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Original Research Article

MR imaging of anterio cruciate ligament injuries

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ABSTRACT

Background: Of all the ligaments of the knee joint the Anterior cruciate ligament (ACL) is the most commonly injured. It is an important pillar of the ligament stabilization of knee joint preventing anterior translation of Tibia over Fibula. Magnetic resonance imaging (MRI) is an excellent modality providing fine-resolution and multiplanar imaging without any radiation, for detection and evaluation of ACL injury with the associated injuries to other ligaments of the knee join. The purpose of the work was to study the role of MRI in classifying the ACL injuries.
Methods: MRI Knee of 162 patients with ACL injuries was studied. All the MR imaging scans were performed on 1.5-T MR system (Siemens magnetom Essenza).
Results: A total of 162 patients were studied in which majority of them i.e. 43 patients had interstitial sprain, 38 patients had complete tear, 33 patients had mucoid degeneration, 27 had partial tear and 14 had high grade partial tear, however 7 patients had normal ACL. There were associated injuries to the other ligaments of the knee joint along with ACL injury, medial meniscus tear being the most common and was seen in 39.50% followed by lateral meniscus tear in 9.87%, MCL tear in 6.79%, LCL tear in 1.85% and PCL tear in 2.46 %.
Conclusions: MRI is a good modality for classifying ACL injury and evaluation of injuries to the associated ligaments.

Keywords: ACL (Anterior cruciate ligament), knee joint, Lateral meniscus, Medial meniscus, MRI (Magnetic Resonance Imaging), PCL (Posterior cruciate ligament)

INTRODUCTION

Knee pain is one of the common disability with which the patients often presents to the clinicians. The knee joint is one of the most important weight bearing joint of our body which consists of carious ligaments for stabilizing the joint for its functioning. Of the many ligaments of the knee joint ACL is one of the most commonly injured ligament. MRI gives us an excellent idea about the normal anatomy and injuries of ACL. There is great impact on the diagnosis and management of ACL injuries after the MR evaluation.[1] Thus the use of MRI as first line investigation in suspected ACL injuries can avoid large number of unnecessary diagnostic arthroscopies. The clinical examination has its limits in case of acute injury with pain or swelling and also with associated meniscal tear and chondral injury limiting their sensitivity and specificity.[2] MRI is highly accurate for diagnosing ACL tears with accuracy, sensitivity and specificity of more than 90%.[3,4] The spectrum of MRI also gives us appropriate information regarding the injuries to the associated ligaments around knee joint and helps in planning the arthroscopic and nonarthroscopic surgery. This article emphasizes on information regarding the normal ACL anatomy and ACL tears with imaging features for diagnosing ACL tears, chronic tear and mucoid degeneration. The aim and objective of this work was to study the MRI features of complete and partial ACL tear and to study the MRI features of chronic tear and degeneration of ACL.

METHODS

This prospective study was carried out for a period of 5 months, with due permission from the ethics committee. The MRI knee of 162 patients were performed who were referred to the Department of Radio diagnosis at Dr. Vasantrao Pawar Medical College, Hospital and Research Centre, Nashik with complaints of knee pain and suspected injury to ACL. The clinical and demographic data were recorded after due consent to correlate the findings. The patients who have underwent ACL reconstruction or repair and those with no associated knee complain were not included in the study.

All the MRI scans were done on 1.5-T magnet MR system (Siemens magnetom Essenza) using dedicated knee coil. Imaging was performed using the surface coil with the affected knee joint of the patient in supine and extended position with slight external rotation. Some cushions ar placed around the to restrict any motion. Another cushion is keep under the ankle to keep the leg straight.

