Associations among preoperative MRI features and functional status following arthroscopic partial meniscectomy

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Summary

Background: Arthroscopic partial meniscectomy (APM) is the most frequently performed orthopedic procedure. Functional outcomes of APM are variable, particularly among patients with underlying knee osteoarthritis. While most patients undergoing APM have knee magnetic resonance imaging (MRI) performed preoperatively, the prognostic value of knee MRI in predicting the functional outcomes of APM has not been evaluated.

Methods: We studied patients who had APM performed by one of five participating surgeons at one institution in 2002. The preoperative MRI scans of these patients were assessed using a standardized rating system by an independent observer who was not involved in the care of the patients and who was blinded to patient outcomes. Patients completed a questionnaire in the summer of 2003, 6–18 months postoperatively. The questionnaire included the Knee Injury and Osteoarthritis Outcome Score (KOOS) and items on satisfaction with the results of surgery. We used bivariate and multivariate techniques to evaluate the associations between MRI findings, other preoperative findings, and the functional status and pain scales of the KOOS.

Results: Eighty-three patients were included in the analyses. The outcome of surgery was variable with average KOOS functional score of 77 and range of 15–100. One-quarter of patients were somewhat or very dissatisfied with the results of surgery and 17% were using a cane at the time of follow-up. In bivariate analyses, preoperative predictors of KOOS function score at follow-up included preoperative functional status and several MRI findings including the extent of cartilage damage, bone marrow edema in the medial compartment, and length of the tear. Multivariate analyses showed that after adjusting for preoperative functional status, the extent of cartilage signal abnormality in the medial compartment on MRI remained an independent predictor of functional status, 6–18 months following surgery. Specifically, preoperative functional status explained 21% of the variability in follow-up KOOS functional status score and the extent of medial tibial cartilage damage on MRI explained an additional 16%. Analyses of knee pain 1 year following APM yielded similar findings, with preoperative functional status accounting for 17% of the variability in pain scores and medial tibial cartilage damage accounting for an additional 13%.

Conclusions: Preoperative MRI findings of cartilage damage have independent prognostic value in predicting the functional outcome of APM. This study was limited by a cross-sectional design with retrospective recall of preoperative functional status. Thus, the findings need to be confirmed in prospective investigations.

Key words: Arthroscopic meniscectomy, Meniscus, Osteoarthritis, Magnetic resonance imaging.

Introduction

Symptomatic tears of the menisci are common sources of pain and disability. While episodes of symptomatic meniscal tear may resolve with nonoperative management, many patients with persistent symptoms elect to have arthroscopic partial meniscectomy (APM). APM is the most frequently performed procedure by orthopedic surgeons, accounting for over 450,000 procedures annually in the US. Half of these procedures are performed in patients
older than 45 years, many of whom have concomitant osteoarthritis. While the outcome of APM in younger patients is generally excellent, APM has a less predictable result among patients with concomitant knee osteoarthritis. In order to provide patients with accurate expectations of the results of APM, it would be useful to identify factors associated with particularly favorable or unfavorable outcomes. Across many series, predictors of worse outcome of APM include the presence and severity of OA on preoperative radiographs and the extent of cartilage damage observed at the time of surgery. In addition, patients with degenerative (vs traumatic) tears, larger tears, malalignment, anterior cruciate ligament deficiency, poor baseline function and Workers’ Compensation have been reported to experience worse outcomes of APM.

These studies suggest that the status of the underlying articular cartilage and that of the meniscal tear influence the outcome of APM. However, these variables have traditionally been assessed either with plain radiographs or at arthroscopy. Plain radiographs are insensitive and indirect measures of cartilage loss and do not visualize menisci at all. Arthroscopic examination occurs after the decision to undertake surgery has been made. Thus, neither approach is suitable for preoperative prognostic assessment. The majority of patients undergoing APM have preoperative magnetic resonance imaging (MRI), which provides excellent visualization of the cartilage and the menisci. Nevertheless, to date there have been no studies of the association between MRI findings and patient outcomes of surgery. The objective of this study is to evaluate the associations between preoperative MRI findings and functional status 6-18 months following APM in patients with concomitant knee osteoarthritis.

