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EVALUATION OF ARTHROSCOPY VERSUS MRI EFFICACY IN DIAGNOSING ACL TEAR AND MENISCUS TEAR: A PROSPECTIVE ANALYSIS

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Abstract

Objectives: To compare the diagnostic efficacy of Magnetic Resonance Imaging (MRI) with arthroscopy in detecting Anterior Cruciate Ligament (ACL) and meniscus tears by evaluating the sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRI.

Methods: A prospective observational study was conducted on 120 patients exhibiting clinical signs of ACL or meniscus tears. All patients underwent MRI followed by arthroscopy, which served as the gold standard for diagnosis. Statistical measures, including sensitivity, specificity, accuracy, positive predictive value, and negative predictive value of MRI, were calculated.

Results: MRI demonstrated high sensitivity (95.5%), specificity (83.3%), and accuracy (92.5%) for diagnosing ACL tears, while meniscus tears showed a sensitivity of 84.2%, specificity of 79.5%, and accuracy of 82.5%.

Conclusion: MRI is a valuable non-invasive diagnostic tool for ACL and meniscus injuries, offering high accuracy in most cases. However, it has limitations in detecting partial ACL tears and complex meniscal injuries. Arthroscopy remains the definitive diagnostic and therapeutic procedure.

Introduction:
Anterior cruciate ligament (ACL) and meniscal injuries often arise from sports activities, trauma, or degenerative processes, potentially leading to significant functional impairment if not diagnosed and managed properly. Arthroscopy is considered the gold standard for diagnosing traumatic intra-articular knee lesions.[1] As an invasive procedure, arthroscopy requires hospitalization and anaesthesia, which brings all the potential complications associated with surgery.[2] Magnetic resonance imaging (MRI) was introduced in the 1980s and has gained popularity as a diagnostic tool for musculoskeletal disorders.[3] The knee is the most frequently examined joint using MRI. Recent advancements in MRI technology provide the necessary imaging to obtain high-resolution images for evaluating ligaments, menisci, tendons, and neurovascular structures.[4]

Many surgeons believe that MRI is an accurate, non-invasive diagnostic method for knee injuries, assisting in the decision for conservative treatment and helping to spare patients from unnecessary arthroscopy. However, MRI is costly, and health economics plays a significant role in patient management. This raises critical questions about when and how often to obtain an MRI, especially when clinical examination has already confirmed a diagnosis of meniscal tear or cruciate ligament rupture.[5] Another important question is whether a negative MRI can prevent unnecessary arthroscopy when clinical examination suggests a meniscal or cruciate ligament injury. To evaluate the accuracy of magnetic resonance imaging in patients with positive clinical signs of traumatic intra-articular knee lesions, we compared its findings with those obtained from subsequent arthroscopies.

Aims and Objectives
- To compare the diagnostic efficacy of MRI and arthroscopy in identifying anterior cruciate ligament (ACL) and meniscus tears.
- To evaluate the sensitivity, specificity, accuracy, positive predictive value (PPV), and negative predictive value (NPV) of MRI using arthroscopy as the reference standard.

Methodology:
This is a prospective observational study. Patients presenting with positive clinical signs of ACL tear and meniscus tear were enrolled from 2019-2024. One hundred twenty patients were observed. All participants provided written informed consent before participation. The institutional ethics committee reviewed and approved the study protocol to ensure patient confidentiality, safety, and compliance with ethical standards.

Inclusion Criteria:
Patients meeting the following criteria were included in the study:
- Age: 18-50 years
- History of knee injury
- No prior knee surgeries
- MRI showing ACL tear or Meniscus tear
- Consenting to arthroscopic evaluation and treatment
- Consenting to participate in the study

Exclusion Criteria:
Patients with the following conditions were excluded:
- Non-traumatic knee injury
- Previous knee surgery
- Fractures around the knee joint
- Inflammatory or infectious diseases around the knee
- Insitu aneurysmal clips or pacemakers
- Inability to undergo MRI

- Not consenting to Arthroscopic evaluation/ treatment
- Not consenting to participate in the study

Demographic data, history, clinical examination findings, and knee joint radiographs were documented in the study proforma to rule out any fractures, along with all intra-articular findings regarding knee derangement observed on MRI. MRI scans were conducted on these patients using standard knee protocols and interpreted by an experienced radiologist who was blinded to the patients' clinical histories. The radiologist evaluated the images for signs of ACL rupture, partial tears, meniscal tears, and other intra-articular abnormalities.

