Postoperative Knee and Shoulder

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Learning Objectives

- Learn normal and abnormal imaging findings on postoperative knee MRI.
- Learn normal and abnormal imaging findings on postoperative shoulder MRI.

Key Points

- Interpretation of postoperative MRIs of the knee and shoulder can be challenging.
- Knowledge of the details of the original lesion, surgery performed, timing of surgery, and expected normal postoperative findings is crucial for the correct interpretation of postoperative MRIs.
- Knowledge of the common complications of each type of surgery and their appearance on MRI is crucial for the correct interpretation of postoperative MRIs.

9.1 Postoperative MRI of the Knee

Common knee operations address abnormalities of the ligaments, menisci, and articular cartilage. Because most procedures are performed arthroscopically, the first challenge for interpretation of a postoperative MRI examination is recognition that prior surgery has occurred. Horizontally oriented, low-signal-intensity fibrotic scarring from arthroscopic portals in Hoffa's fat pad or adjacent to the patellar tendon may be the only clue to prior surgery, especially when no implants or grafts were used (Fig. 9.1a) [1].

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9.2 Ligament Surgery

The knee ligament injuries that most commonly require operative management are tears of the anterior cruciate ligament (ACL) and medial patellofemoral ligament (MPFL). Nonoperative care is typical for isolated tears of the medial collateral or posterior cruciate ligament. Posterolateral corner and combined ligament injuries are less common but usually require surgery.

9.2.1 Anterior Cruciate Ligament

Rarely a proximal ACL tear or avulsion with relatively preserved tissue quality will be treated with primary repair, using suture anchors or pull-out buttons. Postoperatively, the MRI appearance of a repaired ligament should closely mimic a native intact ACL; a tibial tunnel may be visible if augmentation with fiber tape was employed [2]. Most ACL tears aremanaged with graft reconstruction, using autograft harvestedfrom the patellar or hamstring tendons. The graft is passed through tunnels drilled in the distal femur and proximal tibiaand then anchored by bioabsorbable or metal fixation. Somesurgeons use two tunnels and grafts to replace the anteromedial and posterolateral bundles separately [3], although clinical outcomes and stability are similar for single- and double-bundle reconstructions [4].

Hamstring grafts are typically stripped from the distal semitendinosus and gracilis and then quadrupled, resulting in a multi-fascicle appearance. The resected tendons can appear attenuated or regenerate and appear relatively

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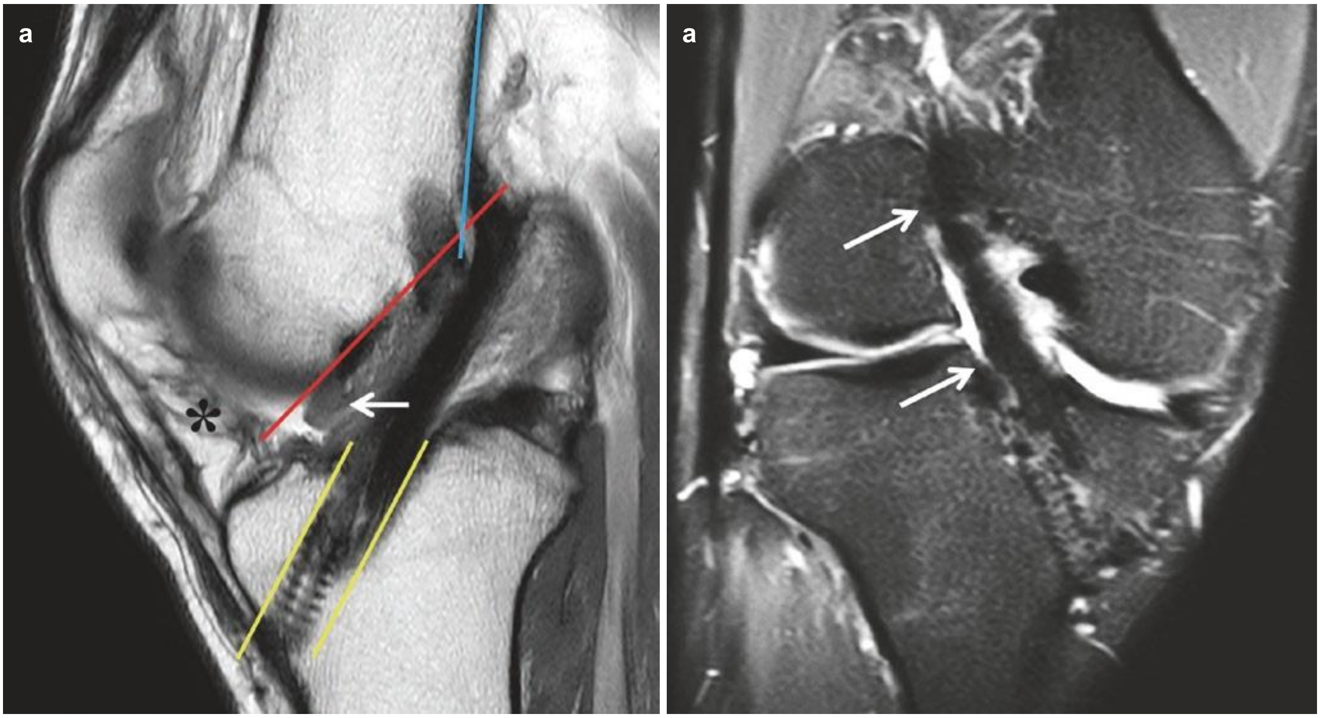

Fig. 9.1 A 27-year-old man with expected findings after anterior cruciate ligament reconstruction. (**a**) Sagittal proton-density-weighted image shows low-signal-intensity intact taut graft in intercondylar notch. Femoral tunnel is near intersection of intercondylar roof (Blumensaat's line, *red line*) and posterior femoral cortex (*blue line*), while tibial tunnel (*yellow lines*) lies in anterior half of tibia but entirely posterior to Blumensaat's line. Note mild linear scarring in Hoffa's fat pad (*asterisk*) from arthroscopy. Small cyclops lesion (*arrow*) was asymptomatic. (a) Coronal fat-suppressed intermediate-weighted sequence was reconstructed slightly obliquely to demonstrate graft course and tunnels (*arrows*) on a single image. Opening of femoral tunnel is at 11:00 position (right knee). Tibial tunnel aperture is in midline

normal after several years [5, 6]. Patellar tendon grafts come from the middle or medial third of the tendon together with attached bone blocks from the inferior patella and tibial tubercle. Postoperatively, a sagitally oriented defect in the residual tendon may persist or heal with hypertrophied scar tissue [7]. Donor site complications are infrequent, with anterior knee pain the most common occurring in approximately 17% of reconstructions using a patellar tendon graft [8]. Patellar fractures are rare. Both a recent prospective series and a 2003 meta-analysis found a higher graft failure rate for hamstring compared with patellar tendon grafts [8, 9].

Tunnel position affects outcomes and should be evaluated on postoperative MRI. On sagittal images the femoral tunnel exits near the junction of the roof of the intercondylar notch (Blumensaat's line) and the posterior femoral cortex [10]. The normal tunnel aperture in the coronal plane is between 10:00 and 11:00 for a right knee and between 1:00 and 2:00 for a left knee [7, 10]. The intra-articular opening of the tibial tunnel belongs midline on coronal images, while on sagittal images it should be just anterior to the midpoint of the tibia but posterior to Blumensaat's line (Fig. 9.1) [10, 11]. Tunnels that are located more anteriorly can predispose to graft impingement and rupture, while tunnel positions that create a nearly vertical graft may result in a lax graft and instability [12, 13]. Tunnel widening, with or without intra-tunnel cyst formation, typically occurs in the first 6 months after surgery and later stabilizes or partly reverses [14]. These intraosseous changes are more common after hamstring reconstructions and within the tibial tunnel and do not affect graft function, but may influence plans for future revisions; cysts can extend into the pretibial soft tissues as a mass [15, 16].

The MRI signal within an ACL graft follows a predictable time course [7]. Initially tendon grafts are avascular and will appear dark on all pulse sequences for the first 3–4 months. Thereafter, vascular ingrowth and "synovialization" increase the signal intensity on both T1- and T2-weighted images; at this point diagnosis of a recurrent tear may be difficult, and close correlation between imaging findings and clinical examination is needed for correct assessment. Maturation ("ligamentization") of the graft by 12–18 months results in predominantly low signal intensity, although small foci of increased signal intensity on intermediate and T2-weighted images can be seen within normally functioning grafts even

Fig. 9.2 Focal and diffuse arthrofibrosis following anterior cruciate ligament reconstruction on sagittal T2-weighted images. (**a**) Intra-articular cyclops lesion (*arrow*) anterior to graft in a 28-year-old man with painful, limited knee extension. (**b**) A 51-year-old woman with severe knee stiffness due to generalized arthrofibrosis. Note band of low-signal-intensity fibrotic scar in anterior interval (*arrows*), extending along posterior margin of Hoffa's fat pad to inferior patella and associated patella infera

several years after reconstruction [17]. Additionally, linear high-signal-intensity bands oriented between the layers of a hamstring tendon allograft are normal [10]. An impinged graft may show a distorted course with indistinctness of the distal fiber contour and focally increased signal intensity [7, 18]. Graft impingement may limit knee extension and predispose to graft failure [10, 19].

