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ORIGINAL RESEARCH

Role of Magnetic Resonance Imaging in Diagnosing Meniscal Tears: Insights from a Tertiary Care Center

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ABSTRACT
Aim: This study aimed to evaluate the role of magnetic resonance imaging (MRI) in diagnosing meniscal tears and assessing associated injuries in patients presenting with knee pain at a tertiary care center.**Material and Methods:** A prospective observational study was conducted, involving 120 patients with clinically suspected meniscal injuries. All participants underwent MRI scanning using a 1.5T Siemens ESSENZA scanner, with imaging sequences including axial, coronal, and sagittal planes. The MRI findings, including tear type, grade, and associated injuries, were analyzed by senior radiologists. Statistical analysis was performed to determine the diagnostic accuracy and correlation with associated pathologies.**Results:** MRI detected meniscal tears in 85 patients (70.83%), with medial meniscal tears observed in 55 cases (45.83%) and lateral meniscal tears in 30 cases (25.00%). Lateral meniscus tears were most commonly located at the posterior horn/anterior horn (12.50%). ACL injuries were present in 37.50% of cases, while joint effusion and bone contusion were identified in 37.50% and 29.17% of patients, respectively. Longitudinal tears were strongly associated with ACL injuries (25.00%), and Grade III tears demonstrated the highest association with joint effusion and bone contusion (20.83%).**Conclusion:** MRI is a valuable diagnostic modality for evaluating meniscal tears, offering precise classification and assessment of associated injuries. Its non-invasive nature and high diagnostic accuracy make it the preferred imaging technique for effective diagnosis and treatment planning. Advancements in MRI technology further enhance its clinical utility.
Keywords: Meniscal tears, MRI, Knee injuries, Ligament injuries, Diagnostic imaging

INTRODUCTION

Knee injuries are among the most common musculoskeletal problems affecting individuals across a wide age range, especially those engaged in sports, physical labor, or high-impact activities. Among knee injuries, meniscal tears are one of the most prevalent conditions requiring clinical attention. The menisci, crescent-shaped fibrocartilaginous structures located between the femoral condyles and tibial plateau, play a crucial role in maintaining knee stability, load distribution, shock absorption, and joint lubrication. Given their importance in knee mechanics, injuries to the menisci can lead to significant pain, reduced mobility, and long-term complications such as osteoarthritis if left untreated.[1]Diagnosing meniscal tears accurately is critical for effective treatment planning and prevention of further damage. Traditionally, the clinical diagnosis of meniscal tears relies on patient history, physical examination, and special tests such as McMurray's test, Apley's test, and joint line tenderness. While these clinical methods provide valuable insights, their diagnostic accuracy is often limited by overlapping symptoms with other intra-articular knee pathologies, particularly ligament injuries or degenerative changes. Consequently, imaging modalities have become indispensable in confirming the diagnosis of meniscal tears.[2]Magnetic resonance imaging (MRI) has emerged as the gold standard for non-invasive evaluation of meniscal injuries due to its superior soft-tissue contrast resolution. Unlike other imaging techniques, such as X-rays or ultrasound, MRI provides detailed visualization of the menisci, cartilage, ligaments, and surrounding soft tissues in multiple planes without the

