# A Database of Segmented MRI Images of the Wrist and the Hand in Patients with Rheumatic Diseases

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**Abstract.** This paper is concerned with the ideation, organization and distribution of a database of segmented MRI images - and associated clinical parameters - of the wrist and the hand in patients affected by a variety of the most frequent rheumatic diseases. The final goal is empowering future biomedical research thanks to the completeness of details and cases. MRI Images were analyzed by means of the software RheumaSCORE (Softeco Sismat Srl), which performs semi-automatic segmentation of the bones, returns the volume of bones and erosions, as well as their tri-dimensional reconstruction. In order to favor its exploitation, the database of segmented images, along with many relevant clinical anthropometric parameters, are available online through the Patient Browser platform (Softeco Sismat Srl). Moreover, the original images and their clinical parameters are accessible online through the dedicated DICOM viewer QuantaView (CAMELOT Biomedical Systems Srl).

**Keywords:** Database · Image segmentation · MRI · Arthritis · DICOM viewer · Rheumascore · Patient browser · Quantaview

## 1 Introduction

Rheumatic diseases, in particular erosive arthritides, represent the most common cause of severe long-term pain and physical disability [1]. In order to minimize them, an early diagnosis, the choice of the most appropriate therapy, and the control of its efficacy are crucial items. In the management of these diseases, the rheumatologist is helped by radiology, which offers different imaging techniques. Even if conventional radiography is traditionally considered the gold standard for assessing structural joint damage [2], it does not visualize the earliest stage of erosive damage and identify the predictor of aggressive disease. Magnetic resonance imaging (MRI) is more effective


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than conventional radiology for detection of bone erosions [3]. At the same time, it allows to depict synovitis and bone oedema, which represent important predictors of bone damage [4]. Articular MRI is highly sensitive to the anatomical changes due to its different sequences [5]; all components of the joint, including soft tissues, articular cartilages, and bones, can be evaluated on a single examination. Moreover, MRI is a non-invasive imaging technique, which does not use ionizing radiation. For all this features it is increasing used in clinical trials, becoming the standard for the follow up of arthritis [6].

In order to standardize this evaluation, the OMERACT (Outcome Measure in Rheumatoid Arthritis Clinical Trials) MRI working group has developed a MRI scoring system called RAMRIS (Rheumatoid Arthritis Magnetic Resonance Imaging Score). The focus is set on the semi quantitative assessment of wrist and metacarpophalangeal joints and three parameters are considered: bone erosion, bone oedema and synovitis [7].

The RAMRIS system has demonstrated good reliability and high levels of reader agreement for all the parameters analyzed, but reliability is less satisfactory in discriminating between two time points. In addition, the feasibility represents a problem, especially for the time necessary for scoring [8].

In order to support the diagnostic process, MRI images can be analyzed and segmented. Segmentation is an important task that allows recognizing anatomical or pathological structures and determining their relevant characteristics such as size, shape, and volume. Moreover, image segmentation is the prerequisite for many interaction techniques to explore data and facilitate treatment planning. Mc Queen et al. have recently shown that a computer-assisted manual segmentation technique for measuring bone erosions significantly correlates with the RAMRIS score with good reliability of the former method [9].

The spectrum of segmentation techniques available in the literature is broad, ranging from manual slice-by-slice outlining to fully automatic techniques. Among them are interactive approaches, which combine the high accuracy, efficiency, and repeatability of automatic methods with the expertise and quality control obtained through human supervision. Interactive segmentation can be based, e.g., on thresholding techniques [10], region growing approaches [11], and level set methods [12,13]. Computer-Aided Diagnosis (CAD) systems, which offer semi-automatic segmentation tools, are being developed.

The aim of this study is to create a database of segmented MRI images in patients affected by the most frequent rheumatic diseases and to provide an automatic score of bone erosions. Rheumatologists collected MRI images of the wrist and hand in patients affected by rheumatic disorders and used a CAD system (RheumaSCORE) to segment these images and to supervise the automatic scoring of bone erosions. The segmented database is available online through the Patient Browser website (Softeco Sismat Srl) and the QuantaView DICOM Viewer (Camelot Biomedical Systems Srl).

The paper is organized as follows. In Section 2, rheumatic diseases will be introduced. Section 3 will describe the collection of the database, including image acquisition, image segmentation, and sharing of the results. Finally, in Section 4 results will be assessed and in Section 5 conclusions will be drawn.

