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Original Article

Diagnostic Accuracy of Magnetic Resonance Imaging for the Assessment of Meniscal Tears Using Arthroscopic Findings as the Gold Standard

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Abstract

Background: Meniscal injuries are a frequent consequence of knee trauma and represent a common cause of pain, instability, and functional limitation. Accurate diagnosis is essential for appropriate surgical planning. Although arthroscopy remains the gold standard for detecting meniscal pathology, it is an invasive procedure. Magnetic resonance imaging (MRI) offers a non-invasive alternative with high diagnostic potential for evaluating meniscal and ligamentous injuries of the knee.

Objective: To determine the diagnostic accuracy of magnetic resonance imaging in the detection of meniscal tears, using arthroscopic findings as the gold standard.

Methodology: This prospective diagnostic accuracy study was conducted in the Diagnostic Radiology Department of Children's Hospital and The Institute of Child Health, Multan, over a six-month period. A total of 200 patients aged 14–55 years with clinical suspicion of meniscal tear underwent knee MRI followed by arthroscopy. MRI examinations were performed using a 1.5-Tesla scanner and interpreted by a consultant radiologist. Arthroscopic evaluation was carried out by a single consultant orthopedic surgeon blinded to MRI findings. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of MRI were calculated using arthroscopy as the reference standard.

Results: The median age of participants was 30 years, and 58.5% were male. MRI detected medial and lateral meniscal tears in 46.5% and 22% of patients, respectively, while arthroscopy identified tears in 55% and 27%. For medial meniscal tears, MRI demonstrated a sensitivity of 84.6%, specificity of 100%, PPV of 100%, NPV of 84.1%, and accuracy of 91.5%. For lateral meniscal tears, sensitivity was 79.6%, specificity 99.3%, PPV 97.7%, NPV 92.9%, and accuracy 94%.

Conclusion: Magnetic resonance imaging demonstrated good diagnostic accuracy for both medial and lateral meniscal tears, with excellent specificity and positive predictive value, particularly for medial meniscal injuries. These findings support the use of MRI as a reliable, non-invasive diagnostic tool prior to arthroscopy.

Keywords: Arthroscopy, Diagnostic Accuracy, Knee Injury, Magnetic Resonance Imaging, Meniscal Tears.

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Introduction

Magnetic resonance imaging (MRI) has become an essential, non-invasive imaging modality in the evaluation of knee injuries and is widely used to supplement clinical examination. Its superior soft-tissue contrast allows detailed visualization of menisci, ligaments, tendons, cartilage, and other intra-articular structures, making it the imaging modality of choice for assessing internal derangements of the knee [1–3]. In contrast, conventional radiography and computed tomography (CT) are primarily limited to the evaluation of osseous abnormalities.

Since 1983, the role of MRI in knee injury assessment has expanded substantially due to improvements in image resolution and diagnostic accuracy [4]. As a result, the knee joint has become one of the most extensively studied anatomical regions in musculoskeletal imaging. MRI is increasingly regarded as a potential alternative to diagnostic arthroscopy for evaluating internal knee structures, particularly the menisci and cruciate ligaments [5]. Although arthroscopy remains the gold standard, MRI offers the advantage of being non-invasive while maintaining high sensitivity and specificity for detecting meniscal pathology [6,7].

Several studies have reported variable diagnostic performance of MRI when compared with arthroscopy. Shahrukh Q et al. evaluated 100 patients with knee trauma and reported MRI sensitivity and specificity of 81.6% and 45.3% for medial meniscal injuries and 37.5% and 91.5% for lateral meniscal injuries, respectively, using arthroscopy as the reference standard [8]. Similarly, Yaqoob J et al. demonstrated high diagnostic accuracy of MRI, reporting 100% sensitivity and 88.4% specificity for medial meniscal tears, and 85.7% sensitivity and 95% specificity for lateral meniscal tears [9]. These variations highlight the influence of imaging protocols, reader expertise, and patient selection on diagnostic outcomes.

