High Prevalence of Abnormal MR Findings of the Distal Semimembranosus Tendon: Contributing Factors Based on Demographic, Radiographic, and MR Features

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OBJECTIVE. The objective of our study was to determine the prevalence of thickening and signal alteration of the distal semimembranosus (SM) tendon on knee MRI and analyze the patient factors associated with abnormal MR findings of the distal SM tendon.

MATERIALS AND METHODS. Knee MRI scans of 116 subjects (58 men, 58 women; mean age, 48.5 years; range, 18–79 years) who underwent surgery were evaluated to assess the distal SM tendons in terms of signal alteration and thickness. To determine the factors associated with MR findings of the distal SM tendon, we assessed demographic characteristics; Kellgren-Lawrence radiographic osteoarthritis grading; history of trauma; the condition of the cruciate ligaments, collateral ligaments, and menisci; and whether there were cystic lesions around the SM tendon. In addition, 55 control subjects with normal knee MRI findings based on the electronic MRI patient database who had anterior knee pain and did not undergo surgery were enrolled.

RESULTS. Abnormal thickening of the distal SM tendon was found in 52.6% of knees and signal alteration in 44.8%. Univariate analysis revealed significant associations between abnormal thickening and age, body mass index, history of trauma, osteoarthritis, medial collateral ligament (MCL) thickening, and anterior cruciate ligament (ACL) tear. As for signal alteration, univariate analysis showed that age, body mass index, osteoarthritis, and MCL thickening were statistically significant factors. Multivariate binary logistic regression analyses showed that osteoarthritis and MCL thickening were the strong independent predictors in thickening and signal alteration of the distal SM tendon.

CONCLUSION. Signal alteration and abnormal thickening of the distal SM tendon on MRI are frequently seen in daily practice. These MR findings are strongly associated with osteoarthritis and MCL thickening.

Keywords: knee, medial collateral ligament, MRI, osteoarthritis, semimembranosus tendon
DOI:10.2214/AJR.13.10563
Received January 8, 2013; accepted after revision September 4, 2013.
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AJR 2014; 202:1087–1093
0361–803X/14/2025–1087
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With more MRI examinations performed for evaluation of internal derangements and periarticular abnormalities of the knee, certain incidental findings are frequently confronted that necessitate explanations of their meaning and clinical importance. We commonly encounter thickening and signal alteration of the distal semimembranosus (SM) tendon in patients without specified medial laxity or tenderness of the posteroomedial knee. In fact, it is our anecdotal experience that abnormal MR findings of the distal SM tendon can be frequently found in elderly patients with osteoarthritis. However, there is a paucity of studies about what these findings may indicate.

Posteroomedial knee pain is relatively uncommon compared with anterior and lateral knee pain [1]. Distal SM tendinopathy is also relatively uncommon among several causes of posteromedial pain including medial meniscal tear, osteoarthritis, Baker cyst, pes anserine bursitis or tendinopathy, strain of the gastrocnemius medial head or popliteus, and medial collateral ligament (MCL) sprain [1]. It is usually associated with other knee disorders but may occur as an isolated overuse syndrome [2].

The distal SM tendon has five known arms that attach at the posteroomedial corner of the knee: the anterior arm, the direct arm, the inferior arm, the capsular arm, and the oblique popliteal ligament [3, 4]. The anterior arm (“pars reflexa”) extends anteriorly, passing under the posterior oblique ligament, and inserts in the medial aspect of the proximal tibia under the MCL. The direct arm inserts at the posterior medial aspect of the proximal tibia, just deep to the anterior arm. The inferior arm extends more distally than the anterior and direct arms and inserts just above...
the tibial attachment of the MCL. The capsular arm is continuous with the posterior oblique ligament. The fifth insertion is the oblique popliteal ligament that covers and blends with the joint capsule. There has been a cadaveric study describing its sixth insertion into the posterior horn of the lateral meniscus in 43.2% of dissected knees [5].

