The Journal of Global Radiology
ENSURING MEDICAL IMAGING ACCESS FOR ALL

PICTORIAL ESSAY

# Evaluation of ACL Graft by MRI: A Pictorial Review

Sandeep Velicheti[1], Amulya Ramadugu[1], Kuladeep Chalasani[1], Raghuram Kotagiri[1], Sateesh Padavala[1]

1. Dr. Pinnamaneni Siddartha Institute of Medical Sciences and Research Foundation, Chinna Avutapalle, Gannavaram, Andhra Pradesh, India

* **Corresponding author.** Current address: Amulya Ramadugu, email: amulyaramadugu.16@gmail.com



**DOI:** 10.7191/jgr.2022.1151

**Published:** 1/20/2022

**Citation:** Velicheti S, Ramadugu A, Chalasani K, Kotagiri R, and Padavala S. J Glob Radiol. 2022;8(1):1151.

**Keywords:** anterior cruciate ligament, tibial tunnel, femoral tunnel, arthrofibrosis

**Word count:** 1,358

## Abstract

The reconstruction of a ruptured anterior cruciate ligament (ACL) is a well established procedure for repair of ACL injury. Knowledge of normal appearances, the expected postoperative changes over time, and potential acute and chronic complications of this reconstruction procedure are essential. This study illustrates the role of MRI in evaluation of ACL reconstructions and their complications. MR imaging is the modality of choice for evaluation of ACL graft reconstruction. ACL graft complications such as abnormal tunnel positioning, partial and complete graft tears, arthrofibrosis, and tunnel cysts can be reliably assessed using MRI.

## Introduction

The anterior cruciate ligament (ACL) is one of the important stabilizers of the knee that is commonly torn in sports injuries. ACL reconstruction is a common and often successful surgical intervention. The increased number of ACL reconstruction surgeries being performed has led to an increased demand for the postoperative knee evaluation when symptoms persist or recur after these procedures. In order to guide treatment management, it is essential to have knowledge of the knee's normal imaging appearances, expected postoperative changes over time, and potential complications from this reconstruction procedure.

The two primary ACL reconstruction procedures are:

- The autologous bone-patella tendon-bone graft
- The autologous four-strand hamstring graft, which is also known as the doubled semitendinosus and gracilis tendon graft [Figure 1] [1].

The ACL graft fixation is done using a wide range of fixation devices. These differ in function, shape, size, material, and biomechanical properties [Figure 16]. The outcome of this procedure is generally good, though graft rupture or clinical failure is known to occur.

Patients with postoperative complications present with symptoms of persistent pain, instability, joint swelling, infection, and stiffness. The possible causes of reconstruction failure and patient complications are graft discontinuity, inappropriate position of the femoral and/or tibial tunnel, hardware failure, infection, and arthrofibrosis [5]. The goals of revision ACL surgery are to achieve stabilization of the knee and to prevent further injury to the articular cartilage and menisci [10].

The indications for evaluating ACL reconstructions with magnetic resonance imaging (MRI) include [5]:

- Instability of the knee joint
- Postoperative re-injury to the knee
- Postoperative stiffness, especially extension loss due to flexion contracture
- Preparation for the revision of a failed ACL reconstruction, which can aid the surgeon in preoperative planning.

### *Imaging Protocol*

MRI examination of the knee should be done in three planes: the axial, coronal, and sagittal planes. Patient should be positioned in a supine position with the knee placed at 10°–15° of external rotation. A knee joint-specific extremity coil should be used. An axial acquisition is taken through the patellofemoral joint. It is used as an initial localizer for the subsequent sagittal and coronal plane images. Axial images should be obtained from the distal portion of the quadriceps tendon to the insertion of the patellar tendon on the tibial tuberosity. Sagittal images should be obtained from the medial to lateral femoral condyles. Coronal images should be obtained with a line parallel to the femoral condyles. The images should be analyzed for the location of the femoral and tibial tunnels, graft characteristics, and graft-related complications.

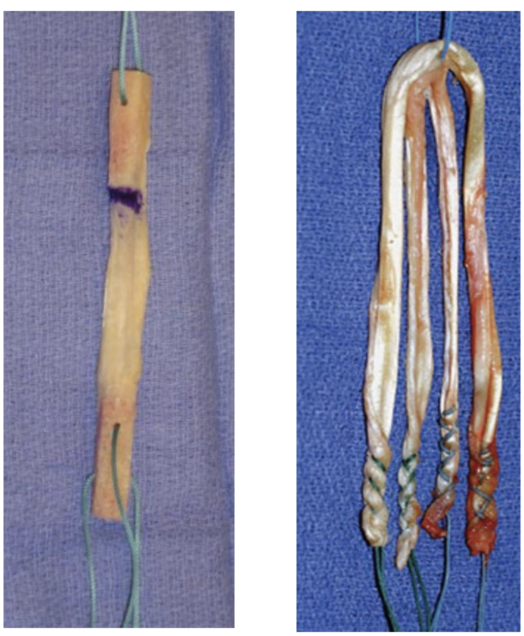

**Figure 1. Images showing preparation of the bone patella bone tendon graft and hamstring graft.**

### *Graft Signal Intensity*

ACL grafts appear in MR images at a uniformly low signal intensity, similar to the signal characteristics of the native graft harvest tissue (patellar tendon or hamstring tendon) [Figure 2]. Increased intrasubstance graft signal changes develop within the first year after surgery and are thought to represent changes related to synovial proliferation, vascularisation, and "neoligamentization" of graft constructs. Complete resolution of such graft signal changes are often described 18–24 months after surgery [3]. Due to ongoing ligamentization of the graft for up to one and a half years, postoperative ligament evaluation MRI may be warranted in patients experiencing severe discomfort or reinjury [11].

### *Femoral Tunnel*

The position of the femoral tunnel is the primary factor in maintaining the isometry of a graft [4]. It should be evaluated in both the sagittal and coronal planes. In the sagittal plane the tunnel is assessed 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.