**Patients and methods**

**SAMPLE ENTRY AND EXCLUSION CRITERIA**

To be eligible for the study, the patients had to have undergone APM in 2002 by one of five participating surgeons at one institution. We identified these patients using administrative data from the orthopedic department. Patients undergoing bilateral procedures on the same day and concomitant anterior cruciate ligament repair were excluded, as were the patients who had inflammatory arthritis or prior total knee replacement on the index knee. We further excluded patients who did not have MRI performed at our institution. In general these patients had MRI performed elsewhere prior to their referral to our hospital. We did not collect data specifically on whether the meniscal problem was related to acute injury.

**PATIENT RECRUITMENT**

We sent letters to potentially eligible patients inviting them to participate in the study. We sent additional letters of invitation to nonresponders. After three letters we called patients to ask if they were interested. Patients who agreed to participate elected whether to receive a questionnaire by mail for self-administration at home, or whether to complete the questionnaire in a phone interview.

**DATA SOURCES AND DATA ELEMENTS**

Data were obtained from two sources, the preoperative MRI and the patient survey.

**Preoperative MRI**

Each patient in the study sample underwent MRI within the 4 months prior to APM. The details of the MRI scanning equipment and protocol are included in the Appendix to this paper.

**MRI assessment.** Assessment of the articular structures was made using the available sequences whichever provided the best information. To avoid potential bias, an independent observer who was not involved in the care of the patients and who was blinded to the intention of this study evaluated the MRI scans.

The scans were evaluated using a comprehensive form developed by the investigators (PL, HY). The form evaluates seven distinct types of pathology: cartilage, menisci, osteophytes, subchondral sclerosis, bone marrow edema, joint effusion and synovitis. Each type of pathology was graded using an ordinal scale with a value of zero indicating no pathology and higher values indicating increasingly severe levels of pathology. Subchondral sclerosis was similarly noted as present or absent for the medial, lateral and patellofemoral knee compartments. The scales for assessing cartilage, meniscal signal and bone marrow edema were based on previous reports.

Cartilage was graded as reported in Biswal et al. Briefly, the size and severity of cartilage lesions were recorded for subdivisions of the medial, lateral and patellofemoral compartments. Lesion severity was graded on a six level scale ranging from 1 = signal heterogeneity to 6 = full thickness cartilage loss. Lesion size was graded on a four level scale from 1 = <1 cm to 4 = >3 cm. Bone marrow edema was graded accordingly on a scale of 0–3 as suggested by Felson et al. The approximate diameter of the edematous lesions was classified using a three level scale (1 = <1 cm to 3 = >2 cm). Other types of pathology were graded using scales developed by the investigators (PL, HY). The type of meniscal tear was recorded as 1 = signal heterogeneity, 2 = simple tear, and 3 = complex tear. The extent of the tear within the anterior horn, body and posterior horn was recorded. Osteophytosis was evaluated in the medial, lateral and patellofemoral compartments. Within each compartment, individual osteophytes were scored from 1 to 3 based on their largest visible dimension (1 = 1–2 mm, 2 = 2–5 mm, and 3 = >5 mm). The scores for all osteophytes in a compartment were totaled to give a composite score from 1 to 3 indicating mild, moderate or severe osteophytosis, respectively. Joint effusion was assessed based on the anteroposterior width of the fluid accumulation (1 = 0.5–1.0 cm, 2 = 1.0–2.0 cm, and 3 = >2.0 cm). Finally, synovitis was assessed based on the number of thickened villi visible on the scans (1 = 6–10 villi, some thickening; 2 = 11–15 villi, mostly thickened; and 3 = >15 villi, marked thickening).

**Patient surveys**

The survey questionnaire asked about age, gender, race, level of education and level of household income. We also assessed the patient’s recollection of preoperative functional status, as we have done in the previous research. Specifically, we asked about four functional areas: use of walking support, limp, walking distance, and stair climbing. We assessed these domains with questions from the Harris Hip Scale and weighted the items as done in the Harris Hip Scale. (These items are as relevant for knee problems as for hip problems. We used items from the Harris scale...
because patients understood them well and completed them thoroughly.) We assessed present pain and functional status with the Knee Injury and Osteoarthritis Outcome Scales (KOOS)\(^{14,21}\). The KOOS pain scale has nine items on pain with activities of daily living and with more advanced activities, rated by the patient on a Likert scale from none (0) to extreme (4). The KOOS Daily Function scale includes 17 items tapping difficulty with activities of daily living and rated from no difficulty (0) to extreme difficulty (4). The KOOS Daily Function scale is identical to the Western Ontario MacMaster Osteoarthritis Index (WOMAC) functional status scale, and the KOOS Pain scale comprised five items of the WOMAC pain scale and four other items\(^{22}\). Both of these scales were normalized to 0–100 scales, with 0 the worst possible score and 100 the best. We as-
sessed satisfaction with surgery, extent of pain relief and improvement in functional activities with single items and Likert scale responses.

