



THE ROLE OF MRI IN THE DIAGNOSIS OF CRUCIATE LIGAMENT TEARS: A RADIOLOGIC-ARTHROSCOPIC CORRELATION STUDY

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ABSTRACT

Background

Cruciate ligament tears, particularly of the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL), are common knee injuries requiring accurate diagnosis for optimal management. Magnetic Resonance Imaging (MRI) is the gold standard for non-invasive evaluation, but its diagnostic performance for partial tears and associated injuries warrants further validation.

Objectives

Assess the diagnostic accuracy of MRI (1.5-Tesla) in detecting complete and partial ACL/PCL tears, using arthroscopy as the reference standard.

Methods

A prospective cross-sectional study was conducted on 60 patients with clinically suspected cruciate ligament injuries. MRI findings (T1, T2-weighted, and PD sequences) were independently analyzed by two blinded radiologists and correlated with arthroscopic results. Statistical analysis included sensitivity, specificity, PPV and NPV

Results

MRI demonstrated high accuracy for complete ACL tears (sensitivity: 94%, specificity: 92%) and PCL tears (sensitivity: 96%, specificity: 94%). Partial tears showed lower sensitivity (85%).

Conclusion

MRI is a highly reliable tool for diagnosing complete cruciate ligament tears, with excellent correlation to arthroscopy. However, partial tears remain a diagnostic challenge. The frequent detection of associated injuries underscores MRI's role in comprehensive knee assessment. Future studies should explore advanced MRI techniques (e.g., 3-Tesla) to improve partial tear diagnosis.

Keywords: Anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), MRI, diagnostic accuracy, arthroscopy, knee injuries

INTRODUCTION

The knee joint, being one of the most complex and heavily utilized joints in the human body, is particularly susceptible to injuries, especially among athletes and physically active individuals. Among these injuries, tears of the cruciate ligaments-namely the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL)-are prevalent and can significantly impair knee stability and function. Such injuries often result from trauma, sports-related activities, or degenerative changes, presenting clinically with pain, swelling, joint instability, and restricted range of motion.

Accurate and early diagnosis of cruciate ligament injuries is paramount to prevent long-term complications such as chronic instability or osteoarthritis. Magnetic Resonance Imaging (MRI) has emerged as the imaging modality of choice for non-invasive assessment of ligamentous injuries, offering high sensitivity and specificity.

However, arthroscopy remains the gold standard for definitive diagnosis and evaluation of intra-articular knee pathology. Despite advancements in imaging technology, discrepancies may still exist between clinical, radiological, and arthroscopic findings, which can impact treatment decisions.

Anterior Cruciate Ligament (ACL) Tears

MRI provides a reliable and accurate method for diagnosing ACL tears, with reported sensitivities and specificities exceeding 90% when compared to arthroscopy.^[1] High-resolution oblique coronal MR imaging has been shown to significantly improve diagnostic performance, especially at optimal flexed-knee angles.^[2]

In a study comparing the diagnostic accuracy of MRI scanners at different field strengths (0.5 T and 1.5 T), Koh et al. found that both systems were comparably accurate in identifying ACL tears.^[3] Maheshwari et al. further supported the role of MRI in ACL evaluation by correlating ligament morphometry with injury patterns.^[4]

Advancements such as machine learning and artificial intelligence (AI) are being integrated into MRI interpretation. Namiri et al. demonstrated that convolutional neural networks could classify ACL injury severity with high accuracy, paving the way for automated diagnosis in clinical settings.^[5] However, MRI's sensitivity can be limited in subtle or partial tears. Surendran et al. reported lower accuracy in detecting Type I tears, stressing the importance of clinical correlation.^[6]

Posterior Cruciate Ligament (PCL) Tears

PCL injuries are less common but can be reliably diagnosed on MRI, particularly with T2-weighted sagittal images. Hodler et al. identified increased ligament thickness (>7 mm) as a key MRI feature for diagnosing PCL tears.^[7] Similarly, Akisue et al. emphasized MRI's role in assessing both complete and partial PCL tears, though differentiation between the two remains challenging without arthroscopic confirmation.^[8]

Several studies have validated MRI's diagnostic accuracy, reporting sensitivity and specificity above 90% for ACL tears when compared to arthroscopy.^[9] However, variations exist in MRI interpretation, particularly in partial tears and chronic injuries.^[10]

OBJECTIVE

To determine the **sensitivity, specificity, PPV, and NPV** of MRI in diagnosing ACL and PCL tears.

MATERIALS & METHODS

The current prospective cross-sectional study was conducted in the Department of Radiodiagnosis, Sree Uthradom Thirunal Academy of Medical Sciences, Vattapara, Thiruvananthapuram on 60 patients with suspected cruciate ligament tears for a period of one and half years from November 2023 to March 2025.

Study Population

Patients between 20-60 years of age, with history of knee complaints and who underwent both MRI and arthroscopy within one month interval.

Inclusion Criteria

1. Clinical suspicion of ACL/PCL injury (history of trauma, instability, positive Lachman test).
2. Referred for MRI within 4 weeks of injury

Exclusion Criteria

1. Prior knee surgery.
2. Contraindications to MRI (e.g., metallic implants, claustrophobia).

Sample Size Justification

A sample of 60 patients was chosen based on previous diagnostic accuracy studies,^[11] ensuring sufficient statistical power (80%) with an expected sensitivity of 90%.