On the coronal MR image, the intra-articular portion of the femoral tunnel should open at the superolateral posterior margin of the intercondylar notch [Figure 5]. If a clock face is superimposed on a coronal MR image with the center at the intercondylar notch, the tunnel should be oriented between ten and eleven o'clock on the right knee or between one and two o'clock on the left knee [Figure 3]. An anteriorly placed femoral tunnel will cause elongation of graft and instability of knee [14].

### *Tibial Tunnel*

The tibial tunnel sagittal should be oriented parallel to the Blumensaat line, which is a line drawn along the intercondylar roof. The distal portion of the tunnel should start near the tibial tuberosity and the intra-articular opening of the tunnel should be completely posterior to the Blumensaat line [1].

### *ACL Reconstruction Complications*

Based on clinical symptoms, the main complications of the reconstruction are divided into two groups: decreased range of motion and laxity [6]. Complications leading to decreased range of motion are an anteriorly placed tibial tunnel, arthrofibrosis, cystic degeneration of the ACL graft, and intra-articular loose bodies [Figure 4].

 10.7191/jgr.2022.1151

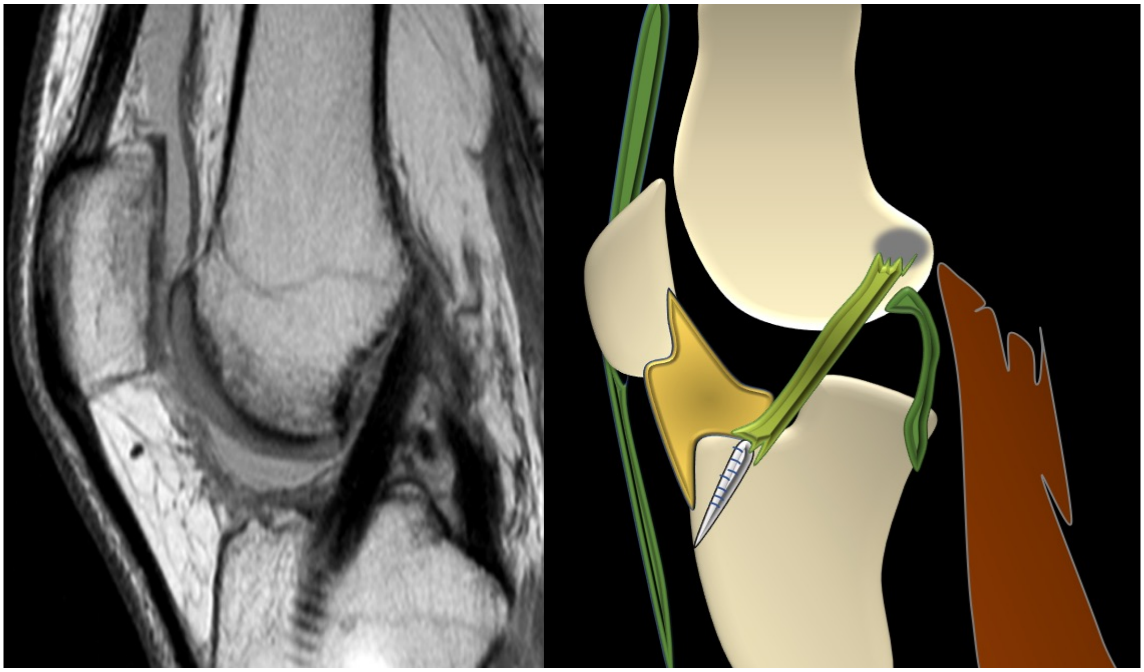

**Figure 2. Sagittal T2W MRI of a 25-year-old male patient three years post ACL reconstruction showing the normal-appearing homogenously hypointense ACL graft.**

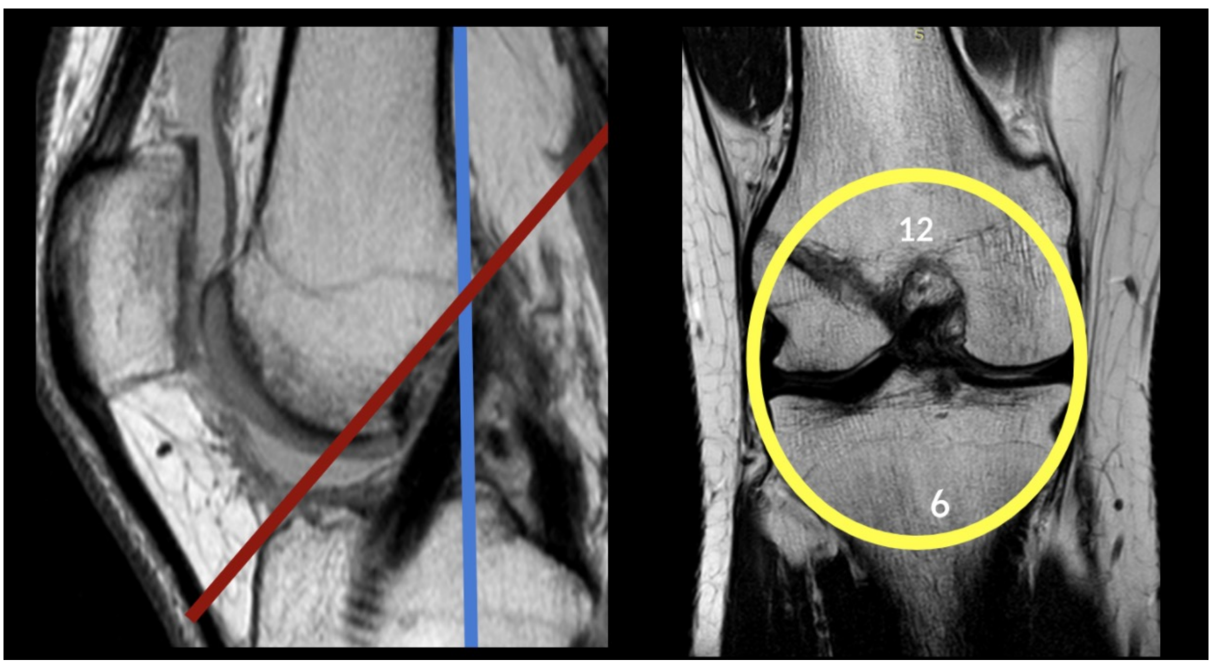


**Figure 3. Normal position of femoral tunnel in a 28-year-old man who presented for follow-up MRI after ACL reconstruction. Sagittal and coronal T2W MR images show a normally positioned femoral tunnel. Position is between ten and eleven o›clock in this right knee.**

