Correlation between manual 0.2 Tesla MRI assessment of synovitis and EULAR-OMERACT scores of the wrist in patients with rheumatoid arthritis

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Purpose

Rheumatoid arthritis (RA) is characterized by progressive and irreversible destruction of articular and periarticular structures. The current gold standard for detection and follow-up of hand bone damage in RA is conventional radiography (CR). However, CR is not sensitive enough for detecting early erosive changes and cannot be used to evaluate other RA-related lesions like synovitis or bone edema.

An alternative for CR to examine wrist joints in RA is magnetic resonance imaging (MRI). The advantages of MRI include the visualization of bone erosions and the depiction of the inflamed synovial membrane and bone marrow edema. MRI findings (synovitis, bone edema, and bone erosions) in the wrist joints have been shown to have prognostic value in predicting subsequent erosive progression on radiographs (1). Recently Outcome Measures in Rheumatology Clinical Trials MRI working group (OMERACT) developed an MRI-based RA scoring system (RAMRIS) (2) for synovitis, bone edema and bone erosions. Since its recommendation it has been shown that RAMRIS is reproducible and relatively sensitive to changes due to therapy or disease progress, although it is a semi-quantitative scoring system (e.g. the actual volumes of erosions or edema are not reported), which can be a source of a substantial inter-operator variability (3). Although RAMRIS outperforms other common methods of assessing RA, some of its limitations are also recognized. Currently RAMRIS scoring is not supported by any dedicated computer-aided diagnosis applications. For this reason RAMRIS scoring is time-consuming since it involves retrieving from picture databases and examining a few different MRI sequences. Moreover it requires analyzing and quantifying multiple, frequently small details in three dimensions (e.g. erosions and bone edema in 15 bones). Next, because RAMRIS is a semi-quantitative scoring system it may seem too rigid, especially for quantifying early changes.

Recently low-field (0.2T) dedicated extremity MRI scanners became popular primarily because these modalities are considerably less expensive and more comfortable for patients than high-field scanners. Low-field scanners offer however lower image quality due to lower signal-to-noise ratio and worse resolution. In the present study we address the problem of estimating the volume of synovitis from 0.2T MR images. Synovitis is scored, based on RAMRIS and the regions of inflamed synovium are manually selected in properly preprocessed MR images. We demonstrate strong correlation between manual segmentation and RAMRIS scores of synovitis in low-field 0.2T images of wrist.

Methods and Materials

Patients and images
Thirty-two patients (thirty-seven study cases) were recruited for the study. The age of the patients varied from 23 to 74 years, with mean age 47 ±13 years. The proportion of women to men was 28:4.

**RAMRIS scores and manual segmentation**

Synovitis is a region in the synovial compartment that shows above normal post-gadolinium enhancement of a thickness greater than the width of the normal synovium (5). According to the OMERACT guidelines (6) three regions of the wrist were included in the assessment of synovitis: the distal radioulnar joint (DRUJ), the radiocarpal joint (RCJ) and the intercarpal-carpometacarpal joints (ICCMCJ). RAMRIS evaluation of synovitis was accomplished by an experienced musculoskeletal radiologist. The RAMRIS scores were in the range from 0 to 3, where 0 is normal, and 1-3 (mild, moderate, severe) are by thirds of the presumed maximum volume of enhancing tissue in the synovial compartment. Since RAMRIS scale of synovitis is proportional to the ratio of the inflamed synovial membrane volume to the whole joint volume (5), both joint and inflammation regions were manually outlined in the axial slices of the pre- and post-contrast Turbo 3D T1-weighted MR images. To ensure that the same regions are evaluated in manual and RAMRIS-based assessments of synovitis, the following assumptions were made:

1. the distal radioulnar joint starts at the carpal articular surface of the radius and extends towards the elbow for at least 10mm until the distance between the radius and the ulna begins to grow,
2. the radiocarpal joint starts at the carpal articular surface and ends at the end of the radial styloid process,
3. the intercarpal-carpometacarpal joints start at the end of the radial styloid process and extend towards phalanges for at least 10mm measured between the second and third metacarpal until the distance between them begins to grow (Fig. 1).

After the preprocessing, the reader outlined the whole joint area on each axial slice of the pre-contrast image. Manual outlining was guided by both coronal and sagittal images to ensure that DRU, RC and ICCMC joint regions are segmented in accordance with the aforementioned propositions. On the next step the regions of enhanced MR signal at the preprocessed post-contrast image were marked (Fig. 2).

**Images for this section:**
**Fig. 1:** Joints borders propositions for DRUJ, RCJ and ICCMCJ respectively. The lines divide axial slices into belonging to the particular joints.

