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Standardisation of the MRI image evaluation in the diagnostics of rheumatoid arthritis within the wrist and metacarpophalangeal joints

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Summary

Rheumatoid arthritis (RA) is a chronic systemic autoimmune disease of the connective tissue, which results in disability and earlier death. Thus it is very important to recognise this pathologic condition as early as possible, to lessen and delay its consequences. Currently, magnetic resonance imaging is the best imaging modality, depicting every stage of this disease and allowing for monitoring of the treatment response. The process of standardisation is needed in assessing MR pictures. The aim of this article was to present the MR protocols of hand and wrist MR examinations for rheumatologic demand and standards of results, according to worldwide OMERACT RAMRIS 2002 and supplemented by tenosynovitis system.

Key words: rheumatoid arthritis • RAMRIS OMERACT • MRI • standardisation • synovitis • tenosynovitis • bone marrow oedema • erosions

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Rheumatoid arthritis is a chronic systemic disease of the connective tissue, of immunological background, leading to disability, invalidity and premature death [1]. It is therefore extremely important to detect this ailment as early as possible, and to introduce a proper course of treatment, in order to delay and limit its sequelae. The successive stages of this pathological process, leading to bone destruction, are as follows: inflammation and hypertrophy of the synovial membrane and of the tendon sheaths, bone marrow oedema, erosions. Further injuries involve the ligamentous apparatus, which results ultimately in dislocations and deformations of the joints [1–4]. Until recently, the basic method in imaging diagnostics of the rheumatoid conditions was the conventional radiography [4–6] in which the first symptom is periarticular osteoporosis mainly. Subsequent radiological symptoms include: narrowing of the articular space, subchondral cysts and erosions. At present, the available diagnostic modalities, such as US, CT or MRI may visualise such erosions that are invisible in the conventional method [2,4,7–9], and this is a well known fact that visualisation of the erosion is an important factor confirming the diagnosis and enabling introduction of an 'aggressive' treatment, with the use of new medicines. Moreover, USG with Doppler imaging mode and MRI with intravenous contrast administration visualise also the

initial stages of the disease, i.e. inflammation and hypertrophy of the synovial membrane. High-frequency probes enable visualisation of small erosions, but, unfortunately, only in the regions accessible to ultrasounds. Only the magnetic resonance imaging allows for a comprehensive evaluation of every stage of the disease [2,10] – i.e. inflammation and hypertrophy of the synovial membrane and of the tendon sheaths (visible mainly after intravenous administration of the contrast medium), bone marrow oedema (an important prognostic factor preceding bone destruction) [11–14] and erosions (an important factor confirming the diagnosis) in all locations.

The MRI evaluation in rheumatoid conditions is difficult and highly subjective, since it is necessary to know the anatomy of the evaluated joints and the course of the pathological processes involved in this condition, their variability, as well as diagnostic traps connected with examination techniques and properties of the tissues [15].

As the MRI examinations become more and more common in the diagnostics of rheumatoid conditions, there has appeared a need for standardisation of the MRI image evaluation of joints involved in this pathological process [16]. That was the aim of the international association,



Figure 1. Coronal T1 Turbo 3D magnetic resonance image demonstrates normal wrist.

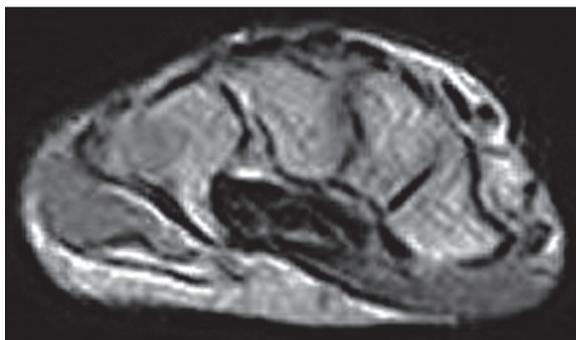


Figure 2. Axial T1 SE magnetic resonance image demonstrates normal wrist.