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need for ionizing radiation. Its ability to detect even subtle changes in the meniscal structure, such as signal alterations or minor tears, has revolutionized the management of knee injuries.[3]The role of MRI in evaluating meniscal tears is multi-faceted. It aids in identifying the presence, type, and extent of the tear while also assessing associated injuries such as ligamentous disruptions, bone contusions, or joint effusion. Meniscal tears can be classified into various types, including longitudinal, radial, horizontal, complex, and bucket-handle tears. MRI enables precise classification, which is critical for determining whether conservative management, surgical repair, or partial meniscectomy is warranted.[4]One of the key advantages of MRI is its ability to provide a comprehensive assessment of the knee joint. Many meniscal tears coexist with other intra-articular injuries, such as anterior cruciate ligament (ACL) tears or medial collateral ligament (MCL) injuries. These associated pathologies significantly influence treatment strategies and prognoses. For instance, detecting concomitant ACL tears in patients with meniscal injuries is essential for determining the sequence and timing of surgical interventions.Furthermore, the accuracy of MRI in diagnosing meniscal tears has been validated in numerous studies, with sensitivity and specificity often exceeding 90% when compared to arthroscopy, which is considered the gold standard. Although arthroscopy remains the definitive diagnostic tool and provides the advantage of simultaneous therapeutic intervention, its invasiveness and associated risks make MRI the preferred initial diagnostic modality in many cases.MRI is particularly useful in detecting degenerative meniscal tears, which are more common in older individuals and often coexist with other degenerative changes in the knee, such as osteoarthritis. Degenerative tears present unique diagnostic challenges as they may not always exhibit classic symptoms or physical examination findings. MRI can distinguish between degenerative and traumatic tears, providing valuable information for tailoring treatment approaches, such as physiotherapy, intra-articular injections, or surgery.[5]Another significant application of MRI is its use in post-treatment evaluation and follow-up. For patients who have undergone meniscal repair or reconstruction, MRI helps assess healing and detect complications such as re-tears, incomplete healing, or synovitis. This capability enhances patient outcomes by allowing timely interventions in cases of suboptimal healing or recurrence.

Despite its many advantages, the use of MRI in evaluating meniscal tears is not without challenges. Factors such as cost, accessibility, and variability in diagnostic accuracy among radiologists can impact its utilization. Additionally, certain limitations, such as false positives in asymptomatic individuals or difficulty differentiating between partial and complete tears, must be addressed to optimize its diagnostic value. Technological advancements, such as higher-resolution imaging and 3T MRI systems, are expected to further improve the accuracy and reliability of MRI in meniscal tear evaluation.[6]MRI has transformed the diagnosis and management of meniscal tears, offering unparalleled insights into the anatomy and pathology of the knee joint. Its ability to provide detailed, non-invasive visualization of meniscal injuries and associated pathologies makes it an indispensable tool for clinicians. As technology continues to advance, the role of MRI in evaluating meniscal tears will likely expand, further enhancing patient care and outcomes. This study aims to evaluate the utility of MRI in diagnosing meniscal tears and explore its role in assessing associated injuries, thereby contributing to the growing body of evidence supporting its use in clinical practice.

MATERIAL AND METHODS

This study was conducted as a prospective observational study in the Department of Radiodiagnosis at a tertiary care center. The primary objective was to evaluate the utility of magnetic resonance imaging (MRI) in diagnosing meniscal tears and assessing associated injuries in patients presenting with knee pain.The study included a total of 120 patients who reported knee pain and were clinically suspected of having meniscal injuries. All patients underwent MRI scanning using standardized imaging protocols, and the findings were reviewed and analyzed by senior radiologists with expertise in musculoskeletal imaging.

Inclusion Criteria

Patients referred to the radiodiagnosis department with complaints of knee pain and a suspected meniscal injury were included in the study. Participation required informed consent, ensuring that all patients understood the purpose and procedure of the study.

Exclusion Criteria

Patients were excluded from the study if they had a history of meniscal reconstruction, repair, or removal. Those with infective conditions of the knee joint, no knee pain, severe claustrophobia, or who were uncooperative were also excluded. Additionally, individuals with metallic implants, pacemakers, aneurysm clips, or prosthetic valves were not eligible due to contraindications for MRI.

Procedure

All participants were provided with a detailed explanation of the MRI procedure, and written informed consent was obtained prior to the examination. MRI scans were performed using a 1.5T Siemens ESSENZA 16-channel scanner. The imaging protocol consisted of sequences in axial, coronal, and sagittal planes, including Proton Density Fat-Saturated (PD FS), T2-weighted Fast Spin Echo

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(FSE), and T1-weighted FSE sequences. The scans were analyzed for the type and grade of meniscal tears, associated injuries such as ligament tears or bone bruises, the dimensions of meniscal cysts, and the presence of degenerative changes.

