MR Imaging of Articular Cartilage in Medial-Type Osteoarthritis of the Knee

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Abstract

Changes in the articular cartilage of 88 knees in 73 cases (age range 40 – 78 years) diagnosed clinically and radiologically as osteoarthritis (OA) were studied by obtaining fat-suppressed magnetic resonance imaging (MRI) of the knee. In order to compare MRI findings to macroscopically observed changes, 27 of the 88 knees underwent direct macroscopic examination. Fat-suppressed MR images were obtained sagittally using 3D-FLASH (fast low angle shot) sequence. Four sites were examined: the medial and lateral condyles of the femur, and the medial and lateral condyles of the tibia. Articular cartilage changes were identified and classified morphologically into 4 stages.

Examination of MR images revealed that articular cartilage defects in medial-type OA knees were most frequently observed at the medial condyle of the femur, with the medial condyle of the tibia, lateral condyle of the femur, and lateral condyle of the tibia following in order of decreasing frequency. Of note was the finding that early changes in the cartilage of the lateral compartment could be visualized on MR.

Only 63% of MR images classified as Stage I were confirmed macroscopically as demonstrating a smooth cartilage surface; the displayed fibrillations or erosions. Thus fat-suppressed MRI has a limited ability to detect the degree of change in mild cases of degeneration. Conversely, 88% of sites displaying cartilage thinning on MRI demonstrated fibrillation macroscopically.

The sensitivity of fat-suppressed MRI to detect cartilage defects as compared with macroscopic examination was 95.7%, with a specificity of 91.8%, and an accuracy of 93.5%. MRI using fat-suppression can therefore provide definitive information on cartilaginous degeneration and defects, and thus can establish the diagnosis and guide the selection of appropriate treatment methods.

Introduction

In order to determine if fat-suppressed MRI is useful in detecting changes in the articular cartilage of the knee, the authors performed fat-suppressed MRI on OA cases diagnosed clinically and radiographically. MRI results were compared to the macroscopically determined classification of the articular cartilage.

Subjects and Methods

The study subjects consisted of 88 knees from 73 cases diagnosed as medial-type OA (OA group) based on clinical and radiographic evidence. The control group consisted of 20 normal knees from 15 cases with no knee pain or

Key words: fat-suppressed MRI, osteoarthritis of knee, articular cartilage, MRI findings vs. macroscopic findings
radiological abnormalities. Thus, a total of 108 knees from 88 cases were examined in this study.

The OA group consisted of 18 knees from 14 males and 70 knees from 59 females, while the control group was composed of 6 knees from 4 males and 14 knees from 11 females. The average age of the OA group was 65.0 years (range 40–78 years), and the average of the control group was 55.7 years (range 37–68 years). MRI was performed using a 1.5 T superconducting unit (Magnetom Vision, Siemens). Multiple sagittal T1-weighted images were obtained with fat-suppressed 3D-FLASH sequence. Imaging parameters were as follows; TR 50 msec, TE 10 msec, Flip angle 40mm and effective slice thickness 2.0–4.0mm.

Weight-bearing cartilage was examined at the following 4 sites in each knee; the medial (FM) and lateral (FL) femoral condyles, and the medial (TM) and lateral

Morphological conditions of the cartilage as displayed on MRI were classified into the following 4 stages:

Stage I-No thinning or defect observed (cartilage thickness $\geq$ 2 mm) (Fig. 1)

Stage II-Evidence of thinning (cartilage thickness $<$ 2 mm) (Fig. 2)

Stage III-Partial defect present (defect width 2 to $<$ 5 mm) (Fig. 3)

Stage IV-Extensive defect present (defect width $\geq$ 5 mm) (Fig. 4)

Defects $<$ 2 mm in width were difficult to differentiate.

Macroscopically, a total of 27 knees were examined; 11 were examined arthroscopically and 16 were directly observed perioperatively. Macroscopic findings were divided into the following 3 groups:

Smooth (S) group-smooth cartilaginous surface (Fig. 5-1, 5-2)

Fibrillation (F) group-fibrillation or erosion noted (Fig. 6-1, 6-2)

Defect (D) group-cartilage defect with subchondral bone exposed (Fig. 7-1, 7-2)

Sensitivity, specificity, and accuracy of MRI were calculated by comparing the number of sites diagnosed with cartilage defects by MRI to the number confirmed macroscopically.

Results

Table 1 compares the MRI findings of the control and OA groups. In the control group, half of the lesions at FM and one quarter of the lesions at TM were classified as Stage II. All lesions in the lateral compartments were classified as Stage I. In the OA group, the percentage of sites in advanced stages demonstrated a steady increase in the order of TL, FL, TM, and FM.

