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Current Concepts

Magnetic Resonance Imaging of the Postoperative Meniscus

Kennan Vance, D.O., Richard Meredick, M.D., Mark E. Schweitzer, M.D.,
and James H. Lubowitz, M.D.

Abstract: Imaging of the postoperative meniscus is a challenge. Nevertheless, magnetic resonance imaging (MRI) of the symptomatic knee after meniscal surgery is a valuable diagnostic study of both the menisci and the entire joint. At present, symptomatic patients who have had partial meniscectomy of less than 25% may be evaluated by MRI. For those with partial meniscectomy of greater than 25% or after meniscal repair, direct or indirect magnetic resonance arthrography (MRA) should be considered. Currently, the decision of whether to perform direct (intra-articular) versus indirect (intravenous) MRA must be reviewed on a case-by-case basis considering both the patient's ability to tolerate intra-articular injection and whether a significant effusion already exists, which will imbue the tear with synovial fluid (making intra-articular injection of less importance). In such cases of significant effusion, indirect MRA would be preferred. If MRI or MRA is contraindicated, computed tomography arthrography seems a promising alternative. For a patient who has undergone meniscal allograft transplantation, MRI seems adequate for detecting meniscocapsular healing, allograft extrusion, and allograft tear. Future improvements in MRI sequencing may obviate the need for invasive modalities. **Key Words:** Magnetic resonance imaging—Magnetic resonance arthrography—Meniscectomy.

Knee arthroscopic meniscal surgery is a most commonly performed procedure. Because tissue loss at meniscectomy correlates with clinical symptoms and diminished function and activity,¹ meniscal repair or meniscal allotransplantation is ideally preferred. Yet, whereas the outcomes of meniscal repair²⁻⁹ or transplantation¹⁰ are good, many such patients have persistent symptoms.¹¹ Identifying the source of these residual symptoms is a challenge.

Magnetic resonance imaging (MRI) is a most accurate test for evaluation of primary meniscal pathology,¹² but

prior meniscal surgery confounds MRI interpretation. The specific challenge is to distinguish between normal postoperative findings and new meniscal tears (or failure to heal).

The purpose of this article is to review the literature regarding MRI of the postoperative meniscus with a goal of aiding clinicians who treat patients with clinical symptoms after prior meniscal surgery.

MENISCECTOMY AND DIRECT (INTRA-ARTICULAR) OR INDIRECT (INTRAVENOUS) ARTHROGRAPHY

After partial meniscectomy, criteria for diagnosis of a recurrent meniscal tear include (1) linear signal abnormality extending to an articular surface (grade 3 signal) on intermediate-weighted images, with fluid extending into a linear abnormality on T2-weighted images, or (2) morphologic appearances not typical for postoperative menisci such as meniscal fragmentation and displaced meniscal tissue.⁸ Yet these criteria must be clarified by caveats.

From the Taos Orthopaedic Institute Research Foundation (K.V., R.M., J.H.L.), Taos, New Mexico, and New York University (M.E.S.), New York, New York, U.S.A.

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Address correspondence and reprint requests to James H. Lubowitz, M.D., Taos Orthopaedic Institute Research Foundation, 1219-A Gusdorf Rd, Taos, NM 87571, U.S.A. E-mail: jlubowitz@kitcarson.net

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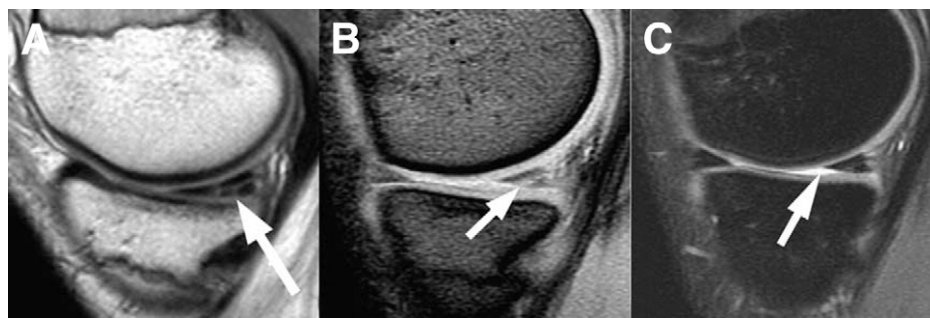


FIGURE 1. (A) The sagittal T1-weighted MRI scan shows a complex tear (arrow) of the posterior horn of the meniscus. (B) After a circumferential resection, there is a persistent “grade 3” signal abnormality (arrow) abutting the inferior articular surface on the T2 sagittal sequence, representing an “intrameniscal signal conversion” that can often be confused with a recurrent tear. (C) The sagittal T2-weighted image shows synovial fluid (arrow) abutting the inferior surface of the posterior horn but not entering the “grade 3” signal abnormality, suggesting that this is not a recurrent or residual tear. (Reprinted with permission.¹⁷)

With regard to fluid extending into a linear abnormality, surgeons must be aware of “false-positive” findings (interpretation of a tear when a tear does not exist) as a result of “intrameniscal signal conversion,”^{13,14} which is quite simply defined as well-performed arthroscopic partial meniscectomy converting intrameniscal signal to grade 3 signal. Such a phenomenon occurs when presurgical intrameniscal signal is found adjacent to torn meniscal tissue. When the torn tissue is treated with partial resection, the presurgical signal may now communicate with the exposed, postmeniscectomy, peri-articular tissue surface, thus creating the specious appearance of a grade 3 signal (Fig 1).

