Imaging the Anterior Cruciate Ligament-Points to Ponder

1. Introduction

The anterior drawer and Lachman tests are used to clinically evaluate anterior laxity resulting from ACL tears. These somewhat subjective tests depend on the experience of the examiner, and patient guarding may limit assessment in acute injuries. Tibial attachment avulsions. Occasionally detected on plain radiograph, are seen more commonly in younger patients¹.

The first reports of MR imaging of the knee are from the early 1980s². After the groundwork was laid for knee MR imaging, throughout the 1980s and early 1990s, any investigations with clinical/radiologic correlation followed. Imaging signs for ACL tear were established, followed by multiple studies analyzing the accuracy of secondary MR imaging signs for diagnosing and corroborating ACL tears^{3–9}. Throughout the 1990s, as MR imaging technique and faster pulse sequences advanced, sharper images optimized delineation of the ACL, 3-dimension (3D) gradient sequences allowed multiplanar re-formatting, and fat-suppressed water sensitive sequences increased detection of bone contusions and trabecular fractures(6). Recent advances in cartilage imaging such as 3D-spoiled gradient sequences have enabled assessment of early and chronic cartilage damage following ligament injury¹⁰. MR imaging offers direct, noninvasive visualization of the ACL and other soft tissue structures, improving the preoperative assessment of internal derangement(5). The accuracy of MR imaging for evaluation of ACL pathology is high. Using direct signs, sensitivities are as high as 92% to 94% and specificities are as high as 95% to 100%^{3–5}. Sensitivity is improved when T2-weighted sequences and oblique sagittal planes are utilized. The use of ancillary signs improves specificity⁴. MR imaging is not as accurate in differentiating complete tears from partial tears or as sensitive in detecting chronic tears.(3)

2. Technical considerations for imaging the ACL

The patient is placed supine with the knee within the extremity coil, avoiding excessive extension or flexion(6). Some radiologists have the technician externally rotate the patient's knee 15° to orient the straight sagittal cuts along the ACL fibers. Sagittal images are the most useful for evaluation of ACL fiber orientation and the femoral and tibial attachments(6). If the ligament is not adequately visualized on routine sagittal views, then additional sequences may be supplemented with thin cuts through the intercondylar notch and oblique images plotted parallel to coronal plane are useful for evaluation of the collateral ligaments and for assessing the signal characteristics of the ACL within the intercondylar notch in equivocal cases(5). On coronal views, the ACL appears oriented like a “hand in a pocket,” coursing posterior-superolateral to anterior-inferomedial(6). Coronal slices should extend posteriorly adequately to cover the subpopliteus bursa and popliteus muscle(6). Axial views are useful for assessment of the ACL and posterior cruciate ligament (PCL) in the notch, bone contusions, para-articular fluid collections, and the joint capsule. A variety of pulse sequences can be protocolled, as per radiologist's choice. T₂-weighted water-sensitive sequences are the most useful for evaluation of contusions, edema, and hemorrhage seen in association with ACL tears. T₁-weighted images, although useful for delineation of bony anatomy, are not adequate alone for evaluation of edema(7). Inversion recovery and/or T₂-weighted images with fat suppression are sensitive for visualization of marrow oedema and fractures, further fast spin-echo or conventional spin echo imaging can be used to assess the ACL. Thin slices (3–4mm) are obtained in all three planes to avoid volume averaging(7). In imaging the postoperative recovery and T₂-weighted sequences without fat suppression are used because these are less susceptible to metallic field in homogeneity artifact than other fat-suppressed and gradient sequences. The routine sequences performed for evaluation of internal derangement are(7):

- Axial T2-weighted images with fat saturation. This allows good visualization of the collateral and cruciate ligaments and paraosseous fluid collections.
- Sagittal spin-echo intermediate density and T2-weighted images. Three-millimeter-thin slices offer good visualization of the cruciate ligaments; conventional spin-echo imaging is chosen for better sensitivity for meniscal pathology.
- Coronal spin-echo intermediate density and inversion recovery sequences. Field of view for all sequences is usually 16 cm.
- Optional sequences include 3D-spoiled gradient sequence for evaluation of the cartilage surfaces of the knee and sagittal oblique sequences for evaluation of the ACL in hard-to-visualize or equivocal cases. Shorter protocols may be practical in some cases, but at least one pulse sequence in all three planes with a T2-weighted sequence in the sagittal plane is necessary for adequate evaluation(7).

