MR Imaging of Complications of Anterior Cruciate Ligament Graft Reconstruction[1]

Jenny T. Bencardino, MD • Javier Beltran, MD • Marina I. Feldman, MD, MBA • Donald J. Rose, MD

ONLINE-ONLY CME

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LEARNING OBJECTIVES

After reading this article and taking the test, the reader will be able to:

- Describe the MR imaging appearance of ACL graft reconstructions with regard to graft caliber, signal intensity, and bone tunnel position.
- Identify the signs of roof impingement and of partial and complete ACL graft tears at MR imaging.
- Recognize complications of ACL graft reconstruction such as tunnel cysts, iliotibial band friction syndrome, hardware loosening, and infection.

TEACHING POINTS

See last page

During the past 3 decades, graft reconstruction of the anterior cruciate ligament (ACL) has become an accepted treatment for symptomatic ACL deficiency. The goal of surgery is to prevent joint instability, which may further damage articular cartilage and menisci. Graft failure is defined as pathologic laxity of the reconstructed ACL. The prevalence of recurrent instability after primary ACL reconstruction ranges from 1% to 8%. Early failures, those that occur within the first 6 months, often are secondary to poor surgical technique, failure of graft incorporation, or errors in rehabilitation. Late failures, those that occur more than 1 year after surgery, likely are related to new trauma and graft tearing. Other complications of ACL reconstruction include roof impingement, postoperative stiffness, tunnel widening due to cyst formation, iliotibial band friction syndrome, hardware failure, and infection. Magnetic resonance imaging is the preferred advanced imaging modality for the evaluation of symptomatic ACL graft reconstructions.

Abbreviation: ACL = anterior cruciate ligament

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[1]From the Departments of Radiology (J.T.B.) and Orthopedic Surgery (D.J.R.), NYU Hospital for Joint Diseases, 301 E 17th St, 6th Floor, New York, NY 10003; Department of Radiology, Mount Sinai School of Medicine, New York, NY (J.B.); and Department of Radiology, Maimonides Medical Center, Brooklyn, NY (J.B., M.I.F.). Presented as an education exhibit at the 2008 RSNA Annual Meeting. Received February 23, 2009; revision requested April 2 and received May 24; accepted June 7. All authors have no financial relationships to disclose. **Address correspondence to** J.T.B. (e-mail: *jenny.bencardino@nyumc.org*).

Introduction

During the past 3 decades, graft reconstruction of the anterior cruciate ligament (ACL) has become an accepted treatment for symptomatic ACL deficiency (1,2). The goal of surgery is to prevent joint instability, which may further damage articular cartilage and menisci. Advances in reconstructive techniques and rehabilitation have led to substantially improved results. Nevertheless, the percentage of patients who develop symptomatic osteoarthritis after ACL reconstruction remains high (13.6%–21.5%) (3). The combination of ACL reconstruction and meniscectomy also has been described as a potential accelerator of osteoarthritis (3). The prevalence of osteoarthritis 10 years after ACL reconstruction increases from 8% to 27% in patients who undergo meniscectomy and have a time interval longer than 1 year between meniscal injury and surgery (3). Graft failure is defined as pathologic laxity of the reconstructed ACL. The prevalence of recurrent instability after primary ACL reconstruction ranges from 1% to 8% (4,5). Early failures, those that occur within the first 6 months, often are secondary to poor surgical technique, failure of graft incorporation, or errors in rehabilitation. Late failures, those that occur more than 1 year after surgery, likely are related to new trauma and graft tearing (5). Other complications of ACL reconstruction include roof impingement, postoperative stiffness, tunnel widening due to cyst formation, iliotibial band friction syndrome, hardware failure, and infection. Magnetic resonance (MR) imaging is the preferred advanced imaging modality for the evaluation of symptomatic ACL graft reconstructions (6,7). Patients with contraindications to MR imaging (eg, pacemakers or stimulators) may undergo high-resolution computed tomographic arthrography of the knee for evaluation of postoperative ACL graft abnormalities.

Teaching Point

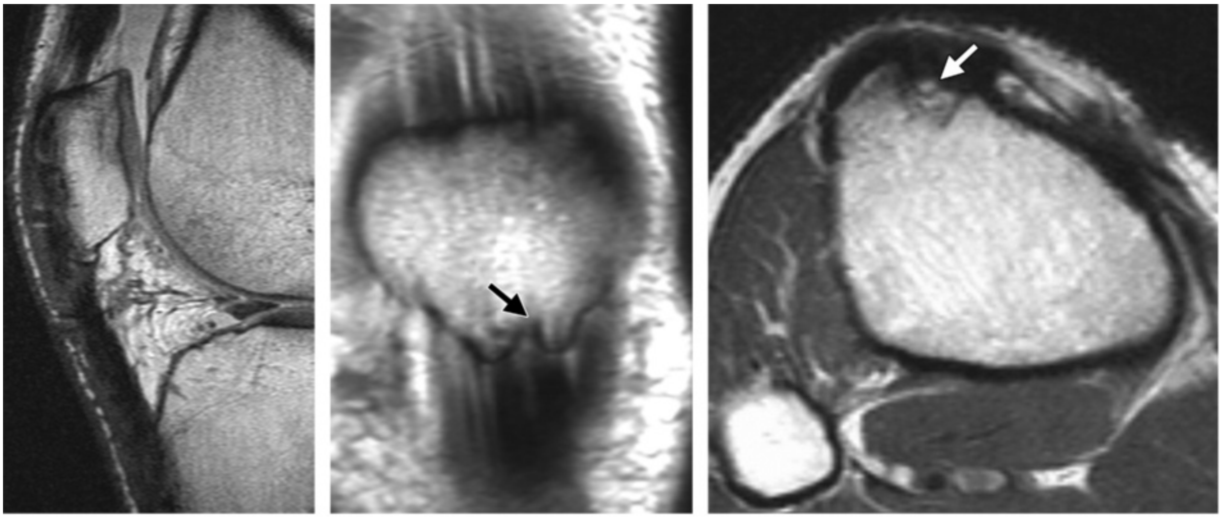
In this article we describe the postoperative MR imaging appearance of normal ACL graft reconstructions and potential complications including roof impingement, partial and complete graft tears, arthrofibrosis, tunnel cysts, iliotibial band friction syndrome, hardware loosening, and infection.

