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The development of the EULAR–OMERACT rheumatoid arthritis MRI reference image atlas

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Based on a previously developed rheumatoid arthritis MRI scoring system (OMERACT 2002 RAMRIS), the development team agreed which joints, MRI features, MRI sequences, and image planes would best illustrate the scoring system in an atlas. After collecting representative examples for all grades for each abnormality (synovitis, bone oedema, and bone erosion), the team met for a three day period to review the images and choose by consensus the most illustrative set for each feature, site, and grade. A predefined subset of images (for example, for erosion— all coronal slices through the bone) was extracted. These images were then re-read by the group at a different time point to confirm the scores originally assigned. Finally, all selected images were photographed and formatted by one centre and distributed to all readers for final approval.

abnormalities of synovitis, bone oedema, and bone erosion.

COLLECTION OF THE IMAGE EXAMPLES

After agreement on the MRI features to be represented in the atlas, one of the co-chairs of the group allocated the task of finding representative examples to four centres involved in the creation of the atlas (Sydney, Copenhagen, Leeds, and Auckland) (table 1). The group recognised that differences between magnet strengths and sequence protocols at the contributing centres could affect image standardisation. Therefore, during selection of images for the atlas, the group tried to provide examples for each region and pathology from a single centre. Where this was not possible, a secondary centre contributed images. All films provided were on standard radiographic film.

LIMITING OF EXAMPLES TO SELECTED AREAS

To make the development and publication of the atlas feasible, it was necessary to limit the examples to certain anatomical areas (rather than every single grade of every abnormality at all sites). The selected examples for the wrist are listed in table 1. It was considered important and feasible to illustrate synovitis of all grades, that is, 0–3, in each of the three wrist areas scored for synovitis in the RAMRIS. The four metacarpophalangeal (MCP) joints were considered sufficiently uniform for one series of illustrations of MCP synovitis grades to give adequate guidance for scoring of all MCP joints.

It was decided that an example from both the lower and higher ends of the range of each grade of synovitis should be presented, in order to provide a range of synovitis examples fulfilling a particular score category. Providing examples of every grade of pathology for every bone in the wrist and every bone in the MCP joints was considered unnecessary and excessive because this would have required the provision of 100 examples for wrist bone erosion alone. Instead, five bones in the wrist were selected as examples, and several grades of pathology are illustrated for each.

One series of image examples was considered sufficient to allow scoring the bone areas of all the MCP joints. The lower bone erosion grades—

Abbreviations: EULAR, European League Against Rheumatism; MCP, metacarpophalangeal (joint); MRI, magnetic resonance imaging; RA, rheumatoid arthritis

The aim of developing the reference film atlas was to create a new tool for standardised assessment of rheumatoid arthritis (RA) joints, based on the OMERACT 2002 rheumatoid arthritis MRI scoring system (OMERACT RAMRIS),¹ which would allow semiquantitative scoring of MR image sets for inflammatory and destructive changes guided by standard reference images. This article describes the process of development of the atlas.

AGREEMENT ON IMPORTANT FEATURES, DEFINITIONS, AND SCORING SYSTEM

Magnetic resonance imaging (MRI) definitions of important RA joint pathologies and a core set of basic MRI sequences to be used for imaging of the RA joint have previously been suggested by the OMERACT MRI in RA group.¹ Furthermore, based on a series of studies,^{2–4} an RA MRI scoring system (OMERACT 2002 RAMRIS) for evaluation of inflammatory and destructive changes in RA hands and wrists has been developed (see the previous paper⁵ in this supplement for details).

