"COMPARISON BETWEEN MAGNETIC RESONANCE IMAGING OF KNEE JOINT AND KNEE ARTHROSCOPY IN THE DIAGNOSIS OF ANTERIOR CRUCIATE LIGAMENT TEARS: A ONE YEAR HOSPITAL BASED CROSS SECTIONAL STUDY"

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
ACL	Anterior Cruciate Ligament
PCL	Posterior Cruciate Ligament
MCL	Medial Collateral Ligament
LCL	Lateral Collateral Ligament
MM	Medial Meniscus
LM	Lateral Meniscus
MRI	Magnetic Resonance Imaging
CT	Computed Tomography
PD	Proton Density
FOV	Field of View
FATSAT	Fat Saturated
TE	Echo Time
TR	Repetition Time
PCLA	Posterior Cruciate Ligament Angle
PCL-PCA	Posterior Cruciate Ligament-Posterior Cortex Angle
ROC	Receiver Operating Characteristic
AUC	Area Under Curve
PPV	Positive Predictive Value
NPV	Negative Predictive Value

LIST OF FIGURES

LIST OF TABLES

LIST OF IMAGES

ABSTRACT

Background and objective: The anterior cruciate ligament (ACL) is crucial for knee stability, and its injury is a common orthopedic concern. Accurate diagnosis is essential for proper management. While MRI is a widely used non-invasive imaging modality, arthroscopy remains the gold standard for diagnosing ACL tears. This study aims to compare the diagnostic accuracy of MRI with arthroscopy in detecting ACL tears.

Methods: A hospital-based cross-sectional study was conducted over one year, involving 50 patients with suspected ACL injuries. All patients underwent MRI examination followed by arthroscopic evaluation. MRI findings were compared with arthroscopy results to assess sensitivity, specificity, and accuracy. The study also evaluated the usefulness of primary and secondary MRI signs in ACL tear diagnosis.

Results: MRI demonstrated high accuracy in diagnosing ACL tears, with a sensitivity of 97.6%, specificity of 87.5%, and an overall accuracy of 95%. Complete ACL tears were diagnosed with 100% accuracy, while partial tears had lower sensitivity (83.3%) and specificity (87.5%). Mid-substance ACL tears were the most common, and lateral meniscus injuries were the most frequent associated injuries. Among primary MRI signs, abnormal axis and fiber discontinuity were the most specific, while secondary signs such as anterior tibial translation and uncovering of the posterior horn of the lateral meniscus showed high specificity.

Conclusion: MRI is a highly effective non-invasive modality for detecting ACL tears, particularly complete tears. However, its limitations in diagnosing partial ACL tears highlight the need for careful interpretation and correlation with clinical and arthroscopic findings.

Keywords: Anterior cruciate ligament, ACL tear, MRI, arthroscopy, knee injury, diagnostic accuracy, ligament injury, knee joint, orthopedic imaging, sensitivity, specificity.

TABLE OF CONTENTS

INTRODUCTION

The knee joint plays an important role in the locomotion and load-bearing activities, relying on the coordination of bones, ligaments, and menisci to maintain both mobility and stability.[1]

The stability of the knee joint is maintained by two cruciate ligaments, namely the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL), two collateral ligaments, namely the medial collateral ligament (MCL) and lateral collateral ligament (LCL) and two menisci, namely the medial meniscus (MM) and lateral meniscus (LM). These structures acts as the primary stabilizers of the knee joint that works in coordination to maintain the functional integrity and strength of the joint.[2]

The ACL is an important ligament that is located within the joint yet outside the synovial membrane and has a significant contribution in maintaining the stability of the knee joint as it helps to prevent the excessive forward translation of the tibia over the femur.[3]

Being one of the most common ligamentous injures to the knee, ACL injuries occur at an estimated annual rate of approximately 68.6 per 100,000 person-years, impacting close to 1 in 3,500 individuals each year.[4]

Partial or complete fiber bundle injuries commonly happen due to abrupt changes in the direction of movement, abnormally high twisting forces or direct trauma to the knee.[5]

Athletes participating in high-impact sports like football, basketball, skiing, and gymnastics face a higher risk of ACL injuries due to the frequent occurrence of sudden stops, rapid directional changes, and high-impact landings.[3,6]

The ACL injuries are significantly higher in females than males, probably due to the difference in anatomy and biomechanics.[6]

Road traffic accidents, especially motorcycle accidents are one of the common causes of ACL injuries leading to severe bundle fiber disruption.[3]

ACL injuries can cause instability of the knee joint thereby affecting a person's ability to carry out daily routine and also increasing the risk of other associated injuries such as injuries to menisci as well as early-onset osteoarthritis if proper treatment is not ensured.[4]

Chronic ACL deficient knees are known to have up to 90 % association with meniscal injuries while acute ACL tears are known to have up to 50% association with meniscal injuries.[4]

Several important questions need to be answered by an orthopedic surgeon before commencing the treatment planning for a patient with ACL injury, these include:

1. Is the ACL healthy or damaged? (This is because if the ACL is not damaged, unnecessary arthroscopy can be avoided)
2. If the ACL is damaged, is it a complete or partial fiber disruption? (This is because conservative management is often sufficient for partial tears while surgery is required for chronic or complete tears)

3. Is there any associated ligamentous or meniscal injuries to the knee joint? (This is important because early management is required if a complete ACL tear is associated with additional injuries to the ligament or menisci).[4]

Both history taking and clinical examination of the patient have an important role to play in the diagnosis of ACL tears but they also have limitations, especially in diagnosing partial tears and other associated ligamentous injuries.[4]

Lachman test and anterior drawer test are two physical tests that are performed to diagnose ACL tears on clinical examination. These tests demonstrate high specificity for ACL injury.[7]

The drawback of these tests are that they cannot help the surgeon in direct visualization of the ligament and therefore cannot correctly locate or analyze magnitude of disruption of the fibers.[7,8]

Hence, advanced imaging modalities such as Magnetic resonance imaging (MRI) and arthroscopy are essential for accurate diagnosis and as well as preoperative planning of ACL tear.[9]

Due to its ability to provide high-contrast imaging of soft tissues in multiple planes, MRI is now widely used as a non-invasive method for assessing ACL tears.[10]

MRI helps in providing detailed visualization of the ACL and also to help to assess the other commonly associated ligamentous and meniscal injuries.[6]

Conventional radiography and CT scan are useful in detecting fractures, however they cannot evaluate the intra-articular and extra-articular soft tissue structures like MRI.

Hence, MRI is a much better imaging modality for assessing the ligamentous injuries.[11]

MRI findings such as signal abnormalities, contour changes and fiber discontinuity are important signs of ACL tears. However, partial tears and ruptures near the insertion site of the ligament may be wrongly diagnosed as intact ligaments.[8,12]

In addition, the sensitivity, specificity and accuracy of MRI for knee injuries vary in the literature. Some studies have reported that the sensitivity for the detection of ACL injuries is low as compared to meniscal tears.[8,9]

The gold standard for diagnosing intra-articular ligament injuries, including ACL tears is considered to be arthroscopy. This is because of its ability to provide direct visualization of the ligament and has 100% diagnostic accuracy.[9]

Arthroscopy enables dynamic evaluation of stability of the ligaments and also helps to detect any associated injuries to the menisci.[3]

Additionally, arthroscopy can also be used for both diagnostic and therapeutic purposes which helps in immediate surgical intervention if necessary.[11]

Although arthroscopy has high accuracy in the detection of ACL tear, arthroscopy also has its limitation. Being an invasive procedure that requires anesthesia and hospitalization makes it more expensive than MRI.[4]

Furthermore, arthroscopy poses the risk of various post-operative complications such as infection, hemarthrosis, and neurovascular injuries.[10]

There is no definitive proof that MRI has been able to reduce the number of unnecessary arthroscopic procedures, prompting concerns about relying solely on MRI for preoperative planning of the patient.[9]

Given the advantages and disadvantages of both MRI and arthroscopy, there is a necessity to compare their diagnostic accuracies systematically. The advantage of MRI is that its non-invasive and widely accessible, however the limitations is that it may miss partial ACL tears and avulsions of ligament.[8]

Arthroscopy, despite its high diagnostic accuracy in the detection of ACL injury, is less ideal as a first line diagnostic tool due to its invasive nature, high cost and associated risks.[3,9]

Although, multiple studies have been conducted to compare the diagnostic accuracy of MRI knee joint keeping knee arthroscopy as the gold standard for diagnosis of ACL tear, there remains a lack of comparative studies within this geographical area.

Hence there is a need to evaluate the consistency of the findings obtained in the previous literatures with the present study within this geographical area as the differences in MRI scanners, expertise of the reporting radiologists and patient demographics plays an important role in determining the diagnostic accuracy, thereby making it essential to validate the findings in a local population.

The decision to perform an arthroscopy typically depends on findings obtained in MRI. If MRI demonstrates high sensitivity and specificity, unnecessary arthroscopic procedures can be avoided thereby reducing healthcare costs as well as patient burden.

Conversely, if MRI shows limitations in detecting certain ACL injuries, clinicians must be aware of its pitfalls to avoid false negative diagnoses that may delay appropriate surgical intervention.

Therefore, there is a need to bridge the gap in existing literature by providing regional data that can help orthopedic surgeons in improving clinical decision making and optimize the management of patients with ACL injuries.

OBJECTIVE OF THE STUDY

- The primary objective of the study was to compare the diagnostic accuracy of MRI knee joint with reference to knee arthroscopy in detecting anterior cruciate ligament tears.
- The secondary objective of the study was to assess the usefulness of the primary and secondary signs of anterior cruciate ligament tears of knee joint using MRI.

REVIEW OF LITERATURE

ANATOMY OF THE ANTERIOR CRUCIATE LIGAMENT:

The anterior cruciate ligament (ACL) is an important structure of the knee joint, that originates from the posteromedial aspect of the lateral femoral condyle and inserts into the anterior aspect of the intercondylar area of the tibia and is mainly responsible for maintaining the stability of the joint by resisting the forward translation of tibia and rotational forces that impact the knee.[13]

The anteromedial (AM) and the posterolateral (PL) bundles of the ACL provide the rotational stability to the knee that is achieved by the process of tightening the AM bundle and PL bundle during the process of flexion and extension of the knee joint respectively.[14]

At the site of the femoral attachment of the ACL, the AM bundle is located proximally and anteriorly and the PL bundle located distally and posteriorly. At the site of tibial attachment, the ACL inserts in front of the intercondylar eminence, with the AM bundle located anteromedially and the PL bundle located posterolaterally.[15]

Histologically, the ACL is composed of dense connective tissue that is abundant in collagen fibers, that helps to provide the tensile strength to resist mechanical loads. Mechanoreceptors are also present within the ACL that play a vital role in proprioception, thereby helping in the detection of changes in position and movement of the knee joint.[13]

The dimensions of ACL differ from person to person with the length ranging from approximately 2.7 to 3.8 centimeters, width ranging from approximately 1.0 to 1.2 centimeter and the cross-sectional area of the ACL on an average being around 4.4 square millimeters. The shape of the ACL is quite similar to that of an hourglass or a bow tie.[16]

The middle genicular artery which is a branch of the popliteal artery provides the major blood supply to the ACL which penetrates the posterior capsule of the knee joint and provides the other arterial branches that supply the synovial and sub-synovial tissues, thereby providing adequate nourishment to the ligament.[13]

The ACL also has mechanoreceptors within it such as the Ruffini's endings, Pacinian corpuscles and free nerve endings which are sensitive to the changes in tension, pressure and joint position and therefore helps in proprioception and neuromuscular control.[13]

Understanding of ACL anatomy is very important for the diagnosis, treatment, and rehabilitation of ACL injuries.[17]

The anterior cruciate ligament's complex anatomy includes not only its macroscopic structure but also its microstructural composition, vascularization and innervation.[13]

MECHANISM OF INJURY:

A large number of injuries to the ACL occur without any direct contact. One study showed that out of 89 athletes with injury to the ACL, 72% of them provided a history of non-contact mechanisms of injury.[18]

It was observed that these injuries occurred during activities that involved sharp deceleration or landing maneuvers, with the knee at near complete extension at the time when the foot strikes the ground and during these conditions, the quadriceps muscle, could exert forces that strain the ACL, leading to its rupture.[18]

