Sports-Related Meniscal Injury

E. De Smet, P. Van Dyck, J. Gielen, and F. M. Vanhoenacker

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Abstract

Meniscal lesions are frequent in both the general and the athletic population and may cause severe functional impairment. In this chapter, the (micro)anatomy, vascularization and function of the menisci are described. In the event of a suspected meniscal injury, conventional radiography and arthrography are no longer recommended. Conventional MRI has become the preferred imaging modality, if necessary followed by MR (or CT) arthrography in the postoperative meniscus. Correct description of tears seen on MRI is essential, as it may guide treatment. The major classifications of meniscal lesions are described as well as some more rare lesions that can be seen in athletes. It must however be stressed that correlation with clinical information is of utmost importance, as some meniscal lesions may be asymptomatic and do not require treatment.

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1 Introduction

Meniscal injuries are very common among professional and amateur athletes and are a major cause of functional impairment of the knee. It is the most common indication for arthroscopic surgery of the knee. For athletes, unnecessary treatment or intervention may be as damaging to a competitive future as failure to diagnose a clinically significant injury. Therefore, rapid and accurate evaluation of possible injuries in this group is crucial (Ludman et al. 1999).

Acquisition of a precise history of the injury mechanism may be difficult, as is performance of an accurate physical examination in the setting of an acute injury (Karachalios et al. 2005).

Magnetic resonance imaging (MRI) is performed more commonly on the knee than on any other joint, and it is an excellent diagnostic tool that can aid in the evaluation of a host of sports-related injuries involving the ligaments, tendons, menisci, osseous structures, and articular surfaces. It has currently become the most widely used non-invasive imaging method for detecting meniscal injuries, with a reported diagnostic accuracy of as high as 98%, compared to arthroscopy, remaining the gold standard for confirming the diagnosis of meniscal tear. MRI is a valuable, cost-effective tool for the preoperative evaluation of the menisci, and proved useful, on the basis of its high negative predictive value, to exclude patients from unnecessary arthroscopy, and, thus, avoiding unnecessary hospitalization, morbidity and waste of limited financial and manpower resources (Karachalios et al. 2005; Elvenes et al. 2000).

However, radiologists must be aware of numerous imaging pitfalls and artefacts simulating a tear and leading to an erroneous diagnosis. Moreover, it must be kept in mind that "silent" meniscal abnormalities in athletes exist and knowledge of these MR appearances is important in order to avoid attributing greater significance to these than is clinically justified.

For many years, the meniscus was treated with disrespect as an unnecessary appendage that could be sacrificed with the first hint of malfunction. As long-term results after major meniscectomy were disappointing, a conservative approach to the management of meniscal tears has developed, with emphasis on meniscal preservation (Rath and Richmond 2000).

2 Anatomy and Function

To adequately evaluate and treat meniscal injuries, understanding of meniscal anatomy and function is necessary. From a gross anatomic perspective, the menisci are C-shaped fibrocartilaginous structures, firmly attached to the anterior and posterior aspects of the tibial plateau by the so-called root ligaments. Conventionally, they are described as having three segments: anterior horn, body and posterior horn. Each meniscus measures approximately 5 mm in height along its periphery and tapers to a thin inner edge such that it demonstrates a triangular shape in cross section. The outer rims of the menisci are convex and attached to the fibrous joint capsule and through it to the edges of the articular surfaces of the tibia. The inner edges are concave, thin and free. Their superior surfaces are slightly concave for reception of the femoral condyles, whereas their inferior surfaces that rest on the tibial condyles are flatter. The anterior horns of the medial and lateral menisci are attached to each other through the (anterior) transverse ligament (Fig. 1).

The *medial meniscus* is C-shaped and occupies 50–60% of the articular contact area of the medial compartment (Arnoczky et al. 1987; Thompson et al. 1991) (Fig. 1). Its posterior horn is wider than the anterior horn. Although anatomic variations in meniscal morphology and attachments exist, the anterior horn of the medial meniscus has a firm bony attachment to the tibia anterior to the anterior cruciate ligament (ACL). The posterior horn is attached immediately in front of the attachment of the posterior cruciate ligament (PCL) (McKeon et al. 2009; Palastanga and Soames 2011). The outer border of the medial meniscus is firmly attached to the knee joint capsule. The meniscotibial and meniscofemoral ligaments attach the meniscus to the tibia and femur, respectively, and are referred to as the deep medial collateral ligaments (Fig. 2).

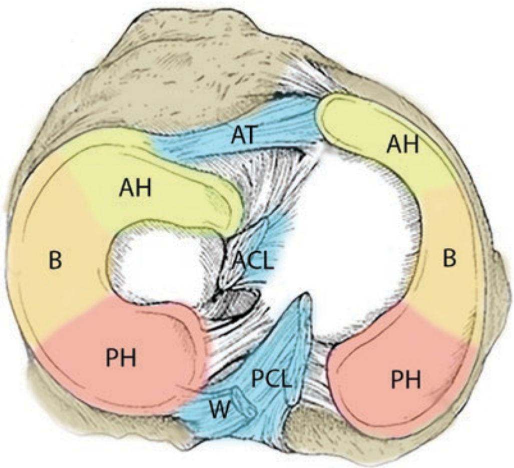

Fig. 1 Schematic drawing of meniscal anatomy. Both menisci are divided into an anterior horn (AH) and posterior horn (PH) with the body (B) in between. The anterior transverse (AT) ligament connects the anterior horns. Wrisberg ligament (W) starts at the posterior horn of the lateral meniscus and follows the posterior cruciate ligament (PCL). *ACL* anterior cruciate ligament

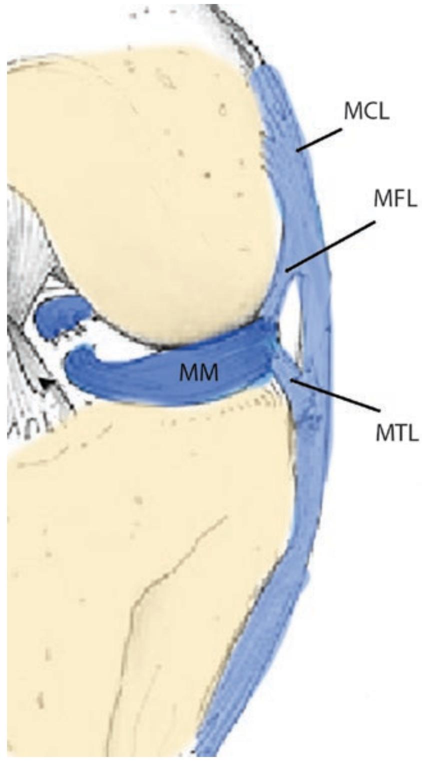

Fig. 2 Schematic drawing of the relation between the medial meniscus (MM) and the medial collateral ligament (MCL). The deep layer of the MCL consists of the meniscotibial (MTL) and meniscofemoral (MFL) ligaments, which are connected to the body of the MM

The *lateral meniscus* is more uniform in width and semicircular, covering 70–80% of the lateral tibial plateau (Arnoczky et al. 1987; Thompson et al. 1991) (Fig. 1). The anterior horn attaches to the inter-condylar fossa, next to the attachment of the ACL. The posterior horn of the lateral meniscus is attached to the medial femoral condyle through the posterior meniscal-femoral (Wrisberg) and anterior meniscal-femoral (Humphrey) ligament. Therefore, during rotation, the motion of the lateral meniscus is coupled with that of the femoral condyle. The lateral meniscus has loose attachments to the joint capsule and is separated from it by the popliteus tendon posterolaterally where it courses through a meniscocapsular tunnel. In this region, the superior and inferior popliteal meniscal fascicles are seen, running from the peripheral margin of the meniscus, around the popliteus tendon, to the joint capsule (Fig. 3). The lateral meniscus is more mobile and is not anchored to the lateral collateral ligament. In flexion and internal rotation, the popliteal tendon retracts the posterior horn, thus reducing entrapment of the lateral meniscus between the femur and the tibia. It is therefore less likely to be injured than the relatively immobile medial meniscus (Rath and Richmond 2000).

The *composition of the menisci* varies with age and may also be altered by injury (Sweigart and Athanasiou 2001). The main component is water (>70%), followed by collagen (±20%, primarily collagen type I with small amounts of types II–VI), glycosaminoglycans, DNA, glycoproteins and elastin (Makris et al. 2011). Within the menisci, a small cell population is present, consisting of fibrochondrocytes, fibroblast-like cells and cells in the superficial meniscus (Verdonk et al. 2005; Van der Bracht et al. 2007).

The *microanatomy of the menisci* may explain injury patterns (Fig. 4). A network of type I collagen fibres arranged in a circumferential direction is the dominant morphological pattern, allowing dispersion of compressive loads and development of “hoop stresses”. Radial oriented

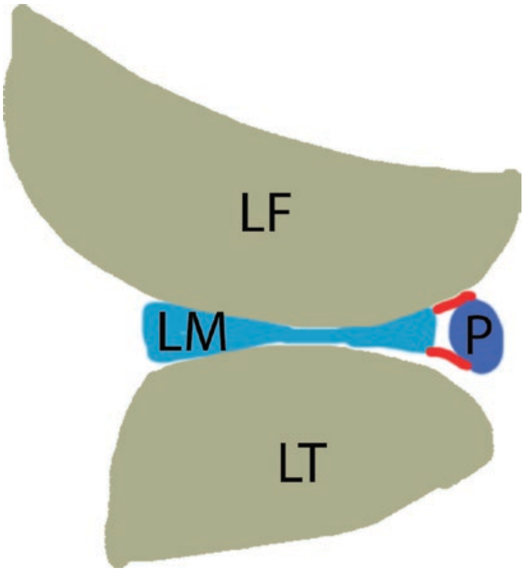

Fig. 3 Schematic drawing of the relation between the lateral meniscus (LM) and the meniscopopliteal fascicles (red). The anteroinferior and posterosuperior fascicles extend from the LM to engulf the popliteal tendon and blend into the capsule

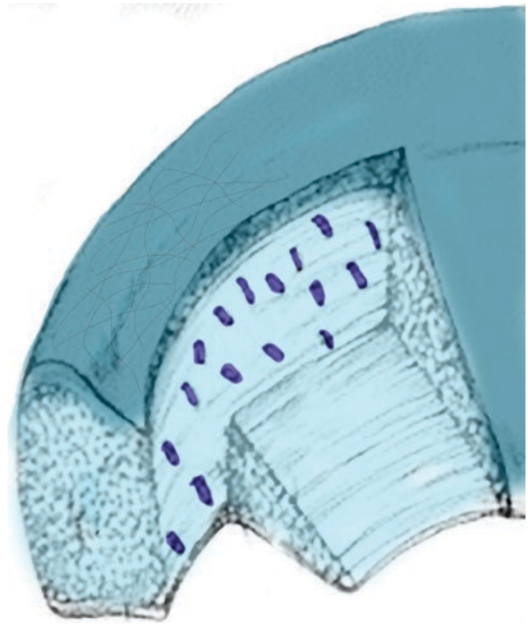

Fig. 4 Microstructure of the meniscus. The majority of the fibres are longitudinal or "hoop" fibres (light blue), following the long axis of the meniscus. These fibres are responsible for the distribution of axial loads. A minority of radial or "tie" fibres run perpendicular to the long axis, from the inner to the outer rim (purple), to withstand longitudinal splitting. The most superficial fibres (dark blue zone) follow a random course

fibres ("tie fibres") may function to restrain motion between circumferential fibres and resist longitudinal splitting. At the surface of the meniscus, fibre orientation is more of a random configuration (Greis et al. 2002).