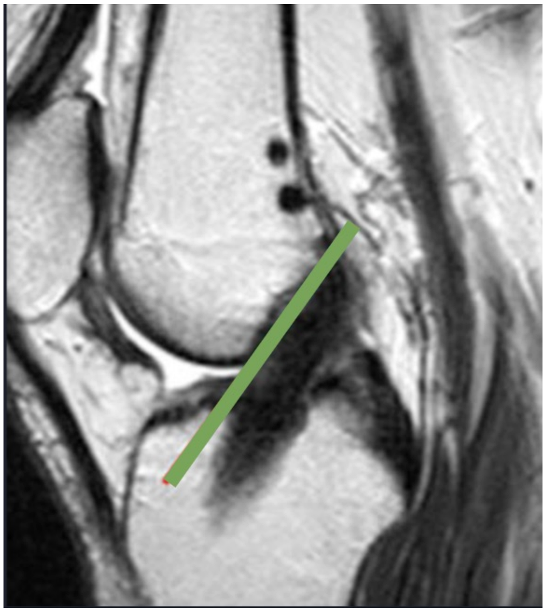

**Figure 4. Sagittal T2W image showing a normally placed tibial tunnel.**

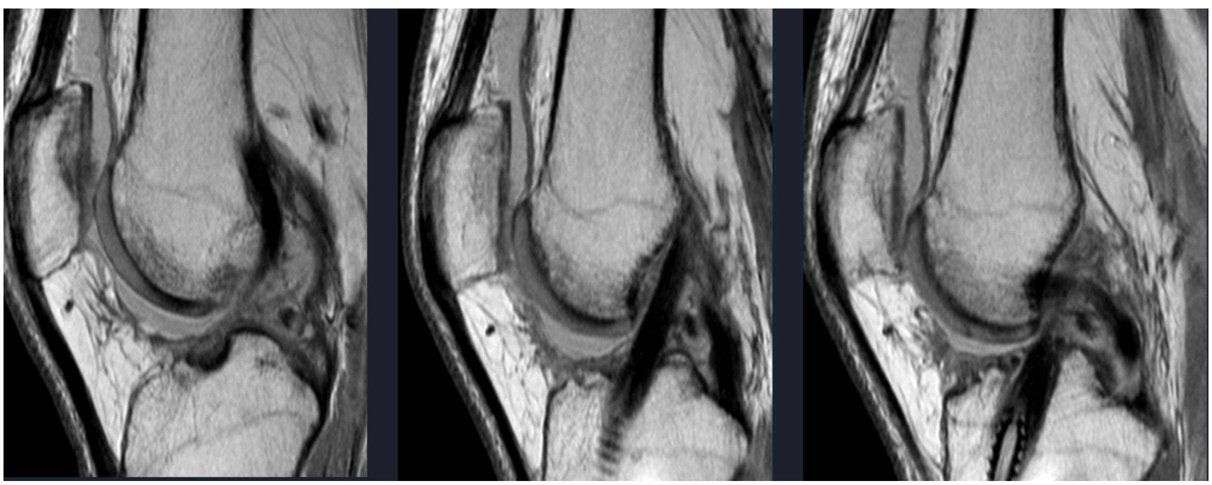

**Figure 5. Sagittal T2W MRI showing the correct positioning of the tibial and femoral tunnels and appearances of the normal graft.**

***Complications Leading to Decreased Range of Motion***

**Anteriorly placed tibial tunnel:** If the tibial tunnel is positioned too far anteriorly (i.e., partially or completely anterior to the intersection of the Blumensaat line), the graft can become impinged on by the roof of the intercondylar notch, which can lead to decreased range of motion [FIgure 6,7].

**Arthrofibrosis:** Two forms of arthrofibrosis are possible in the form of limitation of flexion [8] [Figures 10-12]. In MRI, both forms show low signal intensity on T1-weighted sequences and are predominantly low signal on T2-weighted sequences. Arthofibrosis may be focal or diffuse. The focal form is seen as a nodule of low signal (a cyclops lesion) just anterior to the distal end of the graft between the femur and tibia. The diffuse form seen as an ill-defined spiculated area of low signal within the Hoffa fat pad or a mass-like area of decreased signal anterior and posterior to the graft. This can extend to the joint capsule with possible synovial hypertrophy and capsular thickening [1,4].

**Cystic degeneration (ganglion cyst formation):** This is a late complication and usually occurs in the tibial tunnel within the graft and follows fluid signal on all MR pulse sequences [7] [Figure 13].

**Intra-articular bodies:** These are composed of articular cartilage, cortical bone, or cancellous bone and will show at intermediate to low levels on T2-weighted sequences [Figures 13,14].