With regard to morphologic appearances not typical for postoperative menisci such as meniscal fragmentation and displaced meniscal tissue, this presumes familiarity with “typical” postmeniscectomy MRI,

which is not common, because postmeniscectomy MRI is not clinically indicated in the asymptomatic patient. Arthroscopic surgeons are thus advised to focus on the amount and anatomic location of the prior resection (as well as the morphology of the primary tear when known). The specific foci should include the overall size of the residual meniscus relative to specific areas of meniscal truncation, general appearance of the anterior and posterior meniscal horns, and blunting of the meniscal apical margin (Fig 2).¹⁵ A general clinical pearl is to first assess overall residual meniscal size by use of a midcoronal image; if the previous meniscal resection was less than 25% of the total meniscus, the MRI diagnostic criteria are reliably similar to those of a virgin meniscus.^{13,16} Logically, primary MRI criteria are also applicable in areas remote from a previous surgical site.

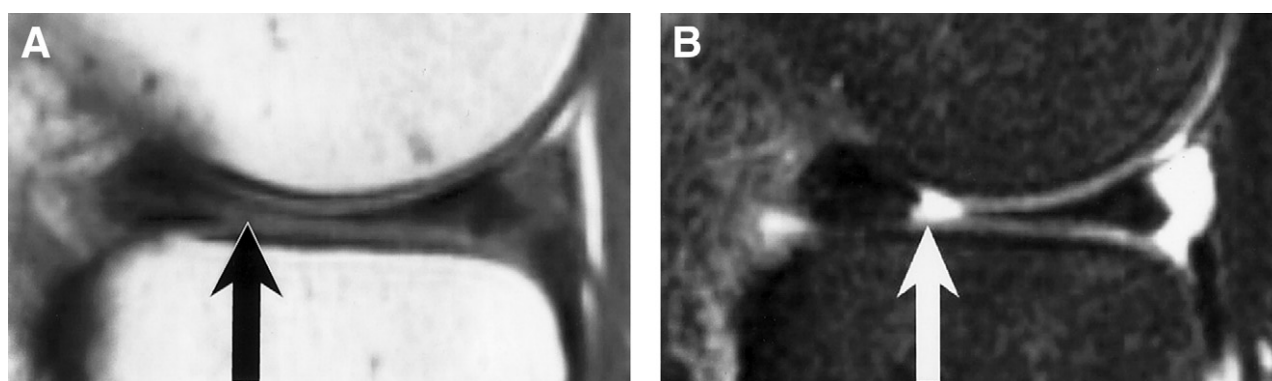


FIGURE 2. True-negative meniscal morphologic changes due to prior meniscectomy with no recurrent tear on conventional MRI. (A) The sagittal intermediate-weighted image shows a linear focus of increased intrameniscal signal intensity extending to the inferior articular surface (arrow) of the anterior horn of the lateral meniscus. (B) The corresponding T2-weighted image shows morphologic changes (blunting and truncation) of the apex of the meniscus (arrow) without an associated increase in surfacing intrameniscal signal intensity. Second-look arthroscopy showed no evidence of a recurrent meniscal tear. (Reprinted with permission.²⁰)

