Original Article

Diagnostic Accuracy of Magnetic Resonance Imaging in Anterior Cruciate Ligament Injury

Shahzad Saeed, Iram Iqbal, Sana Rehman, Ameenah Khan, Mouzma Marrium and Sheheryar Aamir

ABSTRACT

Objective: This research set out to evaluate the diagnostic performance of magnetic resonance imaging (MRI) in identifying injuries of the anterior cruciate ligament (ACL), using arthroscopic assessment as the reference comparator.

Study Design: A cross-sectional analysis with a retrospective review

Place and Duration of Study: This study was conducted at the Department of Radiology, Services Institute of Medical Sciences/Services Hospital, Lahore covered a two-year period, extending from April 2024 to March 2025.

Methods: A cross-sectional analysis with a retrospective review of patient records was carried out. A total of 267 people were included, ages 16 to 60, who had a history of knee trauma and a clinical suspicion of an ACL injury. After undergoing an MRI, each patient had an arthroscopy done. A 1.5-Tesla MRI scanner was used for imaging, and standardized knee imaging sequences were used. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy were then calculated by comparing the MRI observations with the arthroscopy findings. SPSS version 22 was used to process and analyze the data, and findings were considered statistically significant if the p-value was less than 0.05.

Results: MRI demonstrated a sensitivity of 97%, specificity of 95.12%, PPV of 98.5%, NPV of 90%, and overall diagnostic accuracy of 95% for ACL tears. Thickening or edema and discontinuity of ACL fibers were the most sensitive MRI findings, while posterior cruciate ligament angle and index showed the highest specificity. The diagnostic accuracy for both complete and partial tears was 93%.

Conclusion: MRI demonstrates strong diagnostic capability for identifying ACL injuries, assisting orthopedic surgeons in early management and reducing unnecessary arthroscopies.

Key Words: Arthroscopy, Anterior cruciate ligament (ACL); Magnetic resonance imaging (MRI); Knee trauma

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INTRODUCTION

Anterior cruciate ligament (ACL) tears account for a significant segment of knee injuries, which are among the most common musculoskeletal issues in both orthopaedic and radiologic settings[1]. By preventing the tibia from moving forward relative to the femur and preserving rotational stability, the ACL is essential for knee joint stability.[2]

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Such injuries commonly result from rapid deceleration, sudden twisting, or direct impact — particularly in sports or road traffic accidents. If left undiagnosed or untreated, ACL injuries may progress to chronic knee instability and early degenerative joint changes, including osteoarthritis.[3]

Since arthroscopy allows for direct visualization of ligamentous structures and overall joint integrity, it has long been regarded as the gold standard for detecting intra-articular knee disorders.[4] Despite its diagnostic accuracy, arthroscopy is invasive, requires anesthesia, surgical expertise, and is associated with higher procedural risks and costs.[5] Magnetic resonance imaging (MRI), on the other hand, provides a noninvasive alternative capable of high-resolution multiplanar imaging that facilitates the assessment of ligament continuity, signal alterations, and associated soft-tissue lesions such as meniscal or chondral injuries.[6]

Prior studies carried out globally have reported MRI specificities between 92% and 96% and sensitivities between 95% and 97% for identifying ACL injuries.[7–9]

Despite these findings, there remains a lack of region-specific data evaluating MRI accuracy for ACL diagnosis in the Pakistani population relative to arthroscopic findings. Consequently, the current study was undertaken to evaluate how accurately MRI can identify ACL injuries, using arthroscopy as the reference benchmark. In addition, the study explored the utility of posterior cruciate ligament (PCL) angle and PCL index as supplementary indicators of ACL injury in the local clinical context.

METHODS

The Services Institute of Medical Sciences Department of Radiology at Services Hospital Lahore conducted this retrospective study, spanning the period from April 2024 to March 2025. Patients aged 16 to 60 years who presented with knee trauma and clinical suspicion of ACL injury and underwent both MRI and arthroscopy were included. Individuals with osteoarthritis, a history of previous knee surgery, developmental deformities, associated fractures or dislocations, or contraindications to MRI were excluded. Patient selection criteria is explained is shown in figure 1.