MRI Criteria for Meniscal Tears

Meniscal tears were diagnosed based on specific imaging criteria. A tear was identified if there was a linear or complex intrameniscal signal extending to the inferior or superior surface of the meniscus. Gross disruption of the normal meniscal contour, obvious foreshortening, or the complete absence of meniscal tissue were also indicative of a tear. Signals confined within the meniscus and not extending to either surface were graded as Grade 2, while globular signal intensities that did not reach the articular surface were classified as Grade 1. Degenerative tears were noted if tears were associated with surrounding altered signal intensities.

Radiological Reporting

MRI scans were independently interpreted by senior radiologists in the radiology department. Any discrepancies in interpretation were resolved through discussion among the radiologists. Findings were categorized based on the type and grade of meniscal tears as well as associated injuries, including ligament tears and joint effusions.

Statistical Analysis

Data obtained from the MRI scans and patient demographics were analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 25.0. Continuous variables were expressed as mean and standard deviation, while categorical variables were expressed as percentages. Statistical tests such as the unpaired t-test were used to assess differences between groups, and Pearson correlation tests were applied to determine relationships between variables. A p-value of less than 0.05 was considered statistically significant, providing a confidence level of 95%.

RESULTS

The results of the study are described in detail below, integrating findings from Tables 1 to 5 to provide a comprehensive analysis.

Demographic Data (Table 1)

The study included a total of 120 patients, with 72 (60.00%) being male and 48 (40.00%) female. The mean age of the participants was 35.5 years, with a standard deviation of ±10.3. Most patients fell within the 31–40 years age group (41.67%), followed by the 18–30 years group (33.33%). Only 8.33% of patients were in the 51–65 years age range.

Occupationally, sedentary individuals constituted the largest group (45.83%), followed by manual laborers (33.33%), students (12.50%), and others (8.33%). The right knee was affected in 65 patients (54.17%), whereas the left knee was involved in 55 cases (45.83%). Regarding symptom duration, 60 patients (50.00%) reported symptoms lasting 1–3 months, followed by 40 patients (33.33%) with symptoms for less than a month, and 20 patients (16.67%) with symptoms persisting for more than three months.

Overview of MRI Findings (Table 2)

MRI detected meniscal tears in 85 patients (70.83%), with a predominance of medial meniscal tears in 55 cases (45.83%). Lateral meniscal tears were observed in 30 patients (25.00%). These findings highlight the significance of medial meniscus involvement in knee injuries.

Distribution of Lateral Meniscus Tears (Table 3)

Lateral meniscus tears were present in 30 patients (25.00%), while 90 patients (75.00%) did not have such tears. The most common sites of lateral meniscus tears were at PH/AH (posterior horn/anterior horn) in 15 patients (12.50%) and PH (posterior horn) in 6 cases (5.00%).

The types of lateral meniscus tears included bucket-handle tears (5 patients, 4.17%), complex tears (6 patients, 5.00%), horizontal tears (4 patients, 3.33%), and radial/oblique tears (5 patients each, 4.17%). Most cases of lateral meniscus tears were Grade II (10 patients, 8.33%) or Grade III (12 patients, 10.00%), while Grade I (3 patients, 2.50%) and Grade IV (5 patients, 4.17%) tears were less frequent.ACL tears were observed in 45 patients (37.50%), while 75 patients (62.50%) had no ACL involvement.

Other Associated Findings (Table 4)

Among associated ligament injuries, PCL tears were identified in 15 patients (12.50%), MCL tears in 20 patients (16.67%), and LCL tears in 10 patients (8.33%). Joint effusion was present in 45 cases (37.50%), and bone contusion was observed in 35 cases (29.17%).

Additional findings included cysts, osteophytes, or joint effusions. Notably, 65 patients (54.17%) exhibited no additional findings, while 12.50% (15 patients) had CMC (complex meniscus cyst), and 10.00% (12 patients) showed Baker's cyst. Other less common findings included effusion with hypertrophic fold (EHF) in 6 patients (5.00%).

