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A study of role of magnetic resonance imaging in evaluation of traumatic knee joint injuries

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Abstract
Background: MR examination, a noninvasive modality, is now routinely used to assess a wide spectrum of internal knee derangements and articular disorders and has virtually replaced conventional arthrography in the evaluation of the menisci and the cruciate ligaments. It is noninvasive, does not involve ionizing radiation and has multiplanar capability with excellent soft tissue demonstration. Therefore, MRI has become the imaging modality of choice for the evaluation of the painful knee following injury. It can detect soft tissue abnormalities (meniscal, cruciate, collateral ligament tears) and microtrabecular fractures that cannot be detected by plain film.
Materials and Methods: The study was undertaken from June 2023 to November 2023 after obtaining Institutional Review Board (IRB) approval in patients referred to the department of Radio diagnosis, Narendra Modi Medical College & L.G hospital, Ahmedabad. The study population consisted first 200 cases with suspected traumatic knee joint injuries and with supportive MRI findings.
Results: In this study of 200 patients, 115 patients were male while 85 patients were female. The most common age group affected was 15-25 years. In this study, the most common injury was anterior cruciate ligament (ACL) tear of which complete tear was more common. Posterior cruciate ligament tears (6.5%) were less common. Among the meniscal injuries medial meniscal tears were more common than lateral meniscal tear and horizontal tears were more common in both. Other abnormalities like discoid meniscus (1 patient), hemarthrosis (2 patients), joint effusions (162 patients), bony contusions and other myotendinous tears were accurately detected and characterized with the help of magnetic resonance imaging.
Conclusion: MRI is an excellent, noninvasive, radiation free imaging modality with multiplanar capabilities and excellent soft tissue delineation. It can accurately detect, localize and characterize various internal derangements of the knee joint and help in arriving at a correct anatomical diagnosis thereby guiding further management of the patient. MRI has high accuracy for preoperative detection of meniscal tears. In addition, it allows accurate characterization of various tear patterns, which can be instrumental for patient counseling and surgical planning. In addition to diagnostic benefits and in the selection of surgical candidates with preoperative planning, MRI has proved valuable. Further, improved patient–doctor communication and cost effectiveness of MRI knee studies has contributed to their greater acceptance by the orthopaedic community.

Keywords: Magnetic Resonance Imaging (MRI), knee joint, meniscal tear, ligament injury

Introduction
Magnetic Resonance Imaging (MRI) of the knee is a routinely performed diagnostic examination for the detection and assessment of acute and chronic internal derangement injuries of the knee and serves as an important guide to patient management. Although radiography remains the standard initial imaging modality to diagnose knee derangement, MRI improves the evaluation of the bones and soft tissues to a greater extent. Arthroscopy gives excellent visualization of the interior of the joint, but is invasive and can evaluate only the surface abnormalities.
Knee joint is the largest and most complex weight bearing joint of the body and is subject to damage because of its inherent structural complexity and the various types forces subjected to it. Traumatic knee injuries are frequently encountered in the hospital setting and are often caused by sports activities which may even lead to severe pain and disability. Magnetic Resonance Imaging (MRI), with its multi-planar capabilities and excellent tissue contrast has established itself as the leading modality for evaluation of the sports related knee injuries. It is non-invasive and does not involve ionizing radiation.

Imaging of the knee requires excellent contrast, high resolution and the ability to visualize minute structures, all of which are precisely provided by MRI. Advancement in diagnostic MRI tools for the joints is of increased clinical importance as musculoskeletal imaging is a rapidly growing field in MRI applications. Magnetic resonance imaging (MRI) is used more commonly in the knee trauma compared to other joints and is an excellent diagnostic tool that helps clinicians in the evaluation of injuries to menisci and ligaments, osseous structures, articular surfaces and tendon and also helps in determining whether surgery is required or if conservative management will suffice. MRI has supplanted diagnostic arthroscopy as the study of choice for diagnosing internal derangement of the knee and has proven to be cost effective as arthroscopy is invasive and can evaluate only the surface abnormalities.

Materials and Methods

Equipment used: Siemens Magnetom Essenza 1.5 Tesla MRI machine.

1. **Inclusion criteria**
   - All patients referred from clinicians to department of radio diagnosis with clinically suspected traumatic one or both knee joint injuries due to road traffic accident, fall from height, sports injuries, etc. with supportive magnetic resonance imaging findings.
   - All patients irrespective of age group and sex who give consent/assent are taken up for the study.

2. **Exclusion criteria:** Patients with normal magnetic resonance imaging of knee joint.