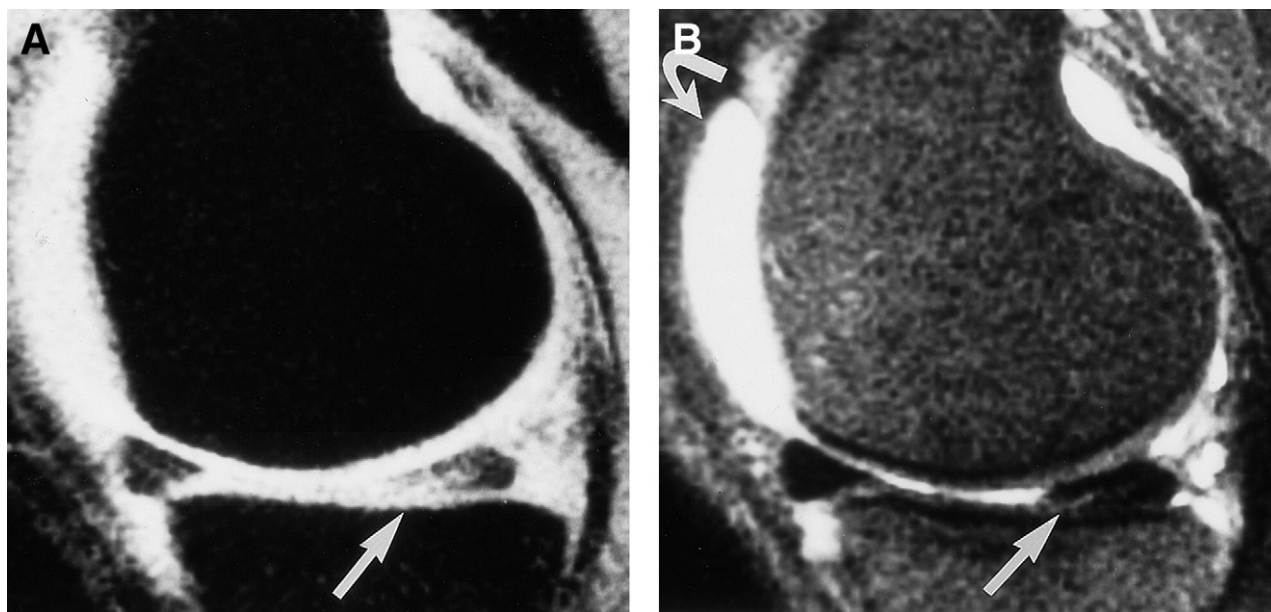


FIGURE 3. Repeat tear of medial meniscus with an intrameniscal linear area of abnormal signal intensity extending to articular surface and fluid within that line. (A) The sagittal proton density-weighted fat-suppressed image shows an oblique linear area of abnormal signal intensity (arrow) extending to the undersurface of the meniscus. (B) The sagittal T2-weighted fat-suppressed image shows fluid within the line (straight arrow) and moderate joint effusion (curved arrow). (Reprinted with permission.¹⁸)

With regard to MRI sequencing, the proton density-weighted and T1-weighted sequences in both coronal and sagittal planes are routinely used for primary meniscal evaluation, with the former being most specific. However, these sequences are less valuable for determining the presence of a recurrent or residual meniscal tear in the postmeniscectomy knee. For this reason, T2-weighted, fat-saturated sequences are often included in an effort to detect synovial fluid signal within the substance of the remaining meniscal tissue (indicating that the articular surface has been breached). In addition, proton density-weighted images are still of value.¹⁷

Bearing in mind the caveat regarding intrameniscal signal conversion (as described previously), the best conventional magnetic resonance sign of recurrent tearing of the postoperative meniscus is grade 3 signal abnormality (Fig 3).¹⁸ Yet, without a significant joint effusion, accuracy may be decreased because joint fluid may not imbue the tear. In such cases direct magnetic resonance arthrography (MRA) is indicated and has an overall accuracy of 82% in detecting repeat meniscal tears.¹⁸ Similarly, whereas conventional MRI has 89% accuracy in patients having undergone resection of less than 25% of the meniscus, the accuracy of noncontrast MRI is significantly less for patients having resection of greater than 25%.¹⁹ In such patients (>25% resection), the accuracy

of conventional MRI was 65%, whereas the accuracy of direct MRA was 87%.¹⁹

MRA results in articular distention and increased intra-articular pressure such that contrast material will

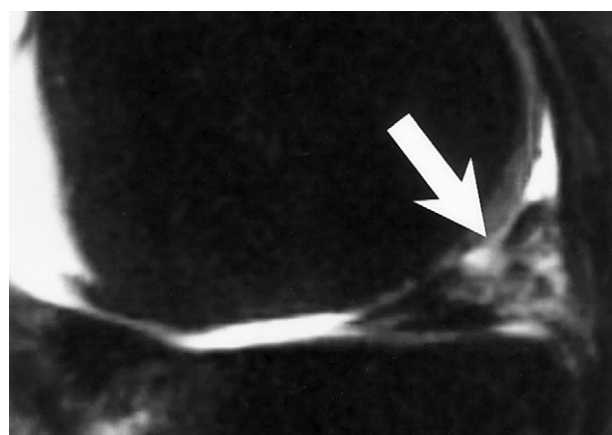


FIGURE 4. True-positive recurrent meniscal tear and fragmentation on direct MRA. The sagittal T1-weighted fat-suppressed image from direct MRA shows extensive morphologic changes and fragmentation of the superior articular surface (arrow) of the posterior horn of the medial meniscus. The intra-articular distention from the arthrogram enables contrast to separate articular surface from meniscus and allows contrast to imbue the tear. These findings correspond to an arthroscopically confirmed recurrent meniscal tear. (Reprinted with permission.²⁰)

