

Ultrasound of the hand and wrist in rheumatology

Violeta Vlad¹, Mihaela Micu², Francesco Porta³, Goran Radunovic⁴, Rodina Nestorova⁵, Tzvetanka Petranova⁶, Annamaria Iagnocco⁷

¹ Sf. Maria Clinical Hospital, Bucharest, Romania

² Division of Rheumatology, Department of Rehabilitation II, Rehabilitation Clinical Hospital Cluj- Napoca, Romania

³ University of Florence, Department of Internal Medicine, Section of Rheumatology

⁴ Institute of Rheumatology, Medical School, University of Belgrade, Belgrade, Serbia

⁵ Centre of Rheumatology "St. Irina", Sofia, Bulgaria

⁶ Clinic of Rheumatology, Medical University, Sofia, Bulgaria

⁷ Rheumatology Unit, Dipartimento Medicina Interna e Specialità Mediche, Sapienza Università di Roma, Rome, Italy

Abstract

Musculoskeletal Ultrasonography (US) is nowadays widely used for clinical grounds and for research purposes in rheumatology. US of the hand and wrist has recently developed due to the technological improvement and use of new, high resolution transducers. US is currently improving clinical examination of the rheumatic hand and wrist and it is commonly used as daily practice by many rheumatologists. The number of publications addressing this area of US scanning has grown exponentially over the last few years. The aim of this paper is to review the current literature on US of the hand and wrist in rheumatology, including US scanning techniques, as well as normal and pathological findings.

Keywords: hand, wrist, ultrasound, anatomy, pathology

Introduction

Ultrasonography (US) assessment of the hand and wrist represents a huge step in rheumatology imaging. As wrist and hand joints are main target areas in both inflammatory and degenerative conditions, they have been heavily studied during the last years. Improvements and corrections have been made with regard to the methodology of scanning, the main structures that could be seen through US windows, pathology definition, description and quantification, but mostly regarding the standardization of the procedure. The development of a unique,

global scoring system for US synovial changes, particularly in rheumatoid arthritis (RA), is an important issue for the implementation of US as an Outcome Measure for clinical trials, and it is still under debate. The aim of this review is to analyze the current literature regarding US of the hand and wrist in rheumatology, including US scanning technique and normal and pathological findings.

US scanning technique

Standard US scanning of the wrist and hand is performed with the patient seated, with the hands resting on the examination table [1-3]. The most appropriate transducer used for that purpose is a high-frequency linear-array probe, with operating frequencies of 12-18 MHz [2]. No compression with the probe on examined tissues is requested. The use of a large amount of gel at the scanning area is recommended, providing good resolution of skin and subcutaneous tissues and moreover reducing the probe pressure over the area of interest. Bilateral examination is important, for left-right com-

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Corresponding author: Annamaria Iagnocco,

Dipartimento Medicina Interna e Specialità

Mediche: Reumatologia,

Sapienza Università di Roma,

V.le del Policlinico 155, Rome – 00161, Italy.

Tel: +39 06 49974634

Fax: +39 06 49974642

Email: annamaria.iagnocco@uniroma1.it

parison. For imaging optimization, particularly regarding power Doppler (PD) examination, the finger joints should be kept in neutral position, obtained with a mild degree of flexion [1]. Standard Doppler settings of the machine are recommended: Pulse Repetition Frequency (PRF) from 500 to 750 Hz, the highest gain and high color persistence without background noise, low wall filter and Doppler frequency of 7MHz or higher [4,5]. To make sure that the signal detected in the area of interest corresponds to a real increase in pathological blood flow and not due to artefacts, it is recommended to check their persistence [5].

US Anatomy

Normal US findings [1,3,5-8] of the main anatomic structures of wrist and hand and the transducer position for structure imaging optimization are reported in table I.