Despite the widespread availability of MRI, local data evaluating its diagnostic accuracy in comparison with arthroscopy remain limited. Establishing reliable evidence in the local clinical setting is essential for optimizing diagnostic pathways and minimizing unnecessary invasive procedures. Therefore, the present study was designed to assess the diagnostic accuracy of MRI in detecting meniscal tears, using arthroscopy as the gold standard. Demonstrating high diagnostic reliability of MRI could help reduce the need for purely diagnostic arthroscopies, assist orthopedic surgeons in surgical planning, and improve patient care through timely and accurate diagnosis.

Methodology

Study Design

This was a prospective diagnostic accuracy study conducted to evaluate the performance of magnetic resonance imaging (MRI) in detecting meniscal tears of the knee, using arthroscopic findings as the gold standard. The study followed a comparative design in which all eligible participants underwent MRI followed by arthroscopy, allowing direct assessment of diagnostic concordance between the two modalities.

Ethics

The study was carried out after obtaining formal approval from the Ethics Review Committee of Children's Hospital and The Institute of Child Health, Multan (ERC# 124/CH&ICH Multan, dated: 18-01-2024). Written informed consent was obtained from all participants or their guardians prior to enrollment. The study adhered to ethical principles outlined in the Declaration of Helsinki, and patient confidentiality was strictly maintained throughout the research process.

Setting

The study was conducted in the Diagnostic Radiology Department of Children's Hospital and The Institute of Child Health, Multan, Pakistan, over a period of six months, from 20th February 2024 to 20th August 2024. Arthroscopic procedures were performed in the same institution, ensuring consistency in clinical protocols and minimizing inter-institutional variability.

Participants

A total of 200 consecutive patients aged 14 to 55 years, of either gender, presenting with clinical suspicion of meniscal tear following knee trauma and referred for MRI, were enrolled. Patients with fractures involving the femoral condyle or tibial plateau, as well as those with isolated cruciate ligament injuries, were excluded to avoid diagnostic confounding. Consecutive sampling was used to minimize selection bias.

Variables

The primary outcome variables were the presence or absence of medial and lateral meniscal tears as detected on MRI and confirmed by arthroscopy. Diagnostic accuracy parameters including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated. Secondary variables included demographic data such as age, gender, body mass index (BMI), and duration of symptoms.

Data Sources/Measurement

All participants underwent knee MRI using a 1.5 Tesla scanner with a dedicated knee coil. Imaging protocols included axial (T1, T2, PD fat-saturated), sagittal (PD fat-saturated/T2 fat-saturated), and coronal (T1, T2, PD fat-saturated) sequences, with a slice thickness of 2 mm. A meniscal tear was defined using explicit MRI diagnostic criteria as a Grade 3 intrameniscal signal extending to the articular surface. The knee was positioned in extension with 15 degrees of external rotation. MRI scans were interpreted by a consultant radiologist. Arthroscopy was performed within seven days of MRI by a single consultant orthopedic surgeon, who was blinded to MRI findings. A systematic examination of all knee compartments was carried out, and findings were recorded as the reference standard.

Bias

To reduce observer bias, MRI interpretations were performed independently by a consultant radiologist, while arthroscopic evaluations were conducted by a single orthopedic surgeon blinded to MRI results. Consecutive patient enrollment minimized selection bias, and the short interval between MRI and arthroscopy reduced the likelihood of disease progression influencing diagnostic agreement.

Study Size

The sample size of 200 patients was calculated using a one-sample sensitivity and specificity formula, based on an assumed 24.1% prevalence of lateral meniscal tear, MRI sensitivity of 85.7%, and specificity of 95%, with a 95% confidence level and 10% precision, using an online calculator (https://wnarifin.github.io/ssc/sssnsp.html).[9]

Quantitative Variables

Continuous variables such as age and duration of symptoms were summarized as median with interquartile range (IQR), while body mass index was expressed as mean ± standard deviation. Categorical variables, including gender and presence of meniscal tears, were presented as frequencies and percentages.

Statistical Methods

Data analysis was performed using SPSS version 25. Arthroscopy was considered the gold standard for diagnostic comparison. Sensitivity, specificity, PPV, NPV, and diagnostic accuracy of MRI were calculated with 95% confidence intervals. Receiver operating characteristic (ROC) curve analysis was performed, and the area under the curve (AUROC) was calculated to assess overall diagnostic performance.

