Ultrasound imaging for the rheumatologist
XX. Sonographic assessment of hand and wrist joint involvement in rheumatoid arthritis: comparison between two- and three-dimensional ultrasonography

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ABSTRACT

In the rheumatology literature, most of the available evidence on three-dimensional ultrasound (3D US) is related to the acquisition process and highlights the virtual operator independence and shortening of the US examination time. The main aim of this study was to compare 3D US using a high-frequency volumetric probe and conventional 2D US at the wrist and hand in patients with rheumatoid arthritis (RA). The 3D US examinations were performed using a Logiq 9 (General Electrics Medical Systems, Milwaukee, WI) with a high-frequency (8-15 MHz) volumetric probe. Overall, there is good-to-excellent agreement between the two modalities relating to both joint inflammation and bone erosion. This study is an initial step towards establishing a methodology necessary for developing multi-centre US studies which are aimed at assessing hand involvement in patients with RA.

Introduction

Over the last ten years, a consistent number of studies has been published providing evidence supporting the validity of ultrasonography (US) in the assessment of patients with rheumatoid arthritis (RA) (1-10) and other rheumatic diseases (11-16). Several important advances have also been made in US technology which have resulted in an impressive improvement in the quality and sensitivity of US imaging. Foremost amongst the latest innovations is the arrival of high frequency volumetric probes which allow the automated acquisition of three-dimensional (3D) data sets (17-23). A volumetric probe contains a transducer which sweeps electronically whilst acquiring a virtually infinite number of scanning planes under the probe footprint.

The advantages of 3D US compared to conventional 2D US have already been described in the literature and are predominantly related to the acquisition process; virtual operator independence and shortening of the examination time.

The main aim of this study is to compare 3D US using a volumetric probe and conventional 2D US in the detection and scoring of US findings in the wrist and hand of patients with RA. As a secondary aim, the inter-observer agreement of sonographers using 2D US was calculated.

Methods

Patients

Two patients with RA fulfilling the American College of Rheumatology diagnostic criteria (24) were enrolled in the study. The two selected patients (a 46-year-old sero-positive female with 10 years of disease duration and bone erosions documented on plain x-ray and a 39-year-old sero-negative male with 3 years of disease duration and no bone erosions on plain x-ray) had clinical involvement of the wrist and hand joints.

US scanning technique

US examinations were performed independently by four rheumatologists experienced in musculoskeletal US, using a Logiq 9 (General Electrics Medical Systems, Milwaukee, WI) equipped with a high-frequency (8-15 MHz) volumetric probe.

The dominant hand of each patient was scanned at the following anatomical sites: radio-carpal, inter-carpal and ulno-carpal joints and second to fifth metacarpophalangeal (MCP) joints.

The acquisition of 3D data sets was obtained first following the standardised scanning protocol described in Table I followed by conventional scanning of the same sites using the conventional 2D multi-planar technique. For each US examination a total of 20 minutes were assigned to each sonographer: 5 minutes for 3D data set acquisition and 15 minutes for the 2D US assessments. The acquisition time of a single 3D data set ranged from 3 to 10 seconds according to the value of the volume angle.

The 2D US multi-planar examinations were conducted using the accessible articular surfaces. All wrist and hand joints were scanned on the dorsal aspect from lateral to medial in both longitudinal and transverse views. Radio-carpal and inter-carpal joints, second and third MCP joints were also scanned on the volar aspects. The 2D US images showing the maximal area of enhancement on power Doppler were stored and considered for interpretation.

In order to avoid elevation of intra-articular pressure, patients were examined in the neutral position and the probe was placed on the area under examination using minimal compression and a thin layer of gel visible between the footprint of the probe and the skin. The setting parameters were as follows: greyscale frequency was 15 MHz, Doppler frequency was 7.5 MHz, pulse repetition frequency was set at 900 Hz, volume angle was variable according to the size of the anatomical site under examination ranging from 14 to 19. The wall filters and the colour gain were set as illustrated by Torp-Pedersen *et al.* (25).

US image interpretation

The following US findings were assessed: joint cavity widening due to either synovial effusion and/or synovial hypertrophy, intra-articular power Doppler signal and bone erosions. Appropriate semi-quantitative scales were used where applicable. OMERACT preliminary definitions were adopted for the identification of the US findings (4).