Normal ACL Graft Reconstruction

The question of which type of graft to employ in ACL reconstruction remains controversial (8). The most commonly used methods are bone–patellar tendon–bone and hamstring autografts. The use of the middle one-third of the patellar tendon, with bone plugs attached to each end, has historically been considered the reference standard for ACL graft reconstruction because of the inherent strength and stiffness of the graft (Fig 1). However, subsequent patellar-tendon abnormalities and anterior knee pain are relatively common complications with this type of graft. A four-strand hamstring graft often is made of segments from the semitendinosus tendon, the gracilis tendon, or both. The tendon segments are folded and braided together to form a quadruple-thickness strand, which is then fixed to the femur and tibia (Fig 2). The hamstring graft became popular because of the low reported morbidity related to the graft harvesting site (9,10) (Fig 3). However, hamstring grafts traditionally have been subject to slippage. New fixation techniques seem to have addressed this problem. Proper fixation of the graft with interference screws, endobuttons (Fig 4), a screw-washer construct, or staples is crucial to avoid changes in the graft position during the initial postoperative incorporation period. Interference screws commonly are used as fixation devices in bone–patellar tendon–bone graft reconstruction.

Positioning of the femoral and tibial tunnels is of paramount importance for proper function of the ACL graft. Accurate location of the femoral tunnel is essential to achieve isometry of the ACL graft (11). Isometry refers to adequate constancy in length and tension of the graft during the complete range of knee motion (from flexion to extension). Over-the-top placement is not isometric; it results in increased graft length and tension

Teaching Point



a. b. c.

Figure 1. Bone–patellar tendon–bone graft. **(a)** Sagittal proton-density–weighted fast spin-echo MR image shows signal heterogeneity of the patellar tendon at the graft harvesting site. **(b)** Coronal T1-weighted MR image shows a patellar cleft (arrow). **(c)** Axial proton-density–weighted fast spin-echo MR image at the level of the anterior tibial tuberosity shows a bone defect (arrow) from bone plug harvesting.

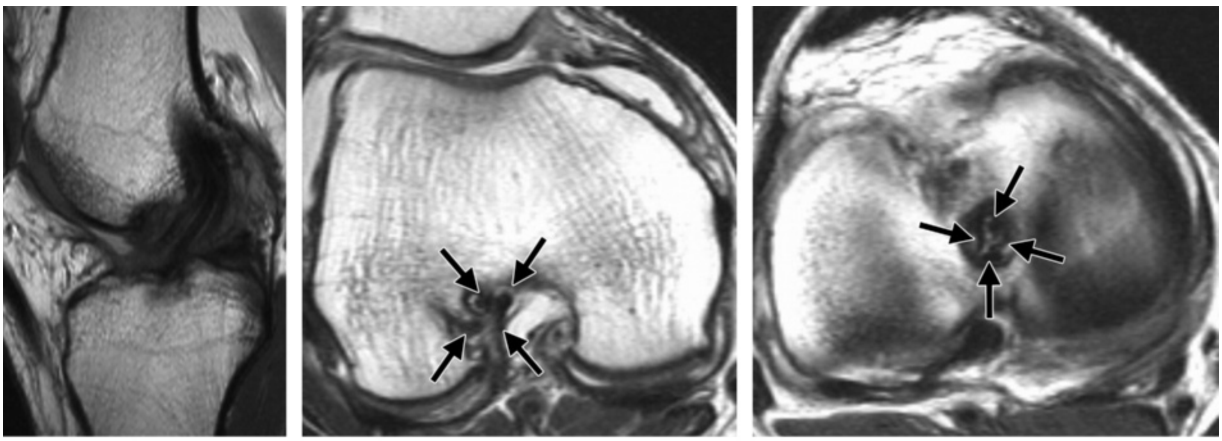


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Figure 2. Four-strand hamstring graft. **(a)** Sagittal proton-density–weighted fast spin-echo MR image shows linear regions of intermediate signal intensity between the strands of a hamstring graft. **(b, c)** Axial proton-density–weighted MR images at the level of the openings of the femoral **(b)** and tibial **(c)** tunnels show the four strands (arrows) of a single-bundle, double-looped hamstring graft.

a. b.

Figure 3. Hamstring graft harvesting site. **(a)** Coronal T1-weighted MR image shows scarring of the fat planes surrounding the distal semitendinosus tendon (arrow). **(b)** Axial proton-density–weighted MR image shows scarring around the insertion of the pes anserinus into the tibia (arrow).

