Imaging of Anterior Cruciate Ligament Repair and Its Complications

Arthur B. Meyers[1]
Andrew H. Haims
Kirsten Menn
Hicham Moukaddam

OBJECTIVE. This article provides a review of anterior cruciate ligament (ACL) reconstruction procedures and their normal postoperative appearance. Then, we review commonly encountered complications: those associated with decreased range of motion (impingement, arthrofibrosis, intraarticular bodies, ganglion cysts) and those associated with laxity (graft tearing, graft stretching). Finally, we review some miscellaneous complications.

CONCLUSION. Given the number of patients undergoing ACL reconstruction, it is important for radiologists to be familiar with the different reconstruction surgeries and their common complications.

Keywords: anterior cruciate ligament reconstruction, arthrofibrosis, autologous four-strand hamstring graft, bone–patella tendon–bone graft, graft impingement, graft tear, sports medicine, trauma

DOI:10.2214/AJR.09.3200

Received June 16, 2009; accepted after revision July 20, 2009.

[1]All authors: Department of Diagnostic Radiology, Yale University School of Medicine, 333 Cedar St., New Haven, CT 06520. Address correspondence to H. Moukaddam (hicham.moukaddam@yale.edu).

CME
This article is available for CME credit.
See www.arrs.org for more information.

AJR 2010; 194:476–484

0361–803X/10/1942–476

Anterior cruciate ligament (ACL) reconstruction is one of the most commonly performed sports medicine procedures in the United States, with approximately 100,000 procedures performed each year [1]. Patients with postoperative symptoms are frequently imaged to evaluate for complications. Therefore, it is incumbent on radiologists to be familiar with the different surgeries performed for ACL reconstruction, the normal postoperative appearance, and complications that can be diagnosed with imaging. In this article, we present a comprehensive review of the imaging of ACL reconstruction and of its complications.

ACL Reconstruction Procedures

The two primary ACL reconstruction procedures are the autologous bone–patella tendon–bone graft and the autologous four-strand hamstring graft, which is also known as the doubled semitendinosus and gracilis tendon graft. The bone–patella tendon–bone graft is harvested by taking bone blocks from the patella and the tibial tubercle with the intervening central third of the patellar tendon (Fig. 1). The second graft is composed of the distal semitendinosus and gracilis tendons, which are harvested from the musculotendinous junction to their tibial insertion. They are then sutured together and doubled back, giving four strands (Fig. 2). Debate as to which procedure leads to better long-term joint stability is ongoing, with some studies showing better long-term stability with one procedure over the other and others showing no significant difference between the procedures [2–4]. However, the bone–patella tendon–bone procedure does lead to more anterior knee pain at the patellar bone harvest site than the doubled semitendinosus and gracilis tendon graft [3]. In the pediatric population, ACL repair using the doubled semitendinosus and gracilis tendon graft is the preferred method because of the ability to avoid crossing the physis with bone blocks [5]. There are differences in the appearances of the two grafts, from an imaging standpoint, that are important and are discussed later in this article.

Other types of procedures have been performed for ACL reconstruction using other autografts, cadaveric allografts, synthetic materials, and even grafts from living related donors [5]. These procedures often use similar bone tunnels and have postoperative appearances similar to the bone–patella tendon–bone and doubled semitendinosus and gracilis tendon procedures.

The two procedures mentioned replace only the anteromedial bundle (AMB) of the ACL. The ACL is functionally divided into an AMB and a posterolateral bundle (PLB) on the basis of their sites of attachment on the tibia [6]. Newer procedures have been developed using double-bundle techniques to replicate a more physiologic function of the ACL by replacing both the AMB and the PLB [7]. The surgical techniques vary using up to four bone tunnels [6].

In this article, we focus on the postoperative appearances of the bone–patella tendon–

bone graft and the doubled semitendinosus and gracilis tendon graft, which are still the most widely used techniques [8]. The appearances of many of the complications are similar among the different types of grafts, and no complications have been reported, to our knowledge, that are specifically related to the use of the double-bundle reconstruction technique, which are not seen with the other procedures [6, 9].

The bone plugs of the bone–patella tendon–bone graft are secured within the tunnels by interference screws, which press them against the walls of the tunnels until bony union occurs. Metallic interference screws are still widely used. However, bioabsorbable screws are increasingly being used because they produce fewer artifacts on subsequent MRI. Interference screws are also used to anchor doubled semitendinosus and gracilis tendon grafts. However, a variety of other methods are also used, including those using devices such as the Endobutton (Smith & Nephew) and transfixation devices [10, 11]. The Endobutton is a device that is pushed through a small hole in the bone and then deploys as a T to anchor the graft in place (Fig. 3). Transfixation devices are cross-pin devices placed in the femoral condyles perpendicular to the long axis of the graft.

Femoral and Tibial Tunnel Anatomy

Correct positioning and alignment of the femoral and tibial tunnels are crucial for graft stability and good clinical outcomes and should be evaluated and documented in every patient who has undergone ACL reconstruction [12].

Femoral Tunnel

The positioning of the femoral tunnel is the primary factor in maintaining graft isometry [13]. Femoral tunnel positioning must be assessed in both the sagittal and coronal planes. The position of the tunnel can be assessed in the sagittal plane by drawing a line along the posterior cortex of the femur and another line along the roof of the intercondylar notch. The inferior portion of the tunnel should be located at the intersection of these two lines [12, 14] (Figs. 4A and 5A).