Results

Participants

A total of 200 patients with clinically suspected meniscal injury following knee trauma were included in the final analysis. All enrolled participants successfully completed both MRI examination and subsequent arthroscopy within the defined study protocol, with no missing diagnostic data. This allowed complete paired comparison between MRI findings and arthroscopic results for both medial and lateral menisci.

Descriptive Data

The median age of the study population was 30 years (IQR: 15.75), with a male predominance (58.5%, n = 117). The mean body mass index was 30.2 ± 4.6 kg/m², and 66.5% (n = 133) of participants were classified as obese. The median duration of symptoms prior to imaging was 6 days (IQR: 13). On MRI, medial meniscal tears were identified in 46.5% (n = 93) of patients, while lateral meniscal tears were detected in 22% (n = 44). Arthroscopy revealed a higher prevalence, identifying medial meniscal tears in 55% (n = 110) and lateral meniscal tears in 27% (n = 54) of patients (Table 1).

Outcome Data

Using arthroscopy as the reference standard, MRI demonstrated high diagnostic performance for both medial and lateral meniscal tears. For medial meniscus evaluation, MRI correctly identified 93 true-positive cases and 90 true-negative cases, with 17 false-negative results and no false positives (Table 2). For lateral meniscal tears, MRI detected 43 true-positive cases and 145 true-negative cases, with 11 false negatives and one false-positive finding. These distributions formed the basis for calculation of diagnostic accuracy indices (Table 3).

Main Results

For medial meniscal tears, MRI demonstrated a sensitivity of 84.6% (95% CI: 76.4%–90.73%), specificity of 100% (95% CI: 95.9%–100%), positive predictive value of 100% (95% CI: 96.1%–100%), negative predictive value of 84.1% (95% CI: 77.4%–89.1%), and an overall diagnostic accuracy of 91.5% (95% CI: 86.7%–94.9%). For lateral meniscal tears, MRI yielded a sensitivity of 79.6% (95% CI: 66.5%–89.4%), specificity of 99.3% (95% CI: 96.2%–99.9%), positive predictive value of 97.7% (95% CI: 85.8%–99.7%), negative predictive value of 92.9% (95% CI: 88.6%–95.7%), and an overall accuracy of 94.0% (95% CI: 89.8%–96.8%). Receiver operating characteristic (ROC) curve analysis further supported these findings, with an area under the curve (AUROC) of 0.92 (95% CI: 0.88–0.96; $p < 0.001$) for medial meniscal tears and 0.89 (95% CI: 0.83–0.96; $p < 0.001$) for

lateral meniscal tears, indicating excellent overall diagnostic performance of MRI for meniscal injury detection (Figure 1).

Table 1: Characteristics of patient with suspected meniscal tear after knee trauma (N=200).

Variables		N(%)
Age (years), median (IQR)		30 (15.75)
Gender	Male	117 (58.5)
	Female	83 (41.5)
Body Mass Index (kg/m^2), mean ± SD		30.2 ± 4.6
Obesity		133 (66.5)
Duration of symptoms (days), median (IQR)		6 (13)
Medial Meniscal tear on MRI		93 (46.5)
Lateral Meniscal tear on MRI		44 (22)
Medial Meniscal tear on Arthroscopy		110 (55)
Lateral Meniscal tear on Arthroscopy		54 (27)

MRI: Magnetic resonance imaging

Table 2: Diagnostic accuracy of MRI for medial meniscal tear taking arthroscopy as gold standard.