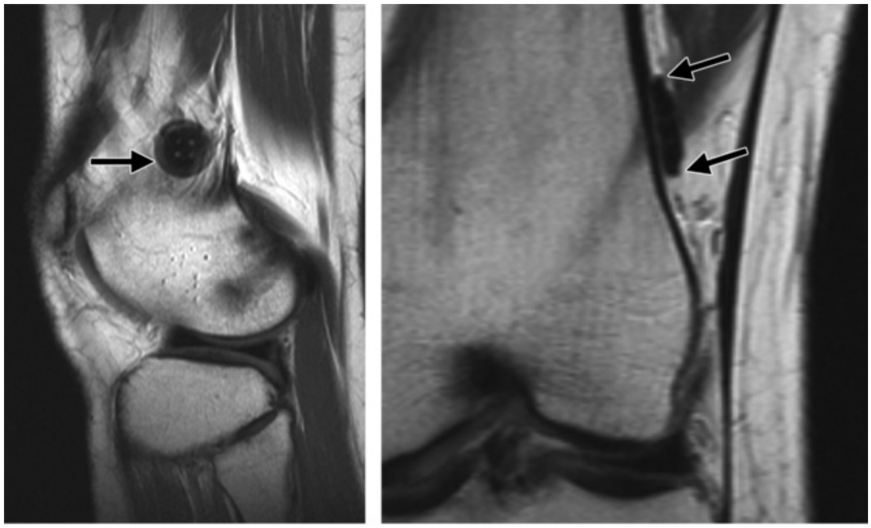

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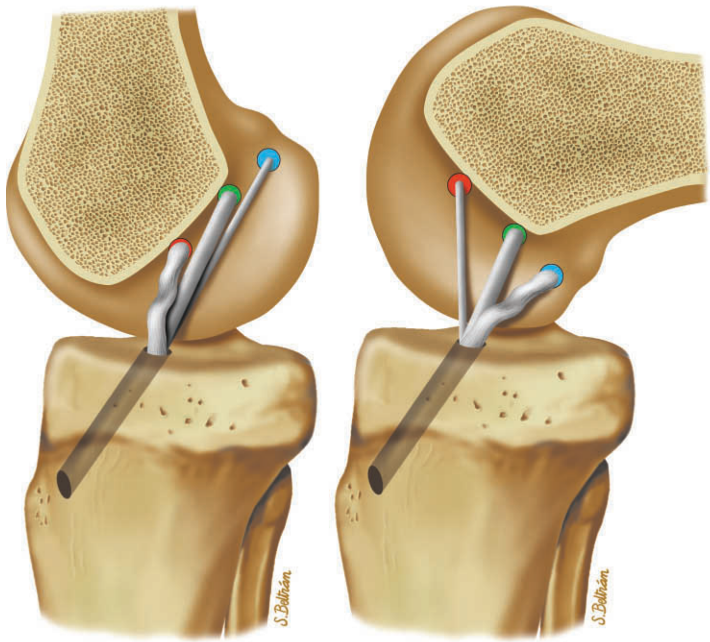
Figure 4. Endobutton used for hamstring graft fixation in ACL reconstruction. Sagittal **(a)** and coronal **(b)** proton-density–weighted fast spin-echo MR images show an endobutton (arrows) affixing the graft at the proximal opening of the femoral tunnel.



a. b.

Figure 5. Effects of femoral tunnel placement on graft length and tension. Diagrams of the knee in extension **(a)** and flexion **(b)** show anterior (red circle), isometric (green circle), and over-the-top (blue circle) positions of the femoral tunnel site in ACL reconstruction. (Adapted, with permission, from reference 11.)

as the knee is extended (Fig 5a). If the femoral tunnel is placed too far anteriorly, the length and tension of the graft greatly increase as the knee is flexed (Fig 5b). The femoral tunnel should be placed as far posteriorly as possible without disrupting the posterior cortex of the femur. Ideally, a 1–2-mm-thick cortical rim should remain.

The ACL consists of two major functional bundles: the anteromedial bundle and the posterolateral bundle. Both contribute substantially to the anterior and rotational stability of the knee. It has been postulated that an anatomic double-bundle, four-tunnel reconstruction technique may restore the biomechanics of the knee better than the classic single-bundle, two-tunnel technique. Recent data suggest that the conventional single-bundle technique, if implemented with a more horizontally positioned femoral tunnel, produces clinical results comparable to those obtained with the double-bundle technique (12). On coronal images, the femoral tunnel should open superiorly above the lateral femoral condyle at the 10–11-o'clock position in the right knee and the 1–2-o'clock position in the left knee (Fig 6) (7,12).

The tibial tunnel should be oriented parallel to the projected slope of the intercondylar roof (the Blumensaat line) (Fig 6b, 6c). In the sagittal plane, the opening of the proximal tibial tunnel should be posterior to the intersection of the Blumensaat line

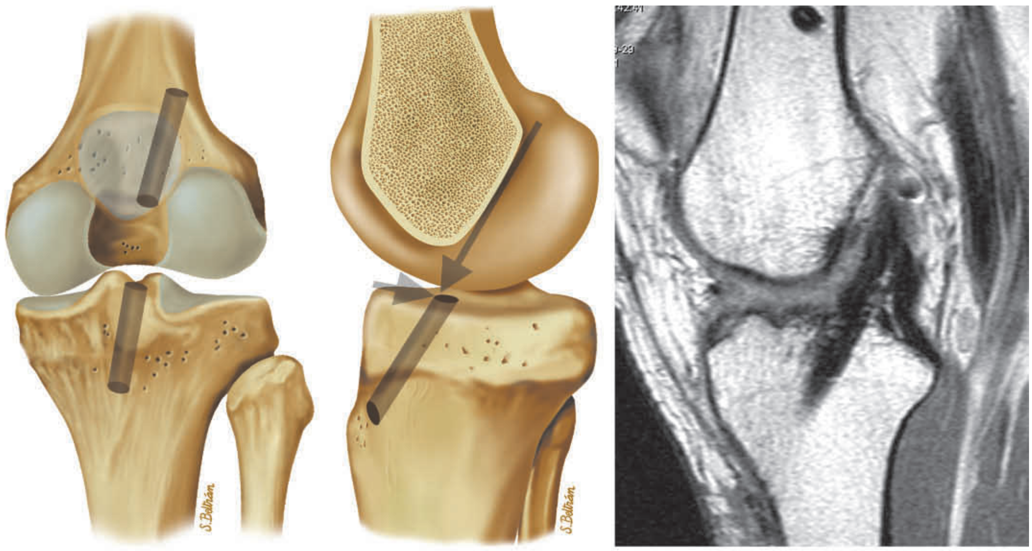


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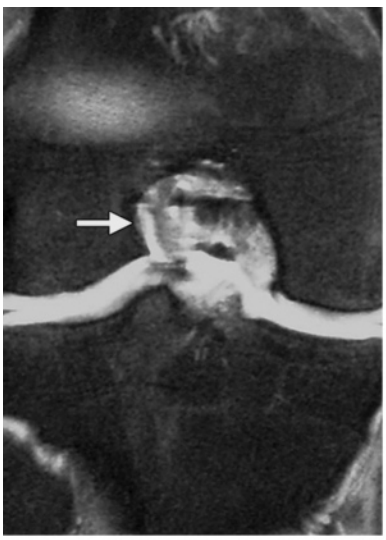
Figure 6. Correct positioning of the femoral and tibial tunnels in ACL reconstruction. **(a)** Diagram shows correct positioning of the tunnels in the coronal plane. In the left knee, the femoral tunnel should open superiorly at the 1–2-o'clock position. **(b)** Diagram shows correct positioning of the tunnels in the sagittal plane. The tibial tunnel should open posterior to the intersection of the Blumensaat line and the tibia (arrows). **(c)** Sagittal proton-density–weighted MR image shows correct orientation and positioning of the tibial tunnel. (Adapted, with permission, from reference 7.)