In an another study, video analyses of ACL injuries in professional male football players was observed which revealed that 85% of the injuries occurred as a result of non-contact or indirect contact mechanisms and the major circumstances that lead to the injury included pressing, kicking and heading.[19]

Although non-contact injuries are frequent, contact mechanisms of injuries also play a major role in causing ACL injuries as observed in a study that included 100 ACL injured knees of which 28% of the injuries were as a result of contact mechanisms and these injuries were often caused by external forces applied to the knee, leading to excessive loading resulting in ligament rupture.[18]

About 88% of ACL injuries usually occurred without any direct knee contact but it is to be noted that indirect contact injuries were as common as non-contact injuries which highlights the significance of mechanical perturbations, which includes being tackled or taking part in pressing actions, in the etiology of ACL injuries.[19]

Study of the biomechanics of ACL has helped in determining specific joint positions and specific movements that are associated with increased risk of ACL injuries. It has been observed that injuries to the knee most commonly tend to happen when the knee is partially flexed and during the deceleration phase of activity.[20]

These injuries are often associated with inward buckling of the knee, also known as a valgus collapse. A thorough understanding of the biomechanics of ACL therefore helps us in identifying the certain movements and positions that exert stress on the ACL, resulting in high risk of injury.[20]

Other factors that has to be taken into account in resulting ACL injuries are the neuromuscular factors such as knee landing kinematics that significantly influence risk of ACL injury. Training programs that targets these neuromuscular factors can aid in reducing the risk of ACL injury, however, the effective elements of such programs are yet to be completely established.[21]

MRI APPEARANCE OF THE ANTERIOR CRUCIATE LIGAMENT:

The sagittal and coronal planes on MRI, are the best planes to optimally visualize the ACL. A low signal intensity band that runs obliquely from the posteromedial aspect of the lateral femoral condyle to the anterior aspect of the intercondylar area of the tibia represents the ACL.[22]

When the knee is in extension, the ligament has a straight configuration or mildly convex posterior contour as opposed to when the knee is in flexion, the ligament has linear configuration. These changes in its configurations represent the adjustments in biomechanics of ACL during movement of the knee joint.[22]

The ACL has two primary bundles which are the anteromedial (AM) and posterolateral (PL) bundles. The vertically oriented AM bundle is longer, and its length approximately measures 3.69 ± 0.28 centimeter and its width approximately measures 0.51 ± 0.07 centimeter on sagittal images. On the other hand, the horizontally oriented PL bundle is shorter, and its length approximately measures 2.05 ± 0.24 centimeter and its width approximately measures 0.44 ± 0.08 centimeter. The widths of the AM and PL bundles approximately measures 0.42 ± 0.08 cm and 0.37 ± 0.08 centimeter, respectively on coronal images.[22]

Correct localization of the anatomical landmarks of the ACL is essential not only for diagnostic purpose but also for surgical purposes. Various MRI studies have been able to conclude that the anterior margin of the tibial insertion of ACL is located approximately 1.4 ± 0.3 centimeter from the articular surface of the anterior aspect of the tibia which extends posteriorly to about 3.1 ± 0.4 centimeter.[23]
These measurements provide valuable information as a reference for understanding the anatomical positioning of the ACL and for planning surgical interventions like graft placements in ACL reconstruction.[23]

The normal ACL appears homogenously hypointense on both T1 & T2 weighted images and this hypointensity of the ligament indicates its dense organized collagenous architecture. If there is any difference in the signal intensity changes from this uniform low signal in the form of areas of increased signal intensity, it can attribute to pathological changes that includes partial tears or mucoid degeneration. However, factors such as patient age, imaging parameters and magic angle effects can cause variations in signal intensity.[24]

The imaging appearance of ACL can vary depending upon the position of the knee at the time of scanning. In normal individuals, when the knee is in extension, the ACL often appears convex posteriorly as opposed to when the knee is in flexion, the ACL becomes straighter in configuration. It is important to understand that this dynamic change is a normal physiological response and should not be misdiagnosed as pathological.[25]

On the other hand in patients with ACL grafts, when the knee is in extension, the graft may have straight configuration, and when the knee is flexion, the ACL will show an anterior convexity which is in contrast as compared to the native ACL's behavior. Knowledge of these morphological variations in different patients can help to distinguish between normal anatomical variants and true pathological conditions.[25]

MRI EVALUATION OF THE ANTERIOR CRUCIATE LIGAMENT INJURY:

The utilization of optimal sequences and imaging planes play a very important role in the correctly detecting ACL injuries. Proton density (PD) and T2 weighted sequences are important for the assessment of ACL, because they help in creating excellent contrast between the ligament and surrounding tissues.[26]

T2 weighted images and T2 weighted images with fat suppression helps in giving valuable information with regard to the presence of fluid within the ligament which represents injury.[26]

A typical standard protocol for evaluation of ACL includes axial T2 turbo spin echo fat saturated, sagittal proton density turbo spine echo, sagittal T2 turbo spin echo fat saturated, coronal T1 spin echo, coronal T2 turbo spin echo fat saturated, coronal-oblique turbo spin echo proton density and sagittal 3D SPACE sequences.[26]

T1 weighted images are usually acquired without fat suppression and are ideal for analyzing the anatomy.[27]

The sagittal plane is essential in visualizing the course and continuity of the ACL. Oblique sagittal images which are oriented parallel to the ACL is helpful in providing optimal assessment of the anteromedial (AM) and posterolateral (PL) bundles of ACL.[26]

For assessing the femoral and tibial attachment sites of ACL, the coronal plane is helpful. The oblique coronal sequences which are oriented along the long axis of the ACL, improve the ability to correctly detect partial tears as well as bundle-specific injuries.[26]

Axial plane is helpful in the assessment of the orientation of ACL and other associated injuries, such as injuries to the posterior cruciate ligament, medial meniscus or lateral meniscus. They also help in identifying presence of fluid in the femoral and tibial tunnels, which are particularly helpful in patients post ACL reconstruction, as it may suggest the possibility of graft issues.[26]

The diagnostic accuracy of MRI in detecting ACL tear can be improved by the addition of oblique imaging planes. Various studies have been able to show that the addition of oblique sagittal and coronal planes can aid in good visualization of the ACL, thus improving the diagnostic accuracy in detecting ACL tears.[27]

PRIMARY SIGNS IN MRI IN THE DIAGNOSIS OF ACL TEAR:

Increased Signal Intensity: A tear of the ACL results in hyperintensity of the ACL on T2- weighted images representing edema within it suggestive of damage to the ACL fibers.[28]

In a study conducted by Zhao M et al, increased signal intensity (which was referred to as "thickening and edema") showed a sensitivity of 83.33% and a specificity of 91.67%.[10]

Abnormal Axis: The orientation of the ACL can be calculated by measuring the angle between the ligament and Blumensaat's line (a line drawn along the roof of the intercondylar fossa of the femur) on a sagittal MRI image which is known as the ACL-Blumensaat line angle. In a normal patient, the ACL has an inclination of about 0° to 15°. In cases of ACL tear, the ligament tends to assumes a more horizontal orientation thereby resulting in an increased ACL-Blumensaat line angle. Studies show that an ACL-Blumensaat line angle greater than 15° is likely suggestive of ACL tear.[29]

In a study conducted by Mellado JM et al, the abnormal axis was found to have a sensitivity of 90% and a specificity of 98%.[30]

Fiber Discontinuity: Complete ACL tears on MRI are usually present with disruption in the fiber continuity within the ligament which is suggestive of a complete ACL tear.[31]

In a study conducted by Zhuang et al, the sensitivity and specificity of MRI for fiber discontinuity sign was found to be 73.89% and 96.81% respectively.[32]

SECONDARY SIGNS IN ACL TEAR:

Bone contusion: It is commonly observed as a secondary sign in ACL tears which occur as a result of the impact between the articular surfaces of the tibia and femur during the event of injury to the ligament that is visible on MRI in the form of areas of increased signal intensity on fluid sensitive sequences like T2-weighted images.[33]

On histological correlation of the MRI findings, tissue alterations has been noted in the form of microfractures of the subarticular spongiosa, necrosis of osteocytes and bone marrow edema.[33]

In a study conducted by Filardo G et al, the sensitivity and specificity of bone contusions was found to be approximately 83% and 96% respectively.[33]

Anterior tibial translation: On MRI, it is assessed by measuring the distance between the line drawn from posterior cortex of the tibia and the posterior cortex of the femur on sagittal MRI images at the level of the lateral condyle of the femur. [34] The resultant measurement denotes the magnitude of anterior displacement of the tibia relative to the femur. A forward displacement of more than or equal to 7 millimeters is considered to be a positive indicator of ACL injury.[34]

In a study conducted by Vahey et al, forward translation of the tibia relative to the femur by 5 millimeters or more was found to have high specificity (93%), high positive predictive value (95%) and moderate sensitivity (58%) for ACL tear while forward translation of the tibia of 7 millimeters or more was found to have 100% specificity and positive predictive value for the presence of an ACL tear.[35]

Uncovering of posterior horn of lateral meniscus: On MRI, in sagittal plane, if a vertical line drawn tangent to the posterior margin of the cortex of the lateral tibial plateau intersects any part of the posterior horn of the lateral meniscus, this sign is considered to be present.[36]

In a study conducted by Tung et al, the uncovering of the posterior horn of lateral meniscus was found to have 100 % specificity and 18 % sensitivity.[24]

Buckling of posterior cruciate ligament (PCL): On sagittal plane, while evaluating patients with ACL tears, if the vertical component of the PCL becomes more upright due to increased anterior tibial translation, it is called as buckling of the PCL. The PCL angle (PCLA) can be calculated for confirming this finding. To calculate the extent of this secondary sign, an another measurement, called as the PCL-posterior cortex angle (PCL-PCA) has shown to have higher sensitivity and specificity.[37]

The PCLA is the angle that is present between a line that is drawn through the central aspect of the femoral insertion of the PCL and a line drawn through the central aspect of the PCL along its tibial insertion. The PCL-PCA angle is assessed in the sagittal plane at the tibial insertion of the PCL along its extreme lateral aspect. The angle is measured between a line drawn from the posterior cortex of the diaphysis of the femur and a line that is drawn parallel to the central portion of the vertical most part of the PCL.[37]

In a study conducted by Tokgoz MA et al, the cut off value for PCLA and PCL-PCA for distinguishing partial ACL tears from normal ACL was 123.13° and 23.77 ° respectively while the values were 113.88° and 16.39° for distinguishing partial tears from complete ACL tears respectively.[37]

The study showed that if the PCLA values were between 113.88 ° and 123.13 ° and PCL-PCA values were between 16.39 ° and 23.77 ° it was considered as partial tear. If the values for PCLA and PCL-PCA were less than 113.88° and 16.39 ° respectively, it was considered as complete tear.[37]

The sensitivity and specificity for detecting partial tears from normal ACL based on PCLA and PCL-PCA was 86.8 % & 89.9 % and 94.5 & 93.2 % respectively while the sensitivity and specificity for detecting complete tears from normal ACL based on PCLA and PCL-PCA was 79.5 % & 78.4 % and 86.1 & 85.3 % respectively.[37]

Deep lateral femoral notch sign: To assess the presence of this sign, the articular surface of the lateral femoral condyle is first identified and then a tangential line is drawn across its sulcus and the measurement is taken from this line to the deepest point of the sulcus. Depth greater than 1.5 millimeters is considered as abnormal and indicates a positive sign.[36]

In a study conducted by Gentili et al, deep lateral femoral notch sign was found to have a sensitivity of 19 % and specificity of 100 %.[38]

PARTIAL ACL TEAR:

Partial ACL tears on MRI shows varying imaging features and may not have all the typical characteristic signs that we come across as in a case of complete ACL tear. In comparison to complete ACL tears, partial ACL tears usually have some intact fibers within the ligament. This helps to differentiate partial ACL tears from complete ACL tear, wherein the continuity is completely lost.[39]

Thinning of the ACL as compared to the contralateral side may indicate partial loss of the fiber, although the ligamentous continuity is maintained. A wavy or curved contour of the ligament indicates laxity and partial fiber tear, which is unlike the normal straight and firm appearance of the ligament.[39]

Increased signal intensity on T2-weighted images within the ligament is often observed due to edema or fiber disruption.[39]

Also the presence of residual straight and tight fibers if visualized in at least one imaging plane indicates that there are portions of the ligament that are intact despite some damage to the fibers.[39]

The "gap" sign, which is a focal discontinuity and the "footprint" sign which is an abnormal signal at the tibial attachment of the ACL are specific imaging features that are characteristic of tears of the posterolateral bundle.[39]

The diagnostic performance of MRI in the detecting partial tears showed variability across multiple studies.