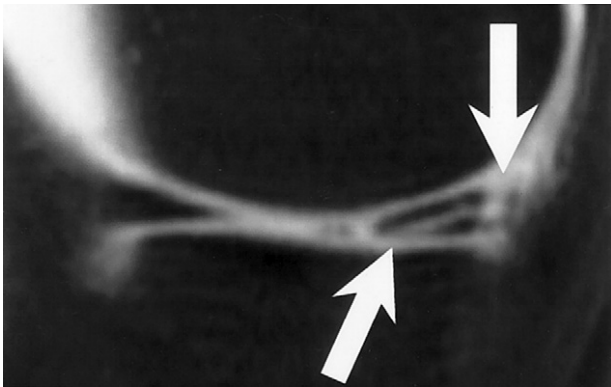


FIGURE 5. True-positive recurrent meniscal tear on direct MRA. Sagittal T1-weighted fat-suppressed direct MRA image shows a linear focus of increased surfacing intrameniscal signal intensity (arrows) within the posterior horn of the medial meniscus. A corresponding recurrent meniscal tear was confirmed at second-look arthroscopy. (Reprinted with permission.²⁰)

imbue a tear cleft as the periarticular surfaces of the menisci separate from the articular cartilage, permitting passage of contrast material into a tear^{15,19} (Figs 4 and 5). The specific use of gadolinium as a contrast material allows excellent MRA resolution as compared with synovial fluid within a meniscal tear. Whereas direct MRA has the disadvantages of intra-articular injection and utilization of the resources of a physician or physician extender, MRA is generally reported to be a safe procedure with a low risk of complications.²⁰

Indirect MRA has an accuracy similar to direct arthrography while offering several advantages. Intravenous injection may be more comfortable to patients with a painful, pre-existing effusion. In addition, intravenous access can be performed by technologists,

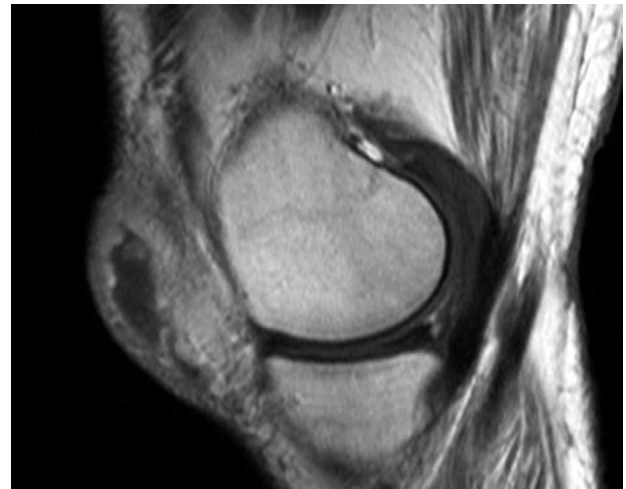


FIGURE 7. Indirect MRA image of postoperative knee showing inadequate delay with only rim enhancement of prepatellar bursitis. One advantage of indirect arthrography is verification of extra-articular pathology such as prepatellar bursitis or other conditions that enhance and otherwise might be overlooked in a direct MRA study.

so a physician's presence is not needed, decreasing costs and scheduling difficulties. Perhaps the greatest advantage of indirect MRI is that the pathologic condition is image enhanced as a result of increased blood flow caused by inflammation²¹ (Fig 6). Similarly, image enhancement of areas of inflammation above may show nonmeniscal sources of pain that may be contributing to the patient's complaints (Fig 7).

A prospective randomized trial evaluating 41 patients for detection of recurrent meniscal tears comparing MRI versus both direct and indirect gadolinium-enhanced MRA showed a sensitivity of 57.9%, specificity of 80%,

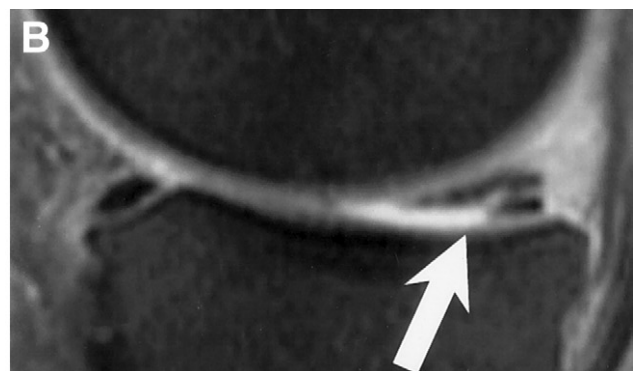
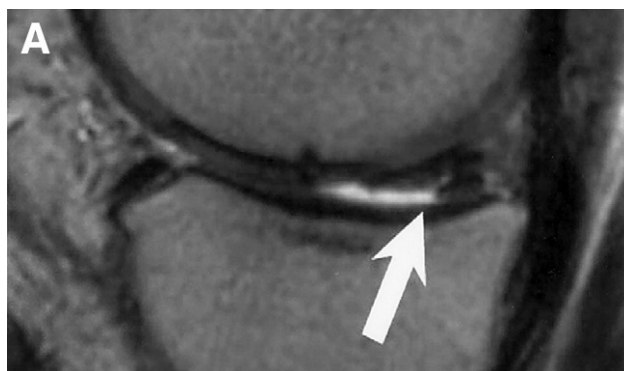