The *blood supply to the menisci* originates from the lateral and medial superior and inferior genicular arteries. These vessels reach the periphery of the meniscus through the synovial covering of the anterior and posterior horn attachments. Vessels are present throughout the substance of the foetal menisci. Beginning at birth, there is a progressive decrease in vascularity proceeding from the inner to the outer regions of the meniscus. The adult meniscus is avascular in the inner two-thirds ("*white zone*") and vessels are most prominent in the peripheral one-third of the menisci and in the adjacent coronary and capsular ligaments ("*red zone*"). In younger persons, an intermediate vascularized "*red-white zone*" is located between the vascular red and avascular white zone (Rath and Richmond 2000) (Fig. 5).

The menisci are important in many aspects of knee function, with the main functions being tibiofemoral load transmission and shock absorption. The menisci compensate for significant incongruity between the femoral and tibial articulating surfaces and increase tibiofemoral contact area, with subsequent reduction in joint contact stresses. The menisci transmit at least 50–70% of the load when the knee is in extension. This increases to 85–90% with 90° of knee flexion. These loads are well distributed when the menisci are intact (Greis et al. 2002). After meniscectomy, tibiofemoral contact area may decrease by 40–70%, leading to a proportional increase in contact and shear stresses across the joint. These changes will lead eventually to joint degeneration. Furthermore, several studies have demonstrated that meniscal tissue is approximately one half as stiff as articular cartilage. The shock absorption capacity of the normal knee is reduced by 20% after meniscectomy (Voloshin and Wosk 1983).

It is important to remember that the menisci are not stationary structures. With flexion and extension of the knee, the medial meniscus translates about 2–5 mm on the tibia, and the lateral meniscus translates about 9–11 mm (Greis et al. 2002).

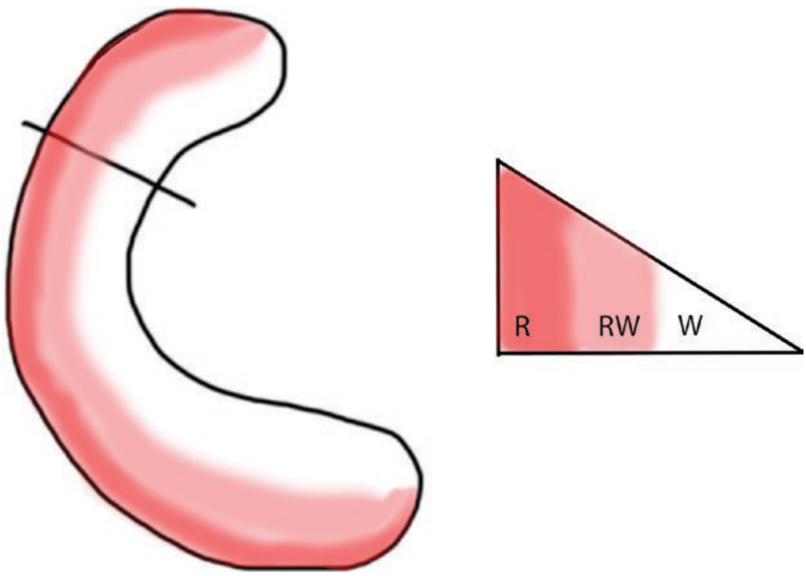

Fig. 5 Vascularization of the menisci. The most peripheral part of the meniscus (red zone, R) is well vascularized. The innermost part or white zone (W) has no vascularization and therefore no healing potential. The red-white zone (RW) is an intermediate vascularized zone, present in young people

Additionally, the menisci play a key role in enhancing joint stability, largely as secondary soft-tissue restraints which prevent anterior tibial displacement (Rath and Richmond 2000). The body of the meniscus prevents the femur from gliding too far off the tibia. Shoemaker and Markolf (1986) demonstrated that the posterior horn of the medial meniscus is the most important structure resisting an applied anterior tibial force in an ACL-deficient knee. Patients who tear the posterior meniscal horn may feel instability—even if their ACL is intact—because this stabilizing effect is lost.

Finally, the menisci contribute significantly to joint lubrication, probably by fluid exudation across their surfaces. Compression squeezes the liquid out into the joint space, to allow smoother gliding of the joint surfaces. This also helps to distribute synovial fluid throughout the joint and aids nutrition of the articular cartilage (Rath and Richmond 2000).

3 Epidemiology of Meniscal Injuries

Meniscal lesions are the most common encountered knee injuries and meniscal tear surgery is one of the most frequent orthopaedic procedures. Therefore, these lesions have a high cost in both morbidity and healthcare expenses.

Meniscal tears have a bimodal age distribution and are most frequently seen in both young sports(wo)men and the elderly population.

Reported risk factors (Snoeker et al. 2013) for degenerative tears include age >60, male gender, squatting, work-related kneeling and stair climbing (>30 flights). Acute traumatic tears were more often seen in rugby and soccer players and patients with delay between ACL rupture and reconstruction greater than 12 months.

Meniscal tears are more frequently seen in the medial meniscus and in the posterior horns of the menisci (Metcalf and Barrett 2004).

4 Imaging of the Meniscus

Although meniscal injuries are extremely common, the clinical history and mechanism of injury are usually non-specific, and are often of little value in determining the diagnosis. Mechanical symptoms of popping, catching, locking or buckling along with joint-line pain are suggestive, but not conclusive, of meniscal pathology, and other types of intra- and extra-articular pathology may confound the clinical picture.

Numerous specialized tests have been described that may aid in making the diagnosis of meniscal tear. These include joint-line palpation, McMurray test, the Apley grind test and many others. Although conflicting results regarding the diagnostic accuracy of the various meniscal tests have been reported, no specific examination manoeuvre has impressive test performance characteristics, with the exception of the joint-line tenderness test, which showed an acceptable diagnostic accuracy (Karachalios et al. 2005).

4.1 Plain Radiography and Conventional Arthrography

Nowadays, plain radiography is not regarded as a suitable examination for the detection of isolated meniscal injury. Depending on patient history and clinical examination, radiographs may however be useful in the detection or exclusion of associated skeletal injury or fracture, presence of loose bodies or degenerative changes.

For decades, conventional fluoroscopic arthrography (after sterile preparation and injection of intra-articular contrast medium) was the radiological technique for investigating meniscal injury. After the development of cross-sectional imaging techniques, conventional radiography only has a place as part of these techniques, i.e. in the context of CT or MR arthrography.

4.2 Ultrasound

Ultrasound is not the preferred method to evaluate meniscal pathology but occasionally meniscal tears or parameniscal cysts may be seen on an ultrasound of the knee performed for other indications (Fig. 6).

4.3 Magnetic Resonance Imaging

Because of its exquisite contrast resolution and ability to simultaneously display the osseous and soft-tissue structures of the knee in virtually any plane, MRI has become the most widely used non-invasive imaging method that can aid in the evaluation of the entire spectrum of internal derangements of the knee.

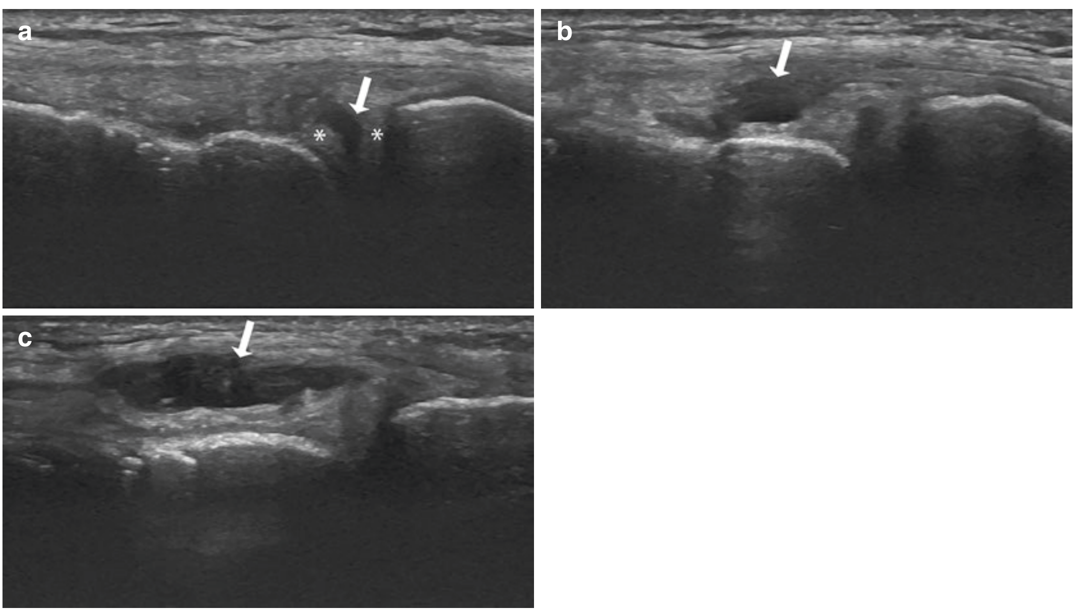

Fig. 6 (**a**–**c**) Ultrasound of the medial aspect of the knee in a 45-year-old long-distance runner. (**a**) An anechogenic fluid cleft (arrow) represents a horizontal tear, which divides two parts of the meniscus (asterisk). (**b** and **c**) Extension of the fluid collection (parameniscal cyst) in the superficial soft tissues anteromedial to the knee (arrows)

4.3.1 Technique

MRI of the knee is performed with the patient in supine position and the knee extended or slightly flexed. An extremity coil is positioned around the knee to optimize signal-to-noise ratio (SNR). Nowadays, the standard field strengths in clinical practice are 1.5 or 3 Tesla (T).

To obtain a full overview of the knee, images in the axial, coronal and sagittal plane are acquired, ideally with a slice thickness of 3 mm or less. The field of view is preferably 160 mm or smaller and imaging matrix 140 × 256 (Tuite et al. 2012).