Tendons

For tendons examination at hand and wrist level, a high frequency transducer and dynamic evaluation are needed, in order to optimize tendon fibers visualization [1]. Sagittal and transverse views are necessary. Extensor tendons have their sheaths at carpal level only, whereas flexor tendons continue with a sheath over the palmar aspect of the fingers [1]. Tendon synovial sheath appears as a thin echogenic linear structure, containing synovial fluid that surrounds the tendon [7]. To avoid anisotropy, which may be mistaken as a tendon rupture, a correct inclination of the probe is recommended [5-7]. At carpal level, on a dorsal transverse scan, the six extensor compartments are visualized by US, separated by the extensor retinaculum; from the radial to the ulnar side they are represented by: 1st - extensor pollicis brevis and abductor pollicis longus, 2nd- extensor carpi radialis longus and brevis, 3rd- extensor pollicis longus, 4th- extensor digitorum, 5th- extensor digiti minimi, and 6th- extensor carpi ulnaris. For an easier recognition of the compartments,

Lister’s tubercle, prominent on the dorsal transverse US image, is commonly used as a landmark – it separates compartments 2 (on its radial side) and 3 (on its ulnar side). The carpal volar transverse scan depicts the flexor tendons – flexor pollicis longus, four flexor digitorum superficialis and four flexor digitorum profundus tendons inside the carpal tunnel, covered by flexor retinaculum [7,9]. At the radial side, flexor carpi radialis and at the ulnar side flexor carpi ulnaris lie in separate compartments, inserting on carpal and metacarpal bones [1,5,7].

Joints

US is able to assess carpal (radio-ulno-carpal, inter-carpal, carpo-metacarpal), metacarpophalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints. For a more panoramic visualization of joint structures, the recommended transducer position for starting US examination is longitudinal; by using longitudinal scans bone profile, cartilage, intra-articular fat-pad and joint capsule can be imaged. Subsequently a multiplanar evaluation is carried out to complete the local joint examination.

The bone contour appears at US as a sharp, continuous and hyperechoic layer [3]. Cartilage over MCP joints is visualized with finger in maximal flexion; the cut-off for its normal thickness is 0.2-0.5 mm [1,3,8]. The capsule is overlying the joint recess, which is filled with fat-pads (hypoechoic) and small amounts of synovial fluid (anechoic) [3]; dynamic evaluation is recommended for a more detailed assessment [1]. The morphology of the normal joints has a high degree of variability, depending also upon the scanning position (volar, dorsal, and lateral) [2]. At carpal and hand joints level the dorsal view is generally first used followed by multiplanar scans, including radial and ulnar assessments [10-12].

Median nerve

The median nerve is visualized by transverse and longitudinal scans over the volar aspect of the wrist; dy-

Table I. Normal sonographic findings of the main anatomic structures of wrist and hand

Anatomic structure	Transducer position	Normal US findings
Tendons	Sagittal	Fibrillar pattern with hyperechoic margins
Tendons	Transverse	Oval to round shape with hyperechoic spots
Bone contours	Sagittal	Hyperechoic and sharp
Intraarticular fatpad	Sagittal	Inverted triangular area with homogenous echogenicity
Cartilage	Sagittal	Anechoic band with hyperechoic margins
Median and ulnar nerve	Transverse	Oval to round shape with hyperechoic spots
Median and ulnar nerve	Sagittal	Fascicular pattern

namic scanning may help an extensive assessment. The nerve is identified under flexor retinaculum, in the carpal tunnel, superficial and parallel to flexor of second and third fingers, and medial to flexor pollicis longus [13]. It has a typical fascicular pattern and, unlike tendons, with a low grade of anisotropy. Nerve measurements are usually performed at the level of the pisiform bone: a cross sectional area $<10\text{mm}^2$ is considered normal, but cut-off values between 9-12 mm^2 have been suggested [1,9,14]. Bifid median nerve together with a prominent median artery represents a possible anatomical variant [15].

Pathological findings

Joint effusion and synovial hypertrophy

According to recently published US definitions, synovial fluid is an abnormal hypochoic or anechoic intra-articular material that is displaceable and compressible and does not exhibit Doppler signal and synovial hypertrophy appears as a hypochoic tissue that is not displaceable and poorly compressible and may exhibit Doppler signal [16].

Both dorsal and volar scans can be used to detect joint effusion and synovial hypertrophy and the use of a multiplanar scan technique is usually recommended (fig 1). However, palmar assessment for finger synovitis has recently proven to be better than dorsal scan: Backhaus et al found 86% of positivity when scanning volar side of the hand compared to dorsal one, with only 14% positivity of dorsal synovitis alone in clinically affected joints [17]. Ostergaard et al found only a third of patients having synovitis on both volar and dorsal side of the fingers, in the majority of cases synovitis being limited to volar- 43% or dorsal- 27% [11]. A radial distribution of synovial hypertrophy was suggested at the level of PIP joints [12].

