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Original Research Article

ROLE OF MRI IN DIAGNOSIS OF ANTERIOR CRUCIATE LIGAMENT INJURIES OF KNEE ASSUMING ARTHROSCOPY AS GOLD STANDARD

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ABSTRACT

Background: The knee is a complex joint with a number of internal structures, all of which can give rise to symptoms in knee injuries. Magnetic Resonance Imaging (MRI) is a good non-invasive procedure to study the injured knee avoiding invasive procedures and further morbidity. The present study was conducted to assess the diagnostic usefulness of MRI in evaluating anterior cruciate ligament pathologies. **Materials and methods:** It was a cross-sectional, observational study that was carried out in the Department of Radiodiagnosis and Modern Imaging, S.M.S. Medical College, Jaip[ur (Rajasthan). The duration of the study was from July 2018 to August 2019. After getting permission from the institutional ethics committee 55 knee injury patients who had given consent were recruited for the study. After obtaining a detailed history, MRI and Arthroscopy were done and findings were noted in pre-tested, semi-structured proforma. The data were statistically analyzed. P-value < 0.05 was considered as statistically significant. **Results:** In the present study, the accuracy of MRI in the diagnosis of anterior cruciate ligament tear of the knee was 94.55% for complete tears, 85.45% for partial tears and 90.91% for interstitial edema. Partial tear of ACL was present in 52.7% cases while a complete tear was found in 43.6% cases. The most common location of ACL tear was at mid-substance. Meniscal tears with bone marrow edema/contusions of femoral and tibial condyles were most commonly associated with ACL tears. **Conclusion:** MRI has proven to be effective in defining complete and partial ACL tears with good diagnostic accuracy. It is cost-effective in the acute knee injury setting, in terms of cost and quality of life perception as a non-invasive replacement for arthrography and non-therapeutic arthroscopy.

Keywords: Knee injuries, Anterior Cruciate Ligament, MRI, Arthroscopy.

INTRODUCTION

The knee is the largest joint in the body, with complex anatomy. The supporting structures of the knee joint are the medial collateral ligament (MCL), the lateral collateral ligament (LCL), the anterior cruciate ligament (ACL), the posterior cruciate ligament (PCL) and the quadriceps femoris and patellar tendons. The medial and lateral menisci are situated within the knee joint surface between the femoral condyles and the tibial plateau. These structures with the muscles and a wide and lax joint capsule, maintain and support knee stability. **(1-3)**

Anterior cruciate ligament (ACL) failure can occur during abduction and hyperextension with external rotation and direct forward displacement of the tibia, or internal rotation with the knee in full extension. If varus or valgus stress, the ACL is injured after collateral ligament failure. Valgus (forcefully) in external rotation is the most common mechanism of injury and causes disruption of the MCL and medial supporting structures. **(4-5)**

The usefulness of MRI in demonstrating knee joint abnormalities involving articular cartilage, bone

marrow, synovium, patellofemoral joint and adjacent soft tissue; the main indication is in the assessment of ligament and meniscal injuries. The low cost of MR knee has also contributed to their acceptance by the orthopaedic community as a non-invasive replacement for non-therapeutic arthroscopy and arthrography. **(6)** MRI is now routinely used to assess a wide spectrum of internal knee derangements and articular disorders. **(7-8)**

The anterior cruciate ligament due to its oblique orientation poses slight difficulty in imaging and subsequent image interpretation. However, with dedicated imaging protocols, it is possible to image anterior cruciate ligament in great detail and come to the almost accurate conclusion of its pathologies. MR evaluation can characterize the spectrum of morphologic and signal intensity changes in ACL tears. The ACL discontinuity, assessed in the sagittal and axial planes, and failure of ACL fascicles to parallel Blumensaat's line are considered primary and accurate signs of a ligament tear.9 Other predictors of an ACL tear include discontinuity of the ACL in one plane, disruption of fascicles, bone contusions on the weight-bearing surface of the lateral femoral condyle and posterolateral tibial plateau, buckling of the PCL, a positive PCL sign and a positive posterior femoral line sign. **(10)**

The main purpose of this study is to assess the sensitivity and specificity of MRI in the diagnosis of anterior cruciate ligament injuries of the knee joint with arthroscopic correlation.

