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MR Imaging of the Meniscus: Review, Current Trends, and Clinical Implications

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The use of MR imaging to diagnose meniscal pathology is extremely common. The sensitivity and specificity for MR imaging in diagnosing meniscal tears in patients without prior surgery varies, depending on the study; however, the consensus is that MR imaging is accurate in this patient population. Because the meniscus plays an important role in the structure and function of the knee, and the absence of a normal meniscus can lead to accelerated and irreversible degenerative changes [1,2], meniscal repair, and even transplantation, have become more common. Evaluation of the postoperative knee is more complicated, and the best imaging technique for these patients is often debated. A through knowledge of meniscal anatomy, meniscal variants, meniscal tears, and the expected postoperative appearance of repaired or partially resected menisci is required, to provide the referring clinician with useful information for patient management.

Anatomy

The menisci are wedge-shaped, semilunar (C-shaped), fibrocartilage structures composed of thick collagen fibers primarily arranged circumferentially, with radial fibers extending from the capsule, between the circumferential fibers. The superior

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surface of the meniscus is concave and the inferior surface is flat, allowing for maximal congruency between the femur and tibia. With weight bearing, the curved femoral condylar surfaces radially displace the menisci, creating circumferential hoop stresses. The circumferential arrangement of the type I collagen fibers provides the meniscus with tensile strength [2]. The menisci transmit more than 50% of body weight in extension, and even more in flexion [3]. These properties allow the meniscus to perform many functions, including the distribution of stresses over the articular cartilage, the absorption of shocks during axial loading, the stabilization of the joint in both flexion and extension, and joint lubrication; they also make a minor contribution toward secondary stabilization of the knee after cruciate ligament injuries [1,2].

The menisci cover 50% of the medial and 70% of the lateral surface of the tibial plateau [1]. Typically, the medial meniscus is larger, has a wider posterior horn, and is more “open” toward the intercondylar notch, with the lateral meniscus typically smaller and more “closed” toward the notch. In adults, the vascularized area, commonly known as the “red zone,” involves the outer 10% to 30% of the meniscus [1,4]. Each meniscus is divided arbitrarily into an anterior horn, a body, and a posterior horn. Usually, the anterior horn of the medial meniscus is attached to the tibial plateau anterior to the anterior cruciate ligament (ACL) [1]. The anterior horn of the lateral meniscus has fibers of the ACL that extend into it at the anterior root attachment where it attaches to the tibial plateau. The transverse or anterior intermeniscal ligament, which is noted in 44% to 58% of patients on MR, has variable attachments; however, 58% of the time it runs between the anterior horn of the medial meniscus and the anterior margin of the lateral meniscus, connecting the two anterior horns [5]. The posterior horn of the lateral meniscus attaches to the posterior tibia, and usually has attachments to the medial femoral condyle and the popliteus by way of the meniscofemoral ligaments and the popliteomeniscal fascicles, respectively. The posterior horn of the medial meniscus attaches to the tibial plateau immediately anterior to the posterior cruciate ligament (PCL) [1].

The meniscofemoral ligaments extend from the posterior horn lateral meniscus usually to the lateral aspect of the posterior medial femoral condyle, but occasionally to the PCL. The incidence of at least one meniscofemoral ligament identified on MR ranges from 66% to 93%, with both identified in anatomic studies more than 30% of the time [6,7]. Typically, when both are present, one is notably thicker. They have properties similar to the posterior bundle of the PCL and may supplement the PCL, providing secondary restraint. The ligament of Humphrey is anterior and the ligament of Wrisberg is posterior to the PCL (Fig. 1). The meniscofemoral ligaments oppose the posterior movement of the posterior horn of the lateral meniscus and “pull” the posterior horn of the lateral meniscus anteriorly and medially [6]. The popliteomeniscal fascicles are synovial attachments of the posterior horn of the lateral meniscus that extend around the popliteus bursa. The superior fascicle arises from the medial fibers of the popliteus tendon aponeurosis, and the inferior fascicle extends from the meniscus to the tibial margin (Fig. 2). At least one fascicle is visualized in 97% of patients with an intact lateral meniscus, best seen on T2-weighted images [8]. The fascicles control the motion of the lateral meniscus in flexion and extension. Disruption of the fascicles allows increased meniscal movement [6], meniscal subluxation, and even locking of the knee [8]. Along with the popliteus muscle, these structures oppose the forces of the meniscofemoral ligaments [6].

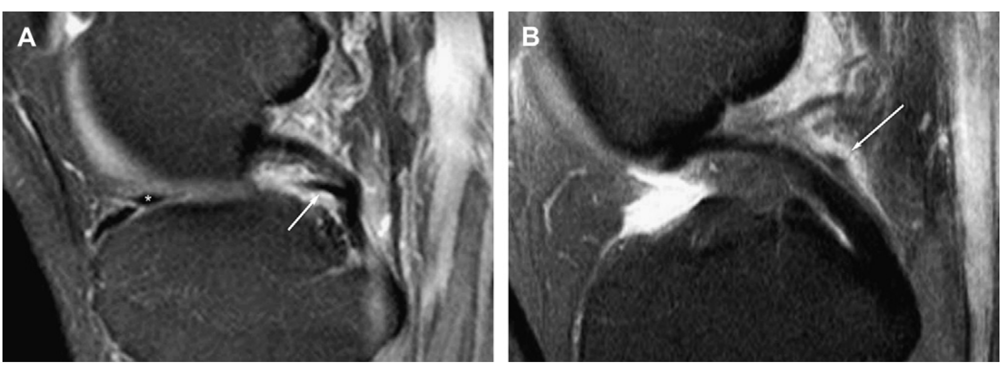

Fig. 1. (*A*) Sagittal gradient echo image of the ligament of Humphrey located anterior to the PCL (*arrow*). Also noted is the anterior or transverse intermeniscal ligament (*asterisk*). (*B*) Sagittal fast spin-echo (FSE) fat-saturated proton density–weighted image of the ligament of Wrisberg, located posterior to the PCL (*arrow*).

Fig. 2. Sagittal proton density–weighted fat-saturated image of the superior (*thin arrow*) and inferior (*thick arrow*) popliteomeniscal fascicles attaching to the posterior horn of the lateral meniscus, with the popliteus tendon (*asterisk*) in between.

Meniscal variants

Many meniscal variants have been reported. Some of the variants described more commonly include the discoid meniscus, meniscal ossicles, and the meniscal flounce.

The discoid lateral meniscus has a reported incidence of 0.4% to 16.6% and is more common in the Japanese and Korean populations (Fig. 3) [9]. Joint line tenderness is noted in 73%, "snapping" in 49%, and locking of the knee in 21% of patients [10]. The three types of discoid lateral meniscus are complete, incomplete, and the Wrisberg variant. Some investigators include a ring-shaped meniscus as a fourth type [11]. The complete and incomplete types have a firm, normal posterior tibial attachment and are stable [6]. Symptomatic patients who have these types of discoid menisci usually are treated with a partial meniscectomy [12,13]. In contrast, the Wrisberg variant has no posterior coronary or capsular attachments [1,13] and increased T2 signal is present between the meniscus and the capsule, simulating a peripheral tear or a fascicular injury [13]. The Wrisberg variant has the most notable symptoms [6], with a "snapping" sensation occurring when the posterior horn moves across the femoral condyle during flexion and extension [13]. Historically, treatment of the Wrisberg variant has been total meniscectomy; however, more recently, some investigators have suggested partial meniscectomy with repair [12,13]. A discoid medial meniscus is much less common, with the incidence reported to be 0.12% to 0.6% [3,14,15].

Fig. 3. GRE coronal image demonstrating a discoid lateral meniscus (*arrows*).

On MR, the diagnosis of a discoid meniscus is suggested by identifying either meniscal tissue on three continuous sagittal 5-mm-thick slices, or a meniscal body on coronal images greater than 15 mm wide or extending into the intercondylar notch [13,14]. The discoid meniscus has an increased incidence of tears and degeneration, likely caused by its abnormal shape, resulting in increased stress on the meniscus [15–17]. Intrasubstance "grade 2" signal, or abnormal signal not extending to an articular surface, is noted in 24% of discoid menisci and is more common in complete discoid menisci [17]. Typically, this abnormal signal is not considered clinically significant however, in the population with discoid menisci, some investigators report that this intrasubstance signal may be significant clinically [16,17].

Meniscal ossicles are reported in 0.15% of patients and are thought to be either developmental or posttraumatic. These small, ossific foci are found typically in the posterior horn of the medial meniscus and are associated with meniscal tears. They can be asymptomatic, or associated with pain and a sensation of locking, clinically simulating a torn meniscus with a flap component. The ossicle follows the signal of bone marrow on MR [18].