On an anteroposterior radiograph or a coronal MR image, the intraarticular portion of the femoral tunnel should open at the superolateral posterior margin of the intercondylar notch. If a clock face is superimposed on an anteroposterior radiograph or a coronal MR image with the center at the intercondylar notch, the tunnel should be oriented between 10- and 11-o'clock on the right knee or between 1- and 2-o'clock on the left knee [12, 14] (Figs. 4B and 5B). We should note that the use of a clock face for evaluating tunnel positioning has significant limitations, particularly when evaluating an ACL repaired using the double-bundle technique, because the orientations of the insertion sites of the AMB and PLB change depending on the degree of flexion of the knee. This is important because imaging is performed with the knee extended, whereas surgery is performed with the knee in flexion. Therefore, if a clock face is used to describe the orientation of the femoral tunnel, the degree of flexion of the knee should be noted [15].

Tibial Tunnel

The positioning of the tibial tunnel is the primary factor in preventing impingement of the graft against the roof of the intercondylar notch [16]. On sagittal images, the tibial tunnel should be oriented parallel to the Blumensaat line. The Blumensaat line is a line drawn on conventional radiographs along the intercondylar roof. The distal portion of the tunnel should start near the tibial tuberosity, and the intraarticular opening of the tunnel should be completely posterior to where the Blumensaat line, or the Blumensaat line equivalent on MRI, intersects the tibia [12, 14] (Figs. 4A and 5C).

Relative lucency is commonly seen around the graft before incorporation, with sclerosis developing at the tunnel margins on follow-up examinations once graft incorporation is complete [17].

Graft MRI Characteristics

A normal ACL graft should have low signal intensity on short-TE sequences [13, 18]. Intermediate signal is often seen within grafts from approximately 4 to 8 months after reconstruction, decreasing with time and usually completely resolving by 12 months [13, 18]. The increased signal is thought to be due to graft revascularization and synovialization [6]. An important distinction between the doubled semitendinosus and gracilis tendon graft and the bone–patella tendon–bone graft should be considered. Because the doubled semitendinosus and gracilis tendon graft is composed of four separate strands, intermediate signal and even fluid signal can normally be seen between the strands of the graft on T2-weighted sequences (Fig. 6). This finding is abnormal for a bone–patella tendon–bone graft, which is composed of a single strand [13]. This normal intermediate or high signal is always oriented along the fibers of a doubled semitendinosus and gracilis tendon graft and is distinguishable from a tear, which is perpendicular to the graft.

Harvest Sites

There are distinct differences in the appearances of the harvest sites depending on which type of procedure was performed. MRI of the patellar tendon after graft harvesting for a bone–patella tendon–bone procedure reveals a defect within the tendon that decreases with time but is still present 1–2 years after surgery [19]. The size of the patellar tendon defect has not been shown to correlate with the patellofemoral pain that is sometimes experienced after this procedure [20, 21]. MRI evaluation of the hamstring harvest sites after a doubled semitendinosus and gracilis tendon procedure shows absence of the tendons. Over a 2.5- to 3-year period, progressive regeneration of the tendons has been shown to begin proximally and extend distally [21].

ACL Reconstruction Complications

The main complications seen after ACL reconstruction procedures can be broadly divided into two groups on the basis of clinical symptoms: decreased range of motion and laxity. The main complications found in patients with decreased range of motion are impingement and arthrofibrosis (focal and diffuse forms). Less common causes of decreased range of motion include intraarticular bodies and ganglion cysts. The main complications in patients with increased laxity are graft disruption and graft stretching. Additionally, there are several miscellaneous complications that do not fit well into these two main categories.

Complications Leading to Decreased Range of Motion

Impingement—Tibial tunnel positioning is the primary factor affecting impingement. Both the femoral and tibial tunnels are most commonly malpositioned too far anteriorly. If the tibial tunnel is positioned too far anteriorly (i.e., partially or completely anterior to the intersection of the Blumensaat line, or to its MR equivalent, with the tibia), the graft can become impinged on by the roof of the intercondylar notch [12, 16, 17].

Radiography, CT, and MRI will show a malpositioned tibial tunnel (Fig. 7). MRI may show increased signal in the graft on T1- and T2-weighted sequences in the setting of notch impingement [13] (Fig. 8). Unlike signal changes that occur during the first year due to revascularization, signal changes from notch impingement are more focal and will persist beyond a year [13]. Partial tears may be seen in chronically impinged grafts. MRI can also show a nonlinear (i.e., bowed) orientation of the graft between the tibial and femoral tunnels. If the tibial tunnel is positioned too far laterally, sidewall impingement can occur on the graft by the medial aspect of the lateral condyle [14]. If untreated, graft impingement can progress to graft rupture. Treatment consists of notchplasty, which is arthroscopic resection of a portion of the lateral aspect of the intercondylar notch.

Arthrofibrosis—There are two types of arthrofibrosis: focal and diffuse. On MRI, both forms are low signal intensity on T1-weighted sequences and are predominantly low signal on T2-weighted sequences [13, 18]. The focal form is a more common complication of ACL reconstruction and is seen as a nodule of low signal just anterior to the distal end of the graft between the femur and tibia (Fig. 9). This area of fibrosis limits complete extension of the knee because the graft is trapped between the femur and tibia. The focal form is commonly referred to as a "cyclops lesion" because of its arthroscopic appearance resembling a head with an area of discoloration resembling an eye [22]. The diffuse form can be seen as an ill-defined spiculated area of low signal within the Hoffa fat pad or a masslike area of decreased signal anterior and posterior to the graft that can extend to the joint capsule with possible synovial hypertrophy and capsular thickening [13, 14].

Intraarticular bodies—Another potential cause of decreased range of motion in a patient who has undergone the ACL reconstruction is the presence of intraarticular bodies (Fig. 10A). Intraarticular bodies may be secondary to an associated chondral injury that occurred during the initial trauma but that were not noticed at the time of ACL reconstruction [22, 23]. Intraarticular bodies may be composed of articular cartilage, cortical bone, or cancellous bone; therefore, their signal intensity can vary but will be intermediate to low on T2-weighted sequences (Fig. 10B). MRI arthrography potentially increases the sensitivity for identifying intraarticular bodies. Gradient-echo sequences may also increase sensitivity if the fragment contains cortical bone, which will be seen as very low signal intensity.