MATERIAL AND METHODS

A hospital-based, cross-sectional, observational study was carried out in the Department of Radiodiagnosis and Modern Imaging, S.M.S. Medical College, Jaipur (Rajasthan) from July 2018 to August 2019. The plan was approved by the research review board and institutional ethics committee. A total of 55 knee injury patients attending Orthopaedics OPD were recruited in the study after taking informed written consent. Patients unfit for MRI, prior arthroscopy or surgical intervention on the affected side of the knee were excluded from the study. Socio-demographic data like age and sex were noted and a detailed history of knee injury was taken and clinical examination was done.

MR imaging was performed with a Philips Ingenia 3T MR Scanner. A dedicated knee coil was used. The examination was done after ruling out the presence of any contraindication in all the patients. The patient was placed in a supine position with the knee extremity coil. The knee was rotated 15-20° externally, in order to facilitate the visualization of ACL completely on sagittal images as it realigns the ACL parallel with the sagittal imaging plane. The knee was 5-10° slightly flexed, to increase the accuracy of assessing the patellofemoral compartment and patellar alignment. Only one knee will be scanned at a time. Images will be acquired in the sagittal, oblique sagittal, coronal and axial planes. An axial acquisition was used through the patellofemoral joint as an initial localizer for subsequent sagittal and coronal plane images. The coronal plane adequately evaluates the collateral ligaments and body of the menisci. The sagittal plane shows the cruciate ligaments, menisci and synovial anatomy especially the suprapatellar pouch. Overall the bones, tendons, muscles, neurovascular structures were fully evaluated by using all three planes. Arthroscopy was performed to obtain corresponding findings.

The statistical analysis was done using SPSS Software Ver. 20. Data were presented in tables and graphs. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy of MRI was assessed in anterior cruciate ligament injuries of knee assuming arthroscopy as a gold standard. Pearson Chi-square test was used for assessing the correlation between MRI and arthroscopic findings. The p-value of <0.05 was considered significant.

RESULTS

A total of 55 cases of knee injuries were selected by simple random sampling. Among these, 40 (72.7%) were men and 15 (27.3%) were women, 19 (34.50%) were between 21 and 30 years, 16 (29.1%) were between 31 and 40 years, 12 (21.9%) were between 41 and 50 years, 7 (12.7%) were between 11 and 21 years and 1 (1.8%) was above 50 years of age. In 33 (60%) patients the right knee was involved while in 22 (40%) it was left knee.

In the present study, 24 (43.6%) patients had full-thickness ACL tears while 29 (52.7%) patients had partial thickness tear and 2 (3.6%) had interstitial edema on MRI while in arthroscopy these findings were 41.8%, 52.7% and 5.5% respectively (Table-1). Maximum number of patients, 34 (61.8%) had mid substance tears followed by 14 (25.5%) patients who had tears at the femoral attachment and 7 (12.7%) patient at the tibial attachment on MRI while these finding were 63.6%, 23.6% and 12.7% respectively on arthroscopy (Table-2). Posterior cruciate ligament

(PCL) tears accounted for the small number of cases 8 (14.5%) out of 55 patients. All the patients had partial-thickness tears with 5 patients having low-grade partial-thickness and 3 patients having high-grade partial-thickness tears (Table-1). All 8 patients of PCL tear on MRI had femoral attachment tears and comparing with arthroscopy 1 had tibial attachment (Table-2).

Out of 55 cases of ACL tears, 51 (92.7%) were associated with meniscal tears. Out of these, 32 (58.2%) were associated with medial meniscal tears and 19 (34.5%) cases were associated with lateral meniscal tears in MRI which are compared with arthroscopy findings as in table-3. Thus, medial meniscal tears were more commonly associated with ACL tears. Out of the 32 patients with medial meniscal tears and degeneration, 23 (71.8%) showed Grade-III signal, 5 (15.6%) showed grade-II signal, 2 (6.3%) showed grade-I signal and 2 (6.3%) showed bucket handle tear (Table-4). Among medial meniscal tears and degeneration, 31 (96.9%) were in posterior horn and 1(3.1%) was in posterior and anterior horn in MRI while on Arthroscopy all 32 patients of medial meniscal tears and degeneration were in the posterior horn. Out of the 19 cases of lateral meniscal tears and degeneration, 13(68.4%) showed Grade-III tear, 5 (26.3%) showed grade-II degeneration and 1 (5.3%) showed grade-I degeneration (Table-4). Among lateral meniscal tears and degeneration, 8 (42.1%) were in anterior horn and 11 (57.9%) in the posterior horn.