MRI examinations were performed using a Canon Vantage-Titan 1.5 T scanner (Canon Medical Systems, Japan) fitted with a dedicated knee coil. Imaging included sagittal, coronal, and axial planes. Sequences acquired comprised T1-weighted, T2-weighted, STIR, and proton-density protocols, each with a 3 mm slice thickness. Sagittal sequences were obtained with the knee positioned in approximately 15° of flexion to improve visualization of the ACL. MRI assessments recorded the ligament's integrity, classified tears as complete or partial, and documented both primary and secondary diagnostic features. Primary findings included discontinuity, thickening or edema, atrophy, and the empty notch sign. Secondary findings consisted of posterior cruciate ligament (PCL) angle, PCL index, bone contusion, and anterior tibial translocation.[10] The interval between MRI and arthroscopy did not exceed three months, and arthroscopic findings were used as the reference standard for comparison.

Mid-sagittal MRI evaluated secondary signs: PCL angle (abnormal <107°) and PCL index (abnormal ≤0.35). Measurements were performed via PACS by a radiologist with >5 years' experience. Arthroscopy, conducted within three months by a similarly experienced surgeon, served as the comparative standard.

Data analysis used SPSS v22, presenting quantitative variables as mean±SD and categorical as frequencies. Chi-square tests assessed correlations (significance: $p<0.05$). Diagnostic accuracy, sensitivity, specificity, PPV, and NPV were calculated via 2x2 tables using arthroscopy as the reference. The study obtained IRB approval and ensured strict patient confidentiality.

RESULTS

A total of 267 participants fulfilled the eligibility requirements for the study. Among them, 201 individuals (75.3%) were male, while 66 (24.7%) were female, with an average age of 28 ± 4 years. More than half of the cohort (59%) was within the 21–40 years age group. Regarding the mechanism of injury, road traffic accidents were the predominant cause, accounting for 67% of cases, followed by sports-related injuries at 33%.

Table No.1: Study Participants' Clinical and Demographic Details (n = 267)

Variable	Categories	Frequency (n)	Percentage (%)
Gender	Male	201	75.3
	Female	66	24.7
Age (years)	Mean ± SD	28 ± 4	—
Age group	16–20	45	16.9
	21–40	158	59.2
	41–60	64	24.0
Mode of injury	Road traffic accident	179	67.0
	Sports injury	88	33.0
Side of injury	Left knee Right knee	164 103	61.4 38.6

Table No. 2: Diagnostic Performance of MRI for ACL Tear (Arthroscopy as Gold Standard)

Diagnostic Parameter	ACL Tear	Complete Tear	Partial Tear
Sensitivity (%)	97.0	91.5	92.0
Specificity (%)	95.12	93.5	92.5
Positive Predictive Value (%)	98.5	94.0	93.0
Negative Predictive Value (%)	90.0	89.0	88.0
Accuracy (%)	95.0	93.0	92.5

Table No. 3 Comparison of Mean PCL Angle and PCL Index between Arthroscopy-Positive and Arthroscopy-Negative Groups

Parameter	ACL Tear– Negative on Arthroscopy (n = 41)	ACL Tear– Positive on Arthroscopy (n = 226)	p-value
PCL Angle (°)	138.6 ± 6.4	104.7 ± 8.1	<0.001
PCL Index	0.44 ± 0.05	0.27 ± 0.04	<0.001

Note: The independent t-test was utilised to ascertain p-values, and numerical findings are displayed as mean ± standard deviation.

