Original Article

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Magnetic Resonance Imaging of Knee Joint: Diagnosis and Pitfalls Using Arthroscopy as Gold Standard

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Abstract

Introduction: Role of magnetic resonance imaging (MRI) in the diagnosis of knee lesions has now become more evident. Efficacy of MRI in comparison to arthroscopy has been studied and proved by many authors reporting high sensitivity and specificity of MRI.

Objective: To find out the efficacy of MRI in diagnosing various ligamentous and meniscal injuries in terms of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) and to retrospectively evaluate limitations of MRI.

Materials and Methods: Total 50 knee MRI's of patients who were posted for/underwent knee arthroscopy were studied in this prospective study. Images were obtained on a 1.5T magnet or higher magnet. MRI images of these patients were evaluated independently by a radiologist with experience in musculoskeletal radiology. The arthroscopic examination and further management were done by an experienced orthopedic surgeon. Findings of MRI and arthroscopy were correlated. Statistical analysis was used to calculate the sensitivity, specificity, PPV, and NPV to assess the reliability of MRI results.

Results: There was male preponderance with 64% males. Maximum patients belonged to 2-4th decade of life. Sensitivity, specificity, PPV, and NPV for anterior cruciate ligament (ACL) tear were 100%, 92%, 92%, and 100%, for ACL avulsion were 100%, 100%, 100%, and 100%, and for myxoid degeneration were 100%, 100%, 100%, and 100%, respectively. Sensitivity, specificity, PPV, and NPV for posterior cruciate ligament tear were 100%, 100%, 100%, and 100%, respectively. Sensitivity, specificity, PPV, and NPV for medial meniscus were 100%, 96%, 96%, and 100% and for lateral meniscus were 100%, 100%, 100%, and 100%, respectively.

Conclusion: MRI is a non-invasive, radiation-free, and an excellent imaging modality to evaluate ligaments and menisci of the knee joint and surrounding soft tissue. Almost all the ligamentous and meniscal injuries can be diagnosed with a high level of confidence.

Key words: Anterior cruciate ligament, Arthroscopy, Meniscus tear, Magnetic resonance imaging

INTRODUCTION

Since the introduction of magnetic resonance imaging (MRI) for clinical use, in 1984, the role of MRI in the diagnosis of knee lesions has now become more evident.[1,2] Efficacy of MRI in comparison to arthroscopy has been studied and proved by many authors reporting high sensitivity and specificity of MRI. Because of technical advancement in MRI scanners, it has become very sensitive modality in picking up signals, which at times may lead to misdiagnosis. In this study, we studied MRI of knee joints diagnosing cruciate and meniscal pathologies and pitfalls about T2W hyperintensity in cruciate and menisci and compared it to arthroscopy findings.

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MATERIALS AND METHODS

Total 50 Knee MRI scans of patients who underwent knee arthroscopy from June 2015 to December 2015

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were studied in this prospective study. MRI images were obtained on 1.5T Philips Achieva with patient supine and knee in extension and 5° of external rotation. Pulse sequences used were spin echo (SE), fast SE, gradient recalled echo, short tau inversion recovery (STIR), and proton density in three standard imaging planes, namely, coronal, sagittal, and axial. Slice thickness of 4 mm, FOV of 15 × 15 cm, and 480 × 480 matrix were used. Patients with neoplasm, previous knee surgery and those with contraindication to MRI were excluded from the study. MRI images of these patients were evaluated independently by a radiologist with experience in musculoskeletal radiology.

