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Standardisation of the USG examination of the rheumatoid wrist and hand

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Summary

Ultrasonography applying high-frequency probes and doppler options is a very valuable diagnostic method for musculo-skeletal pathology imaging, including the pathologies of inflammatory aetiology, such as rheumatoid arthritis (RA). Efficacy of ultrasonography in detecting early stages of RA has been proved in numerous clinical trials.

Magnetic Resonance Imaging and Ultrasonography depict inflammation of synovial membrane (effusion and synovial membrane hypertrophy) and erosions, definitely earlier than conventional radiography. Ultrasonography has become the method of first choice, because of its efficacy and lower than MR costs.

Ultrasound examination is performed by various specialists, thus the need for standardisation is obvious. The aim of this article is to present some standardisation options of rheumatoid hand's ultrasound examination.

Key words: rheumatoid arthritis • ultrasonography • standardisation • synovitis • tenosynovitis • erosions

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Ultrasonography using high-frequency probes and Doppler mode has become a very valuable method of musculo-skeletal pathology imaging, including the pathologies of inflammatory aetiology [1]. Rheumatoid arthritis (RA) is one of the ailments in which the efficacy of the US was confirmed by numerous studies.

Owing to new diagnostic imaging options and thanks to the introduction of medicines modifying the course of the disease, we have witnessed a change in the strategy of patient treatment in the last 20 years [2]. The possibly earliest detection of the disease, leading to a timely introduction of a proper treatment at the first stage of the disease, has become extremely important. The early stages of RA may be visualised with the contrast-enhanced MRI, as well as with the USG examination applying high-frequency probes and Doppler modes [3]. Both methods visualise synovitis (effusion or hypertrophy of the synovial membrane) [4] and erosions – much earlier than the conventional radiography [5]. The MRI allows for visualisation of erosions in all locations and is the only method that is able to show the oedema of the bone marrow – an important prognostic factor preceding the formation of erosions. This is however an expensive method, of limited availability, and connected with a relatively long time of examination. US, on the other hand, is an easily available, cheaper, non-invasive and less time-consuming method, and thus a more commonly and willingly used option, enabling frequent follow-up examinations and evaluations of treatment efficacy. USG efficacy in the early diagnosis of RA is supported by multiple clinical studies. Efficacy, together with cost-effectiveness of that diagnostic mode, makes it the method of first choice [6–10]. Moreover, it is not required to be a specialist in radiology and imaging diagnostics to perform this examination. Therefore it is carried out by the specialists from other fields, including the rheumatologists [11]. It should be remembered that this method depends on the operator (long 'learning curve') and as such it requires standardisation.

The standards of wrist and hand examination – i.e. the regions in which RA lesions are the most frequent and the most early observed – were defined by the European Society for Surgical Research (ESSR) [12]. The guidelines for the physicians performing the USG examination of the musculoskeletal system in patients with suspected rheumatoid conditions were established by the EULAR (European League Against Rheumatism) work group on

Table1. Definitions of the most common symptoms in rheumatoid conditions [14].

Symptom	Definition
Effusion	Hypoechoic or nonechoic intraarticular region, subject to compression under the probe tip, not revealing any colour-coded regions in the Doppler imaging mode (no colour pixels in the colour box, corresponding to blood vessels) (Figure 1 *)
Synovial hypertrophy	Thickening of the synovial membrane – hypoechoic region, not subject to compression under the probe tip, potentially colour-coded in the Doppler imaging mode (presence of colour pixels in the colour box, corresponding to blood vessels) (Figure 1 ^)
Tenosynovitis	Effusion in or thickening of the synovial membrane, visible in two perpendicular planes, potentially involving colour-coded regions in the Doppler imaging mode (Figure 2)
Enthesopathy	Reduced echogenecity with a blurred image of a normal fibrillar structure or thickening of the tendon/ligament at its insertion point – all that visible in two perpendicular planes, and potentially involving colour-coded regions in the Doppler imaging mode or bone lesions such as entesophytes, erosions or irregular outlines. Small hyperechoic foci, corresponding to calcifications, are also possible to appear
Erosions	Intraarticular interruption of the bone surface continuity, visible in two planes (Figure 3)
Bursitis	Cystic widening of the synovial bursa with abnormal hypoechoic or nonechoic material, with or without fluid in the bursa, visible in two perpendicular planes, potentially colour-coded in the Doppler imaging mode

Table 2. Anatomical details being a possible source of mistakes in the USG diagnostics of the hand and wrist [15–19].