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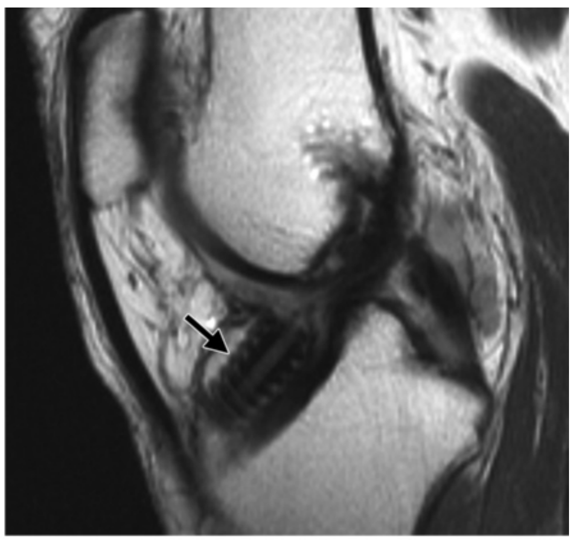

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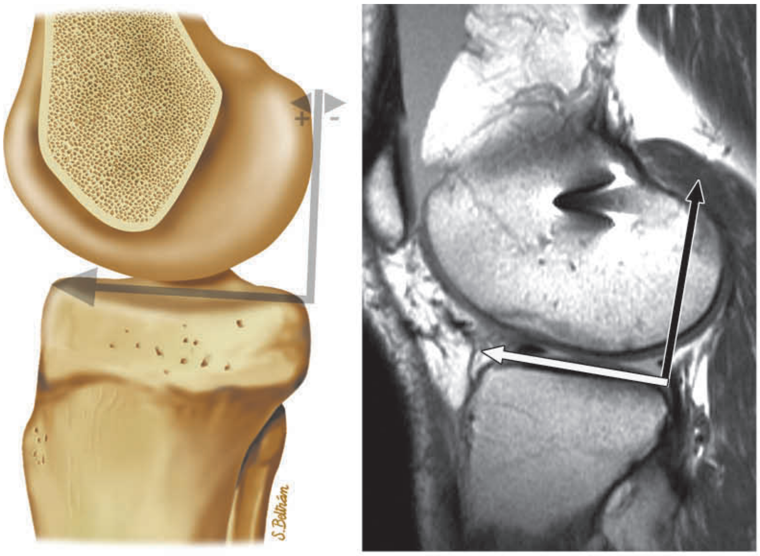
Figures 7, 8. **(7)** Notchplasty. Coronal T2-weighted fat-suppressed MR image shows a focal cortical defect in the anterior aspect of the medial wall of the lateral femoral condyle (arrow), a finding suggestive of notchplasty. **(8)** Tibial interference screw. Sagittal proton-density–weighted MR image shows an interference screw (arrow) within the tibial tunnel, anterior to the ACL graft. The screw was placed to correct roof impingement, which was discovered intraoperatively.

and the tibia. In the coronal plane, the tibial tunnel should open at the intercondylar eminence. At the time of surgery, the knee is extended while 1 cm of the drill bit is left protruding from the tibial tunnel into the joint. If roof impingement is present, anterior notchplasty may be performed. In notchplasty, a few millimeters of bone are removed from the anterolateral aspect of the intercondylar roof (Fig 7) (13). Care must be taken to avoid removing cortical bone superiorly in the femoral notch so as not to decrease contact of the patellofemoral joint surfaces during knee flexion. In addition, a tibial interference screw may be placed along the anterior aspect of the graft to correct roof impingement intraoperatively (Fig 8).



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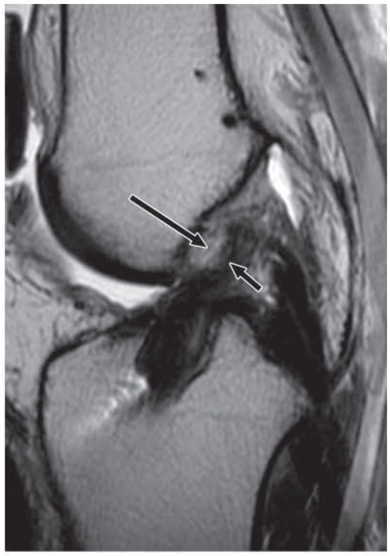

10.

Figures 9, 10. **(9)** Anterior tibial translation. **(a)** Diagram shows normal alignment of the tibia (arrows), with respect to the femur, in the sagittal plane. **(b)** Sagittal proton-density–weighted MR image shows an abnormal anterior position of the tibia (arrows) caused by fixed anterior translation of the tibia over the femur. **(10)** Roof impingement. Sagittal proton-density–weighted MR image shows spurring (long arrow) of the anterior margin of the intercondylar roof and posterior bowing of the graft (short arrow). An area of increased, intermediate signal intensity is seen within the anterior two-thirds of the graft.

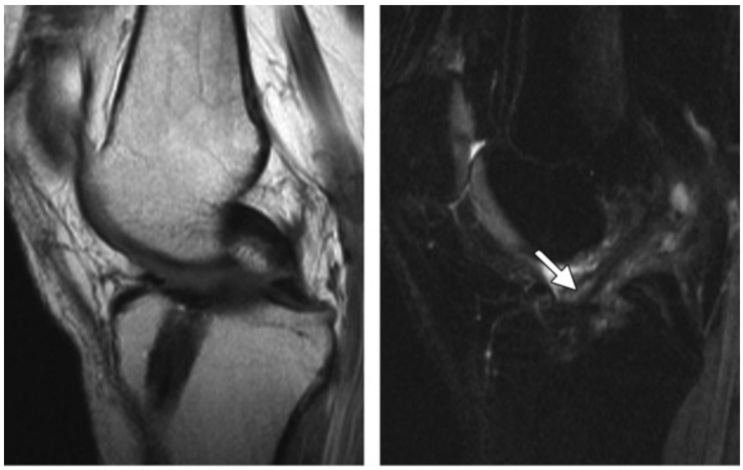

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Figure 11. Partial graft tear. **(a)** Sagittal proton-density–weighted fast spin-echo MR image shows an anterior position of the tibial tunnel with respect to the Blumensaat line. **(b)** Sagittal T2-weighted fat-suppressed fast spin-echo MR image shows an area of increased signal intensity resembling that of intrasubstance fluid (arrow) within the distal intraarticular portion of the graft, a finding indicative of a partial graft tear.