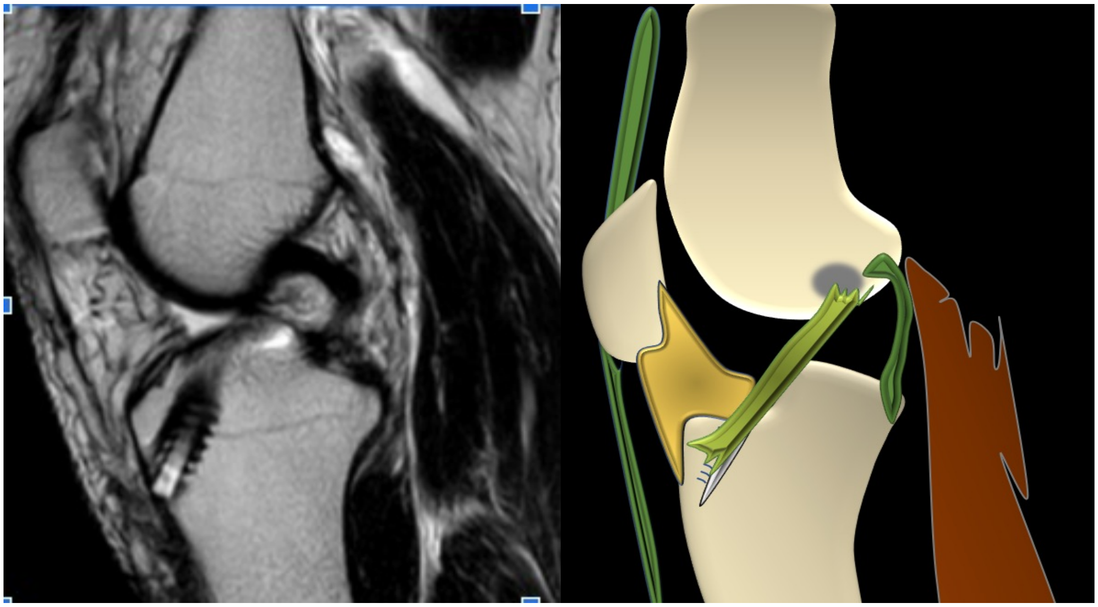

**Figure 6. A 30-year-old man who presented for follow-up imaging six years after ACL reconstruction showing a too-anteriorly placed tibial tunnel.**

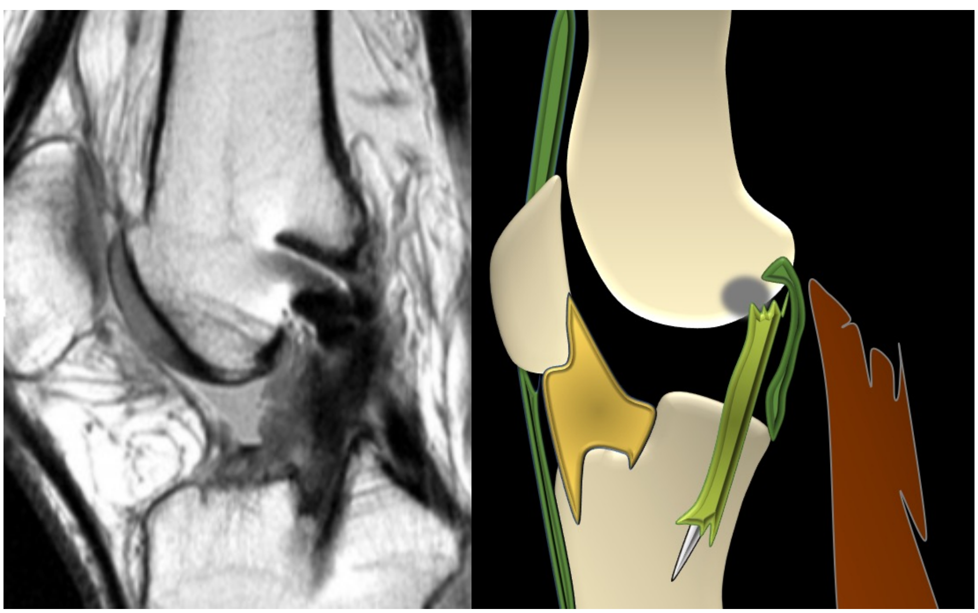

**Figure 7. A 26-year-old man who presented for follow-up imaging 4 years after anterior cruciate ligament reconstruction showing a too-posteriorly placed tibial tunnel.**

**Figure 8. Graft tear in 21-year-old man who presented for follow-up imaging after ACL reconstruction. Sagittal proton density weighted MRI shows complete tear of the ACL graft.**

**Figure 9. Partial graft tear in 21-year-old man who presented for follow-up imaging after ACL reconstruction. Sagittal proton density weighted MRI shows partial tear of the ACL graft with graft laxity.**