Meniscal flounce is a wavy appearance along the free edge of the meniscus. Previously, meniscal flounce was thought to be identified only at arthroscopy, in the presence of joint fluid with the knee flexed, the tibia rotated externally, and a valgus force applied, exposing the posterior-medial compartment of the knee, or in the setting of an ACL or medial collateral ligament (MCL) tear [19,20]. However, a flounce can be seen without a ligament injury [20]. Recently, the meniscal flounce has been identified with MR imaging when the knee is in 10 degrees of flexion. The flounce completely resolves when the knee is extended maximally, and resolves nearly 50% of the time when the knee is flexed maximally [21]. The flounce can appear truncated on coronal images and can simulate a tear or degeneration. The incidence at MR is reported to be from 0.2% to 6%. A flounce-like appearance can be seen with meniscal tears (Fig. 4) [19,20].

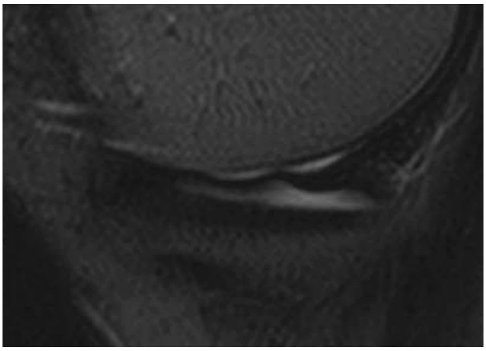

Fig. 4. T2-weighted fat-saturated sagittal image demonstrating a flouncelike appearance to the posterior horn and body of the medial meniscus, in the setting of a meniscal tear.

Meniscal extrusion

Meniscal extrusion is measured from the outer meniscal edge to the proximal tibial margin. Extrusion of the medial meniscus more than 3 mm is considered abnormal (Fig. 5). This degree of extrusion can be seen in patients who have advanced meniscal degeneration, and various types of meniscal tears [22]. Although extrusion of the anterior horn or body of the lateral meniscus sometimes is considered a normal variant [23], others consider extrusion of the lateral meniscus more than 1 mm to be abnormal [24]. Damage to the meniscus and meniscal extrusion can be associated with cartilage abnormalities and likely predisposes to the development of osteoarthritis [22,25].

Tears: etiology

The cause of meniscal tears can be divided into two categories: increased force on a normal meniscus, usually resulting in longitudinal or radial tears, and normal forces on a degenerative meniscus, usually producing horizontal tears in the posterior half of the meniscus [26]. Tears are more common in the medial meniscus [1,6], possibly because the medial meniscus is less mobile, and it bears more force during weight-bearing than the lateral meniscus [22,27], with 56% of tears involving the posterior horn of the medial meniscus [28]. Tears isolated to the anterior two thirds of the meniscus are uncommon, representing only 2% of medial and 16% of lateral meniscal tears [29]. Lateral meniscal tears are more common in younger patients (under 30 years old), who have a higher incidence of tears related to sporting events than do older patients. It is likely that this is related to the higher incidence of concomitant ACL tears in this population [30]. The prevalence of meniscal tears increases with age [1], with degenerative tears also more common in older patients [30].

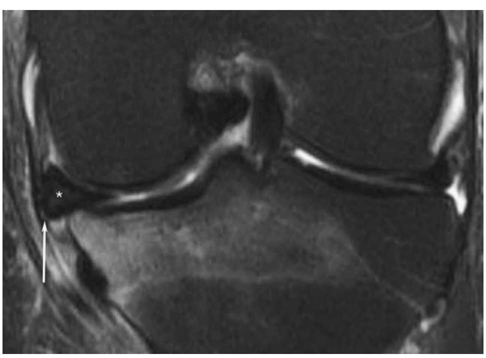

Fig. 5. Coronal FSE T2-weighted fat-saturated image demonstrating medial extrusion (*arrow*) of the body of the medial meniscus (*asterisk*) because of a posterior medial meniscal root tear. Bone contusion is also seen in the medial tibial plateau, with cartilage loss in the medial femoral condyle.

Tears: diagnosis

The diagnosis of a meniscal tear requires high spatial resolution and an optimized signal-to-noise ratio [31], achieved with the use of a dedicated extremity coil, a slice thickness of 3 to 4 mm, a field of view of 16 cm or less, and a matrix size of at least 256 × 192 (frequency and phase). Many MR sequences have been used to evaluate for meniscal tears, and although they vary in other parameters, they all share a short echo time (TE) [32]. The advantages of a short TE include a reduction in scan time, decreased susceptibility and fewer flow artifacts, an ability to acquire more scan slices per sequence, and an improved signal-to-noise ratio.

The most commonly used sequences include spin-echo or fast spin-echo (FSE) proton density with or without fat saturation, T1, and gradient echo (GRE) [32]. Each sequence has investigators who support its use; however, a pooled summary of published articles between 1991 and 2000 reports a sensitivity and specificity with MR imaging of 93% and 88% for medial, and 79% and 95% for lateral meniscal tears [33]. The differences in sensitivity and specificity could be related to the sequences used, observer variation, or sample size [34]. The sensitivity for detecting meniscal tears usually is higher in the medial meniscus, regardless of the technique used [35].

The radiology literature illustrates controversy about the relative accuracies of spin-echo proton density and FSE proton density sequences for detecting meniscal tears [31,36,37]. Conventional proton density spin-echo imaging has a sensitivity and specificity for diagnosing meniscal tears of 88% to 90% and 87% to 90%, respectively

[31,38,39]. The sensitivity and specificity of FSE proton density sequences for diagnosing meniscal tears is 82% to 96% and 84% to 94%, respectively; however, not all of these studies used an echo train length (ETL) less than or equal to five [31,35,40,41]. The overall lower sensitivities reported for the FSE technique are thought to be because of the inherent blurring artifact seen with this technique, which is worsened by a longer ETL and most pronounced with shorter TE sequences [31]. However, the blurring can be reduced by using high-speed gradients and decreasing the ETL and interecho spacing [37]. The addition of fat saturation to FSE and conventional proton density imaging is becoming more common [32,35]. Blackmon and colleagues [42] recently reported a sensitivity of 93% and a specificity of 97% for diagnosing meniscal tears using a fat-saturated conventional spin-echo proton density–weighted sequence, which was 13% more sensitive than a fat-saturated FSE proton density–weighted sequence. Three-dimensional GRE imaging has a sensitivity and specificity for detecting meniscal tears of 87% to 100% and 78% to 94%, respectively [39,43,44], with the best results obtained using an average slice thickness of 3 mm on sagittal and coronal sequences [43]. The limitations of this sequence include a higher signal in normal menisci, compared with spin-echo sequences, and more widespread signal increase in degenerated menisci [39]. This increased meniscal signal can make it difficult to determine if the abnormal signal actually extends to the articular surface, resulting in decreased specificity [44]. The sensitivity and specificity of spin-echo T-1 weighted sequences in detecting meniscal tears is between 77% and 80% and 72% and 98%, respectively [44,45]. Therefore, a sequence with a short TE and an optimized signal-to-noise ratio should be used to evaluate for meniscal pathology, with most using a proton density–weighted sequence.

The normal meniscus has low signal on all MR imaging sequences. On sagittal MR images, the anterior and posterior horns of the lateral meniscus are nearly equal in size, whereas the posterior horn of the medial meniscus is larger than the anterior horn (Fig. 6). The diagnostic criteria for a meniscal tear in a knee without prior meniscal surgery is either an area of abnormal signal within the meniscus on at least one image that extends to the meniscal articular surface, or abnormal morphology of the meniscus [29]. If the abnormal signal extends to the articular surface on two or more images, the sensitivity for a meniscal tear increases from 56% to 94% medially and from 30% to 90% laterally [29]. The sagittal plane is used most commonly to evaluate meniscal pathology; however, studies have reported that the coronal imaging plane improves the detection and characterization of radial, bucket-handle, horizontal, and displaced tears of the meniscal body [46,47], and that the axial plane assists in diagnosing radial, vertical, complex, displaced, and lateral meniscal tears [48,49].

An accurate description of a meniscal tear has become increasingly important, with the emphasis on meniscal preservation and repair [3,28,50,51], because of the known, long-term complications of complete meniscectomy, which include degenerative changes in 21% of cases, patient dissatisfaction in 36% to 40% of cases, marked disability in 30% of cases, and chronic pain in 55% of men and 90% of women [52]. The description should include whether the tear is in the posterior horn, body, or anterior horn, and whether the tear is in the peripheral third of the meniscus (roughly corresponding to the vascularized red zone), the inner two thirds of the meniscus, or both. It should also be stated if the tear is complete, extending from one articular surface to another, or incomplete. The tear should be described as horizontal, vertical (longitudinal, radial, or parrot-beak), or complex.