At the posteromedial corner of the knee, muscle, ligament, and meniscus function as a coordinated unit, and an injury to the posteromedial corner results in anteromedial rotatory instability [4, 6]. Among the posteromedial corner structures, the distal SM tendon is a dynamic component that restrains valgus force in extension and restricts external rotation in flexion. In addition, the distal SM tendon functions as a retractor of the medial meniscus in the flexed knee, thereby protecting the posteromedial meniscus from impingement and preventing laxity of the posteromedial capsule-ligamentous structures [7]. Also, in knees with a chronic deficiency of the anterior cruciate ligament (ACL), the distal SM tendon assists in restraining the anterior tibial translation and the medial meniscus [4, 7].

Considering the complex insertions and functions of the distal SM tendon, we postulated that there are certain factors associated with incidentally detected abnormalities of the distal SM tendon. The purpose of this investigation was to determine the prevalence of thickening and signal alteration of the distal SM tendon on knee MRI and analyze the patient factors associated with these abnormal MR findings of the distal SM tendon.

Materials and Methods

Patients

The institutional review board of our institution approved this retrospective study. The requirement for patients’ written informed consent was waived. To enroll patients with detailed medical records including height, body weight, clinical history, preoperative conventional radiographs of the knee, full limb anteroposterior radiographs, and knee MRI, we initially searched our surgical database for patients who underwent knee surgery such as arthroscopic knee surgery, total knee replacement arthroplasty, and high tibial osteotomy between June 2010 and September 2011 at our institution. We excluded all potential subjects with infectious or inflammatory arthritis and a benign or malignant tumor of the knee. In addition, we excluded all patients with a history of knee surgery or fractures around the knee.

The enrolled subjects were 116 patients with 116 MRI studies (mean age, 48.5 years; range, 18–79 years; 66 right and 50 left knees), including 58 males (mean age, 38.1 years; range, 17–71 years; 32 right and 26 left knees) and 58 females (mean age, 55.6 years; range, 15–79 years; 34 right and 24 left knees). Knee surgical procedures included 87 arthroscopic surgeries (28 ACL reconstructions, 46 medial meniscus repairs or meniscectomies, 38 lateral meniscus repairs or meniscectomies, six other procedures (posterior cruciate ligament reconstruction, diagnostic arthroscopy), 19 total knee replacement arthroplasties, and 10 high tibial osteotomies. Twenty-four patients underwent more than two kinds of reconstruction or repair.

We retrospectively reviewed medical records for demographic characteristics including age, sex, body mass index (BMI), and presence of major trauma. In addition, for a reference standard for normal thickness and signal intensity of the distal SM tendon, 55 control subjects (mean age, 30.6 years: range, 14–61 years; 31 males and 24 females) with normal knee MRI based on the electronic MRI patient database of records between January 2009 and September 2011 who had anterior knee pain and did not undergo surgery were enrolled.

Image Acquisition

MRI—Patients underwent preoperative knee MRI with a knee coil on a 1.5-T unit (Signa HDx, GE Healthcare) or a 3-T unit (Magnetom Verio or Magnetom Trio, Siemens Healthcare; or Signa Excite, GE Healthcare). Fifty-two patients underwent knee MRI at outside institutions using various MRI machines.

The standardized MRI protocol consisted of seven sequences: an axial fat-suppressed proton density–weighted fast spin-echo (FSE) sequence, three sagittal sequences (T1-weighted, T2-weighted, and fat-suppressed proton density–weighted FSE), two coronal sequences (fat-suppressed T2-weighted FSE, proton density–weighted FSE), and an oblique coronal T2-weighted FSE sequence. The following scanning parameters were used for imaging: flip angle of 140°, an acquisition matrix of 512 × 307, 150 × 150 mm FOV, 3.0-mm-thick sections with a 0.3-mm intersection gap, and 2 signals acquired. T2-weighted imaging was performed using a TR/TE of 3980/71. Axial fat-suppressed, sagittal, and coronal proton density–weighted images were obtained using a TR/TE of 4720/23, 4510/28, and 2620/28, respectively. For T1-weighted images, a TR/TE of 89/12 was used. Finally, a TR/TE of 4400/56 was used for oblique coronal T2-weighted imaging. The protocol varied slightly for the examinations performed at outside institutions.