STATISTICAL ANALYSIS

The principal dependent variable was the KOOS function score at follow-up. This variable was essentially normally distributed, justifying use of parametric statistics. The second outcome was the KOOS pain score. We summed the cartilage signal abnormality and cartilage lesion size variables across the anterior, central and posterior segments of each surface to yield a cartilage score for each surface. Thus, the medial tibial surface score was the sum of the signal abnormality and the lesion size scores across the anterior, central and posterior segments of the medial tibial surface. Bivariate associations between preop-
erative and follow-up variables were assessed with Pearson correlation coefficients (for continuous predictors and outcomes), the Student’s \( t \) test (for continuous predictors and dichotomous outcomes) and the Chi square test (for catego-
rical predictors and dichotomous outcomes). We used stepwise multivariate linear regression to assess the associations between MRI variables and the primary outcome, KOOS functional status score. These analyses adjusted for preoperative functional status. We examined residuals from the regression and confirmed that they were distribut-
ed satisfactorily, supporting the use of linear regression with these data. We ascertained partial correlation coefficients from a linear regression that included all MRI and clinical predictors on Table II. All analyses were performed in SAS.

The study protocol was approved by the Brigham and Women’s Hospital Human Investigations Committee.

Results

PATIENT RECRUITMENT

We identified 206 patients over 45 years old who underwent APM performed by one of the five participating ortho-
pedic surgeons in 2002. Of these, 119 (58%) had MRI performed at our institution within 4 months of surgery. These patients were eligible for this study. Of these pa-
ients, 83 (70%) completed the survey. These 83 patients constituted the study sample.

BASELINE FEATURES OF THE COHORT

The subjects had a mean age of 61 years (standard deviation 11, range 45–89). Fifty of the subjects were females (60%) and 71 were Caucasians (88%) (Table I).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>N</th>
<th>%</th>
</tr>
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<tr>
<td>55–65</td>
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<td>36</td>
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<td>&gt;65</td>
<td>27</td>
<td>33</td>
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<tr>
<td>Gender</td>
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<tr>
<td>Male</td>
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<tr>
<td>Female</td>
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<td>&lt;College graduate</td>
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<tr>
<td>College graduate</td>
<td>43</td>
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<tr>
<td>Income</td>
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<tr>
<td>&lt;$50,000</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>&gt;$50,000</td>
<td>56</td>
<td>74</td>
</tr>
</tbody>
</table>

PREOPERATIVE MRI FINDINGS (TABLE II)

All patients had at least some degree of cartilage signal abnormality in at least one compartment. The most com-
monly affected surface was the medial femoral condyle, where 82% of subjects had cartilage signal abnormalities, fol-
lowed by the lateral femoral condyle, where 60 patients (73%) had such abnormalities. All patients had meniscal tears. The meniscal tear was classified as complex in 49 patients (59%). Thirty-six patients (43%) had bone marrow edema, 16 patients had synovitis (19%) and 56 patients (67%) had one or more osteophytes. The aggregated bone marrow edema and cartilage signal scores had a Spearman correlation coefficient of \( r = 0.34 \).

OUTCOMES AT 6–18 MONTHS POSTOPERATIVELY

The mean KOOS functional status score at follow-up was 77 (median 84, standard deviation 23, range 15–100). Twenty-nine percent of patients reported moderate to se-
vvere pain when walking on flat surfaces. Seventeen percent were using a cane or other support at the time of follow-up. Twenty-five percent of patients were somewhat or very dis-
satisfied with the results of surgery.

