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# Comprehensive MRI Assessment of Traumatic Knee Injuries: Diagnostic Spectrum, Correlation with Clinical Findings, and Implications for Management

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## A B S T R A C T

**Background**: Traumatic knee injuries are prevalent in physically active individuals and significantly impact mobility and quality of life. MRI provides a non-invasive and highly sensitive diagnostic tool for evaluating soft tissue and osteochondral injuries.
**Objectives**: This study aims to evaluate the spectrum of traumatic knee injuries using MRI and to correlate imaging findings with patient demographics, mechanisms of injury, and clinical presentation.
**Methods**: A cross-sectional observational study was conducted on 100 patients aged 18–60 years with acute knee trauma. All patients underwent standardized clinical evaluation and MRI scans using a 1.5 Tesla system. Imaging findings were analyzed for ligamentous, meniscal, chondral, and osseous injuries and compared with clinical assessments.
**Results:** MRI detected anterior cruciate ligament (ACL) tears in 35% of patients, chondral defects in 30%, and medial meniscal tears in 25%. Mid-substance was the most commonly affected site in both ACL and PCL tears. MRI showed excellent diagnostic performance, with sensitivity and specificity values over 90% for ACL and PCL tears. Males (62%) were more affected than females (38%), and the age group 31–40 years was most commonly involved.
**Conclusion:** MRI is an indispensable modality in the evaluation of traumatic knee injuries, offering superior diagnostic accuracy and anatomical detail. Its integration into routine assessment protocols improves clinical decision-making and patient outcomes.

**Keywords**: MRI, knee trauma, ACL tear, PCL, meniscus, cartilage injury, diagnostic imaging

## INTRODUCTION

Knee injuries constitute a significant proportion of musculoskeletal trauma cases, particularly among young adults, athletes, and individuals engaged in physically demanding occupations. The knee joint, being a complex hinge-type synovial joint, is anatomically vulnerable due to its limited bony constraints and dependence on soft tissue structures—primarily ligaments, menisci, and tendons—for stability. Trauma to the knee may result in a wide range of internal derangements including ligamentous tears, meniscal injuries, cartilage defects, and occult bone injuries.

Clinical evaluation of knee trauma, although essential, often falls short in identifying the precise nature and extent of internal injuries, especially in the acute setting where pain, swelling, and guarding may obscure findings. Conventional radiography is limited to osseous evaluation and cannot detect soft tissue pathology.
Arthroscopy, though considered the gold standard for direct visualization, is invasive, expensive, and not suitable as a first-line diagnostic tool in all patients.

Magnetic Resonance Imaging (MRI) bridges this diagnostic gap by offering non- invasive, high-resolution imaging of both osseous and soft tissue structures in multiple planes. Its ability to accurately characterize injuries of the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), menisci, cartilage, and periarticular soft tissues makes it the modality of choice in both acute and chronic knee trauma.

This study was undertaken to evaluate the pattern of knee injuries detected by MRI in patients presenting with acute trauma and to correlate imaging findings with clinical presentation, mechanism of injury, and demographic variables. By doing so, the study aims to establish the diagnostic utility of MRI in real-world settings and reinforce its role in guiding appropriate management and improving patient outcomes.

**Review of Literature**

The knee joint is a complex, load-bearing synovial structure comprising bones, ligaments, menisci, cartilage, bursae, and neurovascular elements, all of which contribute to its stability and function. Due to this intricate anatomy, it is highly susceptible to traumatic injuries, especially during sports or high-impact activities. These injuries often involve structures such as the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial and lateral collateral ligaments, menisci, and articular cartilage.

Magnetic Resonance Imaging (MRI) has revolutionized the assessment of knee trauma by enabling detailed, non-invasive visualization of both osseous and soft tissue components. Unlike X-rays and CT, which primarily assess bone, MRI excels in detecting soft tissue pathology with high spatial and contrast resolution. Techniques like T1, T2, STIR, PD, and fat-suppressed sequences offer comprehensive evaluation of the ligamentous, meniscal, and chondral architecture.

Historical milestones in MRI development—beginning with Lauterbur and Damadian—laid the foundation for musculoskeletal applications. [1,2] Researchers like Stoller and Mink provided early imaging criteria for cruciate and meniscal injuries. [3,4]

Subsequent advancements introduced functional techniques such as DWI, MR arthrography [5] , T2 mapping, and dGEMRIC. These have significantly enhanced detection of early cartilage degeneration and complex intra-articular pathologies [6].