OMERACT (Outcome Measures in Rheumatoid Clinical Trials), established in 1992 [17]. OMERACT functions under the aegis of the International League of Associations for Rheumatology (ILAR), being in possession of a group for RA, under the patronage of the World Health Organization (WHO) [18,19]. OMERACT involves a group of experts from different countries who, acting jointly and basing on the clinical trials, develop and revise the guidelines on rheumatoid diseases, including RA. And thus, on the basis of the studies carried out by the EULAR workgroups on RA and OMERACT, there was developed a system of RA lesion evaluation in the MRI examinations (OMERACT RAMRIS 2002; RAMRIS – Rheumatoid Arthritis MRI Scoring System) [20]. This system determines correct MRI sequences and definitions of the basic symptoms in particular stages of the disease, and classifies their severity [21–23].

However, the most important fact was the development of standard protocols of the MRI examinations of wrists, metacarpophalangeal joints, and interphalangeal joints, i.e. the most common regions to be involved with RA.

According to the guidelines, the basic sequences in the MRI examination in patients with rheumatoid arthritis, enabling the evaluation of the inflammatory and destructive lesions of joints, should include:

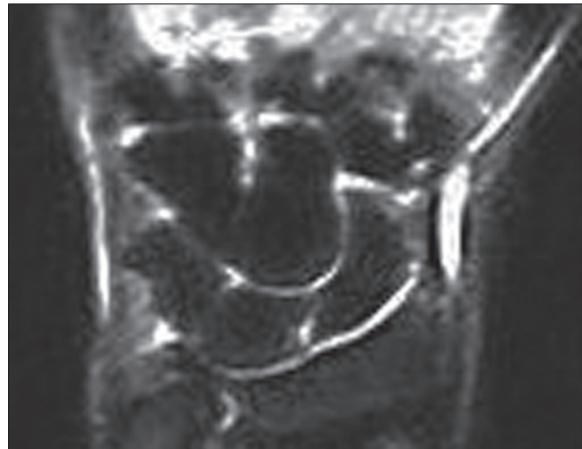


Figure 3A. Coronal STIR magnetic resonance image demonstrates normal wrist.



Figure 3B. Axial STIR magnetic resonance image demonstrates normal wrist.

1. T1-weighted sequences before and after i.v. contrast administration, carried out in two planes: coronal and transverse. It should be also pointed out that intravenous administration of contrast may be unnecessary if the main aim of the examination is to determine the presence of erosions; (Figures 1, 2),
2. T2-weighted sequences with fat saturation or, when impossible to carry out, the STIR (Short Tau Inversion Recovery) sequences; (Figure 3).

And so the specific examination protocol allows for a proper evaluation of the obtained MRI images.

Moreover, the basic definitions of the MRI symptoms were determined. i.e. synovitis, bone marrow oedema, and erosions.

And thus

- Synovitis (Figure 4) is the presence of a thickened synovial membrane, revealing intense enhancement after intravenous contrast administration,
- Bone marrow oedema (Figure 5) – Is an irregular, poorly delineated region within the bone marrow, revealing an increased signal intensity connected with a higher amount of water (higher signal intensity in the STIR and T2-weighted sequence with fat suppression, lower signal intensity in T1-weighted sequences),
- Bone erosion (Figures 6, 7) – sharply delineated, marginal bone defect, with a characteristic periarticular location



Figure 4. Coronal T1 SE magnetic resonance image demonstrates MCPJ synovitis.



Figure 5. Coronal STIR magnetic resonance image demonstrates bone marrow oedema of trapezium.

and a typical signal, found in two planes, with a visible interruption of cortex continuity in at least one of them. A signal typical for erosion is the absence of the normal, low signal intensity within the cortex, and the loss of the normal high signal within the bone marrow in the T1-weighted sequence. Rapid enhancement found in erosions after intravenous contrast administration suggests the presence of an active, hypervascularised synovial membrane (pannus).

Next, the severity of particular symptoms was defined as mentioned below. The OMERACT 2002 RAMRIS classification is the currently applying one.

The severity of synovitis should be evaluated in three regions of the wrist (radio-ulnar distal joint; radio-carpal joint, as well as: mediocarpal and carpometacarpal), and in every intercarpal joint, apart from the first carpometacarpal and the first metacarpophalangeal joint (i.e. joints of the thumb).