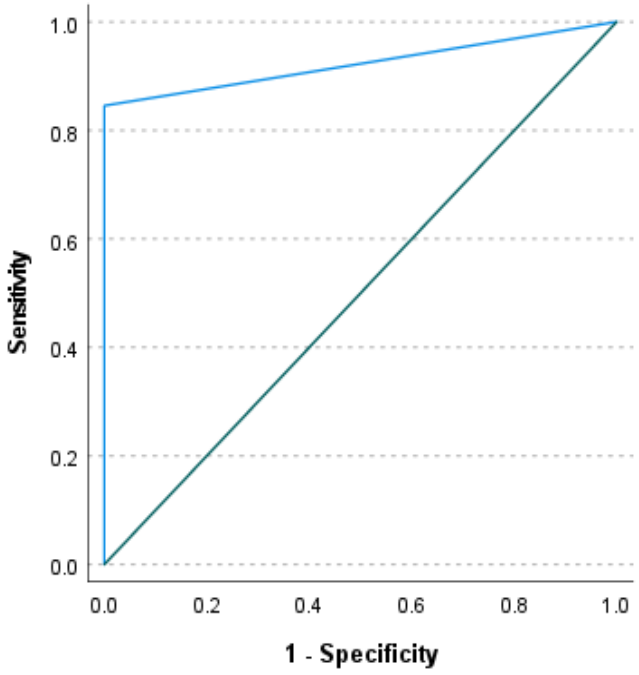
Medial Meniscal tear on MRI	**Medial Meniscal Tear on Arthroscopy**	
	Yes	**No**
Yes	93	0
No	17	90

Sensitivity: 84.6% (95% CI: 76.4% - 90.73%); Specificity: 100% (95% CI: 95.9% - 100%); Positive predictive value: 100% (95% CI: 96.1% - 100%); Negative predictive value: 84.1% (95% CI: 77.4% to 89.1%); Accuracy: 91.50% (95% CI: 86.7% - 94.9%)
MRI: Magnetic resonance imaging

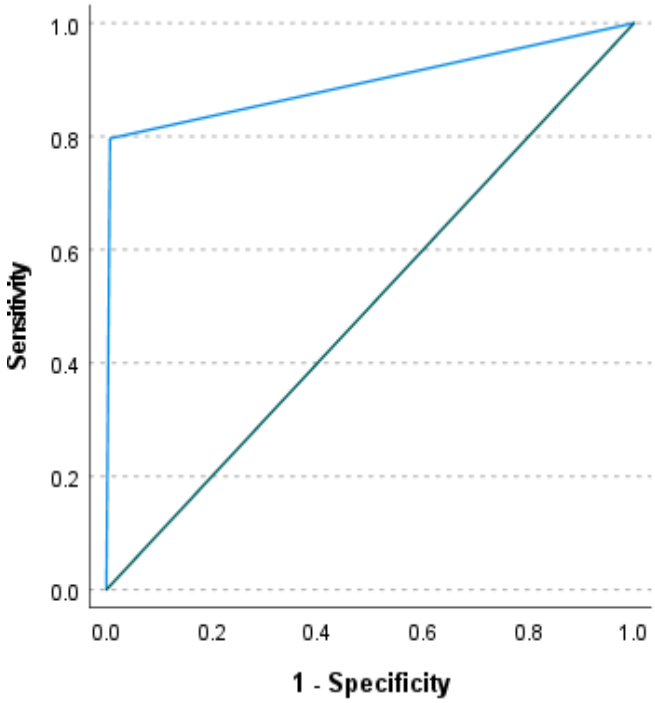
Table 3: Diagnostic accuracy of MRI for lateral meniscal tear taking arthroscopy as gold standard.

Lateral Meniscal tear on MRI	**Lateral Meniscal Tear on Arthroscopy**	
	Yes	**No**
Yes	43	1
No	11	145

Sensitivity: 79.6% (95% CI: 66.5% - 89.4%); Specificity: 99.3% (95% CI: 96.2% - 99.9%); Positive predictive value: 97.7% (95% CI: 85.8% - 99.7%); Negative predictive value: 92.9% (95% CI: 88.6% - 95.7%); Accuracy: 94.0% (95% CI: 89.8% - 96.8%)
MRI: Magnetic resonance imaging



Medial Meniscal Tear
Area Under Curve: 0.92 (0.88 – 0.96)



Lateral Meniscal Tear
Area Under Curve: 0.89 (0.83 – 0.96)

Figure 1: Receiver Operating Characteristic Curve (ROC) Analysis for MRI diagnostic accuracy taking arthroscopy as gold standard

Discussion

Magnetic resonance imaging (MRI) is widely regarded as a reliable, non-invasive modality for the evaluation of internal derangements of the knee. Its high soft-tissue contrast enables detailed visualization of meniscal morphology and associated injuries, allowing clinicians to reduce reliance on diagnostic arthroscopy, which is invasive and associated with procedural risks [10–12]. In the present study, MRI demonstrated good diagnostic accuracy for both medial and lateral meniscal tears when arthroscopic findings were used as the gold standard.