3. **Limitations**
   - It is not done in patients with claustrophobia, having metallic implants, prosthetic valves.
   - Small posterior horn tears and tears that involve less than one-third of the lateral meniscus can be missed.

4. **Source of data:** Hospital based study enrolled for study after obtaining an informed consent. Patients coming to L.G hospital, Narendra Modi Medical College referred to the department of radio diagnosis with suspected traumatic knee joint injuries and with supportive MRI findings.

5. **Study type:** Prospective observational single centered study.

6. **Method of data collection**
   - **Sample size & Study period:** First 200 cases from June 2023 to November 2023 after obtaining IRB approval.

7. **Sample:** Patients suspected for traumatic knee joint injuries coming to L.G. Hospital, Narendra Modi Medical College referred to department of radio diagnosis with supportive MRI findings after obtaining an informed consent and IRB approval in the year 2023 from June 2023 to November 2023.

Routine sequences performed in all participants

Patient is placed in supine position with knee in a closely coupled extremity coil. The knee is externally rotated 15-10° for better visualization of anterior cruciate ligament (ACL) completely on sagittal images. The knee is flexed slightly 5-10°, to increase the accuracy of assessing the patella-femoral compartment and patellar alignment. Excessive flexion or hyperextensions does not permit accurate evaluation of patellar alignment.

Sequences routinely used

Protocol: T1WI in axial and sagittal plane. T2WI in Coronal & sagittal plane. PD fat saturation in sagittal and oblique coronal plane.

T_1 Sequence: TR 650 TE 12 Flip angle 140

T_2 Sequence: TR 4800 TE 72 Flip angle 150

PD Fat Sat sequence: TR 3100 TE 25 Flip angle 150

Results

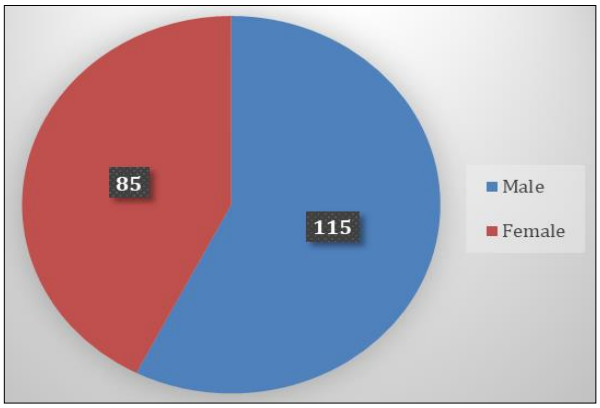

Fig 1: Distribution of patients according to gender (N=200)

Out of 200 patients included in the study, 115 were males (57.5%) & 85 were females (42.5%).

Table 1: Distribution of patients according to age (N=200)

Age	No. of Patients	Percentage
<15	14	7%
15-25	55	27.5%
26-35	50	25%
36-45	30	15%
45-55	26	13%
>55	25	12.5%
Total	200	100%

In this study out of 200 patients, maximum number of patients were from the age group of 15 to 25 years age (27.5%) followed by age group of 26 to 35 year of age (25%). Least number of patients were in age group less than 15 years (7%) followed by age group greater than 55 years (12.5%).

Table 2: Spectrum of MRI injury (N=200)

MRI finding	Positive findings	Percentage
Joint effusion	162	81%
Meniscal injury MM injury (only MM + both MM and LM injury) LM injury (only LM+ both LM and MM injury)	92 72 36	46%
ACL injury	124	62%
PCL injury	13	6.5%
MCL injury	28	14%
LCL injury	12	6%
Osseous-osteochondral changes	66	33%
Cystic lesions	12	6%

Table 3: Number of patients with meniscus injury (N=92)

Type of meniscus injury	No. of patients	Percentage
Only medial meniscus (MM) injury	56	60.8%
Only lateral meniscus (LM) injury	20	21.8%
Both menisci injury	16	17.4%
Total	92	100%

In this study out of 200 patients, 92 patients had meniscus injury out of which 56 patients had only medial meniscus injury (60.8%), 20 patients had only lateral meniscus injury (21.8%) and 16 patients had both menisci injury (17.4%).