Interpretation of Images

Criteria followed for interpretation of images was as following: (1) The anterior cruciate ligament (ACL) was evaluated on sagittal, coronal, and axial images and categorized as intact or torn. (2) A normal ACL was considered when a hypointense band like structure was seen on T2TSE images. (3) Complete absence of ligament, abnormal signal intensity of the ligament, wavy contour or poor definition of its ligamentous fibers were all considered as complete ACL tear (Figure 1).[3] (4) The detection of discrete area or focus of increased signal intensity within the substance of the ACL was diagnosed as partial tear.[4] (5) The "celery stalk" appearance of the ACL with mucoid degeneration and fusiform enlargement of the ligament was diagnosed as ACL myxoid degeneration (Figure 2).[5] (6) ACL avulsion was considered when bone fragment was noted avulsed from the tibia with an intact ACL and adjacent marrow edema (Figure 3).[6] (7) posterior cruciate ligament (PCL) tear was diagnosed as altered signal intensity in ligament on T2TSE images (Figure 4). Normal PCL is labeled as uniform low-signal-intensity band.[7] (8) Hypointense meniscus on T2TSE images without any altered signal intensity was considered normal. (9) The presence of an intrameniscal high signal intensity was regarded as a tear, and its grading was done according to whether it reaches to the articular surface or not as follows:[8] (a) MR Grade I, a non-articular focal or globular intrasubstance increased signal intensity on T2TSE images, (b) Grade II, a horizontal, linear intrasubstance increased signal intensity usually extends from the capsular periphery of the meniscus without involving an articular meniscal surface on T2TSE images, and (c) A meniscus is considered MR Grade III when the area of increased signal intensity communicates or extends to at least one articular surface on T2TSE images. (10) A bucket-handle tear is diagnosed in case of longitudinal type of tear with displaced fragment.[9] (11) While diagnosing bucket-handle tear presence of following signs was also evaluated: (a) The double PCL sign was positive for the presence

Figure 1: Sagittal proton density-weighted image through intercondylar notch shows thickened anterior cruciate ligament (ACL) with hyperintense signal in complete ACL tear

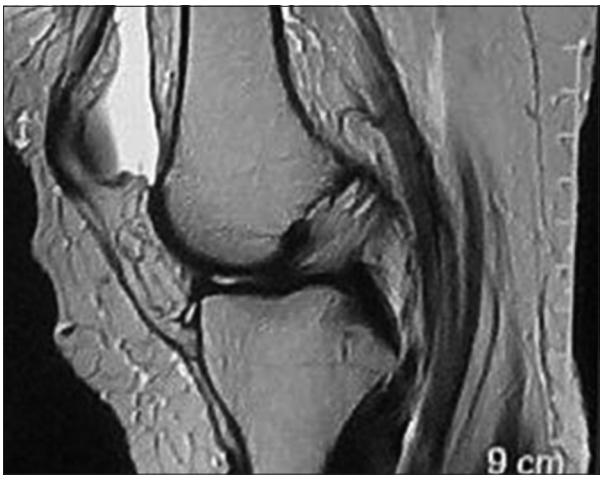

Figure 2: Sagittal T2W image through the intercondylar notch shows fusiform enlargement of anterior cruciate ligament with myxoid degeneration

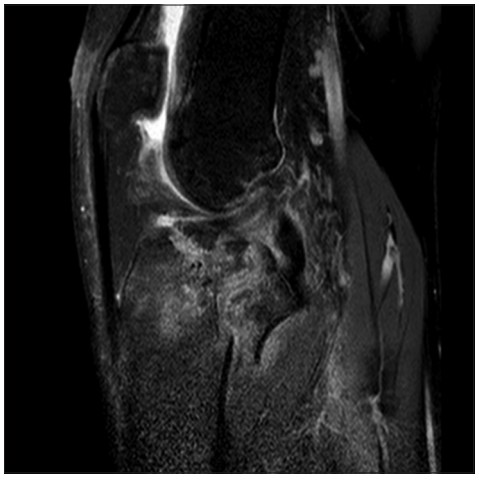

Figure 3: Sagittal proton density-weighted image through the intercondylar notch shows avulsion of tibial attachment of anterior cruciate ligament (ACL) with the bony fragment. Fibers of ACL appear intact

