7)	29 (45.3)*	0	0
PWD = 2	140 (65.1)	26 (18.6)	79 (56.4)	35 (25.0)*	0
PWD = 3	11 (5.1)	0	4 (36.4)	5 (45.5)	2 (18.2)*

A total of 420 joints were assessed. Data indicate the number of joints with 2D US power Doppler scores 0–3 in neutral and flat positions. *n*: number; PWD: power Doppler. $^{*}P < 0.001$ compared with neutral position, according to Chi-square test.

Fig. 2 Global 2D and 3D power Doppler scores for hands in neutral and flat positions



Funnel plots indicate the global 2D power Doppler (PWD)-scores (left) and the global 3D PWD voxel-scores (right) of patients with hands in neutral position and upon flattening. Each dot represents an individual patient. ***$P < 0.001$.

was not possible for technical reasons (see also Methods section).

Sub-analysis of PWD scores in individual joints

Two-dimensional PWD scores and 3D voxel scores of individual joints in neutral and flat position are detailed in Table 4. Overall, we observed a greater reduction in 3D voxel scores (median reduction ranged from −66.4% to −80.1%) than in 2D PWD scores (median reduction −50.0%).

Reliability exercise

Inter- as well as intrareader agreements for 2D PWD scores and 3D voxel scores were good. The inter-reader ICC of 2D PWD scores was 0.82 (95% CI: 0.69, 0.90), intra-reader ICC for 2D PWD scores was 0.75 (0.6–0.86), inter-reader ICC for 3D voxel scores was 0.75 (0.27–0.93) and intrareader ICC for 3D voxel scores was 0.79 (0.38–0.94).

Discussion

The present study demonstrates that in RA, a neutral position of hands is linked with a higher sensitivity of 2D and 3D sonography for detecting PWD signals at wrists and MCP joints as compared with a flat position, leading to a higher number of PWD-positive joints as well as to higher global PWD scores.

The results of our study have a major impact on the conduction of US scans of RA patients in clinical practice and trials: >50% of joints revealing a 2D PWD score of 1 and almost 20% of joints with score of 2 in neutral position were negative upon flattening of hands. Previous studies defined US remission by the absence of PWD signals, and reported that patients with a PWD score of $\geqslant 1$ had worse clinical and radiographic outcomes than patients without a positive PWD scan [3, 5, 6, 23]. Besides, trials have been conducted to investigate whether patients in clinical remission might benefit from a treatment change if PWD signals are still present [24, 25]. We have no longitudinal data to answer the question of whether PWD signals disappearing upon flattening of hands have any impact on clinical and structural outcomes. Our findings, however, underscore the importance of standardizing image acquisition in order to guarantee a reliable PWD assessment and to avoid artificial differences in PWD scores caused by a variation in joint positions.

Several initiatives have been or are currently being conducted to improve standardization of the scanning technique and image interpretation [15–19]; however, only a single previous study systematically investigated the

Table 3 Change of 3D US voxel-scores (neutral *vs* flat positions) according to 2D US scores ($n = 192$ joints)

2D-US	3D-US voxel-score			
	Neutral position	Flat position	Change	*P*-value
PWD = 0	NA	NA	NA	NA
PWD = 1	0.36 (0.97, 1.90)	0.07 (0.0, 0.85)	−76.1 (−100, −22.8)	<0.001
PWD = 2	1.10 (0.17, 7.40)	0.23 (0.0, 1.70)	−76.6% (−100, 217.5)	<0.001
PWD = 3	2.30 (0.31, 7.20)	0.67 (0.01, 1.60)	−83.1% (−96.8, 14.3)	<0.007
All joints	0.93 (0.10, 7.40)	0.20 (0.0, 1.70)	−76.6% (−100, 217.5)	<0.001

Data indicate the median (range) 3D-US voxel-scores in neutral and flat positions, stratified according to the PWD-scores 1–3, or the median voxel-score per joint, considering all joints (All joints). Differences were tested with the Wilcoxon test. NA: not assessed; PWD: power Doppler.

Table 4 2D and 3D power Doppler scores of individual joints in neutral and flat positions

joint	2D-US				3D-US			
	Neutral	Flat	Percentage change	*P*-value	Neutral	Flat	Percentage change	*P*-value
Wrist ($n = 43$)	2 (1–3)	1 (0–2)	−50.0 (−100, 0)	<0.001	1.2 (0.16–7.2)[a]	0.31 (0.0–0.91)	−76.9 (−100, −24.7)	<0.001
MCP 2 ($n = 56$)	2 (1–3)	1 (0–3)	−50.0 (−100, 0)	<0.001	0.72 (0.11–4.3)[a]	0.17 (0.0–1.4)[a]	−80.1 (−100, −28.6)	<0.001
MCP 3 ($n = 38$)	2 (1–3)	1 (0–2)	−50.0 (−100, 0)	<0.001	0.96 (0.10–7.4)[a]	0.2 (0.01–1.6)[a]	−79.0 (−93.1, −39.1)	<0.001
MCP 4 ($n = 28$)	2 (1–3)	1 (0–2)	−50.0 (−100, 0)	<0.001	1.1 (0.12–4.1)[a]	0.13 (0.0–1.7)[a]	−75.3 (−100, 14.3)	<0.001
MCP 5 ($n = 27$)	2 (1–2)	0 (0–2)	−50.0 (−100, 0)	<0.001	0.69 (0.1–3.1)[a]	0.19 (0.02–1.4)[a]	−66.4 (−99.1, 217.4	<0.001