Cystic degeneration—Cystic degeneration of the graft, also known as ganglion cyst formation, occurs within the graft as a late complication. Degeneration usually occurs in the tibial tunnel within the graft and follows fluid signal on all MR pulse sequences [13]. These cystic fluid collections can extend proximally through the tibial tunnel into the joint space or distally into the soft tissues anterior to the tibial tubercle [22]. Ganglion cysts may cause pain and, if large enough, may limit motion, but they have not been shown to be a primary cause of graft failure [24. 25].

Ganglion cysts can be distinguished from graft rupture because the fibers of the graft remain intact but are splayed by the ganglion cyst [14]. However, fluid can accumulate within the tunnels, particularly within doubled semitendinosus and gracilis tendon grafts in the first 2 years after surgery, and as discussed earlier, fluid can even be seen between the separate strands of the graft [26]. Unlike in the setting of cystic degeneration, this fluid is not a lobulated cystic structure but appears as linear areas of fluid signal tracking parallel to and outlining the fibers of the graft. This is a normal finding of the doubled semitendinosus and gracilis tendon graft and has not been shown to lead to cystic degeneration. Again, this appearance is abnormal with a bone–patella tendon–bone graft.

Complications Leading to Laxity

Graft tear—Grafts are most susceptible to injury during the remodeling process, which occurs approximately 4–8 months after surgery [13]. There are primary and secondary signs of graft disruption [27]. Primary signs include graft signal abnormalities—namely, increased signal on T2-weighted sequences, graft thickness, and fiber discontinuity (Fig. 11). Secondary signs include anterior tibial translation and an uncovered posterior horn of the lateral meniscus. Comparing these signs with arthroscopy results, Horton et al. [27] found graft fiber continuity and graft thickness to be the most important primary findings. These investigators concluded that a tear can be excluded if the full thickness of the graft is seen as intact on the sagittal or coronal plane. Complete discontinuity of the graft on both the coronal and sagittal planes was 100% specific for diagnosing tears. However, interobserver agreement in evaluating discontinuity in the sagittal plane was poor, leading the authors to conclude that discontinuity is best evaluated in the coronal plane [27]. The same authors found the secondary signs of both anterior tibial translation and uncovering of the posterior horn of the lateral meniscus to be specific (90% and 100%, respectively) for diagnosing tears but to lack sensitivity (46% and 23%, respectively) [27]. Furthermore, Rispoli et al. [28] found that MRI had a limited ability to distinguish between partial and complete graft tears.

As we mentioned previously, ACL grafts commonly show increased signal on T2-weighted sequences between 4 and 8 months secondary to revascularization. A helpful feature distinguishing revascularization of the graft from disruption is the lack of associated secondary signs, such as anterior tibial translation and uncovering of the posterior horn of the lateral meniscus. Additionally, fluid signal seen within doubled semitendinosus and gracilis tendon grafts during the first 2 years after reconstruction should not be confused with tears because the fibers of the graft remain intact and the secondary signs of graft failure are not present.

It can be difficult to distinguish between graft disruption and the signal changes secondary to graft impingement on MRI, particularly when there are marked signal alterations in the graft. Using the reliable primary signs of graft discontinuity and thickness and secondary signs, as well as the clinical history (laxity vs decreased range of motion), can be helpful in confusing cases [22]. Fluid signal on T2-weighted sequences within the graft is also strong evidence of graft disruption.

Graft stretching—As we noted earlier, if malpositioned, the femoral and tibial tunnels are most commonly positioned too far anteriorly. If the femoral tunnel is placed too far anteriorly, then the graft is subject to increased strain when the knee is flexed, which can lead to graft tightening or stretching [29] (Figs. 12A and 12B). The term "graft stretching" has been used to describe intact graft fibers in the clinical setting of increased laxity [13]. MRI findings may include posterior bowing of the graft seen in the sagittal plane [13, 22].

Miscellaneous Lesions

A number of less common complications seen after ACL reconstruction include complications of the fixation devices, harvest site complications, septic arthritis, and vascular complications.

Fixation site—Failure of fixation hardware can occur at several places. Bone plug fractures, bone plug dislocations, bone reabsorption around bone plugs, interference screw fractures, and interference screw migration have all been reported [14, 17–19] (Figs. 13–15). Fractures can also occur in the femur or tibia during graft placement [6].

Harvest site—Complications that occur at the patellar harvest site of the bone–patella tendon–bone graft include patellofemoral pain, rupture of the remaining portion of the tendon, and patellar fractures [17, 19]. As we noted earlier, the size of the patellar tendon defect seen at imaging does not correlate with the patellofemoral pain that some patients experience [20, 21]. No significant complications have been reported to our knowledge at the hamstring harvest site of doubled semitendinosus and gracilis tendon grafts.

Septic arthritis—Septic arthritis is a rare complication after ACL reconstruction occurring in less than 0.5% of patients [14]. MRI is useful in evaluating the extent of bone infection and identifying abscesses. MRI findings suggestive of infection include joint effusions and synovitis, osteomyelitis with marrow edema and bony erosions, and soft-tissue manifestations including abscesses and sinus tracts. The graft can also show focal or diffuse increased signal on T2-weighted images; this imaging finding has been attributed to fibrinous exudates on the graft surface [14].