of a notch fragment when a band like meniscal fragment was visible under the PCL and created the appearance of a double PCL (Figure 5) on sagittal intermediate-weighted MR images.[10] (b) The flipped-meniscus sign was positive when an anteriorly displaced triangular meniscal fragment was located posterior to the anterior horn of the same meniscus on sagittal intermediate-weighted images.[11] (c) The too-tall anterior horn sign was positive when the anterior horn of the meniscus was too tall or was at least 6 mm in diameter on sagittal intermediate-weighted images.[11] (d) The disproportionate posterior horn sign was positive when the inner portion of the posterior horn was larger than the outer portion on sagittal intermediate-weighted images.[12] (e) The absent bow tie sign was considered to be positive when only one or no meniscal body segment was visible on two consecutive peripheral sagittal sections.[13-15] (f) A root tear is said to be present when a tear was reaching up to meniscotibial attachment of the posterior horn (Figure 6) with presence of ghost meniscus on sagittal images or blunting of the normal meniscotibial attachment and foreshortening of the meniscus toward the posterior aspect of the intercondylar notch on coronal images.[16]

The arthroscopic examination was done by an experienced orthopedic surgeon. Arthroscopy was performed, with spinal anesthesia induced in the patient, using a 30° whole-angle arthroscope (Dyonics, Smith Nephew, Bulgaria) that was 4mm in outer diameter and a one-chip high-resolution camera (Max sar, Germany). High anterolateral and anteromedial portals were routinely used to introduce the arthroscope; accessory portals, including posteromedial, suprapatellar, or high medial portals, were used when necessary. During arthroscopy, a thorough examination of the knee was performed, and the pathological structure was identified. Further surgical intervention was carried out accordingly. The arthroscopic images were digitized on a computer. MRI findings were correlated with arthroscopic findings.

Statistical Analysis

The composite data were tabulated and studies for correlation of MRI findings with arthroscopy findings grouped into 4 categories.

1. True positive
2. True negative
3. False positive
4. False negative.

Statistical analysis was used to calculate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) to assess the reliability of MRI results.

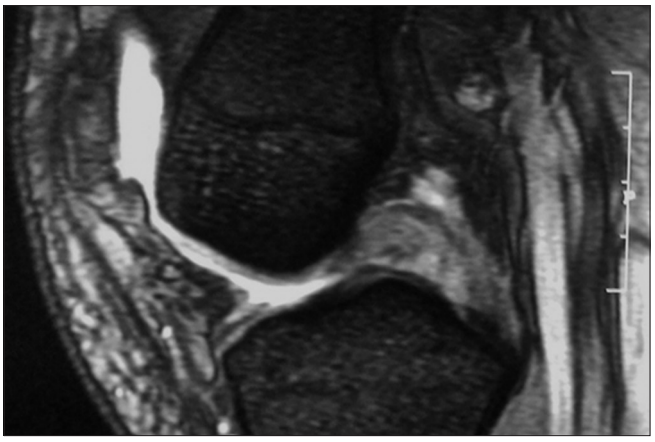

Figure 4: Sagittal T2W image through intercondylar notch shows disruption of posterior cruciate ligament with no normal fibers identified

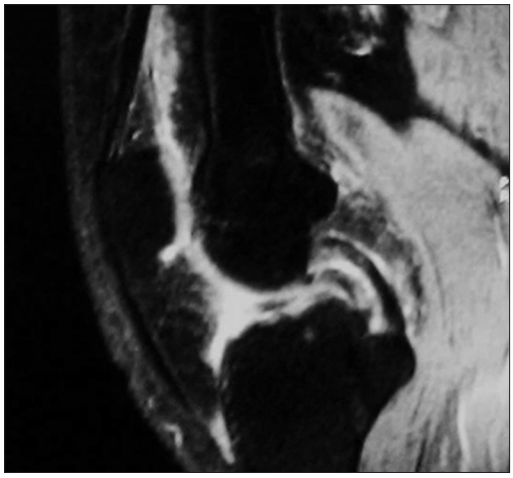

Figure 5: Sagittal image through the intercondylar notch in a patient with a bucket-handle tear shows the displaced fragment anterior to the posterior cruciate ligament - the "double posterior cruciate ligament" sign