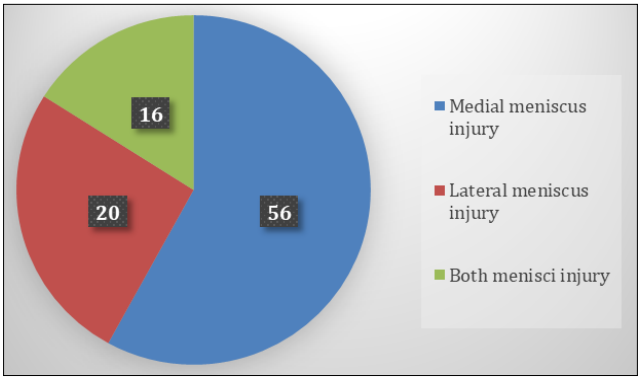

Fig 2: Number of patients with meniscus injury on MRI (N=92)

Table 4: Number of patients with medial meniscus injury (N=72)

Type of meniscus injury	Number of Patients	Percentage
Horizontal	23	31.9%
Complex	16	22.2%
Longitudinal	12	16.7%
Radial	12	16.7%
Root	8	11.1%
Bucket handle	1	1.4%
Total	72	100%

In this study of 200 patients, 72 patients had medial meniscus injury in which maximum number of patients had horizontal tear (31.9%) followed by complex tear (22.2%), while bucket handle tear was least common (1.4%).

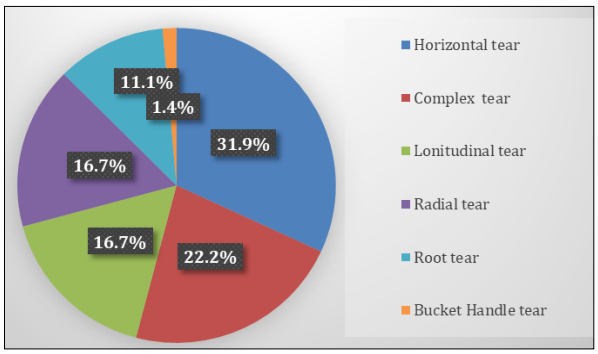

Fig 3: Percentage of patients with medial meniscus injury on MRI

Table 5: Number of patients with lateral meniscus injury (N=36)

Type of meniscus injury	No. of Patients	Percentage
Horizontal tear	11	30.6%
Complex tear	9	25%
Longitudinal tear	8	22.2%
Radial tear	4	11.1%
Root tear	3	8.3%
Bucket handle tear	1	2.8%
Total	36	100%

In this study out of 200 patients, 36 patients had lateral meniscus injury in which maximum number of patients had horizontal tear (30.6%) then complex tear (25%) while Radial and Root tear were less common (Each had 11.1% & 8.3% respectively) & Bucket handle tear was the least common (2.8%).

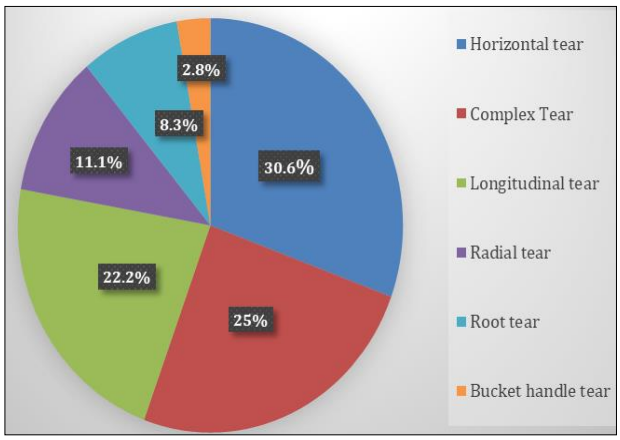

Fig 4: Number of patients with lateral meniscus injury on MRI

Table 6: Number of patients with anterior cruciate ligament injury (N=124)

ACL Tear	No. of Patients	Percentage
Partial	56	45.2%
Complete	68	54.8%
Total	124	100%

In this study out of 200 patients, 124 patients (62%) had anterior cruciate ligament (ACL) injury out of which 56 patients had partial ACL tear (45.2%) while 68 patients had complete ACL tear (54.8%).