Various methods of measurement have been tested for synovitis quantification, and different levels of repro-

ducibility. Two main scoring systems for quantification of synovitis in B-mode US are currently used: a binary method (presence of synovitis yes/no) and a semiquantitative scale, usually based on a four point scale (0-3) with following grades: grade 0= absence of synovitis, grade 1= mild synovial hypertrophy, grade 2= moderate synovial hypertrophy, grade 3= marked synovial hypertrophy [18,19]. Szkudlarek proposed a different method of scoring and defined grade 2 as synovial hypertrophy bulging over the line linking the tops of the bones forming the joint without extension along bone diaphyses, and differentiated two grades of grade 3 (3- extension to one of the two diaphyses and 4- extension to both diaphyses). Both grades 3 and 4 are categorized as severe synovitis. This classification has been extensively applied and demonstrated good inter-observer agreement [18]. When semiquantitative scale values were compared to a quantitative scale (resulted by direct measurement of the hypochoic tissue inside the joint), a correspondence of 2-4 mm above the normal was suggested for moderate synovitis [2].

Iagnocco et al used an easier 0-3 grades semiquantitative scale with 0- absence of any change and 1-3 presence of a mild, moderate and severe change, for all articular and periarticular structures (joints, tendon sheaths, bursae, bone and cartilaginous erosions). The sum of all these indicators for one joint was named the *single-joint score*. The sum of single-joint scores was named the *global score* [20]. Both scores were then calculated before, during and after remissive treatment with Adalimumab for 24 months [20] and, in a different cohort, Etanercept for 12 months [21]. Both single and global scores showed significant reduction after treatment in both studies, parallel to CRP, patient VAS and number of swollen joints at clinical examination.

As US is known to be an operator dependent technique, intra and inter-observer reliability is usually calculated in US studies, in order to establish the reproducibility of the method [17,18]. The level of agreement is calculated using kappa coefficients (k) between readers and also intraclass correlation coefficient (ICC). Using the semiquantitative method of synovitis quantification, an average value for $k = 0.65$ between investigators was obtained in a recently published score [17]. Szkudlarek et al calculated separate k values for different pathology elements: erosions, synovitis, joint effusion and PDUS, and the obtained values were 0.68, 0.63, 0.48 and 0.55, respectively [18]. Regarding intra-observer reliability, an evaluation of several scoring systems found values ranging from 0.53 to 0.97, demonstrating similar results as clinical examination [22].

Synovitis activity assessment and differentiation between inflamed synovium and inactive pannus or fi-



Fig 1. Longitudinal scan over the palmar aspect of the II MCP joint. Grey scale volar synovitis (between calipers).

brous tissue (both hypoechoic intraarticular tissue in GSUS) is completed with Doppler examination (power Doppler Ultrasound- PDUS and colour Doppler Ultrasound- CDUS). PDUS was extensively proven as a useful tool for quantitative estimation of inflammation and of disease activity in RA, and also as a useful method for evaluating responsiveness to treatment [4,20-27,29,30]. In particular, wrist and hand PDUS findings were correlated with clinical and laboratory measurements of activity in RA such as C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), swollen joint count and DAS28 [17,20-22,29,30]. PDUS quantification is usually graded on a 0-3 semiquantitative scale as follows: grade 0= absence of signal: no intraarticular flow; grade 1= mild: up to 3 single vessel signals or 2 single vessels plus 1 confluent signals; grade 2= moderate: signal occupying less than 50% of the synovium; grade 3= marked: vessels signal in more than 50% of the synovial area [22]. PDUS is usually more sensitive than CDUS because it registers any flow, particularly slow one, regardless of direction, whereas CDUS is dependent upon blood flow direction [2]. However, some recent-generation equipment provide similar level of sensitivity for detection of flow both in large and in small, intra-synovial vessels. On the other hand, CDUS is able to make a quantitative estimation of inflammation degree, using Colour Fraction (CF), defined as the number of colour pixels divided by the total number of pixels of the region [24]. CF has been intensely correlated with CRP, ESR, swollen joint count, and DAS28. As Doppler signal can also be found in healthy wrists and finger joints [25], spectral Doppler has been used to calculate Resistive Index (RI), for evaluating the type of flow (upon low/high peripheral resistance in the synovial membrane) and for discriminating between normal resting tissues (high values of RI- maximum 1) and inflammation (low values of RI) [4,25,27]. These calculations, though proven very accurate, imply specific computer software usually unavailable on a daily basis practice.