## 2 Rheumatic Diseases

Erosive arthritides are the most disabling rheumatic diseases. Bone erosions are considered the central feature of Rheumatoid Arthritis (RA) [14] even if they can be found in other rheumatic diseases, such as Psoriatic Arthritis (PSA), gout, Palindromic Rheumatism (PR), Systemic SClerosis (SSC), OsteoArthritis (OA), septic arthritis, systemic lupus erythematosus and other less frequent conditions. In particular, the most frequent erosive arthritides are analyzed: each of them has several distinctive features, both in clinical manifestations and in the pattern of bone damage.

RA is a chronic systemic inflammatory disease characterized by recurrent, poliarticular and symmetrical episodes of arthritis. The chronic inflammation is responsible for the formation of the synovial pannus with bone eroding capacity. In RA, erosions are marginal and localized at the "bare area", the bone surface within the synovial space, which is not protected by cartilage [15]. PSA is an inflammatory disorder characterized by the association of cutaneous psoriasis and inflammatory arthritis. Different type of PSA are described: a symmetrical polyarthritis similar to RA, an oligoarticular form, a spondylitic form characterized by axial involvement and a mutilans form. In PSA, episodes of dactylitis and enthesitis are frequent. Bone erosions, unlike the ones observed in RA, are not in the marginal but in the central area of the articular surface [16].

Gout is a metabolic disease correlated with hyperuricemia, and characterized by recurring acute arthritis, usually monoarticular, and later by chronic deforming arthritis. The characteristic lesion of the chronic stage is the tophus, a nodular deposit of monosodium urate monohydrate crystals that can be found in cartilage, and subcutaneous, articular and periarticular tissues. Characteristic of gout are well-defined, punched-out erosion with overhanging edges [17]. The erosions are often adjacent to the tophus [18].

PR is a form of inflammatory arthritis characterized by sudden and rapidly developing arthritis episodes leaving no residual or radiographic change. In the long term, some patients will develop RA. The risk of progression to RA is associated with serum Rheumatoid Factor (RF) and AntiCitrullinated Peptides Antibodies (ACPA) [19].

Bone erosion can also be found in SSC, a chronic systemic connective tissue disorder characterized by diffuse fibrosis of the skin and internal organs. Joint involvement is frequent and the possible radiological features are distal phalange resorption, demineralization, joint space narrowing and erosions [20].

## 3 Database Collection

MRI images of patients followed in the Academic Division of Rheumatology of the University of Genoa are available. MRI is performed with a 0.2T extremity dedicated machine (Artoscan, Esaote) using 3D T1 weighted sequences with reconstruction on the axial and sagittal plane. Low field extremity-dedicated MRI machines provide similar information on bone damage as high field MRI machines, and the low cost added to better patient compliance explains the emerging role of this technique in the diagnosis and follow-up of rheumatoid arthritis [21].

Image segmentation is carried out by the clinical experts through the support of a CAD system, RheumaSCORE [22,23], developed by Softeco Sismat S.r.l. RheumaSCORE supports the rheumatologist during the segmentation process, by providing a semi-automatic tool for the detection of bones (based on level sets [24]) volume measurement, three-dimensional reconstruction of the segmented structures and automatic evaluation of bone erosions [25,26]. The system provides a GUI for the visualization of MRI images and the selection of the anatomical structures to be segmented. The segmentation feature allows the radiologist to select a starting region, to interactively correct the segmented region during the process and to edit the results. During the segmentation process, the bone surface is automatically reconstructed using the marching cubes algorithm [27]. Once the segmentation has been completed, the system provides automatic scoring of bone erosions.

The collected images and segmentation results are available online, through a DICOM Viewer (QuantaView) and a web browsing application (Patient Browser). These two applications are described in the following paragraphs.

### 3.1 QuantaView DICOM Viewer

The QuantaView DICOM image viewer, designed and developed by Camelot Biomedical Systems, is completely based on web technologies and is accessible through a web browser, also on mobile devices, at www.quantaviewpolo.camelotbio.com upon registration. The user interface is implemented in HTML5/CSS3/JS. The image display is based on WebGL standard, that is supported by all major modern browsers and also by iOS since version 8.