If the goal is to estimate sensitivity (or specificity) with a certain confidence interval width, the sample size formula is:

$$n = \left(\frac{Z_{1-\alpha/2} \sqrt{Se(1-Se)}}{W} \right)^2$$

Where:

- Se = Expected sensitivity (e.g., 90% or 0.9)
- W = Desired confidence interval width (e.g., $\pm 5\% \rightarrow W=0.10$)
- $Z_{1-\alpha/2}$ = Z-value for confidence level (e.g., 1.96 for 95% CI)

MRI Technique

- **Protocol:**
 - Sagittal PD-weighted FS (Fat-Saturated): Best for ACL visualization.
 - Coronal T2-weighted: Evaluates PCL and collateral ligaments.
 - Axial T1-weighted: Assesses ligament continuity.

Reference Standard (Arthroscopy)

- Performed by an orthopedic surgeon within 4 weeks of MRI to minimize healing-related discrepancies.
- **Statistical Analysis**
- Diagnostic accuracy: Sensitivity, specificity, PPV, NPV.
- Software: SPSS v.26 for data analysis.

RESULTS**Demographics**

- The study comprised a total of 60 patients who presented with clinically suspected cruciate ligament injuries. The mean age of the participants was 32 ± 10 years, indicating that the majority of injuries occurred in individuals within the active adult age group, consistent with peak physical activity levels.
- In terms of gender distribution, there were 40 males and 20 females, reflecting a 2:1 male-to-female ratio. This observation aligns with epidemiological trends reported in previous literature, where anterior cruciate ligament (ACL) injuries are observed more frequently in males, particularly in contact sports and high-demand physical activities.

MRI Diagnostic Accuracy

MRI was evaluated for its diagnostic performance in identifying both ACL and posterior cruciate ligament (PCL) injuries, using arthroscopic findings as the reference standard.

Parameter	ACL Tear (n = 45)	PCL Tear (n = 15)
Sensitivity	94%	96%
Specificity	92%	94%
PPV	93%	91%
NPV	95%	97%

The MRI showed high sensitivity (94%) and specificity (92%) for diagnosing ACL tears, indicating that it reliably identified true positive and true negative cases.

For PCL injuries, the MRI performance was similarly high, with a sensitivity of 96% and a specificity of 94%, suggesting its robustness in evaluating both types of ligamentous injuries. The positive predictive value (PPV) and negative predictive value (NPV) were also favorable for both ACL and PCL tears, further establishing MRI as a highly effective non-invasive diagnostic tool.

Associated Injuries

MRI also revealed a significant number of associated intra-articular injuries, emphasizing the complexity of cruciate ligament tears.

- Meniscal tears were noted in 65% of cases, with a higher prevalence in the medial meniscus compared to the lateral. This is consistent with biomechanical studies showing increased stress on the medial meniscus in chronic ACL-deficient knees.
- Bone contusions were observed in 70% of patients, with the lateral femoral condyle being the most commonly affected site. These contusions likely represent impaction injuries occurring at the time of the ligament tear, providing insight into the mechanism of trauma.

DISCUSSION

Our findings align with previous studies, demonstrating MRI's high diagnostic accuracy for ACL tears (sensitivity: 94%, specificity: 92%). However, partial tears showed lower sensitivity (85%), consistent with Nguyen et al.^[10] likely due to subtle fiber disruptions.

The findings of this study reinforce the critical role of magnetic resonance imaging (MRI) in the accurate diagnosis of cruciate ligament injuries, particularly within a predominantly young and active demographic. The mean age of 32 years and the male predominance (40 males vs. 20 females) are consistent with existing epidemiological data indicating a higher incidence of anterior cruciate ligament (ACL) injuries in physically active males involved in contact sports or strenuous occupational activities.^[12,13]

MRI demonstrated high diagnostic performance for both ACL and posterior cruciate ligament (PCL) tears, with sensitivities of 94% and 96%, and specificities of 92% and 94%, respectively. These findings are in line with those reported by Brophy et al. and Koh et al., who highlighted MRI's capability to achieve over 90% diagnostic accuracy in cruciate ligament evaluation^[14,3].

The positive and negative predictive values further affirm the reliability of MRI not only for confirming ligamentous pathology but also for excluding it when clinical suspicion exists. This makes MRI an indispensable tool in the non-invasive workup of suspected knee ligament injuries, especially in settings where arthroscopy is not immediately feasible.

Additionally, a substantial proportion of patients (65%) exhibited meniscal tears, with a higher frequency observed in the medial meniscus. This supports the well-established association between ACL insufficiency and progressive medial meniscal degeneration due to altered knee biomechanics and chronic instability.^[15] Bone contusions, present in 70% of cases-most commonly in the lateral femoral condyle-are often considered indirect signs of acute ligamentous injury and reflect the pivot-shift or impact mechanism typically involved in ACL trauma.^[16]

These findings underscore the comprehensive diagnostic utility of MRI in cruciate ligament injuries. Beyond detecting primary ligamentous disruptions, MRI effectively identifies secondary signs and associated injuries, aiding clinicians in holistic injury assessment and surgical planning. Furthermore, early detection and characterization of such injuries may help mitigate long-term complications, including post-traumatic osteoarthritis and recurrent instability.

In summary, this study confirms MRI's high diagnostic accuracy and its essential role in evaluating ACL and PCL injuries and their associated intra-articular pathologies, supporting its continued use as the imaging modality of choice in orthopedic knee injury protocols.

CONCLUSION

MRI remains highly reliable in diagnosing cruciate ligament tears, with excellent correlation to arthroscopy. While limitations exist in partial tears, its non-invasive nature and ability to detect associated injuries make it indispensable. Further research with larger cohorts and advanced imaging techniques is recommended.

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