The exact MR imaging pulse sequences used to image the knee vary among different institutions. The pulse sequences at our institution for the knee joints are as follows Axial T2-wighted (Repetition time in msec/Echo time in msec, 3500/85) spin echo images (slice thickness, 4 mm; field of view, 170 mm; acquisition matrix, 342 x 384; and number of sections, 19) and Axial Proton density fat suppressed (3000/25) spin echo images (slice thickness, 4 mm; field of view, 170 mm; acquisition matrix, 228 x 256; and number of sections, 19) , Coronal T1 weighted (600/12)) spin echo images (slice thickness, 4 mm; field of view, 180 mm; acquisition matrix, 320 x 320; and number of sections, 16), Coronal Proton density fat suppressed (3000/25) spin echo images (slice thickness, 4 mm; field of view, 180 mm; acquisition matrix, 256 x 256; and number of sections, 16) and Coronal T2 weighted (4500/48) turbo inversion recovery magnitude sequence (slice thickness, 4 mm; field of view, 180 mm; acquisition matrix, 256 x 256; and number of sections, 16), Sagittal T1 weighted (500/12) spin echo images (slice thickness, 4 mm; field of view, 180 mm; acquisition matrix, 320 x 320; and number of sections, 16), Sagittal Proton density fat suppressed (3000/25) spin echo images (slice thickness, 4 mm; field of view, 180 mm; acquisition matrix, 256 x 256; and number of sections, 16) and Sagittal T2 weighted (3300/90) spin echo images (slice thickness, 4 mm; field of view, 180 mm; acquisition matrix, 320 x 320; and number of sections, 16) and lastly Sagittal three dimensional proton density (850/40) fat suppressed images(slice thickness, 1 mm; field of view, 180 mm; acquisition matrix, 256x 256; and number of sections,80). Three-dimensional (3D) sequences with isotropic resolution have are also taken that provide thinner sections and reduce partial volume averaging. An additional advantage of isotropic 3D imaging is the ability to create multiplanar reformations in any plane after a single acquisition. In addition to traditional orthogonal imaging, several oblique acquisitions have also been advocated in the literature for imaging of the ACL. The total acquisition time for the study is approximately 30 minutes.

RESULTS

Total 162 patients with suspected ACL injuries referred to our department in a span of 5 months were studied. The most common age group of patients with ACL injuries was between 21 to 40 years (Figure 1).

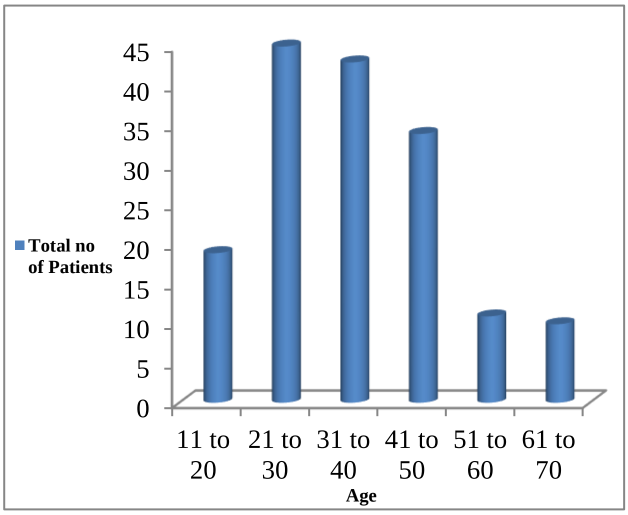

Figure 1: Total no. of patients according to the age.

Majority of the patients i.e. 43 patients (27%) had interstitial sprain, with the remaining 38 (23%) patients had complete tear, 33 (20%) patients had mucoid degeneration, 27 (17%) had partial tear and 14 (9%) had high grade partial tear, however 7 patients (4%) had normal ACL as illustrated in Figure 2.