In one study conducted by Umans et al, the sensitivity and specificity for detecting partial ACL tears by MRI in comparison to arthroscopy ranged from 40 % to 75 % and 62 % to 89 % respectively.[40]

A recent study conducted by Jog AV et al, the sensitivity and specificity of MRI in detecting partial ACL tears in comparison to arthroscopy was found to be 90.9 % and 85.7 % respectively.[41]

In an another study conducted by Van Dyck et al, using 3 Tesla MRI, the sensitivity, specificity and accuracy of detecting partial ACL tears was found to be 77%, 97% and 95% respectively.[42]

ARTHROSCOPY:

A normal ACL is a tense, continuous band of fibers originating from the medial aspect of the lateral femoral condyle and extending obliquely till the tibial plateau with a consistent tension that is maintained in the ligament through its range of motion, particularly tightening of the ligament during the process of extension of the knee joint during arthroscopy.[43]

The techniques of arthroscopy are of great importance in the surgical management of ACL tears. ACL reconstruction via arthroscopy is an accurate and demanding surgical procedure wherein meticulous graft positioning is vital to achieve optimal stability of knee and to restore the function of the knee joint. Therefore, a very high degree of surgical expertise is required.[44]

Partial ACL tears often cause diagnostic and therapeutic challenges. Arthroscopy helps in direct evaluation of the magnitude of the tear and helps in deciding the ideal management strategy in such cases.[45]

A detailed analysis helped to understand that partial tears show distinct clinical features which included an asymmetric Lachmann's test and negative pivot shift test, highlighting the important role of arthroscopic evaluation in verifying these findings and helping in treatment decision making.[45]

Arthroscopy is regarded as the gold standard for identifying internal knee abnormalities including ACL tears, providing direct visualization of the structures within the knee joint and allowing detailed assessment of the integrity of the ligament.[46]

But due to its invasiveness, arthroscopy typically is only performed in those conditions where magnetic resonance imaging (MRI) does not provide a definitive result.[46]

MANAGEMENT:

Injury to the anterior cruciate ligament can have a severe impact in a patient in the form of poor knee functioning, decreased physical activity, and can even affect the long term quality of life of the patient. The approach to the management of ACL tear should include both surgical and non-surgical methods.[47]

For each person the decision making process must be unique which must include meetings between clinicians and patients with the main objective being to restore the knee function, to look into the emotional obstacles of the patient to perform physical activities again and to reduce the risk of future knee injuries as well as osteoarthritis while ensuring long term benefits to the patient.[47]

Rehabilitation has a very important role in the management of ACL tears, irrespective of whether the patient undergoes an ACL reconstruction or conservative treatment. A structured rehabilitation program should begin as quick as possible immediately after injury, giving importance to restoring the stability of the knee, muscle strength and proprioception. Being able to achieve specific clinical and functional milestones are more important considerations in terms of progression in rehabilitation rather than a fixed time frame.[47]

While ACL reconstruction is usually performed to restore the stability of knee joint in active individuals, especially those who take part in pivoting or high-impact sports, the evidence suggests that the long-term outcomes are similar between those patients who undergo an ACL reconstruction with rehabilitation and those who are under a rehabilitation only approach. So it is important to know that the decision to go ahead with surgery should be based on individual patient needs, lifestyle as well as functional goals.[47]

MATERIALS AND METHODS

A prospective study of 50 patients was conducted at the department of Radiology, KLE Dr Prabhakar Kore's Hospital and Medical Research Centre in Belgaum from January 1st to December 31st of 2024

Study design: A one year hospital based cross sectional study.

Source of data: Patients that were referred from the in-patient and out-patient departments of Orthopedics with history of suspected anterior cruciate ligament tears who underwent MRI knee joint and arthroscopic examination.

Sample size: A total 50 patients fulfilling the selection criteria and willing to undergo MRI knee joint were studied. Universal sampling was employed to calculate the sample size based on previous hospital data records (the number of cases of ACL tears posted for arthroscopy during the period of one year was 50)

Study period and duration: The study was carried out from January 1st, 2024 to December 31st, 2024.

Sampling procedure: Universal sampling

Ethical clearance and informed consent: Informed consent were obtained from the patients and the study was conducted following the ethical regulations & with patient's full cooperation.

Sampling data: Through an interview, the study population's demographic details such as age, sex, occupation were gathered along with comprehensive history of the presenting illness.

Inclusion criteria:

1. All patients referred from the Department of Orthopedics with suspected ACL injuries and followed up with Arthroscopy.

Exclusion criteria:

1. Patients with unstable vitals in the setting of trauma
2. Patients suffering from degenerative knee disease
3. Patients with history of claustrophobia
4. Patients with contraindications to MRI such as having metallic foreign body in situ.
5. Patient with prior history of surgeries or arthroscopy.

Imaging using MRI: All 50 patients were subjected to MRI examination. MRI knee was performed using Siemens 3 Tesla MRI (Magnetom Spectra) machine (Erlangen, Germany) using knee coil and the MRI findings were correlated with the arthroscopic findings.

METHOD

Patient is positioned in the supine position with extension of knee and angulation of the knee at 5 to 10 degree of external rotation.

MRI TECHNIQUE USED:

A scout axial view was performed in order to execute the sagittal and coronal sections that are perpendicular and parallel to the posterior femoral condylar lines respectively in order to appreciate the oblique course of the ACL.

The following sequences were used for the evaluation of ACL tear:

1. <u>T2 WEIGHTED SEQUENCE:</u>

TE - 67 ms

TR - 5150 ms

Slice thickness - 3.0 mm

FOV - 140 mm

Number of slices - 22

Time duration - 2 minutes & 31 seconds

2. <u>PROTON DENSITY SEQUENCE:</u>

TE - 36 ms

TR - 3600 ms

Slice thickness - 3.0 mm

FOV - 140 mm

Number of slices - 25

Time duration - 3 minutes & 56 seconds

3. <u>PROTON DENSITY FATSAT SEQUENCE:</u>

TE - 31 ms

TR - 4000 ms

Slice thickness - 3.0 mm

FOV - 100 mm

Number of slices - 30

Time duration - 3 minutes & 26 seconds

4. <u>T1 SEQUENCE:</u>

TE - 12 ms

TR - 650 ms

Slice thickness - 3.0 mm

FOV - 140 mm

Number of slices - 25

Time duration - 2 minutes & 8 seconds

5. <u>SHORT TAU INVERSION RECOVERY SEQUENCE:</u>

TE - 19 ms

TR - 3000 ms

Slice thickness - 3.0 mm

FOV - 100 mm

Number of slices - 30

Time duration - 2 minutes & 56 seconds

STATISTICAL ANALYSIS AND RESULTS

The diagnostic accuracy of MRI in detecting ACL tear was compared with arthroscopy and the results were analyzed using contingency tables. Primary and secondary signs for ACL tear in MRI were also analyzed and correlated with the arthroscopic findings.

The arthroscopic report was accepted as the gold standard against which the findings of the MRI were compared.

The sensitivity, specificity, positive predictive value, negative predictive value and accuracy were calculated for MRI in diagnosing ACL tears in correlation with arthroscopy. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy were also calculated for each of the primary and secondary signs of ACL tear in MRI.

Cohen's kappa coefficient was used to compare the correlation between MRI and Arthroscopy. Following Landis and Koch's criteria, values of kappa were classified as slight agreement (less than 0.2), fair agreement (0.21 – 0.40), moderate agreement (greater than 0.41 - 0.60), substantial agreement (0.61 - 0.80) and almost perfect agreement (>0.80).

For data analysis, statistical software was used to evaluate the diagnostic accuracy of MRI in detecting ACL tears keeping arthroscopy as the gold standard. It was used to calculate various metrics such as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy and Cohen's kappa coefficient. Microsoft excel was also used to create bar graphs & pie charts for demonstrating the patient demographics, location of ACL tear, associated injuries as well as the primary and secondary signs of MRI in ACL tear. A Receiver Operating Characteristic (ROC) curve was also created to evaluate the overall diagnostic performance of MRI in comparison to Arthroscopy.

TABLE 1

GENDER DISTRIBUTION OF PATIENTS WITH ACL TEAR

	MALE	FEMALE	TOTAL
TEAR	38	4	42
NORMAL	5	3	8
TOTAL	43	7	50

Table 1 demonstrates the gender distribution in which males (86%) were more affected than females (14%), with ACL tears more common in males (90.5%).

FIGURE 1

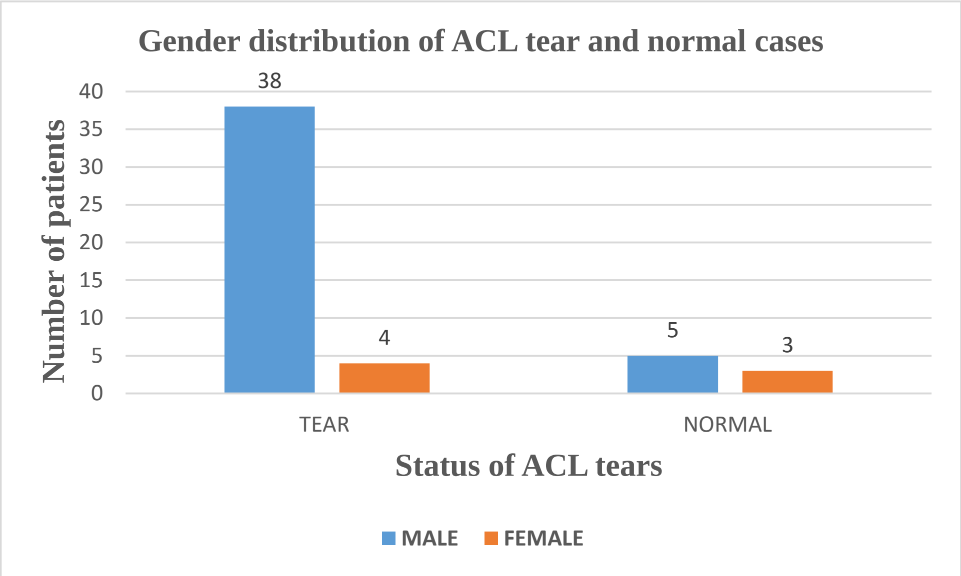

Figure 1 depicts the gender distribution of patients with ACL tear. 38 male patients had ACL tear while 5 male patients had a normal ACL. 4 female patients had an ACL tear while 3 had a normal ACL.

TABLE 2

AGE DISTRIBUTION OF PATIENTS WITH ACL TEAR

SL NO	AGE GROUP	NUMBER OF PATIENTS WITH ACL TEAR
1	< 20	2
2	20-29	8
3	30-39	14
4	40-49	10
5	> or = 50	8

Table 2 demonstrates that ACL tears were most common in the 30 to 39 years of age group (33% of patients)

FIGURE 2

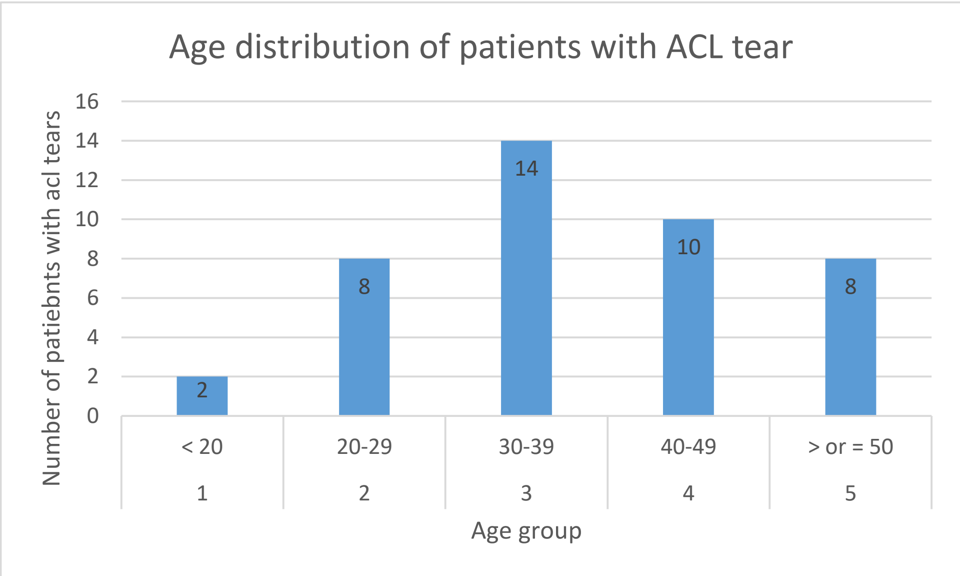

Figure 2 depicts the distribution of patients with ACL tear according to their age group. 14 patients belonged to the age group of 30 - 39. 10 patients belonged to the age group of 40 - 49. 8 patients belonged to the age group of 20 - 29. 8 patients belonged to the age group of more than or equal to 50 and only 2 patients belonged to the age group less than 20.