It is worth remembering that:

1. On the dorsal surface of the head of the metacarpal bones, at the point of a closed epiphyseal plate, there is a fissure, with a smooth bottom surface, without a thickened synovial membrane – not to confuse with an erosion.
2. Healthy individuals possess a small amount of fluid within the tendon sheath of the flexor muscles – however, the longitudinal section reveals an uninterrupted continuity; In case of effusions, the fluid accumulates segmentally, due to the presence of the pulleys.
3. The mesentery of the tendon sheaths includes blood vessels; a normal blood vessel produces a high-resistance Doppler flow pattern.
4. The proximal recess of the metacarpophalangeal joints is filled intracapsular but extrasynovial fatty tissue – not to confuse with hypotrophy of the synovial membrane.
5. Effusion, synovial membrane thickening and osteophytes are often found in thumb joints, both in symptomatic and asymptomatic patients.
6. The scaphoid-lunate ligament is shown in 80% cases – even if not visualised, it may be still uninjured.
7. The retinaculum of the extensor muscles can be visualised as a hypoechoic band forming sections on the dorsal surface of the wrist, with the widest one over the fourth section – not to confuse with the thickening of the tendon sheath in the course of inflammation.
8. A part of the aponeurosis of the extensor muscles of fingers over the metacarpophalangeal joints (extensor hood, extensor expansion) is a thin, echogenic, triangular structure (normal thickness of less than 2 mm), covering in its base the dorsal and lateral parts of the metacarpophalangeal joints – its injury is rare in individuals without RA; it should be suspected in cases of a lateral dislocation of centrally-situated tendon of the extensor muscle of a given finger during the flexion movement.
9. A two-part medial nerve is an anatomical variation, commonly seen with a persistent medial artery.
10. Foramens of the nutrient vessels may imitate erosions, most frequently seen on the dorsal and ventral surface of the lunate bone, in the capitate and triquetrum bone; the nutrient vessels are less than 2 mm thick.
11. The insertion sites of ligaments on the capitate and hamate bone, on the edge of the triquetrum bone and on the dorsal surface of the base of the second metacarpal bone have irregular outlines – not to confuse with erosions.
12. Pathological vessels (created in the course of inflammatory processes) produce a low-resistance flow spectrum (Figure 4), while the normal vessels are connected with a high-resistance spectrum (Figure 5).

musculoskeletal US examinations [13]. The indications concern: examinations within specific body structures, required equipment, recommendations on the learning-teaching process. They also underscore the significance of an excellent knowledge of anatomy of particular examined structures and physical basics of the method. The guidelines name as well some potential pathologies, positioning standards, and acquisition parameters. In 2005, the expert group OMERACT (Outcome Measure Rheumatoid Arthritis Clinical Trial) determined the definitions of some common pathologies found in patients with rheumatoid arthritis [14]. The definitions of particular symptoms were presented in Table 1.

Certainly, to carry out a high-quality examination, it is necessary to know the anatomy of a given structure and its anatomical variations [15–19] – this should prevent the physicians from diagnosing nonexistent pathologies. Details to remember, which may be the source of mistakes, were shown in Table 2.

Moreover, the parameters of image acquisition should be known, especially in the Doppler imaging mode, if we want to obtain reliable and repeatable data. These parameters may differ slightly, depending on the scanner producer, but the main rules – shown in Table 3 – apply to all ultrasound scanners]20].