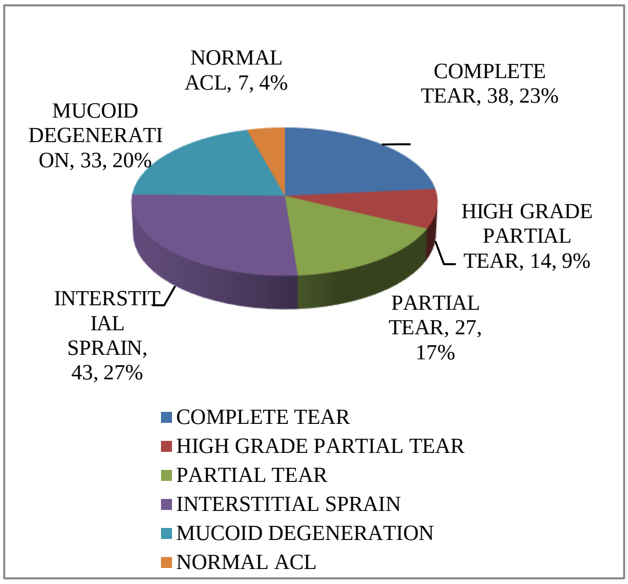

Figure 2: Types of ACL injuries.

Interstitial sprain being the most common type of injury was most commonly seen in the patients in between 11 to 40 years with complete tear and mucoid degeneration being most common in first to third decade and fourth to seventh decade respectively (Figure 3).

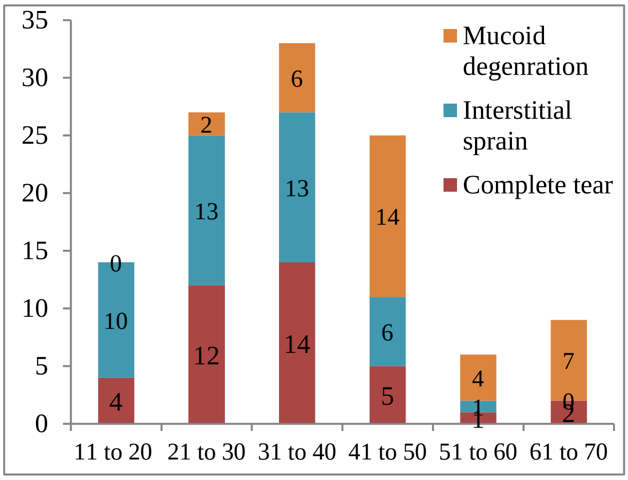

Figure 3: Type of ACL injury common in different age groups.

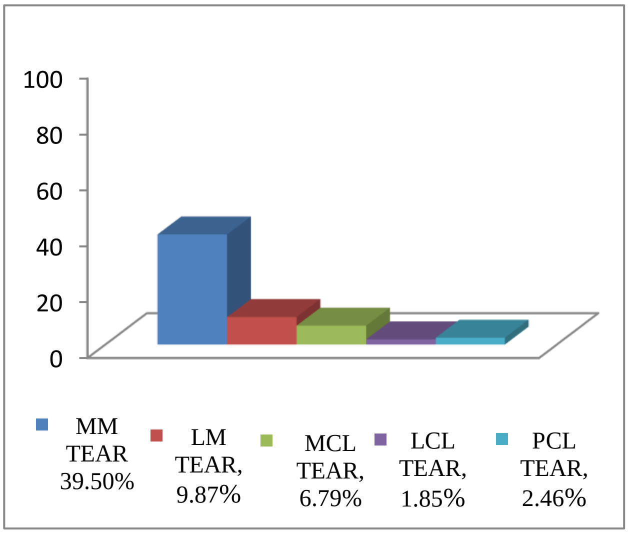

Figure 4: Associated ligamentous injuries with ACL injury.

There are often associated injuries to the other ligaments of knee joint along with the ACL injury which should be mentioned, among them the medial meniscus tear being the most common in 39.50%, followed by lateral meniscus tear in 9.87%, MCL tear in 6.79%, LCL tear in 1.85% and PCL tear in 2.46 % (Figure 4).