Roof Impingement

Teaching Point

Roof impingement often is secondary to an abnormal position of the tibial tunnel anterior to the intersection of the Blumensaat line and the tibia when the knee is fully extended (13). In cases of roof impingement, it is important to determine whether anterior tibial translation is the cause of the abnormal position of the tibial tunnel (Fig 9). In some patients, tightening of the posterior capsular restraints after ACL disruption may lead to fixed anterior translation of the tibia over the femur. At MR imaging, the impinged graft is in contact with the anteroinferior margin of the intercondylar roof and may appear posteriorly bowed (Fig 10). Signal intensity alteration selectively involves the anterior two-thirds of the graft (7).

Partial Graft Tear

At T2-weighted MR imaging, partial graft tears appear as focal areas of increased signal intensity covering a portion of the graft, with intact fibers still present (Fig 11). The differential diagnosis for partial graft tear includes the normal “ligamentization” phase that occurs in immature grafts and signal heterogeneity between the individual bundles

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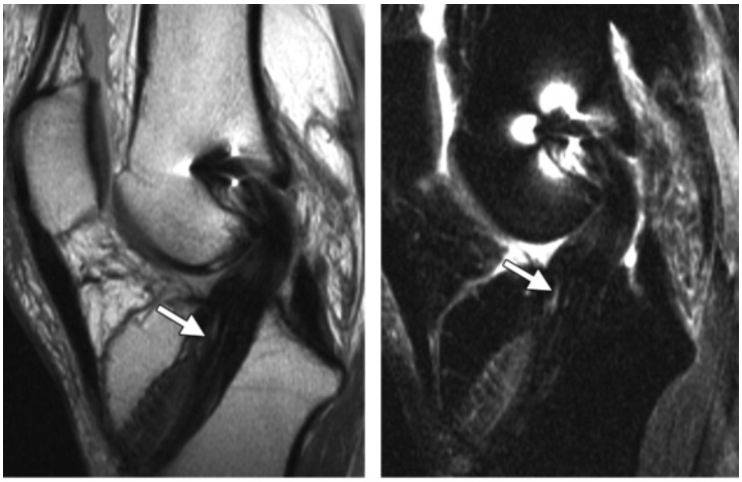

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Figure 12. Ligamentization in a patient who underwent graft reconstruction 8 months earlier. Sagittal proton-density–weighted **(a)** and T2-weighted fat-suppressed **(b)** fast spin-echo MR images show small focal areas of intermediate signal intensity (arrow) within the graft.

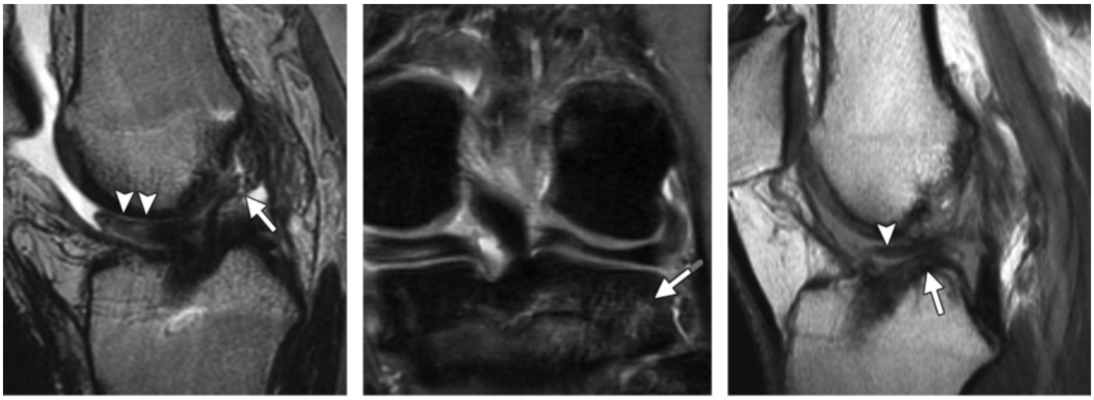

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Figure 13. Complete graft tear. **(a)** Sagittal T2-weighted fast spin-echo MR image shows a fluid-filled graft defect (arrow) and anterior flip of the torn fibers (arrowheads), findings indicative of an acute complete graft tear. **(b)** Coronal T2-weighted fat-suppressed fast spin-echo MR image (obtained in the same patient as **a**) shows a contusion of the tibial bone marrow (arrow), a finding indicative of recurrent trauma. **(c, d)** Sagittal proton-density–weighted **(c)** and coronal T1-weighted **(d)** fast spin-echo MR images obtained in a different patient show resorption of the ACL graft (arrow), which lies horizontally along the floor of the intercondylar notch. A displaced bucket handle–shaped fragment of the medial meniscus (arrowhead in **c**) also is seen. These findings are indicative of a chronic graft tear.

in multistrand hamstring grafts (Fig 2a) (14). It has been reported that ligamentization with small focal areas (<25% of the graft substance) of increased intermediate signal intensity within the graft can persist for as long as 4 years after ACL graft reconstruction (Fig 12) (15).