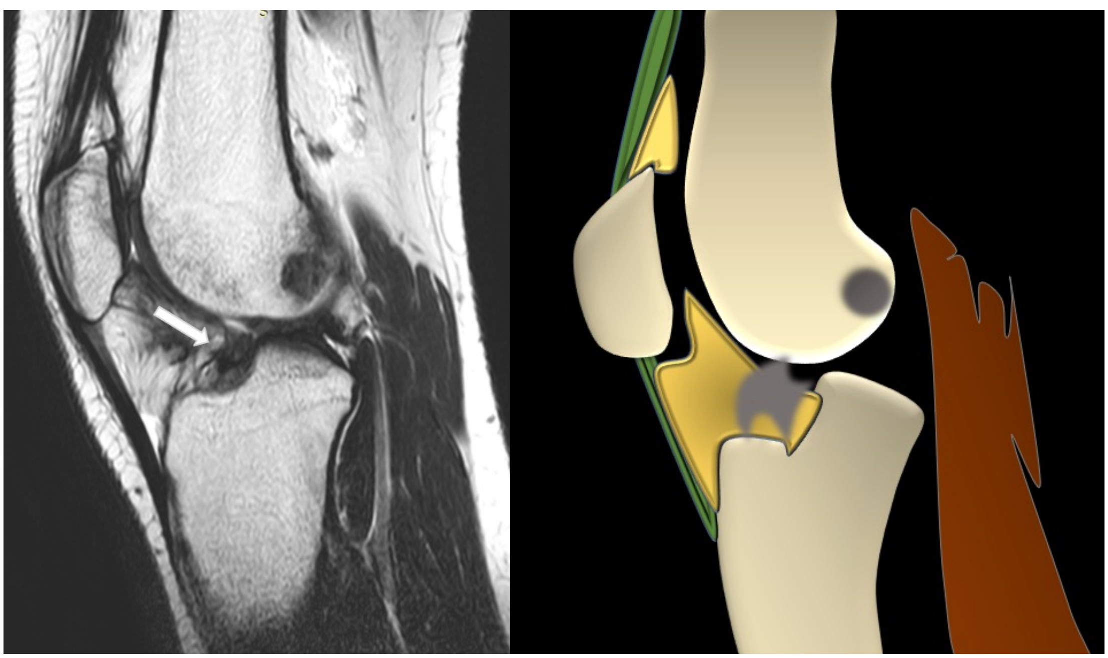

**Figure 10. T2W sagittal MRI shows localized/focal arthrofibrosis.**

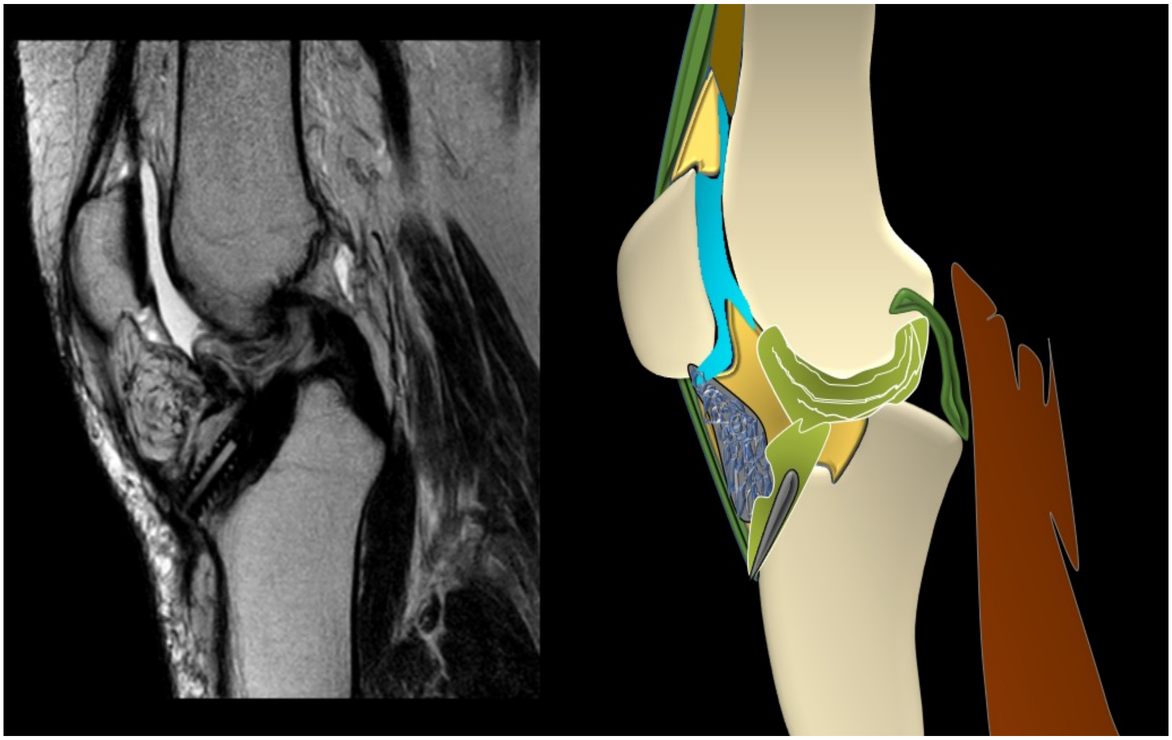

**Figure 11. T2W sagittal MRI shows localized/focal arthrofibrosis and hoffas fat pad fibrosis.**

**Figure 12. T1W sagittal MRI showing diffuse arthrofibrosis, extending up to hoffas fat pad.**

### *Complications Leading To Laxity and Graft Tear*

Grafts are most susceptible to injury during the process of remodelling, which occurs approximately four to eight months after surgery. The primary signs include graft signal abnormalities including increased signal on T2-weighted sequences, increased graft thickness, and fiber discontinuity [13] [Figures 8,9].

Hardware failure is uncommon but is important to recognize because it can cause instability of the graft which can be confused with graft disruption. Hardware failure includes screw displacement and dislodgment of the bone plug [2].

Arthroscopic reconstruction of the ACL is a procedure performed frequently and generally with good results [Figures 2,3]. Complications of the surgical procedure, however, are not infrequent. Technical causes include non-anatomic tunnel placement, hardware failure, improper graft fixation, and insufficient graft material [12]. Biologic causes include failed ligamentization, infection, and arthrofibrosis [Figure 15]. External causes for failure include traumatic rupture, secondary instability of the knee, and improper rehabilitation.

MRI is the most valuable imaging method for postoperative evaluation of the knee [Figures 17-21]. It is non-invasive and has multiplanar imaging capabilities that are useful for assessing the tunnel positioning and other structures of the knee. It offers the added benefit of direct visualization of the graft with excellent soft tissue contrast [9].

Arthrofibrosis is the abnormal proliferation of fibrous tissue in a joint that leads to the loss of motion, pain, muscle weakness, swelling, and functional limitation. It is most commonly associated with joint trauma or surgery. Arthrofibrosis following ACL reconstruction can present as a focal or diffuse process that limits the mobility of the knee. Other factors that can lead to knee stiffness and restriction in motion after ACL reconstruction may also play a role in the development of arthrofibrotic lesions. These factors might include suboptimal femoral or tibial tunnel placement or a stretched and overtensioned ACL graft.

## Conclusion

Given the increasing number of patients to undergo ACL reconstruction, it is critical to be familiar with both normal postoperative imaging appearance and the appearance of complications in the graft reconstruction. MRI is the modality of choice for evaluation of failed ACL graft reconstruction surgery, normal appearance, and all the intermediate and long term complications of the surgery.

## Acknowledgments

Dr. K. Chandrasekhar, Professor and HOD, Department of Radiodiagnosis, Dr. Psims&Rf; Dr. B.N. Chander, Professor, Department of Radiodiagnosis, Dr. Psims&Rf; Dr. P. Gnanaswaroop Rao, Consultant Radiologist, Konnect Imaging and Diagnostics.