Joint cavity widening was graded using a semi-quantitative scoring system which consisted of a 0-3 scale (0 = absent; 1 = mild; 2 = moderate; 3 = marked) (2, 6, 7). Intra-articular power Doppler signal was subjectively graded on a semi-quantitative scale from 0 to 3 (0 = absent; 1 = mild; 2 = moderate; 3 = marked) (3, 6, 7, 9, 10).

MCP joints were examined to evaluate the presence, location and size of bone erosions (4, 5). The site of bone erosion was recorded according to the bone involved (metacarpal head or base of the proximal phalanx) and the quadrant (lateral, dorsal or volar). The size of bone erosion was measured using electronic callipers and a semi-quantitative scale (very small erosion: <1 mm, small erosion 1-2 mm, moderate erosion: 2.1-4 mm, and large erosion >4 mm) (26).

All the 3D data sets were collected and assessed independently by a fifth rheumatologist experienced in musculoskeletal US blind to clinical data. The operator underwent dedicated training for post-processing the 3D data sets lasting approximately three hours and evaluated more than two hundred cubes using the Logiq 9. The software displays automatically the three main perpendicular planes: longitudinal, transverse and coronal; indicating the exact point of intersection of all three. This was particularly useful to confirm the presence of bone erosion according to the definition of findings in two perpendicular views. Intra-articular power Doppler

Table I. Requirements for acquisition of 3D data sets of the hand and wrist in RA patient.

Patient position	Acoustic window	Anatomical landmarks for acquiring the 3D data sets	Pathological condition
Neutral position	Dorsal median aspect of the wrist	The bone profile of the radius, lunate bone and capitate bone and the outline of the tendons lying within the IV compartment of the wrist must be included in the longitudinal dorsal scan and used as a reference for acquiring the 3D data set	Synovitis of the radio-carpal and inter-carpal joints
Neutral position	Medial aspect of the wrist	The bone profile of the head of the ulna and of the medial aspect of the triquetrum bone and the outline of the extensor ulnaris carpi tendon lying within the VI compartment of the wrist must be included in the longitudinal lateral scan and used as a reference for acquiring the 3D data set	Synovitis of the ulno-carpal joint and bone erosion of the ulnar head
Neutral position	Volar median aspect of the wrist	The bone profile of the radius, lunate bone and capitate bone and the outline of the median nerve must be included in the longitudinal volar scan and used as a reference for acquiring the 3D data set	Synovitis of the radio-carpal and inter-carpal joints
Neutral position	Dorsal aspect of the II to V MCP joints	The bone profile of the metacarpal head and proximal phalanx and the outline of the finger extensor tendon must be included in the longitudinal dorsal scan used as a reference for acquiring the 3D data set	Synovitis of the II to V MCP joints, and bone erosion of the metacarpal heads
Neutral position	Lateral aspect of the II MCP joint	The lateral bony profile of the metacarpal head and proximal phalanx must be included in the longitudinal lateral scan and used as a reference for acquiring the 3D data set	Bone erosion of the metacarpal head
Neutral position	Volar aspect of the II to III MCP joints	The bone profile of the metacarpal head and proximal phalanx and the outline of finger flexor tendons must be included in the longitudinal volar scan and used as a reference for acquiring the 3D data set	Synovitis of the II to III MCP joints
MCP joint in maximal flexion	Dorsal aspect of the II MCP joint	The bone profile of the metacarpal head and the outline of its hyaline cartilage	Bone erosion of the metacarpal head

MCP: metacarpophalangeal.

Table II. Inter-observer agreement rates estimated by kappa values.

A. Inter-observer agreement between 3D centralised reading and 2D US results

	Joint cavity widening		Intra-articular PDS		Bone erosions	
	Presence/Absence - unweighted kappa values (95% CI)	Scoring - weighted kappa values (SE)	Presence/Absence - unweighted kappa values (95% CI)	Scoring - weighted kappa values (SE)	Presence/Absence - unweighted kappa values (95% CI)	Scoring - weighted kappa values (SE)
3D centralised reading/ Sonographer 1	0.908 (0.731 – 1.085)	0.783 (0.161)	0.805 (0.548 – 1.063)	0.763 (0.174)	0.817 (0.572 – 1.063)	0.828 (0.140)
3D centralised reading/ Sonographer 2	0.908 (0.731 – 1.085)	0.900 (0.162)	0.904 (0.721 – 1.088)	0.887 (0.179)	0.913 (0.745 – 1.081)	0.848 (0.139)
3D centralised reading/ Sonographer 3	0.814 (0.567 – 1.060)	0.788 (0.166)	0.805 (0.548 – 1.063)	0.763 (0.174)	0.676 (0.326 – 1.025)	0.788 (0.141)
3D centralised reading/ Sonographer 4	0.817 (0.574 – 1.059)	0.900 (0.162)	0.904 (0.721 – 1.088)	0.887 (0.179)	0.817 (0.572 – 1.063)	0.793 (0.141)