TABLE 3

DISTRIBUTION OF PATIENTS ACCORDING TO INVOLVED KNEE JOINT

SIDE	TEAR	NORMAL	TOTAL
LEFT	18	5	23
RIGHT	24	3	27
TOTAL	42	8	50

Table 3 demonstrates the distribution the of side of the involved knee in which ACL tears were more common in the right knee (57%) than the left knee (43%).

FIGURE 3

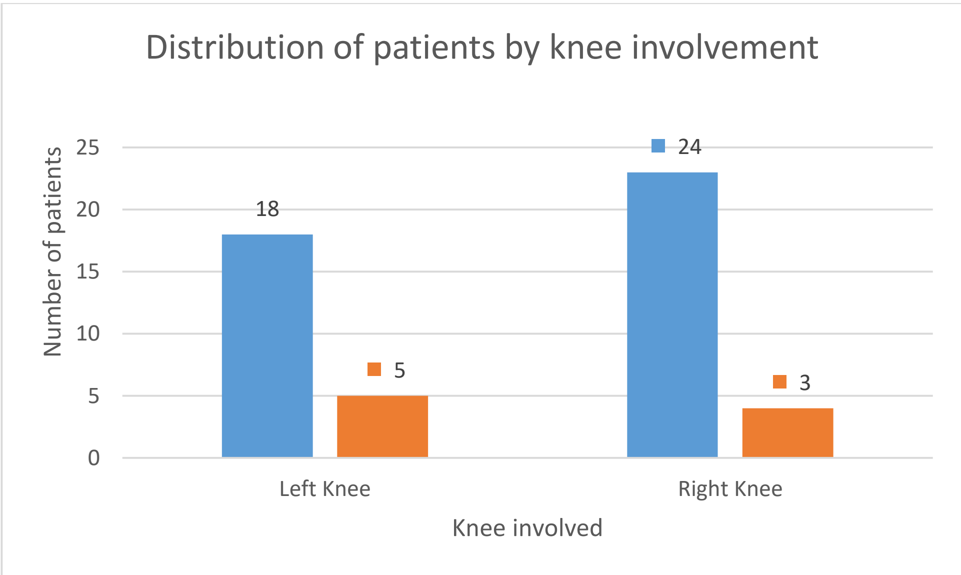

Figure 3 depicts the distribution of patients according to side of knee involved. In patients with left knee involvement, ACL tear was present in 18 cases and a normal ACL was present in 5 cases. In patients with right knee involvement, ACL tear was present in 24 cases and normal ACL was present in 3 cases.

TABLE 4

COMPARISION BETWEEN MRI DIAGNOSIS AND ARTHROSCOPIC DIAGNOSIS OF ACL TEAR

MRI	ARTHROSCOPY			TOTAL
	NORMAL	PARTIAL TEAR	COMPLETE TEAR	
NORMAL	7	1	0	8
PARTIAL TEAR	1	5	10	16
COMPLETE TEAR	0	2	24	26
TOTAL	8	8	34	50

Table 4 demonstrates the comparison of MRI and arthroscopy in the diagnosis of ACL tear. Out of 26 cases of complete ACL tear on MRI, 24 cases were diagnosed as complete ACL tear and 2 cases were diagnosed as partial ACL tear on arthroscopy. Out of the 16 cases of partial ACL tear on MRI, only 5 cases were diagnosed as partial ACL tear while 10 cases were diagnosed as complete ACL tears and 1 case was diagnosed as normal ACL on arthroscopy. Out of the 8 cases of normal ACL on MRI, 7 cases were diagnosed as normal ACL and 1 case was diagnosed as a partial ACL tear on arthroscopy .

FIGURE 4

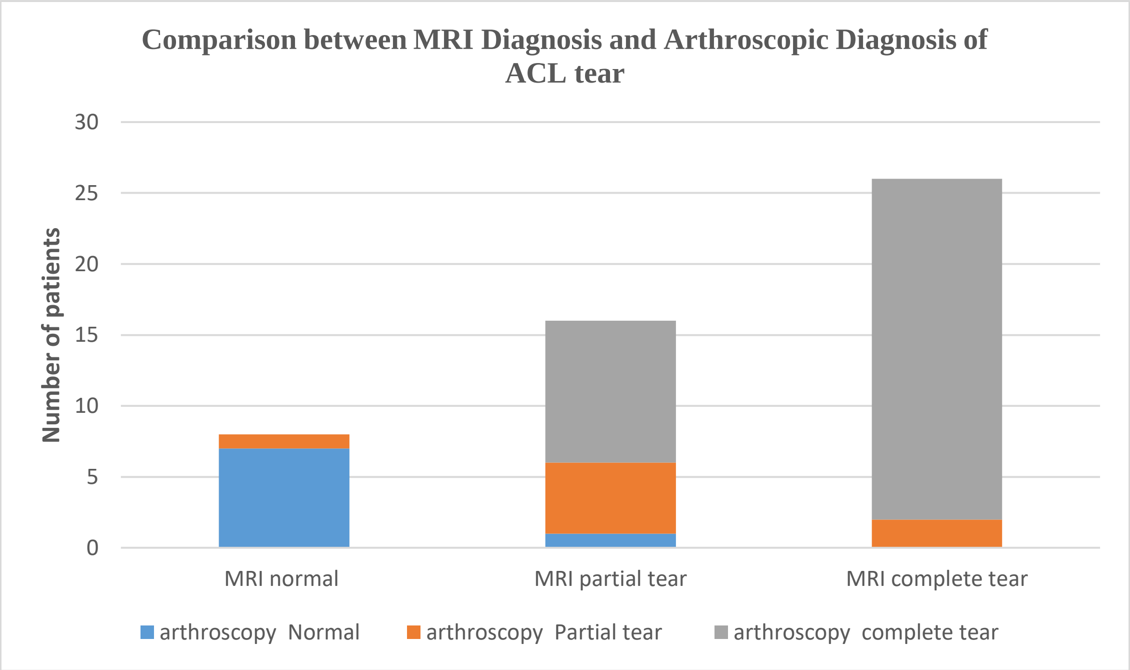

Figure 4 depicts the comparison between MRI and arthroscopy results in the diagnosis of ACL tear.

TABLE 5

LOCATION OF THE ACL TEAR ON MRI IN ARTHROSCOPICALLY PROVEN CASES

LOCATION OF ACL TEAR ON MRI	ARTHROSCOPY		
	PARTIAL TEAR	COMPLETE TEAR	TOTAL
MID-SUBSTANCE	7	19	26
FEMORAL ATTACHMENT	1	11	12
TIBIAL ATTACHMENT	0	4	4
TOTAL	8	34	42

Table 5 demonstrates the distribution of location of the tear within the ACL which showed that the mid-substance was the most common location of ACL tears followed by femoral and tibial attachments.

FIGURE 5

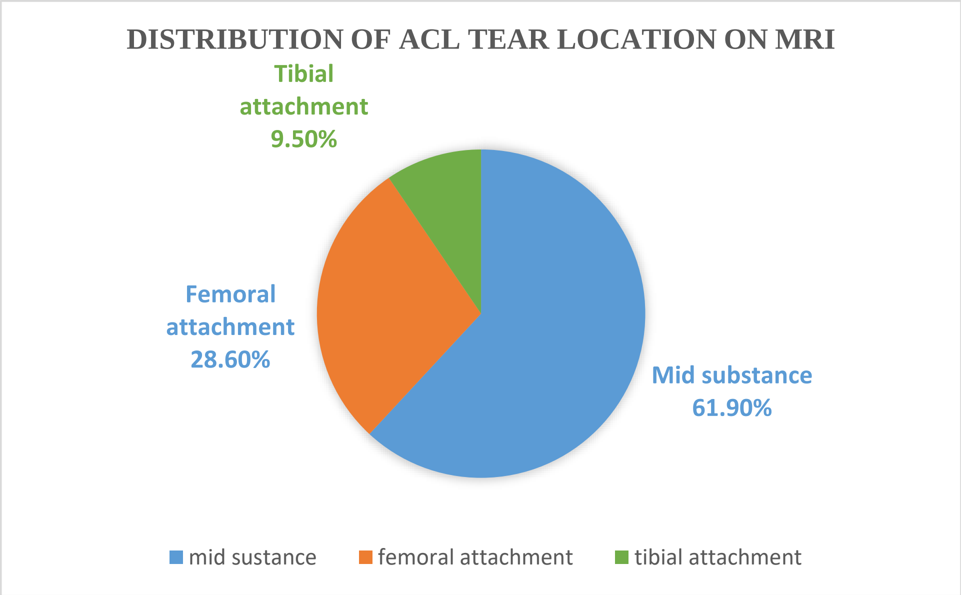

Figure 5 depicts the distribution of patients according to the site of involvement within the ACL. 61.9 % patients had a mid-substance ACL tear, 28.6 % patients had a femoral attachment ACL tear and 9.5 % patients had a tibial attachment ACL tear.

TABLE 6

OTHER ASSOCIATED INJURIES ON MRI IN ARTHROSCOPICALLY PROVEN CASES

ASSOCIATED INJURIES ON MRI	ARTHROSCOPY		
	PARTIAL TEAR	COMPLETE TEAR	TOTAL
MEDIAL MENISCUS	1	11	12
LATERAL MENSICUS	1	12	13
MCL	0	3	3
PCL	1	3	4
LCL	0	9	9
TOTAL	3	38	41

Table 6 demonstrates the other associated injuries on MRI in ACL tear, which showed that the most common associated injury was lateral meniscus (32%), followed by medial meniscus (29%), LCL (22%), PCL (10%), and MCL (7%)

FIGURE 6

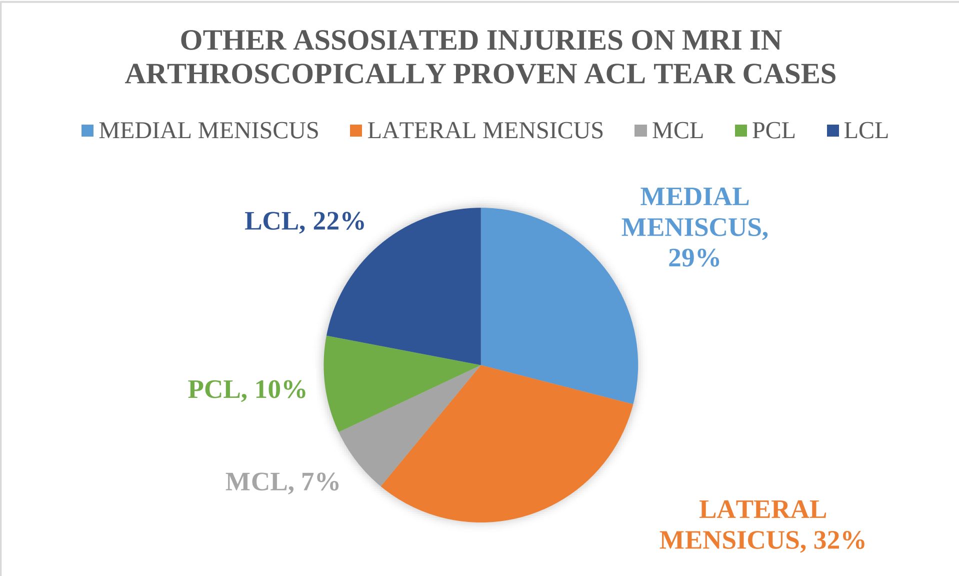

Figure 6 depicts the distribution of the associated injuries on MRI in arthroscopically proven cases of ACL tear in which 32 % of patients had a lateral meniscus injury, 29% of patients had a medial meniscus injury, 22% of patients had a LCL injury, 10% of patients had PCL injury and 7% of patients had MCL injury.