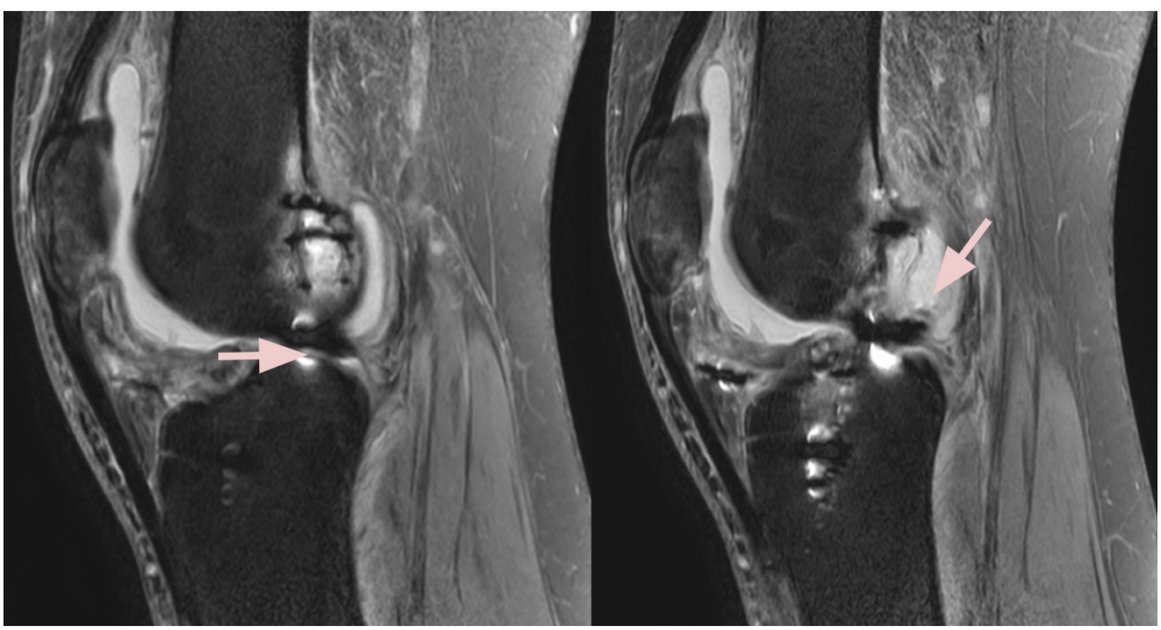

**Figure 13. A 35-year-old male patient presented with swelling and pain following ACL reconstruction surgery after 18 months showing severe cystic degeneration of femoral segment of ACL with adjacent synovial cyst formation. Ganglion cyst also noted.**

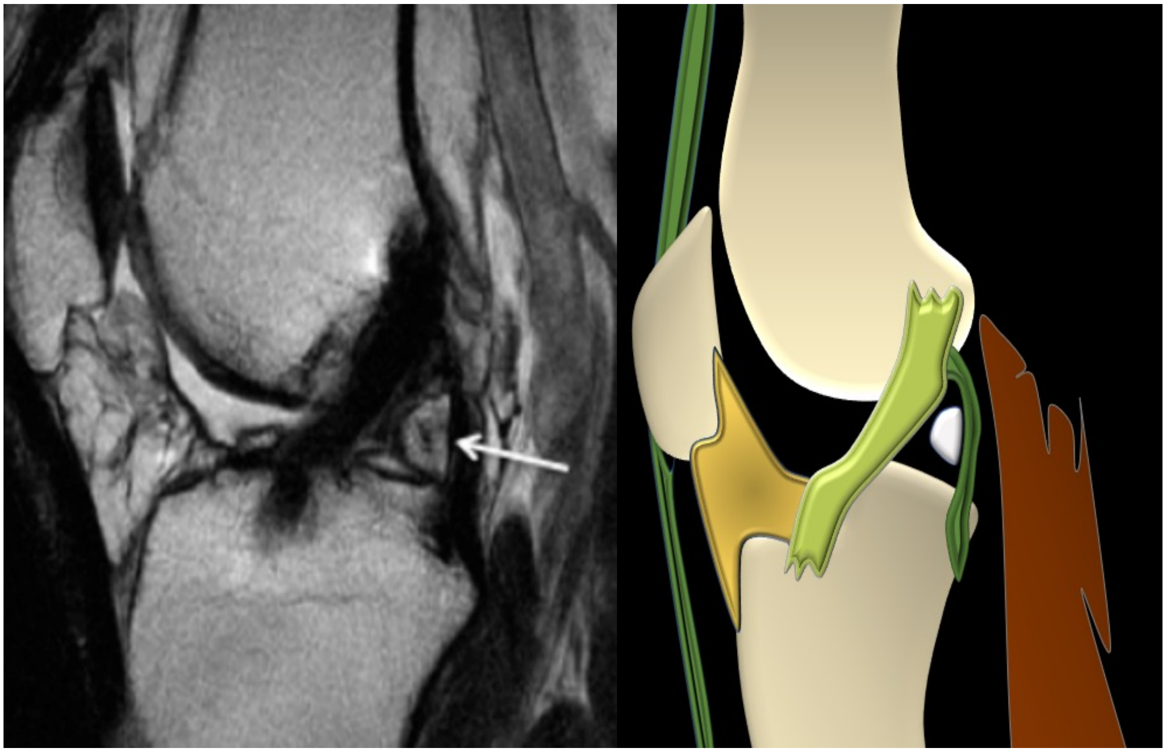

**Figure 14. Sagittal T2W MRI showing an intra-articular loose body in a 24-year-old patient following post ACL reconstruction.**

**Figure 15. Sagittal T1W MRI of a 32-year-old man following post ACL reconstruction showing a displaced bone plug.**

**Figure 16. Sagittal and axial proton-density–weighted MR image shows signal heterogeneity of the patellar tendon at the graft harvesting site.**