B. Inter-observer agreement of 2D US assessments

	Joint cavity widening		Intra-articular PDS		Bone erosions	
	Presence/Absence - unweighted kappa values (95% CI)	Scoring - weighted kappa values (SE)	Presence/Absence - unweighted kappa values (95% CI)	Scoring - weighted kappa values (SE)	Presence/Absence - unweighted kappa values (95% CI)	Scoring - weighted kappa values (SE)
Sonographer 1/ Sonographer 2	0.804 (0.544 – 1.063)	0.658 (0.163)	0.899 (0.706 – 1.092)	0.747 (0.177)	0.913 (0.745 – 1.081)	0.837 (0.141)
Sonographer 1/ Sonographer 3	0.697 (0.379 – 1.016)	0.633 (0.174)	0.790 (0.514 – 1.067)	0.728 (0.178)	0.676 (0.326 – 1.025)	0.679 (0.138)
Sonographer 1/ Sonographer 4	0.713 (0.411 – 1.015)	0.658 (0.163)	0.697 (0.379 – 1.016)	0.621 (0.177)	0.817 (0.572 – 1.063)	0.865 (0.147)
Sonographer 2/ Sonographer 3	0.899 (0.706 – 1.092)	0.778 (0.167)	0.899 (0.706 – 1.092)	0.747 (0.177)	0.600 (0.233 – 0.967)	0.721 (0.139)
Sonographer 2/ Sonographer 4	0.713 (0.411 – 1.015)	0.790 (0.163)	0.804 (0.544 – 1.063)	0.761 (0.180)	0.913 (0.745 – 1.081)	0.882 (0.141)
Sonographer 3/ Sonographer 4	0.805 (0.548 – 1.063)	0.889 (0.167)	0.899 (0.706 – 1.092)	0.747 (0.177)	0.676 (0.326 – 1.025)	0.735 (0.143)

CI: confidence interval; SE: standard error.

signal was evaluated using the 3D image reconstruction and the tomographic ultrasound imaging.

Statistical analysis

Inter-observer agreement was calculated using kappa-statistics (unweighted for dichotomous evaluation and linear weighted for semi-quantitative assessment). A kappa-value of 0-0.20 was considered poor, 0.21-0.40 fair, 0.41-0.60 moderate, 0.61-0.80 good and 0.81-1.00 excellent (27). The MedCalc (Belgium, release 9.0) software for Windows XP was used.

Results

Table II reports the kappa values estimating the inter-observer agreement between the 2D US and the 3D US findings and the rates of agreement of 2D US results obtained by the four experienced sonographers.

Joint inflammation

Good-to-excellent agreement rates were obtained both in the detection of presence/absence of US findings and in the use of the semi-quantitative scoring systems. The inter-observer agreement between 3D and 2D US in the detection of sonographic findings indicative of joint inflammation showed unweighted kappa values ranging from 0.814 to 0.908 for greyscale findings and from 0.805 to 0.904 for intra-articular power Doppler signal. Weighted kappa values estimating the inter-observer agreement between 3D and 2D in scoring greyscale and power Doppler findings ranged from 0.783 to 0.900 and from 0.763 to 0.887, respectively.

The levels of inter-observer agreement of 2D US assessments were also good-to-excellent with unweighted kappa values ranging from 0.697 to 0.899 for both greyscale and power Doppler and weighted kappa values ranging from 0.633 to 0.889 and from 0.621 to 0.761 for greyscale and power Doppler signal, respectively.