TABLE 7

COMPARISION BETWEEN MRI AND ARTHROSCOPY FOR DIAGNOSIS OF ACL TEAR

MRI	ARTHROSCOPY		
	TEAR	NORMAL	TOTAL
TEAR	41	1	42
NORMAL	1	7	8
TOTAL	42	8	50

Parameter	Value	95% Confidence Interval
Sensitivity	97.6%	(87.1 - 99.9)
Specificity	87.5%	(47.3 - 99.7)
PPV	97.6%	(87.1 - 99.9)
NPV	87.5%	(47.3 - 99.7)
Accuracy	95.0%	(83.1 - 99.4)
Kappa	0.85	-

Table 7 demonstrates the diagnostic accuracy of MRI by comparing ACL tear and normal ACL cases on MRI with ACL tear and normal ACL cases on arthroscopy. MRI had high diagnostic accuracy for ACL tears, with a sensitivity of 97.6%, specificity of 87.5%, and overall accuracy of 95%, showing almost perfect agreement with arthroscopy (Kappa = 0.85).

REVIEVER OPERATING CHARACTERSTICS (ROC) CURVE FOR CALCULATING THE OVERALL DIAGNOSTIC ACCURACY OF MRI IN DETECTING ACL TEARS IN COMPARISON TO ARTHROSCOPY

FIGURE 7

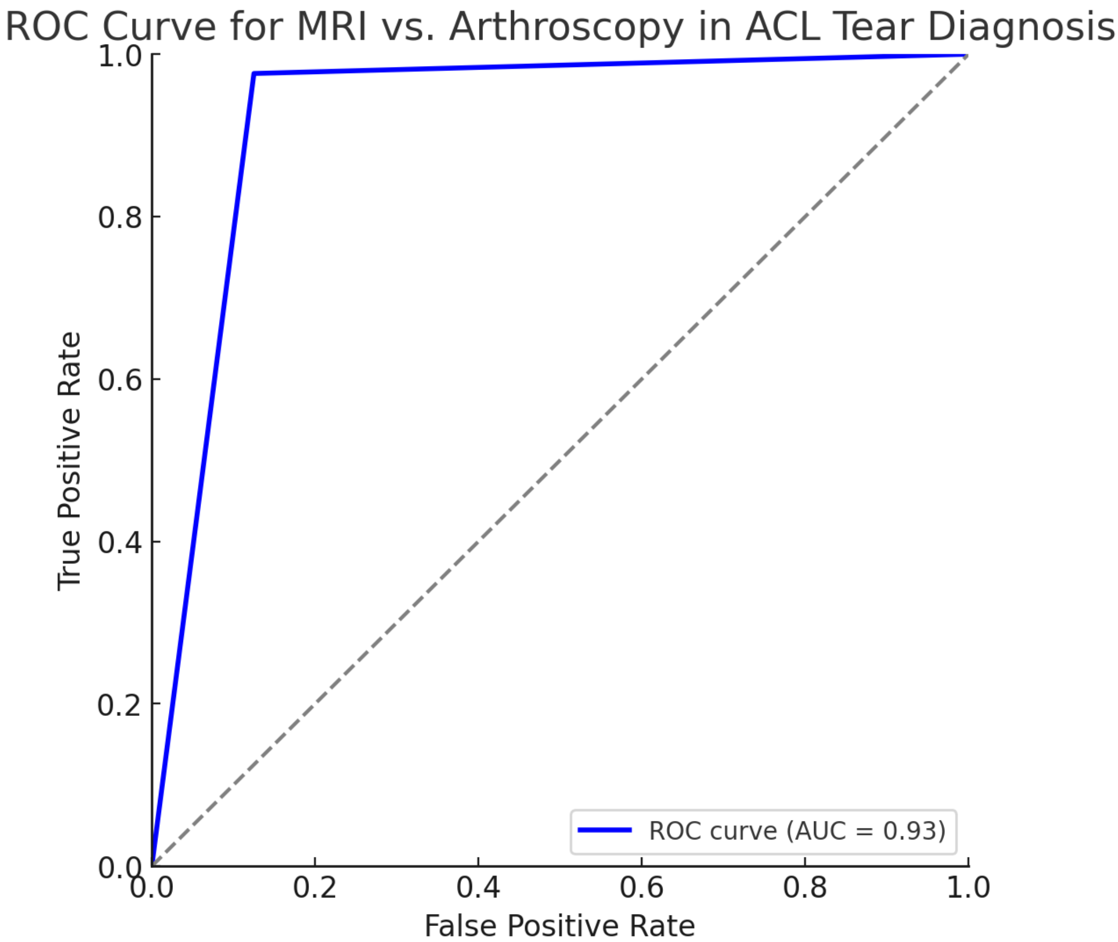

Figure 7 - demonstrates the area under curve (AUC) = 0.93 (indicating excellent diagnostic accuracy in detecting ACL tear with a high degree of differentiation between true positive and false positives)

TABLE 8

COMPARISON BETWEEN MRI AND ARTHROSCOPY FOR DIAGNOSIS OF COMPLETE ACL TEAR

MRI	ARTHROSCOPY		
	COMPLETE TEAR	NORMAL	TOTAL
COMPLETE TEAR	24	0	24
NORMAL	0	7	7
TOTAL	24	7	31

Parameter	Value	95% Confidence Interval
Sensitivity	100%	(86.2 - 100)
Specificity	100%	(64.6 - 100)
PPV	100%	(86.2 - 100)
NPV	100%	(64.6 - 100)
Accuracy	100%	(88.9 - 100)
Kappa	1.0	-

Table 8 demonstrates the diagnostic accuracy of MRI in detecting complete ACL tear by comparing the complete ACL tear and normal ACL cases on MRI with complete ACL tears and normal ACL cases on arthroscopy. MRI had achieved 100% sensitivity, specificity, and accuracy in diagnosing complete ACL tears, showing perfect agreement with arthroscopy (Kappa = 1.0)

TABLE 9

COMPARISON BETWEEN MRI AND ARTHROSCOPY FOR THE DIAGNOSIS OF PARTIAL ACL TEAR

MRI	ARTHROSCOPY		
	PARTIAL TEAR	NORMAL	TOTAL
PARTIAL TEAR	5	1	6
NORMAL	1	7	8
TOTAL	6	8	14

Parameter	Value	95% Confidence Interval
Sensitivity	83.3%	(35.9 - 99.6)
Specificity	87.5%	(47.3 - 99.7)
PPV	83.3%	(35.9 - 99.6)
NPV	87.5%	(47.3 - 99.7)
Accuracy	85.7%	(48.7 - 97.4)
Kappa	0.71	-

Table 9 demonstrates the diagnostic accuracy of MRI in detecting partial ACL tear by comparing the partial ACL tear and normal ACL cases on MRI with partial ACL tear and normal ACL cases on arthroscopy. MRI had moderate diagnostic accuracy for partial ACL tears, with a sensitivity of 83.3%, specificity of 87.5%, and overall accuracy of 85.7%, showing substantial agreement with arthroscopy (Kappa = 0.71).

TABLE 10

DISTRIBUTION OF THE PRIMARY SIGNS OF ACL TEAR IN MRI AMONG ARTHROSCOPICALLY PROVEN CASES OF ACL TEAR

PRIMARY SIGNS IN MRI	ACL TEAR ON ARTHROSCOPY (TOTAL = 42)
INCREASED SIGNAL INTENSITY	41
ABNORMAL AXIS	32
DISCONTINUITY OF FIBRES	30

Table 10 demonstrates that increased signal intensity was present in 41 out of the 42 cases, abnormal axis was present in 32 out of the 42 cases and discontinuity of fibers was preset in 30 out of the 42 cases. The most common primary sign of ACL tears was increased signal intensity (seen in 98% the ACL tear cases) followed by abnormal axis (seen in 76% of the ACL tear cases) and discontinuity of fibers (seen in 71% of the ACL tear cases).

FIGURE 8

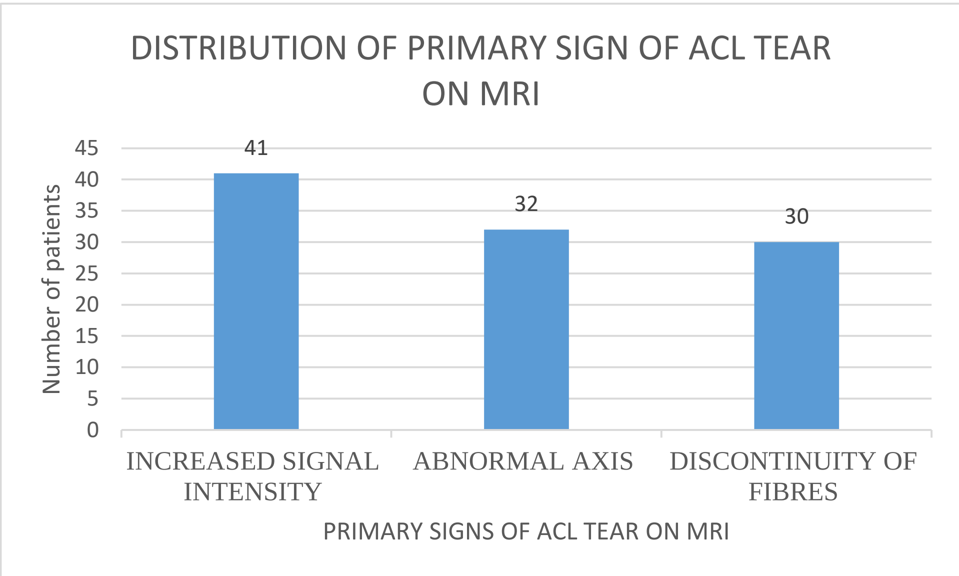

Figure 8 depicts the distribution of the primary signs of ACL tear in arthroscopically proven cases of ACL tear.

TABLE 11

PRESENCE / ABSENCE OF INCREASED SIGNAL INTENSITY IN ARTHROSCOPICALLY PROVEN CASES OF COMPLETE ACL TEAR

INCREASED SIGNAL INTENSITY	ARTHROSCOPY		
	COMPLETE TEAR	NORMAL	TOTAL
PRESENT	34	2	36
ABSENT	0	6	6

Parameter	Value	95% Confidence Interval
Sensitivity	100%	(89.7 - 100)
Specificity	75%	(30.1 - 95.4)
PPV	94.4%	(82.3 - 98.6)
NPV	100%	(51.7 - 100)
Accuracy	95.0%	(83.1 - 99.4)
Kappa	0.80	-

Table 11 demonstrates that increased signal intensity had high sensitivity (100%) and accuracy (95%) for detecting complete ACL tears, though specificity was lower (75%), indicating some false positives. Agreement with arthroscopy was strong (Kappa = 0.80).

TABLE 12

PRESENCE / ABSENCE OF ABNORMAL AXIS IN ARTHROSCOPICALLY PROVEN CASES OF COMPLETE ACL TEAR

ABNORMALAXIS	ARTHROSCOPY		
	COMPLETE TEAR	NORMAL	TOTAL
PRESENT	29	0	29
ABSENT	5	8	13

Parameter	Value	95% Confidence Interval
Sensitivity	85.3%	(69.7 - 93.9)
Specificity	100%	(59.0 - 100)
PPV	100%	(88.1 - 100)
NPV	61.5%	(34.1 - 83.4)
Accuracy	89.0%	(74.6 - 96.1)
Kappa	0.77	-

Table 12 demonstrates that an abnormal axis had high specificity (100%) and accuracy (89%) for detecting complete ACL tears, though sensitivity was slightly lower (85.3%). Agreement with arthroscopy was substantial (Kappa = 0.77).