Studies show MRI sensitivity exceeding 90% for ACL tears and up to 93% for meniscal injuries, far surpassing physical examination. [7,8] Its role in evaluating bone contusions, tendon pathology, synovitis, and postoperative changes has also been well-established.

Recent integration of artificial intelligence and 3T/7T MRI has further expanded diagnostic accuracy and predictive capabilities.[9,10] Consequently, MRI is now regarded as the gold standard in evaluating traumatic knee injuries, allowing for early diagnosis, targeted therapy, and improved patient outcomes.

**MATERIALS AND METHODS**

Study Design and Setting-This was a hospital-based, descriptive cross-sectional study conducted at the Department of Radiology, R.K. Damani medical college (SRIMS), Chatrapati Sambhajinagar , Maharashtra, over a 12-month period.

Inclusion: Patients aged 18–60 with a recent history of knee trauma, clinically indicated for MRI.
Exclusion: Degenerative joint diseases, past surgery, MRI contraindications (e.g., pacemaker, metallic implants).

Sample Size Calculation:
Based on an estimated prevalence of 50% for traumatic knee injuries, a confidence interval of 95%, and precision of 10%, the sample size was calculated to be 100 using finite population correction.

Imaging Protocol:
MRI was performed using a 1.5 Tesla Philips Achieva scanner with a dedicated knee coil. Standard sequences included:

- T1W coronal
- T2W sagittal and coronal
- STIR coronal
- PD-weighted with fat saturation
- FFE sequences

Data Collection:
Demographic data, trauma history, clinical signs, and detailed MRI findings were documented in a structured pro forma. MRI reports were interpreted by radiologists with ≥5 years of musculoskeletal imaging experience.

Statistical Analysis:
Data were analyzed using SPSS software. Sensitivity, specificity, PPV, and NPV of MRI for specific injuries were calculated in comparison to clinical findings.
Statistical significance was evaluated using Chi-square tests ($p<0.05$ considered significant).

**RESULTS**

Demographics: Age Range: 18–60 years; mean: 34.6 years Gender:

| Side | % of Patients |
|---|---|
| Male | 62 % |
| Female | 38% |

Most affected group:

| Age Group (years) | % of Patients |
|---|---|
| 18-20 | 8% |
| 21-30 | 28% |
| 31-40 | 35% |
| 41-50 | 20% |
| 51-60 | 9% |

Mode of Injury:

| Mode | % of Patients |
|---|---|
| Sports related | 45% |
| Road traffic accident | 30% |
| Falls | 20% |
| Others | 5% |

Laterality:

| Side | % of Patients |
|---|---|
| Right Knee | 50 % |
| Left Knee | 40% |
| Bilateral | 10% |

Type of injury:

| Injury Type | (% of Patients) |
|---|---|
| ACL tear | 35% |
| Chondral defects | 30% |
| Medial meniscus tear | 25% |
| MCL injury | 20% |
| Bone contusions | 20% |
| Lateral meniscus tear | 15% |
| PCL tear | 10% |
| Synovitis | 15% |
| LCL | 5% |

Grading of ACL Tears (Total- 35)

| Type of tear | N (% of Patients) |
|---|---|
| Partial: | 18 (52 %) |
| Complete: | 17 (48 %) |

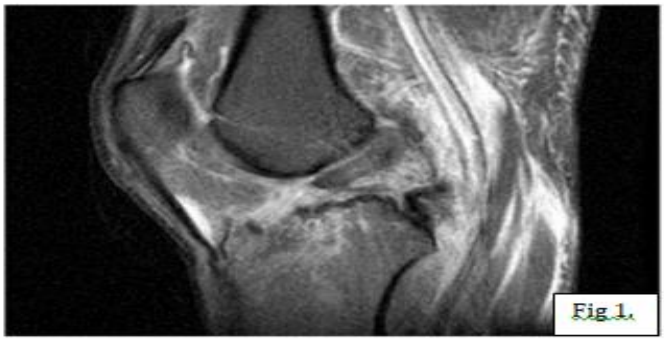
Meniscal Tears (Total =38)

| Type of tear | N (% of Patients) |
|---|---|
| Complex | 13 (34 %) |
| Radial | 8 (21 %) |
| Horizontal/Longitudinal | 17 (45%) |