DISCUSSION

Normal anatomy of ACL and its function

The ACL originates from the medial border of the lateral Femoral Condyle in a semilunar region and inserts onto the proximal Tibia, anterior to the Tibial spines slightly laterally in the intercondylar area which is in close proximity to the anterior root of the lateral meniscus.[5] ACL measures approximately 10-11 mm width and 21 to 39 mm long.[6]

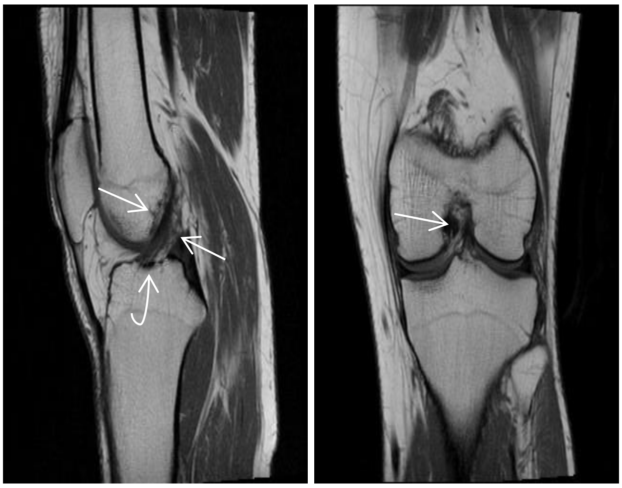

Figure 5: Normal anterior cruciate ligament (ACL) in a 45-year-old male. (a) Sagittal T1 weighted MR image show the anteromedial bundle of ACL inserting at the anterior border of the tibia (large arrow) and the posterolateral bundle which is shorter and thicker. Several lines of increased signal intensity (curved arrow) representing stripes of fat and synovium is seen in between the two bundles at the tibial insertion. (b) Coronal T1 weighted MR image demonstrates parts of a normal AMB (arrowhead) and PLB (arrow).

The ACL consists of 2 anatomically and functionally distinct bundles: the anteromedial (AMB) and posterolateral (PLB) bundles. The two bundles are named according to their Tibial insertion.[5] The AMB has a more proximal origin and is separated from the more distal origin of the PLB by the bifurcate ridge.[7] The AMB inserts onto the Tibia at a point anteromedial to the insertion of the PLB. The AMB and PLB parallel each other in the sagittal plane during knee extension but twist around each other during flexion.[8] ACL is an intracapsular and extra synovial ligament. The ligamentous branches of the middle geniculate artery which is a branch of popliteal artery forms vascular plexus that supplies the ACL. Nerve fibers to ACL are from Tibial nerve.[9] The AMB is maximally taut during knee flexion restraint to anterior translation of the Tibia during knee flexion whereas the PLB is maximally taut in extension and internal rotation and prevents anterior translation during knee extension as well as providing restraint against internal rotation of the Tibia.[7]

Imaging appearance of normal ACL

Normal ACL is seen as a band of low signal intensity in all sequences. The individual low-signal-intensity fiber bundles may be seen separated by linear stripes of intermediate to bright signal intensity on T1-weighted images (Figure 5).

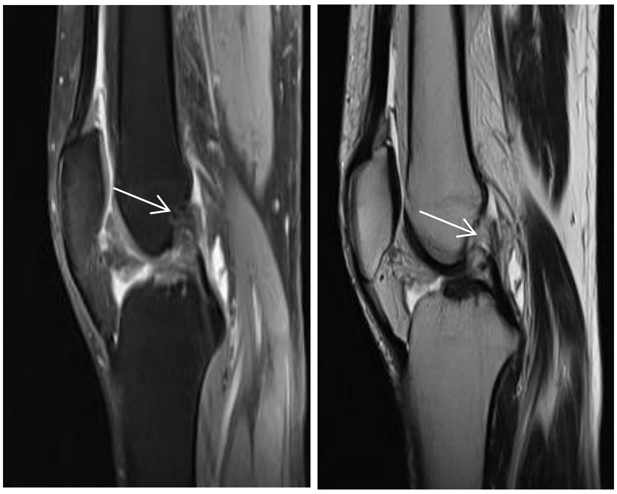

Figure 6: Acute complete tear of anterior cruciate ligament (ACL) in a 36-year-old male. (a) Sagittal PD FSE fat-suppressed image shows complete discontinuity of the ligament in its mid part (arrow) with diffusely abnormal signal intensity within the ACL. (b) Sagittal T2-weighted image shows poorly defined ACL with disordered fibers and increased signal intensity within the ACL substance.