FIGURE 6. True-positive recurrent meniscal tear on indirect MRA. Sagittal T2-weighted (A) and T1-weighted (B) fat-suppressed images obtained as part of indirect MRA show a focus of oblique increased intrameniscal signal intensity extending to the inferior surface (arrow) of the posterior horn of the medial meniscus. A corresponding recurrent meniscal tear was shown at arthroscopy. (Reprinted with permission.²⁰)

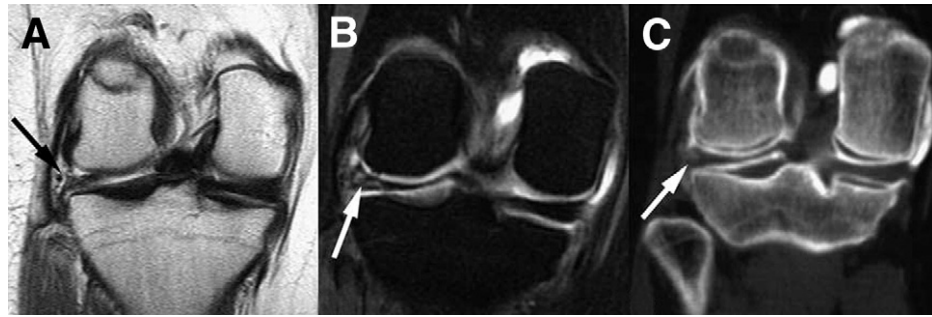


FIGURE 8. (A) Coronal proton density T2-weighted image showing meniscocapsular increased signal (arrow) in and around posterior horn of lateral meniscus after repair of a peripheral vertical tear. (B) Fat-saturated T1-weighted coronal MRA shows persistent high signal (arrow) within the posterior horn of the meniscus, which cannot be traced to an articular surface. (C) Coronal reformatted CT angiogram shows an intact repair site (arrow). (Reprinted with permission.¹⁷)

and overall accuracy of 62.5% using MRI.²¹ Indirect MRA improved sensitivity to 90.9%, specificity to 100%, and overall accuracy to 93.8%. Direct MRA had a sensitivity of 91.7%, specificity of 100%, and an accuracy of 92.9%. Statistical power analysis revealed that to show a true statistical difference between MRI and direct MRA with 90% power, at least 45 patients would have been needed in each group.²¹

In summary, whereas the published literature lacks sufficient statistical power to show evidence-based superiority of MRA, the trend toward improved accuracy of MRA as compared with MRI for patients with prior partial meniscectomy of greater than 25% is compelling.^{16,19-22}

Meniscal Repair

Whereas evaluating patients with pain after partial meniscectomy is a challenging problem, the evaluation of patients with residual symptoms after meniscal repair may be even more challenging because increased MRI signal intensity including grade 3 signal may be expected after successful meniscal repair.^{14,23,24} Such signal may reflect either immature fibrovascular granulation tissue or mature fibrocartilaginous scar tissue at the repair site, and this finding persists in 50% of menisci, after repair, at a mean follow-up of 12.9 years²⁴ (Fig 8).

Bearing in mind the challenge noted in the previous paragraph, 3 criteria may be used to determine the presence of a new tear in a previously repaired meniscus: grade 3 signal intensity with increased intensity on T2-weighted images, a tear at a location other than the prior repair, or a displaced meniscal fragment.²³

The literature regarding MRI versus MRA after meniscal repair is controversial. An early report suggests that MRI is not a useful diagnostic tool for

evaluating recurrent meniscal tears after repair because it is too difficult to distinguish between post-repair scar tissue versus a tear.²⁵ Yet a later report evaluating a small cohort of patients using the gold standard of second-look arthroscopy found that MRI was 100% accurate in diagnosing recurrent tears after meniscal repair.²⁰ In contrast, other investigators report that all patients with symptoms after meniscal repair require MRA to diagnose residual or recurrent meniscal tears (Fig 9).¹⁶ Direct MRA may show con-



FIGURE 9. Direct MRA image showing a recurrent tear of a previously repaired posterior horn (right) of medial meniscus plus anterior effusion (left) and popliteal cyst (far right). (Reprinted with permission.²¹)

trast material extending either completely across or partially across a repair site, indicating either recurrent tear or failure to heal.¹⁶ Indirect MRA may enhance the reparative tissue at the site of prior meniscal repair.²⁶ This again, however, may be confounding because it is not easy to differentiate normal, postsurgical change from pathology. A study comparing serial MRI versus indirect MRA showed abnormal signal in 90% of patients in the indirect MRA group versus only 25% of patients in whom MRI was used, as well as significant reduction in signal-to-noise ratio over time with indirect MRA.²⁷

In summary, MRI evaluation of successful meniscal repair is difficult to distinguish from recurrent tear. In our opinion future development of improved MRI sequencing is required, and additional research is required to distinguish the advantages of various MRA techniques.