Postoperative stiffness affects approximately 3% of patients, more commonly women [20]. One contributor is arthrofibrosis (Fig. 9.2). The focal form results in a synovial-based soft tissue nodule (a "cyclops" lesion) anterior to the distal graft of varying signal intensity [21]. Lesions greater than 5 mm in diameter occur in approximately 25% of patients 6 months after ACL reconstruction; however, the presence and size do not correlate with clinical outcomes through the first 2 years after surgery [22]. In cases where a cyclops lesion contributes to pain or limited motion, arthroscopic resection is indicated [23]. Diffuse arthrofibrosis appears as thick, low-signal-intensity bands within the posterior aspect of Hoffa's fat pad [24]. In severe cases fibrotic scar tissue can involve the entire anterior interval of the knee, extending from the intercondylar synovium to the inferior pole of the patella, resulting in patella infera, severely limited knee motion, and accelerated patellofemoral osteoarthritis [25]. Treatment consists of active motion and physical therapy; failures may undergo manipulation under anesthesia or arthroscopic lysis of adhesions [26].

Graft rupture occurs in 3–8% of cases, usually due to repeat trauma after a patient has returned to activity [7]. The primary signs of a failed graft are similar to those for a native ACL—namely, graft discontinuity, abnormal orientation, or absence of visible fibers (Fig. 9.3) [11, 27]. Acutely, joint effusion, edema within and surrounding the graft, and typical bone contusions may also occur. Accuracy of MRI for diagnosing torn grafts is lower when failure is insidious compared to cases with an acute re-injury [28]. Secondary findings of laxity such as anterior tibial subluxation have low positive predictive value after ACL reconstruction, limiting clinical usefulness [29]. Fractured or migrated fixation implants may contribute to graft failures.

9.2.2 Other Ligaments

Recurrent lateral patellofemoral instability may require operative management. The medial patellofemoral ligament (MPFL) is the most biomechanically important component of the medial patellar retinaculum [30, 31]. In cases where the MPFL is acutely avulsed from the patella, primary suture repair with or without augmentation is possible [32]. When

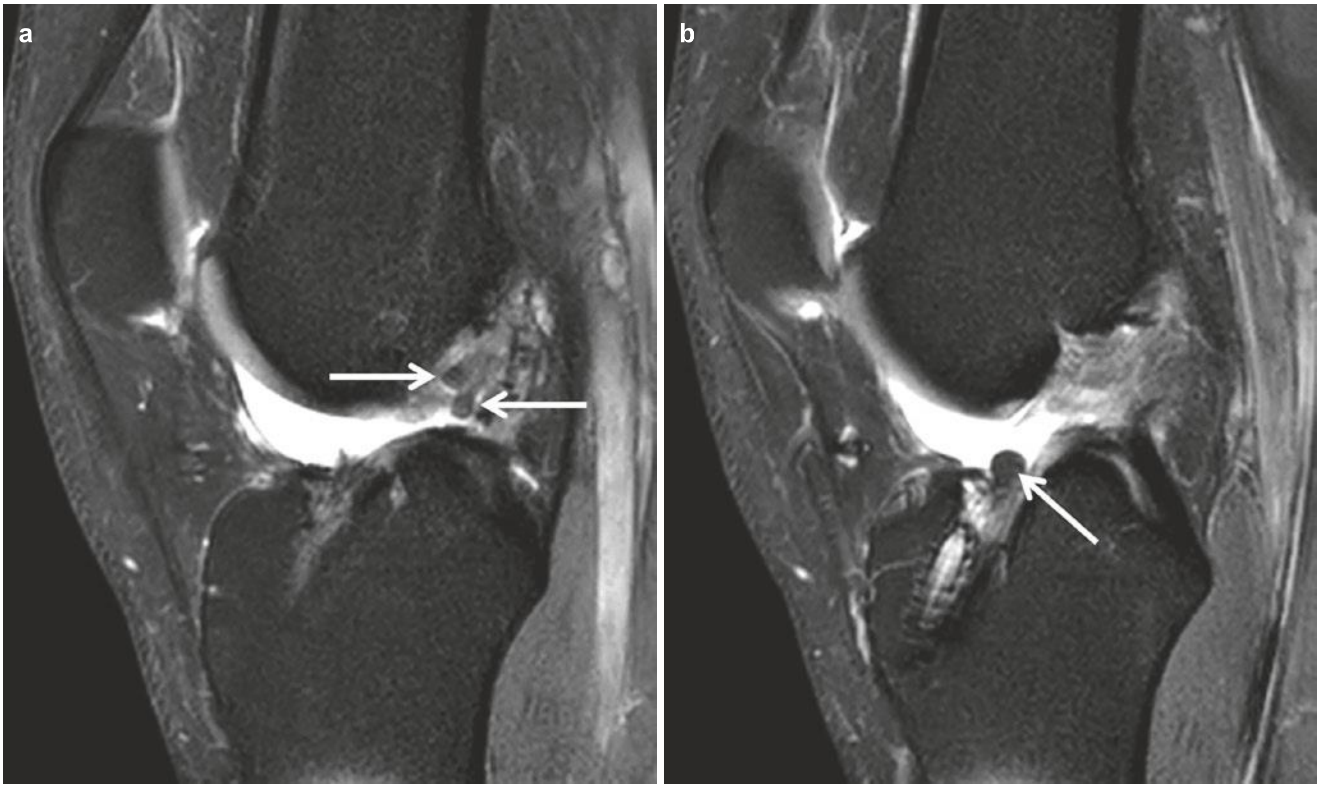

Fig. 9.3 Graft rupture 3 years after anterior cruciate ligament reconstruction in A 25-year-old man. Sagittal fat-suppressed T2-weighted images show discontinuous (**a**) proximal and (**b**) distal graft fibers (*arrows*). Note presence of multiple strands in this hamstring autograft

the ligament is disrupted in other locations or is chronically torn, formal reconstruction with a tendon graft can be performed [30]. Postoperative MRI evaluation is similar to that for ACL reconstructions: the tendon graft signal will evolve over time, but the graft should be taut and continuous. Usually there will be two patellar anchor sites, located within 1 cm of each other in mid and upper part of the bone. The femoral tunnel should be located just caudal and anterior to the adductor tubercle [33]. Complications include fracture around the tunnel or anchor sites, graft laxity, graft rupture, and recurrent patellar dislocation [33, 34].

The same principles outlined above for the ACL and MPFL apply when imaging reconstructions of the less commonly injured ligaments like the posterior cruciate or lateral collateral [35–37]. Bone anchor sites and tunnels should be located so that the single or multiple bundle tendon grafts approximate the native ligament orientations and positions. The anterolateral ligament (ALL), which originates just cranial and posterior to the lateral femoral epicondyle and extends to the lateral tibial rim posterior to Gerdy's tubercle, is a secondary stabilizer to the ACL. ALL reconstruction is sometimes done to augment primary or revision ACL reconstructions, for patients at high risk of ACL graft failure [38, 39].

9.3 Meniscal Surgery

Treatment of meniscal tears continues to evolve. For symptomatic meniscal tears, the current operative approach is to preserve as much meniscal tissue as possible ideally by primary repair. New surgical techniques have expanded the spectrum of which tears may be repaired, including some meniscal root avulsions. Nonrepairable tears typicallyrequire limited resections. Unsalvageable menisci may be replaced by transplantation. Each of these interventions alters the imaging appearance of the meniscus. An understanding of the expected postoperative appearances, the limitations of MRI after meniscal surgery, and the imagingcriteria that can be used is necessary for accurate postoperative interpretation.

9.3.1 Partial Meniscectomy and Meniscal Repair

During partial meniscectomy the surgeon resects as little of the torn meniscus as possible in order to leave a stable residual component, because both radiographic and functional results are worse when more meniscus is resected