These stripes are believed to represent fat and synovium and are usually identified at the Tibial attachment of the ACL. On direct sagittal acquisitions, the entire ACL may not be visualized on a single slice.

Most of the examinations are performed with extension of the patient's knee. In the sagittal plane, the normal ACL is taut and straight. It runs parallel, or within 9 degrees, to the roof of the intercondylar notch.[10]

The AMB forms the anterior border of the ACL. The PLB, representing the bulk of the ACL, may display more intermediate signal intensity on T1-weighted images.[11] The normal ACL fibres demonstrate low signal intensity on conventional T2, FS PD-weighted FSE, and T2-weighted images.[11] On proximal axial images, the proximal ACL has an elongated elliptical appearance.[12]

On coronal images, ACL is identified adjacent to horizontal segment of PCL as linear or mildly convex low signal intensity band (Figure 5b). The AMB and PLB may be distinguished on the axial and coronal planes. The normal ACL forms an approximately 45-degree angle to the long axis of the tibia.[13]

Imaging featues of ACL injury

Most common site of the ACL tear is in the middle substance. Tears at the Tibial or Femoral attachment are less common.[14]

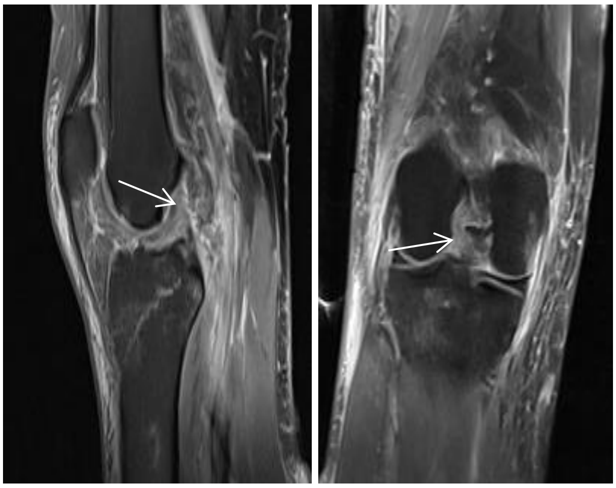

Figure 7: High grade partial tear of the anterior cruciate ligament (ACL) involving more than 75 % of the ligament thickness in a 40-year-old male. (a) Sagittal PD FSE fat-suppressed image shows diffuse high-intensity changes (arrow) which involve the entire posterolateral bundle and partially the anteromedial bundle. (b) Coronal PD FSE fat-suppressed image shows diffusely swollen ACL with increased signal intensity.

Complete tear

The primary signs of ACL tear are as follows.[15,16]

- Ligament discontinuity of ACL (Figure 6),
- Diffuse or focal abnormal signal intensity (coronal images should be used in conjunction with sagittal images to compensate for segmental visualization in the sagittal plane),
- Abnormal orientation or ligament course (abnormal Blumensaat angle),
- A mass-like appearance in the expected location of the ACL,
- Non-visualization of the ACL.

The secondary signs and other predictors of ACL tear are as follows.[11]

- Osseous contusions in the lateral compartment (posterolateral Tibial plateau is most specific), contusion at mid portion of lateral Femoral condyle and posterior portion of lateral Tibial plateau are termed as kissing contusions representing edema and haemorrhages due to impaction microfactures of trabecula.[6]
- Buckling of Posterior cruciate ligament,
- Uncovered posterior horn of lateral meniscus - A vertical line drawn tangentially to the posterior most margin of the lateral Tibial plateau intersects the posterior horn of lateral meniscus,
- Anterior Tibial displacement (assessed in the lateral aspect of the lateral compartment) – The distance between two parallel lines drawn tangential to the

posterior lateral Femoral condyle and posterior lateral Tibial plateau is more than 5mm,