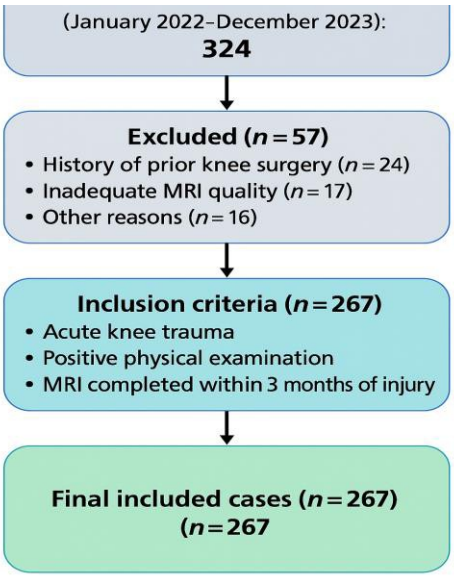


Figure No.1: Flow chart diagram of patient selection criteria

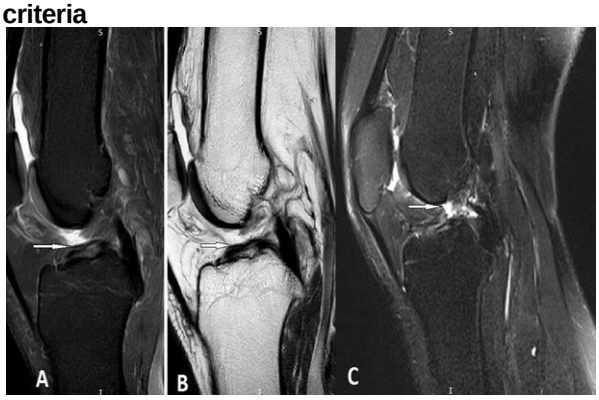


Figure 2 shows a complete ACL tear (white arrows) in both (A) sagittal proton-density fat-suppressed MRI and (B) sagittal T2-weighted fat-suppressed MRI. (C) A mid-substance fibre rupture is visible on the T2-weighted fat-suppressed sagittal MRI (white arrow).

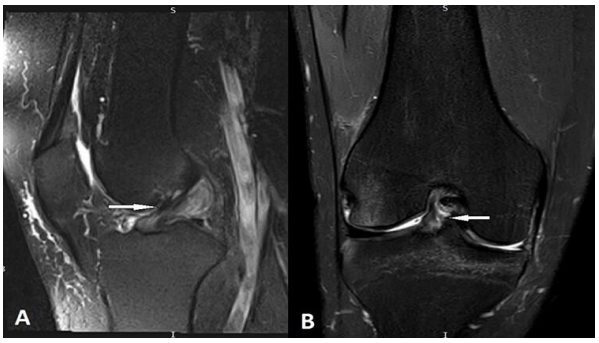


Figure No. 3: ACL partial thickness tear. (A) Thickened ACL fibers with a region of enhanced signal intensity (white arrow) are visible on sagittal fat-suppressed MRI. (B) A partial disruption of the anterior cruciate ligament fibers is shown by a coronal T2-weighted fat-suppressed MRI (white arrows).

MRI achieved 95% accuracy, 97% sensitivity, 95.12% specificity, 98.5% PPV, and 90% NPV compared to arthroscopy (Table 2). Thickening and edema were the most sensitive signs, while the PCL index and empty notch sign offered the highest specificity.

Among the 267 patients included in this study, 226 (84.6%) were ACL tear–positive on arthroscopy, while 41 (15.4%) were ACL tear–negative on arthroscopy and served as controls for comparison of MRI findings. The mean posterior cruciate ligament (PCL) angle and PCL index were significantly lower in arthroscopically confirmed ACL tear cases than in the control group ($p < 0.001$). The mean PCL angle was 104.7° ± 8.1° in the ACL tear–positive group and 138.6° ± 6.4° in the ACL tear–negative group. The mean PCL index was 0.27 ± 0.04 in ACL tear–positive cases and 0.44 ± 0.05 in ACL tear–negative knees. These results shown in table 3 demonstrate that both reduced PCL angle and lower PCL index are statistically significant secondary MRI signs associated with ACL injury.



Figure No. 4: **Proton-density-weighted sagittal MRI of the knee in (a) demonstrates posterior cruciate ligament (PCL) buckling with a reduced PCL angle, a finding suggestive of a total ACL rupture. (b) A schematic illustration of how to measure the PCL index A/B on an oblique sagittal image.**

DISCUSSION

With sensitivity, specificity, and overall accuracy that compare favorably to international standards, MRI is identified in this study as a very sensitive diagnostic technique for the diagnosis of ACL rupture. When compared to the gold standard of arthroscopy, MRI in this series showed a sensitivity of 97%, a specificity of 95.12%, a PPV of 98.5%, and an overall diagnostic accuracy of 95%.