TABLE 13

PRESENCE / ABSENCE OF DISCONTINUITY IN ARTHROSCOPICALLY PROVEN CASES OF COMPLETE ACL TEAR

DISCONTINUITY	ARTHROSCOPY		
	COMPLETE TEAR	NORMAL	TOTAL
PRESENT	28	0	28
ABSENT	6	8	14

Parameter	Value	95% Confidence Interval
Sensitivity	82.4%	(66.1 - 92.0)
Specificity	100%	(59.0 - 100)
PPV	100%	(87.2 - 100)
NPV	57.1%	(30.4 - 80.2)
Accuracy	86.0%	(71.3 - 94.3)
Kappa	0.73	-

Table 13 demonstrates that discontinuity of fibers had high specificity (100%) and accuracy (86%) for detecting complete ACL tears, though sensitivity was slightly lower (82.4%). Agreement with arthroscopy was substantial (Kappa = 0.73).

TABLE 14

DISTRIBUTION OF THE SECONDARY SIGNS FOR ARTHROSCOPICALLY PROVEN CASES OF ACL TEAR

SECONDARY SIGNS IN MRI	ACL TEAR ON ARTHROSCOPY (TOTAL = 42)
BONE CONTUSION	24
ANTERIOR TRANSLATION OF TIBIA	25
UNCOVERED POSTERIOR HORN OF LATERAL MENISCUS	25
PCL BUCKLING	27
DEEP LATERAL FEMORAL NOTCH	6

Table 14 demonstrates that the most common secondary signs of ACL tears was PCL buckling (64%) followed by uncovered posterior horn of the lateral meniscus (60%), anterior tibial translation (60%) and bone contusion (57%) while deep lateral femoral notch (14%) was less frequent.

FIGURE 9

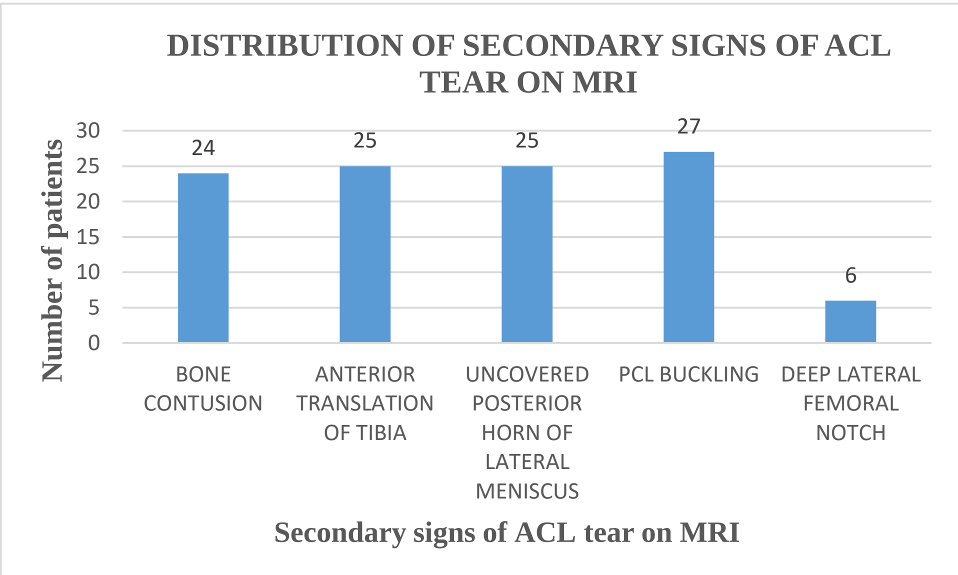

Figure 9 depicts the distribution of secondary signs of ACL tear in arthroscopically proven cases of ACL tear.

TABLE 15

PRESENCE / ABSENCE OF BONE CONTUSION IN ARTHROSCOPICALLY PROVEN CASES OF ACL TEAR

BONE CONTUSION	ARTHROSCOPY		
	TEAR	NORMAL	TOTAL
PRESENT	24	2	26
ABSENT	18	6	24

Parameter	Value	95% Confidence Interval
Sensitivity	57.1%	(42.2 - 70.9)
Specificity	75.0%	(40.9 - 92.9)
PPV	92.3%	(75.9 - 97.9)
NPV	25.0%	(12.0 - 44.9)
Accuracy	60.0%	(46.2 - 72.4)
Kappa	0.18	-

Table 15 demonstrates that bone contusion had a high positive predictive value (92.3%) but low sensitivity (57.1%) and moderate specificity (75%) for detecting ACL tears, with slight agreement with arthroscopy (Kappa = 0.18)

TABLE 16

PRESENCE / ABSENCE OF ANTERIOR TIBITAL TRANSLATION IN ARTHROSCOPICALLY PROVEN CASES OF ACL TEAR

ANTERIOR TIBIAL TRANSLATION	ARTHROSCOPY		
	TEAR	NORMAL	TOTAL
PRESENT	25	0	25
ABSENT	17	8	25

Parameter	Value	95% Confidence Interval
Sensitivity	59.5%	(42.1 - 75.0)
Specificity	100%	(63.1 - 100)
PPV	100%	(84.5 - 100)
NPV	32.0%	(14.9 - 55.2)
Accuracy	70.0%	(52.7 - 83.5)
Kappa	0.40	-

Table 16 demonstrates that anterior tibial translation had high specificity (100%) and positive predictive value (100%) for detecting ACL tears, but sensitivity was moderate (59.5%), resulting in fair agreement with arthroscopy (Kappa = 0.40).

<u>**TABLE 17**</u>

PRESENCE / ABSENCE OF UNCOVERED POSTERIOR HORN OF LATERAL MENISCUS IN ARTHROSCOPICALLY PROVEN CASES OF ACL TEAR

UNCOVERED POSTERIOR HORN F LATERAL MENISCUS	ARTHROSCOPY		
	TEAR	NORMAL	TOTAL
PRESENT	25	0	25
ABSENT	17	8	25

Parameter	Value	95% Confidence Interval
Sensitivity	59.5%	(42.1 - 75.0)
Specificity	100%	(63.1 - 100)
PPV	100%	(84.5 - 100)
NPV	32.0%	(14.9 - 55.2)
Accuracy	70.0%	(52.7 - 83.5)
Kappa	0.40	-

Table 16 demonstrates that uncovering of posterior horn of lateral meniscus had high specificity (100%) and positive predictive value (100%) for detecting ACL tears, but sensitivity was moderate (59.5%), resulting in fair agreement with arthroscopy (Kappa = 0.40).

TABLE 18

PRESENCE / ABSENCE OF PCL BUCKLING IN ARTHROSCOPICALLY PROVEN CASES OF ACL TEAR

PCL BUCKLING	ARTHROSCOPY		
	TEAR	NORMAL	TOTAL
PRESENT	27	2	29
ABSENT	15	6	21

Parameter	Value	95% Confidence Interval
Sensitivity	64.3%	(46.9 - 78.7)
Specificity	75.0%	(35.6 - 95.5)
PPV	93.1%	(76.3 - 98.7)
NPV	28.6%	(12.8 - 51.1)
Accuracy	66.0%	(49.1 - 80.0)
Kappa	0.33	-

Table 18 demonstrates that PCL buckling had a high positive predictive value (93.1%) but moderate sensitivity (64.3%) and specificity (75%) for detecting ACL tears, resulting in fair agreement with arthroscopy (Kappa = 0.33).

TABLE 19

PRESENCE / ABSENCE OF DEEP LATERAL FEMORAL NOTCH SIGN IN ARTHROSCOPICALLY PROVEN CASES OF ACL TEAR

DEEP LATERAL FEMORAL NOTCH SIGN	ARTHROSCOPY		
	TEAR	NORMAL	TOTAL
PRESENT	6	0	6
ABSENT	36	8	44

Parameter	Value	95% Confidence Interval
Sensitivity	14.3%	(6.7 - 27.8)
Specificity	100.0%	(67.6 - 100.0)
PPV	100.0%	(60.9 - 100.0)
NPV	18.2%	(9.5 - 31.9)
Accuracy	28.0%	(17.5 - 41.7)
Kappa	0.05	-

Table 19 demonstrates that the deep lateral femoral notch sign had high specificity (100%) and positive predictive value (100%) but very low sensitivity (14.3%) and overall accuracy (28%) for detecting ACL tears, indicating poor diagnostic reliability (Kappa = 0.05).

DISCUSSION

The aim of this study was to evaluate the diagnostic performance of MRI in detecting ACL tears, using arthroscopy as the gold standard. Additionally, this study also analyzed the usefulness of primary and secondary MRI signs in diagnosing ACL tears.

The results illustrated that MRI has high sensitivity, specificity and overall accuracy in detecting ACL tears. It showed excellent agreement with arthroscopy, especially for complete ACL tears, which were identified with near perfect accuracy. However, partial ACL tears were more difficult to diagnose accurately, with some cases being wrongly classified as complete tears.

Among the primary MRI signs which included increased signal intensity, abnormal axis and discontinuity of fibers, abnormal axis and discontinuity of fibers showed the highest specificity. Among the secondary signs, anterior tibial translation, uncovering of the posterior horn of the lateral meniscus and deep lateral femoral notch sign showed high specificity, while bone contusion and PCL buckling showed more variable diagnostic reliability.

Among location of the tears within the ligament, mid-substance ACL tears were the most common, followed by femoral and tibial attachment tears. Among the most common associated injuries, lateral meniscus tears were the most frequently involved, followed by medial meniscus tears.

These results demonstrated MRI as an excellent non-invasive diagnostic tool for ACL injuries with strong a diagnostic performance for complete tears but some limitations in detecting partial tears.

The majority of patients in this study were males, with a smaller proportion being females. This finding was supported by the findings in the study by Sultana et al.[50], in which males were three times more commonly affected with ACL tear than females. ACL tears were more prevalent among male patients, which could be attributed to increased outdoor activities, greater physical exertion, and higher involvement in sports and vehicle usage.

The age distribution of ACL tears showed that most patients belonged to the young adult age group suggesting that ACL injuries are common in active adults. Age-specific patterns varied in male and female patients, with varying data available in previous literatures. In a study conducted by Sanders TL et al.[51], peak incidence in males and females was observed among young adults and adolescents respectively.

Regarding the laterality of ACL tears, both right and left knee joints were affected, though right knee involvement was slightly more common. This variation may be influenced by individual limb dominance, activity patterns, and external injury mechanisms.

MRI findings correctly classified most cases as normal, partial, or complete ACL tears. However, a small number of false negatives and false positives were also observed, especially in cases of partial tears, where MRI occasionally wrongly classified them as complete tears.

This study found that mid-substance ACL tears were the most common, followed by femoral attachment tears and tibial attachment tears. These findings are consistent with the study by Singh et al.[48], who reported mid-substance tears as the most frequent location of ACL injury.

Among the associated injuries, lateral meniscus tears were the most frequently observed, followed by medial meniscus tears. These results are similar to those reported by Cimino PM.[49], who also found lateral meniscus tears to be the most common associated injury with ACL tears followed by medial meniscus.

MRI demonstrated a high level of agreement with arthroscopy in diagnosing ACL tears. The sensitivity, specificity, and predictive values were all strong, substantiating MRI's reliability as a diagnostic tool. These results align with the findings of Zhao et al.[10] which reported similar diagnostic accuracy.

Complete ACL tears were diagnosed with exceptional accuracy, whereas partial ACL tears had lower sensitivity and specificity, making their classification more difficult. Van Dyck et al.[42] also studied the diagnostic performance of MRI in detecting complete and partial ACL tears, reporting high accuracy for complete ACL tears. Their findings indicated strong sensitivity, specificity, and positive predictive value for complete ACL tears, whereas partial ACL tears were more difficult to diagnose due to overlapping MRI features with complete tears. The lower accuracy for partial ACL tears in both their study and this study suggests that additional imaging techniques or refined MRI criteria may be necessary to improve differentiation between partial and complete tears.