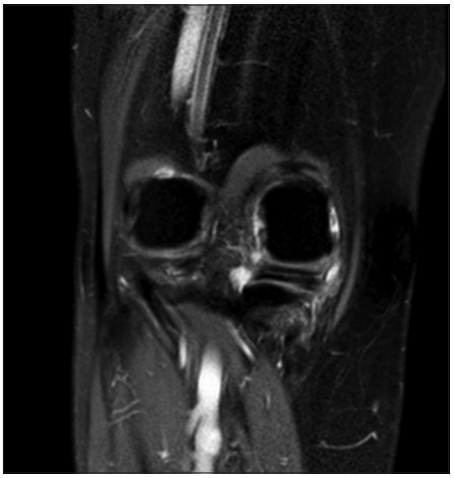

Figure 6: A horizontal root tear of medial meniscus is seen extending to posterior root attachment of medial meniscus to medial tibial eminence

RESULTS

Out of 50 patients, there was male preponderance with 64 % males (Table 1).

Maximum patient belonged to 2nd decade followed by 3rd decade (Table 2).

About 2 patients with a complete tear on MRI had normal ACL on arthroscopy. 1 patient with complete ACL tear on MRI had partial ACL tear on arthroscopy (Table 3).

Posterior horn of medial meniscus was most commonly involved (Table 5).

About 1 patient with Grade III horizontal signal in the posterior horn of medial meniscus was not appreciated on arthroscopy (Table 6).

The bucket-handle tear of medial meniscus was more common. 3 patients were diagnosed as Grade III tear on MRI were the bucket-handle tear on arthroscopy (Table 7).

In cases of the bucket-handle tear, absent bow tie sign was a most common presentation (Table 8).

Table 1: Sex distribution

Sex	No. of patients	% distribution
Male	32	64
Female	18	36

Table 2: Age distribution

Age distribution	Males	Females	Total (%)
11-20	2	1	3 (6)
21-30	16	1	17 (34)
31-40	9	3	12 (24)
41-50	2	8	10 (20)
51-60	3	4	7 (14)
61-70	0	1	1 (2)

DISCUSSION

We evaluated symptomatic knee joints on MRI in 50 patients before surgery, i.e., arthroscopy and MRI findings were compared to arthroscopy findings.

About 64% of patients were males and 36% were females. The age group ranged from 18 to 70 years. We observed maximum patients were in 2nd decade.[17]

Sensitivity and specificity of MRI in diagnosing complete ACL tear were 100% and 89.6% and for partial tear was 100% and 100%, respectively. In three patients, complete tear of ACL was given on MRI, on arthroscopy two were intact and one had a partial tear. In one 65-year-old patient with a history of trivial trauma, diffuse hyperintensity was noted in ACL on T2TSE images and was diagnosed as complete ACL tear. However, arthroscopy noted partial tear involving an anteromedial bundle of ACL. Possibly, the patient was having myxoid degeneration with partial tear which made a differentiation between complete and partial tear difficult. In addition, the patient also had degeneration in PCL, bones, and cartilage. Other two patients in their early 40's one male and one female had diffuse T2W hyperintensity, no normal fibrillar pattern of ACL was seen and were diagnosed as a complete tear (Figure 7). ACL in these two patients appeared normal on arthroscopy. Abnormal signal intensity alone may be associated with either a ligamentous sprain or disruption of collagen fibers,[18] which may remain arthroscopically occult. Dowdy *et al*.[19] documented that a positive MRI for an ACL tear combined with a normal arthroscopy did not necessarily represent a false positive MRI and intrasubstance tear may be present which is difficult to detect with arthroscopy. Several prospective studies have shown a sensitivity of 92-100% and specificity 93-100% for the MR imaging diagnosis of ACL tears.[20,21] Our study closely matches to these.

