Clinical, MRI, and Arthroscopic Findings Associated with Failure to Diagnose a Lateral Meniscal Tear on Knee MRI

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OBJECTIVE. We performed this study to determine whether clinical, MRI, or arthroscopic findings are associated with missed lateral meniscal tears to help understand why these tears are missed on MRI.

MATERIALS AND METHODS. We reviewed the medical records of 483 patients who had undergone knee MRI and arthroscopy. We assessed patient age; spontaneous or traumatic onset of knee pain; interval between pain onset and MRI; interval between MRI and arthroscopy; and arthroscopic type, size, and location of lateral meniscal tear for their association with a missed lateral meniscal tear. Each MR examination with a missed lateral meniscal tear was reviewed to determine whether the tear could be seen in retrospect.

RESULTS. Thirty-six of the 189 lateral meniscal tears found at arthroscopy were not diagnosed on the original MR interpretations. There was a significant association between a missed lateral tear and a posterior horn tear or a tear involving only one third of the meniscus. There was no association between a missed lateral meniscal tear and the other variables. Review of the 36 missed tears revealed that 10 tears were visible retrospectively, six of which were longitudinal peripheral tears in the posterior horn.

CONCLUSION. Lateral meniscal tears are more likely to be missed if the tear involves only one third of the meniscus or is in the posterior horn. Longitudinal peripheral tears of the posterior horn were the most commonly missed tears that could be seen in retrospect.

Keywords: arthroscopy, knee, meniscal tears, meniscus, MRI, sports medicine, trauma

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MRI of the knee has been successfully used to diagnose meniscal tears for more than 20 years. Despite technologic improvements and extensive MR research on meniscal tears during this time, the sensitivity for diagnosing lateral meniscal tears has consistently remained lower than that for medial meniscal tears [1]. Although studies performed in the 1990s investigated errors made in the diagnosis of meniscal tears using MRI [2–5], no study definitely, to our knowledge, identified why the sensitivity for diagnosing lateral meniscal tears is lower.

We undertook this study to determine whether we could identify clinical variables, MRI findings, or arthroscopic findings that are associated with the failure to diagnose a lateral meniscal tear. We hoped that identifying these associations would offer insights into the reasons why these tears were not identified and thus improve the accuracy of diagnosing lateral meniscal tears.

Materials and Methods

Medical Records Review

Before beginning the study, we obtained approval and a waiver of patient informed consent for this retrospective study from our institutional review board. The study was also performed in compliance with HIPAA regulations.

We reviewed the medical records of 1,466 consecutive patients who underwent knee MR examinations at our institution from July 2003 through June 2004. We then selected all patients who met the following criteria: first, MR examination on a 1.5-T MR magnet; second, available medical records with the relevant history and physical examination; third, no history of meniscal surgery; and, fourth, subsequent knee arthroscopy. Using these selection criteria, we identified a group of 483 patients as the patient population for this study.

Each of the 483 patients' medical records was reviewed for the following six clinical variables that we thought might be factors associated with difficultly in diagnosing a tear.

Patient age—We speculated that degenerative tears that occur with increasing patient age might differ in their ability to be diagnosed on MRI

when compared with the tears that occur in younger patients.

Relationship to trauma—We also hypothesized that tears associated with a specific injury might differ in their ability to be diagnosed on MRI when compared with tears in patients whose knee pain began without a specific injury.

MRI delay—We postulated that the time interval between the onset of symptoms and the MR examination might have a relationship to missed tears. Tears that are long-standing in duration could have partial healing that might make the tear hard to identify on MRI.

Arthroscopy delay—If the interval between the MR examination and knee arthroscopy is significant, some patients might have an unreported interval knee injury resulting in a lateral meniscal tear that was not present at the time of the MR examination.

Sensitivity for diagnosing medial meniscal tears—A low-quality MR image due to patient size or motion might cause a missed lateral meniscal tear. If so, then presumably there would be an increase in both missed lateral and medial meniscal tears.

Location and type of lateral meniscal tear and anterior cruciate ligament (ACL) tear—In previous studies, lateral meniscal tears in certain locations and tears associated with ACL tears were found to be more difficult to identify on MRI [2–4].