For routine imaging, proton density (PD)- or T2-weighted 2D turbo spin echo (TSE) sequences and T1-weighted 3D gradient echo (GRE) sequences are used (Recht et al. 2005, Kijowski 2010). The addition of fat suppression techniques to the PD- or T2-weighted sequences allows better identification of bone marrow or soft-tissue oedema. Spectral, inversion recovery and Dixon techniques are available to perform FS. In a study by Fleckenstein et al. (1991), spectral FS proved to have better spatial resolution and SNR than other techniques.

3D TSE sequences have become available in the last decade on almost every vendor platform, allowing for reduced partial volume effect compared to 2D sequences. Additionally, the volumetric source data acquired by these 3D sequences may be rendered in every direction.

3D GRE sequences have also been developed. Despite higher spatial and contrast resolution, these sequences suffer from longer acquisition times, high susceptibility to metallic artefacts and poor visualization of bone marrow, menisci and ligaments (Kijowski and Gold 2011).

During the last decade, (semi)quantitative sequences have been studied for their ability to identify meniscal pathology.

Diffusion-weighted imaging (DWI) is able to detect meniscal tears through ADC mapping (preferably with b-values of 400 s/mm^2), although the sensitivity of DWI does not surplus that of conventional sequences and spatial resolution is lower (Kizilgöz et al. 2013; Aydin et al. 2011).

T1ρ, T2 and T2* mapping sequences have demonstrated alterations in meniscal values after trauma without clinical evidence of subsurface abnormalities, suggestive of subclinical trauma (Williams et al. 2012). Other authors found a correlation between meniscal T1ρ and T2 values and clinical findings of osteoarthritis (Rauscher et al. 2008). Further research is warranted on the possibility to predict long-term meniscal lesions and subsequent (early) osteoarthritis after knee trauma.

4.3.2 MRA

MR arthrography can be performed by direct injection of diluted gadolinium contrast in the knee (direct MR arthrography) or by administering gadolinium contrast intravenously and allowing diffusion from the bloodstream into the joint. Direct nor indirect MRA should be performed in the native (non-operated) meniscus.

4.3.3 Normal MR Anatomy

Menisci must be evaluated on both the sagittal and coronal images. Axial images have proven to be useful in the detection of peripheral meniscal tears as well as small radial tears of the free edge of the meniscus (Tarhan et al. 2004).

The normal menisci demonstrate diffusely low signal intensity on all MRI pulse sequences because of their fibrocartilaginous structure. The most peripheral images of the sagittal plane demonstrate a “bow-tie” appearance of the meniscus. The normal meniscus should have 1.5–2 bow ties (5–13 mm) on 4–5 mm thick images. Broad and disc-shaped menisci (>13 mm) with 3–4 or more bow ties are called “discoid” and are more prone to meniscal tears. The normal meniscus measures 3–5 mm in height. The medial meniscus varies in width from 6 mm at the anterior horn to 12 mm at the posterior horn. The lateral meniscus is approximately 10 mm in width throughout its length.

More centrally, the normal meniscus becomes triangular in appearance. The anterior and posterior horns of the lateral meniscus are nearly equal in size, whereas the posterior horn of the medial meniscus is nearly twice the size of the anterior horn.

4.3.4 Diagnosis of Meniscal Tears

To understand the significance of increased signal intensity in meniscal abnormalities, an MR grading system has been developed and correlated with a histopathologic model (Stoller et al.

1987): ***grade 1***, intrasubstance globular appearing signal not extending to the articular surface; ***grade 2***, linear increased signal patterns not extending to the articular surface (Fig. 7a); and ***grade 3***, the abnormal signal extends to the articular surface (Fig. 7b). The clinical importance of grade 2 signal abnormality in the meniscus, as seen on MRI and not visualized arthroscopically, is still not well understood. Grades 1 and 2 represent intrasubstance mucinous degeneration in an adult or prominent vascularity in a child and have no surgical significance. Grade 3 is visible by arthroscopy and represents a meniscal tear.

In addition to observing increased signal intensity within tears, the morphology of the meniscus should be assessed when evaluating meniscal lesions.

The "*direct*" signs (De Smet et al. 2001) associated with meniscal tears on MRI include

1. Unequivocal grade 3 signal (Fig. 7b)
2. Abnormal meniscal morphology with displaced or missing meniscal tissue:
   (a) Absent bow-tie sign (1 or fewer): either postsurgical or displaced tear (Fig. 8)
   (b) Double-PCL sign: displaced bucket-handle tear of the medial meniscus (Fig. 9)
   (c) Large anterior horn sign: displaced bucket-handle tear of the meniscus with flipped fragment
3. Meniscocapsular separation (Fig. 10)

The "*indirect*" signs (Costa et al. 2004) associated with meniscal tears on MRI include

1. Abnormal superior popliteomeniscal fascicle and posterior pericapsular, oedema: lateral meniscal tear, most commonly posterior horn.
2. Posterior bone bruise of the medial tibial plateau: peripheral tears of the posterior horn of the medial meniscus or tears of the posterior root ligament of the medial meniscus. Tears of this ligament can be associated with ganglion cysts at the posterior aspect of the tibia as well.
3. Extrusion (>3 mm) of the medial meniscus: degeneration, complex or large radial tear, tear involving the meniscal root.

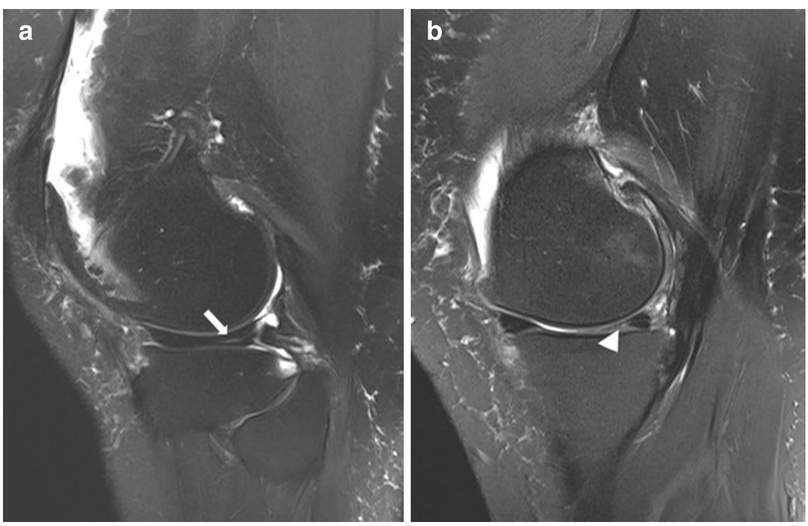

Fig. 7 (**a** and **b**) Sagittal TSE T2 WI with FS through the (**a**) lateral and (**b**) medial femorotibial joint in a 43-year-old footballer with medial knee pain. (**a**) Linear high signal intensity in the lateral meniscus (arrow) without contact with the meniscal surface. This grade II signal represents intrasubstance degeneration and is not clinically relevant in this patient. (**b**) Linear high signal intensity in the medial meniscus (arrow), in contact with the meniscal surface. This is consistent with a grade III signal and proved to be a tear on arthroscopy

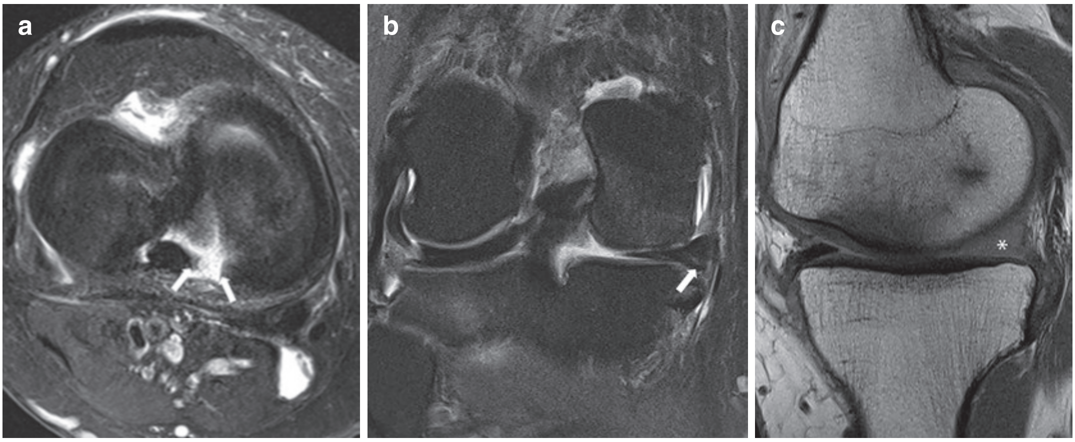

Fig. 8 (**a**–**c**) Tear in the posterior root of the medial meniscus with displacement. Axial (**a**) and coronal (**b**) TSE PD WI with FS reveals a defect in the posterior root of the medial meniscus (arrows in **a**). There is extrusion of the body of the medial meniscus due to the displaced tear (arrow in **b**). (**c**) Sagittal PD WI at the location of the defect reveals an absent bow-tie sign (asterisk)

4.3.5 Classification of Meniscal Tears

A plethora of meniscal classification systems are available, for example based on aetiology or tear pattern. However, findings or descriptions of meniscal tears on MRI do not always correlate with arthroscopic results and may become the cause of confusion between radiologist and orthopaedic surgeon.

In 2011, the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) knee committee proposed a concise and reliable classification pattern for meniscal tears on arthroscopy (Anderson et al. 2011). The inter-observer reliability of this ISAKOS classification amongst orthopaedic surgeons proved sufficient to use this system for pooling of international trial data for comparison. Studies on the use of the ISAKOS classification on MRI also showed acceptable agreement between radiologists when describing meniscal tears, both on 2D and 3D MRI (Chhabra et al. 2019).

The ISAKOS system describes meniscal tears based on seven characteristics: *tear pattern, tear depth, tear length, rim width, radial location, central to popliteus hiatus and quality of tissue.*

Tear pattern: Meniscal tears can be classified into two primary tear planes: vertical and horizontal (Fig. 11). Vertical tears are often of a traumatic origin and occur in younger individuals, whereas horizontal tears are usually secondary to meniscal (mucoid) degeneration and occur at later age.

Vertical tears are further subdivided into *radial* (perpendicular to the surface of the meniscus) and *longitudinal* (parallel to the long axis of the meniscus) varieties.

Radial tears are relatively uncommon meniscal tears and most commonly occur at the junction of the anterior horn and body of the lateral meniscus and at the meniscotibial attachment of the posterior horn of the medial meniscus. They are often seen as blunting of the free edge on coronal (MR) images. On sagittal images, the only evidence of a radial tear may be increased signal intensity on one or two peripheral sections.

Longitudinal vertical tears run perpendicular to the tibial plateau, parallel to the long axis of the meniscus. The meniscus is divided into a central and a peripheral part (Fig. 12).