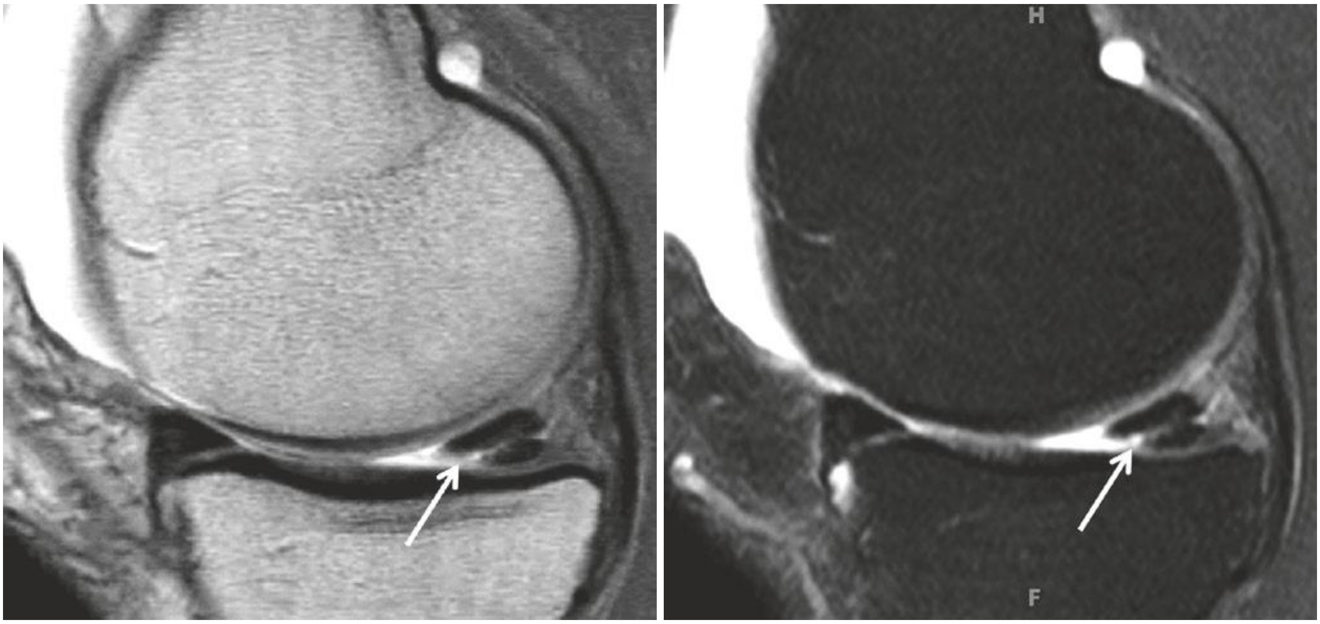

Fig. 9.4 Recurrent meniscal tear following partial meniscectomy in a 39-year-old woman. (**a**) Sagittal proton-density-weighted image shows truncation of inner meniscal margin and intrameniscal signal extending to articular surface (*arrow*), findings diagnostic for tear in native menisci, but unreliable when more than 25% of meniscus has been resected. (**b**) On T2-weighted image, surfacing high signal intensity (*arrow*) indicates recurrent meniscal tear

[40]. Partial resection truncates the normal triangular meniscal cross-section, invalidating one of the chief MRI criteria used for diagnosing tears in native menisci. The altered shape can both simulate and obscure a recurrent meniscal tear [41]. Furthermore, partial excision may allow normal internal signal that was not part of the original tear to now contact the new meniscal surface on a proton-density-weighted image, which invalidates the other major criteria for meniscal tear [42]. If less than 25% of the meniscal width is resected, applying the standard rules for meniscal tears still work well; however, when more meniscus is removed, accuracy decreases [43]. A tear in a new location (if a preoperative MR is available to show the original tear location), displaced meniscal fragments, or a fluid-filled cleft extending into the meniscus on a T2-weighted image remain reliable but insensitive signs of a recurrent meniscal tear, even when greater than 25% of the meniscus is removed (Fig. 9.4) [44, 45].

Primary repair using suture, darts, or other anchors is the preferred treatment for menisci that have the potential to heal. Reparable tears are primarily vertical longitudinal ones near the vascularized meniscal periphery (the “red” zone) [46]. Tears heal with granulation and scar tissue,which may continue to demonstrate high signal intensity, even years later (Fig. 9.5) [47]. Thus, a healed meniscus will frequently fulfill the signal criteria for a meniscal tear, decreasing the specificity for diagnosing a persistent (unhealed) or recurrent tear. When the repaired meniscus shows no signal on any sequence, the meniscus is healed; however, only surfacing signal isointense to fluid on a T2-weighted sequence is reliable for diagnosing a residual or recurrent tear [48]. Approximately 14% of meniscal repairs develop a meniscal cyst, which may be asymptomatic. In contrast to cysts that occur in native menisci, those presenting after meniscal repair do not necessarily indicate an underlying tear [49].

MR arthrography (MRA), most often performed after direct intra-articular injection of a dilute gadolinium mixture, is a useful adjunct in postoperative knees. The primarysign of a tear in a postoperative meniscus is injected contrast (confirmed on T1-weighted imaging) entering the substance of the residual meniscal fragment or repaired meniscus (Fig. 9.5) [50]. Some practices use indirect MRA by injecting gadolinium intravenously, exercising the knee, andallowing contrast to diffuse from the synovium into the joint.However, intravenous contrast injection does not produce joint distention (limiting sensitivity for nondisplaced tears) and enhances granulation tissue (decreasing specificity after meniscal repair) [51]. Accuracy for residual or recurrent tears increases from 57–80% with non-contrast MRI to 85–93% with direct MRA [46]; the added value persists evenwhen conventional MRI is acquired using a 3-T magnet [52].

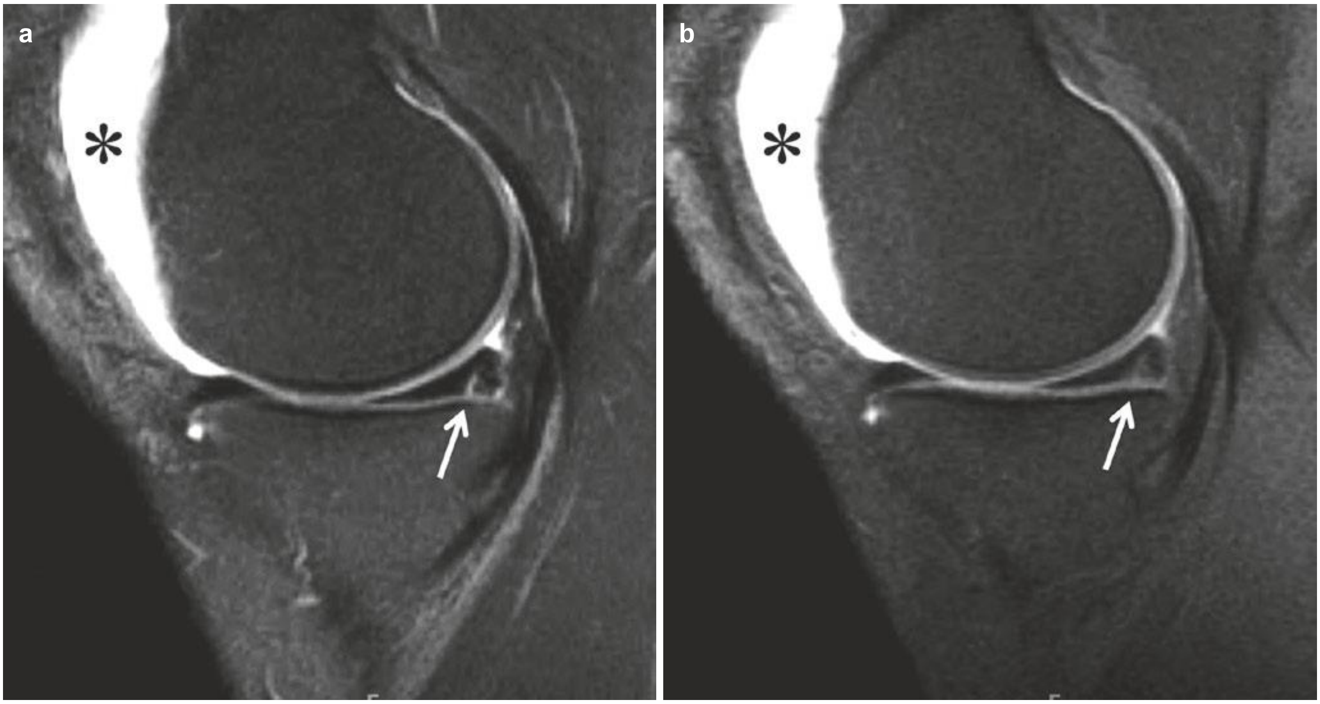

Fig. 9.5 A 32-year-old man with healed meniscal tear, repaired 7 years previously. (**a**) Sagittal fat-suppressed T2-weighted image shows persistent signal (*arrow*) contacting meniscal surface at site of previously repaired peripheral longitudinal tear. Abnormality is bright but less intense than fluid (*asterisk*) in knee joint. (**b**) Fat-suppressed T1-weighted image from direct MR arthrogram shows no contrast extending into meniscus (*arrow*). Compare to gadolinium in joint (*asterisk*). No tear was found at subsequent arthroscopy

9.3.2 Root Repair and Meniscal Transplant

Newer surgical procedures now offer meniscal preservation for a broader range of meniscal injuries. Rupture of the posterior root that anchors the meniscus to the tibia is a devastating condition, rendering the meniscus unable to distribute contact forces [53] predisposing to accelerated osteoarthritis subchondral insufficiency fracture, and osteonecrosis in the affected compartment. Partial meniscectomy in these knees is associated with progressive osteoarthritis, but in some cases, repair can restore normal biomechanics and lessen the negative impact [54]. The torn root is usually reattached by drawing sutures through a transosseous tunneland then anchoring the construct in the tibia [55]. Cadavericreplacement is an option in stable knees with relatively normal articular cartilage that have essentially nonfunctional menisci (due to prior subtotal meniscectomy or recurrent, nonrepairable tears). The allograft meniscus is harvestedwith bone plugs or a bone bridge attached to the anterior andposterior roots, and the osseous components are fixated to the recipient tibia through drilled tunnels or a trough. The periphery of the transplanted meniscus is then sutured to thejoint capsule [56].