Finally, we reviewed the medical records to determine the original interpretations of the MRI examinations and the findings at knee arthroscopy. The MRI examinations had been interpreted by any one of seven fellowship-trained musculoskeletal radiologists with 1–13 years of experience in the interpretation of knee MRI.

All MRI examinations were performed on the same 1.5-T unit (Signa, GE Healthcare) using a cylindric phased-array extremity coil and the same protocol. A field of view of 14 cm, a slice thickness of 3 mm with a 1.5-mm interslice gap, and a matrix of 256 × 192 were used for all four sequences except that the coronal T1-weighted images were obtained using a matrix of 256 × 224. The parameters for the coronal T1-weighted images were TR range/TE, 600–700/17; 1 signal average; and echo-train length of 3. The parameters for the coronal fat-saturated proton density–weighted images were 1,800–2,000/17, 1 signal average, and echo-train length of 4. The parameters for the sagittal proton density–weighted image were 2,000–2,200/17, 1 signal average, and echo-train length of 4. The parameters for the sagittal T2-weighted fat-saturated sequence were 3,000–3,400/60, 1 signal average, and echo-train length of 6. The scanning time for each of the four sequences was between 2 and 3.5 minutes.

Because our goal was to determine MR sensitivity for meniscal tear, we considered an original MR diagnosis of a definite or possible meniscal tear as positive for this study. For the arthroscopic findings, we noted the pattern and location of any lateral meniscal tears and the presence or absence of a medial meniscal tear or an ACL tear. Our arthroscopic surgeons classify meniscal tears as being flap, complex, horizontal, longitudinal peripheral, radial, root, and bucket handle in pattern and localize a tear as being in the anterior horn, body, posterior horn, or a combination of these three locations or in the meniscal root. All four of the arthroscopic surgeons were academic faculty with experience ranging from 6 to 30 years. They do not specify in their arthroscopy reports whether the meniscal fascicles are intact.

MRI Retrospective Review

One of the authors with 16 years of experience in interpreting knee MRI examinations reviewed the MR examinations of the 36 patients in whom a lateral meniscal tear was found at arthroscopy but was not originally diagnosed on MRI.

Each MR study was reviewed with knowledge of the type, extent, and location of the tear. The criteria for diagnosing a meniscal tear used in this retrospective evaluation were visualization of an intraarticular meniscal fragment or the presence of one or more MR images showing distortion of the meniscus or intrameniscal signal contacting the superior or inferior surface of the meniscus.

Statistical Analysis

Differences in patient ages, the time interval between the onset of knee symptoms and the MR examination, and the time interval between the MR examination and arthroscopy were compared using the Student's *t* test. The other clinical and arthroscopic findings were assessed for a statistically significant association with a missed lateral meniscal tear using the chi-square test. The Fisher's exact test for proportions was used instead of the chi-square test when a cell frequency was less than five. A significant difference was defined as a $p < 0.05$ for all comparisons. All analyses were performed using statistics software (SAS version 9.1, SAS Institute).

Results

The MR sensitivity was 81% for diagnosing the 189 lateral meniscal tears and 97% for diagnosing the 305 medial meniscal tears. The MR specificity was 88% for the lateral meniscal tears and 86% for the medial meniscal tears.

Lateral Tear Sensitivity and Clinical Data

There was no significant difference in the mean patient age, the mean interval between the onset of symptoms and the MR examination, or the mean interval between the MR examination and knee arthroscopy when comparing patients whose lateral meniscal tears were diagnosed or missed on MRI (Table 1). When the intervals between injury or symptom onset and the MR examination were grouped as less than 30 days, between 31 and 90 days, and more than 90 days, the percentage of missed lateral meniscal tears was 20% in the first group, 10% in the second group, and 24% in the third group ($p = 0.29$).

The percentage of missed lateral meniscal tears was 20.7% in the 145 patients with knee pain beginning with a specific injury and 13.7% in the 44 patients whose knee pain began without a specific injury ($p = 0.30$).

Lateral Tear Sensitivity and Arthroscopic Findings

The 76% sensitivity for the MR diagnosis of lateral meniscal tears in the 84 patients with an ACL tear and a lateral meniscal tear was lower than the sensitivity of 85% in the 105 patients with a lateral meniscal tear but without an ACL tear. However, the difference was not statistically significantly different ($p = 0.14$). Of the 483 patients, 141 had an ACL tear. Lateral meniscal tears were found at arthroscopy in 60% of the patients with an ACL tear and in 30% of the patients without an ACL tear.