Among primary signs, increased signal intensity was the most commonly observed, though in some cases, it was present in normal ACL's as well. Abnormal axis and discontinuity of fibers were the most specific indicators, as all patients with these signs had ACL tears confirmed by arthroscopy. These findings are consistent with studies conducted by Zhao et al.[10], Mellado JM et al.[30] and Zhuang et al.[32]

Among secondary signs, anterior tibial translation, uncovering of the posterior horn of the lateral meniscus and the deep lateral femoral notch sign were highly specific, confirming ACL tears in all cases where they were present. These results are in agreement with studies by Vahey et al.[35], Tung et al.[24] and Gentili et al.[38]

PCL buckling was observed frequently but had moderate sensitivity and specificity, similar to the findings reported by Tokgoz MA et al.[37]. Bone contusion had a lower specificity in this study compared to the high specificity reported by Filardo et al.[33]

The findings of this study align with previous research on ACL tear diagnosis. The diagnostic accuracy of MRI for ACL tears was comparable to that reported by Zhao et al.[10] and Van Dyck et al.[42] where high sensitivity and specificity were observed, particularly for complete tears. However, the lower sensitivity in diagnosing partial ACL tears was also noted in the study by Van Dyck et al.[42]

The reliability of primary MRI signs is supported by previous studies, with abnormal axis and discontinuity of fibers being the most specific indicators. Similarly, the secondary signs of anterior tibial translation, uncovering of the posterior horn of the lateral meniscus and the deep lateral femoral notch sign proved to be highly specific, confirming findings from studies by Vahey et al.[35], Tung et al.[24] and Gentili et al.[38]

CONCLUSION

This study confirms that MRI is a highly effective non-invasive diagnostic tool for detecting ACL tears, with excellent accuracy in diagnosing complete ACL tears and high agreement with arthroscopy. However, its limitations in identifying partial ACL tears indicate the need for careful evaluation and correlation with clinical findings.

Among primary MRI signs, abnormal axis and discontinuity showed the highest specificity. Among secondary signs, anterior tibial translation, uncovering of the posterior horn of the lateral meniscus and deep lateral femoral notch sign were the most specific, while bone contusion and PCL buckling had more variable reliability.

Mid-substance ACL tears were the most commonly observed and lateral meniscus tears were the most frequent associated injuries.

While MRI remains an essential imaging modality for ACL injuries, its limitations in detecting partial tears highlight the need for clinical judgment and, in some cases, arthroscopy for definitive diagnosis. Future studies with larger sample sizes and advanced imaging techniques may further improve MRI's role in ACL tear evaluation.

In conclusion, MRI plays a crucial role in ACL tear diagnosis, providing strong diagnostic accuracy, particularly for complete tears. However, careful assessment of MRI findings, in correlation with clinical and arthroscopic evaluation is important to ensure accurate diagnosis and optimal patient management.

SUMMARY

A total of 50 patients with suspected ACL tear underwent MRI knee joint examination. Male patients constituted majority of the patients. Maximum number of patients belonged to age group of 30 – 39 years. Right knee was more commonly involved than left knee. MRI correctly classified most cases as normal, partial or complete ACL tears. A small number of false negatives and false positives was also observed, especially in partial ACL tears. Mid-substance ACL tears were the most common location of the tear within the ligament. Lateral meniscus tears were the most frequently observed associated injury. MRI results strongly correlated with arthroscopy, suggesting that it is a highly reliable non-invasive diagnostic tool. Complete ACL tears were diagnosed with exceptional accuracy while partial ACL tears had lower sensitivity and specificity. Increased signal intensity was the most common primary sign present in ACL tears and abnormal axis and discontinuity of fibers were the most specific sign in detecting complete ACL tear. Anterior tibial translation, uncovering of the posterior horn of the lateral meniscus and the deep lateral femoral notch sign were the most specific secondary sign in detecting ACL tears. Overall, this study was able to conclude that MRI is a reliable diagnostic modality to accurately detect ACL tears, particularly complete ACL tears.

LIMITATIONS

This study compared complete ACL tears on MRI only with arthroscopic findings of normal ACL or complete ACL tears, excluding partial ACL tears. Similarly, partial ACL tears on MRI were compared only with arthroscopic findings of normal ACL or partial ACL tears, excluding complete ACL tears. This focused approach aimed to prevent mismatched tear types and reduce the risk of contamination of results and biased estimates, which would have made it difficult to determine the true performance of MRI in diagnosing ACL tears. This may limit the generalizability of the study.

The small sample size may have impacted the statistical reliability, particularly in assessing MRI accuracy for partial ACL tears.

Being a single-center study, the findings may not be generalizable to broader populations or in different clinical settings.

Additionally, the lack of inter-observer variability analysis means the reproducibility of MRI interpretations was not assessed.

Future studies should include a larger sample size and broader comparison between the types of ACL tear, for a more comprehensive assessment of diagnostic accuracy, particularly for partial ACL tears along with multi-center collaboration and inter-observer variability analysis for broader generalizability and assessment of the MRI interpretation reproducibility.

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ANNEXURE – I

INFORMED CONSENT FORM

"COMPARISON BETWEEN MAGNETIC RESONANCE IMAGING OF KNEE JOINT AND KNEE ARTHROSCOPY IN THE DIAGNOSIS OF ANTERIOR CRUCIATE LIGAMENT TEARS – A ONE YEAR HOSPITAL BASED CROSS SECTIONAL STUDY"

Name of Student/Principal Investigator: REG. NO. BS0122001

Name of Guide/Co Investigators: Dr ________________

Introduction: Anterior cruciate ligament is an important stabilizer of the knee joint that provides support to it. Any disease or condition that affects it will cause the patient to have pain and difficulty in being able to walk. The condition usually may be seen in athletes or can also be seen following road traffic accidents

Explanation of procedure: You would be invited to participate in this study to find out the importance and relevance of Magnetic resonance imaging in detecting tear of an important ligament that provides support to the knee joint named anterior cruciate ligament of knee joint by comparing the findings with an invasive procedure called arthroscopy.

Withdrawal from participation in the study: Participation in this study is voluntary. You will be free to decide whether to participate in this study or continue participation once enrolled. In case you decide to withdraw your participation, you are free to do so. However, please convey the decision to the principal investigator.

Possible benefits from participating in the study: You will/will not have nor get any benefits by participating in this study. The data gathered will help the population at large.

Possible risks from participating in the study: There are no risks involved in participating in this study.

Privacy and confidentiality: The information collected from you will be coded, to prevent any person from identifying you. Your identity will never be revealed. The data collected from you will be kept confidential and only processed or aggregated data will be used for publication.

Financial incentives: You will not receive any payment for participating in this study.

Cost of investigations done during the course of the study will be paid by the participant.

Authorization for publication of aggregated data: Results obtained after processing of the aggregated data will be published for scientific purposes and or presented to scientific groups. However, your identity will never be revealed.

Questions: In case of any questions with regard to this study or with regard to your right as study participant, you are free to contact may contact the following persons

REG. NO. BS0122001	**Dr _____________**	**Dr. Harsha Hegade**
Post-Graduate, Department of Radio-Diagnosis. J.N.Medical College, Belagavi	Guide, Professor, Department of Radio-Diagnosis J.N.Medical College, Belagavi	Professor Chairman, J.N. Medical College Institutional Ethical Committee For Human Subjects Research, Belagavi

Legal rights: By signing this consent form, we are not waving any of your legal rights.

CONSENT STATEMENT

I am making a voluntary decision to participate in the study **‘‘Comparison between magnetic resonance imaging of knee joint and knee arthroscopy in the diagnosis of anterior cruciate ligament tears – a one year hospital based cross sectional study’’.** My signature below indicates that I have decided to participate and I have read the information provided above or the information provided above has been read to me in the language that I understand best. I was given the opportunity to ask questions and that they have been answered to my satisfaction.

Name of the participant:

Signature or left thumb impression of the participant:

Name of the witness:

Signature or left thumb impression of the witness:

Name of the investigator:

Signature of the investigator:

ANNEXURE – II

PROFORMA FOR DATA COLLECTION

Name:

Age:

Sex:

Occupation:

IP/OP No:

Address:

Ph.No:

Date: **OT date:**

Ref Dr:

Clinical complaints: **Swelling (Yes / No)**

Pain (Yes / No)

Instability (Yes / No)

Difficulty in walking (Yes / No)

Past History: **H/O Trauma (Yes / No)**

Clinical diagnosis:

MRI evaluation:

1] ACL

a) Primary findings:

FINDINGS	YES	NO
INCREASED SIGNAL INTENSITY		
ABNORMAL AXIS		
DISCONTUINITY		

b) Secondary findings:

FINDINGS	YES	NO
BONE CONTUSION		
ANTERIOR TIBIAL TRANSLATION		
UNCOVERED POSTERIOR HORN OF LATERAL MENISCUS		
PCL BUCKLING		
DEEP LATERAL FEMORAL NOTCH		

c) Status of ACL: Normal
Partial tear
Complete tear

d) Location of tear: Mid-substance
Femoral attachment
Tibial attachment

2] ASSOCIATED INJURIES

FINDINGS	YES	NO
MEDIAL MENISCUS		
LATERAL MENISCUS		
PCL		
MCL		
LCL		
JOINT EFFUSION		
BURSA		
ARTICULAR CARTILAGE		
ADJACENT MUSCLES AND TENDONS		

MR REPORT:

ARTHROSCOPIC FINDINGS:

ACL STATUS: Normal / Partial Tear / Complete Tear

LOCATION OF TEAR: Mid Substance
Femoral Attachment
Tibial Attachment

ASSOCIATED INJURIES: MEDIAL MENISCUS
LATERAL MENISCUS
PCL
MCL
LCL

MRI & ARTHROSCOPIC CORRELATION:

1. The status of the ACL in this patient based on the findings on MRI is classified as ________________________ and the status of the ACL based on the arthroscopic findings is classified as _______________________.

2. The location of the ACL tear (if present) is at the ___________________ region based on the findings on MRI and the location of the tear is at the _______________________ region based on the arthroscopic findings.

3. The associated injuries (if present) based on MRI findings are ____

and these findings are present / absent on arthroscopic correlation.

ANNEXURE III

REPRESENTATIVE CASE IMAGES AND SIGNS OF ACL TEAR

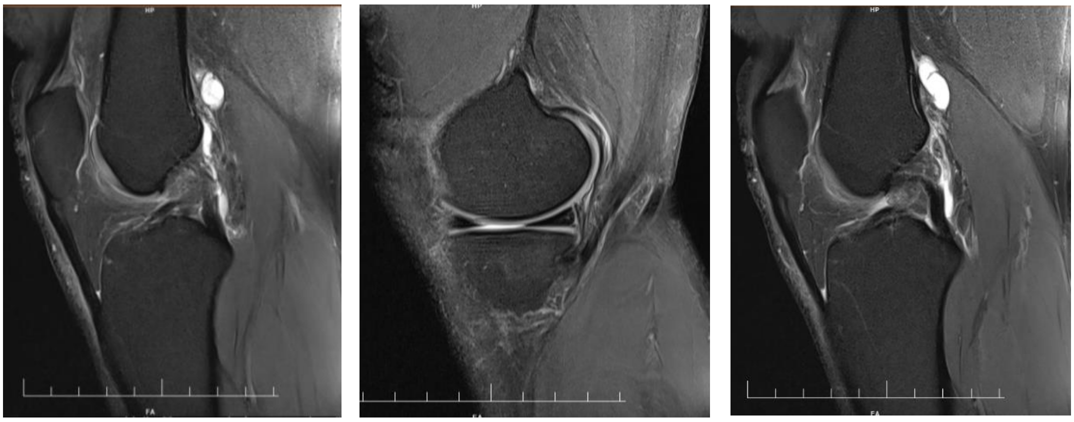
CASE A: 21 year old male patient with history of twisting injury to knee while playing football.

a

b

Image **a** shows PDFASTSAT signal hyperintensities noted involving the ACL with discontinuity of fibers suggestive of complete ACL tear. Image **b** shows horizontal and vertical PDFATSAT hyperintensities noted involving the posterior horn of medial meniscus suggestive of complex tear.

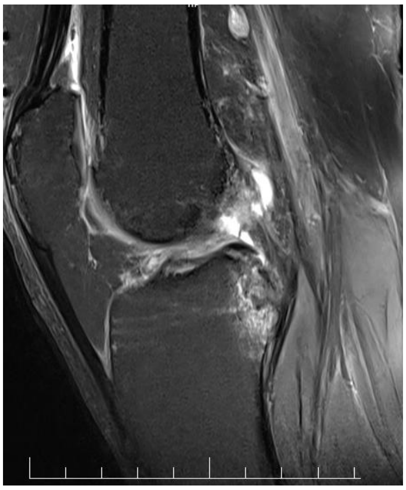
CASE B: 30 year old male patient came with history of road traffic accident.



a **b** **c**

Image **a** shows increased PDFATSAT signal intensity and discontinuity of ACL fibers suggestive of complete tear. Image **b** shows horizontal hyperintensities noted involving the posterior horn of medial meniscus suggestive of tear. Image **c** shows buckling of PCL.