Following a decision of the OMERACT MRI group to develop a standard reference image set (atlas) based on the OMERACT 2002 RAMRIS, it was agreed that the example images should cover the features, definitions, and scoring system of the RAMRIS. The atlas should allow scoring of wrist and metacarpophalangeal (MCP) joints for the commonly described MRI

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Table 1 The example images requested for the EULAR–OMERACT rheumatoid arthritis MRI reference image atlas and the allocated collection centres

Selection	Synovitis		Bone oedema		Bone erosion	
	MCP joint	Wrist	MCP joint	Wrist	MCP joint	Wrist
Areas	Second or third	Distal radioulnar Radiocarpal Intercarpal-CMC	Metacarpal head Phalangeal base	Radius Scaphoid Lunate Capitate Third metacarpal base	Metacarpal head Phalangeal base	Radius Scaphoid Lunate Capitate Second or third metacarpal base
Grades	All (0–3)		All (0–3)		Grade 0–3 + examples of higher grades	
MRI sequences For scoring	Axial precontrast and postcontrast T1 weighted Coronal precontrast and postcontrast T1 weighted		Coronal T2 weighted fat saturated or STIR		Coronal T1 weighted	
Additional			–		Axial T1 weighted (to confirm cortical break)	
Centre allocation (primary/ secondary)	Leeds/Sydney	Copenhagen/ Sydney	Leeds/Sydney	Auckland/Copenhagen	Leeds/Sydney	Copenhagen/Auckland
Origin of final atlas images*	Leeds	Copenhagen, Oslo	Leeds	Copenhagen, Leeds, Oslo	Leeds, Sydney	Copenhagen, Auckland

*In total, 1002 images were included in the atlas.^{6–8} The origin of the images was as follows: Copenhagen, 48%; Leeds, 45%; Auckland, 4.4%; Oslo, 2.2%; and Sydney, 0.5%.
MCP, metacarpophalangeal; CMC, carpometacarpal; STIR, short tau inversion recovery.

that is, 0–3—corresponding to an erosion volume of 0–39% of the original bone, are always represented. In addition, selected examples of scores 4–10 are provided for each bone.^{6–7}

Bone oedema is illustrated in the same bones (table 1) and all grades (that is, 0–3) are illustrated. However, it was not possible to find examples of grade 3 oedema at all sites (in the radius, scaphoid, and lunate).

INITIAL MRI INTERPRETATION AND CONSENSUS

The group met in Sydney, Australia, in April 2003 for a three day period to review the MRI films. Six readers representing four MRI centres (Auckland, Copenhagen, Leeds, and Sydney) reviewed the films together. Four of the six readers had previously taken part (as MRI readers) in the OMERACT and/or EULAR MRI scoring trials.^{2–4, 9–10} As mentioned before, scoring was undertaken using the OMERACT 2002 RAMRIS.¹

For each type of lesion, the primary centre provided three examples for each grade in a selected bone. For each feature, site, and grade, consensus was reached and the most representative film set was chosen for inclusion in the atlas. All readers read all film sets at the same time with consensus reached by discussion. Selection of images for the atlas of bone oedema in the wrist bones was postponed due to the lack of optimal images (see below).

SELECTION OF SEQUENCE TYPE, IMAGE PLANES, AND SUBSET OF IMAGES

After identification of the most representative set of films for each feature and grade, a subset of images was chosen to illustrate the grade in the atlas (tables 1 and 2). The selected sequence types and image planes represent the group's consensus opinion about the best possible image type for scoring this particular feature.

For synovitis, the axial image plane was selected, as it is perpendicular to the main orientation of the synovium and therefore less prone to partial volume artefacts. A short series of axial precontrast and postcontrast T1 weighted images was chosen, as several images are needed to determine the distribution of the synovitis.