Vascular complications—Vascular injuries during ACL reconstruction are rare, but cases of pseudoaneurysm of the medial inferior genicular artery after bone–patella tendon–bone and hamstring grafts have been reported [30]. The geniculate artery runs along the medial side of the tibial condyle; therefore, the vessel can be damaged during periosteal elevation on the medial side of the tibia while making the tibial tunnel or harvesting the hamstring tendon [30, 31].

Conclusion

Given the increasing number of patients undergoing ACL reconstruction, it is imperative for radiologists to be familiar with these procedures and their complications. Here, we have reviewed the normal imaging findings as well as the appearances of common complications that can occur in these patients.

References

1. Csintalan RP, Inacio MC, Funahashi TT, et al. Incidence rate of anterior cruciate ligament reconstructions. *The Permanente Journal* 2008; 12:3
2. Wagner M, Kääb MJ, Schallock J, Haas NP, Weiler A. Hamstring tendon versus patellar tendon anterior cruciate ligament reconstruction using biodegradable interference fit fixation: a prospective matched-group analysis. *Am J Sports Med* 2005; 33:1327–1336
3. Freedman KB, D'Amato MJ, Nedeff DD, et al. Arthroscopic anterior cruciate ligament reconstruction: a metaanalysis comparing patellar tendon and hamstring tendon autografts. *Am J Sports Med* 2003; 31:2–11
4. Jansson KA, Linko E, Sandelin J, et al. A prospective randomized study of patellar versus hamstring tendon autografts for anterior cruciate ligament reconstruction. *Am J Sports Med* 2003; 31:12–18
5. Tállay A, Lim MH, Morris HG. Living related donor allograft for revision anterior cruciate ligament reconstruction in a child: a case report. *Knee* 2008; 15:407–410
6. Roberts CC, Towers JD, Spangehl MJ, et al. Advanced MR imaging of the cruciate ligaments. *Radiol Clin North Am* 2007; 45:1003–1016
7. Casagranda BU, Maxwell NJ, Kavanagh EC, et al. Normal appearance and complications of double-bundle and selective-bundle anterior cruciate ligament reconstructions using optimal MRI techniques. *AJR* 2009; 192:1407–1415
8. Duquin TR, Wind WM, Fineberg MS, et al. Current trends in anterior cruciate ligament reconstruction. *J Knee Surg* 2009; 22:7–12
9. Steckel H, Starman JS, Baums MH, et al. The double-bundle technique for anterior cruciate ligament reconstruction: a systematic overview. *Scand J Med Sci Sports* 2007; 17:99–108
10. Ahmad CS, Gardner TR, Groh M, et al. Mechanical properties of soft tissue femoral fixation devices for anterior cruciate ligament reconstruction. *Am J Sports Med* 2004; 32:635–640
11. Milano G, Mulas PD, Ziranu F, et al. Comparison between different femoral fixation devices for ACL reconstruction with doubled hamstring tendon graft: a biomechanical analysis. *Arthroscopy* 2006; 22:660–668
12. Tomczak RJ, Hehl G, Mergo PJ, et al. Tunnel placement in anterior cruciate ligament reconstruction: MRI analysis as an important factor in the radiological report. *Skeletal Radiol* 1997; 26:409–413
13. Sanders TG. MR imaging of postoperative ligaments of the knee. *Semin Musculoskelet Radiol* 2002; 6:19–33
14. Papakonstantinou O, Chung CB, Chanchairujira K, et al. Complications of anterior cruciate ligament reconstruction: MR imaging. *Eur Radiol* 2003; 13:1106–1117
15. Colvin AC, Shen W, Musahl V, Fu FH. Avoiding pitfalls in anatomic ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2009; 17:956–963
16. Howell SM, Clark JA. Tibial tunnel placement in anterior cruciate ligament reconstructions and graft impingement. *Clin Orthop Relat Res* 1992; 283:187–195
17. Manaster BJ, Remley K, Newman AP, Mann FA. Knee ligament reconstruction: plain film analysis. *AJR* 1988; 150:337–342
18. Recht MP, Kramer J. MR imaging of the postoperative knee: a pictorial essay. *RadioGraphics* 2002; 22:765–774
19. Paessler HH, Mastrokalos DS. Anterior cruciate ligament reconstruction using semitendinosus and gracilis tendons, bone patellar tendon, or quadriceps tendon-graft with press-fit fixation without hardware: a new and innovative procedure. *Orthop Clin North Am* 2003; 34:49–64
20. Kartus J, Lindahl S, Kohler K, et al. Serial magnetic resonance imaging of the donor site after harvesting the central third of the patellar tendon: a prospective study of 37 patients after arthroscopic anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc* 1999; 7:20–24
21. Bernicker JP, Haddad JL, Lintner DM, et al. Patellar tendon defect during the first year after ACL reconstruction: appearance on serial magnetic resonance imaging. *Arthroscopy* 1998; 14:804–809
22. White LM, Kramer J, Recht MP. MR imaging evaluation of the postoperative knee: ligaments, menisci, and articular cartilage. *Skeletal Radiol* 2005; 34:431–452
23. Wu H, Webber C, Fuentes CO, et al. Prevalence of knee abnormalities in patients with osteoarthritis and anterior cruciate ligament injury identified with peripheral magnetic resonance imaging: a pilot study. *Can Assoc Radiol J* 2007; 58:167–175
24. Schatz JA, Potter HG, Rodeo SA, Hannafin JA, Wickiewicz TL. MR imaging of anterior cruciate ligament reconstruction. *AJR* 1997; 169:223–228
25. Bergin D, Morrison WB, Carrino JA, Nallamshetty SN, Bartolozzi AR. Anterior cruciate ligament ganglia and mucoid degeneration: coexistence and clinical correlation. *AJR* 2004; 182:1283–1287
26. Sanders TG, Tall MA, Mulloy JP, Leis HT. Fluid collections in the osseous tunnel during the first year after anterior cruciate ligament repair using an autologous hamstring graft: natural history and clinical correlation. *J Comput Assist Tomogr* 2002; 26:617–621
27. Horton LK, Jacobson JA, Lin J, Hayes CW. MR imaging of anterior cruciate ligament reconstruction graft. *AJR* 2000; 175:1091–1097
28. Rispoli DM, Sanders TG, Miller MD, et al. Magnetic resonance imaging at different time periods following hamstring harvest for anterior cruciate ligament reconstruction. *Arthroscopy* 2001; 17:2–8
29. Fu FH, Bennett CH, Ma CB, et al. Current trends in anterior cruciate ligament reconstruction. Part II. Operative procedures and clinical correlations. *Am J Sports Med* 2000; 28:124–130
30. Milankov M, Miljkovic N, Stankovic M. Pseudoaneurysm of the medial inferior genicular artery following anterior cruciate ligament reconstruction with hamstring tendon autograft. *Knee* 2006; 13:170–171
31. Evans JD, Boer MT, Mayor P, et al. Pseudoaneurysm of the medial inferior genicular artery following anterior cruciate ligament reconstruction. *Ann R Coll Surg Engl* 2000; 82:182–184

