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The Diagnosis of Meniscus Tears

The Role of MRI and Clinical Examination

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Magnetic resonance imaging (MRI) and clinical examination are tools commonly used in the diagnosis of meniscus tears. It has been suggested routine MRI before therapeutic arthroscopy for clinically diagnosed meniscus tears will reduce the number and cost of unnecessary invasive procedures. We designed a systematic review of prospective cohort studies comparing MRI and clinical examination to arthroscopy to diagnosis meniscus tears. Thirty-two relevant studies were identified by a literature review. Careful evaluation by an experienced examiner identifies patients with surgically treatable meniscus lesions with equal or better reliability than MRI. MRI is superior when indications for arthroscopy are solely diagnostic. However, the methods by which such a clinician arrives at a conclusion have not been identified. To create an evidence-based algorithm for the diagnosis of a meniscus tear future investigations should prospectively assess the value of commonly used aspects of the patient history and meniscus tests. MRI is useful, but should be reserved for situations in which an experienced clinician requires further information before arriving at a diagnosis. Indications for arthroscopy should be therapeutic, not diagnostic in nature.

Level of Evidence: Level II, systematic review. See Guidelines for Authors for a complete description of levels of evidence.

Although initially thought to be a functionless, vestigial remnant of a leg muscle, the meniscus is now recognized as an integral component of the complex functioning of the knee.[28] Meniscal injury causes acute physical impairment and sets the stage for later arthrosis of the involved knee.

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Arthroscopic meniscus repair and partial meniscectomy have become two of the most common orthopaedic procedures performed in the United States.[28] However, the correct diagnosis of a meniscal tear is not always obvious, even for the experienced surgeon. This difficulty persists despite the description of many provocative physical examination maneuvers and advancements in magnetic resonance imaging (MRI) technology.

In an increasingly cost-conscious medical environment, the judicious use of expensive arthroscopic versus MRI technology in the diagnosis of internal derangements of the knee has not been clearly defined. Some clinicians suggest physical examination and clinical meniscus tests, along with a carefully taken history, are the most important and cost-effective means of diagnosing meniscal injury.[47] Others have stated the routine use of MRI before arthroscopy will reduce costs and the incidence of unnecessary invasive procedures.[60] If the findings of history and physical examination are sufficiently predictive, then an additional imaging study may not be necessary before proceeding with a therapeutic arthroscopy. The patient can be saved time and expense. A thorough understanding of the value of specific meniscal tests and historical elements, as well as the strengths and limitations of MRI, will help the clinician delineate these patients and decide an effective course of action. We sought to generate a reproducible evidence-based algorithm for approaching the patient with a suspected meniscus tear, based on such information.

We systematically reviewed the existing English-language literature to determine whether an MRI study should be routinely ordered before arthroscopy for clinically diagnosed meniscal tears. Our hypothesis was some clinical scenarios are clear enough that ordering an MRI does not add substantial value to the evaluation and will not reduce the incidence of negative arthroscopy, whereas more ambiguous cases warrant additional imaging.

MATERIALS AND METHODS

We performed a PubMed and Cochrane database literature search to identify all English-language studies evaluating the use

TABLE 1. MRI versus Clinical Examination: Studies that Favored Routine Use of MRI before Arthroscopy

Reference	N	Age (mean and range)	MRI (n)	Patients Treated with Arthroscopy	Clinical Exam Sensitivity/ Specificity/Accuracy
Elvenes et al[20]	40 (41 knees)	32 (10–55)	41	40 (41 knees)	—/—/61%
Spiers et al[56*]	58	28.9 (16–51)	58	58	77%/43%/60.3%
Weinstabl et al[60]	823	34.9/40 (14–79)[§]	143 (every 5th patient)	276 (75 after MRI)	93%/62%/78%
Munk et al[44†]	61	31.4 (15–54)	61	61	100%/6%/44%
Bryan et al[10‡]	118	28 (16–47)	59	66 No MRI patients: 42 MRI patients: 24	—/—/72% (orthopedic consultant) 44% (registrar)

