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Can the Reparability of Meniscal Tears Be Predicted With Magnetic Resonance Imaging?

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Investigation performed at David Geffen School of Medicine at UCLA, Los Angeles, California

Background: Historically, magnetic resonance imaging (MRI) has been very useful in diagnosing meniscal tears but not as valuable in predicting whether a meniscal tear is repairable. Given that several recent studies suggested that MRI can be used to predict tear reparability, the topic has resurfaced as a controversy in the orthopaedic and radiology literatures.

Hypothesis: Experienced musculoskeletal radiologists can use MRI to predict the reparability of meniscal tears with good to excellent accuracy using the same arthroscopic criteria used by surgeons intraoperatively.

Study Design: Cohort study (diagnosis); Level of evidence, 3.

Methods: Fifty-eight patients with meniscal tears treated with repair were matched by age and sex with 61 patients with tears treated with meniscectomy. Two senior musculoskeletal radiologists independently and blindly reviewed preoperative MRI of these 119 meniscal tears. Using established arthroscopic criteria, the radiologists were asked to grade each tear 0 to 4, with 1 point for each of the following: a tear larger than 10 mm, within 3 mm of the meniscosynovial junction, greater than 50% thickness, and with an intact inner meniscal fragment. Only a tear with a score of 4 would be predicted to be repairable.

Results: The 2 radiologists' ability to correctly estimate reparability was poor, with 58.0% and 62.7% correct predictions ($\kappa = 0.155$ and 0.250, respectively). Interrater reliability assessment showed that the raters agreed on a score of 4 (repairable) versus <4 (not repairable) 73.7% of the time ($\kappa = 0.434$) but came to identical scores only 38.1% of the time ($\kappa = 0.156$). Determining the status of the inner fragment was the most predictive individual criterion and the only one to reach statistical significance ($\chi^2 = 14.9$, $P < .001$).

Conclusion: Magnetic resonance imaging is not an effective or efficient predictor of reparability of meniscal tears with the current arthroscopic criteria.

Keywords: magnetic resonance imaging; meniscal tear; meniscus repair; arthroscopy

Meniscal tears are thought to be the most common indication for the more than 1 million knee arthroscopies annually performed in the United States.³ Whereas the absence of a comprehensive ambulatory surgery database precludes precise calculation, it is speculated that more than 850 000 meniscectomies or meniscal repairs are

performed in the United States each year.¹¹ Yet the determination of meniscal reparability and, thus, the decision between meniscectomy and meniscal repair are routinely performed intraoperatively, with consent for both procedures obtained before surgery. Surgeons and patients go into the operating room unsure of which procedure will be performed, despite the notable difference in recovery time, rehabilitation, and surgical time associated with each procedure. Prediction of meniscal reparability would provide important information for patient education, help mitigate postoperative expectations, and allow more accurate surgical planning and scheduling.

Although magnetic resonance imaging (MRI) is widely accepted as an accurate technique for diagnosing meniscal tears, its use to predict the reparability of meniscal tears is far less established. Whereas early reviews suggested that MRI could be used to indicate the likelihood of reparability,⁵ Matava et al⁸ in a 1999 study concluded that MRI "adds little to the predictability of treatment" of meniscal tears. Over the past decade, the conclusion of Matava

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TABLE 1
Patient Demographics

	Meniscal Repair (n = 58)	Meniscectomy (n = 61)	P
Mean age, y	24.4	24.6	.84
Patients, n (%)			
Male	42 (72)	44 (72)	.92
Female	16 (28)	17 (28)	.92

et al has been challenged as imaging modalities have advanced and studies have shown an improved ability of MRI to diagnose meniscal tears.⁹ In fact, some groups have published studies showing that modern scanners allow the accurate prediction of meniscal tear reparability in at least some subsets of patients.^{10,14}

In this study, we evaluated the ability of 2 senior musculoskeletal radiologists to use MRI to predict the reparability of 119 meniscal tears in patients between 16 and 40 years of age, using established arthroscopic criteria of reparability. We evaluated the sensitivity, specificity, positive predictive value, and negative predictive value of MRI as a predictor of reparability when used in experienced hands, as well as the intraobserver reliability among seasoned musculoskeletal radiologists.

MATERIALS AND METHODS

After we obtained approval from our Institutional Review Board, 92 consecutive patients between the ages of 16 and 40 years were retrospectively identified who underwent meniscal repair for a primary diagnosis of a meniscal tear between January 1, 2005, and December 31, 2008. Thirty-three patients were excluded because they had MRI from outside institutions (because of heterogeneity of scan quality) or more than a 3-month delay between MRI and surgery (at higher risk of further damaging the meniscus and thereby altering its reparability status). One patient was excluded because his MRI was on a 3T scanner rather than a 1.5T scanner. This left 58 patients available for review who underwent meniscal repair and had MRI at our institution within 3 months of their surgery.