Complete Graft Tear

Teaching Point

Complete graft disruption often is a result of recurrent trauma. Nonisotropic positioning of the graft tunnel resulting in abnormal stress to the graft during the normal range of motion also has been implicated as a cause of complete graft tear. T2-weighted MR imaging findings of acute complete graft disruption include an absence of intact graft fibers and a fluid-filled defect (Fig 13a). It has been reported that the presence of a large joint effusion and pivot-shift bone bruises in the lateral compartment are highly specific and have great positive predictive value for the identification of complete graft tears (Fig 13b) (16). Other reliable

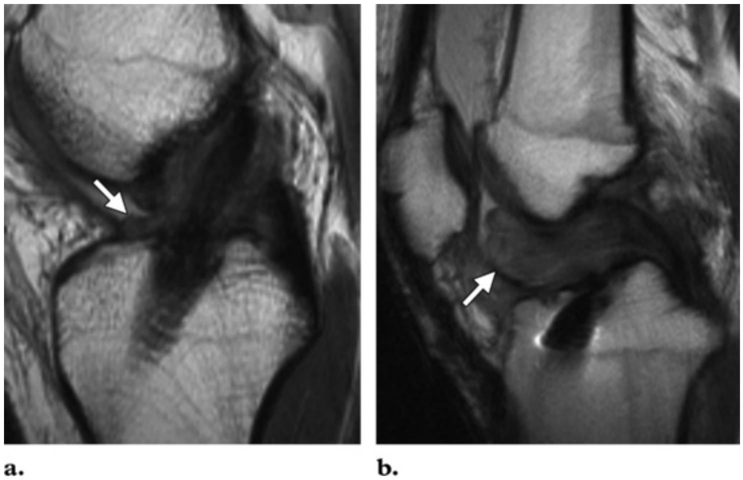


Figure 14. Cyclops lesion. **(a)** Sagittal proton-density–weighted fast spin-echo MR image shows a tiny nodule of arthrofibrosis (arrow) in the anterior intercondylar notch. The nodule is attached to the graft. **(b)** Sagittal proton-density–weighted fast spin-echo MR image obtained in another patient shows a large cyclops lesion (arrow) that was responsible for a loss of knee extension.

MR imaging signs of complete ACL disruption include a horizontal graft orientation or laxity and resorption of graft fibers (Fig 13c, 13d) (15).

Arthrofibrosis

Arthrofibrosis is defined as the presence of scar tissue in at least one compartment of the knee joint, leading to a decreased range of motion. Localized anterior arthrofibrosis, or "cyclops" lesion, has been reported in 1%–10% of patients with ACL reconstruction (3,17,18). A cyclops lesion is a nodular fibrous lesion that is located in the anterior intercondylar notch; sometimes it adheres to the tibial fibers of the ACL graft (Fig 14). It may become caught between the femur and tibia during knee extension. Cyclops lesions typically are small, with average sizes ranging from 10 to 15 mm (19). Two histologic types have been identified: true "hard" cyclops nodules and "soft" cyclopoid scars (20). True cyclops nodules contain osseous or cartilaginous tissue and are more prone to entrapment (cyclops syndrome). Cyclopoid scars contain only fibroproliferative tissue and are easily compressed by adjacent bones without limiting knee extension. MR imaging findings of a cyclops lesion include an anterior intercondylar nodule with mixed intermediate signal intensity on T1-weighted, T2-weighted, and proton-density–weighted fast spin-echo images. The lesion extends in a linear fashion along the intercondylar roof. The differential diagnosis for a cyclops lesion includes focal pigmented villonodular synovitis, synovial chondromatosis, and loose bodies.

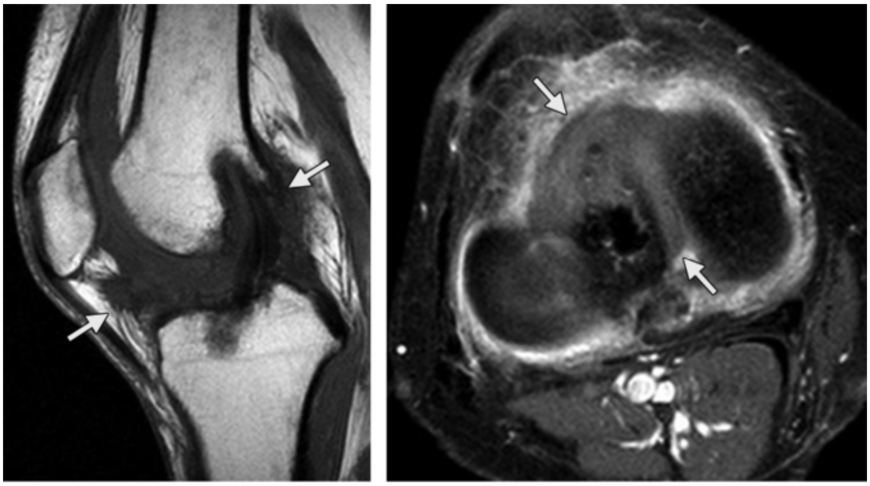
Teaching Point

There is a higher prevalence of generalized knee arthrofibrosis among patients undergoing ACL reconstruction within 4 weeks of experiencing trauma than in those who undergo reconstruction more than 4 weeks after trauma, especially when less than 90° of knee flexion is obtained preoperatively (21). A correlation between preoperative irritation (indicated by swelling, effusion, and hyperthermia) at the time of ACL reconstruction and arthrofibrosis also has been reported (21). Therefore, postoperative pain and irritation should be minimized with the use of nonsteroidal anti-inflammatory drugs, cryotherapy, and lymphatic drainage. At MR imaging, generalized arthrofibrosis is seen encasing the graft and extending into the infrapatellar fat pad and the posterior joint capsule (Fig 15). Arthrofibrosis is treated with arthroscopic débridement and manipulation; the outcome is better if arthrofibrosis is treated within 6 months of ACL reconstruction. Revision of the ACL reconstruction may be necessary if the tunnels are abnormally positioned.