The use of contrast agents to enhance Doppler signal was tried, but some major disadvantages have been registered that make it scarcely feasible in clinical practice [2, 26].

US is currently studied by the OMERACT ultrasound group, in order to establish its reliability, validity, and responsiveness, as defined by the OMERACT filter [22,28]. For that purpose, an US global scoring system to measure disease activity is warranted.

Scoring systems for wrist and hand RA synovitis are currently under evaluation (summary in table II), using "target joints" (i.e. the joints most frequently affected in RA). The wrist, being the most affected joint in RA

(mean prevalence: 67% of cases), has been selected as the "target joint" in clinical trials, being used in most of the scores available to date [10,17, 20-22,29-32]. Backhaus et al recently described the German 7 joint score [17], that proved to be more sensitive than DAS28 in inflammation description. This score was significantly correlated to clinical and laboratory measurements of disease activity. More recently, Hammer et al used a 78 joints score [32], which was found to correlate with clinical parameters and highly responsive to change. The US examination time was 70 minutes for each patient, making this score hardly feasible on a daily basis. A comparison between a 44-joint gray scale and PDUS assessment and a simplified 12-joint assessment had previously been done by Naredo et al, and a highly significant correlation between them was found on a large cohort of RA patients. The simplified score showed high correlations to clinical markers of disease activity and also sensitivity to change after biologic treatment [30]. Regarding sensitivity to change, an overall evaluation of several US scoring systems found it equal or even better than the one calculated for clinical scores, as DAS28, and parallel to CRP [22].

Tendon pathology

Various hand tendons abnormalities were described in early stages of the disease in RA: widening of the tendons sheaths, loss of normal fibrillar echostructure, irregularity of the tendon margins [33]. Focal areas of anechoic or hypoechoic loss of tendons substance are frequently seen on US in all arthritis patients [1].

According to OMERACT definitions, tenosynovitis is hypo/anechoic tissue with/without fluid within the tendon sheath, which is seen in two perpendicular planes and may exhibit a Doppler signal (fig 2) [16]. It appears not only in RA, but also in psoriatic arthritis (sausage digit), bacterial infections, diabetes, amyloidosis and osteoarthritis [5]. For tendons without sheaths, paratenoni-

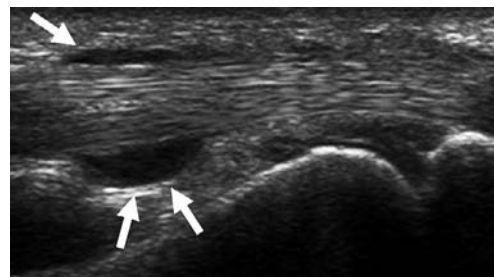


Fig 2. Longitudinal scan over the palmar aspect of the III finger. Tenosynovitis of the flexor tendons with evidence of hypoechoic tissue (arrows) within the tendon sheath.

Table II. Scoring systems for wrist and hand pathology currently available in RA. GSUS- gray scale ultrasonography, PDUS- power Doppler ultrasonography, MCP-metacarpophalangeal joint, PIP-proximal interphalangeal joint, MTP-metatarsophalangeal joint

First author of the study	Year	Number of joints	Joint specification	Elements composing the score
SCHEEL [10]	2005		Different scores: MCP and PIP 2-5, 2-4, 2-3	Synovitis GSUS and PDUS
NAREDO [29]	2005	12	Wrists, both MCP 2, MCP 3, PIP 2,3, knees	Synovitis GSUS and PDUS
LOEUILLE [31]	2006	7	Wrist, MCP 2,3,5, MTP 2,3,5 dominant side	Synovitis GSUS and PDUS
HENSCH [26]	2007	8	MCP 2-5, MTP 2-5 dominant side	Synovitis GSUS and PDUS
IAGNOCCO [20]	2008	10	MCP 2,5, PIP3, wrist, knee, bilaterally	Synovitis GSUS and PDUS Tenosynovitis Bursitis Erosions
NAREDO [30]	2008	12	Elbow, wrist, MCP 2,3, knee, ankle	Synovitis GSUS and PDUS Tenosynovitis Bursitis
BACKHAUS [17]	2009	7	Wrist, MCP 2, 3, PIP 2,3, MTP 2,5 of the dominant side	Synovitis GSUS and PDUS Tenosynovitis Erosions
HAMMER [32]	2010	78	PIP 1-5, MCP 1-5, capometacarpal 1-5, wrist (3 joints), elbow, shoulder, hip, knee, ankle, foot (4 joints), tarsometatarsal 1-5, MTP 1-5, IP 1st toe.	Synovitis GSUS and PDUS

tis is defined as hypoechoic halo around the tendon with possible positive Doppler signal [17].