Horizontal tears extend through the meniscus along a plane parallel to the tibial plateau, dividing the meniscus into inferior and superior segments. A horizontal cleavage tear is the most common type of tear to be associated with a meniscal cyst (Figs. 13 and 14). These cysts occur as a result of fluid extruding through the

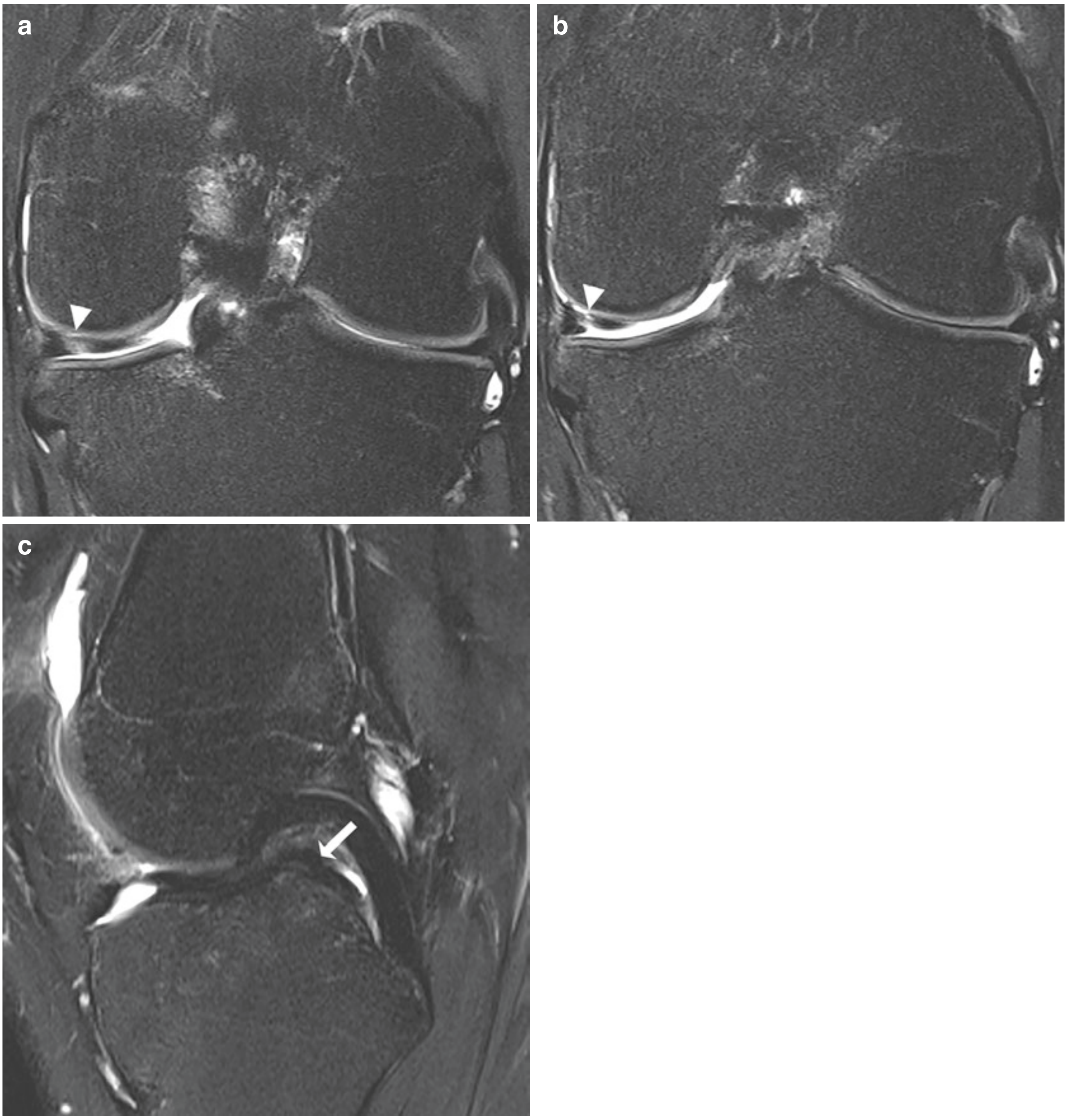

Fig. 9 (**a**–**c**) Bucket-handle tear of the medial meniscus. (**a** and **b**) Coronal TSE PD WI with FS shows a displaced tear in the body of the medial meniscus (arrows). (**c**) Sagittal TSE T2 WI with FS reveals a hypo-intense structure inferior to the PCL ("double-PCL sign", arrow), consistent with the displaced flap ("bucket-handle")

tear by a ball valve effect, and collecting either in the meniscus (intrameniscal cyst) or at the meniscocapsular junction (parameniscal cyst). These cysts tend to recur after resection if the underlying meniscal cyst is not repaired.

Horizontal flap tears are predominantly horizontal tears, where a portion of the meniscus may flip into the adjacent synovial gutter along the margin of the joint. These fragments may be missed easily at arthroscopy, when they are not identified on MRI.

A bucket-handle tear is an important and not infrequent type of meniscal injury, occurring in about 10% of meniscal tears in most series. It typically consists of a vertical or an oblique tear in the posterior horn that extends longitudinally through the body segment and anterior horn, usually occurring acutely with a sudden impact

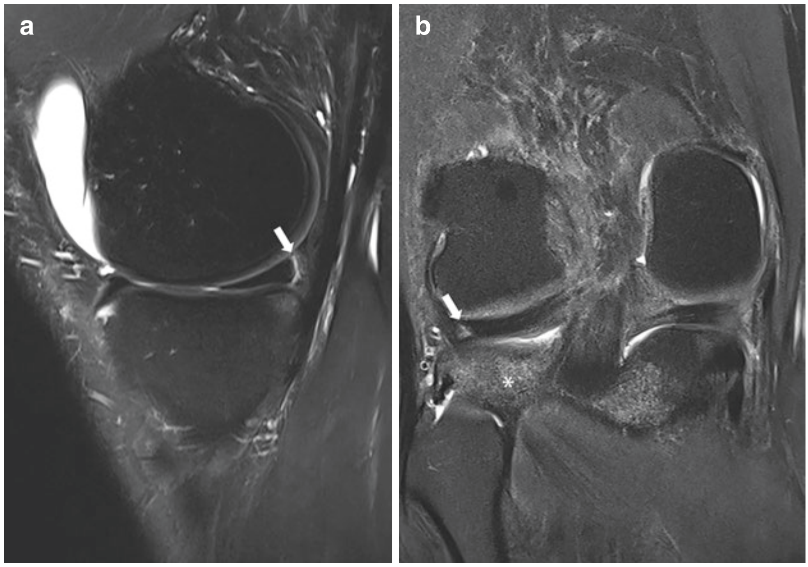

Fig. 10 (**a** and **b**) Meniscocapsular separation in 26-year-old rugby player with lateral knee pain after tackle. (**a**) Sagittal TSE T2 WI with FS and (**b**) coronal TSE PD WI with FS reveal a distinctive cleft (arrow) between the posterior horn of the lateral meniscus and joint capsule, compatible with meniscocapsular avulsion/separation. The coronal image also shows extensive bone marrow oedema in the later tibial plateau (asterisk)

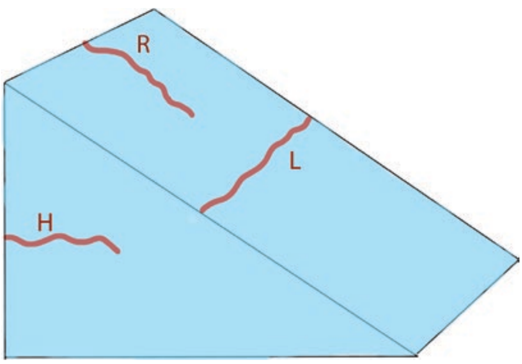

Fig. 11 Drawing of meniscal tear types. Horizontal tears (H) run parallel and vertical tears (R, L) perpendicular to the tibial plateau. Vertical-longitudinal tears (L) follow the long axis of the meniscus. Radial (R) tears transect the longitudinal collagen fibres

splitting the meniscus longitudinally. Coronal and sagittal MR images demonstrate blunting of the meniscus donor with the remaining meniscus being smaller than normal. The inner meniscal fragment is often displaced in the intercondylar notch, creating a "handle". Reported MRI signs for bucket-handle tears include absent bow-tie sign, double-PCL sign, disproportional posterior horn sign, anterior flipped fragment sign and double-anterior horn sign (Aydingöz et al. 2003) (Fig. 9).

Complex meniscal tears display combinations of vertical and horizontal tear patterns (Fig. 15).

Tear depth: extension of tear through one or (partial) or two (complete) meniscal surfaces.

Tear length: length of extension within meniscus (in mm).

Rim width: describes location of the tear in relation to the meniscal rim. Zone 1: 0–3 mm from the inner border; zone 2: 3–5 mm from the inner border; zone 3: >5 mm from the inner border (outer part of the meniscus).

Radial location: anterior, mid body or posterior.

Central to popliteus hiatus: describes extension of the tear in front of the popliteal hiatus.

Quality of the tissue: degenerative tissue exhibits diffusely increased signal, fraying and/or multiple tear patterns.

Chhabra et al. (2019) found fair-to-excellent interrater correlation for these characteristics in both the medial and lateral meniscus. There was moderate-to-excellent inter-method correlation for tear pattern and radial location and moderate correlation for the categorization central or not to popliteus hiatus. The other characteristics showed fair-to-good and moderate-to-good correlation.