Tables 2 through 5 show site-by-site results of the observations on 27 knees, comparing stage as classified by MRI with the group classification determined by macroscopic examination.

Table 2 shows the results at the FM site. No Stage I
sites were found. In Stage II, F group sites were found in the greatest number. Stage III and IV sites were all classified in the D group.

Table 3 shows the results at the TM site. One Stage I site in the S group was found. The majority of Stage II sites were classified as F group, while Stage III sites were predominantly classified as D group. All Stage IV sites were classified as D group.

Table 4 shows the data at the FL site. No Stage I sites were found. Stage II and III sites were predominantly classified as F group. All Stage IV sites were classified as D group.

Table 5 shows the observation results at the TL site.
Table 2 MRI findings and macroscopic findings (FM)

<table>
<thead>
<tr>
<th>Stage</th>
<th>S group</th>
<th>F group</th>
<th>D group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>0</td>
<td>6 (86%)</td>
<td>1 (14%)</td>
</tr>
<tr>
<td>III</td>
<td>0</td>
<td>0</td>
<td>9 (100%)</td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td>11 (100%)</td>
</tr>
</tbody>
</table>

* Number of cases

Table 3 MRI findings and macroscopic findings (TM)

<table>
<thead>
<tr>
<th>Stage</th>
<th>S group</th>
<th>F group</th>
<th>D group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1* (100%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>0</td>
<td>8 (89%)</td>
<td>1 (11%)</td>
</tr>
<tr>
<td>III</td>
<td>0</td>
<td>1 (17%)</td>
<td>5 (83%)</td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td>11 (100%)</td>
</tr>
</tbody>
</table>

* Number of cases

Table 4 MRI findings and macroscopic findings (FL)

<table>
<thead>
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<th>Stage</th>
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<th>F group</th>
<th>D group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
<td>3 (15%)</td>
<td>17 (85%)</td>
<td>0</td>
</tr>
<tr>
<td>III</td>
<td>0</td>
<td>4 (80%)</td>
<td>1 (20%)</td>
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<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td>2 (100%)</td>
</tr>
</tbody>
</table>

* Number of cases

Table 5 MRI findings and macroscopic findings (TL)

<table>
<thead>
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<th>Stage</th>
<th>S group</th>
<th>F group</th>
<th>D group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4* (57%)</td>
<td>3 (43%)</td>
<td>0</td>
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<tr>
<td>II</td>
<td>1 (7%)</td>
<td>13 (93%)</td>
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</tr>
<tr>
<td>III</td>
<td>0</td>
<td>0</td>
<td>3 (100%)</td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td>3 (100%)</td>
</tr>
</tbody>
</table>

* Number of cases

More than half of the Stage I sites were classified as S group, with the remainder as F group. Of the Stage II sites, the overwhelming majority were classified as F group. All Stage III and IV sites were classified as belonging to D group macroscopically.

As shown in Tables 2 through 5, five of the eight (63%) Stage I sites were S group, and 44 of the 50 (88%) Stage II sites were F group.

Among sites where cartilage defects were observed macroscopically, the sensitivity, specificity and accuracy of MRI were determined.

Of 108 sites examined, 47 D group sites with macroscopic cartilage defects were identified, and cartilage defects were confirmed on MRI (Stages III and IV) in 45 sites. Therefore, the sensitivity of MRI was 95.7%.

A total of 61 S and F group sites without macroscopic cartilage defects were observed. Of these, no cartilage defects were observed on MRI (Stages I and II) in 56 sites. Therefore, the specificity of MRI was 91.8%.

Of 108 sites examined, cartilage defects were observed on both macroscopic examination and MRI in 45 sites, and in 56 sites, cartilage defects were not detected on either macroscopic examination or MRI. Therefore, the accuracy of MRI was 93.5%.

Discussion

Most studies on fat-suppressed MR imaging of articular cartilage have dealt with cadaveric materials. Few reports have been published on MRI analysis in living subjects. We have examined sensitivity, specificity and accuracy in fat-suppressed MRI for human patients.

In 1985, Reicher et al. investigated MR images of articular cartilage from cadaveric knees, and reported that MRI was helpful in detecting morphological changes in the cartilage.

Buckwalter et al. examined the accuracy of MRI examination in 1986 by taking images of small holes pierced into different depths in the cartilage of 5 cadaveric knees. He reported that MRI could identify cartilage defects as small as 1 mm deep. Furthermore, Glys-Morin et al. reported visualization of a cartilage defect 2 mm in diameter in 1987, based on MR images of 6 cadaveric knees using the spin echo (SE)-method MRI with Gd-DTPA.