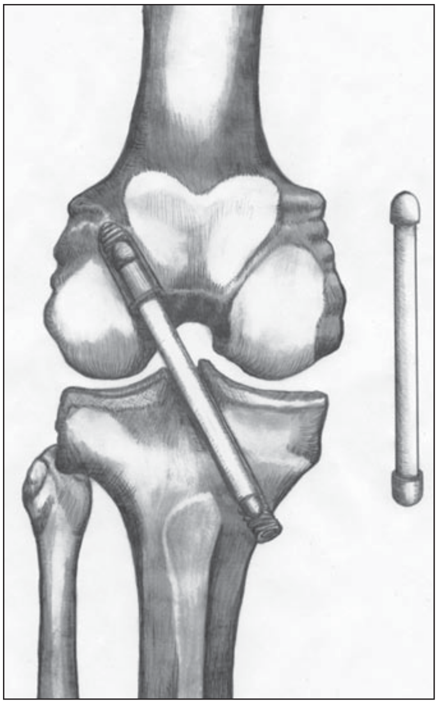


Fig. 1—Illustration shows bone–patella tendon–bone graft ex vivo, interference screw, and graft en vivo with interference screws in femoral and tibial tunnels.

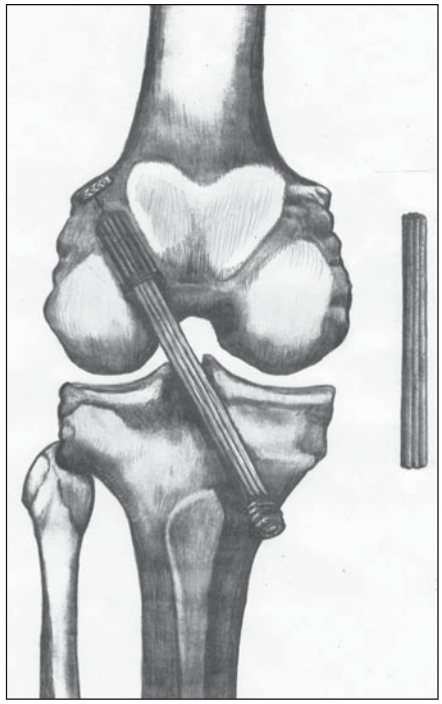
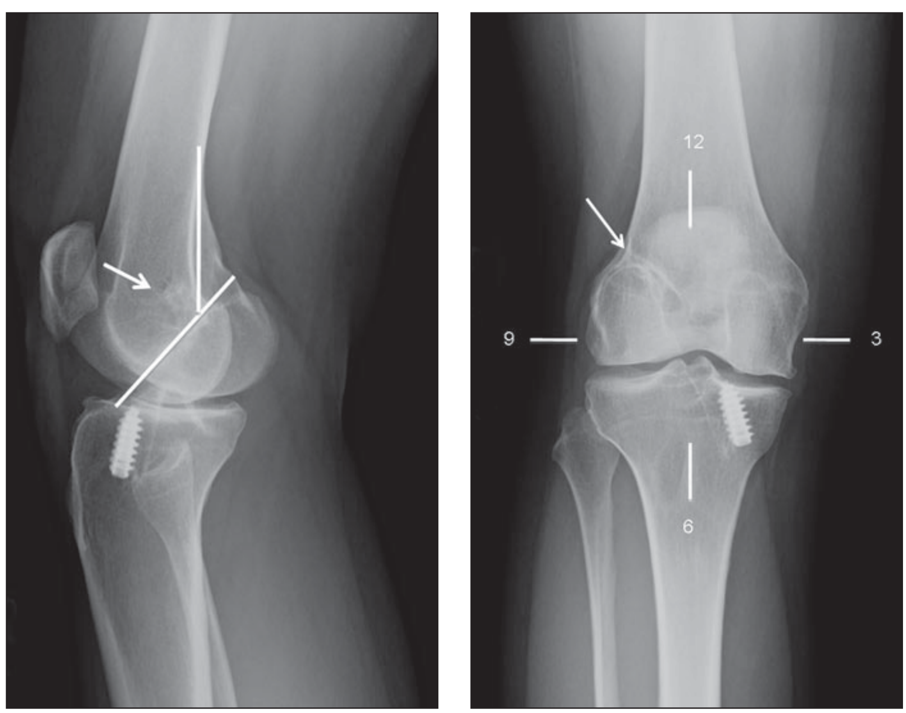


Fig. 2—Illustration shows doubled semitendinosus and gracilis tendon graft ex vivo, fixation device (Endobutton, Smith & Nephew), and interference screw in tibial tunnel. Endobutton anchors femoral portion of graft.