ASSOCIATIONS BETWEEN PREOPERATIVE FINDINGS AND OUTCOME (TABLE II)

We found no association between several preoperative MRI characteristics and functional status score at follow-
up including joint effusion, synovitis, osteophytes, subchon-
dral sclerosis and type of meniscal tear (complex vs other). The length of the meniscal tear had a weak association with functional status at follow-up \( (r = -0.20, \ P = 0.08) \). The strongest MRI predictors of functional status at follow-up were bone marrow edema in the medial femoral compart-
ment \( (r = -0.27, \ P = 0.01) \) and the burden (signal abnor-
mality plus size) of cartilage abnormalities in the medial tibial plateau \( (r = -0.32, \ P = 0.004) \). Age at the time of the procedure was not associated with the KOOS functional status score at follow-up \( (r = -0.09, \ P = 0.41) \), while preop-
erative functional status had a moderately strong correlation with function at follow-up \( (r = 0.46, \ P < 0.0001) \). The corre-
lates of the KOOS functional status score were similar to those of the KOOS pain score (Table II).

We examined partial correlations between MRI and clinical variables and the outcomes (KOOS functional status
The Pearson examined the association between bone marrow edema and KOOS function and pain scores at follow-up. The crude correlation between preoperative functional status and KOOS function was 0.46, and the partial correlation was 0.40. We also found that the results of surgery were variables, with 25% of patients dissatisfied at follow-up. Even after adjusting for preoperative functional status, the preoperative MRI findings were independently associated with outcome. Specifically, we found that patients with greater cartilage signal abnormality in the medial tibial compartment had worse functional status postoperatively, as measured with the KOOS. These are the first data we are aware of showing that preoperative MRI findings may help to predict the outcome of APM. Given that many patients undergo MRI preoperatively, the prognostic information from the MRI will be available routinely prior to surgery in many patients. Clinicians and patients can use this information to assist in setting appropriate preoperative expectations of surgical outcome.

Other studies indicate that intraoperative assessment of cartilage is also an important predictor of outcome. It is important to point out, however, that arthroscopic assessment is not performed until well after the surgical decision has been made, and therefore cannot be used to help patients and physicians to decide whether to undertake APM or to forecast the likelihood of functional benefit. We also were unable to compare the preoperative prognostic value of MRI with that of plain radiographs because many patients had plain films performed at outside hospitals. These studies were not available for us to examine.

The retrospective design imposed limitations, including the need to use recalled, rather than prospectively obtained data on preoperative functional status. Although this method produces valid estimates of recalled functional status, prospective assessment would be more precise and would avoid potential biases in recall. Our study should be repeated in a prospective cohort with preoperative radiographic and prospective assessment. The single center setting may limit generalizability. The strengths of our study included use of a standardized MRI assessment tool, MRI assessment by a trained observer blinded to patient outcome, and patient assessment with reliable, valid measures by an observer blind to MRI findings and uninvolved in the care of the patients.

We conclude that preoperative MRI findings provide valuable prognostic information about the functional outcome of APM in patients over 45 years old. These findings should be confirmed in studies using prospective designs. We cannot comment on whether MRI should be done routinely prior to APM. However, we would suggest that when MRI has been done it should be used not only for diagnostic but also for prognostic purposes.

### Discussion

We investigated the association between preoperative findings on MRI of the knee and the functional outcomes of APM in a cohort of 83 patients who were operated upon in 2002 and were evaluated with questionnaires, 6–18 months later. We found that the results of surgery