Lateral meniscal tears were not missed more frequently when a medial meniscal tear was also missed ($p = 0.18$). The sensitivity of diagnosing a lateral meniscal tear was 77% in 95 patients with a medial meniscal tear and 85% in 94 patients without a medial tear ($p = 0.15$).

The sensitivity for diagnosing a lateral meniscal tear did vary with tear location (Table 2). The sensitivity of MRI to detect tears involving more than one third of the meniscus was 100%. This sensitivity was significantly better than the sensitivity of MRI for tears in the body ($p = 0.003$), in the posterior horn ($p < 0.0001$), and in the root ($p = 0.005$). The 100% sensitivity for detecting tears in the anterior horn was significantly better than the sensitivity in the posterior horn ($p = 0.01$). The 82% and 83% sensitivities for detecting tears in the body or root of the meniscus root, respectively, were significantly better than the sensitivity of 73% for detecting tears in the posterior horn ($p = 0.04$). No other pair-wise comparisons for tear location were statistically significantly different.

Comparison of the sensitivity of diagnosing a lateral meniscal tear for each type of tear revealed an unexpected finding, as shown in Table 3. The sensitivity for the MR diagnosis

TABLE 1: Comparison of Clinical Characteristics of Patients with True-Positive and False-Negative MR Diagnoses of Lateral Meniscal Tears

Clinical Characteristic	True-Positive	False-Negative	p[a]
Mean patient age (y)	38.5	32.6	0.08
Mean delay (d)			
Between symptom onset and MRI	186	246	0.54
Between MRI and arthroscopy	89	73	0.39

[a]Student's *t* test.

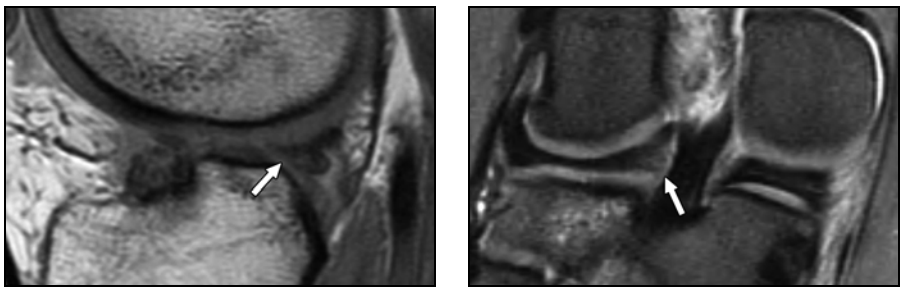
TABLE 2: Comparison of False-Negative and True-Positive MR Diagnoses of Lateral Meniscal Tears by Tear Location

Location of Meniscal Tear	No. (%) of Diagnoses		Total No. of Tears
	False-Negative	True-Positive	
Anterior horn	0 (0)	12	12
Body	7 (18)	32	39
Posterior horn	21 (37)	36	57
Root	6 (17)	30	36
More than one third of meniscus	0 (0)	43	43
Unspecified	2 (100)	0	2
Total	36 (19)	153	189

TABLE 3: Comparison of False-Negative and True-Positive MR Diagnoses of Lateral Meniscal Tears by Type of Meniscal Tear

Type of Meniscal Tear	No. (%) of Diagnoses		Total No. of Tears
	False-Negative	True-Positive	
Bucket-handle	2 (18)	9	11
Complex	2 (8)	22	24
Flap	5 (15)	28	33
Horizontal	2 (8)	23	25
Radial	4 (14)	25	29
Root	7 (19)	30	37
Longitudinal peripheral	6 (29)	15	21
Unspecified[a]	8 (89)	1	9
Total	36 (19)	153	189

[a]Significantly different from specific tear types, $p < 0.0001$.



A **B**

Fig. 1—23-year-old woman with originally missed root tear of lateral meniscus seen on retrospective review. Tear was débrided during arthroscopy for anterior cruciate ligament reconstruction.
A, Sagittal fast spin-echo proton density–weighted image shows signal contacting inferior surface of root (*arrow*). Note is also made of anterior fragments of torn anterior cruciate ligament.
B, Coronal fat-saturated fast spin-echo proton density–weighted image shows disruption of attachment of root with internal signal (*arrow*).