Arthroscopic procedures were performed by an orthopaedic surgeon. Arthroscopy was regarded as the reference standard for diagnosing ACL and meniscus tears. The surgeon examined the knee joint under direct visualisation, documenting the presence, extent, and type of injury, including ACL tears (partial or complete) and meniscus tears (degenerative, horizontal, vertical, complex, etc.).
Mandatory investigations, essential for anaesthesia, arthroscopy, and MRI of the knee joint, were completed. After a comprehensive preoperative assessment and obtaining informed written consent, surgical intervention was undertaken when necessary.
Diagnostic Criteria:

- ACL Tear: A complete or partial rupture of the ACL, identified based on abnormal positioning or discontinuity of the ligament during arthroscopy.
- Meniscus Tear: Any disruption in the meniscus tissue. Type (horizontal, vertical, radial, complex), location, and extent were noted. The tear was verified by visual confirmation of disrupted meniscal tissue using a probe.

After the MRI and Arthroscopy procedure, data were cross-referenced. The diagnostic accuracy (sensitivity, specificity, positive predictive value, and negative predictive value) of MRI was evaluated based on the arthroscopic findings.

- Sensitivity: The proportion of true positive results (correct identification of ACL or meniscus tears by MRI).
- Specificity: The proportion of true negative results (correct identification of no ACL or meniscus tear by MRI).
- Positive Predictive Value (PPV): The probability that patients with a positive MRI result had a tear confirmed by arthroscopy.
- Negative Predictive Value (NPV): The probability that patients with a negative MRI result did not have a tear confirmed by arthroscopy.

Statistical analysis:

A descriptive analysis was conducted on the variables included in the study. The mean was calculated for the continuous variables. Results for dichotomous data were presented as numbers and percentages in tables and figures. MRI findings were compared with arthroscopic findings to identify true positives, true negatives, false positives, and false negatives in pathologies. True Positive: Positive in both arthroscopy and MRI. True Negative: Negative in both arthroscopy and MRI. False Positive: Positive in MRI and negative in arthroscopy. False Negative: Negative in MRI and positive in arthroscopy. To assess the accuracy of MRI in detecting ACL tears and meniscal tears, sensitivity, specificity, positive predictive value, and negative predictive value were calculated.

- Sensitivity = True Positives / (True Positives + False Negatives) - The ability of MRI to correctly identify patients with ACL or meniscus tears.
- Specificity = True Negatives / (True Negatives + False Positives) - The ability of MRI to correctly identify patients without ACL or meniscus tears.
- Positive Predictive Value (PPV) = True Positives / (True Positives + False Positives) - The probability that a positive MRI result truly indicates a tear.