**Fig. 2:** Whole joint and enhanced areas outlined. Upper images are pre-contrast T1-weighted representational slices for DRJ, RCJ and ICCMCJ where whole joint areas are marked. Bottom images are the same slices from the series but post-contrast and with enhanced areas outlined.
Results

Thirty four (92%) of the 37 study cases (32 patients) had active synovitis. Four patients and four study cases had active synovitis in one joint, 7 patients (8 study cases) in two joints and 20 patients (22 study cases) in all three joints. Study cases and patients represented all grades of synovitis in each joint as shown in Tab. 1.

<table>
<thead>
<tr>
<th>RAMRIS</th>
<th>Cases(Patients)</th>
<th>DRUJ</th>
<th>RCJ</th>
<th>ICCMCJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>12 (12)</td>
<td>4 (4)</td>
<td>9 (9)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>18 (16)</td>
<td>17 (16)</td>
<td>18 (16)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4 (4)</td>
<td>9 (9)</td>
<td>5 (5)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3 (3)</td>
<td>7 (7)</td>
<td>5 (5)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Number of cases with particular RAMRIS scores for all wrist joints.

Signal enhancing regions within wrist joints (not associated with blood vessels) were seen in post-contrast images in all subjects. Signal enhancing regions were outlined in 66 axial slices on average, including 12 slices (from 7 to 20) for DRUJ, 13 slices (from 6 to 28) for RCJ and 41 slices (from 24 to 56) for ICCMCJ. The relative volume of signal enhancing regions was less than 1/3 in 17 cases (16 patients) and larger than 2/3 in 7 cases (7 patients).

The volume of signal enhancing regions within DRU, RC and ICCMC joints ranged from about 380mm³ to 32000mm³. The largest volume of signal enhancing regions was found in ICCMC joints but the volume of this joint was also the largest. The average relative volume of signal enhancing regions ranged from 8 to 89%, with the smallest averages corresponding to 0 RAMRIS score and the largest ones corresponding to RAMRIS score equal to 3.

The total volume of signal enhancing regions (i.e. the sum of volumes found for DRU, RC and ICCMS joints) ranged from about 2000mm³ to 54000mm³. Spearman's rank-order coefficients of correlation between RAMRIS scores and the absolute volume of signal enhancing regions were equal to 0.54 (p-value < 0.001), 0.79 (p-value < 0.001) and 0.75 (p-value < 0.001) for DRUJ, RCJ and ICCMJ, respectively, i.e. the correlations were strongly positive. Spearman's rank-order coefficients of correlation between RAMRIS scores and the relative volume of signal enhancing regions were equal to 0.68, 0.84 and 0.78 (all p-values < 0.001) for DRUJ, RCJ and ICCMJ, respectively, i.e. the correlations were either strongly or perfectly positive. We have also correlated the absolute total volume of signal enhancing regions with the total RAMRIS synovitis score and found the
Spearman's rank-order coefficients of correlation equal to 0.76 (p-value < 0.001). The relative total volume of signal enhancing regions was significantly correlated with the total RAMRIS synovitis score ($r_s=0.83$, p-value<0.001). The relative volumes of signal enhancing regions are plotted against the RAMRIS synovitis score in Fig.3, Fig. 4 and Fig. 5 for DRU, RC and ICCMC joints.

Finally, we tested the differences between volumes (either absolute or relative) of signal enhancing regions in patient groups characterized by different RAMRIS scores. Mean ranks calculated for absolute and relative volumes decrease with RAMRIS score and this decrease is statistically significant. The results of the Nemenyi-Damico-Wolfe-Dunn post-hoc test, shown in the table, indicate that RAMRIS scoring can be indeed too rigid - although significant correlation between RAMRIS and volumes of enhancing regions was found, significant differences were observed mainly between group characterized by zero RAMRIS score and other groups, but not between groups with non-zero RAMRIS score.

**Images for this section:**

![Graph](image)

**Fig. 3:** Relative volume of enhancing regions within DRU joint plotted vs. RAMRIS score.
Fig. 4: Relative volume of enhancing regions within RC joint plotted vs. RAMRIS score.
Fig. 5: Relative volume of enhancing regions within ICCMC joint plotted vs. RAMRIS score.
Conclusion

In conclusion, further research can proceed along two courses: in-depth study of the effectiveness of the manual outlining in clinical trials and implementation of the computer application dedicated to RA diagnosis. However, as already noticed by Chand et al. (4), the time necessary to manually outline regions of enhanced signal in post-contrast MR images (parts of an hour) is much larger than the time necessary to evaluate RAMRIS scores (a few minutes). Consequently, manual outlining can not be recommended as an alternative for RAMRIS under clinical conditions. The manual outlining builds however the ground truth for future CAD systems. The results of our study indicate that development of algorithms for automated detection of signal enhancing regions in 0.2T MR images is a reasonable direction of forthcoming studies. Such algorithms should be a core functionality of future CAD systems supporting low-field extremity MR-based diagnosis of RA, because the volumes of signal enhancing regions correlate with RAMRIS scores.

References