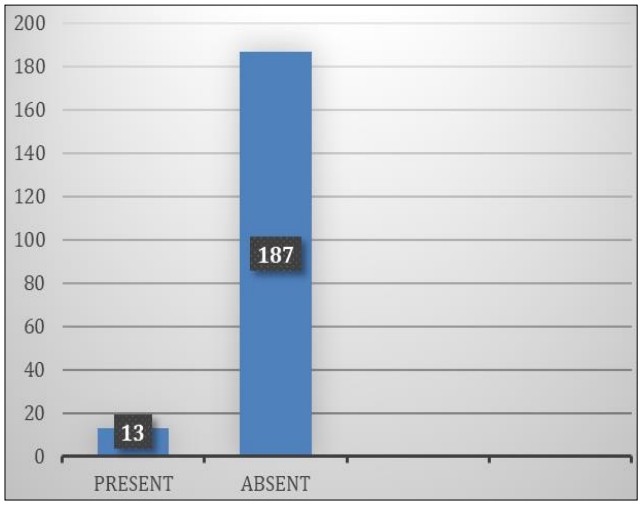

Fig 5: Number of patients with posterior cruciate ligament injury on MRI (N=200)

In this study out of 200 patients, 13 patients (6.5%) had posterior cruciate ligament injury.

Table 7: Number of patients with medial collateral ligament injury (N=200)

Medial collateral ligament tear	No. of Patients	Percentage
Present	28	14%
Absent	172	86%
Total	200	100%

In this study out of 200 patients, 28 patients (14%) had medial collateral ligament injury.

Table 8: Number of patients with lateral collateral ligament injury (N=200)

Lateral collateral ligament tear	No. of Patients	Percentage
Present	12	6%
Absent	188	94%
Total	200	100%

In this study out of 200 patients, 12 patients (6%) had lateral collateral ligament injury.

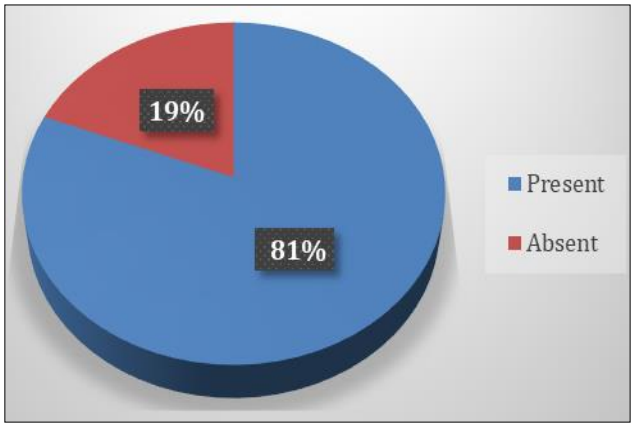

Fig 6: Percentage of patients with joint effusion on MRI

In our study out of 200 patients, 162 patients had joint effusion (81%) which is most common pathology found in this study.

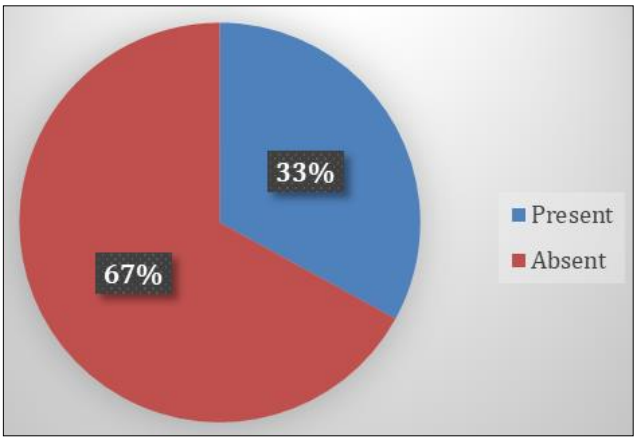

Fig 7: No. of patients with osseous/osteochondral changes on MRI

In our study out of 200 patients, 66 patients had osseous/ osteochondral changes (33%).

Fig 7: Distribution of osseous/osteochondral changes on MRI (N=66)

Injury characteristic	No. of patients	Percentage
Bony contusion	45	68.2%
Hemarthosis	8	12.1%
Lipohemarthosis	2	3.0%
Segond fracture	1	1.5%
Tibial plateau fracture	2	3.0%
Avulsion fracture of femoral or tibial condyle	6	9.2%
Muscle tear	2	3.0%
Total	66	100%

Discussion

Magnetic resonance imaging has steadily increased has become the first line investigation for most of the traumatic and non-traumatic lesions of knee. Pre and post-operative evaluation of the joint can also be done. Complete evaluation of all the internal structures of the knee was not possible with other modalities like conventional radiography, arthrography, ultrasonography and computed tomography. Even with arthroscopy lesions such as peripheral meniscal tears, inferior surface tears and osteochondritis dessicans without articular cartilage damage are most often not detected. Multiplanar MRI modality provides significant improvement in assessing these structures.