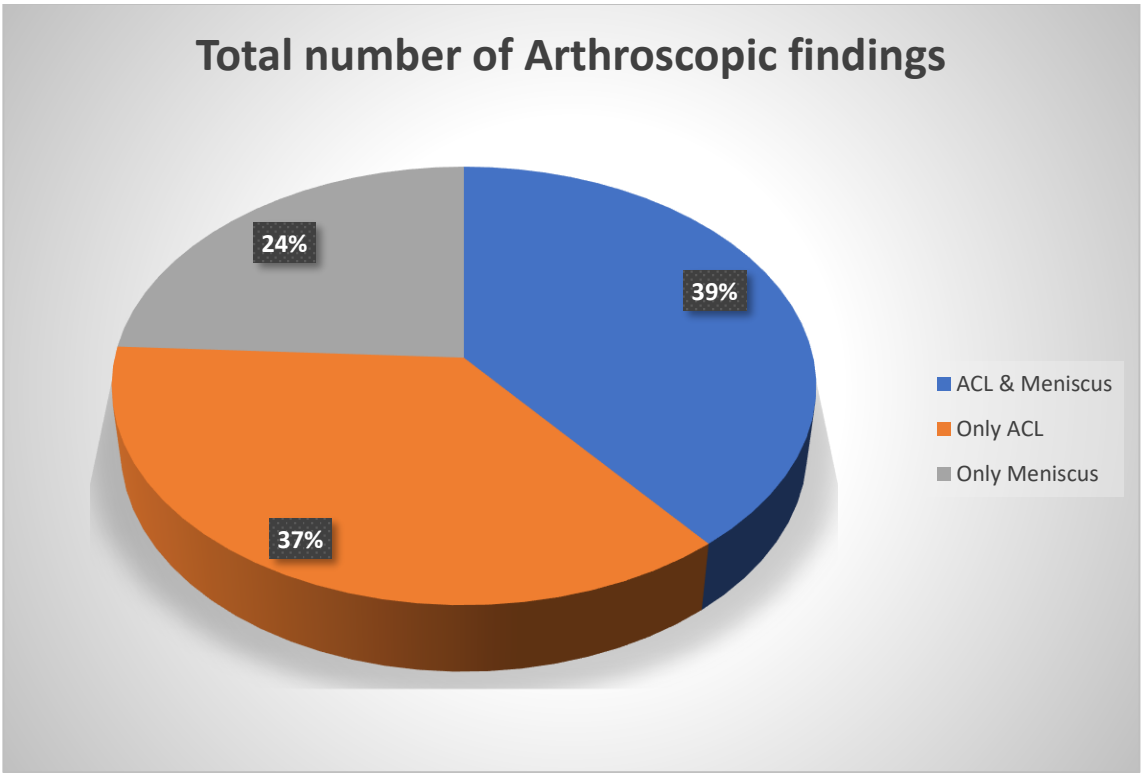
- Negative Predictive Value (NPV) = True Negatives / (True Negatives + False Negatives) - The probability that a negative MRI result truly indicates the absence of a tear.
- Overall accuracy = (True Positives + True Negatives) / (True Positives + True Negatives + False Positives + False Negatives).

These values were calculated using a 2×2 contingency table, comparing MRI findings to arthroscopic results. Higher sensitivity and specificity indicate better diagnostic accuracy, while PPV and NPV help assess the reliability of MRI in clinical practice decision-making.

Results:

In our study, 120 patients were included, with 79 (65.8%) male and 41 (34.2%) female. The mean age of the patients was 31.12 years (range: 18-48). 56 (46.7%) patients were affected by the left leg, while 64 (53.3%) were affected by the right leg. The most common cause of knee injury was road traffic accidents, followed by sports injuries.

Arthroscopic findings showed that both ACL and menisci were torn in 47 cases(39.2%), Only ACL tear in 44 cases (376.7%), and only menisci tear in29 cases (24.2%)



Graph 1: Total number of Arthroscopic findings

Test	True Positive	True negative	False positive	False negative
ACL MRI finding	86	25	5	4
Meniscus MRI finding	64	35	9	12

Table 1: MRI values with Arthroscopy findings as the reference data

1. ACL Tears: (Table 2)

- Sensitivity: MRI demonstrated a high sensitivity of 95.5% for detecting ACL tears. This means that of all patients who had an ACL tear (as confirmed by arthroscopy), MRI correctly identified 95.5% of those cases.

- Specificity: The specificity of MRI for ACL tears was 83.3%. This indicates that among patients who did not have an ACL tear (i.e., those whose arthroscopy findings were negative for ACL tears),

MRI correctly identified 83.3% of these cases as negative for ACL tears. This suggests that MRI is also quite reliable in ruling out ACL tears in patients who do not have them.

2. Meniscus Tears: (Table 2)

- Sensitivity: MRI showed a sensitivity of 84.2% in detecting meniscus tears. This means that 84.2% of the patients with a meniscus tear (as confirmed by arthroscopy) were correctly identified by MRI. While this is still a high detection rate, it suggests that MRI is somewhat less sensitive for meniscal injuries than for ACL injuries, possibly due to the variety of tear types (e.g., horizontal, vertical, complex) and the limitations of MRI in detecting subtle or complex tears.
- Specificity: The specificity for meniscus tears was 79.5%. This means that MRI correctly identified 79.5% of patients who did not have a meniscus tear (i.e., patients confirmed by arthroscopy as having no meniscal injury) as negative for a meniscus tear.

