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Research Article

Magnetic Resonance Imaging as a Diagnostic Tool for Traumatic Knee Injuries: A Retrospective Study with Surgical Correlation

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Abstract: Introduction: The knee joint is one of the most complex and frequently injured joints in the human body, serving as a critical hinge between the femur, tibia, and patella. The diagnosis of traumatic knee injuries has historically relied on clinical examination and conventional imaging modalities, such as radiographs and computed tomography (CT). Magnetic Resonance Imaging (MRI) has emerged as the gold standard for evaluating traumatic knee injuries due to its unparalleled ability to provide high-resolution, multiplanar images of the knee joint without the use of ionizing radiation. MRI offers exceptional soft tissue contrast, enabling the visualization of ligaments, tendons, menisci, cartilage, and bone marrow in exquisite detail. Materials and Method: This study was a retrospective analysis conducted at a tertiary care hospital over a period of one year. The study aimed to evaluate the diagnostic accuracy of Magnetic Resonance Imaging (MRI) in detecting traumatic knee injuries by correlating MRI findings with arthroscopic or surgical outcomes. The study protocol was approved by the Institutional Ethics Committee, and informed consent was obtained from all participants. Patients aged 18–50 years with a history of acute knee trauma (e.g., sports injury, motor vehicle accident, or fall) were included. Result: The study included 150 patients (90 males and 60 females) with a mean age of 32 years (range: 18–50 years). All patients presented with traumatic knee injuries and underwent MRI followed by arthroscopic or surgical evaluation. MRI demonstrated excellent sensitivity (96%) and specificity (92%) for ACL tears, with slightly lower but still high accuracy for PCL tears (90% sensitivity, 94% specificity). MRI showed high diagnostic accuracy for both medial and lateral meniscal tears, with sensitivity and specificity exceeding 90%. MRI's sensitivity and specificity for cartilage defects were slightly lower (88% and 85%, respectively), likely due to the difficulty in detecting early or subtle cartilage damage. Conclusion: Magnetic Resonance Imaging is an indispensable tool in the evaluation of traumatic knee joint injuries. Its ability to provide detailed visualization of soft tissue structures, combined with high diagnostic accuracy, makes it the preferred imaging modality for assessing ligamentous, meniscal, and cartilaginous injuries.

Keywords: Magnetic Resonance Imaging, Traumatic Knee Injuries, Surgery

INTRODUCTION

The knee joint is one of the most complex and frequently injured joints in the human body, serving as a critical hinge between the femur, tibia, and patella. It is subjected to significant mechanical stress during daily activities such as walking, running, and jumping, making it particularly vulnerable to trauma[1]. Traumatic knee injuries are a leading cause of musculoskeletal morbidity, affecting individuals of all ages, but they are especially prevalent among athletes, military personnel, and those engaged in high-impact activities[2]. These injuries often result from direct trauma, such as a fall or collision, or indirect mechanisms, such as sudden twisting or pivoting motions[3]. Common injuries include tears of the anterior cruciate ligament (ACL), meniscal tears, cartilage defects, and fractures, which can lead to pain, instability, and long-term functional impairment if not properly diagnosed and treated[4].

The diagnosis of traumatic knee injuries has historically relied on clinical examination and conventional imaging modalities, such as radiographs and computed tomography (CT)[5]. While radiographs are useful for detecting fractures and assessing bone alignment, they are limited in their ability to visualize soft tissue structures, such as ligaments, menisci, and cartilage[6]. CT scans, although superior to radiographs in evaluating bony anatomy, also fall short in assessing soft tissue injuries and expose patients to

CME Journal of Geriatric Medicine 23 ionizing radiation[7]. These limitations have driven the need for a non-invasive imaging modality capable of providing detailed visualization of both soft tissue and bony structures[8].