- Avulsion fracture of the lateral Tibial rim (Segond fracture).[6]
- A positive PCL sign or PCL angle (A positive PCL sign is failure of a line drawn along the posterior PCL on sagittal images to intersect the medullary cavity within 5 cm of the distal Femur. The PCL angle is the intersection formed between lines drawn through the proximal and distal portions of the PCL and shows a decrease in its normal obtuse shape with anterior Tibial translation in ACL tears.),
- A positive posterior Femoral line sign (failure of a line drawn at a 45° angle from the posterosuperior corner of the Blumensaat angle to intersect the flat portion of the proximal Tibial surface or to intersect a point within 5 cm of its posterior margin),
- The hemarthrosis/joint effusion is a common finding associated with ACL tear.[17]

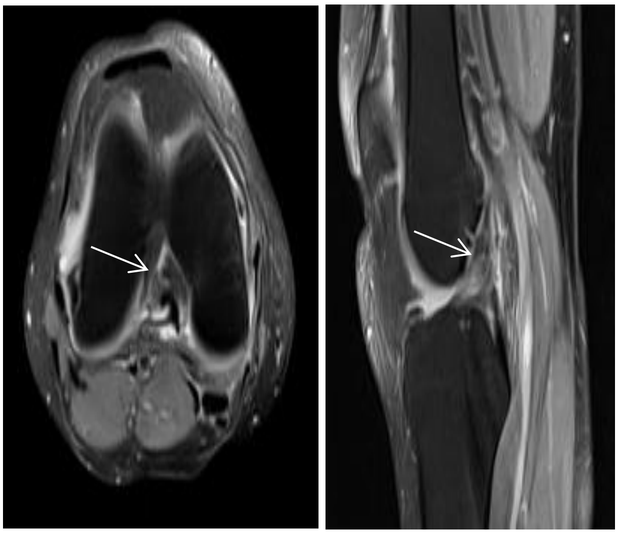

Figure 8: Low grade partial tear of the anterior cruciate ligament (ACL) involving less than 50 % of the ligament thickness in a 28-year-old male. (a) Axial PD FSE fat-suppressed image high intensity changes in ACL. (b) Sagittal PD FSE fat-suppressed image shows high-intensity changes (arrow) predominantly in the postero-lateral bundle.

The absence of secondary signs does not exclude the diagnosis of an ACL tear.[18]

The most accurate assessment for ACL tears requires the combined use of axial, coronal, and sagittal images.[19] Axial images are excellent for showing fluid within the proximal ligament fibers or between the torn ACL and the lateral femoral condyle sidewall. The coronal plane is particularly useful for differentiating grades of ACL injury, especially when sagittal images may display the ACL fibers only segmentally. Coronal plane assessment increases MR specificity in distinguishing partial from complete ACL tears.[11]

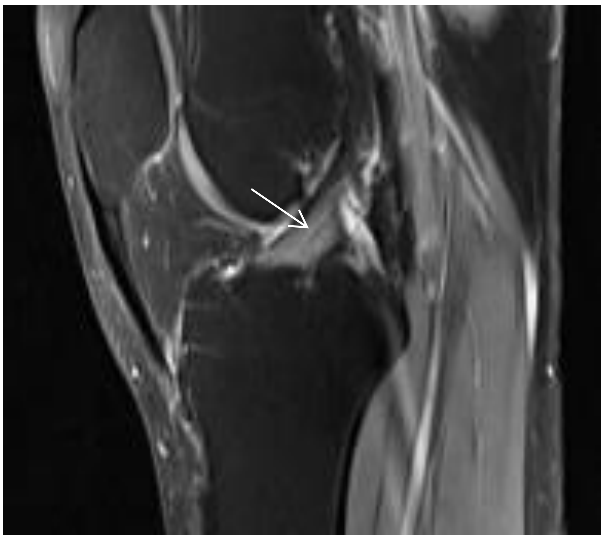

Figure 9: Sprain in the anterior cruciate ligament (ACL) in a 33-year-old male. Sagittal PD FSE fat-suppressed image shows hyper-intense ACL(arrow) however there is no discontinuity of the ACL ligament.