Out of 55 patients, 14 had medial collateral ligament grade-I signal. Osseous fractures were seen in 9 (16.3%) cases. Out of these 9 cases, tibial plateau fractures accounted for 6 (10.9%) cases, femoral condyle fractures for 2 (3.6%) cases and patellar fracture in 1 (1.8%) case. In the present study, tibial plateau fractures were most common and predominantly occurred with the lateral tibial plateau.

The MRI findings of anterior cruciate ligament injury were compared with the arthroscopic results (considered the gold standard for diagnosis) and sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated. The sensitivity and specificity of complete tear were 95.65% and 93.75% while for partial tear these were 86.21% and 84.62% respectively. For complete as well as partial tears, a significant correlation between MRI and Arthroscopic findings (P< 0.001) according to Pearson Chi-Square results.

Table-1: Types of anterior and posterior cruciate ligament tears

Cruciate Ligament	Type of tear	MRI n (%)	Arthroscopy n (%)
Anterior Cruciate Ligament (N=55)	Complete	24 (43.6)	23 (41.8)
	Partial	29 (52.7)	29 (52.7)
	Interstitial edema	2 (3.6)	3 (5.5)
Posterior Cruciate Ligament (N=55)	Partial	8 (14.5)	8 (14.5)
	Nil	47 (85.5)	47 (85.5)

Table-2: Locations of anterior and posterior cruciate ligament tears

Cruciate Ligament	Location of tear	MRI n (%)	Arthroscopy n (%)
Anterior Cruciate Ligament (N=55)	Femoral attachment	14 (25.5)	13 (23.6)
	Tibial attachment	7 (12.7)	7 (12.7)
	Mid substance	34 (61.8)	35 (63.6)
Posterior Cruciate Ligament (N=55)	Femoral attachment	8 (100.0)	7 (87.5)
	Tibial attachment	0 (0.0)	1 (12.5)

Table-3: Meniscal tears and degeneration associated with ACL tear

Meniscal tear and degeneration	MRI n (%)	Arthroscopy n (%)
Medial meniscal tear	17 (30.9)	17 (30.9)
Medial meniscal degeneration	7 (12.7)	7 (12.7)
Medial and lateral meniscal tears	4 (7.3)	3 (5.5)
Medial meniscal tear and Lateral meniscal degeneration	4 (7.3)	5 (9.1)
Lateral meniscal tear	10 (18.2)	9 (16.4)
Lateral meniscal degeneration	1 (1.8)	1 (1.8)
Nil	12 (21.8)	13 (23.6)
Total	**55 (100.0)**	**55 (100.0)**

Table-4: Grades of tear and degeneration associated with ACL tear

Menisci	Grade tear and degeneration	MRI n (%)	Arthroscopy n (%)
Medial Meniscus (N=32)	I	2 (6.3)	2 (6.3)
	II	5 (15.6)	6 (18.7)
	III	23 (71.8)	22 (68.7)
	Bucket handle tear	2 (6.3)	2 (6.3)
Lateral Meniscus (N=19)	I	1 (5.3)	1 (5.6)
	II	5 (26.3)	5 (27.8)
	III	13 (68.4)	12 (66.7)

Table-5: Cross-tabulation of type of ACL tears in MRI and Arthroscopy

Type of ACL tear (MRI)		Type of ACL tear (Arthroscopy)			
		Complete	Interstitial edema	Partial	Total
Complete	Count	22	0	2	24
	% within Type of ACL tear	95.7%	0.0%	6.9%	43.6%
Interstitial edema	Count	0	0	2	2
	% within Type of ACL tear	0.0%	0.0%	6.9%	3.6%
Partial	Count	1	3	25	29
	% within Type of ACL tear	4.3%	100.0%	86.2%	52.7%
Total	Count	23	3	29	55
	% within Type of ACL tear	100.0%	100.0%	100.0%	100.0%

