Diagnostic usefulness of dynamic contrast-enhanced magnetic resonance imaging for assessment of infection in the joints; preliminary results

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Purpose

MRI is considered to be the imaging technique of choice for the detection of joint infection because its high spatial resolution and soft tissue contrast allow accurate depiction of joint effusion and synovial abnormalities. Synovial bacterial infection induces synovitis, in which the classic MRI findings are synovial thickening and joint effusion. The presence of synovial inflammation is associated with a gadolinium-enhanced MR T1 signal increase that helps to distinguish synovial hyperplasia from tendons, cartilage, and effusion [1].

Infectious arthritis is a common, often disabling disease that requires early diagnosis for optimal outcome [2]. Diagnosing infectious arthritis early in its course is important because delayed diagnosis may result in cartilage and joint destruction arising from the action of enzymes released from neutrophils, synovial cells, and bacteria [3].

Therefore, this dynamic study was performed quantitative analysis of the synovial enhancement pattern for the early detection of infectious arthritis.

Methods and Materials

Patients

MR imaging examinations performed from February 2010 to June 2010 of 30 patients (13 women and 17 men with a mean age of 48.8 years [range. 11-75 years]). Dynamic contrast-enhanced MRI (3.0T) was performed in 12 patients with infectious condition and 18 patients with non-infectious condition.

In infectious group, cellulitis in 3 patients, myonecrosis with myositis in 3 patients, synovitis in 2 patients, osteomyelitis in 2 patients and septic arthritis in 2 patients.

Examination Technique

Bone dynamic MR images of the joints were obtained using a 3.0 T MR imager (Intera Achieva, Philips healthcare, The Netherlands). The maximum slew rate was 200mT/m/sec and the maximum gradient strength was 80mT/m. Variation in matrix size and field of view for different infection sites ranged from 160x160 to 256 x 256, respectively.

Bone dynamic MR images were obtained with a THRIVE-SPAIR sequence (T1 High Resolution Isotropic Volume Examination for dynamic using SPAIR fat suppression) [TR/TE, 3.8/1.91 ms; slice thickness/gap, 3 mm/0 mm; field of view, 200 x 200 mm; SENSE
factor, 1; NSA, 1; flip angle, 10°; band width, ±89.4kHz; dynamic number, 20; scan time, 3min 47sec].

20 dynamic MR images were acquired for each slice location. After dynamic MR image acquisition was started, 0.1mmol/kg Body Weight of Gadobutrol 1.0 Molar (Gadovist®, Bayer Schering Pharma AG, Berlin, Germany) was rapidly injected in the antecubital vein and was followed by a 20-mL saline flush. Before an administration of intravenous injection of gadolinium, 4 images were acquired for baseline and additional 16 images were acquired (interval: 10 seconds, total: 200 seconds). Total one hundred sixty images were obtained for dynamic contrast-enhanced MRI. Regions of interest (ROIs) were placed over the region of synovium for each patient. The mean signal intensity-time curves were computed by averaging across voxels within ROI for each dynamic phase and then were normalized using baseline signal intensity. Statistical analysis was performed to test if there are significant differences of dynamic parameters between patients with infectious and non-infectious condition.

Data Analysis

All MR images were analyzed by two radiologists who were unaware of the clinical findings.

DCEMRI(3.0T) was performed in 30 patients. After an injection of gadolinium, 20 images were acquired (interval: 10 seconds, total: 200 seconds). Total one hundred sixty images were obtained for DCEMRI.

Regions of interest (ROI) with a standardized size of 2mm (3.14mm²) were placed over the synovium for each patient. The mean signal intensity-time curves were computed by averaging across voxels within ROI for each dynamic phase and then were normalized using baseline signal intensity.

The normalized signal intensity-time curves were fitted to a sigmoid equation, and then 3 parameters (maximal slope, time of half rising and peak value of enhancement) were computed. Statistical analysis was performed with dynamic parameters between infectious and non-infectious groups.

Semi-quantitative analysis of the signal intensity (SI)-time curve was performed with the region-of-interest technique. The highest amplitude of synovial enhancement was used to determine the SI-time curves for MR imaging enhancement.

Statistical analysis

Statistical analysis was performed using the SPSS Statistics 17 package (SPSS Inc., Chicago, IL). To assess differences between the ROI values for Semi-quantitative
Analysis and Mann-Whitney tests were used. A $p$-values less than 0.05 was indicated significant results.

## Results

For all 30 patients, the study is comprised of 12 infectious lesions and 18 non-infectious lesions.

For 12 patients of infectious group, three patients with cellulitis, three patients with myositis, two patients with synovitis, two patients with osteomyelitis and two patients with septic arthritis.