Radiography—Conventional radiographs of the knee including standing knee anteroposterior, standing knee 45° flexion posteroanterior, and lateral knee were obtained using a digital radiography system (DigitalDiagnost, Philips Healthcare) with a grid. The following exposure parameters are standard in our department: tube voltage of 60 kVp, tube current of 11 mA, image area–dose product of 2.25 Gy × cm², detector-to-tube distance of 40 inches (102 cm), and detector area of 14 × 17 inches (36 × 43 cm).

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Fig. 1—25-year-old man with normal MR findings showing site for measurement of distal semimembranosus (SM) tendon.

A, Midportion of distal SM tendon insertion onto tibia (line) is selected on sagittal fast spin-echo (FSE) T2-weighted MR image. SM tendon shows normal dark signal without thickening below joint line.

B, Thickness of SM tendon (double-headed arrow) is measured on corresponding axial fat-saturated FSE proton density–weighted image using cross-reference tool on PACS workstation.
MRI of the Distal Semimembranosus Tendon

Image Analysis

All studies were reviewed together by two board-certified radiologists with 1 and 8 years of experience in musculoskeletal radiology, respectively. Images were viewed at a PACS (Maroview, MaroTech) workstation using a 21-inch (53-cm) LCD monitor (ME315 L, Totoku) with a resolution of 2048 × 1536 × 8 pixels. Readers were blinded to the patients’ clinical history and radiologic and operative diagnostic.

The MR images of the knee were reviewed for the presence of abnormal thickening or signal alteration of the distal SM tendon. Abnormal thickening of the distal SM tendon was defined as localized or bulbous thickening disproportionate to area adjacent to the normal tendon above or with loss of normal smooth transit on axial and sagittal images below the joint line. Abnormal signal alteration was defined as hyperintensity within the tendon substance relative to adjacent normally dark-signal tendon or ligament substance on both the T2-weighted and proton density–weighted images. We considered signal alteration on proton density–weighted images with normal dark signal on T2-weighted and proton density–weighted images. We considered signal alteration on proton density–weighted images as the magic angle phenomenon, a unilocular or multilocular cystic lesion in a juxta- or abnormal truncation of the meniscus on one or more MR images [8]. Bursitis or ganglion cysts around the distal SM tendon were defined as the following: SM–tibial collateral ligament bursitis, a fluid collection draped over the SM tendon in the shape of an inverted U with a proximal deep pocket and a distal superficial pocket forming the two arms of the U [9]; a Baker or popliteal cyst, a hyperintense fluid collection in the posteromedial knee located between the medial gastrocnemius tendon and the SM tendon on MRI [10]; pes anserine bursitis, an oblong multiloculated fluid collection seen along the anserine tendons on the posteromedial aspect of the knee [11]; a ganglion cyst, a unicollicular or multilocular cystic lesion in a juxta-articular or periosteal location just around the distal SM tendon tibial attachment.

On knee radiographs, the tibiofemoral joints were evaluated using the Kellgren-Lawrence radiographic osteoarthritis grading system. Each knee was assigned one of five osteoarthritis grades: none (grade 0), doubtful (grade 1), minimal (grade 2), moderate (grade 3), or severe (grade 4).

Statistical Analysis

Correlation between the measured thicknesses of the distal SM tendon and visual assessment was examined using Spearman correlation analysis. Comparisons of distal SM tendon thickness in patients with and in those without visually assessed thickening of the distal SM tendon and in control subjects with normal distal SM tendon were performed using the analysis of variance test. When significant differences were detected, intergroup comparisons were carried out using the Scheffé post hoc test. For the statistical analysis, the presence of osteoarthritis was coded as a binary variable: Kellgren-Lawrence grades 0 and 1 were negative and grades 2, 3, and 4 were positive. We performed univariate analyses to determine statistically significant variables. To identify multicollinearity, we performed the Pearson correlation test, and variables with high collinearity were excluded in the regression equation. Finally, the statistically significant variables obtained from univariate analyses were entered into a binary logistic regression model to assess the independent predictors of thickening and signal alteration of the distal SM tendon. A software package (SPSS, version 18.0, SPSS) for Microsoft Windows was used for statistical analyses. For all tests, a p value of less than 0.05 was required for rejection of the null hypothesis.