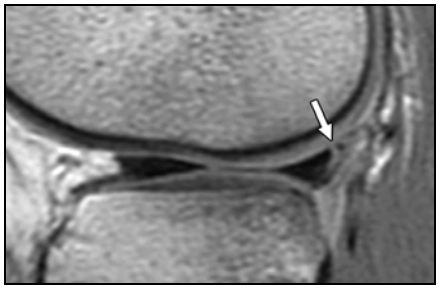


Fig. 2—15-year-old girl with originally missed longitudinal peripheral tear of posterior horn of lateral meniscus seen on retrospective review. Tear was repaired with sutures. Sagittal fast spin-echo proton density–weighted image shows peripheral longitudinal tear with vertical orientation (*arrow*).

of the nine tears in which the pattern was not specified in the operative notes was only 11%. All nine tears in which the type was not specified were débrided at arthroscopy. This value is significantly lower than in all the specific tear patterns ($p < 0.0001$). When these tears without a specified tear type were excluded from the analysis, there was no significant difference between the types of tears ($p = 0.52$).

Retrospective MRI Review

Ten of the 36 missed lateral meniscal tears could be definitely identified on retrospective review of the MR examination. For all 10 of these tears, abnormalities were visible on only two MR images. Three additional tears were questionably identifiable in retrospect. The remaining 23 tears could not be seen in retrospect even with knowledge of the location, type, and extent of the tear. Of the 23 tears that could not be seen in retrospect, four were flap tears, four were peripheral longitudinal tears, six were root tears, two were radial tears, and one was a horizontal tear; in the remaining six, the type of tear was not specified.

Of the tears that could be identified in retrospect, three were root tears (Fig. 1), one was on the superior surface of the posterior horn, and six were peripheral longitudinal tears with a vertical tear orientation occurring at or just lateral to the popliteal hiatus where the popliteus tendon enters the joint (Figs. 2 and 3). An associated ACL tear was present in the six patients with peripheral longitudinal tears.

Two of the three questionably identifiable tears were radial tears of the body of the lateral meniscus and were seen in retrospect as a subtle area of increased signal on the free edge of the meniscus on one sagittal image (Fig. 4). The other questionably missed tear was on an MR examination of

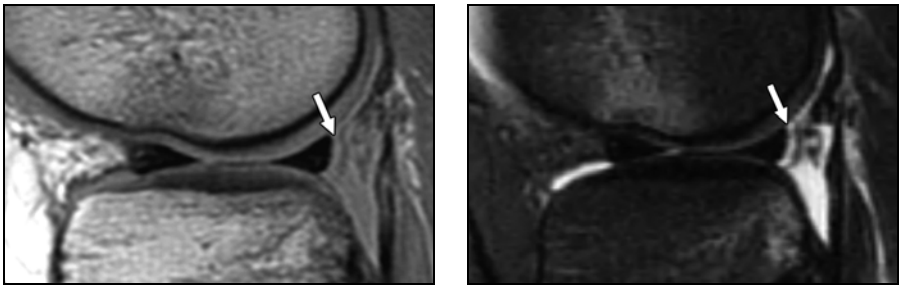


Fig. 3—17-year-old girl with originally missed longitudinal peripheral tear of posterior horn of lateral meniscus seen on retrospective review. Tear was repaired with sutures.
A and **B,** Sagittal fast spin-echo proton density–weighted (**A**) and sagittal fat-saturated fast spin-echo T2-weighted (**B**) images. Peripheral tear (*arrows*) is better seen on fluid-sensitive T2-weighted image than on proton density–weighted image. Prominent bone bruises are also seen in anterior aspect of lateral femoral condyle and posterior aspect of tibia in this patient who also had anterior cruciate ligament tear.