MRI was 100% sensitive and specific in diagnosing ACL avulsion and myxoid degeneration. In patients with myxoid

Table 3: MRI and arthroscopy correlation of ACL pathologies (total patients: 33)

ACl pathologies	MRI	Arthroscopy	Sensitivity (%)	Specificity (%)	PVV (%)	NPV (%)
Complete ACL tear	24	21	100	89.6	87	100
Partial ACL tear	2	2	100	100	100	100
Myxoid degeneration	5	5	100	100	100	100
Avulsion	2	2	100	100	100	100

ACL: Anterior cruciate ligament, MRI: Magnetic resonance imaging

Table 4: MRI and arthroscopic correlation of PCL tears

Pathology	Diagnosis on MRI	Diagnosis on arthroscopy (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
PCL tear	2	1	100	97	50	100

PCL: Posterior cruciate ligament, MRI: Magnetic resonance imaging

degeneration, a typical celery stalk appearance was observed within bulky ACL. In one patient, myxoid degeneration was associated with a ganglion cyst. It was confirmed on arthroscopy and amber colored fluid oozed out of it on puncturing.

Two patients had altered the signal in PCL on T2TSE images and were diagnosed as tear, out of which one was confirmed on arthroscopy (Table 4). In another patient, PCL was diffusely hyperintense and thickened on T2TSE images hence diagnosed as PCL tear. On arthroscopy, PCL was intact in addition patient was having ACL partial tear, gross degenerative changes in joint and bucket-handle tear of the medial meniscus. The hyperintensity was possibly attributed to degeneration with an element of contusion.

Medial meniscus (80.5%) was more commonly injured than lateral meniscus (19.5%). Our result matches with studies done by Singh *et al*. and Bari *et al*.[22,23] Out of 28 patients of meniscal tear, 13 had purely meniscus injury and 15 had associated ACL injury. Only Grade III signals are considered for statistical analysis. Sensitivity and specificity for medial meniscus tear were 100% and 96%, respectively and for lateral meniscus both were 100%. One patient had Grade III signal reaching up to the inferior surface of the posterior horn of medial meniscus on MRI (Figure 8) was normal on arthroscopy. Possibly, the tear was not reaching up to the inferior surface or a stable tear which was not appreciated on probing during arthroscopy. Normal anatomical structures such as transverse and meniscofemoral ligaments, popliteus tendon, genicular artery, and other artifacts such as capsule attachment, bursae of MCL, can lead to misdiagnosis of tear.[24]

In the present study, 10 patients were diagnosed as having bucket-handle tear. Absent bow tie sign was seen in eight patients. In the present study, absent bow tie sign was seen to be a most sensitive sign to diagnose bucket-handle tear.[14,15] In three patients, longitudinal to oblique signals were noted in posterior horn reaching up to the inferior surface not fitting into criteria of bucket-handle tear hence diagnosed as simple meniscal tear without mentioning as the bucket-handle tear. On arthroscopy, all three patients had the bucket-handle tear. Possibly while probing the meniscus the fragment got displaced converting it to bucket-handle tear (Figure 9).

Figure 7: Altered signal intensity in ACL was diagnosed as ACL tear on MRI. However, ACL was normal on arthroscopy in this patient

Figure 8: Grade III signal reaching up to inferior articular surface was diagnosed as medial meniscus tear. However, meniscus was stable on probing during arthroscopy

Table 5: Grades of meniscal signals on MRI (total patients: 36)

Grades	Medial meniscus		Lateral meniscus	
	Anterior horn	Posterior horn	Anterior horn	Posterior horn
Grade I	0	0	0	0
Grade II	2	6	0	0
Grade III	0	21	0	7
Total	2	27	0	7

MRI: Magnetic resonance imaging

Table 6: MRI and arthroscopic correlation of Grade III signal (total patients: 28)

Meniscus	Grade III signal on MRI	Arthroscopy findings	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Medial meniscus	21	20	100	96	96	100
Lateral meniscus	7	7	100	100	100	100

MRI: Magnetic resonance imaging

Table 7: Diagnosis of bucket-handle tear on MRI and arthroscopy (total patients: 10)