Inflammation within tendons and tendon sheaths has been quantified before and after treatment in RA, using a dichotomous scale (absent=0, present=1). Tenosynovitis and paratenonitis scores were calculated together with synovitis score before and after treatment and showed responsiveness [17]. Iagnocco et al used a semiquantitative scale with four grades (0-3) for tenosynovitis scoring before and after biologic treatment in RA patients [20,21].

De Quervain tenosynovitis, a stenosing tenosynovitis of the first extensor compartment of the wrist, is mainly characterized by US as hypoechoic thickening of retinaculum, with inconstant effusion and hypervascularization at this level [34].

In gout, intratendinous urate deposits appear as circumscribed areas of inhomogenous echoic material covered with hyperechoic spots inside the tendon, which may generate acoustic shadow [1].

Giant cell tumor of the tendon sheath appears usually

at finger flexors as a hypoechoic mass with well demarcated walls, which may express a high Doppler signal inside [5].

Erosions

According to the OMERACT definition, erosions are defined as intraarticular discontinuities of the bone surface visible in two perpendicular planes [16]. US was proved to be more sensitive than X-ray in their detection [35]. The lateral side of MCP II and MTP V are their election sites of US detection thanks to the multiplanarity of the US technique [36,37]. Erosions detected by US in early RA have been described to progress to radiographic detection in 1-2 years [37]. Erosions scoring system may use a binary variable: absent=0, present=1 [37] or a semi-quantitative scale: 0= regular bone surface, 1= irregularity of the bone surface visible in two planes, 2= defect in the surface of the bone seen in two planes, 3= extensive bone defect [18]. Erosions have been quantitatively measured and the results included in a scale with three grades: small

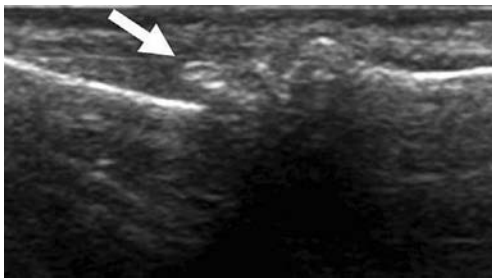


Fig 3. Longitudinal scan over the dorsal aspect of the III PIP joint demonstrate the presence of osteophytes (arrow).

erosion = < 2 mm, moderate erosion = 2–4 mm, and large erosion = > 4 mm [35]. Recent erosions are characterized by irregular margin and a poorly defined base, and in RA are associated with active synovitis and Doppler signal entering the bone [2]. Erosions at DIP joints may be found in seronegative spondylarthritis or osteoarthritis [2].

Carpal Tunnel syndrome

The enlargement of the median nerve cross-sectional area is suggestive for Carpal Tunnel Syndrome (CTS). In most studies the cut-off limit for this area has been reported to be between 9 and 12 mm², but it might be extended up to 15 mm² [9,14]. US is usually able to detect the cause of CTS: flexor tenosynovitis (in the majority of cases), tophaceous deposits in gout, amyloid deposits, neurogenic tumors (rare condition), ganglia or huge synovitis of carpal joints [1,9].

Osteophytes

Osteophytes (fig 3) are defined as cortical protrusions seen in two US planes [38,39]. They are usually found in PIP and DIP joints in osteoarthritis, but also in the 1st carpometacarpal joint, usually accompanied by effusion [39]. For quantification, osteophytes are evaluated using either dichotomous or semiquantitative scales. US was proven better than X-ray in depicting osteophytes, and found more MCP osteoarthritis than described in epidemiological studies [38].

The value of US in depicting small osteophytes makes it relevant for early OA diagnosis.

Conclusion

High resolution US qualifies as a first line tool in the detection and quantification of rheumatic pathology in the hand and wrist area. In case of local swelling, US is the first tool for differential diagnosis. The advantages of being a safe, widely available, non invasive, and widely

feasible imaging technique makes it particularly suitable for being used at the bedside in clinical practice. The use of high quality equipment has markedly decreased the learning curve for US in rheumatic diseases [22,40]. Efforts are made for accurate standardization of the method, for making it suitable for an outcome measure both in clinical practice and clinical trials.

Conflict of interest: none

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