The study included 200 patients with maximum number of patients in age group of 15 to 25 years which was estimated to be 27.5% followed by 26-35 years (25%). Male preponderance over female was found, male value estimated to be 57.5% while female was calculated to be 42.5%. All patients underwent MRI. Our study was similar to the study performed by NoahH. Be hairy, Mohsen A. Dorgham *et al*. which included 70 patients ranging in age between 22 to 59 amongst which male were 55.5% and female were 44.5% and all the patients were examined under MRI.

Menisci lesions

Medial meniscal tears are more common, possibly because it is less mobile and bears more force during weight bearing than the lateral meniscus. The meniscus gets damaged due to rotational forces aimed to a flexed knee with twisting while playing a sport. A lateral meniscus can get torn if a valgus force is applied to a flexed knee with the foot planted and the femur rotated externally. While a medial meniscus tears when a varus force is applied to the flexed knee when the foot is planted and the femur rotated internally.

In our study, out of 200 patients; 72 patients (36%) had medial meniscus injury. Out of which 23 patients had horizontal tear (31.9%), 16 patients had complex tear (22.2%), 12 patients had longitudinal tear (16.7%), 12 patients had radial tear (16.7%), 8 patients had root tear (11.1%), and 1 patient had bucket handle tear (1.4%). In our study, out of 200 patients; 36 patients (18%) had lateral meniscus injury. Out of which 11 patients had horizontal tear (30.6%), 9 patients had complex tear (25%), 8 patients had longitudinal tear (22.2%), 4 patients had radial tear (11.1%), 3 patients had root tear (8.3%), and 1 patient had bucket handle tear (2.8%).

There is preponderance of medial meniscus tears over lateral meniscus tears in our study which is well correlated with the study done by Singh JP *et al*., in a series of 173 cases of which they found 57 (38.23%) patients showed medial meniscus tear and 28 (29.41%) patients showed lateral meniscus tear. Lateral discoid meniscus with visible bow tie configuration in more than three contiguous sagittal images was found in one patient.

The cystic lesions encountered were meniscal cyst, parameniscal cyst and popliteal cyst (Baker's cyst). The meniscal cysts and parameniscal cysts were found to be associated with tear of the lateral meniscus in 6 patients (4 parameniscal and 2 meniscal cysts) and medial meniscus in 4 patients (2 parameniscal and 2 meniscal cysts). In these patients location of the cyst, its relation to the joint space and its communication with joint space were clearly demonstrated on sagittal T_2 weighted images. These

findings were correlated with findings described by Thomas H. Berquist. Popliteal cysts were seen in two patients associated with joint effusion, medial meniscal tear and ACL tear. An association of popliteal cyst with joint effusion, meniscal tear and ACL tear has been previously reported in literature.

Fig 1: MRI Fat suppressed proton density weighted sagittal image shows horizontal tear of posterior horn of meniscus extending up to tibial surface

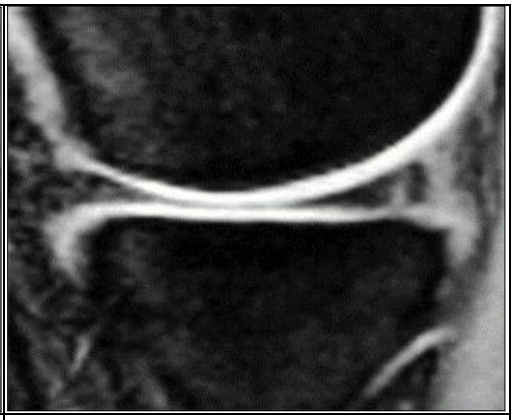

Fig 2: MRI T_2 weighted sagittal images showing longitudinal tear of posterior horn of meniscus

Fig 3: MRI proton density coronal image showing root tear of medial meniscus with associated severe medial subluxation of mensical body

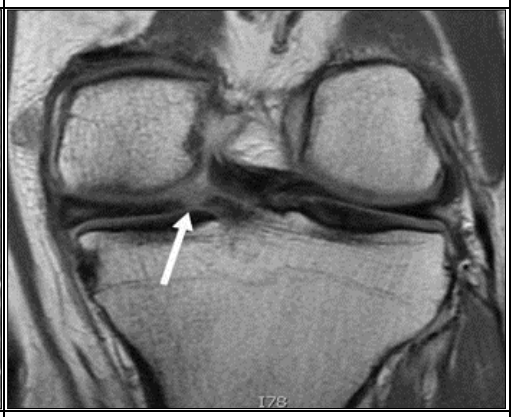

Fig 4: MRI T_1 weighted coronal image showing root tear in posterior horn of medial meniscus in another patient. The meniscus has torn off it's attachment site and tends to subluxate posteromedially.