QuantaView main functionalities are the following:

- PACS connection via DICOM standard, in order to explore and see its contents (query/retrieval commands through C-FIND, C-MOVE and C-STORE are allowed operations).
- Local archive on file-system, directly accessible from the server. DICOM objects can be imported from any physical support (USB, CD, DVD) from the operating system hosting the frontend.
- User management, through authentication. Users are assigned to one or more groups, defining the data and users visibility. Each group has a role, defining a certain configuration of permissions (e.g. writing or reading) on accessible data.
- Browsing data. The user can navigate through the data on all accessible sources. Data are displayed according to the DICOM hierarchy patient/study/series.
- DICOM metadata editing, guaranteed only to a narrow class of users (e.g., data owner, group administrator, etc.).
- Insertion of non-DICOM metadata, such as tags and notes in free text, to objects in each level of the hierarchy (patient, study, series). Permission is guaranteed only to a narrow class of users (e.g., data owner, group administrator, etc.).

- DICOM visualization, which includes: navigation among the series slices, playback of multi-frame, changing windowing parameters, pan, zoom and reset windowing, saving the current slice in jpeg format.
- Image graphical annotations that can be added to the individual slices of a DICOM series. Permission, which can be configured, to view/remove the annotations is guaranteed only to a narrow class of users.

### 3.2 Patient Browser Web Application

Patient Browser is a web application that has been developed by Softeco Sismat S.r.l., in order to assist and support the user in the diagnosis and follow-up processes of rheumatic diseases. The idea is to provide a web-based framework for storing, searching and visualizing MRI images and medical data, as well as to retrieve and display different kinds of diagnostic measurements.

In this context, the Patient browser application is intended to share and retrieve visual data (MRI exams, segmentations and 3D mesh models generated by RheumaSCORE), to compare clinical data (inserted by the radiologists) and diagnostic measurements (e.g. bone volume, erosion volume, erosion scoring, etc., calculated through RheumaSCORE), and to assist the radiologists in the diagnostic procedure. The users interaction with the system may differ depending on the user profile and access rights.

The basic functionalities include:

- Sharing the data analyzed through RheumaSCORE both in terms of meshes and in terms of segmented data.
- Uploading and storing patient studies exported from RheumaSCORE.
- Browsing and visualizing the analysis results of different patient studies.
- Display diagnostic measurements and compare them.
- Downloading the original images, segmentation results and diagnostic measurements.

Access will be provided upon request (please, contact the authors for detailed access instructions).

## 4 Assessment of the Results

The database comprises 100 MRI examinations performed between August 2014 and January 2015. Each examination includes the hand and the wrist districts. Among the 100 MRI images examined, 10 belong to healthy controls, 30 belong to patients affected by RA, 15 belong to patients affected by PSA, 15 to patients affected by gout, 15 to patients affected by PR and 15 to patients affected by SSC. The patients affected by RA are divided into three groups according to disease duration, eight patients for each group. The patients of the first group have disease duration less than 6 months, those of the second group between 6 and 36 months, and those of third group have disease duration longer than 36 months. For six patients a follow up examination is available.

Overall, about 2800 bones are segmented and bone erosions are analyzed and scored. Through the software RheumaSCORE, a tridimensional reconstruction of the bones is obtained, together with the bone and erosion volumes.

The images are segmented and the automatic bone-erosion score is analyzed and corrected, pixel-by-pixel, by a clinical expert. The entire work is supervised by another clinical expert. The time necessary to analyze the segmentation differs, depending on the severity of the disease and ranges from 340 minutes (100 minutes for the district of the hand and 240 minutes for the district of the wrist) to 460 (130 minutes for the district of the hand and 330 minutes for the district of the wrist).

Additionally, for each patient, a set of clinical and laboratory parameters are included within the database, which allow to better understand the severity and the course of diseases. Some of these parameters are common among all diseases and others are specific for each disease. The common parameters are gender, age, disease duration, inflammatory indexes (ESR and CRP), number of tender joints (NTJ), number of swollen joints (NSJ) and the visual analogue scale of pain (a subjective grading of pain).

The disease specific parameters are the same for RA and PR, including RF, ACPA, and DAS28 (Disease Activity Score on 28 joints). High titers of RF and ACPA, in patients affected by RA, are indicators aggressive diseases and correlate with the risk of bone damage [28] The DAS28 is a quantitative measure of disease activity used to monitor the trend of RA and to monitor the efficacy of therapy. DAS28 provides a number on a scale from 0 to 10 indicating current RA disease activity (Remission: DAS28 ≤ 2.6 • Low Disease activity: 2.6 < DAS28 ≤ 3.2 • Moderate Disease Activity: 3.2 < DAS28 ≤ 5.1 • High Disease Activity: DAS28 >5.1). A high score of DAS28 is associated with the risk of bone damage and its progression. The serum positivity of RF and ACPA in patients affected by PR predicts the subsequent development of RA and, therefore, a potentially erosive disease [19].