We then matched this cohort by age and sex with 61 patients who underwent meniscectomy for a primary diagnosis of meniscal tear. Exclusion criteria again included patients with outside MRI, a time lapse of more than 3 months between MRI and surgery, a primary diagnosis other than meniscal tear, imaging on a 3T scanner, and an age younger than 16 or older than 40 years. Table 1 shows the demographic data on both groups (meniscal repair and meniscectomy).

All surgeries (meniscal repairs and meniscectomies) were performed by 2 senior orthopaedic surgeons. Both surgeons used established anatomical criteria to determine reparability intraoperatively: (1) The tear had to be within the vascularized zone of the meniscus, or within 3 mm of meniscosynovial junction; (2) it had to be longer than 10 mm in length; (3) it had to have minimal damage to the torn segment so that suturing is technically feasible;

and (4) it had to be greater than 50% thickness.⁸ These criteria came from practice methods at our institution and established criteria published in the literature.⁸ Time from injury to surgery, presence of a concomitant anterior cruciate ligament tear, and laterality of tear were not used as factors in determining reparability.

Imaging was performed on clinical high-field-strength MRI systems (Signa 1.5 T, GE Medical Systems, Milwaukee, Wisconsin; Sonata or Avanto 1.5 T, Siemens, Erlangen, Germany) using manufacturer-supplied standard knee coils. Coronal fat-saturated proton density, sagittal dual-echo proton density T2-weighted images and axial fat-saturated T2-weighted images were obtained in all cases. The field of view was 14 cm. Slice thickness was 3 mm with a 4.5-mm gap; a 192 × 256 matrix was used. Single acquisitions were used on all knees. The knees were positioned in full extension with 5° to 10° of external rotation of the lower extremity. The images thus acquired were reviewed on a GE Centricity Picture Archiving and Communication System. Measurements were performed using the available tools on this system.

The 2 fellowship-trained senior musculoskeletal radiologists were blinded to the surgical procedure performed for these 119 knees with meniscal tears. The radiologists were also blinded to the age of each patient. Radiologists were provided axial, sagittal, and coronal MRI of the knee for review. They were also provided the arthroscopic criteria used by the orthopaedic surgeons intraoperatively to determine reparability of meniscal tears. To be considered for repair intraoperatively, the tear had to fulfill the 4 established arthroscopic criteria mentioned above. In contrast, partial meniscectomy was performed if the tear was in the avascular zone, shorter than 10 mm, or had significant fraying or degeneration. Tears of less than 50% thickness were treated nonoperatively with debridement of frayed edges or left untreated. The musculoskeletal radiologists were instructed to give each tear a score of 0 to 4, with 1 point each for a tear within 3 mm of the meniscosynovial junction, longer than 10 mm, greater than 50% thickness, and with an intact inner meniscal fragment. The radiologists were forced to give a 1 or 0 for each criterion. Only a tear with a score of 4 would be predicted to be repairable (Figure 1). A tear with a score of 0, 1, 2, or 3 was predicted to be irreparable (Figure 2). Each radiologist reviewed the scans independently.

Unweighted κ analysis was used to analyze the concordance between the MRI results and arthroscopic findings, and thus the surgical procedure performed. Unweighted κ analysis was then used to evaluate interexaminer reliability, comparing the examiners' actual scores (0 to 4) and the examiners' determination of reparability (4 vs "not 4"). Values for strength of observer agreement were qualitatively defined according to the guidelines of Landis and Koch⁷ as follows: poor (< 0.2), fair (0.21 to 0.40), moderate (0.41 to 0.60), good (0.61 to 0.80), and excellent (0.81 to 1.00). Sensitivity, specificity, positive predictive value, and negative predictive value were then calculated. Finally, each individual criterion evaluated by the radiologists was evaluated to determine its predictive value in assessing reparability. Statistical analysis was performed using STATA 10 software (StataCorp LP, College Station, Texas).