of physical examination maneuvers and imaging studies for the diagnosis of meniscus tears. A PubMed search using the words "meniscus" and "knee" with limits set to "English language" and "humans" yielded 1264 results. "Knee" was included because an initial search without it identified numerous articles from the ophthalmology literature, related to the meniscus of the eye. Many articles from this search focused on rehabilitation, meniscal repair, transplantation, biomechanics or other topics not relevant to the diagnosis of a meniscal tear in the clinical setting. One hundred thirty-six articles on physical examination maneuvers or imaging modalities for the detection of meniscus tears in the knee were identified. Further PubMed searches were limited only to "English," with no other limits specified. "McMurray" and "knee" gave 28 results, of which 14 were relevant. "Apley" and "knee" generated seven results, all of which had been previously identified. A Cochrane database search using the search words "meniscus" and "knee" yielded 49 clinical trials, of which four were relevant to the diagnosis of meniscal tears. The search words "MRI, arthroscopy," and "knee" resulted in six clinical trials, three of which were relevant based on their titles. Inclusion criteria were then applied to each of these references. The prospective cohort study is the preferred study design for determining the reliability and validity of diagnostic tests.[57] All prospective cohort studies reporting on a consecutive series of patients with a universally applied gold-standard were reviewed with the aid of a worksheet including the title, author, journal, year, reference, hypotheses, and type of study. Sources of selection, measurement and confounding bias were evaluated for each paper. If bias was subjectively assessed severe, the article was excluded. Although verification bias could be minimized for MRI studies, it was not minimized for clinical examination studies because no patient without clinical symptoms of a meniscus tear could ethically be scheduled for the gold-standard test, arthroscopy. Two of the authors (MR and BP) independently reviewed each of the articles. When there was disagreement, it was discussed with the senior author (RB) until a consensus was achieved.

Studies meeting the initial inclusion criteria could be grouped by the nature of their hypothesis. They included studies on whether the routine use of MRI could reduce the number of negative arthroscopies, studies on the statistical performance of specific physical examination maneuvers, or studies specifically on MRI in the correct identification of patients with meniscal tears found on arthroscopy. Given the different nature of each type of study and the varying quality of literature existing for each subtype, slightly different exclusion criteria were applied.

For studies explicitly evaluating the performance of MRI, we required a minimum of 40 patients. The magnetic field strength (Tesla), number of sequences obtained and criteria for a positive diagnosis had to be reported. We required data for total number of tears as well as explicitly stated, or derivable, values for accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) to be separated for medial and lateral meniscal tears, as statistical performance is variable for each side. Furthermore, any study containing substantial verification bias, which arises if patients are selected to undergo the gold-standard test (arthroscopy) on the basis of the test being evaluated (MRI), was excluded. This is known to overestimate sensitivity and underestimate specificity.[6] Eight studies were selected.[11,27,29,36,38,48,49,54] Additional studies explicitly analyzing adolescent or osteoarthritic patients were reviewed separately; there are mentioned in the text, but not included in the tables.

We elected to report on specific physical examination maneuvers we believe are the most commonly known: McMurray's test (knee is maximally flexed, externally rotated and then slowly extended to evaluate the medial meniscus; internal rotation assesses the lateral meniscus; a palpable or audible thud or click is a positive test; some clinicians have added a varus or valgus stress or expanded the isolated recreation of pain to constitute a positive test); Apley's test (the patient is positioned prone with the knee flexed to 90 degrees; the tibia is compressed into the distal femur and rotated externally to assess the medial meniscus and internally rotated to assess the lateral meniscus; if this produces pain, which is less severe or relieved when the maneuver

TABLE 1. MRI versus Clinical Examination: Studies that Favored Routine Use of MRI before Arthroscopy (*Continued*)

Reference	MRI Sensitivity/ Specificity/Accuracy	Comments	Method of Clinical Diagnosis of Meniscal Tear
Elvenes et al[20]	85%/84%/84%	16 negative arthroscopies correctly predicted by MRI. 3 positive arthroscopies incorrectly negative on MRI	Patients with "clinical signs" of meniscal tear. Not otherwise specified.
Spiers et al[56]*	100%/63%/83%	Number of arthroscpies would have been reduced by 29%. No false negative MRI's. (NPV = 100%)	Referrals from general practioners or the emergency department.
Weinstabl et al[60]	96%/90%/96%	30% negative arthroscopy rate for clinical exam group. All patients from MRI group had surgical pathology	Two positive meniscal tests. Uncertain who performed exams.
Munk et al[44]†	84%/75%/79%	7 normal knees correctly identified with MRI. 14 additional patients only had "cartilage thinning." (34% rate of no arthroscopically treatable lesion)	Not specified.
Bryan et al[10]‡	—/—/68%	Economic analysis: no significant difference in costs between MRI and no MRI group. No significant difference in health outcome at 6 to 12 months. Mechanical symptoms was an exclusion criteria.	Variable in study arms.