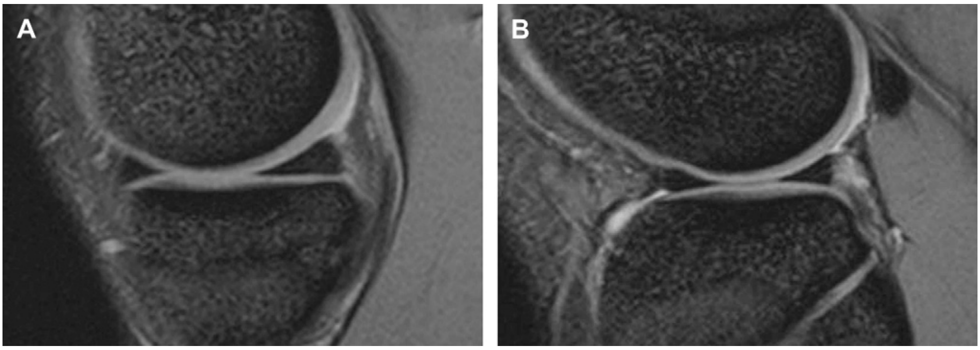

Fig. 6. (*A*) Sagittal GRE image of a normal medial meniscus. (*B*) Sagittal GRE image of a normal lateral meniscus.

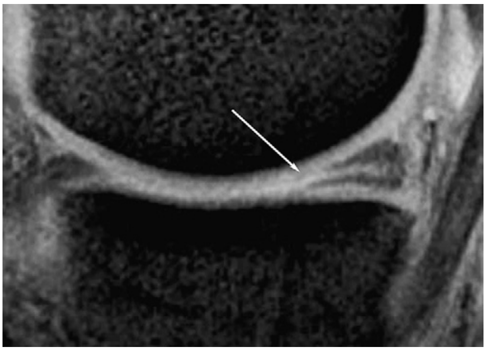

Fig. 7. Sagittal GRE image demonstrating a horizontal tear (*arrow*) of the posterior horn of the medial meniscus.

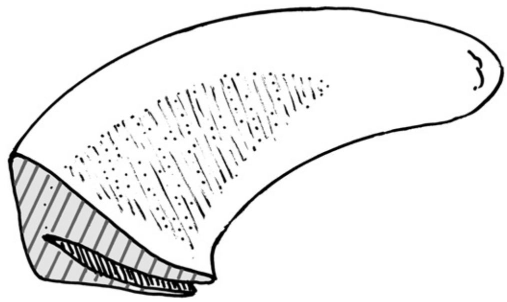

Fig. 8. Horizontal tear.

The length of the tear is also important because it may determine if the tear is repairable [28]. At arthroscopy, tears can be classified as stable or unstable, with unstable lesions being displaceable into the joint with probing, and more often resected or repaired [53].

Classification of tears

Horizontal tears

Horizontal or cleavage tears are parallel to the tibial plateau and divide the meniscus into upper and lower segments (Figs. 7 and 8) [28].

Vertical tears

A vertical longitudinal tear occurs between the circumferential collagen fibers, parallel to the long axis of the meniscus, perpendicular to the tibial plateau, with the tear equidistant from the peripheral edge of the meniscus (Figs. 9 and 10) [28].

A vertical radial tear occurs on a plane perpendicular to the long axis of the meniscus and perpendicular to the tibial plateau [28,54,55]. These tears traverse the circumferential collagen fibers, resulting in either two separate pieces of meniscus, or a single portion of meniscus attached to the tibia in only one location [54,55]. The incidence of radial tears is approximately 14% to 15%, with 79% in the posterior horns [3,32,54]. These tears disrupt the ability to distribute the hoop stresses associated with weight-bearing, and usually are not repairable [3]. Partial thickness radial tears can be debrided, but the meniscus is unlikely to regain full function and likely will displace peripherally and allow contact between articular cartilage surfaces, resulting in accelerated degenerative changes [3,32,54,55]. As a result, even small radial tears can have a significant detrimental effect on the function of the meniscus, and can cause pain [3,56]. The prospective detection of radial tears is reported to be as low as 37%; however, using four signs (ghost, cleft, truncated triangle, and marching cleft), the sensitivity for the detection of radial tears is reported to be 89% [3]. A radial tear can have a ghost appearance if there is either an absent section of meniscus or an area of high signal in the shape of the meniscus on a single image that is parallel to the tear. A marching cleft presents most commonly with a radial tear at the junction of the

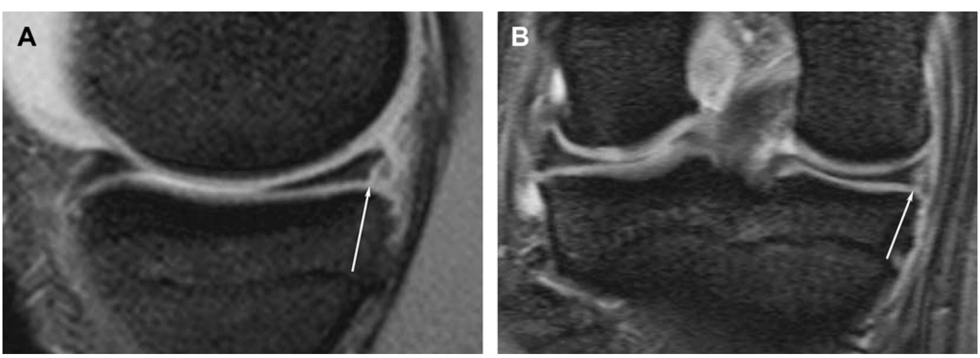

Fig. 9. (*A*) Sagittal GRE image demonstrating a peripheral vertical longitudinal tear (*arrow*) of the posterior horn of the medial meniscus. (*B*) Coronal GRE image demonstrating a peripheral vertical longitudinal tear (*arrow*) of the body of the medial meniscus.

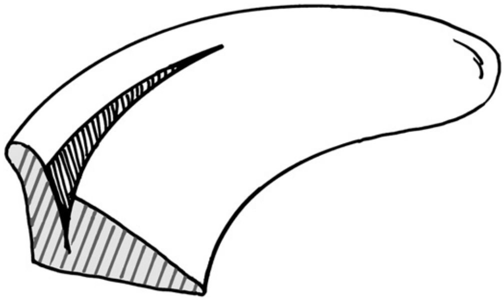

Fig. 10. Vertical longitudinal tear.

posterior horn and body that appears to "move" across the meniscus on successive images. The truncated triangle sign is noted when there is an abrupt truncation of the inner point of the normal meniscus. The cleft sign occurs when there is abnormal signal present in the meniscus perpendicular to the imaging plane (Figs. 11 and 12) [3].

Vertical parrot-beak tears are radial at the inner meniscal edge and longitudinal more peripherally within the meniscus [28,55]. These tears are difficult to detect with MR imaging, with reported sensitivities ranging from 0% to 60% (Fig. 13) [28].

Complex tears

Complex tears either have two or more tear configurations or are not categorized easily into a certain type of tear [28].

Bucket-handle tears

A bucket-handle tear results when the inner meniscal segment of a longitudinal or oblique tear "flips," most commonly into the intercondylar notch. This often involves the entire meniscus but can involve only the posterior horn and body or a single horn of the meniscus [57]. It is the most common type of displaced "flap" tear, occurring in approximately 10% to 26% of patients [58–60], and is more common medially [47,59–61]. The inner flipped portion of the meniscus can remain intact or it can be disrupted.

The overall sensitivity of MR imaging for bucket-handle fragments is 64% to 94% [47,60–64], with higher sensitivities reported if the tear involves the entire meniscus [47,62]. The MR diagnosis of a bucket-handle tear uses many signs [62,64–66]. The double PCL sign consists of meniscal material in the notch, inferior and parallel to the PCL in the same sagittal plane [57]. It has a sensitivity of 27% to 44% and a specificity of 98% to 100% in detecting bucket-handle tears, and it is noted only in medial bucket-handle tears unless there is an associated ACL tear (Fig. 14) [47,60–64]. The fragment in notch sign occurs when a fragment of meniscus is in the notch but not in the same sagittal plane as the PCL (Fig. 15). It is seen more often in lateral bucket-handle tears [57], and it has a sensitivity of 60% to 98% and specificity of 73% to 82% for detecting bucket-handle tears [41,47,60,61,63]. The absent bow tie sign is diagnosed when the meniscus body is not identified on at least two adjacent sagittal 4 to 5 mm-thick images. It has a sensitivity of 58% to 98% and a specificity of 62% to 100% for detecting bucket-handle tears [41,59–61,63,64]. False positives with this sign can occur in children or small adults, in degenerative menisci, in radial tears, and with postsurgical changes [32,61]. False negatives can occur in bucket-handle tears of discoid menisci [61]. A truncated meniscus on coronal images is reported in up to 65% of bucket-handle tears [61,64]. The disproportional posterior horn

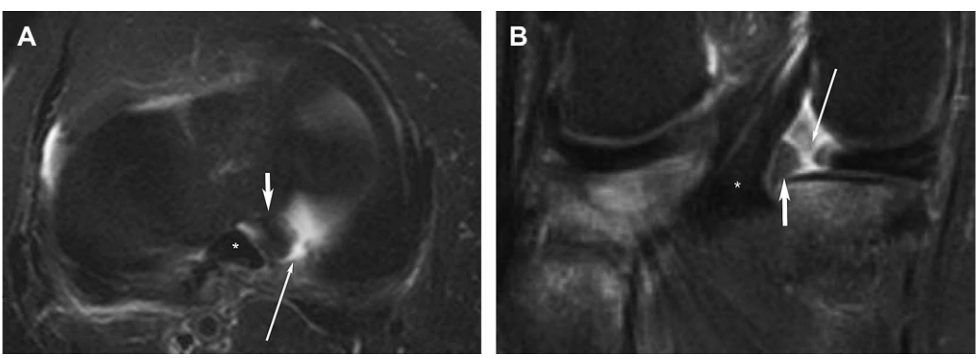

Fig. 11. (*A*) FSE T2-weighted fat-saturated axial image demonstrating a radial tear (*thin arrow*) of the posterior horn of the medial meniscus near the posterior meniscal root attachment (*thick arrow*). Note the proximity of the PCL (*asterisk*) to the posterior root attachment of the posterior horn of the medial meniscus. (*B*) FSE T2-weighted fat-saturated coronal image demonstrating a radial tear (*thin arrow*) in the posterior horn of the medial meniscus with the cleft sign. The posterior medial meniscal root is intact (*thick arrow*). Note the proximity of the PCL (*asterisk*) to the posterior root attachment of the posterior horn of the medial meniscus.