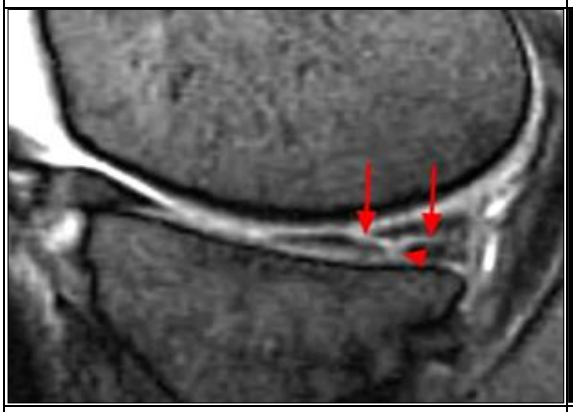

Fig 5: MRI T2*GRE weighted sagittal image shows complex tear of posterior horn of meniscus, having horizontal and longitudinal components

Fig 6: MRI Fat suppressed proton density weighted coronal image shows displaced bucket handle tear of posterior horn of meniscus extending towards intercondylar notch.

Cruciate ligament lesion

Anterior cruciate ligament

The Anterior Cruciate Ligament (ACL) is an important stabilizer of the knee joint against excessive anterior translation and internal rotation of the tibia. The mechanism of the ACL injury includes internal rotation of the tibia over femur commonly occurring during falls while skiing, as well as in contact sports such as football. With valgus stress, the medial femorotibial joint compartment is distracted producing medial collateral injury and medial meniscal injury (O'Donoghue's triad). Another mechanism of ACL injury is hyperextension which can occur during high kick maneuvers, jumping leading to contra-coup bone contusions on the anterior tibia and femoral condyle. Third mechanism is external rotation of tibia relative to the femur with varus stress leading to impaction and bone oedema medially and

distraction laterally resulting in avulsion of the lateral tibial rim (Segond fracture) with tear of lateral collateral ligament.

Both partial and complete ACL tears are considered significant knee injury. Partial tears of the ACL are more difficult to diagnose than complete ACL tears and are characterized by increased signal intensity and fiber laxity with increased concavity or bowing of the ACL and can range from small tear involving few fibres to a high grade near-complete tear involving almost all of the ACL fibres. Also tears of the anteromedial bundle are more common than posterolateral bundle of ACL and the anteromedial bundle is more prone to injury with the knee flexed, whereas the posterolateral bundle injuries occur with hyperextension and internal rotation.

In our study ACL tear was found in 124 patients (62%) among these 56 (45.2%) were partial tears and 68(54.8%) were complete. However, Singh JP *et al*. in their series of 173 patients, 78 patients (45.08%) showed ACL tears, among these 52 (66.67%) are partial, 16 (20.51%) are complete and 10 (12.82%) cases showed non-visualization of ACL. The authors concluded that ACL tears are more common than other 6 ligamentous injuries. In acute full thickness ACL tear, there is oedema within the ligament, with focal complete discontinuity of fibres often with abnormal orientation. In chronic injuries, ACL can be absent or atrophic. Absence of ACL fibres in the femoral notch is suggestive of a proximal tear giving "empty notch sign". Cruciate ganglion cysts and mucoid degeneration of the ACL can be differentiated from tears as they show presence of intact fibres. PCL buckling, anterior tibial translation, and uncovering of the posterior horn of the lateral meniscus were also reported. Bony contusions were noted in many cases patients are best evaluated with fat-suppression techniques such as short time inversion recovery (STIR) or selective partial inversion recovery (SPIR), and these imaging protocols can be used in case of suspected stress-related injury.

Fig 7: MRI T_2 weighted fat saturated sagittal image showing abnormal increased signal intensity in ACL, suggestive of partial thickness tear

Fig 8: MRI proton density fat saturated sagittal image showing partial ACL tear depicting focal increased signal of ACL with wavy contour of posterior fibers