Chi-Square test	Value	Df	P-Value	Association is
Pearson Chi-Square	43.980	4	<0.001	Significant

Table-6: Sensitivity, specificity, PPV, NPV, and accuracy of MRI in ACL tears assuming Arthroscopy as a gold standard

Final diagnosis	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Complete tear	95.65	93.75	91.67	96.77	94.55
Partial tear	86.21	84.62	86.21	84.62	85.45
Interstitial edema	0	96.15	0	94.34	90.91

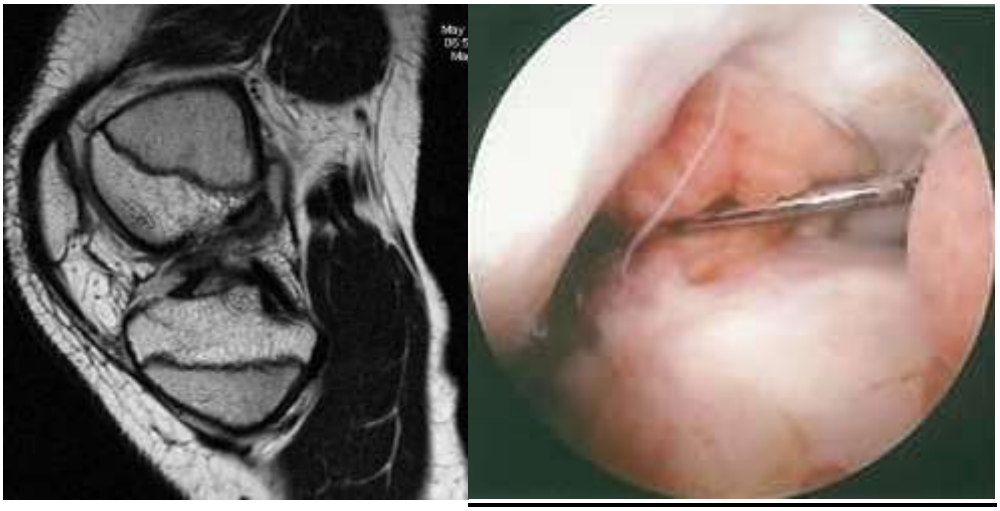

Fig. 1: Sagittal T2 and arthroscopic images showing bulky ACL with hyperintense signal and loss of continuity in its mid-substance s/o complete ACL tear.

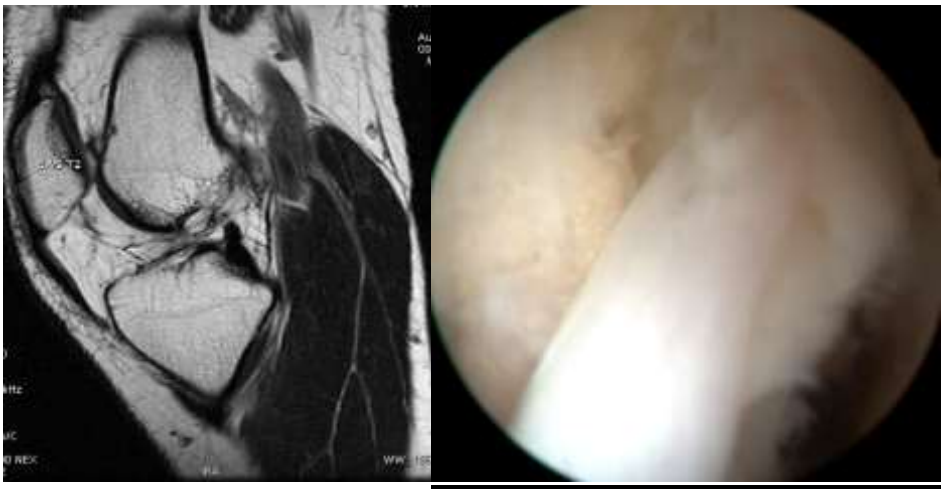

Fig. 2: Sagittal T2 and arthroscopic images of partial ACL tear showing hyperintense signal in ACL and laxity of the ligament on arthroscopy.