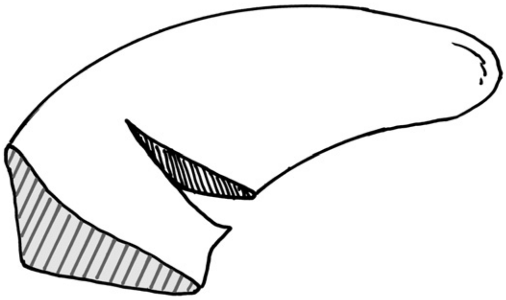

Fig. 12. Vertical radial tear.

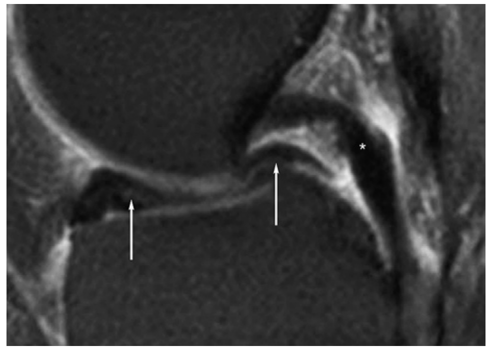

Fig. 14. FSE proton density–weighted fat-saturated sagittal sequence demonstrating a bucket-handle tear of the medial meniscus. The double PCL sign is present, with the flipped fragment of the medial meniscal body (*arrows*) located anterior to the PCL (*asterisk*) within the intercondylar notch.

sign is present when there is a larger posterior horn on sagittal images closer to the root attachment than peripherally, presumably because of a centrally displaced fragment of the more peripheral posterior horn. This sign has a sensitivity of approximately 28% for bucket-handle tears [60,63]. A quadruple cruciate sign can be observed if there are medial and lateral bucket-handle meniscal tears, with both fragments displaced into the notch (Fig. 16) [67].

The flipped meniscus sign, which occurs when the fragment is flipped anteriorly adjacent to the ipsilateral anterior horn [57], is noted in 44% to 61% of medial and 29% to 39% of lateral bucket-handle tears [61,62]. The anterior horn should not measure greater than 6 mm in height; if it does, this should be considered. The double anterior horn sign is the same as the flipped meniscus sign; however, two separate "anterior horns" are identified (Fig. 17). Usually, the flipped meniscus and double anterior horn signs are associated with intercondylar meniscal displacement [57].

Flap tear with displacement

A flap tear or a displaced flap tear is a term that is used often to describe a short-segment, horizontal meniscal tear with fragments either displaced into the notch or into the superior or inferior gutters (Fig. 18) [41,57]. These tears are unstable [41] and are important to recognize and describe, especially if the flap of meniscal tissue extends into the inferior gutter because this is a difficult area for the surgeon to visualize (Fig. 19) [58]. The failure to identify and treat recess fragments is a known cause of poor outcome after meniscal resection [41]. This tear can be suspected when the normal rectangular meniscus is not identified on the most peripheral sagittal image, and meniscal tissue is noted inferior to the body segment [58]. The coronal images are the most useful in confirming the inferiorly displaced meniscal tissue.

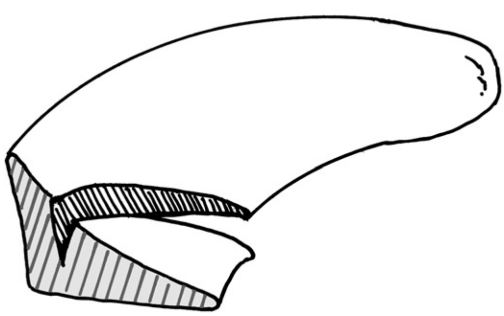

Fig. 13. Vertical parrot-beak tear.

Free fragments

Free fragment displacement is rare, occurring in 0.2% of symptomatic meniscal lesions [57].

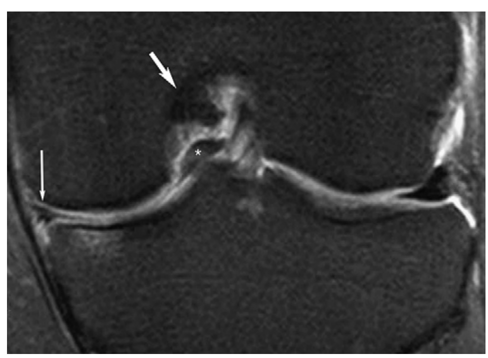

Fig. 15. FSE proton density–weighted fat-saturated coronal sequence demonstrating a bucket-handle tear of the medial meniscus, with a portion of the body of the medial meniscus located in the intercondylar notch (*asterisk*) beneath the PCL (*thick arrow*) and adjacent to the ACL. Note the remainder of the body of the medial meniscus is truncated (*thin arrow*).

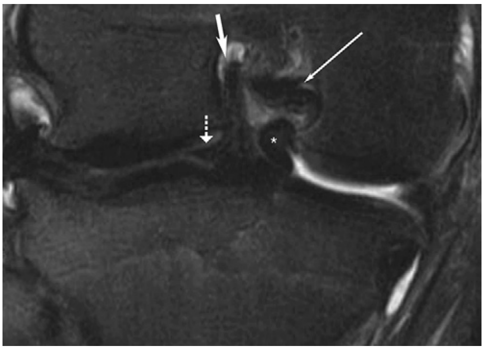

Fig. 16. FSE T2-weighted fat-saturated coronal image demonstrating bucket-handle tears of both menisci, with fragments from both meniscal bodies flipped into the intercondylar notch. The fragment of the medial meniscus (*asterisk*) is inferior to the PCL (*thin arrow*) and the fragment of the body of the lateral meniscus (*dotted arrow*) is adjacent to the ACL (*thick arrow*), producing the "quadruple cruciate sign."

Root tears

A root tear occurs at the tibial attachment or "root" of the meniscus, and it has been described only posteriorly (Fig. 20) [24]. Actually, this type of tear was described by Tuckman and colleagues [55] but was called a full thickness radial tear at, or adjacent to, the tibial attachments. Studies have described an association between extrusion of the medial meniscus, medial compartment arthritis, and posterior-medial meniscal root tears [24,55].

A root tear is reportedly a difficult tear to diagnose because meniscal tissue is noted only on one side of the tear. The diagnosis is easier to make medially because of the close anatomic relationship between the posterior horn of the meniscus and the tibial attachment of the PCL. Normally, on 3-mm sagittal images, the meniscus should be seen on the image medial to the PCL attachment; otherwise, a root tear is suspected and the coronal images can confirm [55]. Meniscal extrusion is more pronounced and nearly four times as common with medial, as opposed to lateral, meniscal root tears [24]. Lateral meniscal root tears are diagnosed when the posterior horn of the lateral meniscus does not cover the most medial aspect of the posterior lateral tibial plateau on at least one coronal image [55]. In the setting of an ACL tear, the lateral meniscal root is torn more than three times as often as the medial root, with lateral meniscal extrusion greater than 1 mm present in 23% of patients who have lateral root tears and in 2% of those who have intact lateral meniscal roots. All patients who had meniscal extrusion but intact roots had another type of meniscal tear, with 60% having radial or complex tears. Extrusion was noted nearly four times as often in lateral meniscal root tears if the meniscofemoral ligaments were absent [24].

Meniscal tears in the setting of anterior cruciate ligament tears

In the setting of an acute ACL injury, the lateral meniscus is torn twice as often as the medial meniscus, with approximately one half representing peripheral longitudinal tears most commonly located in the posterior horn of the lateral meniscus [68,69]. Displaced meniscal tears are also more common in this setting [38]. The sensitivity for diagnosing meniscal tears is decreased in these patients primarily because of failure to detect lateral meniscal tears (Fig. 21) [68,69].