*Sensitivity, specificity and accuracy data are for identification of patients with arthroscopically-treatable lesions of the knee in general.

†Meniscal data extracted from study

‡Study contained two arms. The clinical exam and MRI accuracy data is from the arm intended to compare the two methods. It included 114 patients, all of whom had an MRI. The economic analysis arm of the study recruited 118 patients at a different center who were randomized to MRI or no MRI. For this arm, costs and health outcomes were equivalent, but the no-MRI patients had more operative procedures—the outcome of these procedures is not specified.

§Mean age for MRI group was 34.9 years, mean age for exam group was 40 years

is repeated with distraction of the tibia [putting potentially injured collateral ligaments on stretch and decompressing the meniscus], it constitutes a positive test); and joint line tenderness. We also found well-conducted studies reporting on the Ege's squat test (the patient starts in a standing position, squats with both lower legs in maximum external rotation, and then stands up slowly; to assess the lateral meniscus, the squat is repeated with the lower legs maximally internally rotated; a complete squat in full internal rotation is rarely possible, even for healthy knees, therefore the patient is allowed to steady themselves for a slightly less than full squat;[2] Ege's test is positive when pain and/or a click are felt by the patient; in some cases, there may be a block to flexion); and the Thessaly test (patient is instructed to stand on affected foot; the examiner supports the patient by holding his or her outstretched hands while the patient rotates his or her knee and body internally and externally three times with the knee in variable degrees of flexion; medial or lateral joint line discomfort or a sense of locking or catching constitutes a positive test); these were included as well. Studies had to be a prospective cohort investigation of at least 40 consecutive patients with a universally applied gold standard for inclusion. Six such references were included.[2,14,21,23,25,33]

Papers investigating the possible role of MRI to reduce the number of negative arthroscopies had to be prospective in nature and include at least 40 consecutive patients. Studies that blindly used MRI results to definitively exclude patients from arthroscopy were excluded. The results of arthroscopy for patients with a clinical diagnosis of a meniscal tear had to be reported and compared with those from patients who had MRI. Twelve are summarized in table format.[9,10,20,22,26,34,42–44,50,56,60]

Once the exclusion criteria had been applied, the "related articles" feature of PubMed was used for each of the 21 remaining sources to identify further publications not found in the initial search. This generated a large number of references for each article; therefore, we reviewed the first 60 selections for relevant titles. Additional sources were identified from the references of the articles we selected. All of these studies were put through the same exclusion process described earlier. After application of the exclusion criteria, 11 additional sources—for a total of 32—were included. All conclusions for this systematic review are based on these 32 selections. Twenty-six of these are summarized in table format. The remaining six dealt primarily with adolescents, patients with osteoarthritis, features of clinical history, or the postoperative patient.[1,4,7,19,37,59] They are commented upon in the text.

RESULTS

Studies investigating whether routine MRI could reduce the incidence of negative arthroscopy, compared to proceeding with arthroscopy based solely upon history and clinical examination, were split with regard to their conclusions (Tables 1, 2). It is clear from these studies that varying criteria for clinically diagnosing a meniscus tear is

TABLE 2. Comparison of Physical Examination versus MR: Studies Which Concluded Routine MRI Unnecessary

Reference	N	MRI (n)	Age (mean and range)	Patients Treated with Arthroscopy (n)	Clinical Examination Sensitivity/Specificity/ Accuracy
Gelb et al[26]	17/72 consecutive patients with arthroscopy-proven isolated meniscal tears	72	N/A	37	91%/91%/91%
Esmaili et al[22]	70	70	27.9	70	100% (med) 84.6% lat/95.6% (med) 91.2% (lat)/96.9% (med) 85.5% (lat)
Miller[42]	100	57	37.5 (only mean reported)	100	—/—/80.7%
Rose and Gold[50*]	154	100*	41 (13–87)	154	95% (med) 55% lat/55% (med) 94% (lat)/82% (med) 76% (lat)
Brooks and Morgan[9†]	238	57	Male 43 (16–84) Female 50 (17–78)	238 (240 knees)	—/—/79%
Kocabey et al[34]	50 39 meniscus tears	50	22 (12–42)	50	87% (med) 75% (lat)/68% (med) 95% (lat)/80% (med) 92% (lat)
Muellner et al[43]	93	36	21.9/23.4 (14–38)[§]	93	100% (med) 92% (lat)/76% (med) 98% (lat)/93% (med) 96% (lat)

a major influence on the validity of history and physical examination when compared to MRI. Studies supporting routine MRI often did not specify the positive or negative elements used to formulate a clinical diagnosis, or who made that determination.[10,20,44,56,60] In contrast, those whose conclusions deemed routine MRI unnecessary reported diagnoses made by careful examination by an experienced orthopaedist.[9,22,26,34,42,43,50] This presumed experienced examiner coauthored many of these studies, which introduces bias to the results. In a study that did not contain such bias, Bryan et al[10] demonstrated that a senior examiner was more reliable than a relatively inexperienced one in making a correct clinical diagnosis, and this was the only report to make such a comparison for general examination.