The DAS28 is also analyzed in patients affected by PSA, where the subtype of PSA is also specified. The parameters considered in gout are serum uric acid, the number of acute arthritis episodes and the presence of tophi. Levels of serum uric acid are considered an index of disease activity; high levels promote urate crystal deposition and acute arthritis attacks. A high number of acute episodes is a forerunner of the chronic stadium of the disease, where joint damage is most likely found [29]. Finally, the presence of tophi correlate with the risk of bone erosions [18].

The parameters considered in SSC are nailfold videocapillaroscopy (NCV) score and patterns, and two serum autoantibodies, anticentromer (ACA) and antitopoisomerase I (anti-Scl70). In a large number of patients affected by SSC there are three distinct NCV pattern that are the early, active and late patterns. The NCV pattern is correlated with disease severity, particularly skin and pulmonary involvement [30]. The presence of Scl70 antibodies is related to a more rapid progression of the microangiopathy, whereas ACA positivity is related to a slower progression.

## 5 Conclusions

The segmentation process and the automatic analysis of bone erosions represent two important tools for rheumatologist to visualize and interpret medical images and offer a powerful tool to support the diagnostic process. However, at the time being, the analysis of the automatic-segmentation results is very time-consuming. An increasing automation of the segmentation process is continuously pursued and, hopefully, progresses will be achieved.

The high number of images analyzed, the different diseases considered, their characterization in terms of disease duration and activity, and their online availability make this database interesting for future challenges in image segmentation. Inter-operator reliability and comparison of different segmentation methods could be investigated. Additionally, RAMRIS scoring could be used as a reference for comparison.

In future the database will be extended, in order to include other diseases such as osteoarthritis. Moreover, more MRI examinations of the same patient will be available to the clinicians and will be included in the database, in order to provide more follow-up cases. Finally, in order to create new databases, segmentation of other joints may be investigated.

## References

1. Woolf, A.D., Pfleger, B.: Burden of major musculoskeletal conditions. Bulletin of the World Health Organization **81**(9) (2003)
2. American college of rheumatology subcommittee on rheumatoid arthritis: 2002 update. Guidelines for the management of Rheumatoid arthritis: 2002 update. Arthritis Rheum. **46**(2), 328–346, February 2002
3. Baillet, A., Viala, C.G., Mouterde, G., et al.: Comparison of the efficacy of sonography, magnetic resonance imaging and conventional radiography for the detection of bone erosions in rheumatoid arthritis patients: a systematic review and meta-analysis. Rheumatology (Oxford) **50**(6), 1137–1147 (2011)
4. McQueen, F.M.: Bone marrow edema and osteitis in rheumatoid arthritis: the imaging perspective. Arthritis Res Ther. **14**(5), 224 (2012). doi:10.1186/ar4035
5. Haavardsholm, E.A., Ostergaard, M., et al.: Reliability and sensitivity to change of the OMERACT Rheumatoid Arthritis Magnetic Resonance Imaging Score in a Multireader, longitudinal setting. Arthritis and Rheumatism **52**(12), 3860–3867 (2005)
6. Cimmino, M.A.: Does magnetic resonance represent the gold-standard of imaging for the follow-up of arthritis? Reumatismo **58**(4), 245–252 (2006)
7. Østergaard, M., Edmonds, J., McQueen, F., et al.: An introduction to the EULAR-OMERACT Rheumatoid Arthritis MRI reference image atlas. Ann. Rheum. Dis. **64**, i3–i7 (2005). doi:10.1136/ard.2004.031773
8. McQueen, F., Lassere, M., Edmonds, J., et al.: OMERACT rheumatoid arthritis magnetic resonance imaging studies. Summary of OMERACT 6 MRImaging module. J. Rheumatol. **30**(6), 1387–1392 (2003)
9. Crowley, A.R., Dong, J.: A. McHaffie et all. Measuring bone erosion and edema in rheumatoid arthritis: a comparison of manual segmentation and RAMRIS methods. J. Magn. Reson. Imaging **33**(2), 364–371 (2011). doi:10.1002/jmri.22425