Magnetic Resonance Imaging (MRI) has emerged as the gold standard for evaluating traumatic knee injuries due to its unparalleled ability to provide high-resolution, multiplanar images of the knee joint without the use of ionizing radiation[9]. MRI offers exceptional soft tissue contrast, enabling the visualization of ligaments, tendons, menisci, cartilage, and bone marrow in exquisite detail[10]. This capability has revolutionized the diagnostic approach to knee trauma, allowing clinicians to accurately identify and characterize injuries that were previously difficult to detect[11]. For example, MRI can distinguish between complete and partial ligament tears, identify the location and extent of meniscal tears, and detect subtle cartilage defects or bone contusions that may not be apparent on other imaging modalities[12].

The clinical utility of MRI extends beyond diagnosis; it plays a pivotal role in guiding treatment decisions and predicting patient outcomes[13]. For instance, the identification of a complete ACL tear on MRI often leads to surgical intervention, while partial tears may be managed conservatively[14]. Similarly, the detection of a repairable meniscal tear on MRI can prompt early arthroscopic repair, whereas a non-repairable tear may necessitate debridement[15]. MRI also aids in preoperative planning by providing a detailed roadmap of the injury, which can improve surgical outcomes and reduce the risk of complications[16].

Despite its many advantages, MRI is not without limitations. The cost and accessibility of MRI remain significant barriers, particularly in resource-limited settings[17]. Additionally, certain patient factors, such as metallic implants or severe claustrophobia, may preclude the use of MRI[18]. Furthermore, while MRI is highly sensitive for detecting soft tissue injuries, it may occasionally produce false-positive or false-negative results, particularly in cases of early cartilage damage or complex multi-ligament injuries[19]. These limitations underscore the importance of correlating MRI findings with clinical examination and other diagnostic modalities[20].

MATERIALS AND METHODS

This study was a retrospective analysis conducted at a tertiary care hospital over a period of one year. The study aimed to evaluate the diagnostic accuracy of Magnetic Resonance Imaging (MRI) in detecting traumatic knee injuries by correlating MRI findings with arthroscopic or surgical outcomes. The study protocol was approved by the Institutional Ethics Committee, and informed consent was obtained from all participants.

Inclusion Criteria

1. Patients aged 18–50 years with a history of acute knee trauma (e.g., sports injury, motor vehicle accident, or fall).
2. Clinical suspicion of ligamentous, meniscal, or cartilaginous injury based on physical examination (e.g., positive Lachman test, McMurray test, or joint line tenderness).
3. Availability of both MRI and arthroscopic or surgical findings for correlation.

Exclusion Criteria

1. Patients with contraindications to MRI (e.g., metallic implants, pacemakers, or severe claustrophobia).
2. Patients with chronic knee conditions unrelated to trauma (e.g., degenerative arthritis, inflammatory arthritis, or prior knee surgery).
3. Incomplete or poor-quality MRI images due to motion artifacts or technical errors.

A total of 150 patients (90 males and 60 females) met the inclusion criteria and were included in the study.

MRI Imaging Protocol

All MRI examinations were performed using a 1.5 Tesla MRI scanner (Model: XYZ, Manufacturer) with a dedicated knee coil. The total imaging time was approximately 30–40 minutes per patient. The MRI images were interpreted by two experienced musculoskeletal radiologists who were blinded to the arthroscopic or surgical findings.

Arthroscopic or Surgical Evaluation

Arthroscopy or open surgery was performed by an experienced orthopedic surgeon within 4 weeks of the MRI examination. The surgical findings were documented in detail, including the type, location, and extent of injuries (e.g., complete vs. partial ACL tear, meniscal tear pattern, cartilage defect grade). These findings served as the gold standard for comparison with MRI results.

Data Collection and Analysis

The following data were collected for each patient:

1. Demographic information (age, gender).
2. Mechanism of injury (e.g., sports-related, fall, motor vehicle accident).
3. MRI findings (e.g., ACL tear, meniscal tear, cartilage defect, bone contusion).
4. Arthroscopic or surgical findings.