The degree of synovitis ranges from 0 to 3. The 0 degree indicates a normal state, while the degrees from 1 to 3 (mild, moderate, severe) involve subsequent $\frac{1}{3}$ of the probable maximal volume of the synovial membrane in a given joint, revealing enhancement after intravenous contrast administration.

The degree of bone marrow oedema should be evaluated for every bone of the examined joint separately (wrist bones: scaphoid, lunate, triquetrum, pisiform, trapezium, trapezoid, capitate, hamate, distal part of the radial bone, distal part of the ulna, bases of the metacarpal bones and bones of the metacarpophalangeal joints: head of the



Figure 6. Coronal T1 Turbo 3D magnetic resonance image demonstrates erosion of 3rd metacarpal head.



Figure 7. Sagittal T1 Turbo 3D magnetic resonance image demonstrates erosion of 3rd metacarpal head.

metacarpal bones and the base of the proximal phalanx). The division of the severity of bone marrow oedema into three degrees, from 0 to 3, bases on the proportion of bone involvement (%) and is as follows: 0 degree – no bone marrow oedema, 1 degree – involvement of 1–33% of the volume of the examined bone; 2 degree – 34–66% of the bone involved, 3 degree – 67–100% of the bone involved.

The severity of erosions, similarly to the degree of bone marrow oedema, should be evaluated separately for every bone of the examined joints (wrist bones: scaphoid, lunate, triquetrum, pisiform, trapezium, trapezoid, capitate, hamate, distal part of the radial bone, distal part of the ulna, bases of the metacarpal bones and bones of the metacarpophalangeal joints: head of the metacarpal bones and the base of the proximal phalanx).

The division into the degrees from 0 to 10 is connected with the proportion of bone destruction (%), and so: 0 degree – a normal bone, 1 degree – 1–10% of bone defect, 2 degree – 11–20%, 3 degree – 21–30%, 4 degree – 31–40%, 5

OMERACT RAMRIS evaluation sheet
On the basis of reference atlases of EULAR-OMERACT RA MRI

Wrist joints

Patient's name and surname: Evaluation date:

Synovitis - evaluation

Joint	Distal radioulnar joint (DRUJ)	Radiocarpal joint (RCJ)	Intercarpal/mediocarpal joint and carpometacarpal joints (IC-CMCJ)
Synovitis (0-3)			

Erosions and bone marrow oedema - evaluation

Bone erosion – degrees from 0 to 10; according to the proportion of the destructed bone surface (10-percent ranges):
 0: 0%, 1: 1-10%, 2: 11-20%, 3: 21-30%, ..., 10: 99 – 100%

Bone marrow oedema – degrees from 0 to 3; percentage of the involved bone surface (33-percent ranges):
 0: 0%, 1: 1-33%, 2: 34-66%, 3: 57-100%

In case of the carpal bones, the surface of the whole bone is evaluated; in long bones, the area from the bone surface to the depth of 1 cm is evaluated.

		Bases of the metacarpal bones				
		1	2	3	4	5
Erosions (0-10)						
Bone marrow oedema (0-3)						

Bone	Trapezium	Trapezoid	Capitate	Hamate
Erosions (0-10)				
Bone marrow oedema (0-3)				

Bone	Scaphoid	Lunate	Triquetrum	Pisiform
Erosions (0-10)				
Bone marrow oedema (0-3)				

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Evaluating physician

On the basis of: "An introduction to the EULAR-OMERACT rheumatoid arthritis MRI reference image atlas" M Østergaard, J Edmonds, F McQueen, C Peterfy, M Lassere, B Ejlberg, P Bird, P Emery, H Genant and P Conaghan; Ann Rheum Dis 2005; 64 (Suppl 1): 13-17.

Figure 8. Axial T2 SE magnetic resonance image demonstrates tenosynovitis of digits flexors.

degree – 41–50%, 6 degree – 51–60%, 7 degree – 61–70%, 8 degree – 79–80%, 9 degree – 81–90%, 10 degree – 91–100%.

When determining the degree of bone marrow oedema and of erosions within the long bones (i.e. distal part of the radial bone, distal part of the ulnar bone, bases of the metacarpal bones and bases of the phalanges), one should take into consideration the lesions in a given region 1 cm deep from the articular surface of the examined bone.