In ACL-deficient knees, the increased shear forces on the less mobile posterior horn of the medial meniscus may account for the increased rate of medial meniscal tears [1,70], which possibly is related to

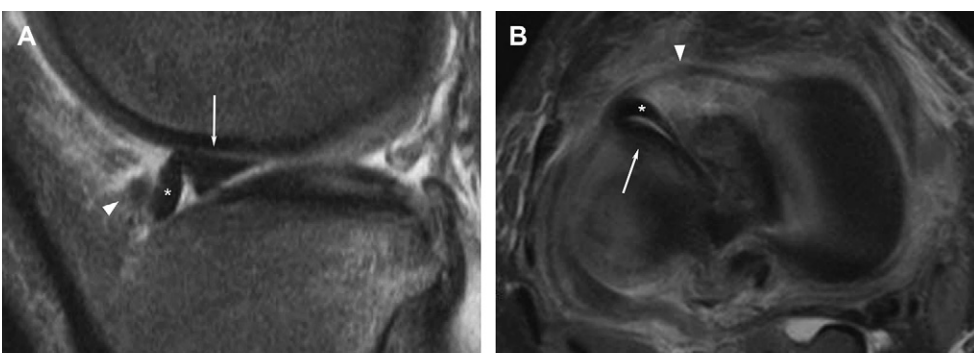

Fig. 17. (*A*) Sagittal FSE proton density–weighted fat-saturated image demonstrating a tear of the lateral meniscus, with the fragment of the body (*long arrow*) flipped adjacent to the anterior horn (*asterisk*). Note the anterior transverse intermeniscal ligament (*arrowhead*). (*B*) Axial FSE proton density–weighted fat-saturated image demonstrating flipped fragment of lateral meniscus body (*long arrow*) adjacent to the anterior horn of the lateral meniscus (*asterisk*). Note bowing of the anterior transverse intermeniscal ligament (*arrowhead*).

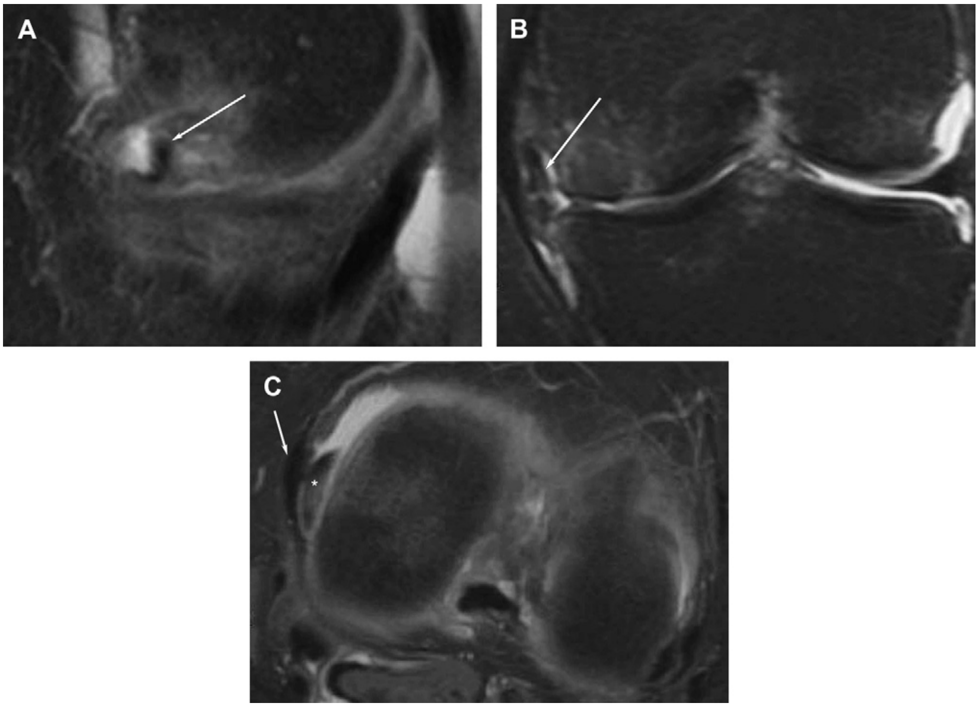

Fig. 18. (*A*) FSE proton density–weighted fat-saturated sagittal image demonstrating a flap of meniscal tissue (*arrow*) extending from the anterior horn body junction of the medial meniscus into the superior recess medially. (*B*) Coronal short tau inversion recovery (STIR) image demonstrating the flap of meniscal tissue (*arrow*) extending into the superior aspect of the medial recess. Medial compartment chondromalacia is also noted. (*C*) FSE proton density–weighted fat-saturated axial image demonstrating a flap of meniscal tissue (*asterisk*) deep to the MCL (*arrow*) and superficial to the medial femoral condyle in the superior aspect of the medial recess.

the increased posterior translation of the femur in relation to the tibia with flexion in ACL-deficient knees [70]. These tears are often less amenable to repair; therefore, early ACL repair in certain populations (athletes and manual laborers) should be considered [1].

Meniscal pitfalls

Seventy percent of false-positive MR imaging findings occur in the posterior horns of the menisci, which are the most difficult areas to evaluate at arthroscopy [29,52,71,72]. The standard arthroscopic technique for evaluating the posterior horn of the medial meniscus is to probe the tibial surface while compressing the femoral surface [52]. Because evaluation of the meniscal gutters is also difficult, the accuracy of arthroscopy for diagnosing meniscal tears is 69% to 98%, depending on the arthroscopist and the location and type of tear [71]. Therefore, some of the cases considered false positives on MR imaging might, in fact, represent false negatives on arthroscopy.

False positives can also occur with healed meniscal tears or postoperative menisci, in which abnormal signal extending to the surface remains on standard MR imaging sequences [29,52]. False positives because of magic angle phenomenon on sequences with a TE less than 37 can also occur in the posterior horn of the lateral meniscus because of the central upsloping of the meniscus [73]. Truncation artifact can also be a cause of false positives;

Fig. 19. GRE coronal image demonstrating truncation of the body of the medial meniscus (truncated triangle sign), with the flap of meniscal tissue flipped under the meniscus into the inferior recess medially (*arrow*).

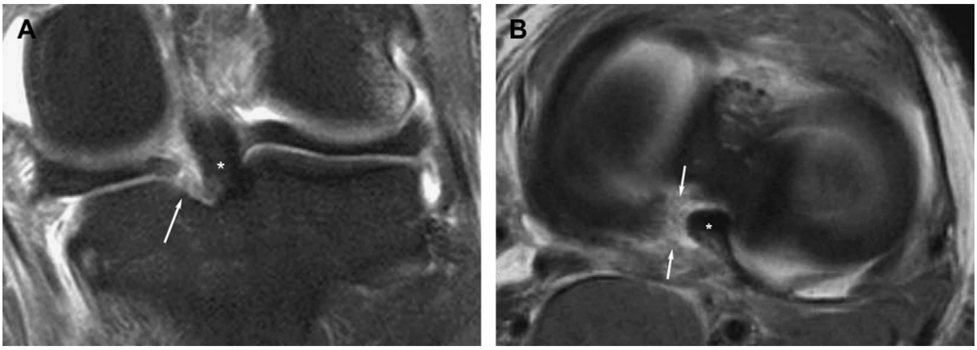

Fig. 20. (*A*) FSE proton density–weighted fat-saturated coronal image demonstrating a tear of the posterior medial meniscal root (*arrow*). Note the tibial attachment of the PCL (*asterisk*). (*B*) Axial FSE proton density–weighted fat-saturated image demonstrating a tear of the posterior medial meniscal root (*arrows*). Note the proximity to normal tibial attachment of PCL (*asterisk*).

however, the use of a matrix of at least 192 × 256 minimizes this artifact such that it is seen rarely today [74]. Radially orientated collagen "tie" fibers, which have linear intermediate signal within the meniscus, and myxoid degeneration can also simulate tears [4].

Abnormal signal having a speckled or spotty appearance on T1 and proton density images can occur in the anterior horn of the lateral meniscus near the central attachment on the most central sagittal images [32], thought to be caused by high signal striations from the ACL fibers [75]. Sometimes, the transverse intermeniscal ligament can simulate a tear in the anterior horns of either menisci (Fig. 22) [5,76]. The lateral inferior genicular artery can simulate a tear of the lateral meniscus, and the normal concavity of the peripheral aspect of the meniscus can mimic a horizontal tear on peripheral sagittal images caused by a volume-averaging artifact [76]. The meniscal attachments of the meniscofemoral ligaments can simulate a tear in the posterior horn of the lateral meniscus [77]. The popliteus tendon adjacent to the posterior horn of the lateral meniscus can also be a source of error because of fluid tracking along the intra-articular portion of the tendon [8,76]. The medial and lateral oblique meniscomeniscal ligaments and [78] the anterior meniscofemoral ligament of the medial meniscus [79] can also simulate tears. However, following these structures on multiple images, evaluating the meniscus in different imaging planes, and having a thorough understanding of the anatomy often can prevent these errors.

Meniscal contusion can demonstrate abnormal amorphous or globular meniscal signal that contacts an articular surface but is less discrete and less well defined than the signal associated with a tear and intrasubstance degeneration, respectively. All patients have adjacent bone contusions and most have ACL tears. The abnormal signal can resolve over time [80].