To better identify which patients might have an uncertain diagnosis and may benefit from MRI, we compiled the highest quality available literature on the statistical performance of clinical meniscal tests (Tables 3–7). McMurray, Apley, and Thessaly tests at 5° could be considered high specificity but low sensitivity tests.[2,14,23,25,33] Joint line tenderness tends to be higher in sensitivity but lower in specificity.[2,21,25,33] The only available study evaluating Thessaly's test at 20° of knee flexion found had high sensitivity and specificity.[33] Ege's test is based on the often-repeated notion that patients with meniscal tear have pain with or a block to squatting.[2] The authors found it more specific than sensitive, and reported degenerative-type tears pose the greatest diagnostic difficulty.

In clinical practice, several tests are generally performed on one patient. In the only study reporting the results of a combination of tests, Akseki et al[2] found McMurray's test, joint line tenderness, and Ege's test all were negative in 9% of subsequently confirmed meniscus tears. Such data for combined tests are exceedingly rare.

There was a general trend for all clinical tests to decrease their reliability when there was concomitant ligamentous injury. Furthermore, clinical examination in general was less accurate for patients with degenerative lesions compared with young patients with acute injuries.[2,19] There are no prospective English-literature data on several common meniscal tests often used in the MRI versus clinical examination literature. These include Steinmann, Payr, and Böhler tests.

TABLE 2. Comparison of Physical Examination versus MR: Studies Which Concluded Routine MRI Unnecessary (*Continued*)

Reference	MRI Sensitivity/Specificity/ Accuracy	Comments	Method to Establish Clinical Diagnosis
Gelb et al[26]	82%/87%/85%	In 2 of 72 patients MRI changed non-surgical to surgical management study does not specify these patients diagnosis	100% by attending surgeon
Esmaili et al[22]	75% (med) 66.6% (lat)/94% (med) 86.2% (lat)/85.9% (med) 73.8% (lat)		By senior resident and author of paper at time of acute injury, and again 3 weeks later
Miller[42]	73.3%/81.3%/73.7%	All knees that did not have meniscal tear at arthroscopy had intraarticular surgical pathology	100% by the operating surgeon
Rose and Gold[50*]	73% (med) 35% (lat)/79% (med) 100% (lat)/75% (med) 69% (lat)	13/40 negative arthroscopy findings after a clinically suspected, but MRI negative, meniscal tear. Arthroscopy found a tear suspected on clinical exam in 27/40 patients where MRI was negative	100% by senior author of the paper
Brooks and Morgan[9†]	—/—/77%	10/240 (4%) of arthroscopies negative for treatable pathology. Data not reported specifically for MRI beyond 4 false negative MRIs and one false positive MRI	91% by consultant orthopaedist
Kocabey et al[34]	80% (med) 85% (lat)/79% (med) 97% (lat)/80% (med) 90% (lat)		100% by senior author of the paper. JLT, McMurray, Apley and Steinmann tests
Muellner et al[43]	71% (med) 100% (lat)/71% (med) 100% (lat)/91% (med) 100% (lat)		100% by both a senior resident and attending with > 10 years experience[‡]

Med = medial; Lat = lateral

*Data in the table for sensitivity, specificity and accuracy is only reported for the 100 patients who underwent both MRI and arthroscopy. Clinical examination data was not significantly different in the 54 patients who did not undergo MRI.

†Meniscal data not fully extractable. 114 knees with pre-operative diagnosis of meniscal tear

‡Two positive findings on the following tests were required for clinical diagnosis of a meniscal tear: JLT, Bohler, McMurray, Steinmann, Apley and Payr tests.

§Mean age for clinical exam group was 23.4 years, mean age for MRI group was 21.9 years.