DISCUSSION

Multiple imaging techniques are used to evaluate the pathologic conditions of the knee in the present era. In the past several years, the role of MRI in knee imaging has steadily increased and is often the main or the only imaging tool for the evaluation of suspected internal derangements. **(11)** Complete evaluation of the menisci, collateral ligaments, capsule and tendons about the knee has been difficult with conventional and CT arthrography. Multiplanar MR images provide significant improvement in assessing these structures.

In the present study, evaluation of anterior cruciate ligament injuries of the knee was done by MRI and then, based on the findings and arthroscopy was conducted. In the present study, it was observed that positioning knee with 5-10° of flexion and 15-20° of external rotation was optimal. If ACL was incompletely seen repeat oblique images were obtained. T2WI and PDW FS images were preferable, as acute lesions were seen as high signal intensity with a great degree of accuracy. A total of 55 patients over a period of 12 months were included, among these 40 were male and 15 were female affecting 33 right and 22 left knee joints. The majority of the patients were adults in the age group of 21- 50 years.

On MRI, Out of 55 patients of ACL tears (43.6% complete, 52.7% partial and 3.6% interstitial edema), 34 (61.8%) patients had mid-substance tears, 14 (25.5%) patients had tears at the femoral attachment and 7 (12.7%) at the tibial attachment were detected. In this study, the mid-substance tear

location was the most common. Similar results were observed by previous studies by Lakhar et al **(12)** and Berquist et al **(13)** in their study where they reported mid-substance tear as the most common type. PCL tears were found in 8 (14.5%) cases. Lakhar et al12 observed in their study on 173 patients, that ACL tears were to be more common (45.08%) than PCL tears (5.78%).

Meniscal tears were the most common 51 (92.7%) associated finding with ACL tears. Out of these 51 cases of meniscal tears, 32 patients had medial meniscal tears while 18 patients had lateral meniscal tears. McDaniel et al **(14)** reported in their study that meniscal tears were associated with 85% to 91% of chronic ACL-deficient knees. Bone marrow contusions/edema of the femoral condyle and lateral tibial plateau was seen in 25 (45.5%) cases of ACL tears. Murphy et al **(15)** had found posterolateral tibial plateau (94%) and lateral femoral condyle (91%) subchondral bone impactions to be relatively specific signs of an acute ACL tear.

The classic O'Donoghue's triad of injury to the ACL, MCL, and medial meniscus was less commonly seen (only 3.6% cases) in this study. Segond's fracture was not seen in any case of an ACL tear. Tibial spine avulsion was noted in 9% of cases of an ACL tear. Kezdi-Rogus et al **(16)** showed that Segond's fracture was associated with rupture of the ACL in 75% to 100% of cases and tibial spine avulsion was an uncommon but specific finding for ACL injury. They also stated that distal ACL injuries were frequently associated with avulsion injuries because the distal ACL fibers are relatively stronger than adjacent bone.

In this study, 22 ACL tears arthroscopically proven complete ACL tears. The sensitivity (95.65%), specificity (93.75%), positive predictive value (91.67%), negative predictive value (96.77%) and accuracy (94.55%) of MRI as described respectively. These values were within the ranges of previously reported MR imaging strategies using conventional spin-echo sequences. For partial ACL tears the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of MRI was 86.21%, 84.62%, 86.21%, 84.62%, and 85.45% respectively. Vaz et al **(17)** found sensitivity, specificity, positive predictive value, negative predictive value and accuracy of MRI for ACL tears to be 99%, 95.4%, 91.9%, 99.5% and 96.6% respectively while Nikolaou et al **(18)** showed specificity, accuracy and positive predictive value of MRI for ACL tears to be 89%, 86% and 90% respectively and Ha et al **(19)** showed 96% sensitivity of MRI for 56 arthroscopically proven tears. The specificity was 98%, yielding an overall accuracy rate of 98%. The positive and negative predictive values were 95% and 99%, respectively.

CONCLUSION

It was inferred by the present study that MRI is unique in its ability to evaluate the ACL tears, including discontinuity, non-visualization, abnormally increased signal intensity and was proved to be quite useful and showed good diagnostic accuracy with good arthroscopic correlation. The ability to detect complete and partial ACL tears on MRI had the diagnostic accuracy of 94.55% and 85.45% with sensitivity and specificity of 95.65%, 93.75% and 86.21%, 84.62% respectively.

CONFLICT OF INTEREST: Nil

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