3. Diagnostic Accuracy of Arthroscopy

Arthroscopy provided a 100% sensitivity and 100% specificity for diagnosing ACL tears and meniscus tears.

Injury type	Sensitivity	Specificity	Positive predictive value (PPV)	Negative predictive value (NPV)	Accuracy
ACL tears	95.5%	83.3%	94.5%	86.2%	92.5%
Meniscus tears	84.2%	79.5%	87.6%	74.4%	82.5%

Table 2: Diagnostic Accuracy of MRI for ACL and Meniscus Tears

- **Sensitivity**: Proportion of true positives correctly identified by MRI.
- **Specificity**: Proportion of true negatives correctly identified by MRI.
- **PPV**: Proportion of patients with a positive MRI who have the condition.
- **NPV**: Proportion of patients with a negative MRI who do not have the condition
- **Accuracy**: Proportion of correctly diagnosed cases out of all cases evaluated.

Injury Type	MRI Findings	Arthroscopy Findings	Discrepancies
ACL Tears	High sensitivity (95.5%), occasionally missed partial tears	100% sensitivity, 100% specificity	MRI sometimes misses partial tears
Meniscus Tears	Sensitivity (84.2%), sometimes missed complex or subtle tears	100% sensitivity, 100% specificity	MRI may miss complex meniscus tears

Table 3: MRI vs. Arthroscopy – Comparison of Findings

Feature	MRI	Arthroscopy
Advantages	Non-invasive and pain-free High sensitivity and specificity for ACL and meniscus tears Comprehensive evaluation of soft tissues, bones, and cartilage	Direct visualization of intra-articular structures Enables therapeutic intervention (repair/debridement) Gold standard for definitive diagnosis
Limitations	False positives/negatives, particularly in partial ACL and complex meniscus tears Expensive and may not be readily available in resource-limited settings	Invasive procedure with surgical risks (infection, anaesthesia complications) Requires skilled personnel and operating room resources

Table 4: Advantages and Limitations of MRI vs. Arthroscopy

Discussion

MRI has increasingly become a vital tool for diagnosing knee injuries and is the investigation of choice.[6] It is a non-invasive technique that does not require contrast administration, is not operator-dependent, and is radiation-free.[7,8] Other modalities, such as radiography, arthrography, and ultrasonography, are limited in their ability to completely evaluate the internal structures of the knee.[6] The ACL is the most commonly injured ligament in the knee joint.[9] It is often associated with meniscal injuries.[10] ACL tears can lead to significant instability in the knee. If not diagnosed and treated promptly, they may result in meniscal, cartilage, and other ligament injuries. In our study,

we included 120 patients, of whom 79 (65.8%) were male and 41 (34.2%) were female, with right knee injuries occurring more frequently than left knee injuries. These findings align with the study by Nageswara et al.[11] In a study by Uppin et al.[12] the most common cause of knee injuries was road traffic accidents, followed by sports injuries, with the majority of patients aged between 20 and 40 years. Similarly, our study also identified road traffic accidents as the leading cause of knee injuries, with most patients aged 18 to 39 years. We found that the majority of patients had combined cruciate and meniscal injuries (39.2%), followed by isolated ACL injuries (36.7%).