The disadvantage of this classification is the absence of several types of meniscal tear patterns

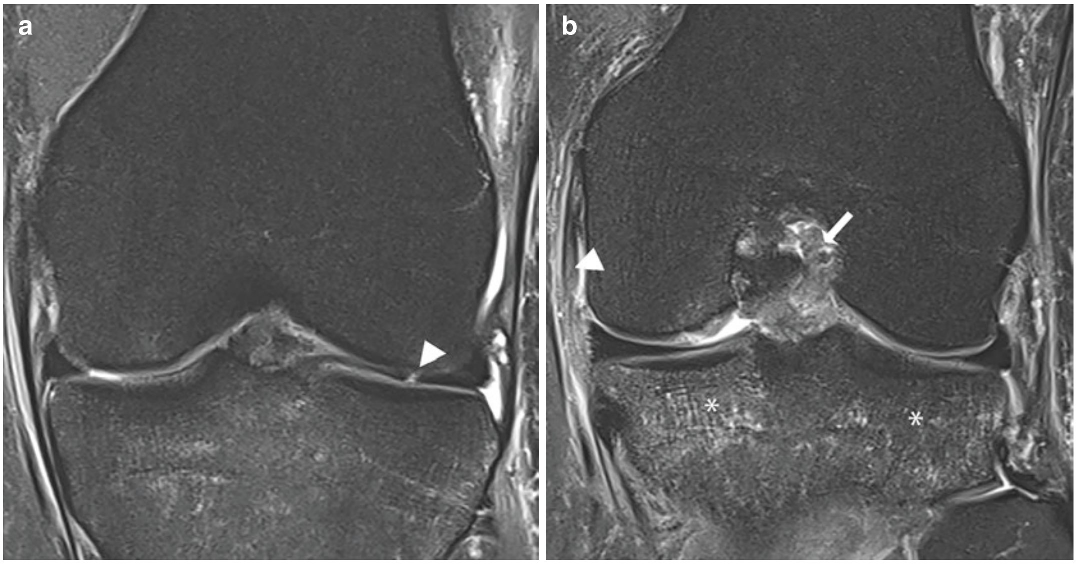

Fig. 12 (**a** and **b**) Coronal TSE PD WI with FS in a 38-year-old snowboarder. A longitudinal-vertical tear in the lateral meniscus (arrowhead in **a**) is noted, without significant displacement. Additionally, extensive bone marrow oedema in the medial and lateral tibial plateau (asterisks) is present, as well as a rupture of the ACL (arrow) and sprain grades 2–3 of the MCL (arrowhead in **b**)

(oblique, meniscocapsular separation, root ligament injuries), meniscal variants (discoid meniscus) and post-operative menisci.

Meniscocapsular separation (Fig. 10) is a subtype of meniscal tear, occurring most commonly along the medial meniscus, but the lateral meniscus may be affected also. Typically, the posterior meniscal horn is separated from the capsule with displacement of the posterior meniscal margin from the posterior tibial border by more than 8–10 mm.

An *oblique tear* (Fig. 16) is the most common meniscal tear type and demonstrates both radial and longitudinal components, as it courses obliquely across the meniscus, resulting in a flap of unstable meniscus. They most commonly affect the posterior horn and are seen as predominantly horizontal on sagittal MR images originating along the inferior surface at the free edge.

4.3.6 Accuracy and Limitations of MRI

Although arthroscopy still remains the gold standard in the diagnosis of meniscal injuries, the accuracy of MRI has made it a useful screening tool to avoid diagnostic interventional procedures (Elvenes et al. 2000). The pooled weighted sensitivity and specificity for medial meniscal lesions are 93.3% and 88.4%, respectively. For the lateral meniscus, these are 79.3% and 95.7%, respectively (Oei et al. 2003).

However, MR findings do not always agree with surgical findings. A study by Van Dyck et al. (2007) of 200 menisci analysed the various causes of incorrect MR diagnoses. They found 27 cases of discrepancy between MRI and arthroscopic findings. 44% of discrepancies between MRI and arthroscopy were determined as unavoidable, 37% as equivocal (or “borderline”) and 19% as interpretation errors.

4.3.6.1 Unavoidable Errors

Unavoidable errors are defined as those in which the diagnosed anomalies on MRI do not correlate with those on arthroscopy, even when multiple observers agree on the MRI diagnosis.

Unavoidable false-positive results are rare (1%) (Van Dyck et al. 2007). They may be the result of a healing or healed meniscal tear (Deutsch et al. 1990). A healing tear (e.g. after meniscal repair) may be seen as hyperintense signal intensity in meniscal substance owing to the

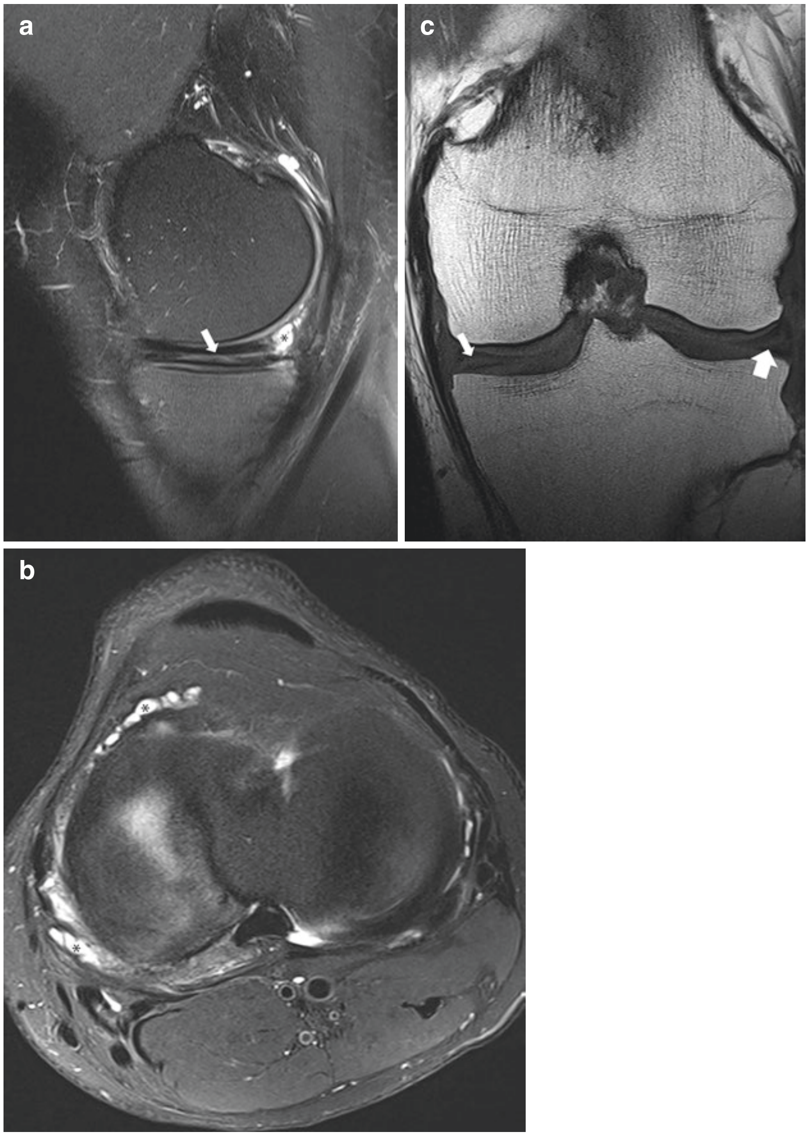

Fig. 13 (**a**–**c**) MRI in the 45-year-old long-distance runner in Fig. 6. (**a**) Sagittal T2 WI with FS shows a horizontal tear (arrow) in the body of the medial meniscus with parameniscal cyst (asterisk). (**b**) Axial TSE PD WI with FS reveals the true extent of the parameniscal cyst(s). (**c**) On TSE T1 WI, there is also abnormal signal intensity in the body of the lateral meniscus, consistent with a horizontal tear (thick arrow)

presence of granulation tissue (Farley et al. 1991). Also, they may be related to incomplete arthroscopic evaluation of the meniscus (Quinn and Brown 1991). Blind spots for the arthroscopist include the anterior horn of each meniscus, the extreme inner portion of the posterior horn of the medial meniscus and the undersurface of both menisci. Therefore, it is important to describe any tear in these areas clearly, because they may be easily missed during arthroscopy. Confusion between what represents fraying and what represents a tear may be another source of erroneous MR diagnosis.

Unavoidable false-negative errors are due to limitations of the MR sequences and imaging planes and do not represent observer errors. Small meniscal tears may not be discernible because the edges of small tears may be very closely apposed. The largest percentage of these false-negative results are found in the lateral meniscus. In the aforementioned study by Van Dyck et al. (2007), 23% of lateral meniscal

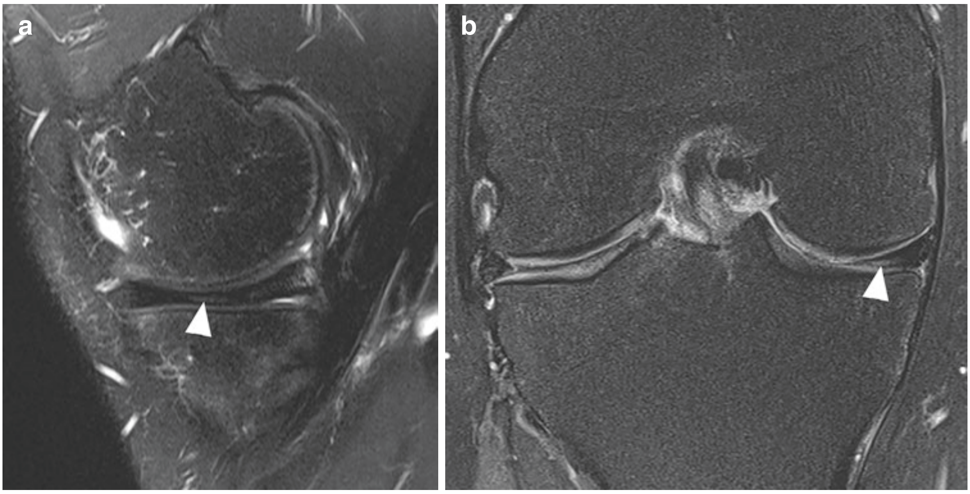

Fig. 14 (**a** and **b**) Horizontal tear (arrowheads) in the body and posterior horn of the medial meniscus on (**a**) sagittal TSE T2 WI with FS and (**b**) coronal TSE PD WI with FS

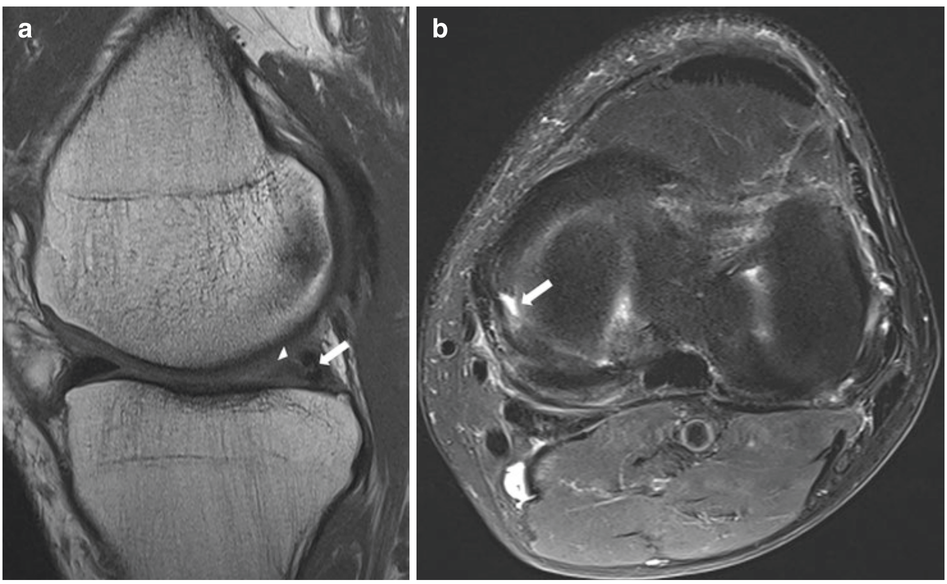

Fig. 15 (**a** and **b**) Complex tear in the posterior horn of the medial meniscus. (**a**) On the sagittal TSE PD WI, vertical (arrowhead) and horizontal (arrow) tears are revealed. (**b**) The axial TSE PD WI with FS shows a small defect in the posterior horn and body of the medial meniscus (arrow)

lesions were missed by MRI. Another study by De Smet et al. (1994) reported a lower yet also significant 11% of lateral meniscus lesions that were not detected on MRI. Furthermore, if a tear of the ACL is present, meniscal tears are more likely to be missed on MR images. Presumably, the biomechanical forces that result in an ACL tear cause meniscal tears that are difficult to diagnose on MR, namely in the posterior and peripheral parts of the lateral meniscus (De Smet and Graf 1994).