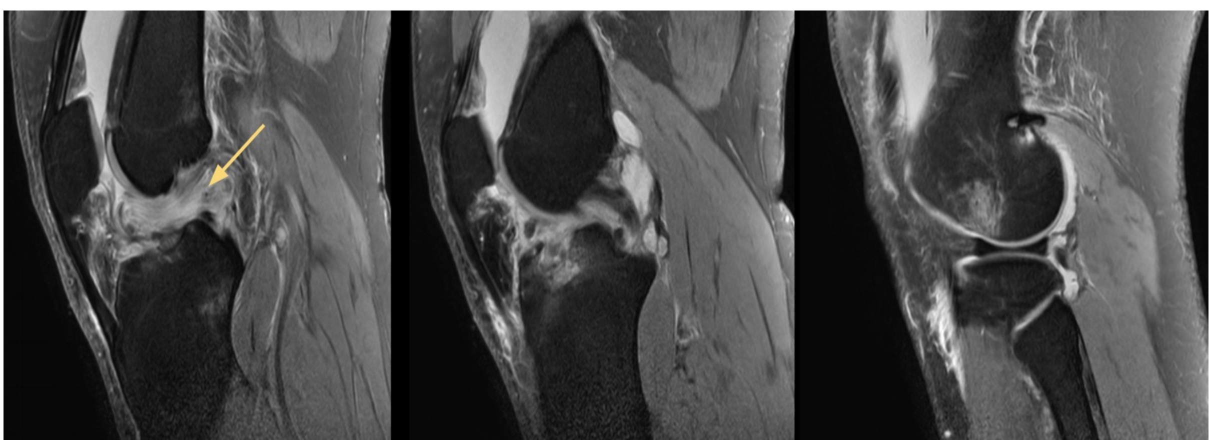

**Figure 17: A 28-year-old male patient who underwent ACL reconstruction presented with retrauma. Sagittal PDW images show joint effusion extending to suprapatellar bursa with loss of normal ACL graft signal and mucoid degeneration. Reinjury signs seen in the form of pivot shift contusions.**

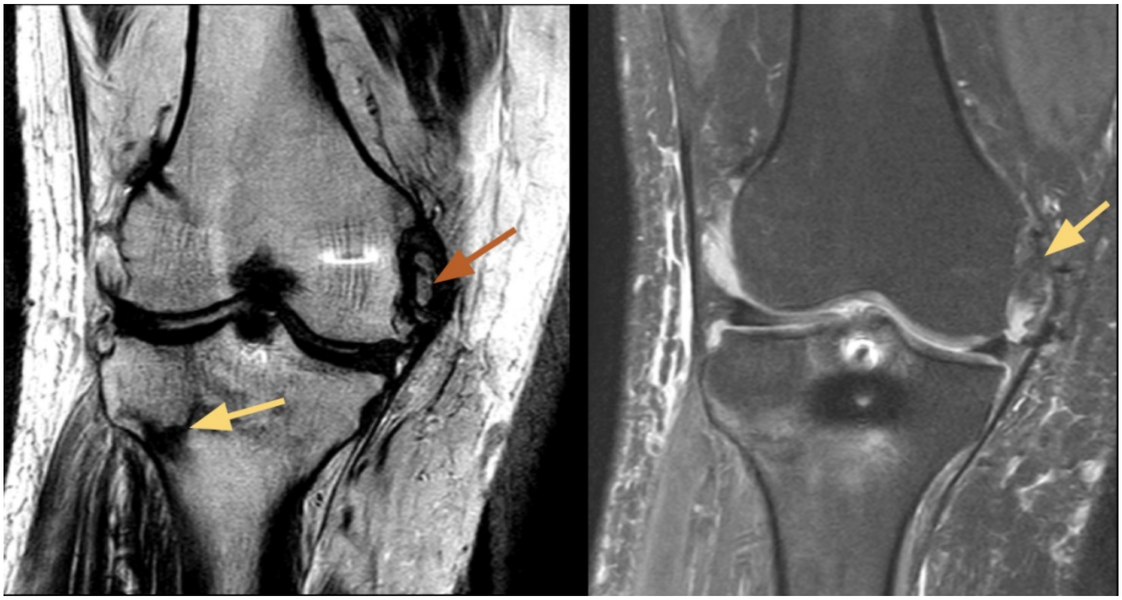

**Figure 18: A 36-year-old male presented with retrauma after ACL reconstruction coronal T2W and PDW images show tibial fracture and malunited medial femoral condyle fracture (Steida fracture).**