No standardized criteria have been validated for imaging evaluation of meniscal root repairs. A completely healed repair should show continuous tissue from the posterior root through the drilled tunnel. The tissue may be intermediate in signal intensity on proton-density-weighted sequences, but fluid intensity signal on a T2-weighted image or fragment displacement at the repair site indicates operative failure (Fig. 9.6) [55]. New tears may also develop separate from the repaired root. Studies have found both reduced and increased degrees of meniscal extrusion after root repair, with a meta-analysis showing no overall change in extrusion and varying degrees of progressive degenerative arthritis [57]. However, the short-to-medium-term clinical improvement seems to be independent of these MRI findings [58].

Imaging after a meniscal allograft procedure is challenging. Normal, functioning grafts can shrink (especially if the graftwas fresh as opposed to frozen) or may demonstrate extrusion, but neither imaging finding is associated with clinical outcomes [57]. After 4 years, knees with >3 mm extrusion ofthe allograft do show significantly more joint space narrowing compared to those with non-extruded grafts, but the clinical results in the two groups do not differ [59]. At least for the first year, signal intensity of the transplanted meniscus is higher compared to native menisci (especially in the anterior horn) [60]. A systemic review of meniscal allografts found an 11% average failure rate at approximately 5 years [61]. Failure mechanisms include fracture of the native tibia

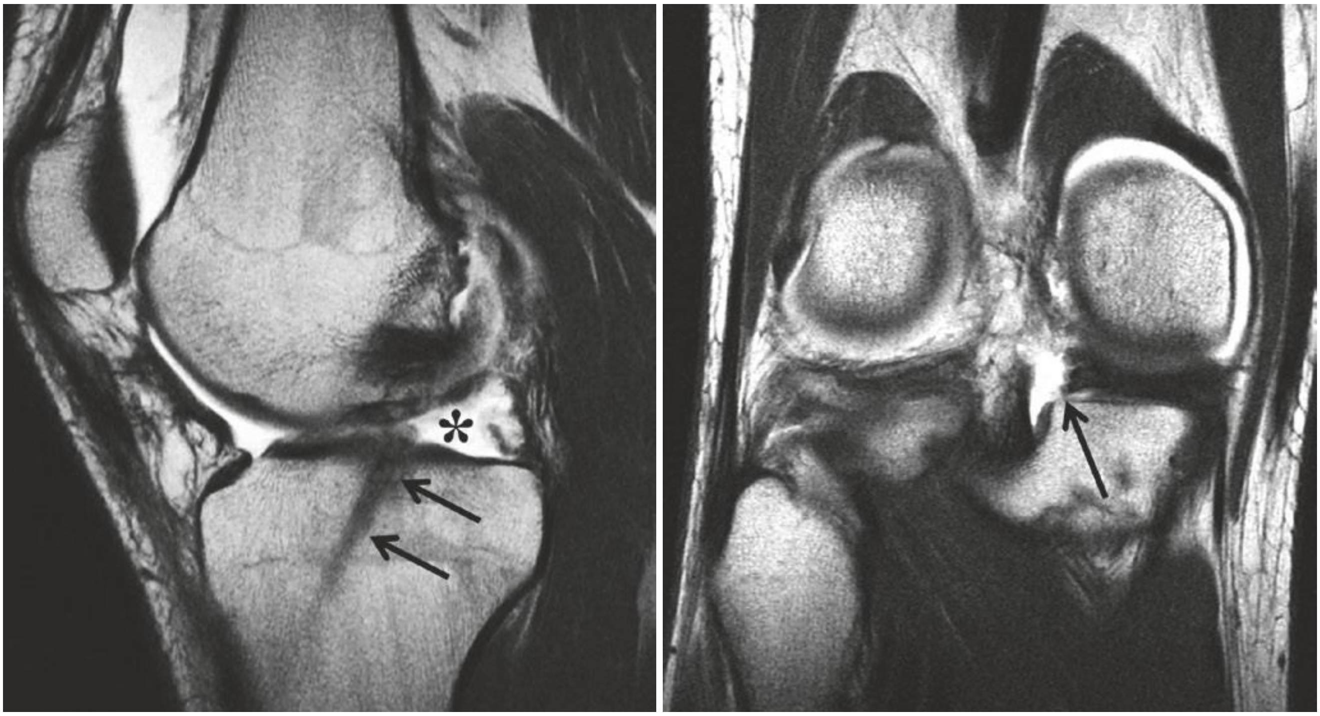

Fig. 9.6 Failed posterior medial meniscal root repair in a 23-year-old man. (**a**) Sagittal T2-weighted image shows transtibial tunnel (*arrows*) drilled for suture passage without attached meniscal tissue (*asterisk*). (**b**) Coronal T1-weighted image from MR arthrogram demonstrates re-torn meniscal root (*arrow*) separated from anchor site

around the fixation, new tears within the meniscal substance, and peripheral separation at the meniscocapsular junction. In these latter cases, the meniscus may displace like a bucket handle tear into the intercondylar notch [46].

9.4 Articular Cartilage Surgery

Articular cartilage is avascular, which limits its ability to self-repair or for surgically reattached chondral fragments to heal. Simple debridement of symptomatic focal cartilage defects ("chondroplasty") leads to formation of reparative fibrous or fibrocartilaginous tissue that lacks the gliding and protective qualities of normal hyaline cartilage and breaks down in a few years. Nevertheless, recovery after chondroplasty is rapid, and patients may get short-term relief, so it is used in high-end athletes [62]. Procedures that aim to create more functional hyaline-like cartilage include techniques to stimulate the underlying bone marrow, replace the cartilage surface by transplanting intact osteochondral fragments, or implant new cartilage cells and substrate into a defect. The choice of procedure depends on the patient age and physical demands, the size of the lesion, and concomitant abnormalities of the knee ligaments, menisci, and alignment. Procedures can also be combined with each other or with bone grafting, especially when a chondral defect is associated with extensive bone loss [63].

9.4.1 Marrow Stimulation

During microfracture, the surgeon debrides the chondral lesion and then repeatedly punctures the underlying subchondral bone plate with an awl, pick, or drill, allowing blood and marrow stem cells to fill the cartilage crater. The resultant blood clot later differentiates into fibrous tissue or fibrocartilage. Patients may get short-term relief, but the reparative tissue typically fails by 5 years, with poorer outcomes in athletes [62, 64]. On postoperative MRI, the signal of the fibrocartilage is initially brighter than surrounding normal hyaline cartilage [65, 66]. The amount of the defect that is ultimately filled correlates with clinical success [67]. Ideally, the new articular surface will be congruent by 1–2 years (Fig. 9.7). Overgrowth of the subchondral bone including osteophyte formation at the base of the lesion increases the risk of failure by a factor of 10× [68]. Underlyingbone marrow edema is common and decreases over time; marrow edema persisting beyond 2 years can be associated with treatment failure and should be noted [69].

9.4.2 Osteochondral Grafting

In osteochondral transfer, the articular surface is reconstructed by implanting one or more cylinders composed of a bone core and overlying hyaline cartilage into a chondral