Bone erosions

Good-to-excellent agreement rates were found both in the detection of presence/absence of bone erosions and in their semi-quantitative assessment. The analysis comparing 3D and 2D results showed unweighted kappa values for the dichotomous evaluations ranging from 0.676 to 0.913 and weighted kappa for semi-quantitative assessments ranging from 0.788 to 0.848. The kappa values estimating the inter-observer agreement of 2D US evaluations ranged from 0.600 to 0.913 for the dichotomous evaluations and from 0.679 to 0.882 for the semi-quantitative assessments.

Discussion

To the best of our knowledge, this is the first study designed to compare 3D centralised reading and 2D US findings indicative of joint involvement in patients with RA. The results indicate that good to excellent agreement rates can be obtained for both joint inflammation and bone erosion.

Disagreement can be explained by the fact that 2D US assessment may overestimate or underestimate the number of US findings and their severity with respect to 3D US reading. Representative 2D images obtained with the aim of showing the highest expression of intra-articular power Doppler signal may overestimate the total amount of signal given that it can be focally distributed in a circumscribed part of the joint cavity. Thus, an image obtained at that level can be scored relatively highly but the remaining part of the joint cavity may have a significantly lower degree of power Doppler signal. Conversely, 2D US may underestimate the amount of intra-articular power Doppler signal or the presence of bone erosion because the operator could have failed to identify them owing to pressure of time. The acquisition of the 3D data set includes all the volume under the footprint and its assessment is made afterwards by a reader who has no time limitation.

The operators were experienced sonographers who were familiar with the US equipment used in the study. This aspect may explain in part the high kappa values of the inter-observer agreement in 2D US.

The main limitation of the present study is the restricted number of patients which reduces both the anatomical and pathological variability of the examined districts.

Conclusion

The present study represents the first step towards establishing the methodology necessary for developing multicentre US studies aimed at assessing hand involvement in patients with RA. The results justify the development of the process with a larger number of patients in a multi-centre study.