MRI's ability to visualise soft tissue structures without invasive procedures has made it an essential imaging technique for evaluating structures like the ACL and meniscus. In assessing morphological changes in ACL injuries, MRI offers the benefits of good soft tissue contrast and high spatial resolution while enabling multi-parameter evaluation. However, misdiagnosis of ACL injuries can occur due to the overuse of MRI, particularly in chronic incomplete ACL tears. This is likely due to synovial hyperplasia and its special sensitivity to hydrogen atoms, which may be affected by volume effects.[13] The training and experience of a radiologist are crucial for the accurate interpretation of MRI results. An independent reference standard is also vital for evaluating the diagnostic value of MRI. In most studies, including ours, arthroscopy is the reference standard for knee MRI. This implies that arthroscopy is 100% accurate in diagnosing every possible knee pathology, though this is not always true.[14][15] Arthroscopy is a technically demanding procedure, and outcomes can vary depending on the surgeon's expertise, especially in complex cases. Some research indicates that the accuracy of arthroscopy is approximately 95%.[15,16] This leads to questions regarding the reliability of MRI.[17] Mackenzie et al.[17] raised a debate regarding the authenticity of false positives and false negatives in MRI results. This debate arose from several factors, including technically challenging arthroscopies, delays between MRI and arthroscopy, and ambiguities in the wording of the referral letter and radiological report. According to Chang et al.[18], MRI should be utilized as an adjunct tool in diagnosing meniscal and ligament injuries. They demonstrated MRI sensitivity of 92% and specificity of 87% for meniscal injuries. An analysis by Yousef et al.[19] showed that the sensitivity, specificity, and accuracy values of MRI in correlation with arthroscopy were 90%, 93%, and 92% for ACL tears, 89%, 72%, and 81% for medial meniscus injuries, and 64%, 88%, and 76% for lateral meniscus injuries. He concluded that MRI is an appropriate investigation for diagnosing ligament and meniscal injuries of the knee. Our study results indicated high sensitivity (95.5%) and specificity (83.3%) for ACL tears, with somewhat lower sensitivity (84.2%) and specificity (79.5%) for meniscus tears using MRI. Compared to a study by Ruth Crawford et al.[20] and F. Rayan et al.[21], our study showed lower sensitivity but higher specificity for ACL tears. However, the sensitivity and specificity for meniscus tears demonstrated similar findings to those of our study study. Arthroscopy, when used only for diagnosis, is an invasive tool, and it is more expensive and slower than MRI. According to Rose NE et al.,[22] there is a risk of 8% in arthroscopy surgical procedures. Hence, we did not use arthroscopy only as a diagnostic procedure but also as a therapeutic procedure.