Fig. 3—Anteroposterior radiograph of 21-year-old man who presented for follow-up evaluation after reconstruction of right anterior cruciate ligament using doubled semitendinosus and gracilis tendon graft. Endobutton (Smith & Nephew) fixation device is seen at superior aspect of femoral tunnel.



A

B

Fig. 4—Normal position of tunnel in 35-year-old man who presented for follow-up radiography after anterior cruciate ligament reconstruction.
A, Lateral radiograph shows first line drawn along posterior cortex of femur and second line along intercondylar notch. Inferior portion of femoral tunnel is located at intersection of these two lines (*arrow*). Opening of tibial tunnel is positioned posterior to intersection of Blumensaat line and tibia.
B, Anteroposterior radiograph shows that femoral tunnel can be seen as lucency (*arrow*) between 10- and 11-o'clock positions.

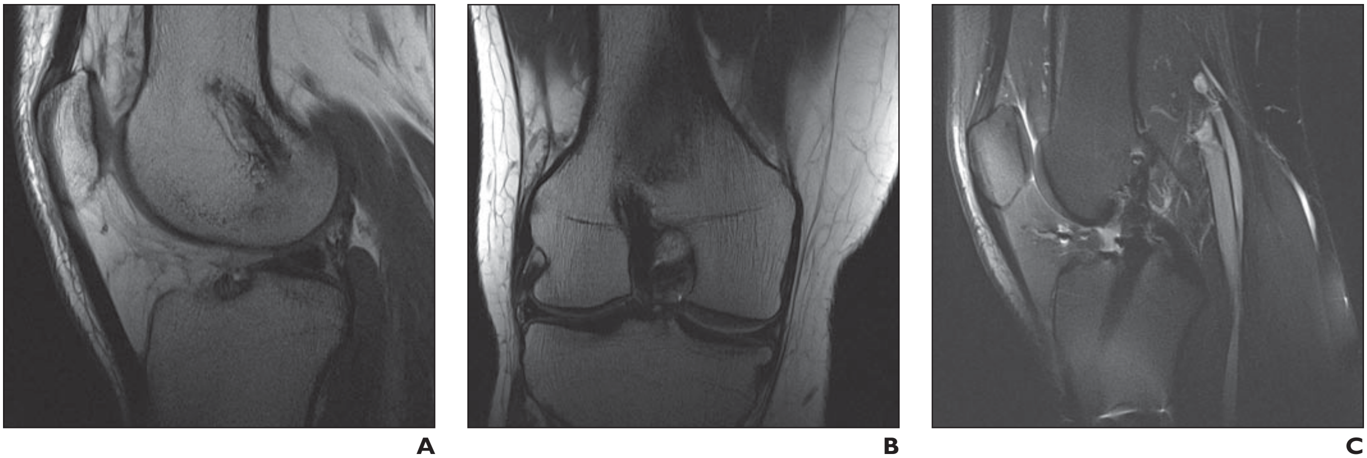


Fig. 5—Normal position of tunnel in 18-year-old man who presented for follow-up MRI after anterior cruciate ligament reconstruction.
A and **B,** Sagittal (**A**) and coronal (**B**) proton density–weighted MR images show normally positioned femoral tunnel. Position is between 10- and 11-o'clock in this right knee.
C, Sagittal T2-weighted fat-suppressed MR image shows normally positioned tibial tunnel opening. Entire tunnel opening is positioned posterior to intersection of MRI equivalent of Blumensaat line (not shown) and tibia.

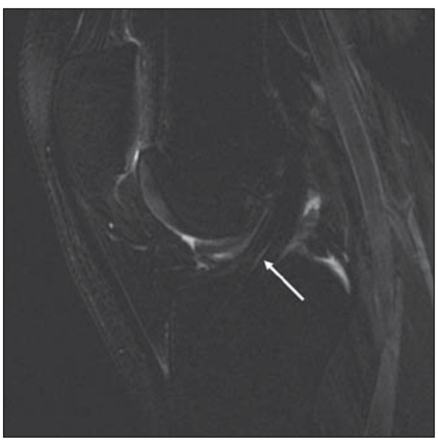


Fig. 6—Sagittal T2-weighted fat-suppressed MR image of 25-year-old man who presented for follow-up imaging after anterior cruciate ligament reconstruction. Image shows normal appearance of doubled semitendinosus and gracilis tendon graft: Graft is of low signal with linear areas of increased signal (*arrow*), representing fluid tracking between strands of graft.

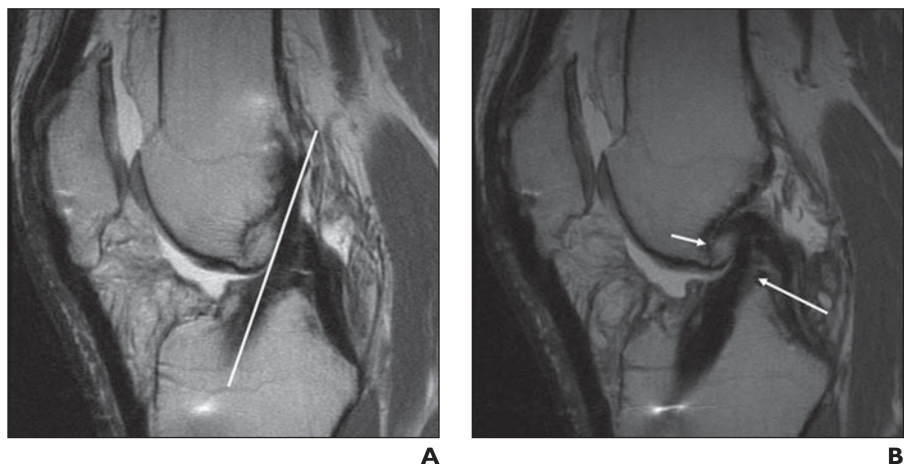


Fig. 7—Impingement secondary to placement of tibial tunnel too far anteriorly in 30-year-old man who presented with limited range of motion after anterior cruciate ligament repair.
A, Sagittal T1-weighted MR arthrogram shows part of tibial tunnel is anterior to intersection of extension of MRI equivalent of Blumensaat line and tibia (*line*).
B, Same study as shown in **A** at slightly different sagittal plane shows posterior bowing of graft (*long arrow*) secondary to impingement by intercondylar notch (*short arrow*).