For each grade of MCP and wrist erosion, all coronal precontrast T1 weighted slices through the bone were selected for presentation, in order to allow performing the scoring procedure, that is, calculation of the percentage of the bone volume occupied by erosion. In addition, an axial image was chosen to confirm that erosion was visible in two planes, as required by definition.⁵

The group agreed that coronal T2 weighted fat saturated or short tau inversion recovery (STIR) sequences images provided the most sensitive visualisation and scoring of bone oedema. In the wrist, however, such images were only

Table 2 The most frequently used MRI sequence parameters for visualisation of synovitis, bone oedema, and bone erosion in the centres contributing reference images of the individual features for the atlas

	Centre*	Field strength, Magnet	Sequence	TE (ms)	TR (ms)	TI (ms)	Acq.	FOV (mm)	Matrix	ST (mm)	Gap (mm)
Synovitis	Copenhagen	1.0 T Siemens	T1 SE	15	600	–	2	109×145	192×256	3	0
	Leeds	1.5 T Philips	T1 SE	20	485	–	4	100×50	205×256	1.5	1.0
	Oslo	1.5 T Gen. El.	T1 SE	13	420	–	2	100×100	512×320	3	0.5
Oedema	Leeds	1.5 T Philips	T2 SPIR	100	2000	180	3	100×100	202×256	2.0	0.2
	Oslo	1.5 T Gen. El.	STIR	12	3760	150	2	100×100	288×192	2.5	0.5
	Copenhagen	1.0 T Siemens	STIR	30	4500	150	3	145×108	256×182	3.0	0.0
	Sydney	1.5 T Gen. El.	TIRM	30	3289	130	2	130×130	217×256	3.0	0.3
Erosion	Copenhagen	0.2 T Esaote	T1 3D GE†	12	30	–	1	140×140	192×160	2.0	0.0
	Leeds	1.5 T Philips	T1 SE	20	485	–	4	100×50	205×356	1.5	1.0
	Auckland	1.5 T Gen. El.	T1 SE	14	680	–	1	80×80	256×192	3.0	1.0

*Centres are listed ordered after the number of presented images of this particular type of pathology.

†T1 weighted three dimensional gradient echo with subsequent multiplanar reconstruction. The flip angle was 65°.

Acq, number of acquisitions; FOV, field of view; GE, gradient echo; Gen. El., General Electric; SPIR, spectral prepulse inversion recovery; ST, slice thickness; STIR, short tau inversion recovery; T1 SE, T1 weighted spin echo; TE, echo time; TI, inversion time; TIRM, turbo inversion recovery magnitude; TR, repetition time.

available in the axial plane at the first meeting. As a consequence, at a second round of image viewing, consensus was reached for coronal wrist bone oedema images. Candidate images for this second round were collected in Copenhagen, Leeds, and Oslo. During the same process, a few of the original synovitis illustrations were replaced with new selections, considered to be of a better quality and/or more representative for the upper or lower end of this particular grade of synovitis.

Each of the selected images was marked and recorded.

SECOND READING OF ALL IMAGES

Following completion of the initial selection of images, all images were re-read by all five observers to confirm the feature and grade allocated on initial scoring. Agreement was reached by consensus as per the initial reading. These selections were marked and recorded.

PREPARATION OF IMAGES

All images were photographed, cropped, and formatted at the Copenhagen University Hospital at Hvidovre (MØ, BE). Subsequently, the images were distributed to all readers for approval prior to publication.

FINAL PROCEDURES

In June 2003, the group assembled to review the photographed examples, to clarify any issues relating to the image examples, and to discuss these issues with other members of the OMERACT MRI RA group (CP, HG, PE) who had been unable to attend the meeting in Sydney. Alternative image sets were available in case of need for revisions. Consensus was reached regarding the presentation of the image examples, including page set up.

Even though numerous new image sets were reviewed, a sufficient number of candidate wrist bone oedema images were still not available. Between July 2003 and April 2004, the remaining wrist joint bone oedema images were collected. At a series of group meetings at the OMERACT 7 conference at Asilomar, CA, in May 2004, the final image selections and revisions were made by consensus, following procedures as described above. In total, 1002 images were included (see table 1).⁶⁻⁸

Between June and August 2004, the final formatting, circulation, and approval by all members were completed. Finally, the atlas was submitted, with images prearranged page by page, to the *Annals of the Rheumatic Diseases*, with financial support from EULAR.

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