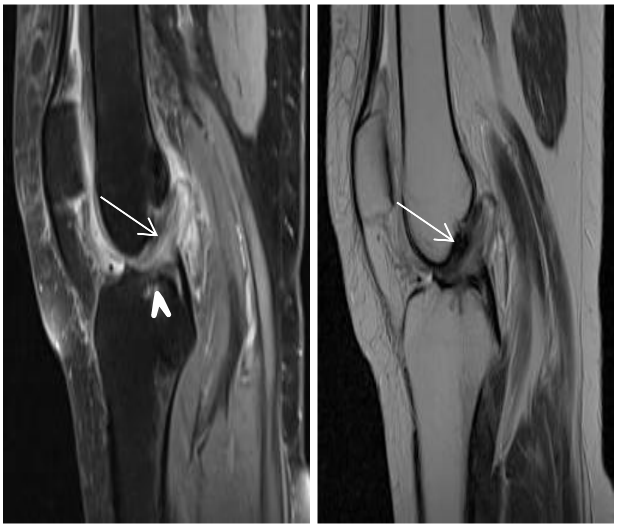

Figure 10: Mucoid degeneration of anterior cruciate ligament (ACL) in a 40-year-old female. (a)Sagittal PD FSE fat-suppressed image shows the ACL is expanded with increased signal intensity (arrows) and intact fibers. Small area of intraosseous increased signal intensity at the ACL insertion (arrowhead) consistent with reactive edema/intraosseous ganglion cyst formation. (b) Sagittal T1-weighted FSE image show typical linear signal changes with intact fibers (arrow) known as the "celery stalk" sign.

In MRI the T2W images allows high signal intensity joint fluid to be distinguished from a normal ligament. If volume averaging is excluded, intermediate signal intensity area on T1W images that generally increase in intensity on T2W images is indicative of tear.

In an acute ACL tear, there is loss of ligament continuity associated with a wavy or lax contour. The ACL itself usually demonstrates increased signal intensity on T2-, FS PD FSE, or T2*-weighted images. Changes in signal intensity may be less pronounced with FSE or FS FSE techniques. If the normally hypo intense ACL fibers are identified with intermediate signal intensity with or without loss of fiber striation on T1- or PD-weighted coronal images, the ACL is abnormal.[11]

Partial tear

Accurate assessment of partial ligamentous tears is more difficult than the detection of complete tear.[11]

- Partial injuries may consist of the following:
- Complete tear of the AMB with either a normal or a partially torn PLB. This pattern is the most common.[20]
- Complete tear of the PLB with either a normal or a partially torn AMB,
- Partial tears of both bundles,
- The AMB is most commonly involved in incomplete or partial ACL tears.[21] However specific commitment of AMB versus PLB tears is not possible most of the time.[5]

The signs or appearance that indicates partial tear are

- Discrete focus of increased signal intensity within the substance of the ACL with a normal ACL course (Figure 11),
- Hyperintense intrasubstance signal with identification of intact fibers (Figure 9),
- Non- visualization of the ACL on one MRI sequence with visualization of the fibers on other sequences,
- Bowing or undulating course of otherwise intact ACL.[5,22]

Although the bulk of the ligament appears to be intact, with a relatively normal axis, at times there may be localized angulation of the ligament at the site of disruption of fibres.

It is more helpful to correlate sagittal FS PD-weighted FSE images and complementary coronal T1- or PD-weighting plus FS PD FSE T2-weighting so as to be more precise in interpretation the areas of increased signal intensity with partial tears.[11]

Partial low-grade ACL tears, involving less than 25% of the substance (Figure 12) are associated with a more favorable outcome than high grade tears involving 50% or more (Figure 11), which predispose to ACL deficiency and reinjury.[23,24]

The widening of the entire length of ligament is associated with an interstitial tear pattern. An interstitial disruption shows variable increases in signal intensity on T2-weighted images.

Grading and diagnosis of a partial tear is of clinical significance because the management and risk of progression to ACL insufficiency is related to the grade of ligament injury.