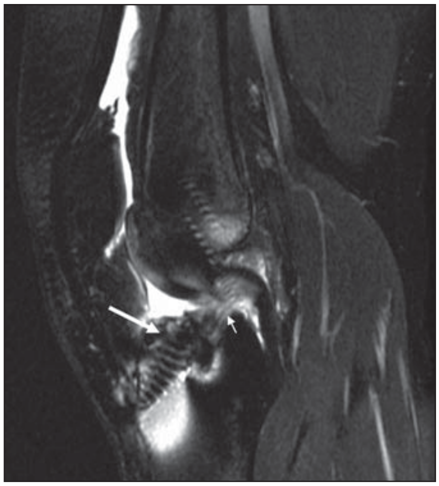


Fig. 8—Impingement in 28-year-old man who presented for follow-up imaging 8 years after anterior cruciate ligament reconstruction. Sagittal T2-weighted fat-suppressed MR image shows part of tibial tunnel (*large arrow*) is anterior to intersection of extension of MRI equivalent of Blumensaat line and tibia (line not drawn). There is posterior bowing of graft with thinning and increased signal intensity (*small arrow*) representing edema.

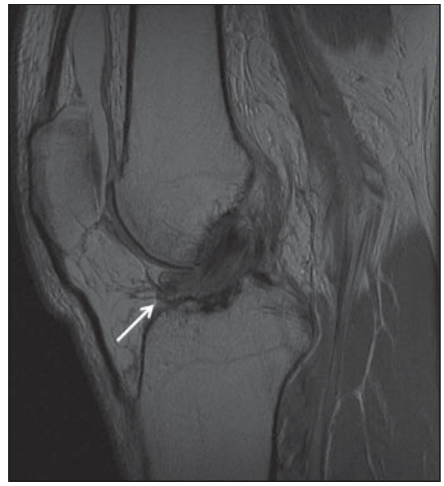
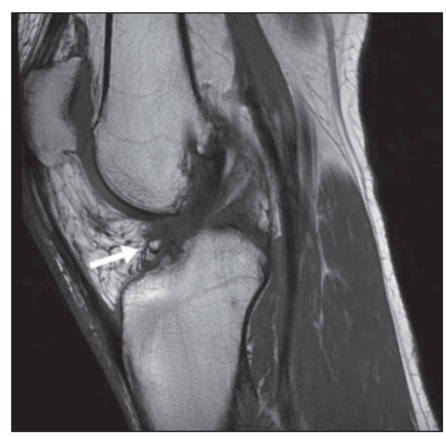


Fig. 9—Focal arthrofibrosis in 26-year-old man who presented for follow-up imaging after anterior cruciate ligament reconstruction. Sagittal proton density–weighted MR image shows focal area of decreased signal intensity (*arrow*) just anterior to distal end of graft between femur and tibia.

A

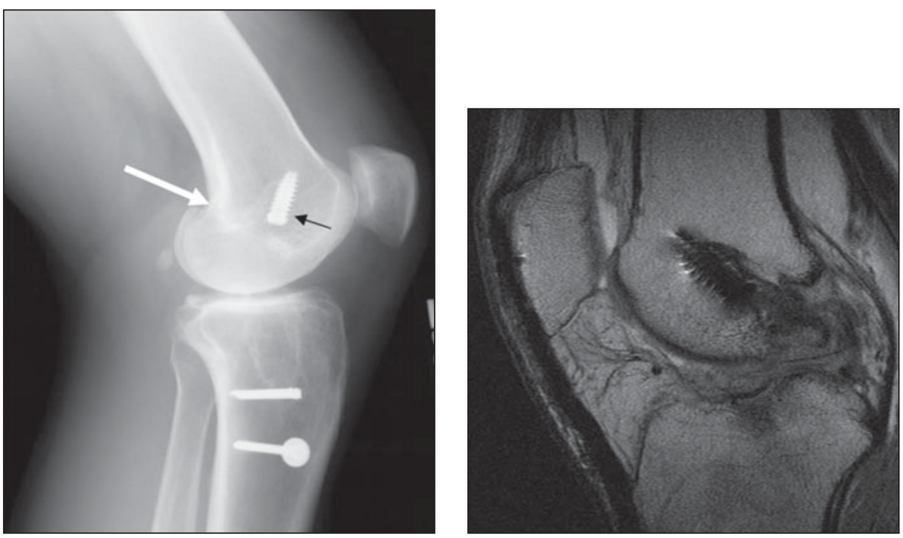


B

Fig. 10—Intraarticular body in 28-year-old man who presented with decreased range of motion after undergoing double-bundle anterior cruciate ligament reconstruction.
A, Lateral radiograph shows ossified intraarticular body (*arrow*) between anterior femur and tibia.
B, Sagittal T1-weighted MR image shows same intraarticular body (*arrow*) as **A** with high signal intensity that is equal to that of bone marrow.