Correlation of Meniscal Tear Types and Grades with Associated Injuries (Table 5)

Longitudinal tears were most commonly associated with ACL injuries, affecting 30 patients (25.00%). Bucket-handle tears showed a strong association with joint effusion (15 patients, 12.50%), while horizontal tears were linked to bone contusion (10 patients, 8.33%). Complex tears were frequently associated with both ligament injuries and effusion (20 patients, 16.67%).Regarding grades of meniscal tears, Grade III tears were the most severe, with joint effusion and

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bone contusion present in 25 patients (20.83%). Grade IV tears were observed in 15 patients (12.50%) and were often linked to severe ligament damage. Minimal effusion was noted in 5 patients (4.17%) with Grade I tears, and Grade II tears were associated with PCL injuries in 15 patients (12.50%).

Table 1: Demographic Data

Parameter	Number of Patients (n)	Percentage (%)
Gender		
Male	72	60.00
Female	48	40.00
Mean age (years)	35.5 ± 10.3	-
Age group (years)		
18–30	40	33.33
31–40	50	41.67
41–50	20	16.67
51–65	10	8.33
Occupation		
Sedentary	55	45.83
Manual laborers	40	33.33
Students	15	12.50
Others	10	8.33
Side of injury		
Right knee	65	54.17
Left knee	55	45.83
Duration of symptoms		
<1 month	40	33.33
1–3 months	60	50.00
>3 months	20	16.67

Table 2: Overview of MRI Findings

Parameter	Number of Patients (n)	Percentage (%)
Patients with meniscal tears	85	70.83
Medial meniscal tears	55	45.83
Lateral meniscal tears	30	25.00

Table 3: Distribution of Patients Based on Lateral Meniscus Tears

Category	Subcategory	Number of Patients (n)	Percentage (%)
Lateral Meniscus Tear Presence	Present	30	25.00
	Absent	90	75.00
Lateral Meniscus Tear Site	No	90	75.00
	AH	5	4.17
	B/PH	4	3.33
	PH	6	5.00
	PH/AH	15	12.50
Lateral Meniscus Tear Type	No	90	75.00
	BH	5	4.17
	COMP	6	5.00
	HOR	4	3.33
	MCS	3	2.50
	VER	2	1.67
	RAD	5	4.17
	RAD/OBL	5	4.17
Lateral Meniscus Tear Grade	No	90	75.00
	I	3	2.50
	II	10	8.33
	III	12	10.00
	IV	5	4.17
ACL Tear Presence	Present	45	37.50
	Absent	75	62.50

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Table 4: Distribution of Patients Based on Other Associated Findings

Category	Subcategory	Number of Patients (n)	Percentage (%)
PCL Tear Presence	Present	15	12.50
	Absent	105	87.50
MCL Tear Presence	Present	20	16.67
	Absent	100	83.33
LCL Tear Presence	Present	10	8.33
	Absent	110	91.67
Joint Effusion	Present	45	37.50
	Absent	75	62.50
Bone Contusion	Present	35	29.17
	Absent	85	70.83
Associated Findings	No	65	54.17
	CMP	10	8.33
	BAK	12	10.00
	CMC	15	12.50
	EHF	6	5.00
	GC-ACL	4	3.33
	MC	3	2.50
	MD/ACL/PCL	3	2.50
	MMD	2	1.67

Table 5: Correlation of Meniscal Tear Types and Grades with Associated Injuries

Meniscal Tear Type/Grade	Subcategory	Associated Injury	Number of Patients (n)	Percentage (%)
Tear Type	Longitudinal	Ligament injury (e.g., ACL)	30	25.00
	Bucket-handle	Joint effusion	15	12.50
	Horizontal	Bone contusion	10	8.33
	Complex	Ligament injury + Effusion	20	16.67
Tear Grade	Grade I	Minimal effusion	5	4.17
	Grade II	Ligament injury (e.g., PCL)	15	12.50
	Grade III	Joint effusion + Contusion	25	20.83
	Grade IV	Severe ligament damage	15	12.50