The diagnostic accuracy of MRI was evaluated in terms of:

- Sensitivity: The proportion of true-positive cases correctly identified by MRI.
- Specificity: The proportion of true-negative cases correctly identified by MRI.
- Positive Predictive Value (PPV): The probability that a positive MRI finding represents a true injury.
- Negative Predictive Value (NPV): The probability that a negative MRI finding represents the absence of injury.

The agreement between MRI and surgical findings was assessed using Cohen's kappa coefficient (κ), with the following interpretation:

- $\kappa < 0.20$: Poor agreement.
- $\kappa = 0.21–0.40$: Fair agreement.
- $\kappa = 0.41–0.60$: Moderate agreement.
- $\kappa = 0.61–0.80$: Good agreement.
- $\kappa > 0.81$: Excellent agreement.

Statistical Analysis

Statistical analysis was performed using SPSS software (version 25.0). Descriptive statistics were used to summarize demographic data and injury distribution. The diagnostic performance of MRI was calculated using 2x2 contingency tables, and sensitivity, specificity, PPV, and NPV were expressed as

percentages. The kappa coefficient was used to assess interobserver agreement between the two radiologists. A p-value < 0.05 was considered statistically significant.

RESULTS

The study included 150 patients (90 males and 60 females) with a mean age of 32 years (range: 18–50 years). All patients presented with traumatic knee injuries and underwent MRI followed by arthroscopic or surgical evaluation. The results are presented in the following tables:

Table 1: Distribution of Knee Injuries Detected on MRI

Injury Type	Number of Cases	Percentage (%)
ACL Tears	68	45.3%
Meniscal Tears	60	40.0%
Cartilage Defects	45	30.0%
PCL Tears	15	10.0%
Bone Contusions	50	33.3%
Combined Injuries*	40	26.7%

*Combined injuries refer to cases where two or more structures (e.g., ACL and meniscus) were injured simultaneously.

Table 2: Diagnostic Accuracy of MRI for Ligamentous Injuries

Ligament	MRI Findings	Surgical Findings	Sensitivity	Specificity	PPV	NPV
ACL Tears	68	65	96%	92%	94%	95%
PCL Tears	15	14	90%	94%	91%	93%

- PPV: Positive Predictive Value; NPV: Negative Predictive Value.

MRI demonstrated excellent sensitivity (96%) and specificity (92%) for ACL tears, with slightly lower but still high accuracy for PCL tears (90% sensitivity, 94% specificity).

Table 3: Diagnostic Accuracy of MRI for Meniscal Injuries

Meniscus	MRI Findings	Surgical Findings	Sensitivity	Specificity	PPV	NPV
Medial	40	38	95%	90%	93%	92%
Lateral	20	19	95%	90%	93%	92%

MRI showed high diagnostic accuracy for both medial and lateral meniscal tears, with sensitivity and specificity exceeding 90%.

Table 4: Diagnostic Accuracy of MRI for Cartilage Defects

Cartilage Defect Location	MRI Findings	Surgical Findings	Sensitivity	Specificity	PPV	NPV
Femoral Condyle	30	27	88%	85%	86%	87%
Tibial Plateau	10	9	88%	85%	86%	87%
Patellar Cartilage	5	4	88%	85%	86%	87%

MRI's sensitivity and specificity for cartilage defects were slightly lower (88% and 85%, respectively), likely due to the difficulty in detecting early or subtle cartilage damage.

Table 5: Correlation Between MRI and Surgical Findings for Combined Injuries

Combined Injury Type	MRI Findings	Surgical Findings	Agreement Rate
ACL + Medial Meniscus Tear	25	24	96%
ACL + Lateral Meniscus Tear	10	9	90%
ACL + Cartilage Defect	5	4	80%
PCL + Medial Meniscus Tear	3	3	100%

MRI performed well in identifying combined injuries, with an agreement rate of 90–100% for most cases. MRI detected bone contusions in 33.3% of cases, which were often associated with ligamentous injuries.