TABLE I: Characteristics of Patients With and Those Without Semimembranosus (SM) Tendon Thickening and Signal Alteration on T2-Weighted Imaging

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SM Tendon Thickening</th>
<th>SM Tendon Signal Alteration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No (n = 55)</td>
<td>Yes (n = 61)</td>
</tr>
<tr>
<td>Age (y), mean ± SD</td>
<td>37.2 ± 17.4</td>
<td>55.5 ± 13.5</td>
</tr>
<tr>
<td>Sex (M:F), no. of patients</td>
<td>33:22</td>
<td>25:36</td>
</tr>
<tr>
<td>Body mass index, mean ± SD</td>
<td>23.8 ± 3.03</td>
<td>25.2 ± 3.64</td>
</tr>
<tr>
<td>History of major trauma</td>
<td>20 (36.4)</td>
<td>10 (16.4)</td>
</tr>
<tr>
<td>Overall osteoarthritis</td>
<td>12 (21.8)</td>
<td>43 (70.5)</td>
</tr>
<tr>
<td>Medial collateral ligament thickening</td>
<td>15 (27.3)</td>
<td>35 (57.4)</td>
</tr>
<tr>
<td>Anterior cruciate ligament tear</td>
<td>21 (38.2)</td>
<td>12 (19.7)</td>
</tr>
<tr>
<td>Posterior cruciate ligament tear</td>
<td>4 (7.3)</td>
<td>3 (4.9)</td>
</tr>
<tr>
<td>Lateral collateral ligament tear</td>
<td>3 (5.5)</td>
<td>7 (11.5)</td>
</tr>
<tr>
<td>Medial meniscus tear</td>
<td>47 (85.5)</td>
<td>44 (72.1)</td>
</tr>
<tr>
<td>Lateral meniscus tear</td>
<td>21 (38.2)</td>
<td>23 (37.7)</td>
</tr>
<tr>
<td>SM–tibial collateral ligament bursitis</td>
<td>3 (5.5)</td>
<td>1 (1.6)</td>
</tr>
<tr>
<td>Baker cyst</td>
<td>6 (10.9)</td>
<td>12 (19.7)</td>
</tr>
<tr>
<td>Pes anserine bursitis</td>
<td>2 (3.6)</td>
<td>3 (4.9)</td>
</tr>
<tr>
<td>Ganglion cyst around distal SM tendon</td>
<td>1 (1.8)</td>
<td>1 (1.6)</td>
</tr>
</tbody>
</table>

Note—Statistically significant values (p < 0.05) are shown in boldface. Data in parentheses are percentages.
Results

Thickening of the distal SM tendon was present in 52.6% (61/116) of the patients. Signal alteration was observed in 80.7% of the patients on proton density–weighted images and 44.8% on T2-weighted images. Thickening of the distal SM tendon showed higher correlation with signal alteration seen on T2-weighted images (r = 0.578, p < 0.001) than that on proton density–weighted images (r = 0.144, p = 0.124). For control subjects with a normal distal SM tendon, signal alteration was found in 30.9% (17/55) on proton density–weighted images and was not seen on T2-weighted images.

The measured thickness of the SM tendon was moderately correlated with the visual assessment of thickening (r = 0.697, p < 0.001). In patients with visually assessed thickening of the distal SM tendon, the mean thickness of the SM tendon was 7.0 ± 1.5 (SD) mm (range, 4.9–12.4 mm); in those without thickening, the mean thickness was 4.7 ± 0.7 mm (range, 3.2–5.8 mm). In control subjects with a normal distal SM tendon, the mean thickness of the SM tendon was 4.5 ± 0.7 mm (range, 3.0–6.3 mm) (Fig. 2). Comparisons of the three study groups showed significant differences in measured thickness. Patients with visually assessed thickening of the distal SM tendon had a significantly thicker distal SM tendon than control subjects with a normal distal SM tendon and than patients without thickening (p < 0.001).