Meniscal Transplantation

Few articles review MRI of the post-transplantation meniscus. In general, the MRI criterion for a successful transplantation is complete meniscocapsular healing. Unsuccessful results are defined as a totally or partially detached allograft, grade 3 signal, extrusion of allograft over the peripheral border of the tibial plateau, or progressive loss of the adjacent articular cartilage (which may be independent of allograft healing).²⁸ It appears that most meniscal allografts show signal intensity alterations during remodeling as part of healing, and low signal intensity is common in the body of a meniscal allograft until remodeling is complete.²⁹

MRI of the postoperative meniscal allograft must be correlated with clinical findings.³⁰⁻³² Some authors suggest that MRI of a transplanted meniscus does not predict clinical outcome.³² Others report good correlation between MRI and second-look arthroscopy plus increased signal intensity in the posterior horn of meniscal allografts associated with moderate or severe chondral degeneration.³⁰ Still others report that MRI correlates with second-look arthroscopy but not with clinical outcome³¹ or, in contrast, that clinical results correlate with arthroscopy but not MRI. In sum, the literature is not conclusive.

No studies have been published evaluating MRI versus MRA for assessment of the meniscal allograft. Conventional MRI may (Fig 10) or may not be adequate. In the future weight-bearing MRI may be of value. In our opinion current weight-bearing scanners are of less-than-optimal field and gradient strength. In

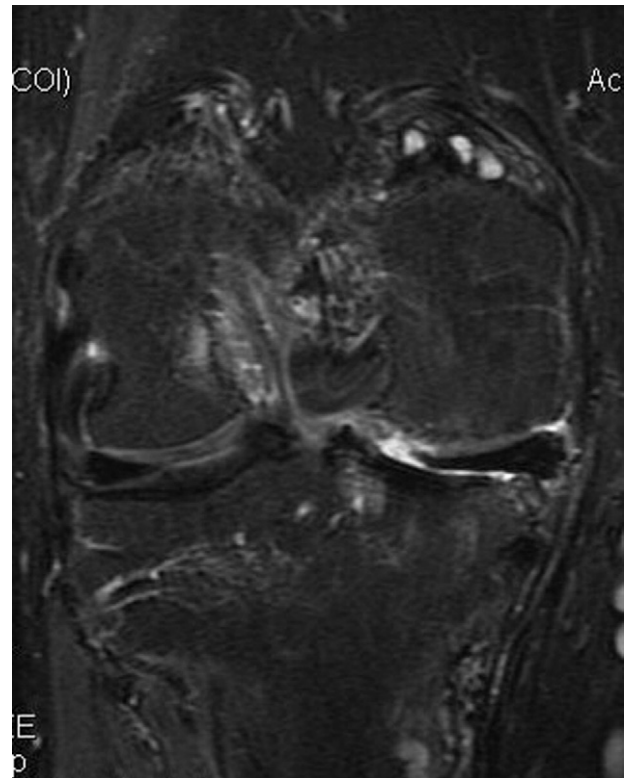


FIGURE 10. Coronal T2-weighted image of 1-year follow-up after right knee medial meniscal allograft transplantation (right). Note meniscocapsular healing and no significant extrusion of the graft over the tibia. In this situation indirect MRA is less than ideal. (Courtesy of Kevin Stone, M.D.)

addition, it is difficult for symptomatic patients to maintain a weight-bearing position without movement, which denigrates scan quality.

Other Imaging Modalities

For the patient who is unable to undergo MRI, there are other viable options for evaluation of the postoperative meniscus. Conventional arthrography of the postoperative meniscus has not been extensively studied. One study reports only 58% accuracy for conventional arthrography of the postoperative meniscus,²² whereas another concludes that conventional arthrography is better than MRI.²³ However, a significant limitation of the second study is that second-look arthroscopy was not used as the gold standard.

Computed tomography (CT) arthrography, much like direct MRA, uses an intra-articular injection of contrast material followed by tomographic imaging. Evaluation of spiral CT arthrography in 20 postmeniscectomy patients (with second-look arthroscopy used as