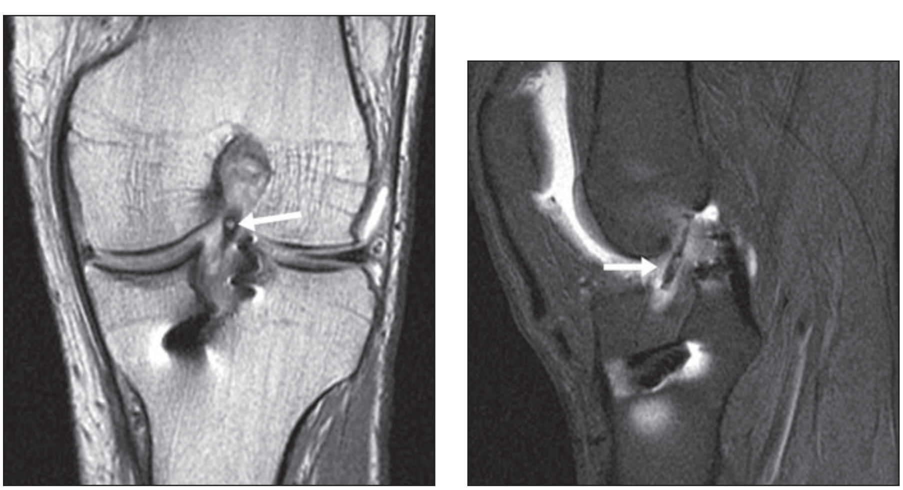
A B C

Fig. 11—Graft tear in 19-year-old man who presented for follow-up imaging after anterior cruciate ligament (ACL) reconstruction.
A and **B,** Sagittal (**A**) and coronal (**B**) T1-weighted MR arthrograms show complete discontinuity of fibers of ACL graft with intervening contrast material (*arrows*).
C, Sagittal T2-weighted fat-suppressed MR image shows complete discontinuity of graft, which is replaced with fluid signal.



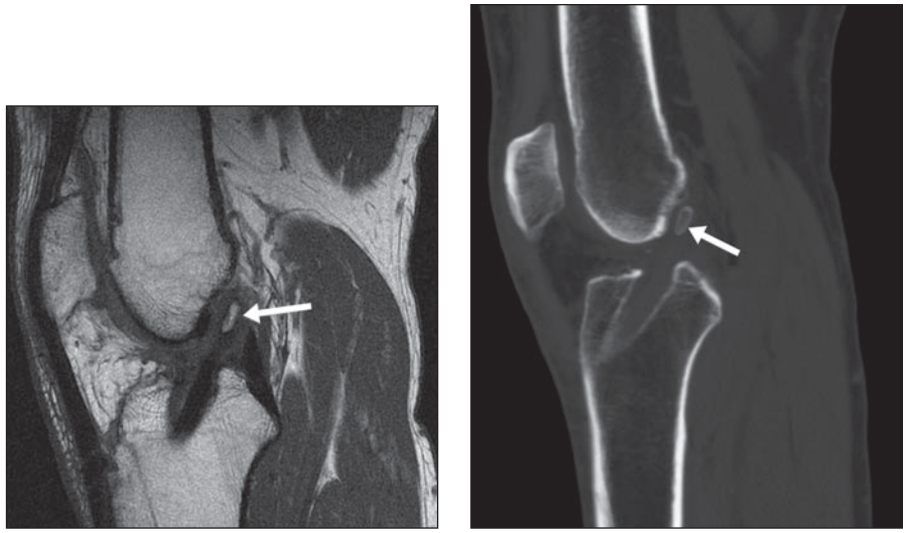
A B

Fig. 12—Malpositioned tunnels in 50-year-old man who presented for follow-up imaging after anterior cruciate ligament reconstruction.
A, Lateral radiograph shows position of femoral tunnel (*black arrow*) is anterior to intersection of posterior cortex of femur and Blumensaat line (*white arrow*).
B, Sagittal T1-weighted MR arthrogram shows femoral tunnel is positioned too far anteriorly and abnormal signal within graft.



A B

Fig. 13—Displaced tibial bone plug in 25-year-old man who presented for follow-up imaging after undergoing anterior cruciate ligament reconstruction with bone–patella tendon–bone graft.
A, Coronal T1-weighted MR image shows tibial bone plug (*arrow*) is displaced into intercondylar notch.
B, Sagittal T2-weighted fat-suppressed MR image shows that tibial plug (*arrow*) is displaced superiorly out of tibial tunnel.



A B

Fig. 14—Displaced femoral bone plug in 40-year-old man who presented with laxity after anterior cruciate ligament reconstruction.
A and **B**, Sagittal T1-weighted image (**A**) and sagittally reconstructed image from unenhanced CT scan (**B**) show femoral bone plug (*arrow*) has become inferiorly displaced and is within intracondylar notch.

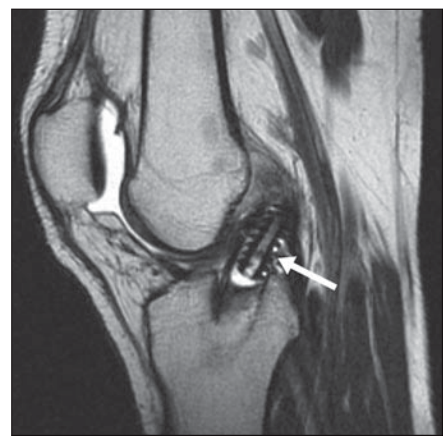


Fig. 15—Sagittal T1-weighted MR arthrogram in 24-year-old man who presented for follow-up imaging after anterior cruciate ligament reconstruction shows that interference screw (*arrow*) anchoring tibial portion of graft has migrated superiorly out of tibial tunnel.

FOR YOUR INFORMATION

This article is available for CME credit. See www.arrs.org for more information.