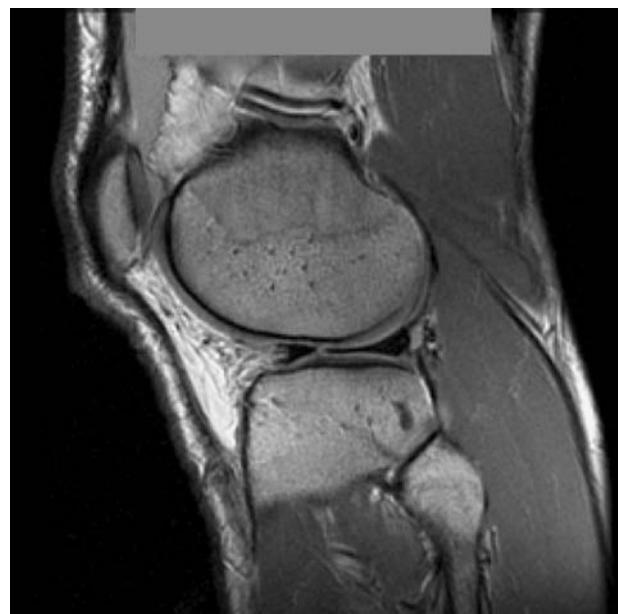


Figure 1. Sagittal cut, MRI of knee. This image shows a medial meniscal tear given a score of 4 by both examiners—that is, it is within 3 mm of the meniscosynovial junction, is longer than 10 mm, has an intact inner meniscal fragment, and is greater than 50% thickness. The tear was in fact repaired at the time of surgery.

Figure 2. Sagittal cut, MRI of knee. This image shows a lateral meniscal tear given a score of 2 by both examiners; it is less than 10 mm and does not have an intact inner meniscal fragment. This tear was predicted to be irreparable and was in fact debrided with a meniscectomy at the time of surgery.

TABLE 2
Treatment Predictions Compared With Procedures Performed

Procedure	Examiner 1 Predictions		Examiner 2 Predictions	
	Meniscectomy	Repair	Meniscectomy	Repair
Meniscectomy: n = 61 ^a	41	20	48	12
Repair: n = 58	30	28	32	26

^aExaminer 2 read 1 image as not having a tear.

TABLE 3
Predictors for Meniscal Repair, %

	Accuracy	Sensitivity	Specificity	Predictive Value	
				Positive	Negative
Examiner 1	58	48	67	58	58
Examiner 2	63	45	80	68	60
Mean	60	47	74	63	59

RESULTS

The examiners' interpretation of the MRI was compared for interexaminer reliability. When compared for exact score (0 to 4), examiners agreed only 38% of the time, for a κ value of 0.16. When the examiners interpretations were compared for repairable versus nonrepairable tears (ie, 4 or not 4), they agreed 74% of time, for a κ value of 0.43.

The MRI interpretations were then compared with the intraoperative assessment and, thus, the actual procedure performed (Table 2). Examiner 1 predicted the correct outcome 58% of the time, achieving a κ value of 0.16. Examiner 2 predicted the correct outcome 63% of the time, achieving a κ value of 0.25. Of note, examiner 2 read 1 image as not having a tear. Sensitivity, specificity, positive predictive value, and negative predictive value are shown for each examiner (Table 3).

TABLE 4
Positive Predictive Value of Each Criterion by Examiner

	Examiner 1			Examiner 2		
	Coefficient	SE	P	Coefficient	SE	P
≥10 mm in length	0.79	0.68	.249	0.56	0.86	.517
Within 3 mm of meniscosynovial junction	0.86	0.62	.165	0.54	0.45	.237
>50% thickness	-1.29	0.76	.123	-0.03	0.46	.995
Inner fragment intact	0.61	0.39	.088	1.21	0.46	.008

Each variable was then analyzed for its independent positive predictive value for each examiner. For both examiners, finding an intact inner fragment was the most predictive individual criterion, reaching statistical significance for one examiner and approaching statistical significance for the other (Table 4).

DISCUSSION

Meniscal repair has long been established as an effective method of treatment for certain types of meniscal tears, given that it restores the shock-absorbing function of the meniscus.^{2,4,12} Not all meniscal tears are reparable, however. Meniscal tears that are in the avascular, "white" zone of the meniscus will not often heal; those that have significant damage to the 2 fragments (ie, degenerative rather than traumatic) will not often hold suture; and those that are short in length or limited in thickness are often technically challenging and unnecessary to repair.¹ Although MRI is sensitive and specific for diagnosing meniscal tears, there has been much debate regarding whether it can be used to predict tear reparability.^{8,14} Given that meniscal repair portends a significantly longer rehabilitation period with more postoperative restrictions, the ability to inform a patient whether his or her tear is likely to be repaired would be valuable information to mitigate expectations and help the patient prepare for postoperative recovery. The additional operating room time and surgical equipment required for repair means that accurate foresight of the procedure would be valuable to the surgeon, hospital administration, and operating room staff.