The diagnostic accuracy of MR imaging for meniscal tears decreases in patients who have chondrocalcinosis because the calcium deposits may demonstrate high signal on T1-weighted, intermediate-weighted, and short tau inversion recovery (STIR) sequences [81]. Reviewing radiographs can alert the radiologist to the chondrocalcinosis. In addition, most meniscal tears are more linear than the signal abnormalities seen with chondrocalcinosis; however, there is overlap [32].

Common false negatives at MR imaging include small meniscal tears and abnormalities involving the meniscal free edge [52].

Meniscocapsular separation

Meniscocapsular separation occurs when the meniscus detaches from the capsular attachments [82], which is more common medially and usually is associated with other injuries [83]. The medial capsuloligamentous structures can be thought of

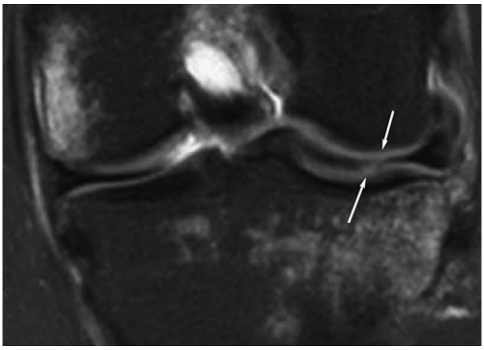

Fig. 21. FSE proton density–weighted fat-saturated coronal image demonstrating a subtle area of abnormal signal, representing a meniscal tear, extending to the articular surfaces (*arrows*) of the posterior horn of the lateral meniscus in a patient who had an ACL tear. The meniscal tear was not diagnosed prospectively.

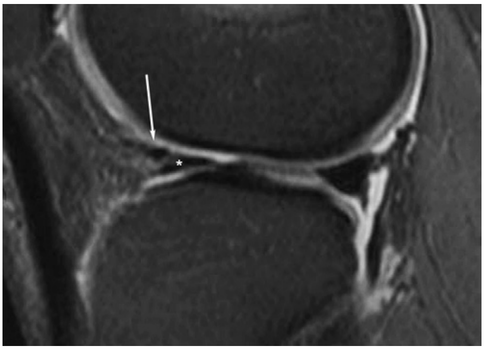

Fig. 22. Spin-echo proton density–weighted fat-saturated sagittal image demonstrating the anterior (transverse) intermeniscal ligament (*arrow*) simulating a tear of the anterior horn of the lateral meniscus (*asterisk*). A similar finding was present at the junction with the anterior horn of the medial meniscus.

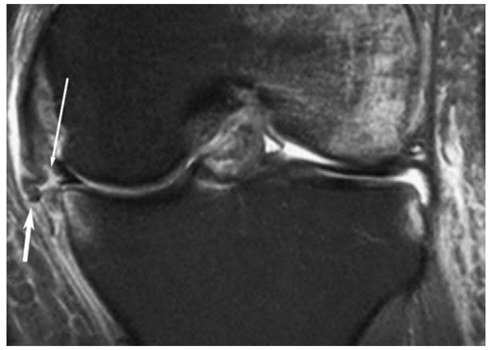

Fig. 23. FSE proton density–weighted fat-saturated coronal image demonstrating fluid signal and widening (*thin arrow*) between the medial edge of the body of the medial meniscus and the MCL, consistent with meniscocapsular separation. Note the complete disruption of the tibial attachment of the MCL (*thick arrow*).

as three layers, from superficial to deep: layer 1: crural fascia; layer 2: superficial portion of the MCL; and layer 3: capsule and deep portion of the MCL [84]. The medial meniscus is attached to the femur by way of the meniscofemoral ligament, and to the tibia by way of the coronary (meniscotibial) ligament, which are extensions of the deep fibers of the MCL [84].

Meniscocapsular separation is evaluated best on coronal and sagittal T1- or proton density–weighted sequences for anatomy, and fat-saturated T2-weighted or STIR sequences for pathology [84]. Signs that have been described in meniscocapsular separation include displacement of the meniscus relative to the tibial margin, extension of the tear into the superior or inferior corner of the peripheral meniscus, and an irregular outer margin of the meniscus body on coronal images. Additional signs include increased distance between the meniscus and the MCL, or fluid between the meniscus and the MCL [83,84]. A study by Rubin and colleagues [82] reported a positive predictive value of only 9% for the MR diagnosis of medial meniscocapsular separation using these signs; however, the positive predictive value improved to 17% if the surgery was performed within 2 weeks of the MR imaging, likely because these injuries occur in an area with an extensive blood supply and many heal conservatively [82–84]. Overall, the presence of perimeniscal fluid and an irregular meniscal outline are the best predictors of meniscocapsular separation (Fig. 23) [84].

Findings associated with meniscal tears

The use of indirect signs to increase the accuracy for the detection of lateral meniscal tears has been reported [85]. A torn or absent superior popliteomeniscal fascicle was noted in 31% of patients with, and 4% without, lateral meniscal tears [86]. Presumptive subarticular stress reactions of the knee are characterized by an edema-like pattern in the subarticular marrow, which encompasses a focal, linear, or curvilinear low-signal area. Of these patients, 76% have a meniscal tear in the same compartment, with 53% being either radial or root tears. These lesions occur in a much older population and likely are caused by radial or root tears that predispose the knee to increased stress which, in an older population, results in insufficiency-type lesions [87]. The lesions have a similar appearance to spontaneous osteonecrosis of the knee, which is a reported complication of radial tears, especially in older patients with large body habitus [55], and in patients who have had a prior medial meniscectomy or degenerative medial meniscal tears [88,89].

Subchondral bone contusions involving the posterior margin of the medial tibial plateau in patients who have ACL tears are associated with posterior horn medial meniscal tears in 64% of patients and meniscocapsular separation/injury in 56% of patients, with either one of the two injuries noted in 96% of the patients. The mechanism is thought to be a contrecoup impaction injury, with 62% of the medial meniscal tears in the far peripheral 20% of the meniscus. Lateral meniscal tears were also noted in 36% of these patients [90].

Meniscal cysts

Meniscal cysts are identified on 4% to 6% of knee MR examinations, are located twice as often medially, and may be lobulated or septated in appearance [32,91,92]. The cysts can be confined within the meniscus (intermeniscal) or can extend into the adjacent soft tissue (perimeniscal), with the latter more common [93]. The most widely accepted cause of a meniscal cyst is extension of fluid through a meniscal tear [91], with 57% noted in horizontal cleavage and 33% in complex tears with a horizontal component [91,93]. Medially, the cysts are adjacent to the posterior horn, with anterior extension adjacent to the body in 74% of cases (Fig. 24) [91,92]. Laterally, the cysts are adjacent to the anterior horn, with posterior extension adjacent to the body in 54% of cases. Direct communication between the meniscal cyst and the meniscal tear is noted in 98% of cases. Lateral meniscal cysts more often present as palpable masses, likely because of the thinner, overlying, lateral soft tissues [91]. Occasionally, a posterior horn medial meniscal tear can produce a cyst that extends centrally within the joint adjacent to the posterior central aspect of the PCL or surrounding the PCL, simulating a ganglion [93]. Treatment of meniscal cysts involves decompression of the cyst and repair or resection of the tear, usually from an exclusively intra-articular approach [91]. Therefore, detection of an associated tear is important; it may alter therapy because perimeniscal cysts without an underlying tear often are treated percutaneously. The cysts can be symptomatic with or without a tear [32].

MR imaging field strength

Several studies suggest similar accuracy for diagnosing meniscal tears with 0.2 T and 1.5 T MR imaging, although some controversy remains [94,95]. Undoubtedly, scanning time is longer at lower field strengths, 15 minutes longer at 0.2 T than at 1.5 T in one article [95]. A higher confidence for diagnosing meniscal tears at 1.5 T, compared with 0.2 T, has been reported, with the exception of the posterior horn of the lateral meniscus, likely because of the inherent increased signal-to-noise ratio at 1.5 T [96].