Table 3. Recommended settings of the Doppler parameters [20].

Parameter	Recommendation	Comments
PRF – pulse repetition frequency	The lowest possible	Not to produce movement artefacts
Colour priority	All priority for the colour	Option found in some scanners
Wall Filter	The lowest possible	Conjugated with PRF
Persistence	The lowest possible	Parameter conjugated with the averaging of preceding colour images
Gain	Close to noise	Slightly below the level of colour pixels in the region depicting the layer of the gel on the probe
Focus	At the level of an observed pathology	Most of the time conjugated with the colour box
Doppler frequency	Must be set in practice	Compromise between the degree of penetration and the resolution

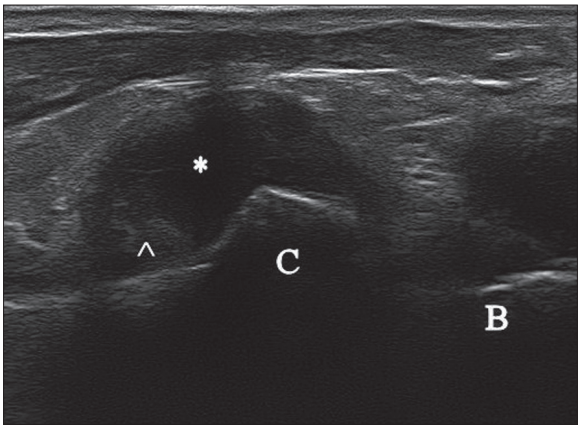

Figure 1. Effusion (*) i synovial membrane hypertrophy (^) in proximal interphalangeal joint of hand (PIP). Ventral sagittal US image of PIP joint; C – head of proximal phalanx, B – basis of middle phalanx.

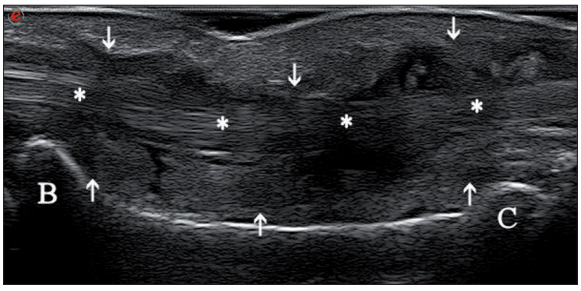

Figure 2. Tenosynovitis (arrows) of the deep flexor muscle of fingers in patient with advanced RA. Ventral sagittal US image at the level of middle phalanx. C – head of proximal phalanx, B – basis of middle phalanx, tendon (*).