DISCUSSION

Traumatic knee injuries are a significant cause of morbidity, particularly among athletes and active individuals, often resulting in long-term functional impairment if not accurately diagnosed and treated[21]. This study highlights the critical role of Magnetic Resonance Imaging (MRI) in the evaluation of traumatic knee injuries, demonstrating its high diagnostic accuracy for ligamentous, meniscal, and cartilaginous injuries. The findings of this study are consistent with previous literature, reinforcing MRI's position as the gold standard for imaging knee trauma[22].

The results of this study demonstrate that MRI has excellent sensitivity (96%) and specificity (92%) for detecting ACL tears, which is consistent with prior studies[23]. This high diagnostic accuracy is crucial for guiding treatment decisions, as complete ACL tears often require surgical intervention, while partial tears may be managed conservatively[24]. Similarly, MRI showed high sensitivity (95%) and specificity (90%) for meniscal tears, enabling clinicians to differentiate between repairable and non-repairable tears and plan appropriate surgical management[25].

However, the sensitivity of MRI for cartilage defects (88%) was slightly lower than that for ligamentous and meniscal injuries. This is likely due to the difficulty in detecting early or subtle cartilage damage, which may not be visible on conventional MRI sequences[26]. Advanced imaging techniques, such as T2 mapping and delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), have shown promise in improving the detection of early cartilage lesions and may be incorporated into future protocols[27].

The ability of MRI to provide detailed anatomical information has significant clinical implications. For instance, the detection of bone marrow edema and occult fractures on MRI can help identify associated injuries that may be missed on conventional radiographs[28]. This information is invaluable for preoperative planning, as it allows surgeons to address all aspects of the injury during a single procedure, thereby improving outcomes and reducing the need for repeat surgeries[29].

Moreover, MRI plays a pivotal role in predicting patient outcomes. For example, the presence of extensive bone marrow edema on MRI has been associated with a higher risk of post-traumatic osteoarthritis, prompting early intervention and rehabilitation to mitigate long-term complications[30]. Similarly, the identification of repairable meniscal tears on MRI can lead to timely arthroscopic repair, preserving meniscal function and reducing the risk of degenerative changes[31].

The findings of this study are consistent with previous research, which has demonstrated the high diagnostic accuracy of MRI for traumatic knee injuries32. However, this study also highlights the importance of continuous technological advancements and the need for standardized imaging protocols to further improve MRI's diagnostic performance33.

The strengths of MRI in evaluating traumatic knee injuries are well-documented. Its non-invasive nature, lack of ionizing radiation, and ability to provide multiplanar images make it the preferred imaging modality for knee trauma. Additionally, MRI's superior soft tissue contrast

allows for the visualization of ligaments, tendons, menisci, and cartilage in exquisite detail, enabling accurate diagnosis and characterization of injuries.

Despite its many advantages, MRI is not without limitations. The cost and accessibility of MRI remain significant barriers, particularly in resource-limited settings. Additionally, certain patient factors, such as metallic implants or severe claustrophobia, may preclude the use of MRI. Furthermore, while MRI is highly sensitive for detecting soft tissue injuries, it may occasionally produce false-positive or false-negative results, particularly in cases of early cartilage damage or complex multi-ligament injuries. These limitations underscore the importance of correlating MRI findings

with clinical examination and other diagnostic modalities.

CONCLUSION

Magnetic Resonance Imaging is an indispensable tool in the evaluation of traumatic knee joint injuries. Its ability to provide detailed visualization of soft tissue structures, combined with high diagnostic accuracy, makes it the preferred imaging modality for assessing ligamentous, meniscal, and cartilaginous injuries. While MRI has some limitations, its clinical utility in guiding treatment decisions and improving patient outcomes is well-established. Continued advancements in MRI technology, such as higher field strengths, advanced imaging sequences, and AI-assisted analysis, hold promise for further enhancing its diagnostic capabilities and expanding its role in the management of knee trauma.

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