Figures 8 and 9 presenting suggestions of the descriptive sheets used for wrist and hand evaluation, respectively.

The degrees defined by the aforementioned criteria are given an equivalent number of points – i.e. the first degree – 1 point, 2 degree – 2 points, 3 degree – 3 points, and so on. The final score results from summing up the points obtained in the evaluation of particular symptoms of all joints. For synovitis, the maximal score for the 2–5 metacarpophalangeal joints, carpal joints and all joints (of one hand) amounts to 0–12, 0–9, and 0–21 points, respectively. Likewise, for bone marrow oedema: 0–24; 0–45, and 0–69 points; for erosions – 0–80; 0–150, and 0–230.

The presented system does not include the evaluation of severity of tenosynovitis (Figure 10) – a symptom frequently present in RA. On the basis of the sequences and grading used in OMERACT RAMRIS 2002, there was developed an analogue system for this pathological symptom as well [24]. The evaluation involved all six dorsal compartments (I

OMERACT RAMRIS evaluation sheet
On the basis of reference atlases of EULAR-OMERACT RA MRI

Metacarpophalangeal joints

Patient's name and surname: Evaluation date:

Synovitis - evaluation

		Metacarpophalangeal joints			
		2	3	4	5
synovitis (0-3)					

Erosions and bone marrow oedema - evaluation

Bone erosion – degrees from 0 to 10; according to the proportion of the destructed bone surface (10-percent ranges):
 0: 0%, 1: 1-10%, 2: 11-20%, 3: 21-30%, ..., 10: 99 – 100%

Bone marrow oedema – degrees from 0 to 3; percentage of the involved bone surface (33-percent ranges):
 0: 0%, 1: 1-33%, 2: 34-66%, 3: 57-100%

The bone is evaluated from the articular surface, to the depth of 1 cm.

		Metacarpophalangeal joints			
Erosions (0-10)	Proximal	2	3	4	5
		Distal			
Bone marrow oedema (0-3)	Proximal				
	Distal				

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Evaluating physician

On the basis of: "An introduction to the EULAR-OMERACT rheumatoid arthritis MRI reference image atlas" M Østergaard, J Edmonds, F McQueen, C Peterfy, M Lassere, B Ejlberg, P Bird, P Emery, H Genant and P Conaghan; Ann Rheum Dis 2005; 64 (Suppl 1): 13-17.

Figure 9. OMERACT RAMRIS evaluation sheet – metacarpophalangeal joints.

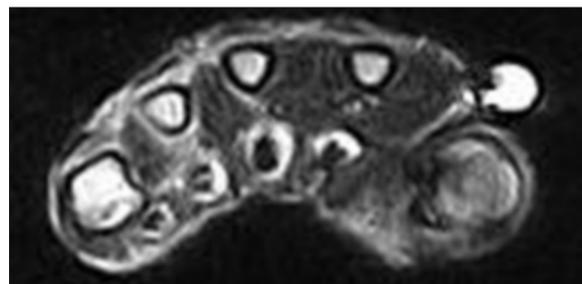


Figure 10. Sequence T2 SE, transverse plane, tenosynovitis of the digital flexors.

compartment – tendon sheaths of the extensor pollicis brevis and of the abductor pollicis longus; II – tendon sheaths of the extensor carpi radialis longus and brevis; III – tendon sheath of the extensor pollicis longus; IV – tendon sheaths of the extensor digitorum and the extensor indicis; V – tendon sheath of the extensor of little finger; VI – tendon sheath of the ulnar extensor of wrist) and 4 sheaths of the flexors on the ventral side (tendons of the flexor carpi radialis, of the flexor hallucis longus, common for the tendons of the flexor digitorum superficialis and profundus, tendons of the flexor carpi ulnaris). The lesions are most visible in transverse cross-sections, in T1-weighted sequences, before and after intravenous contrast administration, where tenosynovitis may appear as a fluid inside the sheath or a thickening (synovial hypertrophy) of the sheath, undergoing enhancement after intravenous contrast administration.