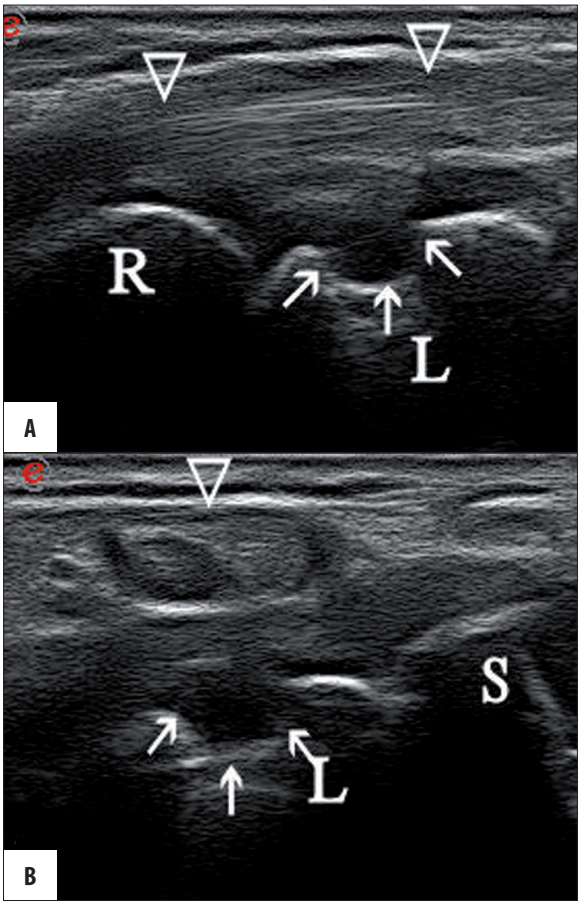

Figure 3. Lunate bone erosion (arrows). Dorsal sagittal (**A**) and transverse (**B**) US image. L – lunate bone, S- scaphoid bone; arrows' heads – tendon sheet and tendon for index finger extensor muscle.

The false-negative results can be prevented by a correct examination technique. It should be underscored at that point how significant it is not to compress the tissues under examination – this may be avoided by proper holding of the probe (using the fifth finger as a 'support') and by applying gel between the probe and the skin.

Due to the increasing popularity of the USG in early detection of rheumatoid conditions and monitoring of treatment effectiveness [21,22], there has appeared a need for standardisation of the degree of severity of different pathologies.

Attempts of standardization concern most of the time the metacarpophalangeal and proximal interphalangeal (PIP) joints of the hand [4,5,8,23], because the examination is

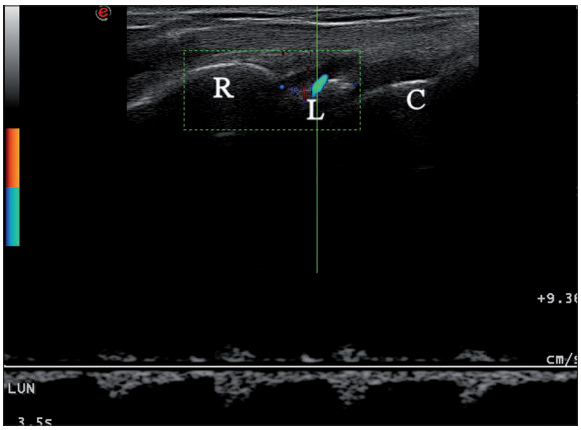

Figure 4. Spectral Doppler wave image obtained from blood vessel seen in lunate erosion, low-resistance type. Dorsal sagittal US image; R – distal part of the radius, L – lunate bone, C – capitate bone.

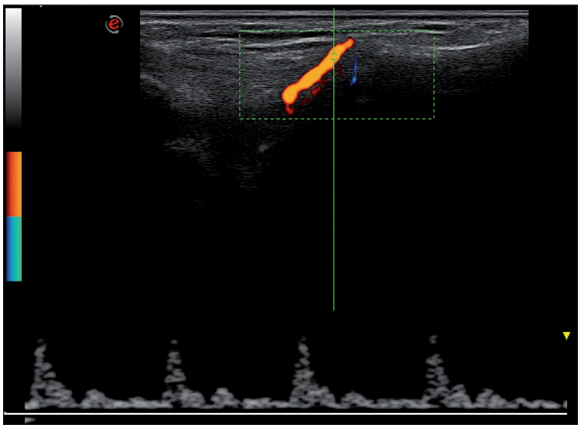

Figure 5. Spectral Doppler wave image obtained from normal blood vessel, high-resistance type. Dorsal close to sagittal US image at the level of carpo-metacarpal joint of the thumb.

easy to repeat at that site – the sagittal images of the MCP II-V joints; the frontal images of the MCP within the second finger, from the radial side, and within the fifth finger, from the ulnar side; sagittal planes of the proximal interphalangeal (PIP) joints and of the distal interphalangeal (DIP) joints, dorsally and ventrally, as well as the frontal radial and ulnar planes. Mean widths of the recesses within the MCP joints: proximal dorsal, distal dorsal, proximal ventral, in the dorsallo-palmar diameter dimension, in the sagittal plane amount to 2.5 mm, 1.5 mm and 3 mm, respectively; and in the frontal plane of the second and fifth MCP – 2.5 mm (from the surface of the bone to the external outline of the collateral tendon). In PIP joints of the fingers II–V, the distances from the proximal phalangeal bones to the surface of extensor and flexor muscle tendons amount to 1 mm and 2 mm, respectively. The measurements within the PIP joints, in the frontal plane, from the ulnar and radial side, gave the following result: 2.5 mm. Increase in the above mentioned values by at least 1 mm is regarded as a pathology [8].