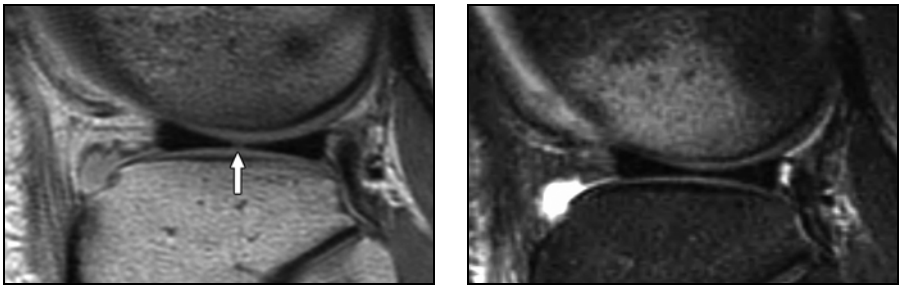


Fig. 4—16-year-old boy with originally missed radial tear of body of lateral meniscus that was questionably seen on retrospective review. Tear was trimmed to saucerize lesion.
A and **B,** Sagittal fast spin-echo proton density–weighted (**A**) and sagittal fat-saturated fast spin-echo T2-weighted (**B**) images. Tear is seen as subtle area of increased signal intensity on free edge of meniscus (*arrow,* **A**) in **A** but is not evident in **B**. No other sagittal or coronal image depicted meniscal abnormality suggesting tear.

marginal quality due to patient motion. We think that these tears were unlikely to be diagnosed if the MR examinations were interpreted prospectively.

Of the 36 missed meniscal tears, 23 tears were débrided, nine longitudinal peripheral tears were repaired, three radial tears were treated with saucerization, and one shallow peripheral tear was stable and was not treated surgically. Five of the six peripheral longitudinal tears that were missed and could be seen in retrospect were repaired rather than resected.

Discussion

The sensitivity of 81% in our study for diagnosing lateral meniscal tears is comparable to that previously reported in the literature. In a recent meta-analysis of the accuracy of MRI for diagnosing meniscal tears [1], a pooled weighted sensitivity of 79.3% was calculated for diagnosing lateral meniscal tears after review of 120 articles on knee MRI.

We did not find an association between missed lateral meniscal tears and patient age, posttraumatic versus spontaneous knee pain, the time interval between pain onset and the MR examination, or the time interval between MRI and arthroscopy. In one previous study, researchers compared the interval between knee MRI and arthroscopy and also found no association with missed lateral meniscal tears [2]. Whether there is an association between missed lateral meniscal tears and patient age, traumatic or spontaneous onset of knee pain, and the interval between pain onset and MRI has not been previously reported, to our knowledge.

Because failing to diagnose a lateral meniscal tear did not correlate with failure to diagnose a medial meniscal tear, poor-quality MR examinations due to patient size or motion are not likely to account for some of the missed tears. This association has also not been previously reported. Thus, we were not able to identify any clinical factors or associated intraarticular abnormalities that would help us understand why lateral meniscal tears are not identified on MRI as reliably as are medial meniscal tears.

We also did not find a change in sensitivity due to the presence or absence of an associated medial meniscal tear or ACL tear. Although one previous study found an increased incidence of missed lateral meniscal tears in the presence of an ACL tear [2], our study results are in agreement with those of two other studies that did not find a statistically significant association [3, 4]. However, in our study and both of these latter studies, a lower sensitivity—but not a statistically significantly lower sensitivity—was found for lateral meniscal tears in the presence of an ACL tear. This consistently lower sensitivity suggests that if we had studied more patients, we might have found a statistically significant lower sensitivity when an ACL tear was present.

We found that MRI was significantly more sensitive in depicting tears when the tear involved more than one third of the meniscus and was significantly less sensitive in depicting tears in the posterior horn. The improved sensitivity for large tears is not surprising because large tears should be more evident on MRI than small tears. A lower sensitivity in diagnosing tears in the posterior horn of the lateral meniscus than elsewhere in the lateral meniscus has been noted in four studies, with statistical significance found for the lower sensitivity in one study [6] but without analysis for statistical significance in the other three studies [3, 5, 7].

Thus, our study did not identify a cause for the lower sensitivity for detecting lateral meniscal tears on MRI in the clinical, MRI, or arthroscopic findings in these patients. In previous studies analyzing the cause for false-negative MR diagnoses of meniscal tears, investigators have hypothesized that the causes for the lower sensitivity in diagnosing lateral meniscal tears might include small tear size, oblique visualization of the posterior horn due to both the sloping upward course at its attachment and the small radius of the curvature of the lateral meniscus, the more complex anatomy of the posterior horn, the magic angle effect, and arterial pulsation artifact [2, 3, 5, 6].

