

Three-dimensional volumetric ultrasonography. Does it improve reliability of musculoskeletal ultrasound?

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ABSTRACT

Objective. To compare the interobserver reliability of three-dimensional (3D) volumetric ultrasonography (US) and 2D real-time US in detecting inflammatory and destructive changes in rheumatoid arthritis (RA) wrist and hand.

Methods. Two RA patients were selected by a rheumatologist who performed independently a grey-scale and power Doppler (PD) volumetric acquisition at three anatomic sites in their more symptomatic wrist/hand using two identical scanners equipped with 3D volumetric probe. Twelve rheumatologists expert in MSUS were randomly assigned to a US scanner and a patient. In the first part of the study, each group of experts blindly, independently, and consecutively performed a 2D real-time grey-scale and PD US investigation of inflammatory changes and/or bone erosions at the three anatomic sites. In the second part of the study, each group of investigators blindly evaluated the same pathologic changes in the 6 volumes from the patient not scanned by them.

Results. The kappa values were higher for 3D volumetric US than for 2D US in the detection of synovitis/tenosynovitis (0.41 vs. 0.37) and PD signal (0.82 vs 0.45) and in the PD signal grading (0.81 vs. 0.55).

Conclusion. 3D volumetric US may improve the interobserver reliability in RA multicentre studies.

Introduction

Within the last decade, there has been an increasing use of musculoskeletal (MS) ultrasound (US) in the evaluation and monitoring of patients with inflammatory arthritis in both rheumatologic clinical practice and research (1-4). MSUS with Doppler technique allows accurate assessment of joint inflammatory and structural changes (5-8). MSUS has been viewed as the most operator-dependent imaging technique. This fact has been mainly attributed to the intrinsic real time nature of ultrasound image acquisition.

For the last few years, volumetric probes (VPs) have been available in some high-end ultrasound machines.

VPs are mechanical transducers that emit ultrasound beams in a volumetric fashion. They have a large footprint that allows us to scan a relatively wide anatomic area. The acquisition of the ultrasound volume consists of an auto-matic sweeping scan movement of the piezoelectric crystals located inside the VP. Both grey-scale and colour or power Doppler (PD) mode can be used in volumetric scanning. The ultrasound images generated can be examined on longitudinal, transverse and coronal planes by navigating through the three planes and by producing a three-dimensional (3D) reconstruction of the anatomic area. This can be carried out at any time with or without the presence of the patient. In addition to volumetric acquisition, these VPs allow 2D real-time US scanning as in any linear transducer.

The principal advantages of 3D volumetric MSUS over conventional 2D MSUS given in the literature are the lack of influence of the examiner's experience over the image acquisition, the availability of the coronal plane and image reconstruction that may add useful information to 2D images, and the lower scanning time (9-11).

Filippucci *et al.* (11) demonstrated a good-to-excellent agreement between 3D centralised reading and conventional 2D US imaging of joint inflammation and bone erosions in rheumatoid arthritis (RA) patients. The purpose of this pilot study was to compare the interobserver reliability of 3D volumetric US and conventional 2D real-time US in detecting inflammatory and destructive changes in the wrist and hand of RA patients.

Methods

Patients

Two patients with RA according to the American College of Rheumatology 1987 criteria (12) were selected by a rheumatologist (IM) expert in MSUS. They were a 54-year-old man (disease duration, 22 months) and a 35-year-old woman (disease duration, 36 months). Both patients had clinical wrist and hand inflammatory activity at the time of the study.

Oral informed consent was obtained from the patients. The study was con-

ducted in accord with the Declaration of Helsinki and its revisions.

Observers

Observers consisted of 12 rheumatologists expert in MSUS (mean experience 9.7 years; range, 7-14 years). Before the study, they had occasionally used VPs. The observers were randomly distributed into two groups of 6 members. They were blinded to the patients' clinical data.

US investigation

The 13 experts met for one day to perform the reliability study. The US study was carried out using two identical commercially available US scanners (Logiq 9, Wauwatosa WI, USA) equipped with multifrequency electromechanical 3D dedicated VP (8-15 MHz). Each patient was assigned to a US machine.

Before the reliability exercise began, the investigator who selected the patients (IM) performed independently a grey-scale and PD volumetric acquisition at three anatomic sites in the more symptomatic wrist/hand of each patient (6 volumes per patient). These sites were the dorsal aspect of the radiocarpal (RC) joint, the dorsal aspect of the second metacarpophalangeal (MCP) joint and the extensor carpi ulnaris (ECU) tendon at the styloid process (SP) of the ulna. The settings of both US machines were adjusted before the acquisition process and were standardised for the whole study. These settings resulted in a grey-scale frequency of 15 MHz, Doppler frequency of 7.5 MHz, dynamic range of 66 dB, gain of 39 dB, pulse repetition frequency of 900 Hz, and volume angle of 14°. Each volumetric sweeping scan took 20 seconds. The total time spent on the US acquisition of the 12 volumes was 10 minutes. The 6 volumes acquired from each patient were stored in the respective US machine.