Treatment

The four main options for treating meniscal tears are complete meniscectomy, partial meniscectomy, meniscal repair, and conservative treatment without meniscal surgery [28]. The treatment of meniscal lesions depends on many factors, including the type, location, and size of the tear. Initially, meniscal lesions were treated with complete meniscectomy because the importance of the meniscus and its function were not understood well [97,98]. Unfortunately, complete meniscectomy has been shown to result in accelerated cartilage loss and the development of osteoarthritis [1,4,51,97–100]. Partial meniscectomy is less damaging to the joint and is preferred to a complete meniscectomy in patients who have unstable tears [1], when a primary meniscal repair is not possible [28]. Preservation of as much of the meniscus as possible, especially the outer third, and removing only unstable tissue, is the desired result; usually, however, some stable tissue is resected to approximate the original meniscal shape, in an attempt to reduce the inevitable increased stress on the remaining meniscal tissue [97]. Many studies have shown progressive, long-term wear on the joint after partial meniscectomy, with a declining number of patients reporting excellent or good results over time [99]. This result is possibly because of the altered biomechanics of the meniscus, with the decreased ability of the meniscus to transmit hoop stresses, thereby resulting in increased stress on the remaining meniscus, additional tears, and accelerated degenerative change [101]. As a result, meniscal repair has

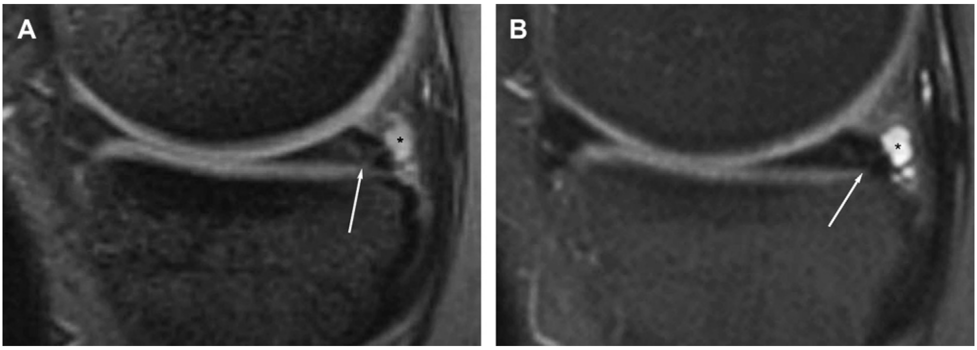

Fig. 24. (*A*) GRE sagittal image demonstrating a perimeniscal cyst (*asterisk*) adjacent to the posterior horn of the medial meniscus, with the tear (*arrow*) extending to the cyst. (*B*) FSE proton density–weighted fat-saturated sagittal image demonstrating a perimeniscal cyst (*asterisk*) adjacent to the posterior horn of the medial meniscus, with the tear (*arrow*) extending to the cyst.

become more common, to maintain as much of the normal biomechanical function of the meniscus as possible [28,50,102]. Repairable meniscal tears usually are unstable, peripheral, longitudinal, or oblique tears. Radial, horizontal, or complex tears usually are not amenable to repair [28,102]. After meniscal repair, patients are kept non- or partially weight bearing for several weeks, in contrast to partial meniscectomy, after which patients can resume full weight bearing much more quickly [28]. Healing usually takes 4 months and once the tear heals, patients are usually asymptomatic. The long-term success of meniscal repairs varies from 67% to 92%, depending on the type and location of the tear [1]. Factors that predispose to a favorable repair outcome include surgery within 8 weeks of injury, patient age under 30 years, tear length less than 2.5 cm, a peripheral tear, a lateral meniscus tear, and concomitant ACL reconstruction [1,28]. Therefore, an accurate description of meniscal tears as repairable and irreparable has significant clinical implications, especially for athletes, because continued stress on a potentially repairable tear might make it irreparable [28].

Tears in the peripheral, vascularized portion of the meniscus can heal from an ingrowth of capillaries and eventually resemble fibrocartilage [26,51,97]. Many of these tears may heal spontaneously and not require arthroscopy [51,52]. Longitudinal tears greater than 7 to 10 mm in length, especially post-traumatic vertical peripheral tears, may heal if they are stable [97]. Some surgeons may not operate on horizontal or oblique partial-thickness tears [103], and if a partial meniscectomy is performed on one of these tears, only the unstable portions may be removed, leaving a horizontal defect extending to the articular surface [97]. In patients who have both lateral meniscal and ACL tears, the tear is typically in the periphery of the posterior horn or at the posterior root, and it is important to report if the tear extends anterior to the popliteus hiatus because tears posterior to the hiatus will not always be repaired.

Autologous meniscal transplantation has become more common, especially in younger patients who have had prior partial meniscectomy or who have irreparable meniscal tears [97]. Other appropriate candidates are those with mild to moderate single-compartment cartilage degeneration, those with progressive loss of meniscal tissue but an appropriate varus/valgus alignment, and those having an ACL repair in which a meniscal transplant might improve stabilization [104,105]. Often, meniscal transplantation is performed concomitantly with other procedures, including cruciate ligament or cartilage repair and high-tibial osteotomies [105]. The procedure involves attaching the allograft to the tibia with bone plugs and then suturing the allograft to the capsule. Some reports indicate that MR imaging may be helpful in determining the appropriate size of the meniscal transplant [106]; however, other studies suggest radiographs are nearly as accurate as MR [107]. MR imaging is helpful preoperatively to evaluate the integrity of the ligaments and cartilage [102].

Postoperative imaging

Postoperative imaging of the meniscus is complicated. The standard criteria for a tear has limited diagnostic usefulness when diagnosing a tear at the site of meniscal repair or partial resection, with sensitivity up to 100% but specificity as low as 23% [50,51,100], because of either intermeniscal granulation tissue, which can have abnormal T1-weighted or proton density signal extending to the meniscal surface in the repaired or healing meniscus, or the possible "conversion" of grade 1 or 2 intrameniscal signal to an apparent tear or grade 3 signal by performing a partial meniscectomy [51,97,108]. This appearance can persist for years after a repair [102]. The specificity for diagnosing a tear in this population can be improved if fluid signal is noted in the meniscus on T2-weighted images or if a displaced meniscal fragment is identified (**Fig. 25**) [97]. The exception may be in the early postoperative period (<12 weeks) when scar tissue at the repair site may demonstrate increased T2-weighted signal [100]. Therefore, the use of gadolinium with either direct or indirect arthrography to detect residual or recurrent tears has been proposed.

Indirect arthrography involves the acquisition of MR images 10 to 20 minutes after the intravenous injection of gadolinium (usually 0.1 mmol/kg). Synovial excretion of contrast occurs, and a tear can be diagnosed if gadolinium signal is noted in the meniscus. However, the natural appearance of a meniscal repair on indirect MR arthrography is abnormal signal extending to the articular surface, seen in 90% of patients, which is seen in only 25% of patients with conventional MR imaging [109]. Therefore, false positives occur because granulation tissue or scar may enhance [97].

Direct arthrography involves the intra-articular injection of approximately 20 mL of a gadolinium-saline mixture (1:150 solution) into the knee. The patient should then walk on the knee before the MR imaging, to force the contrast into meniscal clefts. The extension of contrast into the meniscus diagnoses a recurrent or residual tear (**Fig. 26**). A healed or repaired tear has abnormal intermeniscal signal without gadolinium extending into the meniscus (**Fig. 27**) [97]. Even though the intra-articular injection of gadolinium is considered

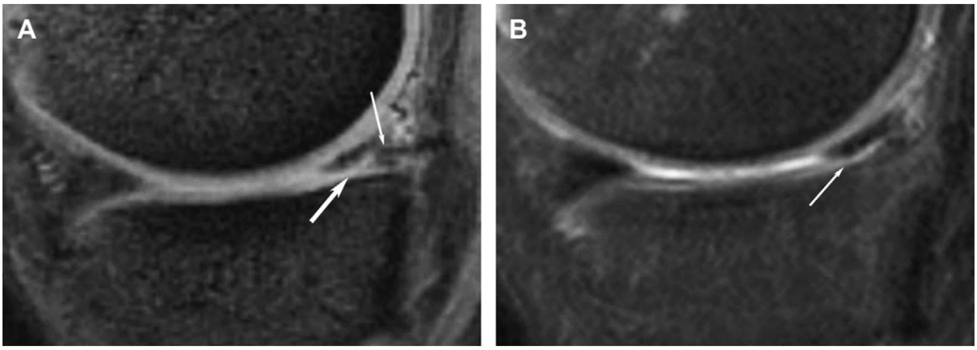

Fig. 25. (*A*) GRE sagittal image demonstrating abnormal signal extending to the articular surface (*thick arrow*) of the posterior horn of the medial meniscus after meniscal repair. Note focal area of susceptibility artifact from meniscal repair (*thin arrow*). Arthroscopy confirmed a recurrent tear. (*B*) FSE proton density–weighted fat-saturated sagittal image demonstrating abnormal (fluid) signal extending to the articular surface (*arrow*) of the posterior horn of the medial meniscus after meniscal repair. Arthroscopy confirmed a recurrent tear.

an off-label use by the US Food and Drug Administration, direct arthrography has three advantages over the other methods of evaluating the postoperative meniscus. These advantages include the lower viscosity of gadolinium compared with synovial fluid, making it more likely to extend into a tear; contrast distension of the joint, making fluid more likely to extend into a tear; and the inherent higher signal-to-noise ratio of the T1-weighted sequences used to evaluate the gadolinium contrast [108].