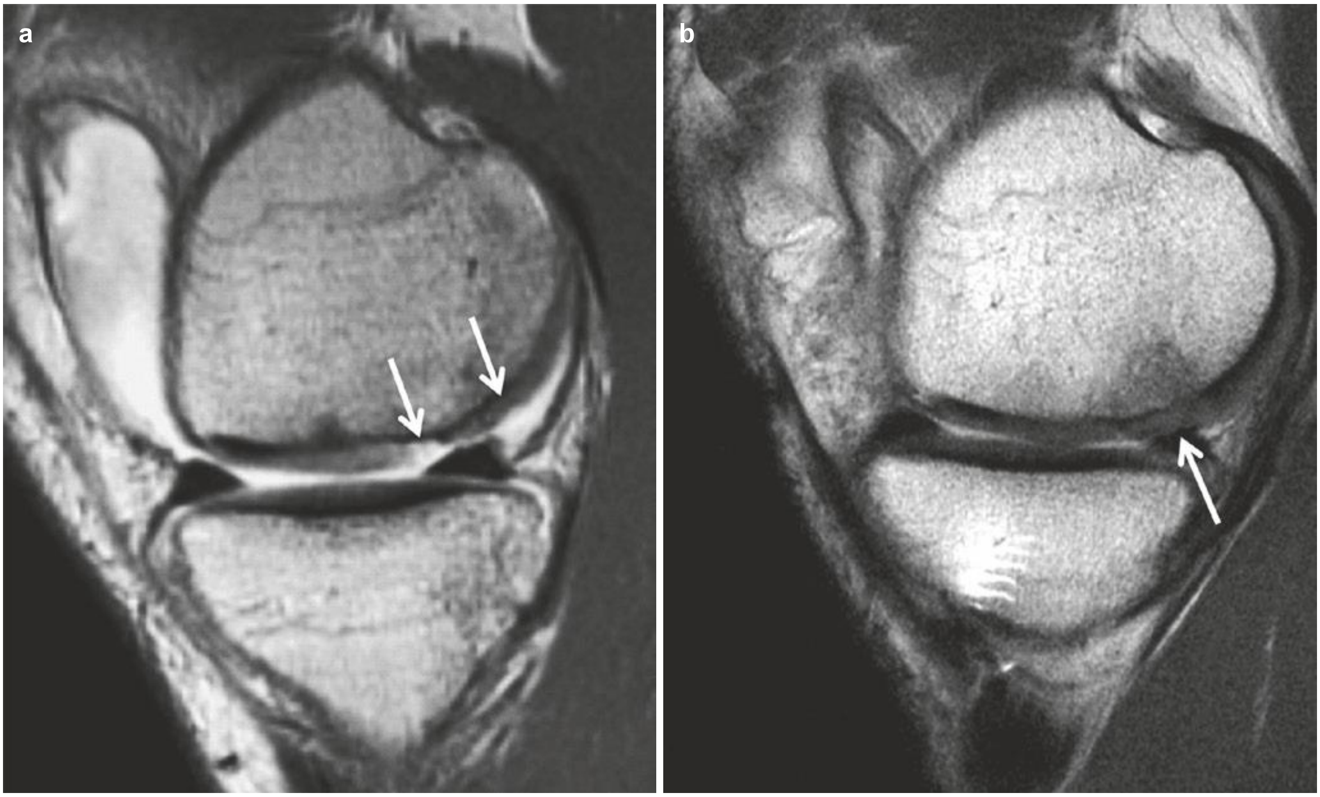

Fig. 9.7 A 39-year-old man with medial femoral condyle cartilage lesion managed by microfracture. (**a**) Initial sagittal T2-weighted image shows areas of partial- and full-thickness cartilage loss (*arrows*). (**b**) Three years after procedure reparative fibrocartilage remains slightly hyperintense compared to normal hyaline cartilage but fills defect and demonstrates smooth articular surface (*arrow*)

defect (Fig. 9.8). The graft may come from a relatively low-stress surface in the patient's knee (an autograft, sometimes called Mosaicplasty™ or OATS™) or from a cadaver donor (an allograft). Ideally the deep (ossified) portion will integrate with the surrounding bone, while the overlying cartilage will remain viable and merge with the bordering healthy cartilage [70]. Results of osteochondral autograft proceduresare better compared to microfracture, especially for small lesions in young patients [64, 71]. Allografts are typically used for larger defects, with extensive bone loss, or for revi-sion after other failed procedures [72].

The postoperative imaging appearance after osteochondral grafting can be deceptive—a step-off may be present between of the donor and recipient subchondral bone plates due to different thicknesses in the overlying cartilage [69]. The surgeon places the graft(s) to create a smooth articular surface, which should be evident on postoperative imaging [24]. For autografts, the MRI signal in the overlying cartilageis variable and does not correlate with outcomes. Marrow edema in the graft and underlying bone is common and can persist normally for up to 3 years [73]. However, cyst formation at the base of the graft is a sign indicating poor integration [69]. Underfilling of the original defect is weakly associated with clinical failures. Osteonecrosis of a graft can occur without clinical manifestations [73]. The harvest site typically heals with bone and fibrocartilage (Fig. 9.8b), but donor site morbidity (typically patellofemoral pain or crepitus) occurs in approximately 6% of procedures [74].

Imaging findings following allograft reconstruction are similar. One difference is that extensive marrow edema in the host bone, graft, and interface can be associated with an immunologic reaction against the donor's bone [75]. MRI signs portending failure at 1 year include persistent marrow edema deep to the transplant, cysts or fluid at the bone inter-face, and collapse of the articular surface [65, 66, 72].

9.4.3 Cellular Repair

Autologous chondrocyte implantation (ACI) is usually a multi-step procedure, initially harvesting a sample of the patient's own cartilage cells, then growing them in vitro as a cell culture or embedded in a collagen scaffolding (the later for third generation, matrix-assisted chondrocyte transplan-tation, M-ACI), and finally implanting them into the original debrided defect during a second operation. In first-generation

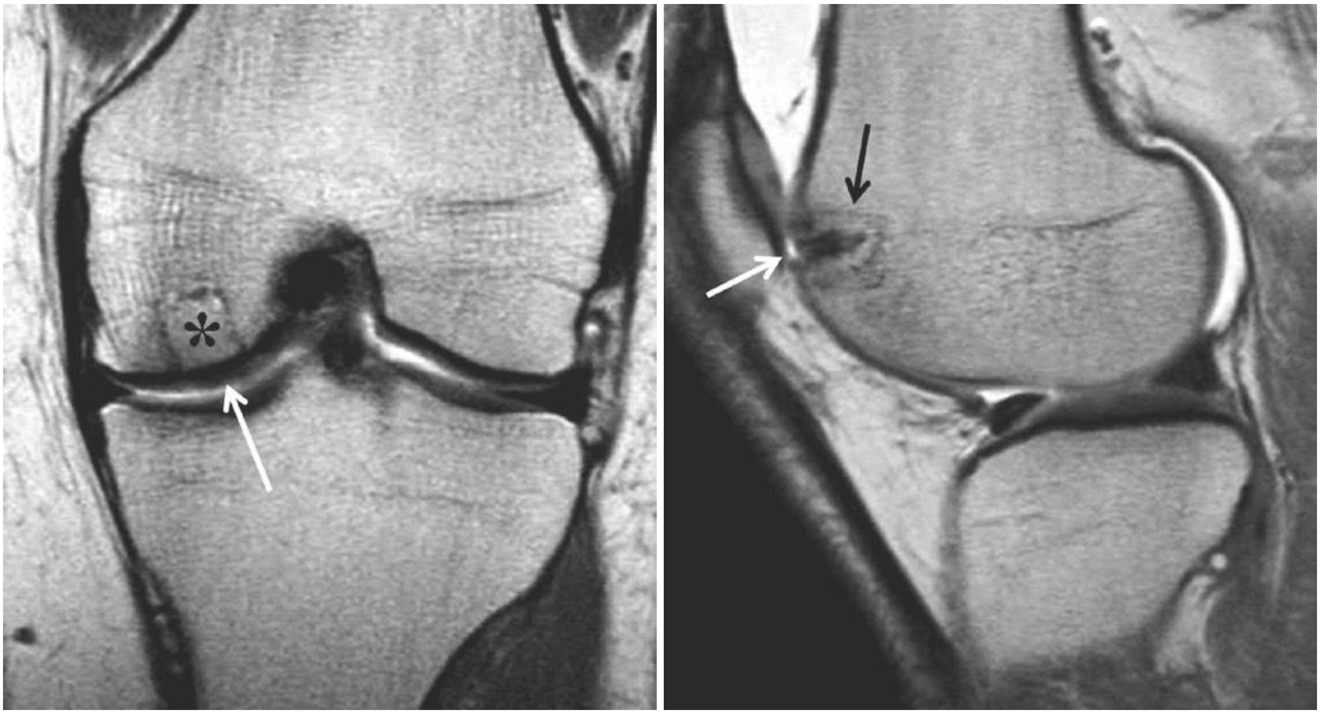

Fig. 9.8 Osteochondral autograft for medial femoral condyle chondral defect in a 26-year-old man. (**a**) Coronal T1-weighted image from MR arthrogram shows complete incorporation of osseous (*asterisk*) and cartilage (*arrow*) portions of graft. (**b**) On sagittal T2-weighted image, harvest site in lateral femoral trochlea is nearly refilled with bone (*black arow*). Thin layer of high-signal-intensity fibrocartilage (*white arrow*) covers the donor site

ACI, the cultured cells are injected under a periosteal or similar membrane that is sewn over the lesion. For M-ACI a plug of the new cells together with the ancillary supporting tissues are shaped to fit the lesion [66]. Reported outcomes are similar to those for microfracture and osteochondral grafting at 2 years and equivalent or better than microfracture at 5 years [76, 77].

Postoperatively the transplanted cells are initially hyperintense compared to native hyaline cartilage and then begin to normalize at approximately 1 year [65]. Complete filling of the chondral defect is expected after first-generation ACI [78]. Lesions can appear initially underfilled with M-ACI, which improves over time (Fig. 9.9). Graft hypertrophy may be symptomatic and require debridement [66, 69]. Most findings on conventional MRI sequences (including lesion underfilling, bone marrow edema for up to 3 years, and the signal intensity of the transplanted tissue) do not necessarily correlate with clinical outcomes [69, 79]. First-generation procedures can fail by sudden delamination of the covering membrane with or without the underlying cells. Delamination typically occurs in the first few months and appears as a fluid-filled cleft beneath the graft [66]. Adhesions develop in 5–10% of patients and may cause knee stiffness; on MRI adhesions may be difficult to appreciate but appear as relatively low-signal-intensity intra-articular bands extending to the graft [80].

Fig. 9.9 Trochlear cartilage defect in a 34-year-old man managed with matrix-assisted autologous chondrocyte implantation. Sagittal proton-density-weighted image 14 months postoperatively shows implanted cartilage slightly underfilling defect (*white arrow*). Thin strands of tissue extending to articular surface (*black arrow*) may represent small adhesions

9.5 Postoperative MRI of the Shoulder

Shoulder arthroscopy is one of the most commonly performed arthroscopic procedures. Most radiologists are familiar with the interpretation of preoperative shoulder MRI as it is one of the most commonly performed joint MRI examinations. However, when interpreting postoperative shoulder MRIs, certain factors must be considered given the associated alterations in anatomy and signal intensity of tissues.