3. Normal ACL appearance on MR imaging

On sagittal views, the normal ACL (with knee in extension) should have a taut, straight anterior margin. With low signal intensity of its fibers on all pulse sequences fiber striations are visible at its attachments. Parallel striations with slightly increased but not bright signal intensity represent areas of fat interleaved between fibers(8). Because the ACL has a “propeller” or “fanlike” configuration, gray, slightly inhomogeneous signal intensity may be seen in the normal ligament, and the ligament may not be seen in its entirety on a single sagittal slice(8). If the knee is flexed, the signal intensity of the ligament may increase and the fibers may show a lax or slightly curved course.

Increased signal indicating fluid may. From its insertion on the tibia, the ACL extends posterior-superolaterally(9). The ligament twists on itself in its mid

and upper portion and fans out to its origin on the posteromedial surface of the lateral femoral condyle(9). A small amount of fluid signal anterior to the ligament is normally seen. Normally be seen anterior to the ligament. Volume averaging of the low signal ligament with adjacent intercondylar notch contents may occur when the slices obtained are too thick.

The proximal attachment of the ACL is at the lateral femoral condyle posteromedial fossa. The ligament courses inferomedially, attaching anterior/lateral to the anterior tibial spine where the fibers pass deep to the transverse meniscal ligament(11). The fascicles are divided into two functional but not grossly discrete bundles: the anterior medial band and the posterior lateral band. On sagittal images, ACL fibers are normally oriented parallel or nearly parallel to Blumensaat's line, inclining about 55° from the tibial plateau¹¹.

4. The injured ACL: direct and indirect MR imaging signs

Direct MR imaging signs of acute ACL tear include poor or no visualization of the ACL on sagittal images, an amorphous edematous mass with focally increased signal on T2-weighted images irregular contour with wavy redundant fibers, and/ or interruption of fibers with tears seen mid-substance or at the tibial or femoral attachments. Diagnosis of ACL tear on MR images is usually made by direct signs. Secondary signs of ACL tear are useful for diagnosis if, MR imaging findings are equivocal, particularly if edema obscures the ligament, potentially limiting the accuracy of assessment(11). Other causes of intermediate or increased signal within the ligament in the absence of a tear include eosinophilic degeneration of the ACL fibers, and volume averaging or incorrect fiber orientation on sagittal slices. In patients of advanced age, the ACL may be naturally attenuated, spontaneously torn, or absent(11).

5. Ancillary/indirect signs of ACL tear that may be detected at MR imaging include(7,11)

1. MR imaging “drawer” sign/with anterior subluxation of tibia relative to femur. This is determined on lateral cuts on sagittal images with visualization of posterior translation of the femoral condyles relative to the posterior translation of the femoral condyles relative to the posterior margin of the tibia of 7 mm or greater. MR imaging drawer sign may be seen in association with displacement of the posterior lateral meniscus relative to the margin of the tibia(11).
2. Bone injuries. These are useful for continuing suspicion of acute or subacute ACL injury, as is **the bone bruise pattern in cases in which direct signs are equivocal**, best detected on water sensitive sequences (T2 with fat saturation, inversion recovery). Bone contusions, not likely to be confirmed histologically, presumably represent intramedullary hemorrhage, edema, and / or micro-fracture. Commonly seen contusions after ACL injury include the lateral medial posterior tibial plateau and lateral sulcus. Concavity of the lateral femoral sulcus greater than 1.5 mm, best detected on sagittal views, raises suspicion of osteochondral injury. Bone bruises of the margin of the medial femoral condyle are occasionally seen. The location of contusions is affected by the complex of injuries sustained and the position of the knee at injury. ACL tibial attachment avulsion is well delineated on coronal and sagittal views.(11)

6. Other secondary signs(4,11,12)

1. Abnormal orientation of the fibers in the intercondylar notch; failure of the ACL to parallel the intercondylar roof on midsagittal images; flattened or more-horizontal-than-normal orientation of the ACL fibers.
2. Buckling of the PCL with acute angulation of the PCL. Because the assessment of the buckling is subjective, a variety of measurements have been established to improve detection of abnormal PCL orientation(13,14). patients with MR imaging and arthroscopic confirmation of ACL tears, McCauley et al⁴ found the most specific secondary signs for ACL tear to be posterior displacement of the posterior horn of the lateral meniscus (sensitivity 56%, specificity 97%-100%) and bone bruising of the posterior lateral tibial plateau (sensitivity 46%-50%, specificity 97%). PCL angle of less than 105° was sensitive but was less specific for detecting ACL tears (sensitivities 72% and 74%, specificities 79% and 86%..

7. Conclusion

Non contrast MRI remains the mainstay in the ACL imaging as of today. MRI Arthrogram has its own indications in specified cases. Plain radiographs has got much role in isolated ACL imaging especially to detect bony avulsion and Computerized Tomography is must in revision situations.

References

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Further Reading

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