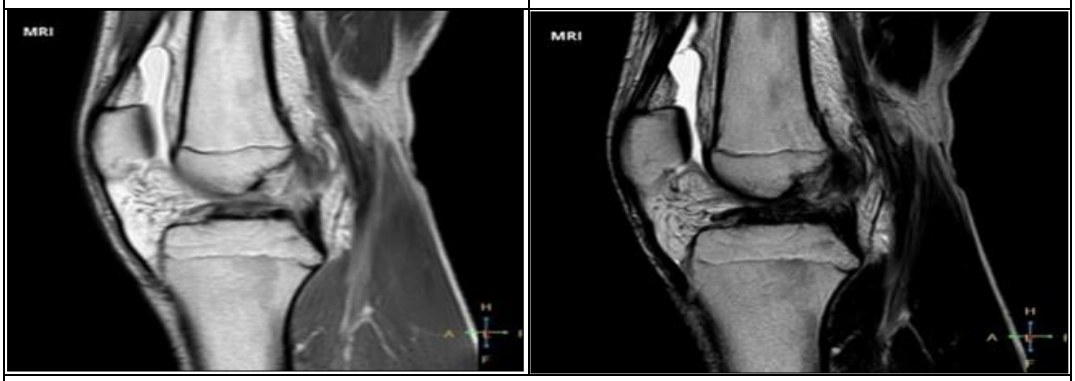

Fig 9: MRI Proton density & T_2 weighted sagittal images showing discontinuity and abnormal signal intensity of ACL fibres-complete ACL tear with joint effusion.

Posterior Cruciate Ligament (PCL)

Three major mechanisms of trauma to PCL include posterior displacement of the tibia in a flexed knee, hyperextension, and rotation combined with an adduction or abduction force. The spectrum of injuries include partial or intra-substance tear, complete ligamentous rupture, and avulsion of the PCL insertion site on the posterior tibia.

It provides anterior-posterior stability and in PCL deficient knee, the medial tibia sags posteriorly. PCL injuries are relatively uncommon, with isolated PCL injuries accounting for 4% of all knee ligamentous injuries. However, this may be also be due to fact that some isolated PCL injuries go unrecognized, and many athletes successfully return to play despite PCL insufficiency. In our study, PCL injury was found in only 13 patients (6.5%) demonstrated as thickening of the ligament with abnormal signal intensity (partial tear). Sonnin *et al*. found the incidence of PCL tear to be 3 percent; in a series of study analyzing 350 case of knee injury only 10 patients had PCL tear. Indirect signs of PCL injury including bone bruises of the anterior tibia and posterior femoral condyles, indicating forced posterior displacement of the tibia with the knee flexed were noted in a few cases.

Fig 10: MRI T_2 weighted fat saturated images showing partial mid substance PCL tear

Fig 11: MRI Proton Density weighted Fat saturated sagittal image in another patient showing hyperintensity along mid substance fibers of posterior cruciate ligament, suggestive of PCL tear

Fig 12: MRI T_1 weighted sagittal image showing complete PCL tear

Collateral ligaments

Medial collateral ligament (MCL) injury is one of the most common injury affecting knee. It mostly results from a valgus force in sport activities, motor vehicle accidents or fall from height. MCL injury can occur in isolation or in association with other knee ligaments such as O'Donoghue unhappy triad or knee dislocations. If it remains undiagnosed and untreated it can lead to instability, pain and loss of function. The lateral collateral ligament is an important stabilizer for varus instability and for posterolateral corner. Compared to other ligaments of the knee, lateral collateral ligament injuries are less common and usually involve multiple structures of the posterolateral corner.

In our study, MCL tears (14%) were found to be more common than the LCL tears (6%). All these patients had history of trauma with associated multiple injuries. This suggests that presence of a single injury should prompt the examiner to look for other subtle associated injuries. This was further confirmed by Mink JH *et al*. stating that 11 patients who has Lateral collateral ligament tear also had tear of Medial collateral ligament (7 patients), tear of lateral meniscus (4 patients) and tear of medial meniscus (1 patient) on MRI and arthroscopy.

Fig 13: T_2 weighted coronal image showing hyperintensity in medial collateral ligament with associated bone marrow edema within medial femoral condyle

Fig 14: T_2 weighted coronal image showing hyperintensity in lateral collateral ligament-s/o tear

Joint effusion

In our study joint effusion was the most common finding affecting 162 patients (81%).