Several investigators report an overall accuracy in detecting recurrent tears of 62% to 77% with conventional MR imaging, 93% with indirect arthrography, and 88% to 92% using direct MR arthrography [108,110,111]. In contrast, White and colleagues reported accuracies of 80%, 81%, and 85% in the diagnosis of recurrent meniscal tears using conventional MR imaging, indirect MR arthrography, and direct MR arthrography, respectively. Although the detection of recurrent tears with direct MR arthrography was minimally higher in White and colleagues [50] study, it did not reach statistical significance. The consensus is that in patients with resection of less than 25% of the meniscus, conventional MR imaging is as accurate as MR arthrography, and that the criteria to diagnose a tear in these patients should be the same as that used for a meniscus without prior surgery [50,110,112]. However, in patients with resection of more than 25% of the meniscus, Applegate and colleagues [110] results demonstrate an accuracy for detecting recurrent tears of only 63% using conventional MR, and an accuracy of 89% using direct MR arthrography. Similar findings led Magee and colleagues [112] to conclude that, in the absence of chondral injuries, avascular necrosis, or severe degenerative changes, patients who have undergone meniscal repair or those who have had more than 25% of the meniscus resected should have direct MR arthrography performed to detect recurrent tears, because abnormal signal may persist in the meniscus after surgery. In addition, if more than one third of the meniscus is removed, the meniscus can demonstrate surface irregularity on conventional MR images but be found normal at second-look arthroscopy. This surface irregularity can simulate a tear [97] or obscure a recurrent or residual tear [113]. In contrast, menisci with less than one third resection do not demonstrate as much irregularity [113]. Magee and colleagues [101] also reported more than twice the incidence of radial tears in patients who had had prior partial meniscectomies, compared with those without prior surgery, likely because of altered biomechanics.

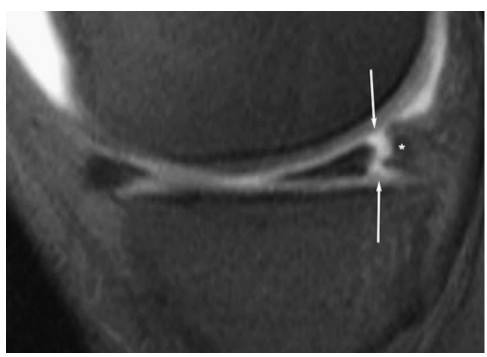

Fig. 26. T1-weighted fat-saturated sagittal MR arthrogram demonstrating a new peripheral vertical longitudinal tear (*arrows*) of the posterior horn of the medial meniscus. Note peripheral aspect of the posterior horn of the medial meniscus (*asterisk*).

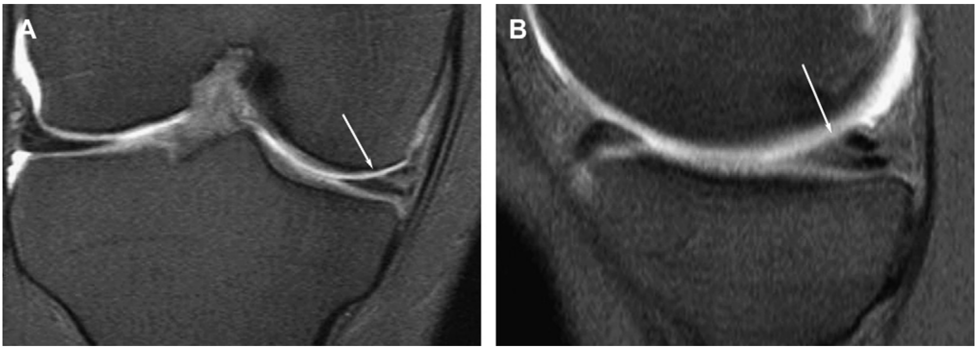

Fig. 27. (*A*) T1-weighted fat-saturated coronal image from a direct MR arthrogram in a patient following meniscal repair demonstrating abnormal signal extending to the superior surface of the body of the medial meniscus (*arrow*). No gadolinium extends into this area, confirming a healed meniscal repair. (*B*) T1-weighted fat-saturated sagittal image from a direct MR arthrogram in a patient following meniscal repair demonstrating abnormal signal extending to the superior surface of the body of the medial meniscus (*arrow*). No gadolinium extends into this area, confirming a healed meniscal repair.

The role of MR imaging in evaluating meniscal allografts is not defined clearly [97]. GRE sequences should be avoided and FSE imaging should be considered instead, because extensive susceptibility artifacts associated with meniscal transplantation and the often associated procedures, including ACL repair or high tibial osteotomy, invariably are present [104]. Reports of MR imaging follow-up are limited, but several suggest that MR findings may not correlate with clinical results; however, these findings were performed on low-intermediate strength magnets and only small numbers of patients were evaluated [114,115]. Other studies, at least one performed on a high-field strength magnet, have suggested that MR can provide information about the position of the meniscus, the meniscal anchors, the meniscocapsular junction, meniscal degeneration, and cartilage defects [104,116]. Most meniscal transplants demonstrate focal degeneration in the posterior horn, associated with moderate to severe cartilage degeneration. As a result, performing pretransplant MR imaging to access for cartilage changes, which might result in a less favorable outcome, should be considered [104]. Increased T2-weighted signal is noted occasionally at the periphery of the transplanted meniscus and is considered normal, likely related to cellular ingrowth or revascularization [116]. Abnormal signal extending to the articular surface of the allograft is noted in 59% of the transplants after 10 or more years; however, the signal is stable in 82% of the allografts and was noted initially on the 1-year posttransplant follow-up MR imaging [114]. Partial extrusion of the allograft is noted in 70% of cases, with progressive extrusion noted in 59% [114,117]. Lack of progressive cartilage loss is reported in just under one half of the viable meniscal transplanted knees [114]. Findings suggestive of meniscal transplant failure include meniscalfragmentation, progressive articular cartilage loss, and peripheral meniscal extrusion (Fig. 28) [102].

Future imaging: ultrashort echo time imaging, parallel imaging, and 3 Tesla

Ultrashort TE imaging (TEs of 0.08–0.2 ms) is a technique in which the normal meniscus demonstrates increased signal and tears have decreased signal, and is performed best without fat suppression [118]. In contrast to fat-suppressed T1 and Fast Low Angle Shot (FLASH) sequences with intravenous gadolinium, which cannot differentiate between the vascular and avascular zones of the meniscus [4], contrast administration on ultrashort TE images can make this differentiation [118,119].

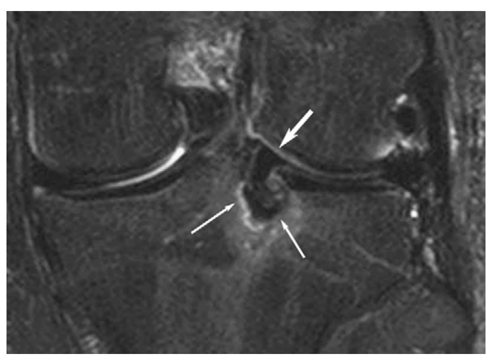

Fig. 28. FSE T2-weighted fat-saturated coronal image of a lateral meniscal transplant. Tunnel (*thin arrows*) for posterior root (*thick arrow*) adjacent to lateral tibial spine.

The full benefit of this sequence has not been described yet.

Parallel imaging reportedly provides a comparable performance to FSE proton density imaging using an ETL of five for meniscal lesions, with nearly a 50% reduction in scan time [120]. No appreciable difference in the sensitivity, specificity, and accuracy for detecting meniscal tears using FSE techniques with and without parallel imaging has been reported [121].

Higher diagnostic confidence is reported with 1.5 T imaging, as opposed to 0.2 T imaging, for the diagnosis of meniscal tears, probably because of the inherent increased signal-to-noise ratio at 1.5 T [33,96]. One could suppose that with 3 T imaging, the confidence and accuracy of detecting meniscal lesions will continue to increase. Three tesla imaging, using FSE proton density–weighted sequences with an ETL of six in the sagittal plane, 2- to 3-mm slice thickness, and a total acquisition time of approximately 20 minutes, has an overall sensitivity and specificity for meniscal tears of 95% to 96% and 92% to 97%, respectively according to McGee and colleagues and Ramnath and colleagues [122,123]. However, Craig, and colleagues [124] reported a sensitivity and specificity of 100% and 83% for medial, and 67% and 97% for lateral meniscus tears with an overall sensitivity and specificity for meniscal tears of 90% and 92% respectively. Further studies are required to determine the true impact of 3 T in evaluating the meniscus, but these results compare favorably to results at 1.5 T using conventional spin-echo sequences.

Summary

MR imaging is the preferred imaging modality for evaluating meniscal pathology, with high accuracy reported in most studies. Achieving this high accuracy requires a thorough knowledge of the anatomy of the meniscus and perimeniscal structures, an understanding of normal variants and interpretive pitfalls, an awareness of the common findings associated with meniscal tears, and an understanding of the diagnostic criteria for a meniscal tear. In patients who have partial meniscal resection or meniscal repair, diagnosing a recurrent tear is more complicated, and the addition of T2 fat-saturated coronal and sagittal sequences to a routine conventional MR protocol is recommended. If there is knowledge of resection of more than 25% of the meniscus or a meniscal repair, most advocate the use of direct MR arthrography. Recent developments in the area of 3 T and faster imaging techniques are not yet evaluated fully, but offer promise for accurate meniscal evaluation with even shorter scan times.

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