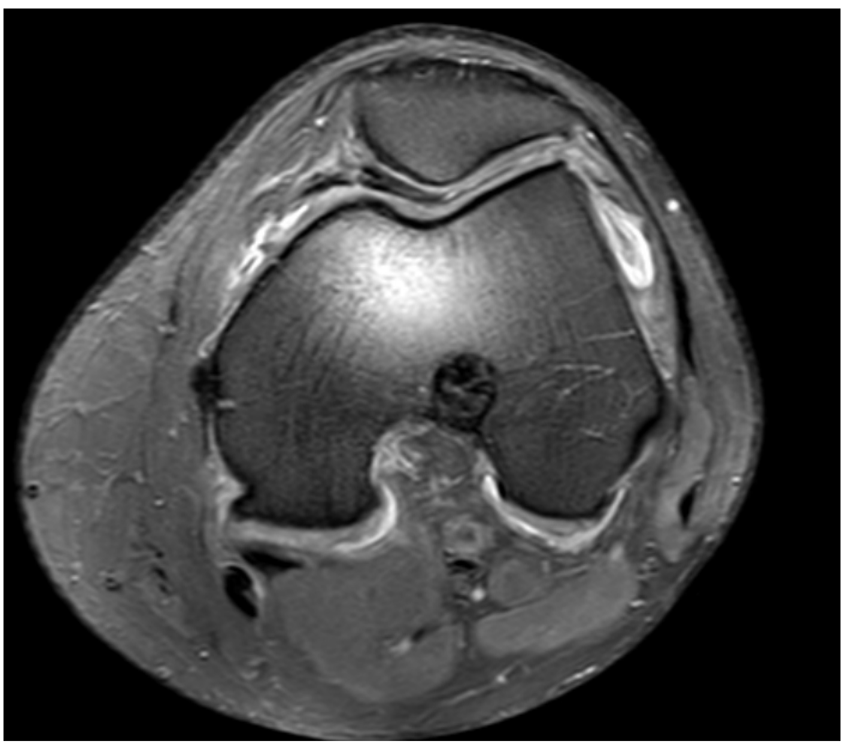

**Figure 19. Axial PDW MRI showing diffuse synovitis in a 27-year-old patient following post ACL reconstruction.**

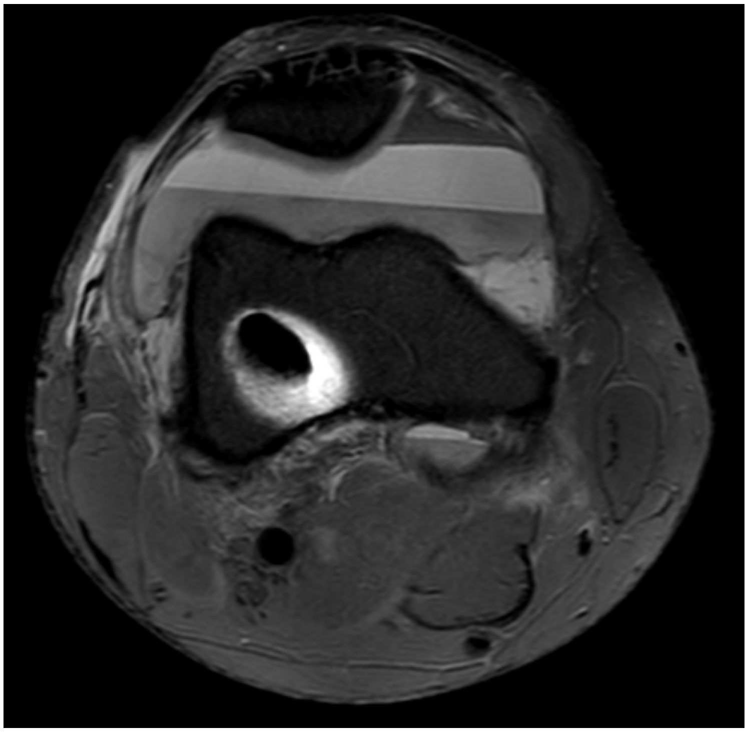

**Figure 20. Axial PDW MRI showing lipohemarthrosus in a 30-year-old patient following trauma after post ACL reconstruction.**

**Figure 21. Sagittal PDW MRI showing displaced tibial screw in a 25-year-old patient.**

## References


1. Casagranda BC, Maxwell NJ, Kavanagh EC, Towers JD, Shen W, Fu FH. Normal Appearance and Complications of Double-Bundle and Selective bundle Anterior Cruciate Ligament Reconstructions Using Optimal MRI Techniques. American Journal of Radiology. 2009; 192:1407-1415. Available from: https://doi.org/10.2214/AJR.08.1185

2. Michael P. Recht, MD. Josef Kramer, MD, PhD. MR Imaging of the Postoperative Knee: A Pictorial Essay. RadioGraphics 2002; 22:765-774. Available from: https://doi.org/10.1148/radiographics.22.4.g02jl11765

3. Saupe N, White LM, Chiavaras MM, et al. Anterior cruciate ligament reconstruction grafts: MR imaging features at long-term follow-up: Correlation with functional and clinical evaluation. Radiology 2008; 249:581-590. Available from: https://doi.org/10.1148/radiol.2492071651

4. McCauley TR. MR imaging evaluation of the postoperative knee. Radiology. 2005; 234:53-61. Available from: https://doi.org/10.1148/radiol.2341031302

5. Recht MP, Kramer J. MR imaging of the postoperative knee: A pictorial essay. Radiographics 2002; 22:765-774. Available from: https://doi.org/10.1148/radiographics.22.4.g02jl11765

6. Bencardino JT, Beltran J, Feldman MI, Rose DJ. MR imaging of complications of anterior cruciate ligament graft reconstruction. Radiographics 2009; 29:2115-2126. Available from: https://doi.org/10.1148/rg.297095036

7. Arthur B. Meyers, Andrew H. Haims, Kirsten Menn, Hicham Moukaddam. Imaging of Anterior Cruciate Ligament Repair and Its Complications. AJR 2010; 194:476-484. Available from: https://doi.org/10.2214/AJR.09.3200

8. Risberg MA, Lewek M, Snyder-Mackler L. A systematic review of evidence for anterior cruciate ligament rehabilitation: how much and what type? Physical Therapy Sport. 2004; 5:124-145. Available from: https://doi.org/10.1016/j.ptsp.2004.02.003

9. G. Myklebust, R. Bahr,Return to play guidelines after anterior cruciate ligament surgery. Br J Sports Med, 2005; 39: 3 127-131. Available from: https://doi.org/10.1136/bjsm.2004.010900

10. Allen CR, Giffin JR, Harner CD. Revision anterior cruciate ligamentreconstruction. Orthop Clin North Am 2003;34(01):79–98. Available from: https://doi.org/10.1016/S0030-5898(02)00066-4

11. S. M. Howell, J. A. Clark, and R. D. Blasier, "Serial magnetic resonance imaging of hamstring anterior cruciate ligament autografts during the first year of implantation: a preliminary study," The American Journal of Sports Medicine, vol. 19, no. 1, pp. 42–47, 1991. Available from: https://doi.org/10.1177/036354659101900107

12. Tomczak RJ, Hehl G, Mergo PJ, Merkle E, Rieber A, Brambs HJ, et al. Tunnel placement in anterior cruciate ligament reconstruction: MRI analysis as an important factor in the radiological report. Skeletal Radiol 1997;26:409-13. Available from: https://doi.org/10.1007/s002560050256

13. M. S. Collins, K. P. Unruh, J. R. Bond, and J. N. Mandrekar,"Magnetic resonance imaging of surgically confirmed anteriorcruciate ligament graft disruption," Skeletal Radiology, vol. 37,no. 3, pp. 233–243, 2008. Available from: https://doi.org/10.1007/s00256-007-0423-2

14. White LM, Kramer J, Recht MP. MR imaging evaluation of thepostoperative knee: ligaments, menisci, and articular cartilage.SkeletalRadiol 2005;34(08):431–452. Available from: https://doi.org/10.1007/s00256-005-0914-y