Data indicate the median (range) 2D-US power Doppler as well as 3D-US voxel-scores in neutral and flat positions according to individual joints (bilateral sites of affected joints were grouped together). Differences were tested with the Wilcoxon test. [a]Data not normally distributed.

impact of joint positioning on image results [20]. In that study, a board was placed on the knee of patients, and finger joints were examined in flat position as well as at different levels of flexion or hyperextension using a protractor. They demonstrated that highest GSS and PWD scores were obtained when hands were in a flat position [20]. Our study extended these results, demonstrating that PWD sensitivity can be improved dramatically by a neutral compared with a strictly flat position of hands. Future EULAR (as well as other) guidelines on the conduction of sonography in rheumatology should therefore reference our findings and comment on the relevance of joint positioning for PWD studies.

The most likely explanation for our result is the occurrence of a higher intracapsular pressure upon contraction of extensor muscles and tendons, which leads to a compression of the small neo-vessels within the inflamed synovium [20]. GSS appears to be less affected by neutral *vs* flat positioning, whereas a 30–90° flexion of wrist and finger joints reduced the GSS scores at dorsal sites, as demonstrated previously [20]. This is most likely due to a consumption of the synovial reserve following a major joint flexion, leading to a reduction in the apparent thickness of the synovia.

We used the 3D US technique in addition to the conventional 2D method for two specific reasons.

(i) The semi-quantitative 2D PWD scoring system is imprecise. The present and previous studies noted that the majority of inflamed joints are classified as PWD Grade 2, which includes a wide range of vascularization from a few confluent vessels affecting <5% of the synovium up to extensive PWD signals covering only slightly <50% of the synovium [26–29]. The sensitivity for detecting differences is therefore lower compared with quantitative methods [30].

(ii) Three-dimensional US techniques enable a more objective assessment of vascularization. Although the sonographer was blinded to the clinical assessment, 2D PWD was scored subjectively during US examination, and the sonographer was thus aware of patients' joint position. This might have biased the results with an overestimation of the observed differences. In contrast, 3D voxel scores were calculated *post hoc* on saved image series by a semi-automated method (i.e. the ROI was placed manually but the voxel score was calculated by the computer), thus reducing the possible bias from a lack of blinding to joint position. The major limitation of 3D US is the fact that feeding vessels, other types or non-inflammatory vascularization as well as artefacts are all included in the final PWD voxel score [31]. We did our best to avoid these

factors (such as using careful placement of the ROI, slow image acquisition), but a certain degree of background noise can nevertheless never be avoided. We feel, however, that this noise is similar, at least at the group level, in scans of both neutral and flat joint positions.

Another limitation of this study was the heterogeneity of the patient cohort in regard to disease duration, clinical activity and treatment. Previous studies demonstrated that treatment with NSAIDs reduced the PWD signal, and a proportion of our patients used these drugs [32]. On the other hand, it is unlikely that treatment had an influence on the observed differences between neutral and flat joint positions, given that examinations were conducted within the same session. Further limitations included the small sample size and the fact that the reliability exercise was conducted in a small subgroup of patients only. On the other hand, the high statistical significance of our data suggest that the results would not have changed in principle if a larger group had been studied. Besides, the data of the reliability exercise suggested a good reproducibility of 2D and 3D PWD findings, similar to previous reports [20, 33].

In conclusion, 2D and 3D PWD US assessments of wrists and MCP joints were found to be more sensitive if hands were in a neutral (with relaxed extensor muscles) compared with in a flat position. A standardization of the scanning procedure is essential for obtaining comparable US results in trials and clinical routine.

Funding: No specific funding was received from any bodies in the public, commercial or not-for-profit sectors to carry out the work described in this manuscript.

Disclosure statement: C.D. reported receiving consultancy fees and honoraria from Merck Sharp & Dohme (MSD), Pfizer, UCB, AbbVie, Roche, Novartis, Lilly, Celgene, Merck and Sandoz; clinical trials design advisory board consultancies from Glaxo Smith Kline; unrestricted grant support from Pfizer and MSD; and material support from Esaote. All other authors have declared no conflicts of interest.

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