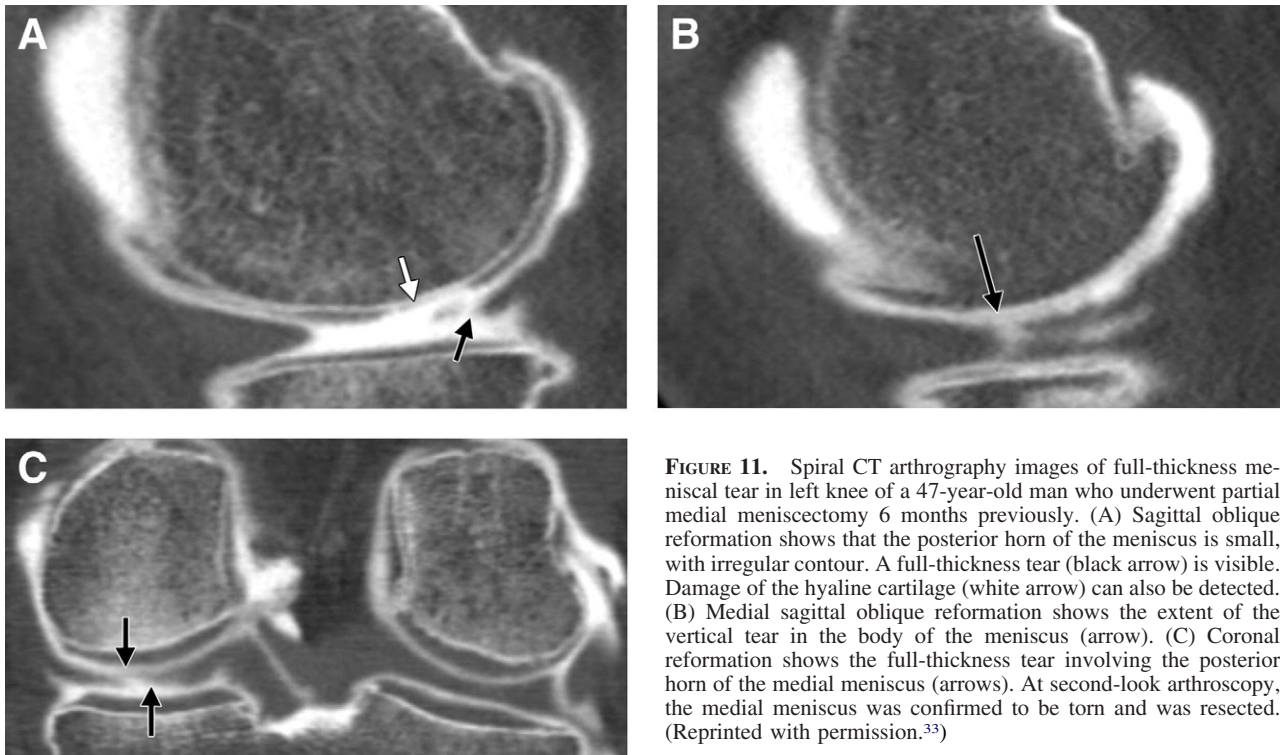


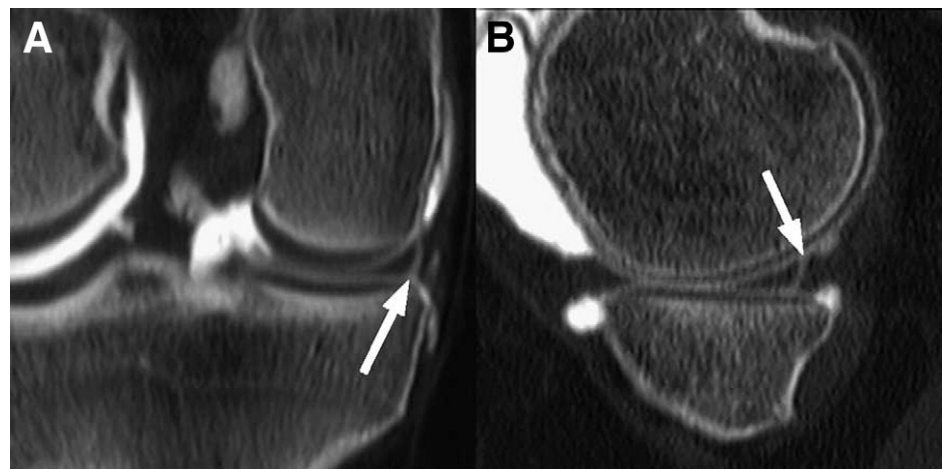
FIGURE 11. Spiral CT arthrography images of full-thickness meniscal tear in left knee of a 47-year-old man who underwent partial medial meniscectomy 6 months previously. (A) Sagittal oblique reformation shows that the posterior horn of the meniscus is small, with irregular contour. A full-thickness tear (black arrow) is visible. Damage of the hyaline cartilage (white arrow) can also be detected. (B) Medial sagittal oblique reformation shows the extent of the vertical tear in the body of the meniscus (arrow). (C) Coronal reformation shows the full-thickness tear involving the posterior horn of the medial meniscus (arrows). At second-look arthroscopy, the medial meniscus was confirmed to be torn and was resected. (Reprinted with permission.³³)

the gold standard) showed (initial) interpretation of 100% sensitivity and 78% specificity for detecting residual or recurrent tearing after meniscectomy by use of conventional criteria for a meniscal tear.³³ When the same images were reanalyzed by use of more stringent criteria, the sensitivity fell to 93% but specificity increased to 89% (Figs 11 and 12). The CT arthrography technique appears to show great promise.