DISCUSSION

This study aimed to evaluate the role of MRI in diagnosing meniscal tears and associated injuries in patients presenting with knee pain. The study population consisted predominantly of males (60%), with a mean age of 35.5 years. This is consistent with findings by Smith et al. (2018), who reported a mean age of 34 years in a similar cohort of 100 patients, with males constituting 58% of cases.[7] Studies, including Khan et al. (2020), have shown that knee injuries are more common in males due to higher participation in sports and physically demanding activities.[8]The occupational distribution in this study aligns with findings by Gupta et al. (2022), who reported that 40% of knee injury patients were sedentary workers, 35% were manual laborers, and the rest included students and other professions.[9] The involvement of the right knee in 54.17% of cases is also similar to reports by Chauhan et al. (2019), who noted right knee involvement in 55% of their cases, possibly reflecting right-leg dominance in the general population.[10]MRI detected meniscal tears in 70.83% of patients, with a higher incidence of medial meniscal tears (45.83%) compared to lateral meniscal tears (25.00%). This predominance of medial meniscal involvement is consistent with Wang et al. (2021), who found medial tears in 48% of cases and lateral tears in 22%.[11] The medial meniscus is more prone to injury due to its limited mobility and fixed anatomical position, as highlighted by Rahman et al. (2017).[12]The detection rate of meniscal tears (70.83%) is higher than the 60% reported by Singh et al. (2020). This discrepancy could be attributed to the advanced imaging protocols used in this study, including proton density fat-suppressed (PD FS) sequences, which enhance tear visualization.[13]Lateral meniscus tears were present in 25% of patients, with PH/AH tears (12.50%) being the most common site. This finding aligns with Patel et al. (2019), who observed a 20% incidence of lateral meniscus tears and noted PH involvement in 10% of cases.[14] The types of lateral tears observed (e.g., bucket-handle, complex, horizontal) are also consistent with prior studies, such as Zhang et al. (2022), which reported a similar distribution of tear types in their cohort.[15]The grades of lateral meniscus tears predominantly included Grade II (8.33%) and Grade III (10.00%), which is comparable to the findings of Sharma et al. (2018), who reported that moderate to severe grades were more frequent due to delayed presentation and higher

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biomechanical forces involved in lateral injuries.[16] ACL tears were present in 37.50% of patients, aligning with Taylor et al. (2020), who reported ACL injuries in 40% of their study population with lateral meniscal involvement.[17]Ligament injuries were significant, with PCL tears in 12.50% and MCL tears in 16.67% of cases. These findings are similar to the 10% and 18% rates reported by Rana et al. (2017), respectively.[18] Joint effusion was present in 37.50% of patients, consistent with Lee et al. (2019), who reported effusion in 40% of knee injury cases.[19] Bone contusion was observed in 29.17% of patients, slightly lower than the 35% reported by Ahmed et al. (2022).[20]Additional findings, such as complex meniscus cysts (12.50%) and Baker's cysts (10.00%), were consistent with Kumar et al. (2021), who noted similar cystic abnormalities in 15% and 12% of their cases, respectively.[21]Longitudinal tears were strongly associated with ACL injuries (25.00%), which aligns with findings by Davis et al. (2020), who reported a similar correlation in 28% of cases.[22] Bucket-handle tears were associated with joint effusion in 12.50% of patients, consistent with Thomas et al. (2018), who noted effusion in 15% of bucket-handle tear cases.[23]Grade III tears, with the highest association with joint effusion and bone contusion (20.83%), mirror findings by Huang et al. (2023), who observed similar complications in 22% of their cases.[24]The association of Grade IV tears with severe ligament damage (12.50%) aligns with Park et al. (2021), who reported a 14% prevalence of severe ligament injuries in advanced-grade meniscal tears.[25]

CONCLUSION

Magnetic resonance imaging (MRI) has proven to be an indispensable tool in the diagnosis and evaluation of meniscal tears. Its ability to provide detailed visualization of meniscal injuries, classify tear types, and detect associated pathologies such as ligament injuries and joint effusion makes it a gold standard non-invasive imaging modality. MRI aids in guiding treatment decisions, distinguishing between degenerative and traumatic tears, and monitoring post-treatment outcomes. With advancements in technology, the accuracy and accessibility of MRI are expected to improve further, enhancing its utility in clinical practice for optimal patient care and outcomes.

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