Despite advances in MRI technology, this study suggests that with our current criteria, MRI is not an effective or efficient tool for predicting reparability. Paying heed to previous work illustrating how valuable experience and training are in terms of the ability to accurately detect meniscal lesions on MRI,¹⁵ we evaluated the effectiveness of MRI to predict meniscal reparability with only senior musculoskeletal radiologists. We also controlled for variability in the image quality by excluding all patients with outside MRI studies. Finally, we excluded all patients with MRI more than 3 months before arthroscopy, given that a noted weakness of previous studies was the possibility of additional injury to the meniscus during the interval between MRI and surgery.¹⁴

Nourissat et al¹⁰ recently published results suggesting that they were able to use MRI to correctly predict

reparability in 90 of 100 cases of meniscal tear. Their report of a sensitivity of 94% in predicting meniscal tear reparability is in stark contrast to our results. However, a closer examination of the methods of their study shows that they reviewed 200 images and excluded 100 that did not have longitudinal full-thickness lesions. Therefore, although MRI may be more successful in predicting the meniscal reparability of a subset of meniscal tear patients, the methods used in the Nourissat et al study allowed for significant selection bias that may have resulted in data different from what we observed. This same group published a second study in which MRI allowed correct prediction of reparability in 26 of 28 buckle-handle meniscal lesions.¹⁴ Again, although reparability of certain subsets of meniscal tears may be better predicted by MRI, the low percentage of meniscal tears that are of the bucket-handle variety make these results less generalizable to the majority of meniscal tears. Finally, in another study of a subset of meniscal tears, Shiozaki et al¹³ reviewed 61 semilunar lateral meniscal tears by MRI and found that the sensitivity for predicting reparability was only 33%.

In the only published report of using MRI to predict reparability in an all-inclusive set of meniscal tears, Matava et al⁸ concluded that MRI was of little benefit in predicting meniscal reparability. Although our results echo this conclusion, we believe that our findings demonstrate even stronger evidence against using MRI to predict reparability. We took several measures to eliminate confounding factors that may artificially improve our ability to predict reparability, and our results show that we were even less effective at predicting reparability based on MRI than the examiners in the Matava et al study. First, we excluded patients older than 40 and younger than 16 years because older patients are far more likely to have irreparable, degenerative tears. In the Matava et al study, raters were not blinded to patient age and thus had additional information from which to make predictions of reparability. The researchers also permitted their reviewers to classify some tears as *questionable* for repair, whereas our examiners were forced to give each tear a definitive *reparable* or *not repairable*. The former may have artificially improved results because *questionable* examinations were included in some of their statistical analyses.

The first limitation of the current study is the fact that we did not control for concomitant procedures. Although we excluded patients with primary diagnosis codes other than that for meniscal tear, patients with concomitant

anterior cruciate ligament injuries, posterolateral corner, or osteochondral injuries were included in the study and therefore present a somewhat heterogeneous patient population. Second, given that the study is retrospective, we cannot guarantee that the arthroscopic criteria defined by the surgeons for repair were strictly adhered to when making an intraoperative decision on reparability. If there were other variables involved in the decision, it was not the inability of the MRI to assess the arthroscopic criteria but rather a flaw in our definition of reparability criteria. In other words, the retrospective nature of the study prevented us from comparing MRI read to intraoperative findings and forced us to use the surrogate—that is, the surgical procedure performed—as the gold standard. It is clear that this introduces the possibility of confounding because it is difficult to retrospectively ascertain how strictly anatomical criteria were applied in surgical decision making. Finally, the study was performed using 1.5T scanners, and the improved resolution on 3T scanners now widely used may allow better predictions of meniscal reparability in the future. However, recent studies showed no improvements in the sensitivity of 3T MRI for detecting meniscal tears when compared with 1.5T scanners,⁶ so further study is needed to investigate this question.

A final potential source of bias exists in the fact that all tear types were included in this study. There may be meniscal tear types that are definitely not suitable for repair, and their inclusion would provide the reviewer a method by which to predict reparability outside of applying the arthroscopic criteria. However, one must remember that this bias would lead to an artificially improved ability of MRI to predict reparability. If there were a subset of clearly irreparable tears, the reviewers would have had no difficulty identifying them as *irreparable*, and their ability to predict reparability would be overestimated. That we had such a poor ability to predict reparability despite including all tears renders our study a stronger condemnation of using MRI to predict reparability.

In sum, this study demonstrates that MRI is not an effective or efficient predictor of reparability of meniscal tears with the current arthroscopic criteria. Patients must therefore continue to be counseled about the possibility of meniscectomy versus meniscal repair when going to the operating room, given that arthroscopy remains the only accurate tool by which to assess reparability. We believe there is room for improvement in establishing radiographic definitions for meniscal reparability that

may be different from current arthroscopic criteria and so may have improved predictive value. There remains ample room for large-scale, prospective study in this area.

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