CASE C: 30 year old male patient came with history of road traffic accident.



a

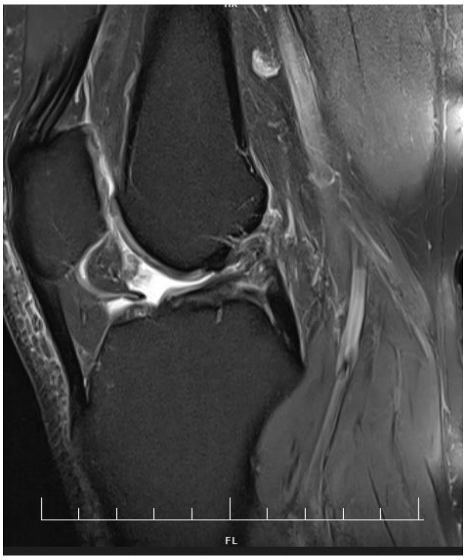
b

c

d

Image **a** (sagittal) and **b** (coronal) shows increased PDFATSAT signal intensity with discontinuity of ACL fibers and abnormal axis suggestive of complete ACL tear. Increased signal intensity is noted involving the femur and tibia suggestive of bone marrow contusion. Increased signal intensity and wavy appearance is also noted involving the LCL suggestive of grade I sprain. Image **c** shows increased signal intensity involving the PCL with no discontinuity of fibers suggestive of partial tear. Image **d** shows horizontal tear of posterior horn of medial meniscus.

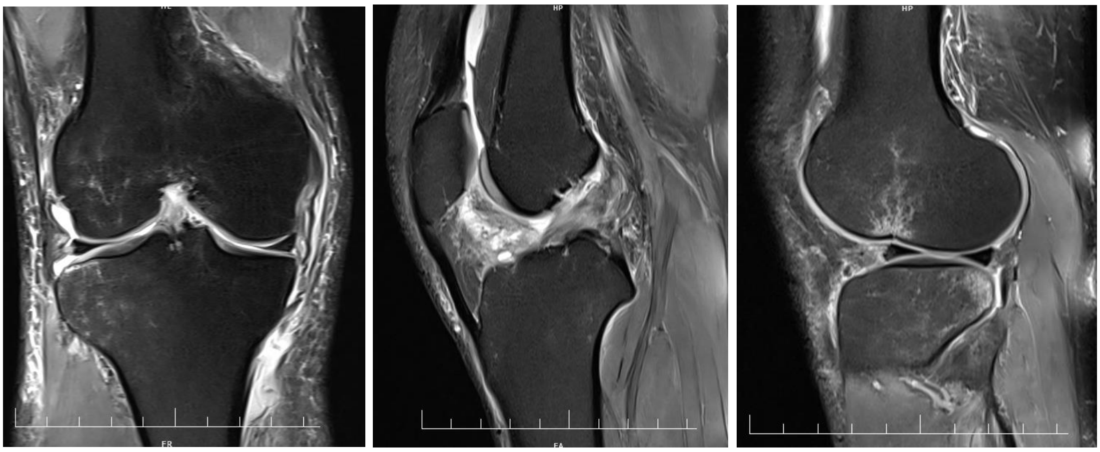
CASE 4: 37 year old male patient with history of twisting injury to knee while playing volleyball.



a **b**

Image **a** shows increased PDFATSAT hyperintensities noted involving the ACL with no discontinuity of fibres suggestive of partial ACL tear. Image **b** shows horizontal hyperintensites involving posterior horn of medial meniscus suggestive of tear.

CASE 5: 43 year old male patient with history of slip and fall while running.



a b c

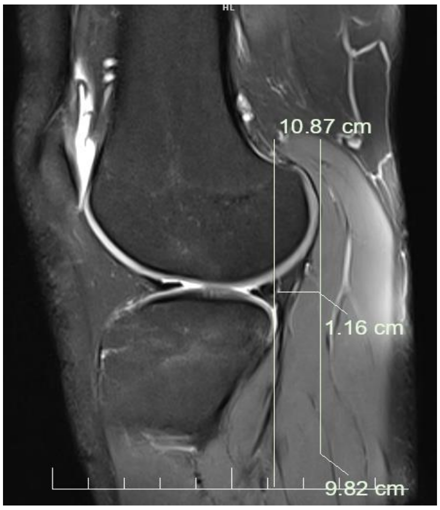
Image **a** (coronal) shows increased PDFATSAT signal intensities involving the MCL with wavy appearance suggestive of grade I sprain. Image **b** and **c** (sagittal) shows increased signal intensity with discontinuity of fibers & abnormal axis involving the ACL suggestive of complete tear. PDFATSAT hyperintensities are also noted involving the lateral femoral and lateral tibial condyle suggestive of bone marrow contusions with subchondral injury at the lateral femoral condyle

PRIMARY SIGNS OF ACL TEAR ON MRI:

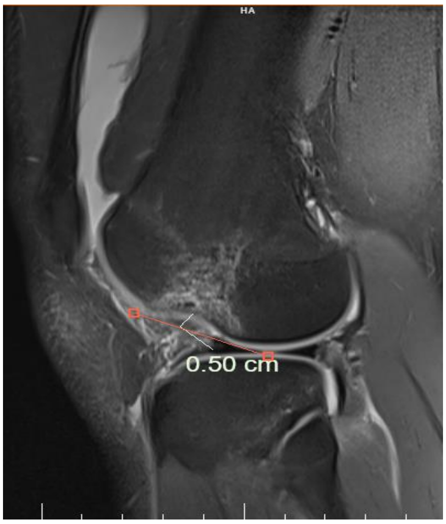
a. Represents **increased signal intensity** and **discontinutiy** of the ACL fibres.

b. Represents **abnormal axis -** angle between the ligament and Blumensaat's line (a line drawn along the roof of the intercondylar fossa of the femur) is 17°.

SECONDARY SIGNS OF ACL TEAR ON MRI:



a. Represents **anterior tibial translation** (forward translation of tibia over the femur by 1.16 cm) and **uncovering of posterior horn of lateral meniscus.**



b. Represents **deep lateral femoral notch sign** (the distance between the articular surface of the lateral femoral condyle and the tangential line drawn across its sulcus is 5.0 mm) and **bone contusion** involving the lateral femoral condyle.

c. Buckling of PCL

ANNEXURE IV

KEY TO MASTER CHART

DESCRPTIVE PARAMETERS	FINDINGS	ABBREVATION
SEX	MALE	1
	FEMALE	2
SIDE OF INVOLVED KNEE	LEFT	1
	RIGHT	2
MRI REPORT	NORMAL	0
	PARTIAL TEAR	1
	COMPLETE TEAR	2
ARTHROSCOPY REPORT	NORMAL	0
	PARTIAL TEAR	1
	COMPLETE TEAR	2
PRIMARY SIGNS	INCREASED SIGNAL INTENSITY	A
	ABNORMAL AXIS	B
	DISCONTINUITY OF FIBRES	C
SECONDARY SIGNS	BONE CONTUSION	a
	ANTERIOR TIBIAL TRANSLATION	b
	UNCOVERED POSTERIOR HORN OF LATERAL MENISCUS	c
	PCL BUCKLING	d
	DEEP LATERAL FEMORAL NOTCH SIGN	e
	PRESENT	1
	ABSENT	0
ASSOCIATED INJURIES	MEDIAL MENISCUS	MM
	LATERAL MENISCUS	LM
	MEDIAL COLLATERAL LIGAMENT	MCL
	LATERAL COLLATERAL LIGAMENT	LCL
	POSTERIOR CRUCIATE LIGAMENT	PCL
	PRESENT	1
	ABSENT	0
SITE OF ACL TEAR	FEMORAL ATTCHMENT	1
	MID SUBSTANCE	2
	TIBIAL ATTACHMENT	3

MASTER CHART

SL NO.	AGE	SEX	SIDE OF INVOLVED KNEE	CLINICAL DIAGNOSIS	MRI REPORT	ARTHROSCOPY REPORT	A	B	C	a	b	c	d	e	MM	LM	PCL	MCL	LCL	SITE
1	21	1	2	1	2	2	1	1	1	1	1	1	1	0	0	1	0	0	0	1
2	34	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	2
3	48	2	2	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1
4	29	1	1	1	2	2	1	1	1	1	1	1	0	0	0	1	0	0	0	2
5	40	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
6	52	1	1	1	1	2	1	0	1	1	0	0	1	0	1	1	0	0	0	1
7	15	1	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	
8	35	1	1	1	2	2	1	1	1	1	1	1	0	0	0	1	0	0	0	1
9	30	1	2	1	2	2	1	1	1	1	1	1	1	0	0	0	0	0	0	1
10	56	1	2	1	2	2	1	1	1	1	1	1	1	0	0	1	0	0	0	2
11	20	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	31	1	2	1	2	2	1	1	1	1	1	1	1	0	1	0	1	0`	1	2
13	21	1	1	1	2	2	1	1	1	1	1	1	1	0	0	0	0	0	0	1
14	28	1	2	1	2	2	1	1	1	1	1	1	0	0	0	0	0	0	0	2
15	20	1	2	1	2	1	1	1	1	1	1	1	1	0	0	0	0	0	0	2
16	30	1	1	1	2	2	1	1	1	0	1	1	1	0	1	0	0	0	0	2
17	60	1	2	1	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	
18	54	1	1	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	
19	34	2	1	1	2	2	1	1	1	0	1	1	0	0	1	0	0	0	0	2
20	40	1	2	1	2	2	1	1	1	1	1	1	0	1	1	1	0	0	1	3
21	32	1	1	1	1	2	1	0	1	0	0	0	1	0	0	0	0	0	1	3
22	54	1	1	0	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	
23	21	1	2	1	2	2	1	1	1	1	1	1	0	1	0	0	0	0	1	2
24	18	1	1	1	2	2	1	1	1	0	1	1	1	0	1	0	0	0	0	2
25	33	1	2	1	1	2	1	1	0	0	0	0	1	0	0	0	0	1	0	2
26	32	1	2	1	2	2	1	1	1	1	1	1	0	1	0	0	0	0	1	2
27	54	1	2	0	1	2	1	0	1	0	0	0	1	0	0	1	0	0	0	2
28	41	1	1	1	2	2	1	1	1	0	1	1	1	0	0	1	0	0	0	2
29	34	2	1	0	1	0	1	1	0	0	0	0	1	0	1	1	0	0	0	2
30	65	2	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	
31	54	2	2	0	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	
32	52	1	2	1	1	2	1	1	0	0	0	0	1	0	1	1	0	0	0	1
33	38	1	1	1	2	2	1	1	1	0	1	1	1	0	0	1	0	1	1	1
34	37	1	2	1	1	1	1	0	0	0	0	0	1	0	0	1	0	0	0	2
35	45	2	2	1	2	2	1	1	0	1	1	1	0	1	1	0	0	0	0	2
36	38	2	1	0	2	2	1	1	1	1	1	1	1	0	0	1	0	0	1	2
37	15	1	2	1	2	1	1	1	0	0	1	1	1	0	0	0	0	0	0	1
38	25	1	2	1	1	2	1	1	0	0	0	0	0	0	0	0	0	0	0	1
39	41	1	2	1	2	2	1	1	1	0	1	1	1	0	1	0	0	0	0	2
40	66	1	1	1	1	1	1	1	0	1	0	0	1	1	1	0	0	0	0	2
41	46	1	1	1	1	2	1	1	0	0	0	0	1	0	0	0	0	0	0	3
42	35	1	2	1	2	2	1	1	1	0	1	1	1	0	0	0	0	0	1	1
43	40	1	2	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	2
44	44	2	1	1	2	2	1	1	1	0	1	1	1	0	0	0	1	0	0	1
45	22	2	2	1	2	2	1	1	1	1	0	0	1	0	0	0	0	0	0	2
46	40	1	1	1	1	2	1	1	0	1	0	0	0	0	0	0	0	0	0	3
47	43	1	1	1	1	2	1	0	1	1	0	0	1	0	1	0	0	0	0	2
48	34	2	2	1	2	2	1	1	1	1	1	1	0	1	0	0	1	1	0	1
49	71	1	1	1	1	2	1	0	1	1	0	0	0	0	1	0	0	0	0	2
50	55	1	2	1	2	2	1	1	1	1	1	1	0	1	0	1	0	0	1	2