Tunnel Cysts

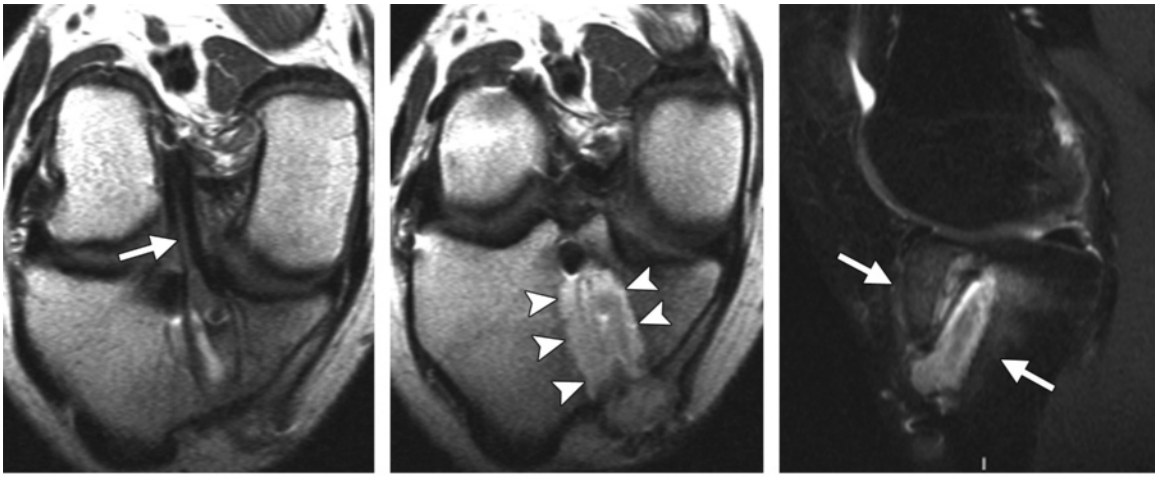
Small amounts of fluid may be seen within the tibial and femoral tunnels during the 1st year after ACL reconstruction (22). This fluid generally is reabsorbed within 18 months after surgery and does not necessarily lead to tunnel expansion, ganglion formation, or graft failure. In a prospective study of 89 cases of ACL reconstruction, pretibial cyst formation was present in 2.2% (23).

The formation of tunnel cysts after ACL reconstruction has been attributed to several causes. Incomplete incorporation of allograft tissue within the bone tunnels and subsequent tissue necrosis may allow synovial fluid to be transmitted through the tibial tunnel to pretibial subcutaneous tissues (23). Tunnel cysts also have been observed in the presence of patellar tendon autografts, hamstring autografts, and synthetic ligaments (24,25). Bioabsorbable interference



a. b.

Figure 15. Generalized arthrofibrosis. Sagittal **(a)** and axial **(b)** proton-density–weighted fast spin-echo MR images show encasement of the ACL graft by fibrovascular proliferative tissue (arrows) that extends into the infrapatellar fat and suprapatellar bursa.



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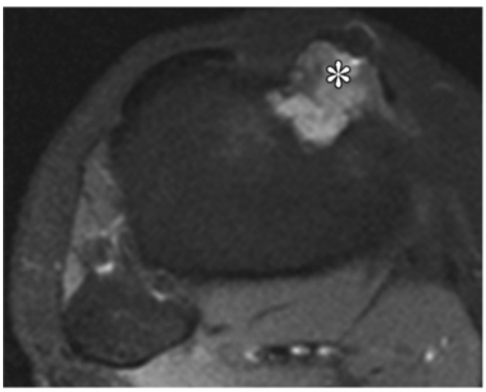

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Figure 16. Tibial tunnel cyst. **(a, b)** Oblique coronal proton-density–weighted MR images show a linear intrasubstance tear of the ACL graft (arrow in **a**), a finding associated with a tibial tunnel cyst (arrowheads in **b**). **(c)** Sagittal T2-weighted fat-suppressed MR image shows reactive marrow edema (arrows) surrounding the tibial tunnel cyst. **(d)** Axial T2-weighted fat-suppressed MR image shows extension of the cyst (*) into the pretibial soft tissues.

screws, nonabsorbable suture fragments, and joint fluid leakage during failed ACL revision surgery also have been implicated in tunnel cyst formation. “Bungee-cord” or “windshield-wiper” tunnel widening may occur when intraosseous fixation is not performed. Extrusion of joint fluid into the tunnel may lead to formation of a ganglion, which may enlarge over time and cause postoperative pain. Tibial tunnel cysts may be incidentally found at MR imaging, or they may manifest as a palpable mass in the pretibial soft tissues (Fig 16). Femoral tunnel cysts are less common than tibial tunnel cysts; there are no reports in the literature regarding their prevalence. All four femoral cysts from our teaching file collection were associated with complete disruption of the ACL graft (Fig 17).

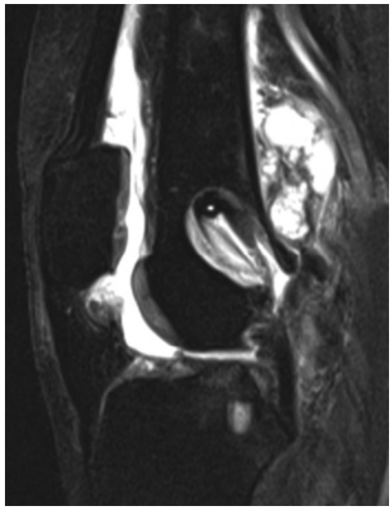

Figure 17. Femoral tunnel cyst in a patient with a complete ACL graft tear. Sagittal proton-density–weighted fast spin-echo MR image shows a large, multiloculated femoral tunnel cyst with extraosseous extension into the popliteal fossa.

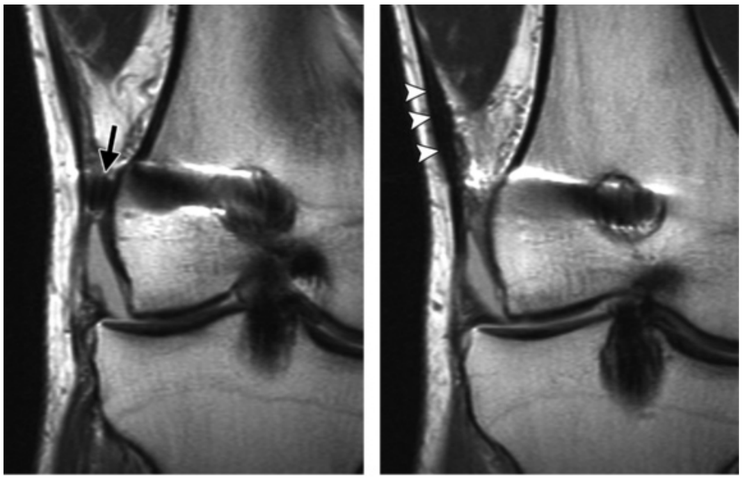

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Figure 18. Iliotibial band friction syndrome. Sequentially acquired coronal proton-density–weighted fast spin-echo MR images show focal fusiform thickening of the iliotibial tract (arrowheads in **b**) due to friction caused by contact with a femoral ACL fixation pin (arrow in **a**).