These findings support the various published reports regarding the diagnostic reliability of MRI for ACL injuries.[11,12] International studies have recorded sensitivities as high as 94-98% and specificities from 92% to 96%, thus coming quite close to our results. Regional data also show similar diagnostic performances, supporting that MRI is a highly reliable modality. [13,14]

The high diagnostic performance observed in this study may be attributed to multiple factors, including the use of a high-field 1.5-Tesla MRI scanner, optimized knee protocols, and interpretation by experienced musculoskeletal radiologist. Thin-slice sagittal and coronal images obtained with proton-density and T2-weighted sequences were particularly useful for delineating ACL fiber integrity. Previous studies have pointed out that proper imaging orientation and inclusion of oblique sagittal sequences increase the sensitivity in detecting ACL disruption.[15,16]

The present study also demonstrated the importance of secondary MRI signs like the PCL angle and the PCL index in the diagnosis of ACL deficiency. In the ACL-deficient knee, the PCL angle was decreased and the PCL index was found to be lesser compared with studies conducted earlier . These parameters indicate indirect injury to the ACL and are especially useful in cases where the primary signs are subtle, such as in discontinuity or signal abnormality. Dar et al. further emphasized the clinical utility of MRI-based grading for ACL tears, enhancing the role of MRI in both diagnosis and treatment planning. [17]

In contrast to all other imaging modalities, MRI remains unparalleled for assessing soft tissue knee injuries, including meniscal tears and collateral ligament involvement, which very often accompany ACL injuries. Ultrasonography is relatively inexpensive and widely available; however, it lacks the spatial resolution for deep intra-articular structures. Similarly, CT arthrography is useful for delineation of bony details but is not reliable for visualization of ligamentous tissue or edema. [18]

Some variation in diagnostic performance across the published literature may arise from differences in sample size, magnetic field strength, sequence parameters, and the inclusion of partial tears. For example, lower-field MRI systems (0.3–1.0 Tesla) have resulted in reduced sensitivity, especially for partial ACL tears, because of poor spatial and contrast resolution. These, along with variations in patient positioning and knee flexion during scanning, may affect ligament visualization. [19]

The small number of discordant cases (two false positives, three false negatives) likely reflects acute haemorrhage and technique-dependent limitations.

Matching meta-analyses, MRI confirms >90% accuracy for ACL and meniscal/cartilage injuries. Although mucoid degeneration or scarring can mimic tears, MRI prevents unnecessary arthroscopies when correlated clinically [20]. It enables early surgery to prevent osteoarthritis and chronic instability, serving as a cost-effective triage tool in resource-limited settings [22]

CONCLUSION

Magnetic resonance imaging is a highly sensitive and specific modality for diagnosing anterior cruciate ligament injuries, demonstrating excellent agreement with arthroscopic findings. Its noninvasive nature, multiplanar capability, and ability to identify both primary and secondary signs of ligament disruption make it an indispensable tool in the diagnostic workflow of knee trauma.

Future multicenter studies with larger and more diverse populations, standardized imaging protocols, and multi-observer validation are recommended to refine diagnostic criteria, reduce interobserver variability, and further improve accuracy in differentiating partial from complete ACL tears. Incorporating advanced imaging techniques, including 3D isotropic sequences and quantitative MRI biomarkers, may provide additional insights into ligament integrity and postoperative healing assessment.

Ethical Considerations: Approval for this study was obtained from the Institutional Review Board of the Services Institute of Medical Sciences, Lahore (IRB/2024/1286/SIMS). Because the study relied on retrospective data, the requirement for individual informed consent was waived. All patient information was anonymized, and strict confidentiality protocols were followed during data handling and analysis.

Author's Contribution:

Concept & Design or acquisition of analysis or interpretation of data:	Shahzad Saeed, Sana Rehman, Sheheryar Aamir, Mouzma Marrium
Drafting or Revising Critically:	Ameenah Khan, Iram Amir
Final Approval of version:	All the above authors
Agreement to accountable for all aspects of work:	All the above authors

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