4.3.6.2 Equivocal Errors

It is not always possible to neatly categorize meniscal signal and determine if it is confined to the substance of the meniscus or extends

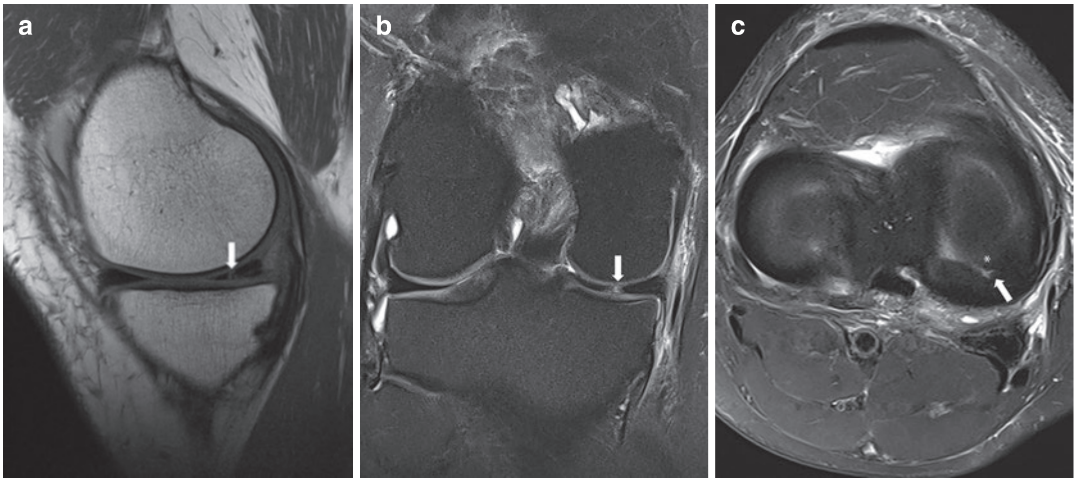

Fig. 16 (**a**–**c**) Oblique ("parrot beak") tear in the posterior horn of the medial meniscus of a 42-year-old footballer. Grade 3 signal (arrow) is seen on the (**a**) sagittal TSE PD WI and (**b**) coronal TSE PD WI with FS, consistent with a radial orientated tear. (**c**) The axial image reveals a slight oblique course of the tear (arrow) which creates a small, non-displaced flap (asterisk)

through the surface (Kelly et al. 1991). These equivocal MR imaging findings may lead to both false-positive and false-negative results compared to arthroscopy. De Smet et al. (1993) found that menisci with signal possibly contacting the surface had the same frequency of tears as menisci without signal contacting the surface. Furthermore, only 55% of medial and 30% of lateral menisci with signal contacting the surface on only one image were torn. Therefore, we suggest when linear signal closely approximates, but does not convincingly violate an articular surface, it is best to be descriptive rather than overcall a questionable finding. If surface contact is seen on only one image, the diagnosis should be qualified as a possible tear. Menisci with internal signal that only possibly contacts the surface should be considered intact.

Interestingly, it is not clear whether improved image quality leads to decrease of these equivocal errors (Van Dyck et al. 2010).

4.3.6.3 Interpretation Errors

This type of error may occur due to normal variants (Fig. 14). Radiologists must be aware of numerous pitfalls simulating a meniscal tear, including normal anatomical structures in close proximity to the meniscus (anterior transverse ligament, oblique meniscomeniscal ligament, meniscofemoral ligament, popliteal tendon, Wrisberg variant of discoid lateral meniscus), MR artefacts (volume averaging of adjacent bright structures, e.g. fat or fluid, truncation and motion-blurring artefacts, magic-angle phenomenon) and pathologic conditions (gas within the joint-vacuum phenomenon or iatrogenic, chondrocalcinosis, cartilage defects, meniscal ossicle) (Vanhoenacker et al. 2016).

4.4 CT Arthrography

The major indication of CT arthrography in meniscal evaluation is the detection of meniscal tears in the post-operative meniscus (see the following paragraph). Additionally, CTA is an alternative in patients with relative or absolute contraindications for MRI, including claustrophobia or implants such as defibrillators, or when MRI is not readily available.

Limitations inherent to the performance of this technique include invasiveness, possible allergic reaction, use of ionizing radiation and limited value for detection of associated ligamentous and/or soft-tissue disorders.

Multidetector CT arthrography (CTA) of the knee is an accurate and reproducible method for detecting meniscal abnormalities. Vande Berg et al. (2000) found a sensitivity and specificity for the detection of meniscal abnormalities of 98% and 94%, respectively, equivalent to those in most studies with MR imaging. More recent studies found a significantly lower accuracy (Fox et al. 2016), although this may be attributed to a delay between contrast injection and CT scan (≥60 min). Furthermore, CTA proved to be an accurate technique for detection of unstable meniscal tears with a sensitivity and specificity of 97% and 90%, respectively. Poor performance of MR imaging in the recognition of displaced meniscal fragments smaller than one-third of the meniscus has been reported (Wright et al. 1995).

5 Therapeutic Management in Athletes

When faced with a meniscal tear, the orthopaedic surgeon has three options: (1) leave the tear alone, (2) attempt a primary meniscal repair or (3) perform a partial or complete meniscectomy. When clinical symptoms persist after complete meniscectomy, meniscal replacement may be considered.

The treatment goal is to preserve as much functional meniscal tissue as possible to lessen the probability of developing osteoarthritis while addressing the clinical symptoms caused by meniscal tears.

Evaluation of the clinical situation is essential for optimal treatment planning, as well as meniscal tear location, extent and stability (Weiss et al. 1989).

Although MRI provides valuable information by displaying the location and extent of the tear, it is often impossible to determine with certainty whether or not a tear is stable using MRI (unless a displaced fragment is present). Meniscal tear stability is best determined with direct depiction and palpation at arthroscopy (Dandy 1990).

However, on MRI, tears that are considered stable include (1) a partial-thickness tear (less than half the height of the meniscus), (2) a full-thickness oblique or vertical tear measuring less than 7–10 mm in length and (3) a radial tear measuring less than 5 mm (Matava et al. 1999).

5.1 Conservative Treatment

In older or less active patients with minor symptoms, a more conservative approach is often employed. The mere presence of a meniscal tear in the degenerative knee is not an indication for arthroscopy. Research demonstrated that meniscal tears were a very common magnetic resonance imaging finding in asymptomatic patients and that there was no difference in pain or function between osteoarthritic patients with and without meniscal tears (Miller 2004). Other studies suggested that horizontal (degenerative) tears should be treated non-operatively in the presence of cartilage damage (Katz et al. 2013). However, in athletes, non-operative treatment is usually inadequate for a patient with high physical demands associated with sport, as the reduction in activity necessitated by the symptoms is not acceptable (Ludman et al. 1999).

5.2 Surgical Interventions

Based on MR images, it is important to classify the location of the tear relative to the blood supply of the meniscus. This allows repair potential of the lesion to be predicted. A red-red tear is located at the meniscal periphery within the vascularised zone or represents capsular detachment. It has the best prognosis for healing, as the blood supply persists in this region (Fig. 17). The red-white tear has no blood supply from the inner surface of the lesion; however the remaining vascularity is usually sufficient for the healing process. A red-red and red-white tear may spontaneously heal or may be repaired. White-white tears need to be resected, as they are located in the avascular zone and have no healing potential.

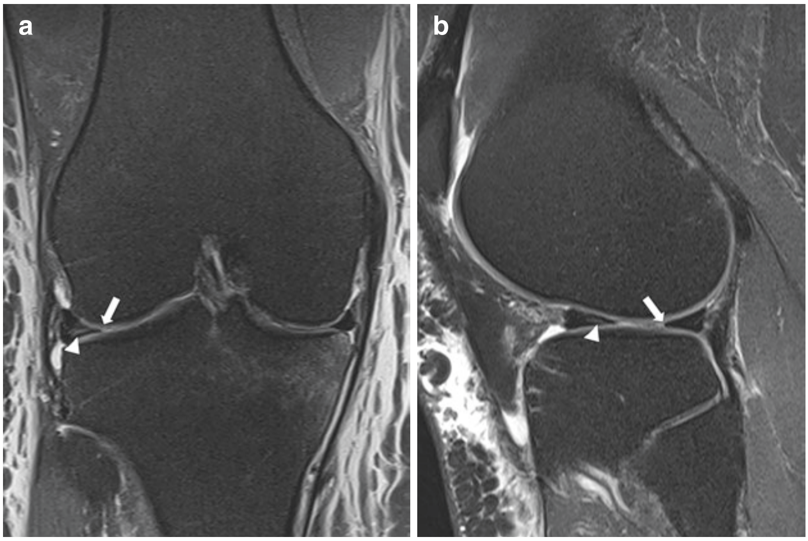

Fig. 17 (**a** and **b**) Potential retear after previous partial lateral meniscectomy on (**a**) coronal TSE PD WI with FS and (**b**) sagittal TSE T2 WI with FS. Discrete blunted aspect of the body of the lateral meniscus suggests previous partial lateral meniscectomy (arrows). There is linear high signal intensity in contact with the resection surface, suggestive of retear. However, clinical information stated the presence of a stable residual tear that was left by the surgeon in order to minimize meniscal volume loss. The patient was pain free

5.2.1 Meniscectomy (Partial-Complete)

Partial meniscectomy is often the treatment of choice in symptomatic horizontal tears persistent to conservative treatment, unstable flap tears, radial tears, longitudinal-vertical tears in the white-white zone and complex tears. Associated parameniscal cysts are preferably debrided to reduce symptoms (Tafur et al. 2018). Other indications include irreparable root tears or vertical tear or failed meniscal repair.

Short-term clinical results were demonstrated for this type of surgery, but long-term follow-up revealed a high rate of progression to osteoarthritis (Fauno and Nielsen 1992).