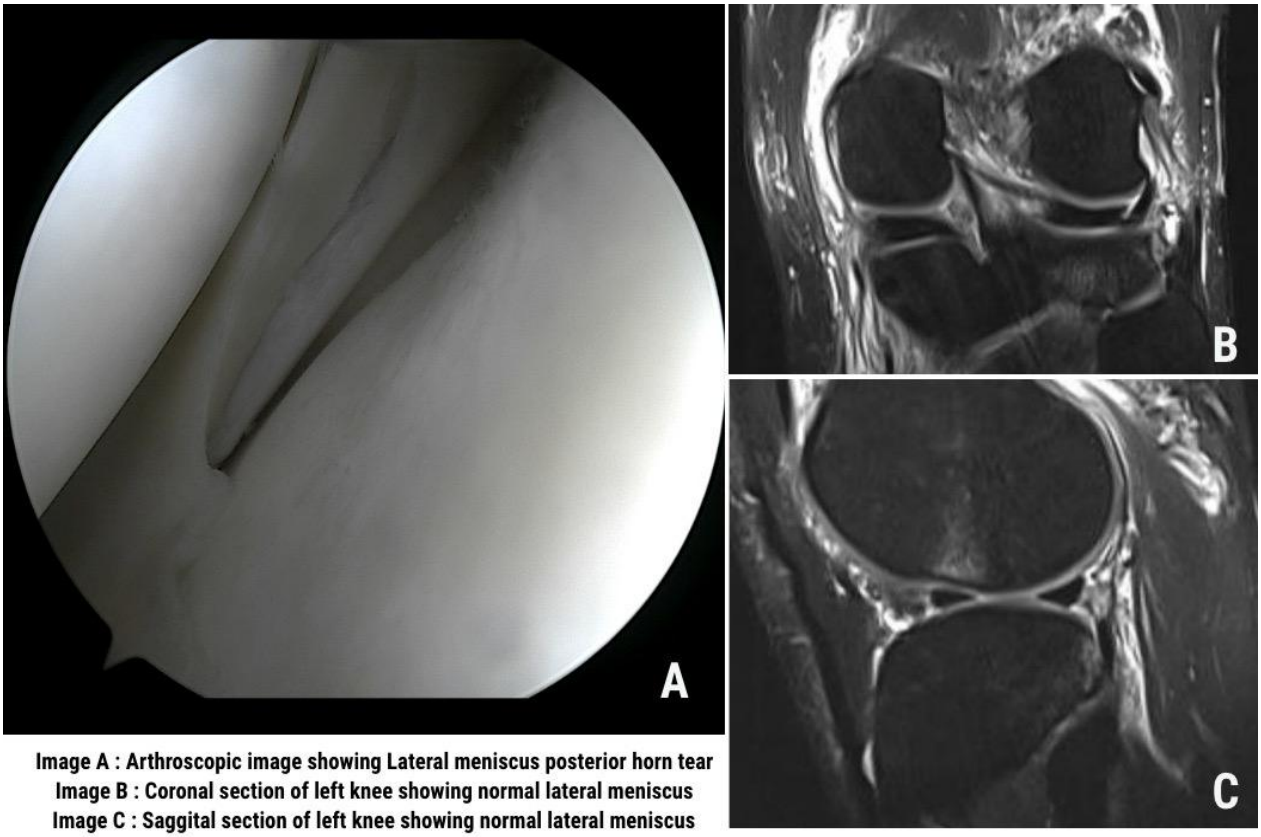


Image A : Arthroscopic image showing Lateral meniscus posterior horn tear
Image B : Coronal section of left knee showing normal lateral meniscus
Image C : Saggital section of left knee showing normal lateral meniscus

FIGURE 1: Lateral meniscus tear seen during arthroscopy procedure but reported negative on MRI