The following chapter will focus on postoperative MRI of the shoulder following rotator cuff surgery, labral/instability surgery, and long head biceps tendon surgery, some of the most commonly performed arthroscopic procedures of the shoulder.

9.6 MRI Technique

In most cases, routine MR sequences can be used in imaging of the postoperative shoulder. However, gradientrecalled echo (GRE) sequences may be distorted due to susceptibility artifact depending on the type of surgery and materials used. As such, these sequences are often less useful in imaging the postoperative shoulder. In addition, if there is inhomogeneous fat suppression, frequency-selective fat suppression can be replaced with metal artifact reduction sequences or STIR sequences to achieve more homogeneous fat suppression (Fig. 9.10). Following rotator cuff repair surgery, conventional non-arthrographic protocols are usually sufficient. Following labral or instability surgery, and in cases of equivocal results following non-arthrographic MRI following rotator cuff surgery, directMR arthrography or CT arthrography can be used. Finally, in the setting of instability surgery, imaging in the ABER position may prove beneficial.

9.7 Imaging Following Rotator Cuff Repair

As in most fields of arthroscopy, the indications and techniques for arthroscopic surgery for rotator cuff pathology continue to evolve. The most common procedures include rotator cuff repair and rotator cuff debridement, with the latter being performed in the setting of partial-thickness tears. When a rotator cuff repair is performed, the rotator cuff tendon or tendons are fixated to the greater tuberosity of the humerus with the use of screws, anchors, and/or sutures. Depending on the morphology and concomitant pathology of the acromioclavicular joint, acromioplasty and/or distal clavicular resection (Mumford procedure) may also be performed.

9.7.1 Normal MRI Findings After Rotator Cuff Repair

When only debridement has been performed for small articular surface partial-thickness tears, postoperative MR

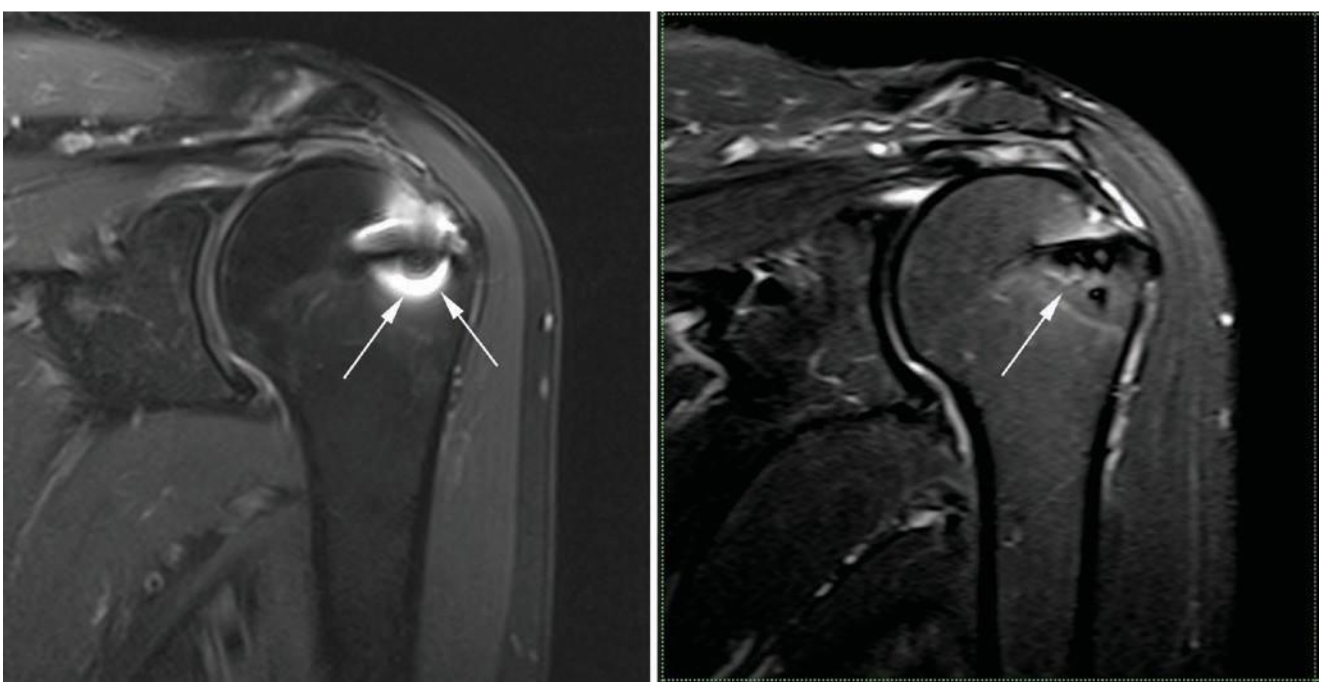

Fig. 9.10 Coronal oblique fat-saturated proton-density (FS PD)-weighted image (left, arrows) demonstrates inhomogeneous fat suppression and susceptibility artifact adjacent to a screw after rotator cuff repair. Coronal oblique short tau inversion recovery (STIR) image (right, arrow) in the same patient on the same day demonstrated minimal artifact and excellent homogenous fat suppression

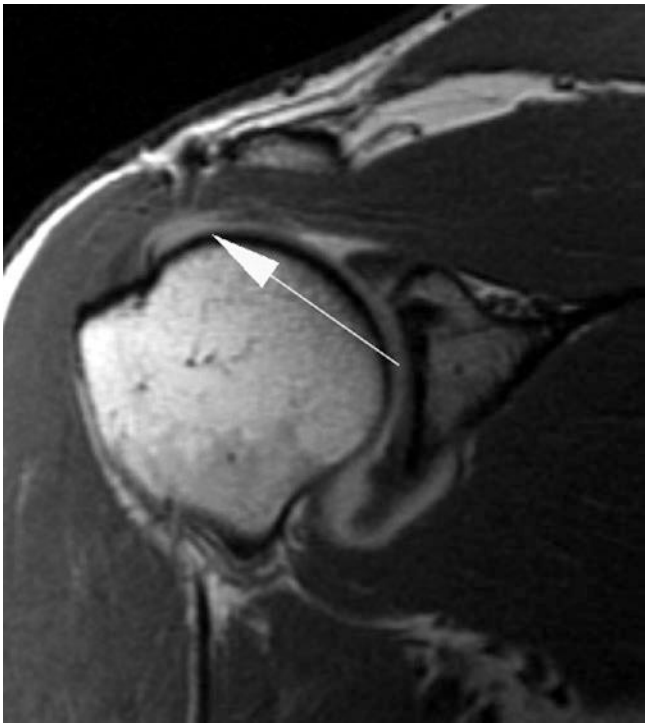

Fig. 9.11 Coronal oblique PD-weighted image demonstrates a smooth articular surface defect (arrow) along the undersurface of the supraspinatus following debridement of a small articular surface tear. Note that the defect is wider than deep, a common finding following debridement/shaving

imaging may have an appearance which is quite similar to if not identical to a small partial-thickness articular surface tear (Fig. 9.11). In these instances, it is imperative to know the size and location of the original tear and theextent of debridement. It has been reported that the regionof debridement may show a defect that is wider than it is deep [81]. However, this is not always clearly evident at MRI. In general, the role of postoperative imaging in these settings is to assess for complications of the debridement or extension of the tear into a larger partial-thick-ness tear or full-thickness tear.

When a rotator cuff repair is performed, the resulting repair may not be watertight. As such, a small usually vertically oriented cleft of fluid (or contrast in the setting of direct MR arthrography) traversing the tendon and communicating with the subacromial-subdeltoid bursa may be present and may represent a small normal postoperative finding (Fig. 9.12) [82]. Within the greater tuberosity, a small amount of edema-like signal near the anchors may persist for months following surgery [83]. If an acromioplasty was performed, there will be flattening of the undersurface of the acromion, diminution of the size ofthe acromion, and, in more extensive acromioplasties and Mumford procedures, widening of the acromioclavicular joint.