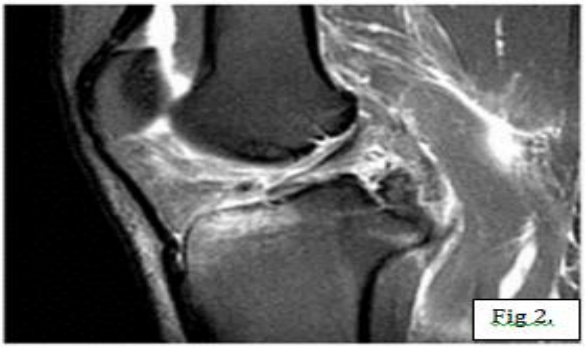
Posterior cruciate ligament (Total =10)– Mostly mid substance was involved.
LCL and MCL (Total 25) – Partial thickness tear was more common than full thickness tear.

Diagnostic Accuracy of MRI

| Injury | Sensitivity | Specificity | PPV | NPV |
|---|---|---|---|---|
| ACL Tear | 95% | 90% | 93% | 92% |
| PCL Tear | 90% | 85% | 87% | 88% |
| Meniscus Tear | 85% | 88% | 87% | 86% |
| Chondral Defect | 80% | 85% | 83% | 82% |
| Bone Contusion | 90% | 95% | 93% | 92% |




sagittal PD image of knee joint showing diffuse PD hyperintense signal within ACL with complete discontinuity of fibers near tibial attachment (complete ACL tear).




sagittal PD image of knee joint showing diffuse hyperintense signals in PCL with complete discontinuity of fibres in midpart (complete PCL tear)

Fig. 3 and 4 show medial meniscus tear in sagittal and coronal planes.

**DISCUSSION**

This study reaffirms the pivotal role of magnetic resonance imaging (MRI) as the gold standard in the non-invasive evaluation of traumatic knee injuries. The ability of MRI to simultaneously visualize intra-articular ligaments, menisci, articular cartilage, and osseous structures provides a comprehensive assessment that surpasses both clinical examination and conventional imaging modalities.

In our cohort of 100 patients, the anterior cruciate ligament (ACL) was the most frequently injured structure (35%), a finding that mirrors global epidemiological trends, especially in physically active young adults. The majority of ACL tears were localized to the mid- substance, which is consistent with biomechanical studies demonstrating this region as a common site of tensile failure due to its relative avascularity and mechanical stress susceptibility.

Importantly, our results revealed a high diagnostic accuracy of MRI in identifying ACL and posterior cruciate ligament (PCL) tears, with sensitivities of 95% and 90% respectively.
These findings align with those of De Smet et al. and Recht et al., who reported similar diagnostic performance of MRI for cruciate ligament injuries.[11,12] Notably, our study showed that in patients with ACL tears, associated lateral femoral condyle bone contusions were present in more than half of the cases, reinforcing the classic pivot-shift mechanism of injury, where impaction between the femur and tibia leads to bone bruising.

Meniscal injuries were the second most common pathology, with medial meniscus involvement (25%) exceeding lateral meniscus injuries (15%). This supports the well- established biomechanical concept that the medial meniscus is more prone to degenerative and traumatic tears due to its reduced mobility and greater load-bearing role. MRI demonstrated high specificity (88%) and a positive predictive value (87%) for meniscal pathology, underlining its role in preoperative planning, particularly for identifying complex or bucket-handle tears that require urgent arthroscopic intervention.

Chondral defects were identified in 30% of cases, which is significant given their silent presentation on clinical examination and the inability of X-rays to detect early cartilage loss. Our MRI protocol's inclusion of PD and STIR sequences enhanced the visualization of subtle chondral thinning and subchondral changes. The early detection of cartilage injuries is vital, as untreated defects may progress to osteoarthritis. Similar findings were reported by
Potter et al., who emphasized MRI's ability to detect early-stage cartilage degeneration and its role in preventive orthopaedic strategies.[13]

Collateral ligament injuries, especially of the medial collateral ligament (MCL), were also common. Most were partial tears or Grade I/II sprains and often accompanied ACL injuries, reinforcing the valgus stress mechanism typically observed in contact sports. MRI effectively delineated the extent of ligament fiber disruption and associated edema, aiding in conservative vs surgical decision-making.