In the first part of the study, each group of experts was randomly assigned to a US scanner and a patient. The 6 members of each group blindly, independently, and consecutively examined the assigned patient. The investigators performed a multiplanar grey-scale and

PD examination of the dorsal aspect of the RC joint, the dorsal aspect of the second MCP joint, the ECU tendon, and the SP of the ulna using the VP in the 2D real-time mode. The presence of inflammatory changes (grey-scale synovitis or tenosynovitis and synovial or tenosynovial power Doppler signal) and/or bone erosions were investigated at the three sites. The Outcome Measures in Rheumatology Clinical Trials (OMERACT) definitions for US pathology were used (13, 14). The PD signal was graded on a semiquantitative scale of 0-3 (3). After finishing the 2D US scanning, each investigator carried out a grey-scale and PD volumetric acquisition at the three anatomic sites (6 volumes per patient) which were stored anonymously in the US machine. Each investigator was given a maximum of 10 minutes for 2D scanning, anonymously filling in a standardised report sheet with the US findings and to acquire the 6 volumes.

In the second part of the study, each group of investigators was moved to the other US scanner. The 6 investigators each simultaneously and blindly evaluated the 6 volumes acquired and recorded before the start of the reliability exercise from the patient not scanned by them. A US application specialist showed to each group the US volumes by navigating through the longitudinal, transverse, and coronal planes along with the 3D reconstruction. They were given a maximum of 10 minutes for this task. The observers assessed the same pathologic changes as they did during the 2D US evaluation of the other patient.

In the last part of the study, each group

was given 30 minutes for independently and anonymously evaluating the diagnostic quality of the 6 volumes acquired and recorded by each member of the other group (total, 36 volumes). A 1-5 Likert scale was used to assess the volumes in which 1 indicated "very bad quality"; 2, "insufficient quality"; 3, "sufficient quality"; 4, "good quality"; and 5, "excellent quality". After the volume assessments, the investigators reviewed together those recorded volumes scored below 3.

Statistical analysis

Interobserver reliability for the 2D US and the 3D volumetric US assessment were calculated using an unweighted kappa (κ) test. Mean \pm SD and range were calculated for the quality assessment of the US volumes. *P*-values less than 0.05 were considered significant.

Results

Table I displays the kappa values for the pathologic changes in 2D real-time US and 3D volumetric US. The kappa values were higher for 3D volumetric US than for 2D US for the detection of synovitis/tenosynovitis, and for the detection and grading of PD signal. For bone erosions, the 3D US interobserver reliability was slightly better than in 2D US.

The mean (\pm SD; range) score for the volume diagnostic quality obtained by the 12 investigators was 3.85 (\pm 0.55; 2.50-4.70). Only 5 volumes from 2 investigators were scored below 3 (all were scored 2) because of lack of contact of the VP with the skin and PD movement artefacts.

Representative images of 3D volumetric US are shown in Figures 1 and 2.

Table I. Interobserver reliability of two-dimensional ultrasonography and three-dimensional volumetric ultrasonography.

Pathologic findings	2D US Kappa value (<i>p</i>)	3D V US Kappa value (<i>p</i>)
Synovitis/tenosynovitis	0.372 (0.001)	0.410 (<0.0005)
PD signal	0.452 (<0.0005)	0.819 (<0.0005)
PD signal grade	0.550 (<0.0005)	0.813 (<0.0005)
Bone erosions	0.450 (<0.0005)	0.474 (<0.0005)