Iliotibial Band Friction Syndrome

Iliotibial band friction syndrome recently was reported as a potential complication of ACL reconstruction with the use of a hamstring graft and bioabsorbable cross pins (transfix device). Partially dislodged or fragmented cross pins may contact the adjacent iliotibial band and cause frictional thickening or tearing (Fig 18) (26).

Hardware-related Complications

Weak graft fixation is another cause of ACL graft reconstruction failure that requires revision surgery. Fixation devices that may loosen or become displaced include bioabsorbable interference screws, metallic setscrews, and pins (Fig 19) (27). If the subcutaneous prominence of cortical fixation devices leads to symptoms, the devices may need to be removed.

Infection

Septic arthritis following ACL reconstruction is uncommon, with a reported cumulative incidence of 0.1%–0.9%. The difficulty of correctly diagnosing such infections at an early stage is well established; the classic symptoms of infection, such as erythema, warmth, severe restricted motion, and severe pain, often are absent. However, mild local pain and effusion associated with an increased C-reactive protein level and increased erythrocyte sedimentation rate that extended beyond the 1st postoperative week were common findings in a

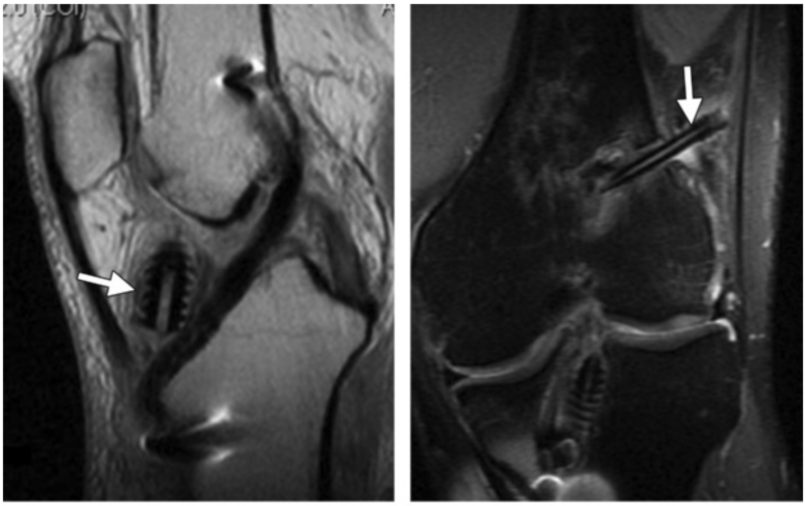

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Figure 19. Hardware failure. **(a)** Sagittal proton-density–weighted fast spin-echo MR image shows a loosened tibial interference screw (arrow). **(b)** Coronal T2-weighted fast spin-echo MR image shows a loosened and partially dislodged cross pin (arrow) used for femoral fixation in ACL graft reconstruction.

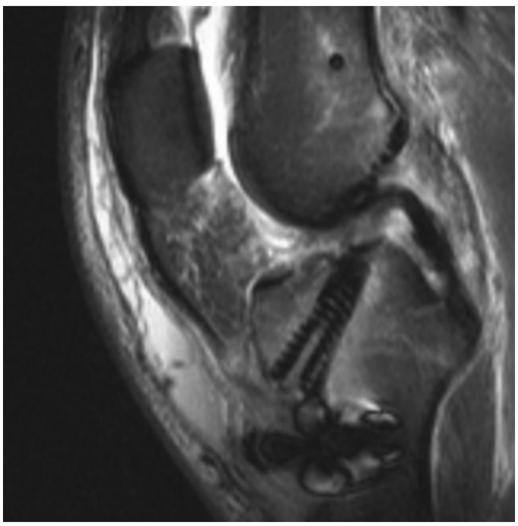

Figure 20. Infected infrapatellar bursitis. Sagittal T2-weighted fat-suppressed fast spin-echo MR image shows a subcutaneous fluid collection overlying the opening of the anterior tibial tunnel. Reactive marrow edema is seen in the proximal tibia. No evidence of osteomyelitis was found at intraoperative biopsy.

series of 10 patients with septic arthritis after ACL graft reconstruction (28). MR imaging may be used to validate a clinical diagnosis of infection as well as to determine the extent of infection and the presence of potentially drainable fluid collections or abscesses (Fig 20). MR imaging findings of infection include synovitis, bone erosion, periarticular edema, marrow edema, sinus tracts, and soft-tissue abscesses (7).

Conclusions

MR imaging is the modality of choice for evaluation of failed ACL graft reconstruction surgery. ACL graft complications such as abnormal tunnel positioning, roof impingement, partial and complete graft tears, arthrofibrosis, tunnel synovial cysts, iliotibial band friction syndrome, hardware loosening, and infection may be reliably assessed at MR imaging.

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MR Imaging of Complications of Anterior Cruciate Ligament Graft Reconstruction

Jenny T. Bencardino, MD, et al

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Page 2116
Magnetic resonance (MR) imaging is the preferred advanced imaging modality for the evaluation of symptomatic ACL graft reconstructions.

Page 2116
Positioning of the femoral and tibial tunnels is of paramount importance for proper function of the ACL graft.

Page 2120
Roof impingement often is secondary to an abnormal position of the tibial tunnel anterior to the intersection of the Blumensaat line and the tibia when the knee is fully extended.

Page 2121
Complete graft disruption often is a result of recurrent trauma. Nonisotropic positioning of the graft tunnel resulting in abnormal stress to the graft during the normal range of motion also has been implicated as a cause of complete graft tear.

Page 2122
Localized anterior arthrofibrosis, or “cyclops” lesion, has been reported in 1%–10% of patients with ACL reconstruction.