Detection bias in terms of criteria required for a positive test, particularly in the McMurray test, plays a role in disparate results between studies. A lower threshold for a positive test will detect more tears, and thus improve the sensitivity, but likely at the expense of specificity. Selection bias will also influence results of studies, as inclusion varied for patients with concomitant anterior cruciate ligament injury or for older patients in whom there are more numerous likely etiologies, such as arthrosis, causing intraarticular knee pain.

We sought to find prospective cohort studies commenting on historical elements such as feeling a pop during a sudden twist or squat at the time of injury, or the presence of mechanical locking and recurrent effusions. To our knowledge, only two exist in the English-language literature. In a prospective study of 145 patients, Abdon et al[1] found a history of mechanical locking, patient's localization of pain to the joint line, and a decreased ability to participate in sporting activities associated with meniscus tears. Pain at rest, sick leave, and medial patellar tenderness were all negatively correlated with a meniscus tear.[1] Although not the focus of the study, Corea et al[14] reported more than 50% of patients with meniscal tears had mechanical symptoms and recurrent effusions. Currently the clinician must rely primarily on retrospective studies to confirm such stereotypical notions of clinical symptoms and mechanism of injury for meniscal tears.[12,15,30,32,52]

There were more studies evaluating MRI for diagnosing meniscus tears than those of any other type. Therefore, we were able to apply the most stringent exclusion criteria to this group of studies (Table 8). The magnetic field strength or number of sequences did not alter the utility of MRI.

TABLE 3. McMurray Test

McMurray Test Citation	N	Asymptomatic Control Group	Age (mean and range)	Included ACL-deficient Patients	Sensitivity	Specificity	PPV	NPV
Evans et al[23]*	104	Yes	Not specified	Not specified	16% (medial) 50% (lateral)	98% (medial) 94% (lateral)	83% (medial) 29% (lateral)	65% (medial) 93% (lateral)
Fowler et al[25]	161	No	33 (13–67)	Decreased value of the test	28.8%	95.3%	—	—
Karachalios et al[33]	213	Yes	29.4 (18–55)	Decreased value of the test	48% (medial) 65% (lateral)	94% (medial) 86% (lateral)	—	—
Akseki et al[2]	150	No	36 (17–73)	Did not decrease performance of the test	67% (medial) 53% (lateral)	69% (medial) 88% (lateral)	80% (medial) 59% (lateral)	—
Corea et al[14]	93	No	25.3 (only mean reported)	Not specified	64.7% (medial) 51.6% (lateral)	93.2% (medial) 93.5% (lateral)	84.6% (medial) 80% (lateral)	82.1% (medial) 79.5% (lateral)

PPV = positive predictive value; NPV = negative predictive value; Gold-standard in all studies was arthroscopy

*Positive test was a medial thud or lateral joint line pain for each respective side.

This is consistent with previous studies not meeting the exclusion criteria which specifically investigated this question.[5]

The results of Lundberg et al[38] may stand out in Table 8 as inferior compared to the others. This is the only study that explicitly studied patients with acute injuries, with MRI performed at a mean of 3 days after injury.[38] In this setting, 10 meniscal lesions requiring surgical treatment were missed in 69 patients. These would have been considered patients in whom MRI had prevented "unnecessary" arthroscopy if the study design had included verification bias. Investigations not meeting the exclusion criteria for this review which have reported the outstanding utility of MRI in evaluating the acutely injured or locked knee are plagued by verification bias, as MRI results were exclusively used to determine indications for arthroscopy.[41]

A final subgroup of patients worth mentioning is those who have recurrent pain after a previous meniscal repair or partial meniscectomy. High-quality literature focusing on clinical examination in these patients does not exist. We identified four prospective cohort studies comparing conventional MRI to MR arthrography. All patients underwent the gold standard test in two of these investigations.[4,59] Both of these concluded MR arthrography was a superior imaging method to evaluate the meniscus after a repair, or if there had been greater than 25% resection of the meniscus. Vives et al[59] showed similar reliability of MRI performed with intravenous contrast, which they referred to as indirect arthrography, compared to direct intraarticular contrast arthrography. A meniscus that had been previously operated upon was an exclusion criterion for most studies evaluating clinical examination, giving the clinician no data to guide decisions in these patients other than which imaging study to order.

DISCUSSION

A discussion of the diagnosis of meniscal tears is ultimately a discussion of indications for arthroscopy. One approach to utilization could be simply trying to reduce the absolute number of nontherapeutic invasive procedures, without missing substantial numbers of those that are necessary. Reducing cost is another issue. This could be achieved by avoiding MRI study before arthroscopy when the clinical diagnosis is relatively certain. Or alternatively, minimizing cost by reducing the number of arthroscopies if the routine use of MRI could do so without missing a large number of lesions.