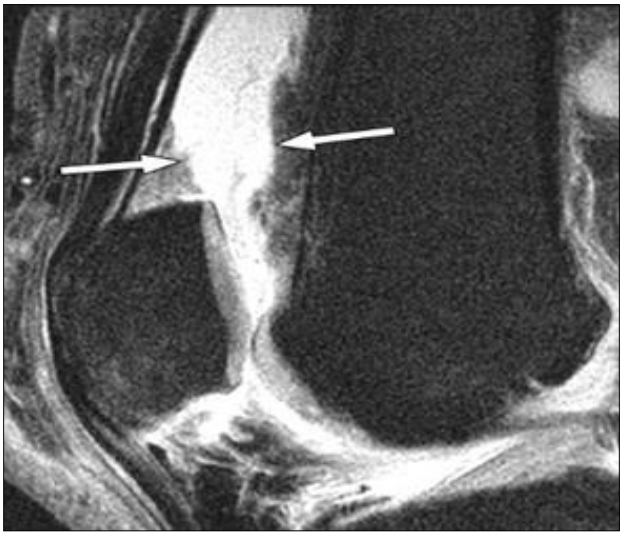

Fig: MRI knee T_2 weighted sagittal image showing joint effusion

Osseous and Osteochondral changes

In our study Osseous/Osteochondral changes were seen in 66 patients (33%). Most of these were bony contusions involving the femoral and tibial condyles (45 patients). Avulsion fracture of tibia and femur was reported in few cases. Tibia was more commonly involved than femur by contusions and lateral femoral condyle was involved more frequently than its medial counterpart. A patient of Segond's fracture of the lateral tibial rim with bony contusion of the lateral femoral condyle was also seen. Tibial spine avulsion fractures were also noted in two cases. In our study we found a patient of comminuted bicondylar fracture of proximal end of tibia with intra-articular and intra-condylar extension. Fracture of medial tibial condyle in postero-lateral aspect displaced antero-medially was also noted. These findings were correlated with findings described by Thomas H. Berquist stating osseous injuries may be articular, extra-articular, or physeal, and may be related to direct trauma, avulsion forces, or chronic microtrauma.

The finding of hemarthrosis (8 patients) and lipo-hemarthrosis (2 patients) was associated in with presence of intercondylar fractures. Partial tear of proximal fibers of medial head of Gastrocnemius muscle was seen in one patient in our study. Avulsion of the semimembranosus tendon at insertion site, an uncommon injury in adults with a high association with ACL injury was reported in 1 patient. These findings were correlated with findings described by Thomas H. Berquist who stated that muscle and tendon injuries about the knee may occur alone or in association with more significant osseous and ligament injuries.

Other osseous pathologies (subchondral cyst and osteoarthritic changes) found on MRI were not included in our study.

Conclusion

- Magnetic resonance imaging is an excellent, non-invasive, radiation free imaging modality with multiplane capabilities and excellent soft tissue delineation that can accurately detect, localize and characterize various internal derangements of the knee joint and helps in arriving at a correct anatomical diagnosis thereby guiding further management of the patient.
- With application of the "two-slice-touch" rule, Magnetic resonance imaging has high accuracy for preoperative detection of meniscal tears. In addition, it allows accurate characterization of various tear patterns, which can be instrumental for patient counseling and surgical planning. Familiarity with the normal anatomy, common anatomic variants, and indirect secondary signs of meniscal tears can help reduce interpretation error.

In the present study, 200 patients with suspected knee joint injuries followed by trauma, referred for magnetic resonance imaging of the knee joint, were evaluated and following patterns of knee injuries were seen.

In this study of 200 patients, 115 patients were male (57.5%) while 85 patients were female (42.5%).

Out of 200 patients, the most common age group affected was 15-25 years (27.5%) followed by 26-35 years (25%). Least common age group affected was < 15 years which included 14 patients (7%).

In this study, the most common injury was ACL tear (62%) of which complete tear (54.8%) was more common than partial ACL tear (45.2%). Posterior cruciate ligament tears (6.5%) were less common.

Among the meniscal injuries seen in 46% of all patients, medial meniscal tears were more common than lateral meniscus tears and horizontal tears were more common in both. Out of 200 patients, 92 patients had meniscus injury out of which 56 patients had only medial meniscus injury (60.8%), 20 patients had only lateral meniscus injury (21.8%) and 16 patients had both menisci injury (17.4%).

Medial collateral ligament tears (14%) outnumbered lateral collateral ligament tears (6%).

Osseous/Osteochondral changes were seen in 66 patients (33%). Most of these were bony contusions involving the femoral and tibial condyles seen in 45 patients (68.2%).

Other abnormalities like myotendinous tears, joint effusions (162 patients), hemarthrosis (8 patients), and discoid meniscus (1 patient) were accurately detected and characterized with the help of magnetic resonance imaging.

Cystic lesions were seen in 12 patients (6%) out of which meniscal cysts and parameniscal cysts were found to be associated with tear of the lateral meniscus (4 parameniscal and 2 meniscal cysts) and medial meniscus in 4 patients (2 parameniscal and 2 meniscal cysts). Popliteal cysts were seen in two patients.

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