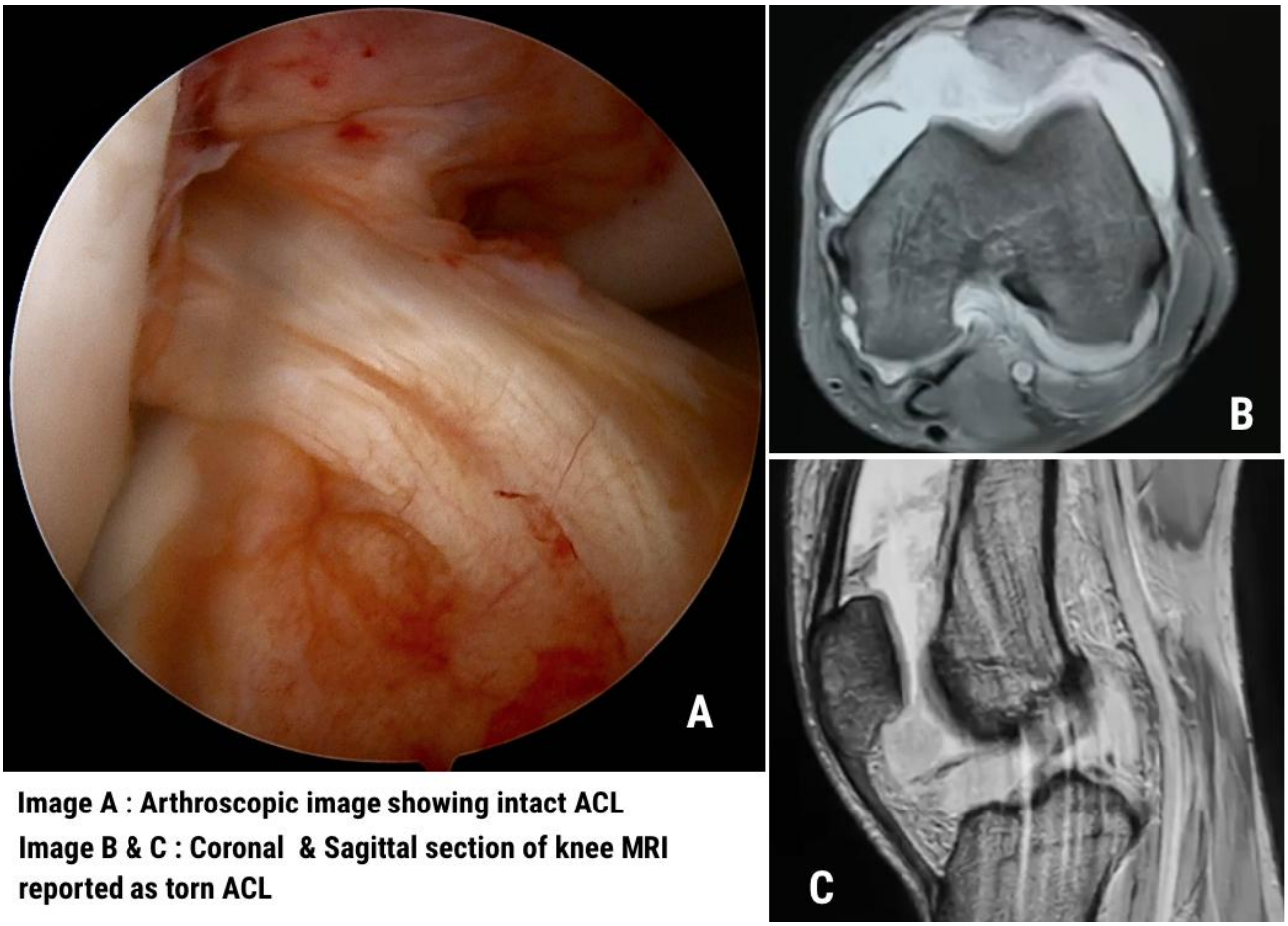


Image A : Arthroscopic image showing intact ACL
Image B & C : Coronal & Sagittal section of knee MRI reported as torn ACL

FIGURE 2 : ACL seen intact during arthroscopy procedure but reported tear on MRI

Arthroscopy offers direct visualisation of intra-articular structures, making it the most trusted method for diagnosing ACL and meniscus injuries.[20] Additionally, it allows for therapeutic interventions that MRI cannot provide. Despite giving a definitive diagnosis, arthroscopy is invasive and carries risks such as infection, anaesthesia complications, and possible joint stiffness.[23] It also demands considerable resources, including an operating room, surgical skills, and post-operative care, which limits its accessibility in resource-poor areas compared to MRI, a non-invasive imaging technique that can be performed on an outpatient basis.

Clinical diagnosis can be challenging in acute cases and with overweight individuals, making MRI often the preferred first-line diagnostic option, especially for obtaining initial diagnoses or when injuries are suspected but not confirmed. Future studies should aim to enhance MRI's diagnostic capabilities, particularly for identifying partial ACL tears and complex meniscal injuries. Innovations in MRI technology, like higher field strength scanners, improved sequences, and advanced contrast agents, could boost the sensitivity and specificity of the method.

There are limitations in this study. MRI was conducted at various imaging centers, potentially increasing data variability. The time elapsed between injury, MRI scanning, and surgery wasn't considered, which could mean new injuries occurred during that period. Furthermore, the MRI results were accessible to the surgeon before the operation, indicating that the study was not double-blinded. In conclusion, both MRI and arthroscopy are vital in diagnosing and managing ACL and meniscus injuries. MRI is a superb non-invasive diagnostic tool.

Clinicians need to thoughtfully assess clinical presentations, available resources, and the requirement for therapeutic intervention when choosing the best diagnostic strategy for patients with suspected ACL and meniscus injuries.

Conclusion

This study examines the advantages and drawbacks of MRI and arthroscopy for diagnosing ACL and meniscus tears. Both techniques are crucial in clinical settings, but their use is dependent on particular diagnostic and treatment requirements.

MRI serves as a powerful, non-invasive diagnostic method, demonstrating high sensitivity and specificity for complete ACL tears and the majority of meniscus injuries. Its proficiency in imaging soft tissues and cartilage is essential for pre-surgical preparation and initial evaluation. Nonetheless, MRI's reliability diminishes when identifying partial ACL tears and minor or degenerative meniscal injuries. For arthroscopy to be regarded as the gold standard, the surgeon performing the procedure must be well-trained.

Future studies should focus on improving MRI's diagnostic accuracy, enhancing cost-effectiveness, and developing integrated diagnostic approaches.

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