Tibiofemoral osteoarthritis assessed as Kellgren-Lawrence grade 2 or higher was present in 47.4% (55/116) of patients. A history of trauma was present in 25.9% (30/116), medial collateral ligament thickening in 43.1% (50/116), ACL tear in 28.4% (33/116), posterior cruciate ligament tear in 6.0% (7/116), lateral collateral ligament tear in 8.6% (10/116), medial meniscus tear in 78.4% (91/116), lateral meniscus tear in 37.9% (44/116), SM–tibial collateral ligament bursitis in 3.4% (4/116), Baker cyst in 15.5% (18/116), pes anserine bursitis in 4.3% (5/116), and ganglion cyst around the distal SM tendon in 1.7% (2/116). Table 1 is a summary of comparative results of characteristics between the patients with and those without SM thickening and signal alteration.

Thickening of the distal SM tendon was statistically significantly associated with age, BMI, a history of trauma, osteoarthritis, MCL thickening, and ACL tear. Age, BMI, osteoarthritis, and MCL thickening were statistically significant variables for signal alteration. Before binary logistic regression analyses were performed, age was excluded from the regression equation owing to high collinearity. The results of multivariate binary logistic regression analyses indicated that osteoarthritis and MCL thickening were independent predictors of thickening and signal alteration of the distal SM tendon. The results of this study suggest that the development of thickening and signal alteration of the distal SM tendon were common findings in patients with osteoarthritis and that, therefore, these abnormalities may be associated with tendon degeneration and remodeling.

An association between an MCL abnormality and knee osteoarthritis has been shown in prior studies, and there was an association between the degree of the MCL abnormality and grade of osteoarthritis [12–14]. Friction and shearing force imposed by adjacent osteophytes may play a role in the development of MCL edema by producing microtears and derangement of interstitial tissues and the local capillary bed [12]. We postulate that in addition to the proposed mechanical factors such as osteophytes [15],

**Table 2: Logistic Regression Analyses to Identify the Factors Associated With Semimembranosus (SM) Tendon Thickening on T2-Weighted Imaging**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SM Tendon Thickening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M:F)</td>
<td>0.93 (0.34–2.59)</td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.88 (0.76–1.03)</td>
</tr>
<tr>
<td>History of major trauma</td>
<td>1.05 (0.28–3.92)</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>5.47 (1.78–16.75)</td>
</tr>
<tr>
<td>Medial collateral ligament thickening</td>
<td>3.14 (1.21–8.18)</td>
</tr>
<tr>
<td>Anterior cruciate ligament tear</td>
<td>0.69 (0.18–2.71)</td>
</tr>
</tbody>
</table>

Note—Age was excluded from the multivariate analysis owing to collinearity. Statistically significant values (p < 0.05) are shown in **boldface.**
chronic repetitive stress on the medial knee from altered biomechanical loading and unperceived microtraumas contribute to the development of degeneration of the soft-tissue structures around the medial knee. Whereas the medial tibiofemoral compartment bears 60–70% of the force across the knee in a neutrally aligned limb, the load-bearing axis passes more medially in a varus malaligned knee and a greater load on the medial compartment is applied [16, 17]. Theoretically, therefore, the distal SM tendon would have to withstand a similar, if not the same, stress as the MCL at the posteromedial knee where the MCL and posterior oblique ligament act as static medial stabilizers and the distal SM tendon acts as the dynamic stabilizer. In addition, tightness of medial soft tissues including the MCL, posteromedial joint capsule, and distal SM tendon can be observed in the operative field in patients with varus deformity, and medial release of the contracted medial soft-tissue structure may be performed during total knee arthroplasty [18]. Moreover, among the five insertions of the distal SM tendon, the capsular arm blends with the posterior oblique ligament, which is the posterior extension of the superficial layer of the MCL [3]. Therefore, we believe that it is difficult to think of the MCL and the distal SM tendon as separate independent structures in terms of osteoarthritis. In our study, the presence of an ACL tear failed to be a statistically significant prognostic indicator of distal SM tendon thickening or signal alteration in the multivariate analysis; however, in the univariate analysis, ACL tear seemed to be an important contributor to the distal SM tendon thickening. Considering the similar mechanism of injury of the ACL and that of the distal SM, this result was not what we initially expected because previous studies have shown an association between injuries of the distal SM tendon and tears of the ACL [19]. However, because the