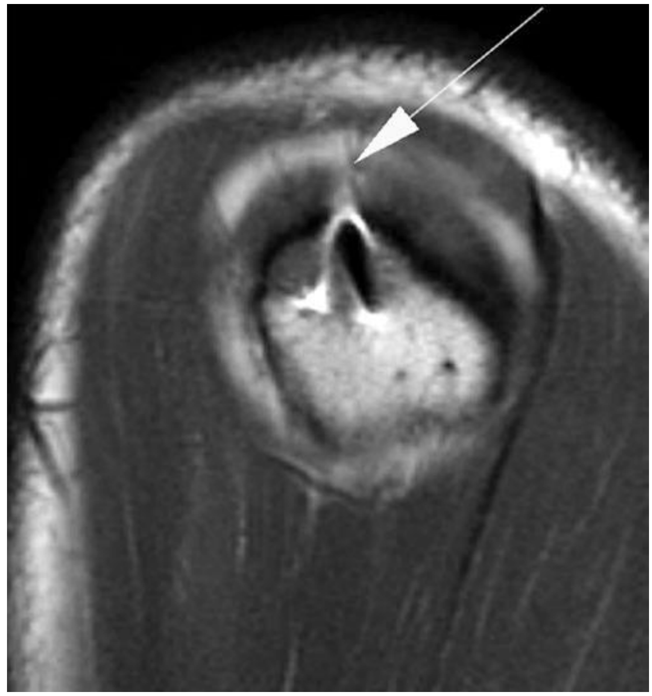

Fig. 9.12 Sagittal oblique T1-weighted image from direct MR arthro- gram demonstrates a thin vertical full-thickness cleft (arrow) followingrotator cuff repair. This can be a normal finding as the repairs are oftennot watertight

9.7.2 Abnormal MRI Findings After Rotator Cuff Repair

Abnormal findings following rotator cuff repair include a discreet gap within the tendon, tendon retraction, and new regions of tendon delamination (Fig. 9.13). Occasionally, a recurrent tendon tear may be masked due to fibrous tissue and scarring filling the tendon gap (Fig. 9.14) [84]. If there is new or worsening atrophy of the rotator cuff muscles, the integrity of the tendon repair should again be closely scrutinized to assess for recurrent tear. In these instances, close attention should be paid to the location of the myotendinous junction. Typically, the myotendinous junction of the supraspinatus will be medially displaced and closer to the superior glenoid rim. This can be a secondary sign of a recurrent tendon tear with retraction.

Less common complications following rotator cuff surgery include dislodged or displaced sutures, anchors and screws, deltoid dehiscence following acromioplasty, and, rarely, chondrolysis and septic arthritis.

9.8 Imaging Following Superior Labral Surgery

Depending on the location and configuration of labral tears, labral debridement or labral repair may be performed.

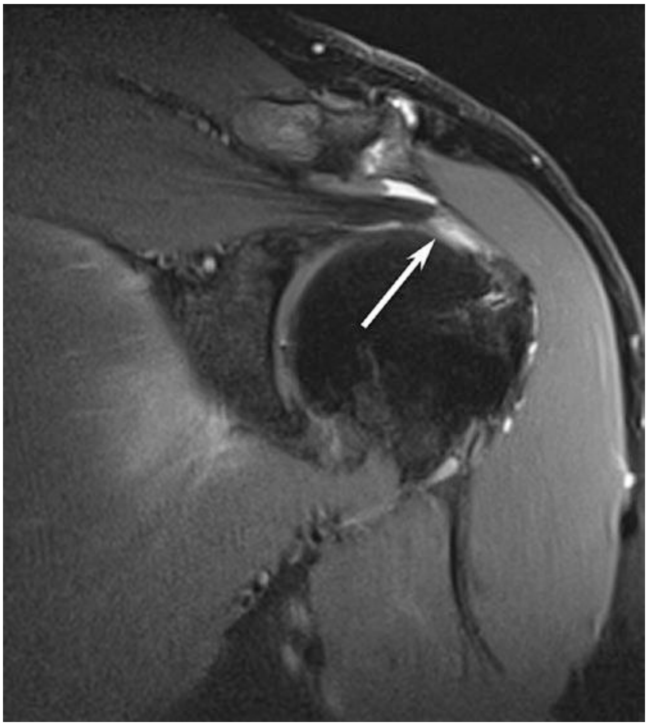

Fig. 9.13 Coronal oblique FS PD-weighted image demonstrates a recurrent full-thickness tear of the supraspinatus with retraction (arrow) and a fluid-filled gap

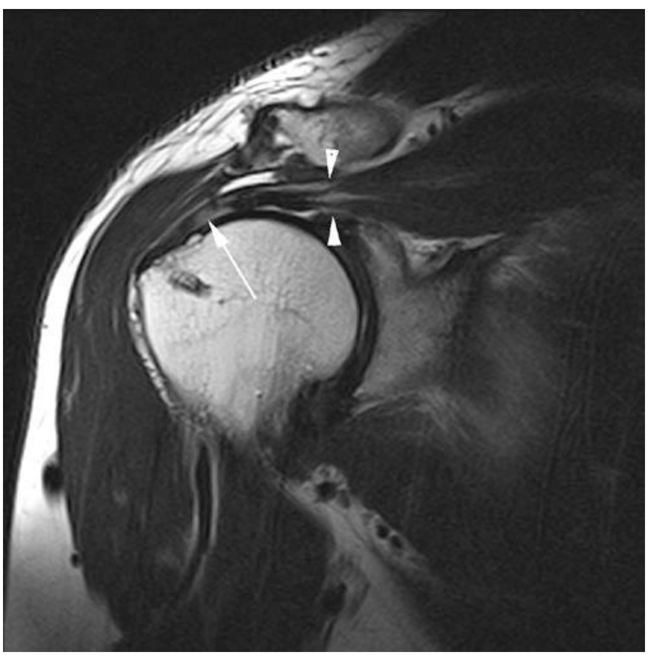

Fig. 9.14 Coronal oblique T2-weighted image demonstrates intermediate signal scarring/fibrosis (arrow) filling the gap at the site of a recurrent supraspinatus tear. Another clue to the presence of a tear with retraction is the medial displacement of the myotendinous junction of the supraspinatus (arrowheads) nearly to the level of the glenoid

Fig. 9.15 Coronal oblique T1-weighted image from direct MR arthrogram shows a normal small smooth cleft (arrow) partially undercutting the superior labrum after SLAP repair. The labral repair was intact at second look arthroscopy

In the superior labrum, degenerative fraying and degenerative tearing are commonly found in middle-aged andolder patients. If there is no associated extension of the labraltearing into the proximal portion of the tendon of the long-head biceps brachii and if there is no significant instability ofthe origin of the long-head biceps, these are often treated with simple debridement and shaving of the frayed portion of the labrum. If there is significant extension of the tear intothe biceps tendon and/or associated instability of the origin of the biceps tendon (biceps anchor), then a superior labral repair may be performed.

9.8.1 Normal MRI Findings After Superior Labral Surgery

If only shaving and debridement of the labrum are performed, postoperative MR imaging may demonstrate increased signal within the superior labrum, often indistinguishable from the original preoperative MRI if minimal debridement was performed. With more extensive debridement and shaving, the postoperative superior labrum may appear blunted or truncated [85]. If a superior labral tear is repaired, a persistent cleft undercutting the labrum may be present on postoperative imaging (Fig. 9.15) [86].

Fig. 9.16 Coronal oblique FS T1-weighted image from direct MR arthrogram demonstrates a recurrent SLAP tear with contrast undercutting the entire thickness of the labrum in an irregular fashion (arrow)

9.8.2 Abnormal MRI Findings After Superior Labral Surgery

Differentiating residual cleft from a residual or recurrent tear can be challenging. In order to make a confident diagnosis of a residual or recurrent superior labral tear, high signal should be clearly seen extending to and through the base of the labrum and/or involving a portion of the labrum which was normal on preoperative imaging (Fig. 9.16). If conventional MR is inconclusive, MR arthrography can be performed to better assess the status of the postoperative superior labrum. Imaging in slightly exaggerated external rotation will put additional traction on the biceps tendon and thus make superior labral tears more conspicuous [87].

9.9 Imaging Following Instability Surgery

Tears of the anterior inferior labrum are typically seen in the setting of anterior shoulder instability. These are the so-called Bankart lesions and their associated variants. The goal of arthroscopic surgery is to recreate the “bumper” of the labrum along the glenoid rim, thereby reducing the chance of humeral head displacement over the edge of the rim and resultant humeral head subluxation or dislocation. Depending on the size and configuration of the original Bankart lesion and the presence or absence of associated involvement of the osseous glenoid rim, operative techniques may be limited to a soft tissue repair/reconstruction including a capsular shift versus associated osseous repair/augmentation including bone grafting or a Latarjet procedure whereby a portion of the coracoid is transferred to the glenoid rim for osseous augmentation.

If there is a large Hill-Sachs lesion, this may be elevated/reduced or augmented with a remplissage technique.

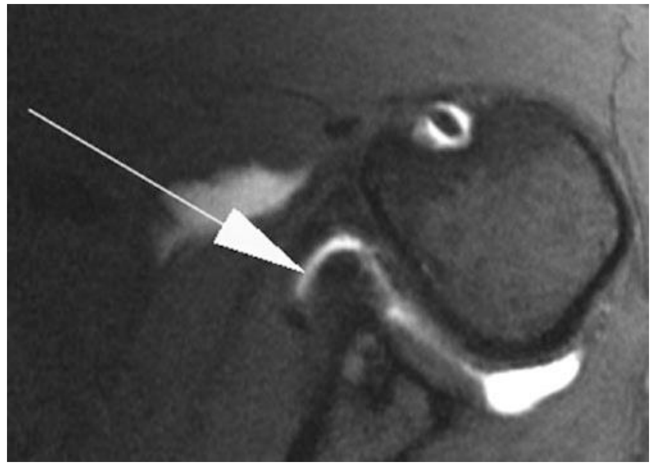

Fig. 9.17 Axial FS T1-weighted image from direct MR arthrogram demonstrates a normal postoperative globular anterior inferior labrum (arrow) following soft tissue Bankart repair. Note how the anterior glenoid “bumper” has been restored, and no contrast is seen undercutting the labrum

9.9.1 Normal MRI Findings After Instability Surgery

If a soft tissue Bankart repair has been performed, postoperative imaging should show restoration of the anterior inferior bumper along the glenoid rim. This can be low to intermediate signal intensity but should be clearly visible as a labral-like structure along the osseous rim, although it often has a more rounded appearance (Fig. 9.17). Imaging in the ABER position is highly recommended following Bankart repair to assess for small nondisplaced recurrent tears [88].