For medial meniscal tears, MRI showed a sensitivity of 84.6%, specificity of 100%, PPV of 100%, NPV of 84.1%, and overall accuracy of 91.5%. These findings are comparable with previously published literature, although reported sensitivities and specificities vary across studies. Razvi et al. reported a sensitivity of 57% and specificity of 94% using a 1.5-T MRI system, attributing the lower sensitivity to prolonged intervals between imaging and arthroscopy and difficulty detecting subtle tear patterns [13]. In contrast, other studies have reported higher sensitivities exceeding 90%, particularly in cohorts limited to acute traumatic injuries where tear morphology is more conspicuous [14]. The excellent specificity observed in our study suggests that MRI is particularly reliable in ruling in medial meniscal tears when positive findings are present.

The diagnostic performance of MRI for lateral meniscal tears in the current study was slightly lower in sensitivity (79.6%) but remained high in specificity (99.3%) and accuracy (94.0%). Similar trends have been reported in earlier investigations, where lateral meniscal tears were more frequently underdiagnosed on MRI due to their complex anatomy and peripheral tear patterns [17,18]. Variations in reported diagnostic accuracy may also be related to magnet strength, slice thickness, imaging sequences, and interpreter experience [19,20]. The short MRI-to-arthroscopy interval in this study likely minimized interval progression of tears and contributed to the observed diagnostic reliability.

Receiver operating characteristic (ROC) curve analysis further confirmed excellent diagnostic performance, with AUROC values of 0.92 for medial and 0.89 for lateral meniscal tears, aligning closely with pooled estimates reported in systematic reviews [16]. Collectively, these findings reinforce the role of MRI as a dependable diagnostic tool in the preoperative assessment of suspected meniscal injuries.

Strengths and Limitations

One of the major strengths of this study is its prospective design with consecutive patient enrollment, which reduces selection bias and enhances internal validity. The relatively large sample size of 200 patients provided sufficient statistical power to generate precise diagnostic accuracy estimates for both medial and lateral menisci. Additionally, the use of arthroscopy as the reference standard, performed by a single experienced orthopedic surgeon, minimized inter-observer variability in outcome assessment. The short interval between MRI and arthroscopy further reduced the likelihood of disease progression affecting diagnostic concordance. However, certain limitations should be acknowledged. MRI scans were interpreted by a single radiologist, preventing assessment of inter-observer variability, which may limit generalizability to routine clinical practice. The study focused exclusively on meniscal tears and did not evaluate associated ligamentous, chondral, or meniscal root injuries, which may also influence surgical decision-making. Furthermore, as this was a single-center study using a 1.5-T MRI system, the findings may not be fully generalizable to settings employing different magnet strengths or imaging protocols.

Future Recommendations

Future studies should incorporate multi-center designs with larger and more diverse patient populations to enhance external validity. Inclusion of multiple radiologists with varying levels of experience would allow assessment of inter-observer agreement and real-world diagnostic performance. Comparative studies using higher-field MRI systems (3-T) and advanced imaging sequences may further clarify the impact of technical factors on diagnostic accuracy. Additionally, evaluating MRI performance for associated ligamentous, chondral, and meniscal root injuries could provide a more comprehensive understanding of its role in preoperative knee assessment.

Conclusion

Magnetic resonance imaging demonstrated good diagnostic accuracy for detecting both medial and lateral meniscal tears, with excellent specificity and positive predictive value, particularly for medial meniscal injuries, when compared with arthroscopy as the gold standard. These findings support the use of MRI as a reliable, non-invasive diagnostic modality for the evaluation of suspected meniscal tears and reinforce its role in guiding clinical decision-making and reducing unnecessary diagnostic arthroscopies.

Authors' Contributions:

All authors meet the ICMJE criteria for authorship.

Author 1: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 2: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 3: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 4: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.
Author 5: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.

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