The ability to reliably diagnose meniscal tears and other intraarticular pathologies of the knee by noninvasive MRI makes the concept of routinely proceeding to arthroscopy for purely diagnostic purposes obsolete. However, an experienced examiner can generally identify patients for whom a therapeutic arthroscopy is indicated with efficacy similar to, or better than, MRI. If there is uncertainty in clinical examination, then the additional data gathered from an MRI study may be of use in decision making.

Limitations of our study were dictated by the varying quality of existing literature. Different selection criteria were used for different types of studies. We were able to minimize bias for MRI studies, but clinical examination

TABLE 4. Apley's Test

Reference	Sensitivity	Specificity	Accuracy
Karachalios et al[33]	41% (med) 41% (lat)	93% (med) 86% (lat)	75% (med) 82% (lat)
Fowler et al[25]	16%	80%	—

med = medial; lat = lateral

TABLE 5. Joint Line Tenderness: Sequential Palpation of the Medial and Lateral Joint Line

Reference	N	Age (mean and range)	Asymptomatic Control Group	Gold Standard	ACL-deficient Knees	Sensitivity/ Specificity	PPV/Accuracy
Akseki et al[2]	150	36 (17–73)	No	Arthroscopy	Did not decrease statistical performance of test	88% (med) 67% (lat)/44% (med) 80% (lat)	74% (med) 47% (lat)/71% (med) 77% (lat)
Fowler et al[25]	161	33 (13–67)	No	Arthroscopy	Decreased value of test	85.5%/29.4%	—/—
Karachalios et al[33]	213	29.4 (18–55)	Yes	Arthroscopy	Decreased value of test	71% (med) 78% (lat)/87% (med) 90% (lat)	—/81% (med) 89% (lat)
Eren[21]	104	19.2 (18–20)	No	Arthroscopy	Decreased value of test	86% (med) 92% (lat)/67% (med) 97% (lat)	59% (med) 92% (lat)/74% (med) 96% (lat)

ACL = anterior cruciate ligament; med = medial; lat = lateral; PPV = positive predictive value

studies contained greater bias. We did not compare the results of studies focusing on MRI to those evaluating the value of physical examination maneuvers. Data on history and physical examination will generally contain more bias than data from MRI because of more varying criteria for what constitutes a positive test. It is more difficult and to define and combine numerous clinical findings versus identifying Crues Grade 3 signal on an MRI. Patients who have no clinical signs of meniscal tear generally do not undergo the gold standard test, arthroscopy. Therefore some degree of verification bias is nearly unavoidable.

Limitations of MRI must also be recognized. Most of the clinical studies have been performed in institutions with specialists in musculoskeletal radiology. Some investigations suggest a variation in reliability of reports and images generated from different centers.[24] Others have confirmed the extent of training of interpreting radiologist is an important factor in gaining diagnostic accuracy.[61] However, among those who specialize in musculoskeletal radiology, diagnoses tend to be fairly consistent.[61]

Physicians who interpret MRI images must be familiar with the various known specific pitfalls in interpretation of meniscal tears, such as a meniscal flounce, radial tears, or ligament of Wrisberg at the posterior horn of the lateral meniscus.[39,46,56,63] There is also a documented rate of meniscal tears found on MRI imaging of asymptomatic knees. Crues Grade 3 changes have been found in the asymptomatic knees of skeletally mature patients as young as the second decade, including a 13% rate in patients younger than 45 years.[8,35,36] The rate increases with age. One study reported horizontal or oblique tears are often found in asymptomatic knees, whereas radial, vertical, complex, or displaced tears are almost exclusively correlated with symptoms.[64] The above findings suggest the importance familiarity with the institution at which MRI is performed, as well as clinical correlation with any positive or negative findings.

The criteria of high-intensity signal contacting the articular surface of the meniscus (Crues Grade 3) is well established to diagnose a meniscal tear on MRI.[16,18] Explicit criteria for clinical diagnoses are less defined. The literature does not specify the method by which the experienced clinician whose diagnostic ability is equivalent to or better than MRI arrives at a conclusion.

Improving the clinician's ability to clinically diagnose meniscal tears by history and physical examination is paramount to reducing costs, while avoiding unnecessary invasive arthroscopy. Furthermore, many countries have long waiting times for MRI studies, and therapeutic arthroscopy based on reliable clinical examination may allow for more timely treatment of a lesion.