In six patients, the infectious process involved single knee joint, four patients involved ankle joint and two patients involved the foot.

The final diagnoses, proven surgically in 7 cases (Incision and drainage : 5 cases, partial synovectomy : 1 case and amputation : 1 case) and 2 cases proven by joint fluid aspiration and culture study. But 3 cases examined only bloody tests.

**Dynamic Contrast-enhanced MR Imaging**

The three parameter mathematical model used in earlier studies was fitted to the MR enhancement time-intensity curves using the equation [4].

The results showed that the maximal slope for the infectious group (mean:0.14, SD:0.10) was steeper than that of the non-infectious group (mean:0.04, SD:0.05) ($P<0.05$). The T1#2max for the infectious group (mean:7.07, SD:1.93) was shorter than that of the non-infectious group (mean:63.48, SD:246.21) ($P<0.05$). The peak value of enhancement for the infectious group (mean:1.25, SD:0.57) was higher than that of the non-infectious group (mean:0.79, SD:1.32) ($P<0.05$) (Fig 2).

In patients with infections, there was a rapid and persistent enhancement, but in normal controls, there was slow and plateau of enhancement. The enhancement of patients with infection was rapider and higher than those of normal controls (Fig 3).

**Images for this section:**
Figure 1. Graph shows enhancement amplitude (EA), time of half rising (T1/2max), to maximal slope (MS), or the value of the slope of the tangent line to the curve on point T1/2max.

Semi-quantitative Analysis
Figure 2: SI-time curves of (a) normal (b) infectious joints. Enhancement curves were fitted to a sigmoid equation.
Table 1. Comparison of Dynamic Contrast-enhanced MR Imaging Parameters for normal and infectious joints.

<table>
<thead>
<tr>
<th>MR Parameter</th>
<th>Normal joints ((n = 18))</th>
<th>Infectious joints ((n = 12))</th>
<th>(P) Value</th>
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<tr>
<td>EA (%)</td>
<td>0.79 (0.00-5.46)</td>
<td>1.25 (0.06-2.25)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>T1/2max (sec)</td>
<td>63.48(0.00(3.47)-1307.48)</td>
<td>7.07 (4.60-12.79)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>MS (%/sec)</td>
<td>0.04(0.004-0.215)</td>
<td>0.14 (0.006-0.385)</td>
<td>&lt;0.05</td>
</tr>
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Fig. 3
Infectious arthritis can result in serious disability, so pertinent treatment based on a specific diagnosis is imperative. [5]. Traditionally, MR imaging is widely used to diagnose a musculoskeletal infection, because of its sensitivity in the detection of marrow abnormalities, soft tissue extent of disease, and the presence of fluid collections. [2]. Especially, bone erosions and marrow edema are highly suggestive of infectious arthritis, and the added presence of synovial thickening, synovial edema, soft tissue edema, or bone marrow enhancement is even more suggestive of infection [6].

So, we determine that dynamic contrast-enhanced MR imaging is capable of differentiating infectious and non-infectious joints. Our study findings show the diagnostic performance of dynamic contrast-enhanced MR imaging for distinguishing between normal and infectious joints on the basis of their distinct enhancement patterns.

The signal intensity-time curve analysis demonstrated that the enhancement pattern in the infectious arthritis were statistically higher maximal slope, peak value of enhancement and shorter T1/2 max than normal group. Maybe, the role of contrast material would have made such differences.

We used contrast-enhanced MR imaging with injection of Gadobutrol (Gadovist®, Bayer Schering Pharma AG, Berlin, Germany) is rapidly distributed in the extracellular space.

Enhancement of signal intensity after intravenous injection of gadolinium-based contrast agents reflects perfusion, plasma protein content, permeability and enlargement of the extracellular fluid compartment, all of which are associated with the activity of inflammatory joint diseases. The acquisition of dynamic MR imaging is not part of clinical routine in the MR evaluation of inflammatory joint disease. The use of intravenous contrast agent is very helpful in diagnosing and characterizing inflammatory joint disease [7].

This study strongly supports the view that the early and fast synovial enhancement reflects infectious condition of joints. So dynamic MRI may prove a clinically useful measure of synovial infection.

Our study had several limitations. First, the patient selection may have been biased because only patients referred for MR imaging were examined. Second, the enhancement was measured in small circular areas of the synovium, Finally, the enhancement values were calculated automatically by our workstation by using the single first image.

In conclusion, we have shown that dynamic contrast enhanced MR imaging can be a useful imaging modality in the evaluation of musculoskeletal infection.
References


Personal Information