An underappreciated yet clinically relevant observation was the presence of bone contusions in 20% of patients. These were typically located in the lateral femoral condyle and posterior tibial plateau. MRI was instrumental in identifying these marrow changes, which have been shown in prior studies to predict future cartilage degradation and post- traumatic osteoarthritis.

The gender distribution in our study (62% males) likely reflects greater participation in high-risk activities and sports among males in our demographic. However, female patients—especially athletes—are known to be at increased risk of ACL injuries due to biomechanical and hormonal factors, a dimension warranting further exploration in future sex-specific analyses.

From a clinical standpoint, the integration of MRI into routine trauma protocols ensures early diagnosis and guides tailored management strategies. For instance, in suspected ACL injury, MRI not only confirms the diagnosis but also identifies associated injuries like meniscal tears or chondral defects, allowing for comprehensive surgical planning.

One of the significant strengths of our study is the prospective design with real-world applicability. However, the lack of arthroscopic correlation in all cases represents a limitation, as surgical findings remain the gold standard for definitive diagnosis.
Furthermore, the cross-sectional nature of the study precludes assessment of long-term functional outcomes, particularly for patients managed conservatively.

Recent advances in knee MRI—such as 3T scanners, quantitative cartilage mapping (T2 mapping, dGEMRIC), and AI-assisted analysis—promise even greater diagnostic yield. Machine learning models, for example, have demonstrated the potential to automate tear classification and predict surgical outcomes based on baseline imaging. Although not employed in our setting, future studies could integrate such tools to enhance diagnostic workflows.

Clinical Implications
For Radiologists: MRI should be considered an essential tool in the diagnostic workflow for acute and subacute knee trauma. Familiarity with injury patterns and grading systems enhances reporting precision and clinical relevance.
For Orthopaedic Surgeons: Preoperative MRI allows for better surgical planning, anticipating combined injuries, and choosing between conservative and operative treatment.
For Sports Medicine Practitioners: Early MRI aids return-to-play decisions and injury prevention strategies, especially in high-risk athletes.
Future Research Recommendations
Multicenter trials with arthroscopic correlation to validate MRI findings across diverse populations and equipment setups.
Longitudinal studies to track healing, reinjury rates, and development of osteoarthritis. Integration of AI in MRI interpretation to enhance diagnostic speed and accuracy.
Comparative studies using 1.5T vs 3T MRI in assessing soft tissue resolution and cartilage grading.

**CONCLUSION**

Magnetic Resonance Imaging (MRI) has emerged as an indispensable modality in the comprehensive evaluation of traumatic knee injuries. This study demonstrated the high diagnostic accuracy of MRI in detecting a wide spectrum of internal derangements, including cruciate ligament tears, meniscal injuries, cartilage defects, and bone contusions. The non-invasive, radiation-free, and multiplanar imaging capabilities of MRI make it superior to conventional diagnostic tools, especially in cases where clinical assessment may be inconclusive.

Our findings confirm that ACL tears are the most prevalent injury pattern in acute knee trauma, often associated with lateral compartment bone contusions and meniscal injuries. The ability of MRI to not only confirm these diagnoses but also provide precise localization and grading plays a pivotal role in treatment planning—whether conservative management or surgical intervention. Furthermore, the detection of associated occult injuries such as bone marrow edema or chondral fissuring helps in prognostication and rehabilitation planning.

The clinical impact of MRI extends beyond diagnosis. By guiding early and accurate intervention, MRI helps prevent complications like chronic knee instability, mechanical locking, or early-onset osteoarthritis. This is especially important in athletes and younger patients, where functional preservation and return to activity are key concerns.

Although this study was limited by the absence of arthroscopic validation and short-term outcome data, the results emphasize the robust diagnostic performance of MRI in a real- world clinical setting. In future, the integration of quantitative MRI techniques and AI-based image analysis may further enhance diagnostic precision and standardize reporting.

In conclusion, MRI should be considered the first-line imaging modality in patients with suspected traumatic knee injuries. Its early use not only refines diagnosis but also significantly contributes to improved patient outcomes, reduced morbidity, and better resource allocation in musculoskeletal healthcare.

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