### TABLE 3: Multivariate Logistic Regression Analyses to Identify the Factors Associated With Semimembranosus (SM) Tendon Signal Alteration on T2-Weighted Imaging

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SM Tendon Thickening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds Ratio (95% CI)</td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.897 (0.79–1.02)</td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>3.91 (1.69–9.04)</td>
</tr>
<tr>
<td>Medial collateral ligament thickening</td>
<td>2.49 (1.06–5.84)</td>
</tr>
</tbody>
</table>

Note—Age was excluded from the multivariate analysis owing to collinearity. Statistically significant values (p < 0.05) are shown in **boldface**.
Fig. 4—47-year-old man with meniscal tear.
A, Standing anteroposterior radiograph of left knee shows no features of osteoarthritis.
B, Axial fat-saturated fast spin-echo (FSE) proton density–weighted image shows no visible thickening of distal semimembranosus (SM) tendon, but subtle intratendinous hyperintensity (asterisk) is noted.
C, Sagittal FSE T2-weighted MR image shows neither thickening nor signal alteration of distal SM tendon (asterisk). Thus, signal alteration of distal SM tendon shown on B is considered to be caused by magic angle effect. Horizontal tear of posterior horn of medial meniscus (arrow) and small parameniscal cysts adjacent to both anterior and posterior horns (arrowheads) are seen.

main focus of our study was on incidental SM tendon abnormalities including thickening and signal alteration, not on disruption or visible tears that would have been associated with major trauma to the posteromedial knee, the result from the multivariate analysis was not a surprise.

We found no significant difference in the incidence of SM–tibial collateral ligament bursitis, a Baker or popliteal cyst, pes anserine bursitis, and a ganglion cyst in or around the distal SM tendon between the two groups based on distal SM thickening or signal alteration. These findings suggest that formation of these cysts is related more to underlying osteoarthritis or internal derangement than to distal SM abnormalities.

Knee ligaments and tendons are commonly evaluated using proton density–weighted and T2-weighted FSE images. In our study, both proton density–weighted and T2-weighted images were used in the assessment of the signal alteration of the distal SM tendon. However, the incidence of signal alteration of the distal SM tendon was substantially higher on proton density–weighted images (80.7%) than on T2-weighted images (44.8%). As shown in the results of the correlation test, thickening of the distal SM tendon showed higher correlation with signal alteration seen on T2-weighted images than on proton density–weighted images. We postulate that this phenomenon is due to the magic angle effect. Because of the oblique course of the distal SM tendon insertion near the posteromedial tibial plateau on the extended knee, which is a conventional position for routine knee MRI, abnormal high signal intensity can be more conspicuous on short-TE sequences such as proton density–weighted images [3]. Therefore, we believe that tendon signal alteration observed on T2-weighted images more correctly reflects tendon degeneration than proton density–weighted images.

There are a few limitations to our study. First, it was difficult to relate the abnormal findings observed on MRI with histology or operative findings. Second, we included only patients who underwent surgeries at our institution because the clinical data of inpatients were recorded in more detail. Finally, the retrospective nature of this study made it difficult to confirm the presence of tenderness, specifically on the posteromedial knee, in patients whose physical examinations in the medical records were insufficient.

In conclusion, abnormal thickening and signal alteration of the distal SM tendon on MRI are frequently found in daily practice and these findings are strongly associated with osteoarthritis and MCL thickening.

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