NONMENISCAL FINDINGS

In evaluation of the symptomatic patient after knee arthroscopy, it is important to evaluate not only the meniscus but the entire knee. There may be concomitant disorders, not always related, and history, physical examination, and MRI must be correlated to identify the symptom generator. Of the concomitant

FIGURE 12. CT arthrogram performed for persisting pain after a repair of a full-thickness peripheral vertical tear of medial meniscus. Contrast medium (arrow) is shown within a persistent cleft that runs the full thickness of the body (A, coronal reformation) and posterior horn (B, sagittal reformation), suggesting a failure of this repair. (Reprinted with permission.¹⁷)



disorders, perhaps the most important with regard to long-term prognosis is degeneration of articular cartilage. For surface defects, proton density-weighted and T2-weighted images are best. However, for earlier detection of articular cartilage pathology, indirect MRA has the potential to be used to assess proteoglycan content.³⁴

CONCLUSIONS

Imaging of the postoperative meniscus is a challenge. The character of a patient's symptoms and signs, timing of previous surgical intervention, and details of surgery are all important pieces of information that can aid in the diagnosis of a recurrent or residual meniscal tear. MRI of the symptomatic knee, after meniscal surgery, is a valuable diagnostic adjunct of not only the previously treated meniscus but

the entire joint. Future research is required to define criteria for imaging options and interpretation.

At present, symptomatic patients who have had partial meniscectomy of less than 25% may be evaluated by use of MRI. For those with partial meniscectomy of greater than 25% or after meniscal repair, direct or indirect MRA could be considered. Currently, the decision of whether to perform direct versus indirect MRA could be reviewed on a case-by-case basis considering both the patient's ability to tolerate intra-articular injection and whether a significant effusion already exists, which will imbue the tear with synovial fluid and make knee injection of less value (such that less invasive, indirect MRA may be preferred). If MRI or MRA is contraindicated, CT arthrography seems a promising alternative. For a patient who has undergone meniscal allograft transplantation, MRI seems adequate for detecting menis-

Algorithm.

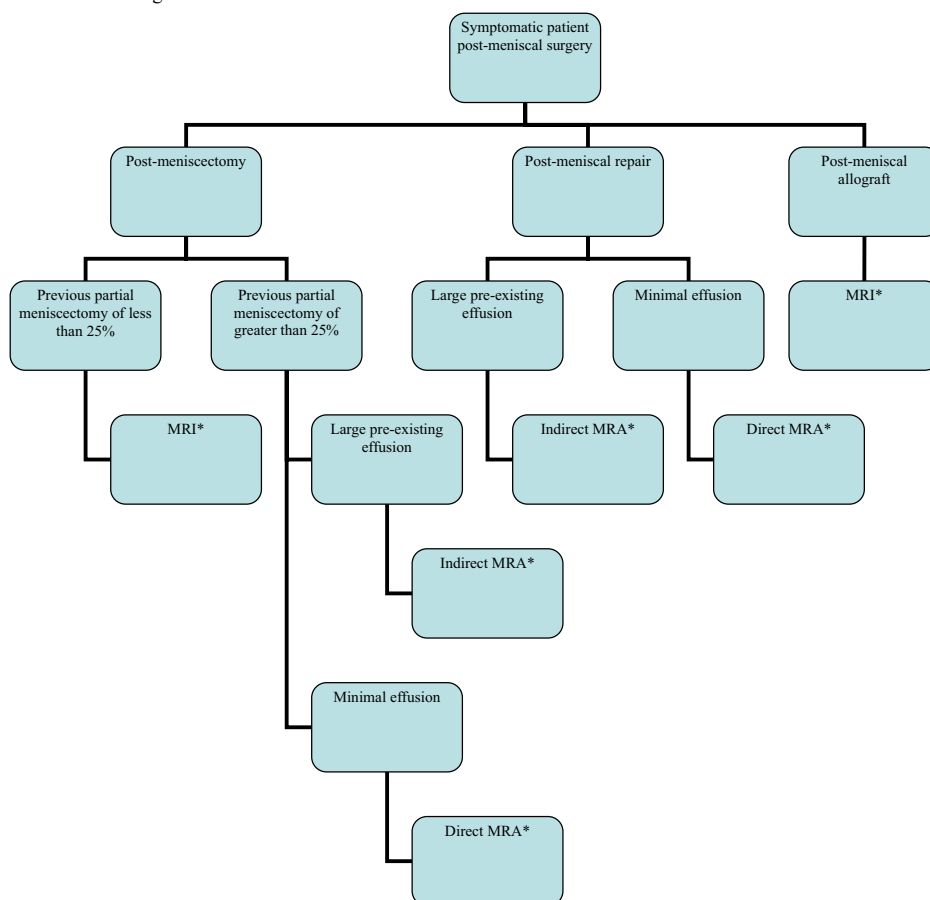


FIGURE 13. Algorithm for evaluation of postoperative meniscus. (Direct, intra-articular injection; Indirect, intravenous injection.)

* MRI contraindicated: consider CT Arthrography.

cocapsular healing, allograft extrusion, and allograft tear.

To implement an appropriate algorithm for the imaging of a postoperative meniscus (Fig 13), a thorough understanding of the strengths and limitations of each modality is required. Selecting the appropriate technique and correlating the findings with the patient's clinical picture are crucial to reaching the correct diagnosis. As the quality of the various imaging modalities continues to improve, so must our ability to apply them in the most appropriate fashion. Future improvements in MRI sequencing may obviate the need for invasive tests.

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