5.2.2 Meniscus Repair

The main indication for meniscal repair is acute, traumatic longitudinal-vertical tears within the red-red zone (Vaquero and Forriol 2016). Extended indications for meniscal repair surgery include tears red-white zone in younger patients, radial tears, root avulsions and meniscocapsular avulsions/meniscal ramp lesions (Kurzweil et al. 2014; Thaunat et al. 2016). Contraindications are extensive degenerative changes or ligamentary instability without concomitant ligament repair.

A recent meta-analysis concluded that reoperation rates were higher for meniscal repair than those for meniscectomy but it leads to better long-term function outcome and better activity level (Xu and Zhao 2015).

5.2.3 Meniscus Reconstruction

Persistent joint-line pain and swelling after complete or partial meniscectomy are possible indications for meniscal replacement. Meniscal allograft transplantation is mostly reserved for patients under 50 years of age. For older patients with chronic meniscal problems, synthetic (polycarbonate urethane (PCU) or collagen) implants are available.

Prophylaxis for further advancement of osteoarthrosis is not the main goal in these patients. Rather, the main aims are to restore normal knee mechanics, improve joint function and relieve pain (Doral et al. 2018).

6 Imaging of the Post-operative Meniscus

Because meniscal surgery is so common in the young, athletic population, many patients who have undergone meniscal surgery present with recurrent knee injury or pain. For the radiologist, imaging the post-operative meniscus remains a challenge. Contour abnormalities and diffuse signal changes may be present in both normal post-operative menisci and recurrent meniscal tears. As in preoperative patients, MR imaging is the most valuable imaging method for post-operative evaluation of the knee (McCauley 2005). Standard MR imaging protocols, however, are less reliable in imaging post-operative knees than in unoperated knees, especially for the diagnosis of meniscal tears, with accuracies ranging from less than 50% to 80%.

6.1 MR Appearance After (Partial) Meniscectomy

Following partial meniscectomy, the meniscus has a smaller aspect, possibly with some degree of deformity. Intermediate signal intensity on a proton density/intermediate-weighted sequence-weighted image extending to the meniscal surface ("grade 3 signal") may represent fibrovascular or fibrocartilaginous repair tissue, pre-existing degenerative signal abnormalities abutting the post-operative surface or a new tear (Figs. 17 and 18).

Increased signal on a T2-weighted image extending into the meniscus is a stricter criterion for recurrent or residual tear, providing higher specificity (73% versus 53%) but lower sensitivity (72% versus 76%) (White et al. 2002).

6.2 MR Appearance After Meniscus Repair

Following meniscal repair, the fibrovascular repair tissue and later fibrocartilaginous scar tissue may present as abnormal signal intensity contacting the meniscal surface on intermediate-weighted sequences (Toms et al. 2005) (Fig. 19). Differentiating these normal post-operative findings from recurrent tear remains challenging. The presence of high signal on T2-weighted images has a higher specificity and accuracy (90–99% and 83–91%, respectively) than PD- and T1-weighted sequences (Miao et al. 2009, 2011). Additional signs suggestive for retear include diastasis of the suture edges >1 mm or displaced meniscal flaps (Recht and Kramer 2002).

6.3 MR Appearance After Meniscal Replacement

Meniscal allograft transplants often develop diffuse signal abnormalities, even shortly after transplantation. These grade 3 alterations may remain stable or progress, most frequently in the lateral knee compartment (Buma et al. 2004). It was suggested by Verdonk et al. (2006) that these changes were alterations in the extracellular matrix composition and water content rather than real tears.

Often, radial displacement of the body of the transplant meniscus is seen. This phenomenon was more frequently observed in the medial than lateral meniscus. The relevance of this finding remains debated, as some authors believe this to be a sign of subsequent degeneration (Costa et al. 2004; Gale et al. 1999) while other studies did not find a correlation with clinical outcome (Verdonk et al. 2006; Lee et al. 2015).

Only few studies examined the MR findings of artificial meniscal implants. Both PCU and collagen implants show higher signal intensity on T2-weighted sequences. In PCU implants, defects in the posterior horn have been described (Huysse et al. 2008). Radial displacement may also be seen in PCU implants but, as in allograft transplantation, has no significant effect on clinical outcome (De Coninck et al. 2013).

6.4 Conventional MR Versus MRA Versus CTA in the Post-operative Meniscus

The discussion on which imaging modality is the most accurate for diagnosing recurrent tear after

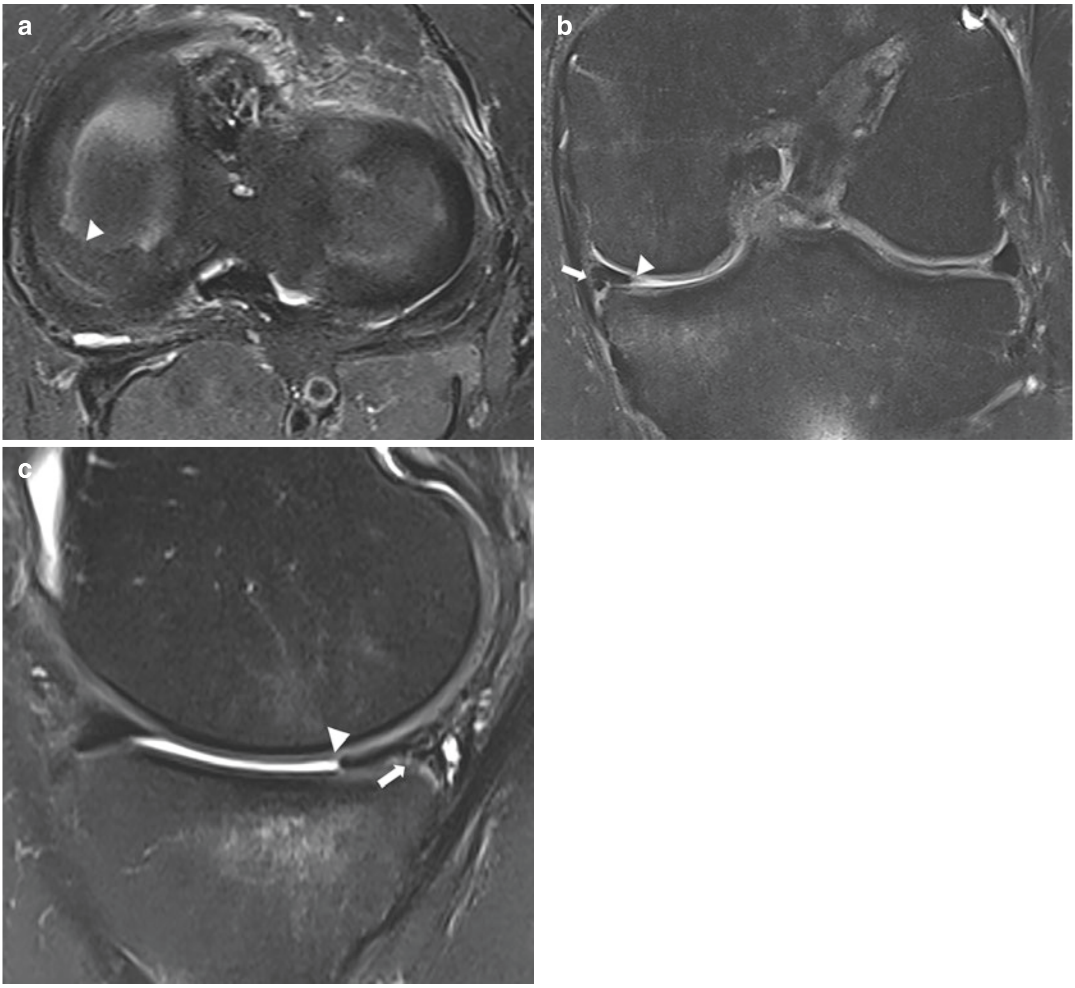

Fig. 18 (**a**–**c**) New meniscal tear after partial meniscectomy. (**a**) On axial TSE PD WI with FS, irregularity of the inner rim of the medial meniscus is noted (arrowhead), consistent with previous partial medial meniscectomy. (**b**) Coronal TSE PD WI with FS and (**c**) sagittal TSE T2 WI with FS confirm partial volume of the medial meniscus (arrowheads). High signal intensity is seen at a distance of the surgery site (arrows), compatible with a new oblique tear

meniscal surgery has been the subject of many studies.

Most authors report a higher accuracy for direct and indirect MR arthrography than MRI. In a recent meta-analysis, reported accuracies for recurrent tear for both partial meniscectomy and meniscal repair are 57–80% for MRI, 81–93% for indirect MRA and 85–93% for direct MRA (Baker et al. 2018). In CTA, the reported sensitivity and specificity after partial meniscectomy are 93% and 89%, respectively (Mutschler et al. 2003).

In partial meniscectomy, the accuracy of the different techniques varies according to the amount of meniscus that was resected. When less than 25% of the meniscus was resected, the accuracy of conventional MRI was 89%. In larger resection volumes (greater than 25%), the accuracy of conventional MRI dropped to 69%, significantly less than that of direct MRA (89%) (Applegate et al. 1993, Magee et al. 2003).

CT arthrography or direct MR arthrography may reveal contrast extravasation within (partial-thickness recurrent tear or partial-healed repair)

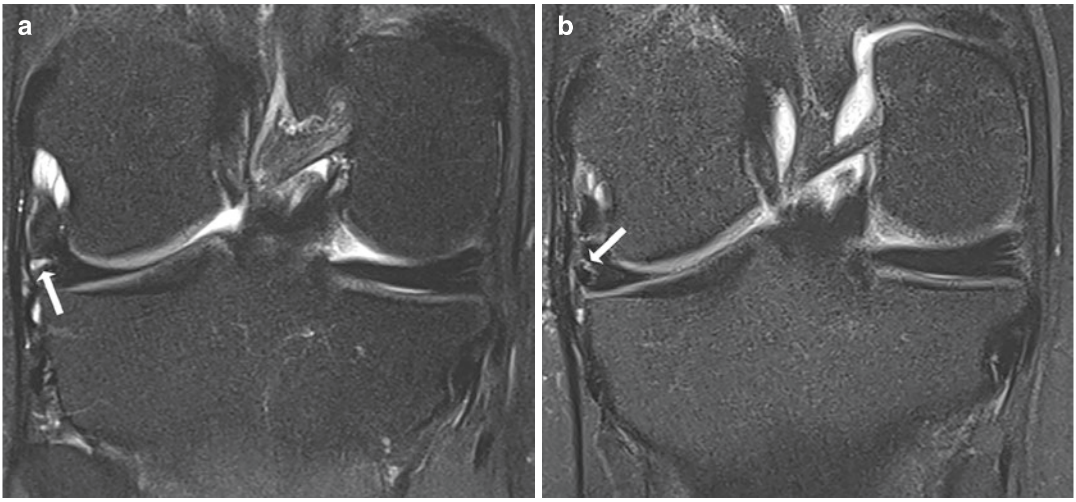

Fig. 19 (**a**) Preoperative and (**b**) post-operative coronal TSE PD WI with FS. The preoperative image (**a**) reveals a grade 3 signal/horizontal tear (arrow) in the red zone of the body of the lateral meniscus. 3 months after repair surgery (**b**), persistent high signal (arrow) is noted at the surgery site. This represents fibrovascular repair tissue and not a new tear

or through the meniscus (full-thickness recurrent tear or failed repair). However, these findings are not present in every retear, possibly due to mechanical obstruction (e.g. scar tissue) (De Smet et al. 2006; Magee 2014).