Our studies have found that MRI is able to detect cartilage defects as small as 2 mm in diameter. The cartilage defects described by Buckwalter et al. and Glys-Morin et al. seemed to be detected more easily than those in our living subjects, perhaps because their defects were produced artificially.

In 1993, Recht et al. obtained MR images of the patellofemoral articular cartilage of 10 cadaveric knees (age 70-89 years) using MRI-related methods such as SE, gradient-recalled acquisition in steady state (GRASS).
spoiled GRASS (SPGR), and fat-suppressed SPGR. Recht et al.\textsuperscript{a} compared the various techniques and concluded that fat-suppressed SPGR was the most effective method for visualizing the condition of articular cartilage. Nevertheless, fat-suppressed MRI data on the knees of living subjects are currently limited to patients with chondromalacia\textsuperscript{a}. We were unable to find any reports documenting MR changes occurring in the articular cartilage of each compartment of osteoarthritic knees.

Current treatment for OA of the knee includes both conservative and operative approaches. The former include physical therapy, pharmacotherapy (orally or by injection), and prosthetic therapy. Operative interventions include high tibial osteotomy, unicompartmental knee arthroplasty, and total knee arthroplasty.

The indication for the use of the lateral wedge-shaped insole, commonly used in prosthetic treatment, depends upon the condition of cartilage in the lateral compartment. Fat-suppressed MRI is of use in such cases, as it is able to provide detailed information on the state of the lateral cartilage in a noninvasive manner. Fat-suppressed MRI can therefore serve as an important diagnostic tool in guiding the choice of conservative treatment, such as the insole.

In addition, fat-suppressed MRI is useful in the selection of operative therapy. When the cartilage of the lateral compartment is intact, less invasive high tibial osteotomy or unicompart mental arthroplasty can be employed instead of total knee replacement. Fat-suppressed MRI allows easy assessment of the condition of articular cartilage in the lateral compartment, and thus facilitates the choice of treatment.\textsuperscript{a,b}

In some of our cases, MRI suggested degenerative changes in the cartilage in the control group, whereas no abnormalities were detected on clinical examination or plain radiography. This fact suggests that changes in the cartilage might have already started, even in cases judged normal on radiographic examination.

Hasegawa\textsuperscript{a} macroscopically examined articular cartilages in 58 cadaveric knees and reported that cartilage defects were found more frequently on the medial side than the lateral side, and on the femoral side more than the tibial side. Likewise, our study demonstrated that cartilaginous changes were more frequently encountered in the medial compartment; most frequently at the FM (52%: Stage III 25%; Stage IV 27%), and then at the TM (37%: Stage III 18%; Stage IV 19%).

Of particular note is the fact that medial-type OA was accompanied by cartilage changes in the lateral compartment in 13% of FL sites (MR Stage III 10%; Stage IV 3%) and 10% of TL sites (MR Stage III 7%; Stage IV 3%). No reports of MR changes in the lateral cartilage in cases of medial-type OA with mild changes on plain radiographs were found. This important finding can contribute to the selection of appropriate treatment.

Only 63% of sites classified as Stage I on MRI were in fact in S group macroscopically. The remainder were falsely identified as smooth cartilage by MRI, whereas macroscopic examination revealed fibrillation (F group). Thus, fat-suppressed MRI possesses a limited ability to differentiate between mild cases of degeneration. However, 88% of Stage II sites on MRI were macroscopically classified as F group. This suggests that MRI could be used to estimate the presence of fibrillation. Unfortunately, the inability of arthroscopy to estimate thickness of the cartilage makes it difficult to compare thinning observed macroscopically with that visualized on MRI.

The sensitivity of MRI in detecting a cartilage defect was 95.7%, with a specificity of 91.8%, and an accuracy of 93.5%. These high levels of correlation demonstrated that fat-suppressed MR imaging is very reliable in diagnosing cartilage defects.

Examination of the joint space on plain knee radiographs, even with weight bearing, is not a reliable method of assessing the condition of the lateral cartilage. The advantage of fat-suppressed MR imaging is that it provides information about both medial and lateral sides simultaneously, and thus allows accurate assessment of the degree of cartilaginous degeneration of the lateral compartment.

Conclusions

Using fat-suppressed MRI, 88 knees in 71 cases were examined for changes to articular cartilage, to determine the sensitivity of different methods. The sensitivity of fat-suppressed MRI to detect cartilage defects as compared to macroscopic examination was 95.7%, with a specificity of 91.8%, and an accuracy of 93.5%. MRI using fat-suppression can therefore provide definitive information.
on cartilaginous degeneration and defects, and thus can establish the diagnosis and guide the selection of appropriate treatment methods.

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References