10. Huang, D., Wang, C.: Optimal multi-level thresholding using a two-stage Otsu optimization approach. Pattern Recognition Letters **30**, 275–284 (2009)
11. Adams, R., Bischof, L.: Seeded region growing. IEEE Trans. Pattern Anal. Machine Intell. **16**, 641–647 (1994). doi:10.1109/34.295913
12. Caselles, V., Kimmel, R., Sapiro, G.: Geodesic Active Contours. ICCV, 694–699 (1995)
13. Chan, T., Vese, L.: Active Contours without Edges. IEEE TIP (2001)
14. American college of rheumatology subcommittee on rheumatoid arthritis. Guidelines for the management of Rheumatoid arthritis: 2002 update. Arthritis Rheum **46**(2), 328–346, February 2002
15. Resnick, D.: Early abnormalities of pisiform and triquetrum in rheumatoid arthritis. Ann. Rheum. Dis. **35**(1), 46–50 (1976)
16. Lange. Mc Graw Hill Education. Current medical diagnosis & treatement 2015
17. Gentili, A.: Advanced imaging of gout. Semin. muscoloskelet Raiol. **7**(3), 165–174 (2003)
18. Dalbeth, N., et al.: Mechanisms of bone erosion in gout: a quantitative analysis using plain radiography and computed tomography. Ann. Rheum. Dis. **68**(8), 1290–1295 (2009)
19. Gonzalez-Lopez, L., Gamez-Nava, J.I., Jhangri, G.S., Ramos-Remus, C., Russell, A.S., Suarez-Almazor, M.E.: Prognostic factors for the development of rheumatoid arthritis and other connective tissue diseases in patients with palindromic rheumatism. J. Rheumatol. **26**(3), 540–545 (1999)
20. Avouac, J., Guerrini, H., Wipff, J., et al.: Radiological hand involvement in systemic sclerosis. Ann. Rheum. Dis. **65**(8), 1088–1092 (2006)
21. Ejbjerg, B., Narvestad, E., Jacobsen, S., et al.: Optimized low cost, low field dedicated extremity MRI is highly specific and sensitive for synovitis and bone erosions in rheumatoid arthritis wrist and finger joints: comparison with conventional high field MRI and radiography. Ann. Rheum. Dis. **64**, 1280–1287 (2005)
22. RheumaSCORE. http://www.research.softeco.it/rheumascore.aspx
23. Parascandolo, P., Cesario, L., Vosilla, L., Viano, G.: Computer aided diagnosis: state-of-the-art and application to musculoskeletal diseases. In: 3D Multiscale Physiological Human, pp. 277–296. Springer London (2014)
24. Parascandolo, P., Cesario, L., Vosilla, L., Pitikakis, M., Viano, G.: Smart brush: a real time segmentation tool for 3D medical images. In: 2013 8th International Symposium on Image and Signal Processing and Analysis (ISPA), pp. 689–694, September 4–6, 2013
25. Barbieri, F., Parascandolo, P., Vosilla, L., Cesario, L., Viano, G., Cimmino, M.A.: Assessing MRI erosions in the rheumatoid wrist: a comparison between RAMRIS and a semiautomated segmentation software. Ann. Rheum. Dis. **71**(Suppl 3) (2012)
26. Catalano, C.E., Robbiano, F., Parascandolo, P., Cesario, L., Vosilla, L., Barbieri, F., Spagnuolo, M., Viano, G., Cimmino, M.A.: Exploiting 3D part-based analysis, description and indexing to support medical applications. In: Greenspan, H., Müller, H., Syeda-Mahmood, T. (eds.) MCBR-CDS 2012. LNCS, vol. 7723, pp. 21–32. Springer, Heidelberg (2013)
27. Lorensen, W.E., Cline, H.E.: Marching cubes: a high resolution 3D surface construction algorithm. In: Proc. of ACM SIGGRAPH, pp. 163–169 (1987)
28. Kocijan, R., Harre, U., Schett, G.: ACPA and bone loss in rheumatoid arthritis. Curr. Rheumatol. Rep. **15**(10), 366 (2013). doi:10.1007/s11926-013-0366-7
29. Doghramji, P.P., Wortmann, R.L.: Hyperuricemia and gout: new concepts in diagnosis and management. Postgrad. Med. **124**(6), 98–109 (2012). doi:10.3810/pgm.2012.11.2616
30. Sulli, A., Ruaro, B., Alessandri, E., et al.: Correlations between nailfold microangiopathy severity, finger dermal thickness and fingertip blood perfusion in systemic sclerosis patients. Ann. Rheum. Dis. **73**(1), 247–251 (2014)