Because a small amount of fluid within the sheath may be also visible in healthy individuals, it is important to reveal this symptom at least two adjacent slices.

Tenosynovitis is described similarly to synovitis. The classification involves degrees from 0 to 3. The following features are scored: width of the fluid layer or sheath

Tenosynovitis – descriptive sheet

Patient's name and surname: Evaluation date:

The lesions must be present in at least two consecutive transverse sections.

Degrees of tenosynovitis:
 0 degree (normal state): No effusion or hypertrophy of the synovial membrane after contrast enhancement;
 1 degree: effusion in the sheath > or = 2 mm or hypertrophy of the synovial membrane after contrast enhancement;
 2 degree: effusion in the sheath > or = 2 and < 5 or hypertrophy of the synovial membrane after contrast enhancement;
 3 degree: effusion in the sheath > or = 5 or hypertrophy of the synovial membrane after contrast enhancement;

Dorsal side:

Range	I	II	III	IV	V	VI
Tenosynovitis (0-3)						

Ventral side:

Tendon sheath	Ulnar flexor muscle of wrist	Common sheath of the digital flexors	Long flexor muscle of thumb	Radial flexor muscle of wrist
Tenosynovitis (0-3)				

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Evaluating physician

On the basis of: "Introduction of a novel magnetic resonance imaging tenosynovitis score for rheumatoid arthritis: reliability in a multireader longitudinal study" EA Haavardsholm, M Østergaard, B Ejbjerg, N Kvan, T Kvien; Ann Rheum Dis 2007; 66: 1216-1220.

Figure 11. Tenosynovitis – a descriptive sheet.

thickening found on examination, with post-contrast enhancement.

- 0 degree – no fluid or thickening with post-contrast enhancement,
- 1 degree – the width of the fluid layer and the thickening of the sheath (synovial hypertrophy) with post-contrast enhancement: less than 2 mm,
- 2 degree – the width of the fluid layer and the thickening of the sheath (synovial hypertrophy) with post-contrast enhancement: equal to or higher than 2 mm and lower than 5 mm,
- 3 degree – the width of the fluid layer and the thickening of the sheath (synovial hypertrophy) with post-contrast enhancement: at least 5 mm.

The width of the evaluated layer is measured at the point of maximal thickness, perpendicularly to the surface of the tendon. Figure 11 shows a suggestion for a descriptive sheet for tenosynovitis. Next, as in OMERACT RAMRIS 2002, the

mentioned degrees are scored with an adequate number of scores – i.e. 1 degree – 1 point, 2 degree – 2 points, 3 degree – 3 points. In case of a lacking tendon (anatomical variant), the evaluated structure receives 0 points. The maximal number of points that can be obtained by one patient during tenosynovitis evaluation amounts to 30. This evaluative system supplements the OMERACT RAMRIS 2002 system.

The previously mentioned subjectivity of the MRI evaluations carried out by radiologists, depending on their experience and knowledge, induced OMERACT to develop the reference atlases including MRI images of the wrist and metacarpal joints, with divisions of symptoms and their severity [21,22]. Such atlases include:

- A complete series of images of all degrees of synovitis in metacarpophalangeal joints and in every region of the wrist (distal radioulnar joints, radiocarpal joint, medio-carpal joint and carpometacarpal joints) and
- Images of different kinds of erosions and of bone marrow oedema of selected bones: two bones of the metacarpophalangeal joint (head of the metacarpal bone and the base of the proximal phalanx) and 5 carpal bones (distal radial bone, scaphoid bone, lunate bone, capitate bone, and the bases of the metacarpal bones).

As far as the severity of synovitis is concerned, the atlas includes the instances from the upper and the lower limit of a given range, which facilitates a correct classification of the compared image.

Application of the presented reference atlases is extremely important, especially at the beginning of the learning process involving the evaluation of the MRI images of the rheumatoid conditions, as well as in case of clinical uncertainties. Moreover, the use of the OMERACT RAMRIS 2002 system in the daily practice, supplemented with the scale of tenosynovitis evaluation, allows for an objective assessment of the lesions. This also enables a comparison of results obtained in different examinations, carried out at different time points, in different centres, as well as a better communication between the diagnostic imaging specialists and the clinicians.

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