Szkudlarek et al. suggest the following grading of effusions, synovitis, inflammation and erosions [23].

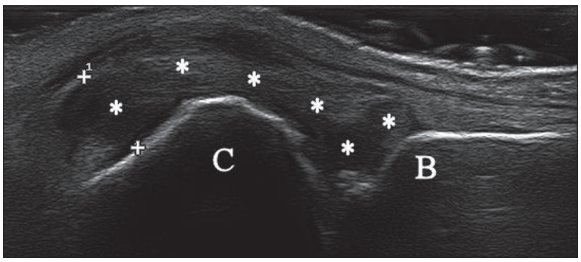

Figure 6. Synovial membrane hypertrophy (*) in III metacarpophalangeal joint (MCP) – grade 3. Dorsal sagittal US image of MCP joint. C – head of III metacarpal bone; B – basis of proximal phalanx.

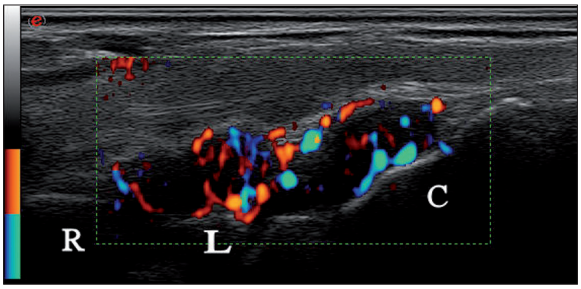

Figure 7. Synovial membrane inflammation in radio-carpal and intercarpal joints – grade 3. Dorsal sagittal US Power Doppler image. R – distal part of the radius, L – lunate bone, C – capitate bone.

Effusions:
- 0 degree – no effusion,
- 1 degree – a minimal amount of fluid within the joint,
- 2 degree – a moderate amount of fluid within the joint (no extension of the joint capsule),
- 3 degree – a considerable amount of fluid within the joint (with extension of the joint capsule).

Hypertrophy of the synovial membrane:
- 0 degree – no thickening of the synovial membrane,
- 1 degree – a minimal thickening of the synovial membrane, filling the angle between the periarticular bone, not exceeding the line joining two apexes of bones that form the joint,
- 2 degree – a moderate thickening of the synovial membrane, exceeding the line joining two periarticular apexes of bones that form the joint, without a thickened synovial membrane along the shafts,
- 3 degree – a considerable thickening of the synovial membrane, exceeding the line joining the periarticular apexes of the bones that form the joint, with a thickened synovial membrane along at least one shaft (Figure 6).

The severity of synovitis:
- 0 degree – no colour pixels in the colour box in the Doppler imaging mode,
- 1 degree – visible singular colour pixels in the colour box on Doppler image,
- 2 degree – colour pixels constituting <50% of the region of the hypertrophied synovial membrane,
- 3 degree – colour pixels constituting >50% of the region of the hypertrophied synovial membrane (Figure 7).

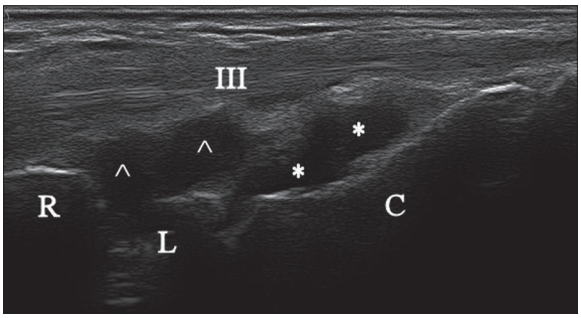

Figure 8. Inflammation of the radio-carpal (^) and intercarpal (*) joints– moderate grade. Dorsal sagittal US image; R – distal part of the radius, L – lunate bone, C – capitate bone.