One unexpected finding was that eight (89%) of the nine tears not classified as a specific tear type in the arthroscopy report were missed. The sensitivity for diagnosing tears in this group was significantly lower than that for diagnosing tears in patients in whom a specific type of tear was reported. Because we do not

know what type of tears these nine tears were, it is difficult to hypothesize why these tears were missed on MRI. The failure to describe the tear type may have been only an oversight in the dictation of the arthroscopy report. However, it is puzzling why sensitivity was significantly lower in these cases.

We did find that 10 of the 36 missed lateral meniscal tears could be identified in retrospect. Our results are similar to those previously reported in which only a minority of missed tears on MRI could be seen in retrospect [2, 3, 6].

One unexpected finding on the retrospective review was that six of the 36 missed tears had a longitudinal peripheral pattern with a vertical tear orientation. This pattern of tear has not been emphasized in the literature. The meniscofemoral ligaments arose just medial to these tears. Possibly because the experienced original interpreters of these studies were aware of the potential for misdiagnosing these normal ligaments as tears, they may have assumed that the tears were variations in the meniscofemoral ligament attachment to the lateral meniscus.

Many of these peripheral longitudinal tears are unstable and can progress to bucket-handle detachment. A recent report in the sports trauma literature described eight elite athletes who developed displaced bucket-handle lateral meniscal tears after apparently normal MR examinations [8]. The authors of that report thought that the MR studies had missed nondisplaced peripheral longitudinal tears in these athletes [8]. The results of this recent series emphasize that identification of these tears is important because repair with sutures or fixation devices is now the recommended method of surgical management for unstable peripheral vertical tears [9, 10].

Five of the six longitudinal peripheral tears seen in retrospect in our study were found to be unstable at arthroscopy and were repaired. Because all six of these tears were associated with ACL tears, it may help prevent a tear from being missed on MRI if this tear pattern is considered when an ACL tear is noted on MRI of the knee and a lateral meniscal tear is not identified. In our study, 60% of the patients with an ACL tear had a lateral meniscal tear found at arthroscopy.

We found that 35 (97%) of the 36 tears not diagnosed on the original MRI were treated surgically with débridement or repair. Our findings are similar to those of a previous study in which 83% of lateral meniscal tears not diagnosed on MRI were treated surgically [5]. However, in that study, only 40% of the missed medial meniscal tears required surgical treatment [5].

As we noted earlier, the sensitivity in our study for detecting lateral meniscal tears on MRI is similar to those in studies dating back to 1991 [1]. Whatever the cause for lower MR sensitivity for the diagnosis of a lateral meniscus tear, interval improvement in MR magnet technology and extremity coil design did not reduce the frequency of missed tears. One point to consider is that we used fast spin-echo imaging for our pulse sequences, but we do not believe that using conventional spin-echo imaging would have changed our findings. Although one study found that fat-saturated conventional spin-echo imaging was superior to fat-saturated fast spin-echo imaging [11], another found that for sequences without fat saturation, the accuracy of fast spin-echo sequences was comparable to that of conventional spin-echo sequences for the diagnosis of meniscal tears [12].

More recently, Magee and Williams [13] reported that the sensitivity of diagnosing meniscal tears using 3-T fast spin-echo MRI with 2-mm-thick images was 96% for 66 medial and 46 lateral meniscal tears. If this accuracy is confirmed in additional studies, thinner slices with the higher signal-to-noise ratio of a 3-T magnet may prove to be the best way to use MRI to diagnose lateral meniscal tears.

In summary, we found no clinical variables or associated intraarticular abnormalities that correlated with the failure to diagnose a lateral meniscal tear. We did find that the sensitivity for diagnosing a lateral meniscal tear was significantly higher when the tear involved more than one third of the meniscus or the anterior horn and was significantly lower for tears in the posterior horn. Six of the 10 missed tears that could be seen in retrospect were longitudinal peripheral tears with a vertical tear orientation. Although peripheral longitudinal tears were not missed significantly more frequently than other tear patterns, an increased awareness of this tear pattern seen in association with ACL tears has helped us identify these tears in our practice.

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