PD: power Doppler; 2D: two-dimensional; 3D: three-dimensional; V: volumetric

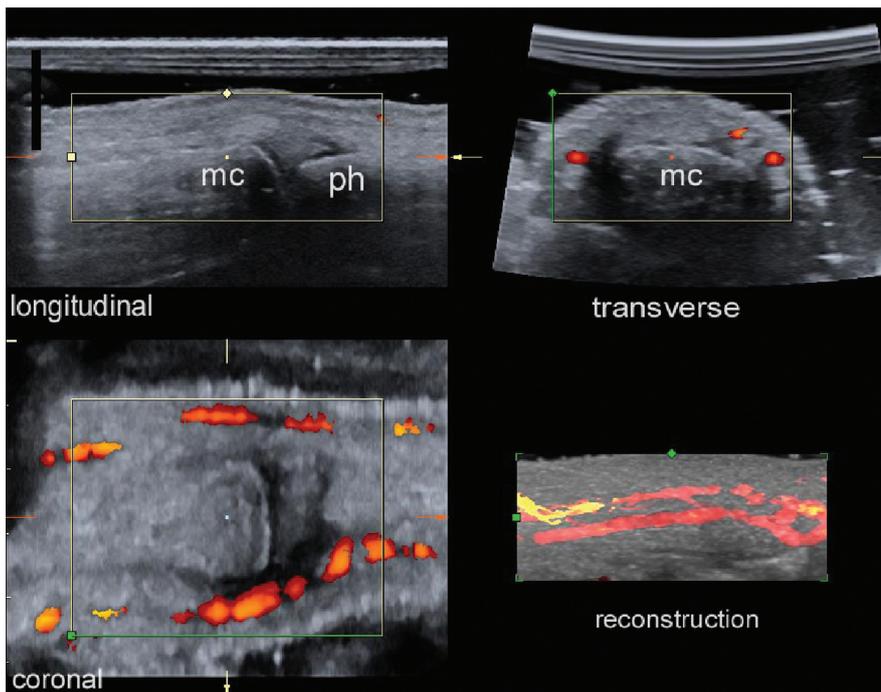


Fig. 1. Grey-scale images and power Doppler of a normal metacarpophalangeal joint obtained with three-dimensional volumetric ultrasonography. The longitudinal, transverse, and coronal planes at a selected anatomic level (central yellow point in the longitudinal plane) of the joint and the reconstruction volume are shown. The normal digital vessels are visualised. mc: metacarpal bone; ph: proximal phalanx.

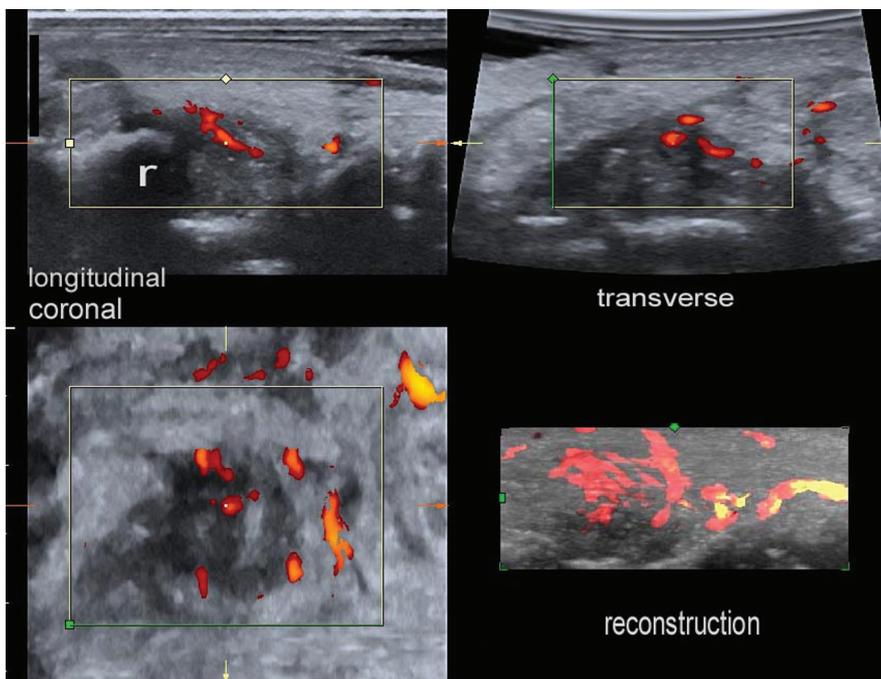


Fig. 2. Grey-scale and power Doppler images of the wrist obtained with three-dimensional volumetric ultrasonography show synovitis with power Doppler signal. The longitudinal, transverse, and coronal planes at a selected anatomic level (central yellow point in the longitudinal plane) of the joint and the reconstruction volume are visualised. r: radius.

Discussion

A good US interobserver reliability between two examiners has been reported

in previous RA studies conducted by individual research centres (15). The European League Against Rheu-

matism (EULAR)-OMERACT group for MSUS has communicated a good interobserver reliability for assessing RA synovitis after strict image acquisition standardisation (14). However, operator-dependence can be a barrier to MSUS wide use in multicentre studies in which ultrasonographers with different background and training participate.

In keeping with the results from Filippucci *et al.* (11), interobserver reliability for evaluating inflammatory and structural RA changes was better using 3D volumetric US than using 2D US. In our pilot study, this fact was especially relevant for PD findings. Of particular note is that our study design is complementary to the study method used by Filippucci *et al.* (11). These authors (11) demonstrated that centralised 3D US volumes reading can be more reliable than 2D real-time US performance. We showed that interobserver reliability between multiple ultrasonographers improved in 3D US reading as compared with conventional 2D US.

Surprisingly, 3D US reliability was almost similar to 2D reliability for bone erosions. It is probably that the variability in detecting erosions was mainly related to the image interpretation instead of the acquisition process.

The diagnostic quality of the volumes acquired by most investigators was qualified as sufficient to almost excellent. Although US image acquisition with VP seems to be not-operator dependent, the knowledge of the anatomic landmarks, the correct placement of the probe, the use of an appropriate amount of gel and the avoidance of movement of the patient and the examiner are all necessary to obtain US volumetric images with sufficient diagnostic quality. In conclusion, 3D volumetric US may improve the interobserver reliability in RA multicentre studies.

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