6.4.1 Imaging Pathway in the Post-operative Meniscus

In general, most patients do not need to undergo MR arthrography and conventional MRI should be considered as the first-line investigation (38) (Fig. 16). We look for unequivocal sites of fluid intensity signal within the meniscal remnant, displaced fragments or tears in a new location, as the only reliable criteria for a recurrent or residual tear. Standard criteria can be used to interpret areas of the menisci known to be separated from the site of prior surgery. Investigation with MRA (or CTA) could then be considered if conventional MRI is normal (no severe degenerative arthrosis, avascular necrosis, chondral injuries, native joint fluid extending into a meniscus or a tear in a new area), if the clinical suspicion of recurrent tear is high, or if conventional MRI is inconclusive. In particular, MRA may be useful when there is prior knowledge of significant meniscal resection (more than 25%) or meniscal repair with new symptoms in the same area as the initial symptoms. Furthermore, MR arthrography is of additional value in assessing the articular cartilage, deteriorating more rapidly after meniscectomy.

7 Specific Sports and Overuse Trauma of the Meniscus

7.1 Injury Mechanisms in Sports Injury

Sports-related meniscal tears may result from excessive application of force to a normal meniscus (in the young athlete) or normal forces acting on a degenerative meniscus (in older patients). Meniscal injury, particularly sports-related injuries, usually involves damage due to twisting motions, which are common in sports, with a varus or valgus force directed to a flexed knee. Contact with another player typically does not occur, nor does lunging or landing awkwardly. A single "wrong" step is sufficient.

The most common traumatic mechanism, accounting for nearly half of all injuries, combines valgus force directed to a flexed knee with the tibia in exorotation (Hayes et al. 2000). Therefore, compression with impaction injury usually occurs in the lateral compartment, whereas tension with distraction injury occurs in the medial compartment. Thus, the medial meniscus is at risk for peripheral avulsion injury at the capsular attachment site resulting in peripheral meniscal tear (and/or meniscocapsular injury) whereas the lateral meniscus gets entrapped by compressive force, splays and splits (because of its more circular shape and decreased radius of curvature) the free margin resulting in a radial tear.

In contact sports, tackles are often directed towards the lateral side of the knee, resulting in the same injury mechanism and type of (meniscal) lesions.

Injury to the medial meniscus is about five times more common than injury to the lateral meniscus. Compared to the lateral meniscus, the medial meniscus is relatively immobile because of its firm attachment to the medial capsule along its peripheral border. The lateral meniscus, loosely applied to the joint capsule, moves freely with the condyle and usually can escape entrapment (Muller 1983).

The trauma-related medial meniscal tear typically demonstrates a vertical orientation extending across the full thickness of the meniscus. It may redirect itself obliquely towards the free margin of the meniscus, creating a flap configuration.

Radial tears are rare in the medial meniscus and appear to follow more severe forms of athletic trauma. Kidron and Thein (2002) described the presence of a small radial root tear in the posterior horn of the medial meniscus in 11 of the 1270 operated knees (0.86%). Each of these 11 patients, all active in demanding sports, including handball, judo and gymnastics, had a history of acute flexion injury and medial joint-line pain. Arthroscopic trimming of the edges of the tear revealed a developing cleavage plane tear extending to the body of the meniscus, resulting in partial meniscectomy.

Moreover, according to a study by Magee et al. (2004), the prevalence of meniscal radial tears may be increased in the post-operative knee due to the altered hoop mechanism of the meniscus and decreased ability to transmit loads. These authors found a prevalence of meniscal radial tears of 32% in the post-operative knee as opposed to a reported prevalence of 14% in the non-operated knee.

There are significant regional differences in sports-related meniscal injuries depending upon the popularity of specific sports. In a study by Baker et al. (1985), meniscectomies performed in Syracuse, New York, from 1973 to 1982 were reviewed. Medial versus lateral meniscus injury was 81 versus 19%. Football had a 75% predominance of medial meniscectomy; basketball, 75%; wrestling, 55%; skiing, 78%; and baseball, 90%. These data indicate that there are differences in the ratio of medial versus lateral meniscal disruption associated with specific sports activities. Medial meniscal injuries were consistently more common in all sports categories, except wrestling, where the frequency of lateral meniscal tear is nearly equal to that of a medial meniscal tear.

7.2 Symptomatic and Asymptomatic Meniscal Lesions in Athletes

Asymptomatic or "silent" grade 3 intrameniscal signal abnormalities have been described in both athletes and less active patients (Ludman et al. 1999). The incidence of asymptomatic meniscal tears increases with age, with 5.6–13% of those less than 45 years old and 36% of those more than 45 years old (Greis et al. 2002). Some studies have suggested that athletic groups, including American football players and marathon runners, show an increased incidence of meniscal abnormalities (Shellock et al. 1991). In a study by LUDMAN et al. (1), the overall incidence of grade 3 changes (13%) in gymnasts was not significantly different from the incidence in the controls. However, when compared with the control group, the group of gymnasts had a significantly different distribution of grade 3 intrameniscal changes, preferentially involving the lateral meniscus (evenly divided between the anterior and posterior horns), whereas in the control group, grade 3 changes were mostly found in the medial meniscus (only posterior horn). The reason why the lateral meniscus of gymnasts is preferentially affected is unclear. Nevertheless, knowledge of these MR appearances is important when evaluating the lateral menisci within this group of athletes to prevent unnecessary treatment or intervention. This is particularly important when the imaging findings do not closely correlate with the site of symptoms.

On the other hand, symptomatic grade 2 intrameniscal signal has been described in athletes (Biedert 1993). In 35 of 43 patients (77.7%) with clinical features of a possible meniscus lesion, a pure intrasubstance tear with linear grade 2 signal was identified on MRI. This type of lesion in the posterior horn represents a frequent cause of false-negative result on arthroscopy. All patients were free of symptoms after conservative treatment or partial meniscectomy. In this study, the highest rates of intrasubstance tears were found in soccer, running and ice hockey.

Although not specifically described in any sports branch, a potential source for false-positive interpretation for meniscal tear in the MR evaluation of the post-traumatic knee is the so-called *meniscal contusion*. Cothran et al. (2001) described focal signal abnormalities in the knees of six patients who had a history of acute knee trauma, associated with tears of the ACL and bone contusions. This signal reached the articular surface of the meniscus, but did not meet the criteria for a meniscal tear or degeneration. The meniscus gets trapped between the femur and tibia during a traumatic event. The adjacent bone contusion should alert one to the possible presence of a contusion rather than a meniscal tear.

Meniscocapsular separation (“ramp lesions”) has been partially discussed previously in this chapter. They are most commonly seen along the medial meniscus, which is more tightly adherent to the joint capsule. Small avulsed corners of the medial meniscus may be difficult to identify unless a directed search is made for them.

George et al. (2000) have found that anterolateral meniscocapsular separations of the lateral aspect of the knee were frequently missed on MRI reporting in a group of athletes presenting with lateral joint-line pain suggestive of meniscal injury. During arthroscopy, in all patients meniscocapsular separation was confirmed and no meniscal tears were found. Meniscocapsular tears can also occur along the posterolateral corner of the joint, with disruption of the meniscopopliteal fascicles.

Another entity, recently described in severe acute (sports) injury of the knee by Bikkina et al. (2005) is the so-called *floating meniscus*, corresponding to a meniscal avulsion or detachment from the tibial plateau with an associated disruption of the meniscotibial coronary ligaments, which attach the meniscus to the tibia, allowing fluid to encompass the meniscus. It is usually seen as a sequela of high-impact (sports) injury or trauma. The presence of a “floating meniscus” on MRI is often associated with significant ligamentous injury without evidence of a tear within the substance of the meniscus. Alerting the surgeon to the presence of a meniscal avulsion facilitates appropriate surgical planning with meniscal reattachment to the tibial plateau.

8 Conclusion

Meniscal injuries are very common among professional and amateur athletes and are a major cause of functional impairment of the knee. For athletes, unnecessary treatment or intervention may be as damaging to a competitive future as failure to diagnose a clinically significant injury. Therefore, rapid and accurate evaluation of possible meniscal injuries is crucial in these patients.

For detection of meniscal pathology, MRI is an excellent diagnostic imaging tool, with accuracy of as high as 98%, compared to arthroscopy, remaining the gold standard. Furthermore, MRI proved useful, on the basis of its high negative predictive value, to avoid unnecessary arthroscopy and hospitalization, morbidity and waste of limited financial and manpower resources.

However, radiologists must be aware of numerous pitfalls simulating a meniscal tear. Furthermore, MRI pictures contain many details with an uncertain clinical relevance, delineating the need to correlate MR with clinical findings in order to plan treatment optimally.

Things to Remember

1. Meniscal tears are the most common cause of knee pain and instability in athletes.

2. Symptoms and clinical findings are usually non-specific and must be regarded as of little value in making the correct diagnosis.
3. MRI has replaced other imaging techniques for diagnosis of meniscal tears.
   MR criteria for classifying meniscal tears have been clearly described. In addition to diagnosing meniscal tears, the radiologist should describe the features of each meniscal tear that may affect treatment.
4. As the long-term protective effect of the menisci on the joint surfaces has been well documented, meniscal preservation should be the goal of treatment. Stability, location and type of meniscal tear are essential in deciding whether to repair, resect or leave alone a meniscal lesion. Allograft replacement is an evolving technique.

9 Imaging Boxes

Box 1

Plain radiography and standard arthrography

Have been replaced by other (cross-sectional) imaging techniques for the evaluation of meniscal injury.

Ultrasound

No significant role for the detection of meniscal tears, although meniscus extrusion and parameniscal cysts are suggestive of tear.

Box 2

MR arthrography and CT arthrography

High accuracy for the evaluation of meniscal injury.

Invasive.

Useful for the evaluation of the post-operative meniscus.

Standard MRI

Non-invasive.

The dominant imaging technique for the assessment of meniscal lesions.

Box 3

Because both asymptomatic grade 3 and symptomatic grade 2 lesions exist, MRI findings need to be correlated with clinical symptoms in order to plan treatment optimally.

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