<table>
<thead>
<tr>
<th>KOOS domain</th>
<th>Median (range)</th>
<th>Function (r)</th>
<th>Pain (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>60 (45, 89)</td>
<td>−0.09</td>
<td>0.04</td>
</tr>
<tr>
<td>Preop functional status</td>
<td>66 (5, 100)</td>
<td>0.46***</td>
<td>0.40***</td>
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<tr>
<td>Cartilage score</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Medial tibial</td>
<td>0 (0, 20)</td>
<td>−0.32**</td>
<td>−0.27*</td>
</tr>
<tr>
<td>Medial femoral</td>
<td>9 (0, 25)</td>
<td>−0.17</td>
<td>−0.12</td>
</tr>
<tr>
<td>Lateral tibial</td>
<td>0 (0, 19)</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>Lateral femoral</td>
<td>5 (0, 21)</td>
<td>−0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Patellar</td>
<td>9 (0, 22)</td>
<td>−0.17</td>
<td>−0.13</td>
</tr>
<tr>
<td>Bone marrow edema</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Medial femoral</td>
<td>0 (0, 3)</td>
<td>−0.27*</td>
<td>−0.20</td>
</tr>
<tr>
<td>Medial tibial</td>
<td>0 (0, 3)</td>
<td>−0.21</td>
<td>−0.13</td>
</tr>
<tr>
<td>Lateral femoral</td>
<td>0 (0, 1)</td>
<td>0.06</td>
<td>0.16</td>
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<tr>
<td>Lateral tibial</td>
<td>0 (0, 3)</td>
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<td>Patellar femoral</td>
<td>0 (0, 2)</td>
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<tr>
<td>Synovitis</td>
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<td>−0.01</td>
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<tr>
<td>Osteophyte</td>
<td>2 (0, 9)</td>
<td>−0.07</td>
<td>−0.05</td>
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<td>Subchondral sclerosis</td>
<td>1 (0, 3)</td>
<td>−0.05</td>
<td>−0.04</td>
</tr>
<tr>
<td>Meniscal tear</td>
<td>44 (11, 97)</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*P < 0.05, **P < 0.01, and ***P < 0.001.

score and KOOS pain score). The partial correlations adjust for the effect of other predictor variables. In general the partial correlations were remarkably similar to the crude correlations, suggesting little to no confounding. For example, the crude correlation between preoperative functional status and KOOS function was 0.46 and the partial correlation was 0.49. Similarly, the crude correlation of medial tibial cartilage score and KOOS function was −0.32 and the partial correlation was −0.37. The crude correlation between medial femoral bone marrow edema score and KOOS function was −0.27 and the partial correlation was −0.20. We also examined the association between bone marrow edema and cartilage signal scores (aggregated across the joint). The Pearson r was 0.31. Put differently, just 10% of variability in cartilage signal scores is attributable to bone marrow edema.

In multivariate analyses, preoperative functional status explained 21% of the variability in follow-up KOOS functional status score. After accounting for preoperative functional status, the MRI finding of the extent of medial tibial plateau cartilage damage (signal abnormality plus lesion size) accounted for an additional 16% of the variability. In analyses done with KOOS pain score as the outcome variable, preoperative functional status accounted for 17% of the variability in pain scores and medial tibial cartilage damage score accounted for an additional 13%. For the analyses of the KOOS functional status score and the analyses of the KOOS pain score, no additional demographic or imaging variables entered the model once preoperative functional status and medial tibial plateau cartilage damage score were included.

### Appendix. MRI protocol

MRI of each knee was performed with a General Electric 1.5 T, three plane T1- and T2-weighted scanner (GE Medical Systems, Milwaukee, WI). The protocol consisted of coronal T1-weighted spin echo (repetition time (TR) 550 ms, echo time (TE) 20 ms) with 3.5 mm thick sections, a 0.5 mm intersection gap, 20.83 kHz bandwidth (BW), two numbers of excitations (NEX), a 14 cm field of view (FOV), 512 × 256 matrix; sagittal fast spin echo proton density weighted sequences (TR 2400 ms, TE 37 ms) with 3.5 mm thick sections, a 0.5 mm intersection gap, 32 kHz BW, two NEX, a 14 cm FOV, 512 × 256 matrix; sagittal fat saturated fast spin echo proton density weighted...
sequences (TR 2950 ms, TE 20 ms) with 3.5 mm thick sections, a 0.5 mm intersection gap, 32 kHz BW, two NEX, a 14 cm FOV, 160 ms) with 4.0 mm thick sections, a 1.0 mm intersection gap, 31.25 kHz BW, two NEX, a 14 cm FOV, 512 × 256 matrix; coronal short tau inversion recovery (STIR) sequences (TR 2950 ms, TE 13 ms, T1 10.160 ms) with 4.0 mm thick sections, a 1.0 mm intersection gap, 31.25 kHz BW, two NEX, a 14 cm FOV, 256 × 192 matrix; and axial proton density weighted and T2-weighted fast spin echo (TR 3625 ms, TE1/TE2 20/130 ms) with 3.5 mm thick sections, a 0.5 mm intersection gap, 17.86 kHz BW, one NEX, a 14 cm FOV, 256 × 224 matrix. Scans were performed using a dedicated extremity coil.

References