The conclusions we reached in our systematic review agree with those from the metaanalysis by Solomon et al[55]

TABLE 6. Thessaly's Test[33] at 5 and 20°

Thessaly Test	Medial Meniscus 20°/5°	Lateral Meniscus 20°/5°	Combined with Ligament Injury 20°/5°
Sensitivity	89%/66%	92%/81%	80%/65%
Specificity	97%/96%	96%/91%	91%/83%
False positive	2.2%/2.9%	3.7%/8%	9%/17.6%
False negative	3.6%/11.4%	0.73%/1.7%	1%/1.7%
Accuracy	94%/86%	96%/90%	90%/82%

TABLE 7. Akseki et al[2] Ege's Test

Ege's Test	Ege's (medial/lateral)
Accuracy (%)	71/84
Sensitivity (%)	67/64
Specificity (%)	81/90
PPV (%)	86/58
NPV (%)	57/90

PPV = positive predictive value; NPV = negative predictive value

TABLE 8. MRI for Evaluation of Meniscus Tear

Reference	Magnetic Field Strength	Number of Sequences	Number of Patients	Meniscus	Number of Tears
Gluckert et al[27]	1.5 T	1	80	Medial	35
				Lateral	12
Grevitt et al.[29]	0.2 T	2	55	Medial	25
				Lateral	9
LaPrade et al[36]	1.0 T	5	72	Medial	34
				Lateral	20
Lundberg et al[38]	1.5 T	3	69	Medial	19
				Lateral	26
Bui-Mansfield et al[11]	1.5 T	4	50	Medial	20
				Lateral	15
Rappeport et al[48]	0.1 T	3	47	Medial	14
				Lateral	5
Riel et al[49]	0.2 T	6	244	Medial	114
				Lateral	46
Winters and Tregonning[62]	1.5 T	3	67	Medial	31
				Lateral	13

who concluded the composite examination for meniscal injuries of the knee performed much better than specific maneuvers. This suggests a synthesis of examination findings and historical items must be refined for adequate diagnosis. This has been reinforced in the German literature.[31] To perform such a synthesis of information, the clinician must be familiar with the value of each positive or negative finding.

Multiple studies document no single meniscus test provides adequate diagnostic utility in isolation. Furthermore there currently are no English-language data to help the clinician evaluate the importance of positive or negative findings for many commonly used meniscal tests. Future studies should recognize these shortcomings and also account for the fact that a combination of positive and negative findings on physical examination maneuvers is more relevant to the clinician.

Several of the papers comparing clinical examination to MRI specified two or more positive findings of numerous meniscal tests were considered diagnostic.[22,34,43,60] It is uncertain how rigidly this was adhered to by the experienced examiner. We believe at least one of the positive findings must be for one of the numerous tests considered more specific than sensitive. Perhaps there are elements of the clinical history, such as mechanism of injury or mechanical symptoms, which future prospective investigations will find highly specific. Basing decisions on multiple positive, highly sensitive—but not very specific—tests will likely lead to a number of erroneous diagnoses. However, evidence-based data to support this hypothesis are lacking.

Certain situations and patient groups will continue to be challenging in meniscal tear diagnosis. The acutely injured knee is often difficult to examine with the described physical examination tests, and MRI has a reduced performance in this setting.[38] Most of the studies documenting meniscus tests excluded acutely injured knees because the pain decreases the reliability of the examination.[1,2,25,33] The high-level athlete who requires timely decision making is most adversely impacted by the lack of evidence-based direction in this setting.

Although meniscal examination is less reliable in patients with coexisting anterior cruciate ligament injury, it could be argued this is of limited importance because the patient may already have an indication for therapeutic arthroscopy.[50,53] Furthermore, MRI accuracy also tends to diminish in the presence of concomitant ligamentous derangement. Tears in the meniscal periphery and posterior horn of the lateral meniscus are frequently not identified on imaging.[17,50,51]

The patient with a suspected degenerative meniscal tear is also a therapeutic challenge. Clinical examination is less reliable in these patients who often have a different, less acute mechanism of injury, and have numerous other possible degenerative causes contributing to their intra-articular knee pain.[19] In one study of patients with symptomatic osteoarthritis of the knee, MRI detected meniscus tears in 91%, whereas asymptomatic age-matched control subjects (mean age, 67 years) had a rate of 76%, making MRI findings difficult to interpret.[7] There is also debate about the value of therapeutic arthroscopy in these patients.