Link

For ultrasound images, go to www.clinexprheumatol.org/ultrasound

References

1. FILIPPUCCI E, IAGNOCCO A, MEENAGH G *et al.*: Ultrasound imaging for the rheumatologist VII. Ultrasound imaging in rheumatoid arthritis. *Clin Exp Rheumatol* 2007; 25: 5-10.
2. BROWN AK, QUINN MA, KARIM Z *et al.*: Presence of significant synovitis in rheumatoid arthritis patients with disease-modifying antirheumatic drug-induced clinical remission: evidence from an imaging study may explain structural progression. *Arthritis Rheum* 2006; 54: 3761-73.
3. NAREDO E, MÖLLER I, CRUZ A, CARMONA L, GARRIDO J: Power Doppler ultrasonographic monitoring of response to anti-tumor necrosis factor therapy in patients with rheumatoid arthritis. *Arthritis Rheum* 2008; 58: 2248-56.
4. WAKEFIELD RJ, BALINT PV, SZKUDLAREK M *et al.*: Proceedings from the OMERACT Special Interest Group for Musculoskeletal Ultrasound including definitions for ultrasonographic pathology. *J Rheumatol* 2005; 32: 2485-7.
5. FILIPPUCCI E, IAGNOCCO A, MEENAGH G *et al.*: Ultrasound imaging for the rheumatologist II. Ultrasonography of the hand and wrist. *Clin Exp Rheumatol* 2006; 24: 118-22.
6. SZKUDLAREK M, COURT-PAYEN M, JACOBSEN S, KLARLUND M, THOMSEN HS, OSTERGAARD M: Interobserver agreement in ultrasonography of the finger and toe joints in rheumatoid arthritis. *Arthritis Rheum* 2003; 48: 955-62.
7. FILIPPUCCI E, IAGNOCCO A, SALAFFI F, CERIONI A, VALESINI G, GRASSI W: Power Doppler sonography monitoring of synovial perfusion at the wrist joints in patients with rheumatoid arthritis treated with adalimumab. *Ann Rheum Dis* 2006; 65: 1433-7.
8. ALBRECHT K, MÜLLER-LADNER U, STRUNK J: Quantification of the synovial perfusion in rheumatoid arthritis using Doppler ultrasonography. *Clin Exp Rheumatol* 2007; 25: 630-8.
9. MEENAGH G, FILIPPUCCI E, DELLE SEDIE A *et al.*: Ultrasound imaging for the rheumatologist XVIII. Ultrasound measurements. *Clin Exp Rheumatol* 2008; 26: 982-5.
10. IAGNOCCO A, EPIS O, DELLE SEDIE A *et al.*: Ultrasound imaging for the rheumatologist. XVII. Role of colour Doppler and power Doppler. *Clin Exp Rheumatol* 2008; 26: 759-62.
11. MEENAGH G, FILIPPUCCI E, IAGNOCCO A *et al.*: Ultrasound imaging for the rheumatologist VIII. Ultrasound imaging in osteoarthritis. *Clin Exp Rheumatol* 2007; 25: 172-5.
12. RIENTE L, DELLE SEDIE A, FILIPPUCCI E *et al.*: Ultrasound imaging for the rheumatologist IX. Ultrasound imaging in spondyloarthritis. *Clin Exp Rheumatol* 2007; 25: 349-53.
13. DELLE SEDIE A, RIENTE L, FILIPPUCCI E *et al.*: Ultrasound imaging for the rheumatologist X. Ultrasound imaging in crystal-related arhtropathies. *Clin Exp Rheumatol* 2007; 25: 513-7.
14. IAGNOCCO A, FILIPPUCCI E, MEENAGH G *et al.*: Ultrasound imaging for the rheumatologist. XI. Ultrasound imaging in regional pain syndromes. *Clin Exp Rheumatol* 2007; 25: 672-5.
15. RIENTE L, DELLE SEDIE A, FILIPPUCCI E *et al.*: Ultrasound imaging for the rheumatologist XIV. Ultrasound imaging in connective tissue diseases. *Clin Exp Rheumatol* 2008; 26: 230-3.
16. DELLE SEDIE A, RIENTE L, FILIPPUCCI E *et al.*: Ultrasound imaging for the rheumatologist. XV. Ultrasound imaging in vasculitis. *Clin Exp Rheumatol* 2008; 26: 391-4.
17. FILIPPUCCI E, MEENAGH G, EPIS O *et al.*: Ultrasound imaging for the rheumatologist XIII. New trends. Three-dimensional ultrasonography. *Clin Exp Rheumatol* 2008; 26:1-4.
18. MEENAGH G, FILIPPUCCI E, ABBATTISTA T, BUSILACCHI P, GRASSI W: Three-dimensional power Doppler sonography in short-term therapy monitoring of rheumatoid synovitis. *Rheumatology* 2007; 46: 1736.
19. FILIPPUCCI E, MEENAGH G, DE AGUSTIN JJ *et al.*: Level of agreement between rheumatologists on US image acquisition using a 3D volumetric probe. *Clin Exp Rheumatol* 2007; 25: 116.
20. STRUNK J, LANGE U: Three-dimensional power Doppler sonographic visualization of synovial angiogenesis in rheumatoid arthritis. *J Rheumatol* 2004; 31: 1004-6.
21. STRUNK J, STRUBE K, MÜLLER-LADNER U, LANGE U: Three dimensional power Doppler ultrasonography confirms early reduction of synovial perfusion after intra-articular steroid injection. *Ann Rheum Dis* 2006; 65: 411-2.
22. STRUNK J, STRUBE K, RUMBAUR C, LANGE U, MÜLLER-LADNER U: Interobserver agreement in two- and three-dimensional power Doppler sonographic assessment of synovial vascularity during anti-inflammatory treatment in patients with rheumatoid arthritis. *Ultraschall Med* 2007; 28: 409-15.
23. JU JH, YOON CH, KIM HY, PARK SH: Clinical images: visualization of the inner synovial surface with three-dimensional ultrasonography. *Arthritis Rheum* 2007; 56: 214.
24. ARNETT FC, EDWORTHY SM, BLOCH DA *et al.*: The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. *Arthritis Rheum* 1988; 31: 315-24.
25. TORP-PEDERSEN ST, TERSLEV L: Settings and artefacts relevant in colour/power Doppler ultrasound in rheumatology. *Ann Rheum Dis* 2008; 67: 143-9.
26. KANE D, GRASSI W, STURROCK R, BALINT PV: Musculoskeletal ultrasound – a state of the art review in rheumatology. Part 2: Clinical indications for musculoskeletal ultrasound in rheumatology. *Rheumatology* 2004; 43: 829-38.
27. LANDIS JR, KOCH GG: The measurement of observer agreement for categorical data. *Biometrics* 1977; 33: 159-74.