Meniscus involved	Diagnosis on MRI	Diagnosis on arthroscopy
Medial meniscus	8	2
Lateral meniscus	9	4

MRI: Magnetic resonance imaging

Table 8: Correlation of different signs in cases of bucket-handle tear

Meniscus involved	MRI diagnosis				
	Flipped meniscus sign	Double PCL sign	Absent bow tie sign	Too tall anterior meniscus	Disproportionate posterior horn of meniscus
Medial meniscus	2	2	6	0	0
Lateral meniscus	0	0	2	0	0

PCL: Posterior cruciate ligament, MRI: Magnetic resonance imaging

Table 9: Diagnosis of root tear on MRI and arthroscopy

Root tear of meniscus	MRI	Arthroscopy
Medial meniscus	5	5

MRI: Magnetic resonance imaging

Table 10: Chondral defect

Pathology	MRI	Arthroscopy
Chondral defect	2	2

MRI: Magnetic resonance imaging

Table 11: Associated findings

Pathology	Diagnosis on MRI	Diagnosis on arthroscopy
Parameniscal cyst near medial meniscus	3	3
Parameniscal cyst near lateral meniscus	4	4
Baker's cyst	4	-

MRI: Magnetic resonance imaging

In this study, we had five patients having posterior root tear which were diagnosed on MRI and confirmed on arthroscopy (Table 9). All had horizontal signal intensity on coronal images representing tears. All patients were having medial root involvement. Sensitivity and specificity of our study in diagnosing root tears were 100%. The meniscal roots represent the attachment sites of the menisci to the medial tibial eminence. The posterior meniscal root of the medial meniscus attaches immediately anterior to the PCL. In the coronal plane, the posterior meniscal root is horizontally oriented and extends to attach at the medial tibial eminence.

Two patients with cartilage loss were diagnosed correctly on MRI as focal loss and T2TSE hyperintensity along the curvature of cartilage (Table 10). In seven patients, para meniscal cysts were associated with meniscal tear.

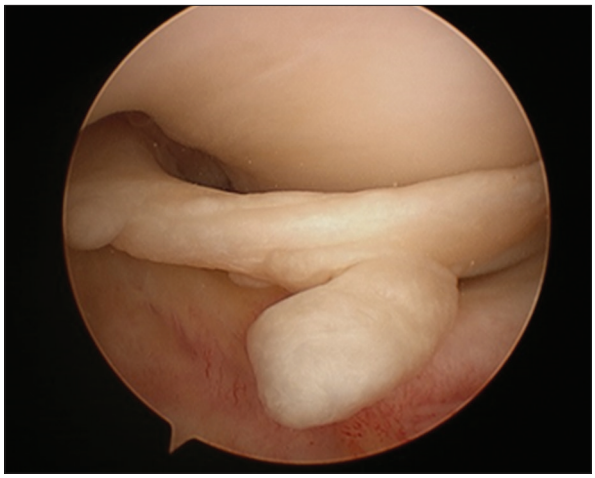

Figure 9: Arthroscopy image showing bucket-handle tear of medial meniscus

Other associated findings bone marrow edema, both collateral ligament injuries, Baker's cyst, soft tissue edema, which were not seen on arthroscopy (Table 11).

Interpretation of knee MRI has a long learning curve. Technical factors such as imaging parameters, coil strength, planes of image, quality of imaging equipment also affect interpretation.

CONCLUSION

The sensitivity and specificity for diagnosing complete ACL tear were 100% and 89.6%, respectively. Intrasubstance T2W hyperintensity in ACL or PCL may represent intrasubstance tear and/or degeneration in situation of trauma to the knee joint. Stable meniscal tear with Grade III signal cannot be appreciated on arthroscopy. In the present study, absent bow tie sign was the most sensitive sign to diagnose bucket-handle tear. Bucket-handle tear can be seen as simple Grade III signal. MRI has 100% sensitivity for root tears.

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