On the other end of the age spectrum, difficulties in MRI interpretation of pediatric and adolescent menisci have been well described. Morphologic changes of intra-articular structures are known to occur during growth and alter their appearance on MRI. Grade 2 and 3 signal is seen in many young patients due to normal hypervascular-

TABLE 8. MRI for Evaluation of Meniscus Tear (*Continued*)

Reference	Accuracy	Sensitivity	Specificity	PPV	NPV
Gluckert et al[27]	95%	97%	93%	92%	98%
	100%	100%	100%	100%	100%
Grevitt et al[29]	91%	92%	90%	88%	93%
	96%	89%	98%	89%	98%
LaPrade et al[36]	99%	100%	97%	97%	100%
	90%	70%	98%	93%	89%
Lundberg et al[38]	68%	74%	66%	45%	89%
	71%	50%	84%	65%	73%
Bui-Mansfield et al[11]	94%	90%	97%	95%	94%
	88%	60%	100%	100%	85%
Rappeport et al[48]	77%	86%	73%	57%	92%
	91%	40%	98%	67%	93%
Riel et al[49]	95%	93%	94%	97%	94%
	94%	83%	96%	84%	96%
Winters and Tregonning[62]	92%	87%	92%	89%	90%
	82%	46%	91%	88%	55%

PPV = positive predictive value; NPV = negative predictive value; T = Tesla

ity.[13,58] In the only prospective cohort study, Luhmann et al[37] demonstrated MRI interpretations did not add value to the clinical diagnosis of an experienced pediatric sports medicine physician and were often grossly misleading. These data are limited by the fact that it was for one clinical examiner who was skilled in the examination of this difficult patient population in whom lesions may present differently than in the typical adult population.

The most enlightening studies for our review were those comparing clinical diagnosis to MRI. The conclusions of these studies could generally be predicted by the description, or lack of description, of how the clinical diagnosis of a meniscus tear was made. A careful examination by a physician experienced in knee evaluation is required for optimal results compared to MRI. However, the generalized application of these results is uncertain. There were few data in terms of specific methodologies to arrive at a clinical conclusion; and there is room for argument regarding who should be considered an experienced examiner.

Likewise, data for specific physical examination maneuvers were available only as isolated tests. This is not how these tests are used in clinical practice where several of them should be performed on a given patient. They are performed in the context of a clinical history, for which almost no prospective data exist. One of our goals was to develop an algorithm for evaluating a patient with a suspected meniscus tear. Given the above limitations, we did not feel we could reasonably generate a specific standardized evidence-based approach.

Other potential reasons to order an MRI before proceeding to therapeutic arthroscopy can be cited. Retrospective studies have suggested MRI is not useful for predicting meniscal repairability.[40,54] Some clinicians may desire a noninvasive imaging study because of catastrophic, but very rare, incidences of tumors around the knee misdiagnosed as athletic injuries.[45] Our hypothesis is these cases are sufficiently unusual to an experienced examiner upon history and physical examination that an MRI instead of a diagnostic arthroscopy would be indicated. Medico-legal concerns and patient expectations have not been addressed in the literature.

Careful examination by an experienced clinician can generally diagnose meniscus lesions as well or better than MRI. In such cases, a judgment is made to proceed with a therapeutic arthroscopy, rather than one for diagnostic purposes. MRI should be reserved for instances in which the experienced clinician requires additional information before making a decision. The results of the imaging study should be considered in the context of the broader clinical picture.

In the past, diagnostic arthroscopy was commonly used to evaluate the painful knee. However, noninvasive MRI is such a useful adjunct in the evaluation of intraarticular knee disorders that routine diagnostic arthroscopy should be considered obsolete. Arthroscopy should only be undertaken with intention of treating a specific clinical diagnosis.

Further investigations of the statistical value of commonly used meniscus tests, the importance of various combinations of positive and negative examination findings, and of relevant elements of the clinical history are essential for aiding the clinician whose judgment should drive decision making. This will be necessary before any type of evidence-based decision-making algorithm can be created. Such an algorithm must recognize adolescents, patients with osteoarthritis, acutely injured patients, ACL-deficient patients, and a meniscus that had been previously

operated upon represent unique population groups. Despite the development of highly specialized imaging techniques and physical examination maneuvers, Graham Apley's statement, made in 1947 is still true today. "There is no constant and pathognomonic sign for a meniscus tear."[3]

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