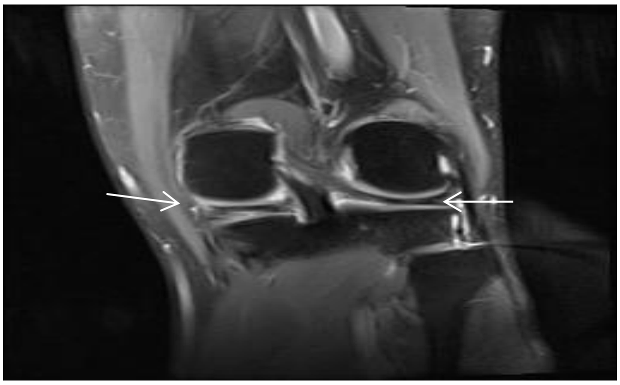

Figure 11: Associated meniscal ligamentous injuries with ACL tear. Coronal PD FSE fat-suppressed image shows medial and lateral meniscus tear (arrows).

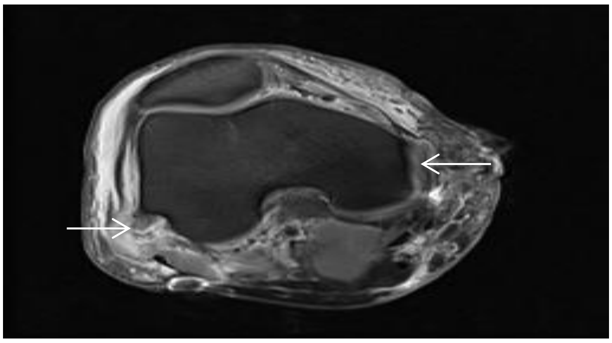

Figure 12: Associated collateral ligamentous injuries with ACL tear. Axial PD FSE fat-suppressed image shows medial and lateral collateral tear (arrows).

Chronic tear

In chronic tears of the ACL, there is no edema and synovitis nor there is irregularity of the free concave edge of Hoffa's fat pad. Although there can be small chronic joint effusion. The ACL may not be visualized on sagittal or coronal images. The absence of ACL in the lateral intercondylar notch on coronal MR images is termed as empty notch sign (empty lateral wall).[25]

The ACL may also appear attenuated or small in chronic tears. Anterior translation of the tibia on the femur is also associated with chronic ACL dysfunction.[11]

With chronic complete ACL tears, the remnant may reattach and thus the severity of the injury may not be appreciated at that time. The chronically teared ACL can be scarred to the surrounding adjacent structures, patterns of ACL scarring include the following.[26]

- End-to-end scarring of the torn ACL,
- Scarring of the ACL to the PCL,

- Scarring of the ACL to the roof of the intercondylar notch,
- Scarring of the distal remnant onto the anatomic origin of the ACL.

Degeneration

The mucoid degeneration of ACL is a rare cause of knee pain which predominantly affects elderly women.

Mucoid degeneration may coexist with ACL ganglia, as well as with intraosseous cysts at the femoral and Tibial attachments.[27]

There is diffuse thickening and increased signal intensity of the ACL with subtle appearance of some linear, low-signal-intensity fibers parallel to the long axis of the ligament giving it a striated appearance ("celery stalk" sign) is likely indicative of mucoid degeneration of the ligament (Figure 10). There are intact contiguous ligament fibers visible along its entire length.[28]

The points to be included in the report for helping the referring clinician

- Grade of injuries: whether complete or partial, if partial whether its high grade or low grade,
- Whether there is any avulsion fracture,
- Whether there is associated injury of menisci or any chondral injuries and status of articular cartilages,
- Status of other ligamentous structures,
- Normal postoperative appearance-normal positioning of the tunnels and normal ACL graft, any signs of postoperative complications,
- Measurement of tunnel width before revision surgery,
- In case of reconstruction it's important to identify the cause of loss of terminal extension (graft impingement or focal fibrosis),
- Other post-operative complications if present.

CONCLUSION

MRI plays a primary and crucial role in ACL injuries and its management by allowing confident diagnosis of whether there is an ACL injury or not, especially in patients with equivocal physical examination and also provides additional information regarding the injuries of associated ligaments. The points to be mentioned in the report as detailed above helps in further management of the ACL injuries.

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