If an osseous Bankart repair has been performed, whether with reattachment of the bone fragment, augmentation with bone graft, or a Laterjet procedure, a prominent anterior inferior glenoid rim should be present with or without associated overlying soft tissue depending on the repair technique. Again, the goal of the repair is to re-create a prominence or bumper along the anterior inferior glenoid rim to prevent the humeral head from dislocating out of the concave portion of the glenoid.

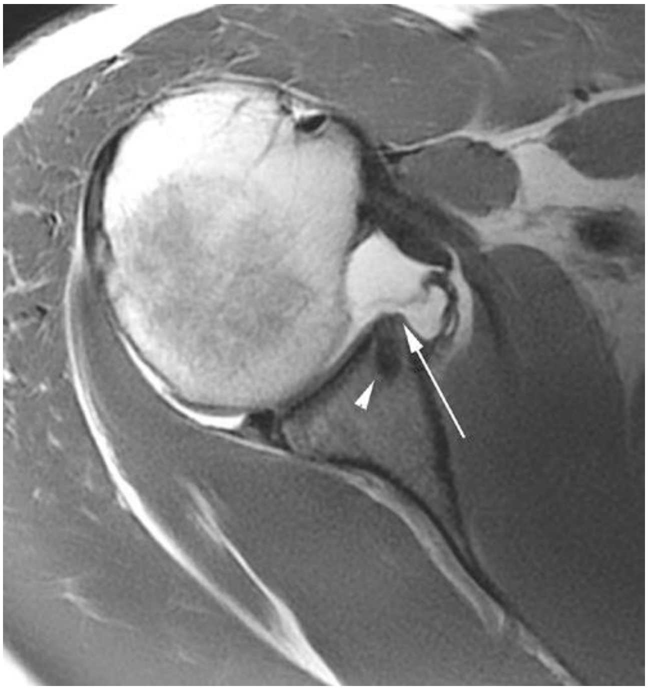

Fig. 9.18 Axial T1-weighted image from direct MR arthrogram demonstrates a failed Bankart repair with a missing antero-inferior labrum (arrow) and lack of the “bumper” along the glenoid rim. Note artifact from prior repair (arrowhead)

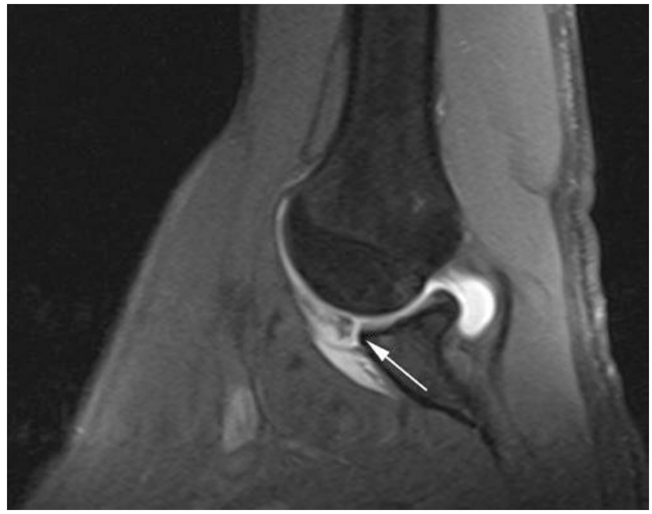

Fig. 9.19 Oblique coronal FS T1-weighted image in the ABER position from direct MR arthrogram demonstrates a recurrent tear of the antero-inferior labrum (arrow) following a Bankart repair

9.9.2 Abnormal MRI Findings After Instability Surgery

Abnormal findings following instability surgery include absence of the soft tissue prominence along the anterior inferior glenoid rim (bumper), detachment of the labrum or labro-ligamentous complex, and detachment or displacement or failure or consolidation/union of the osseous augmentation (Fig. 9.18). In addition, if there has been overtightening of the anterior capsule, the shoulder may beprone to posterior subluxation or dislocation, thereby resulting in a posterior labral tear. The use of direct MR arthrography and imaging in the ABER position are often preferred asthey better delineate the intra-articular structures and help inthe detection of subtle nondisplaced anterior inferior labro-ligamentous tears (Fig. 9.19) [89].

9.10 Imaging After Biceps Tenotomy and Tenodesis

Pathology of the intra-articular portion and, to a lesser degree, the extra-articular portion of the tendon of the long head biceps brachii is commonly seen when imaging the shoulder. In many cases, it is an incidental finding in patients with rotator cuff pathology. However, symptomatic biceps tendonopathy either in isolation or in combination with rotator cuff pathology or labral pathology, particularly superior labral pathology, may undergo surgical treatment. In advanced cases of symptomatic tendonopathy, a biceps tenotomy, with or without tenodesis, may be performed. When tenotomy alone is performed, the tendon is allowed to retract distally into the upper arm. The short head of the biceps ensures at least partial maintenance of the function of the biceps brachii. If tenodesis is performed, the tendon of the long head of the biceps is secured to the proximal humeral diaphysis with a screw or other fixation device.

9.10.1 Normal MRI Findings After Biceps Tenotomy and Tenodesis

When biceps tenotomy is performed, the tendon of the long head of the biceps is severed at its origin along the superior aspect of the glenoid (the supra-glenoid tubercle) at its junction with the superior labrum. If there is concomitant superior labral pathology, that is also addressed in the form of repair or shaving. At MRI, the tendon of the long head of the biceps will not be visible within the glenohumeral joint. No significant tendon stump should be visible along the superior glenoid rim. Depending on the degree of distal retraction, a portion of the tendon may or may not be visible within the bicipital groove. If a tenodesis has been performed, the actual point of fixation of the tendon onto the humeral diaphysis may be below the level of the axial images and thus may only be seen on the oblique coronal and oblique sagittal images. Depending on the fixation device used, the actual point of tenodesis may be difficult to appreciate unless there is

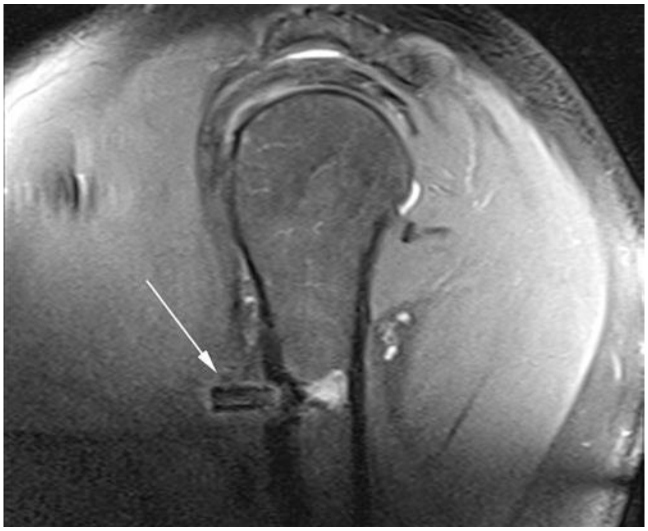

Fig. 9.20 Sagittal oblique FS T1-weighted image from direct MR arthrogram demonstrated a dislodged interference screw (arrow) following biceps tenodesis

susceptibility artifact. If an interference screw has been used,the screw may be slightly “proud” and protrude beyond the cortex of the humerus. This is a normal finding [90].

9.10.2 Abnormal MRI Findings After BicepsTenotomy and Tenodesis

Complications specific to biceps tenotomy are rare since it isa straightforward procedure that merely involves releasing the tendon origin. Rarely, a residual stump is present along the glenoid rim and appears as a small protuberance of low signal tissue at the origin of the tendon. If a tenodesis has been performed, the most common anatomical complicationis dislodgement of the interference screw and/or detachment/failure at the fixation site (Fig. 9.20) [91]. As mentioned above, a slightly proud interference screw is a normal finding. However, significant protuberance or dislodgement is abnormal. Rarely, intra-osseous ganglia may form, similar toganglia that may form in the tibial tunnel following anteriorcruciate ligament repair.

9.11 Concluding Remarks

Interpretation of postoperative MRI of the knee and shouldercan be challenging due to the variety of surgical techniques.Detailed knowledge of the original lesion, surgical techniqueemployed, time since surgery, and potential postoperative complications is critical to the proper interpretation of the imaging findings. Following most types of knee surgery, rotator cuff surgery and biceps tendon surgery, high-quality non-arthrographic MRI is usually sufficient. Following meniscal repair, shoulder instability surgery, and possibly SLAP repair, direct MR arthrography (with ABER positioning in the shoulder) should be considered.

Take Home Message

- Detailed knowledge of the original lesion, surgical technique employed, time since surgery, and potential postoperative complications is critical to the proper interpretation of postoperative MRIs of the knee and shoulder.

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