The severity of erosions:
- 0 degree – regular bone outline,
- 1 degree – irregularities of the bone outline found in one plane only,
- 2 degree – irregularities of the bone outline found in two planes,
- 3 degree – a considerable bone defect found in two planes (Figure 3).

As far as the effusion, hypertrophy of the synovial membrane and erosions are concerned, the 0 and 1 degrees are within the normal range. In Doppler examinations, only the 0 degree is regarded as normal [23].

Some author suggest accepting the erosion in the situation of unevenness equal to or exceeding 2 mm and visible in two planes [9]. It should also be remembered that with appearance of more sensitive ultrasound scanners, the colour pixels in the Doppler images may be also found in healthy individuals [17].

The standardisation of the wrist examinations is more difficult than in the case of finger joints. The highest repeatability may be obtained in the sagittal planes, including the cross-section of the radial, lunate, capitate bone and the third bone of the metacarpus. The width of recesses in radiocarpal and mediocarpal joints at that level should not exceed 2 mm. However, the width measured from the surface of the bone to the inferior outline of the extensor muscle is very variable (up to 7 mm), and there may appear some focal lesions (i.e. in one part, e.g. radial or ulnar). That is why the measurements performed in that axis solely would be a considerable oversimplification [8]. E.G. McNally suggested a division of the inflammation within the radiocarpal, mediocarpal and carpo-metacarpal

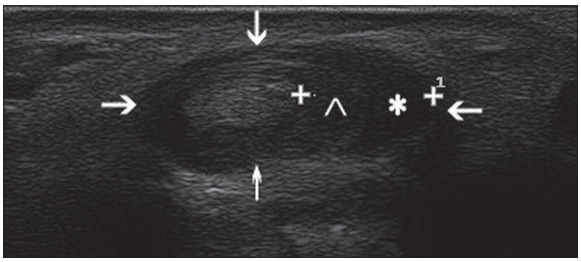

Figure 9. Severe grade tenosynovitis – effusion (*) and synovial membrane hypertrophy (^). Dorsal transverse US image of tendon sheet.

joints, as well as in the MCP and PIP joints, into 3 degrees – mild, moderate, severe – depending on the thickness of the abnormal synovial membrane and the effusion.
- Mild degree: widening of the recesses (effusion or hypertrophy of the synovial membrane) by up to 2 mm above the normal range,
- Moderate degree: widening of the recesses by 2–4 mm above the normal range (Figure 8),
- Severe degree: widening of the recesses by over 4 mm above the normal range [8[.

This system may also be applied in the evaluation of the severity of tenosynovitis (Figure 9) where physiologically there is a minimal amount of fluid. High-frequency probes guarantee a very good resolution and allow for visualisation of the articular cartilages, especially well visible on the surface of the head of the metacarpal bones [9]. Possible pathologies of that cartilage include thinning (1.5 mm), thickening (>2.5 mm), outline irregularities and inhomogenous echogenicity.

The current technological level of the ultrasound scanners and the broadband high-frequency probes allow for an accurate evaluation of the structures within the wrist and hand, the joints of which are in most of the cases the first ones to be diagnosed with RA lesions. Early detection of the inflammatory features within these joints allows for an introduction of a proper treatment inhibiting or preventing the disease progress. Due to the fact that the USG diagnostics is highly dependent on the operator, the standardisation of that examination is required. A wide application of hand and wrist USG standards developed by the European Society for Surgical Research (ESSR) and by EULAR (European League Against Rheumatism) work group on musculoskeletal US examinations is significant in the proper management of patients, both in the early diagnosis, and in monitoring of treatment outcomes.

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