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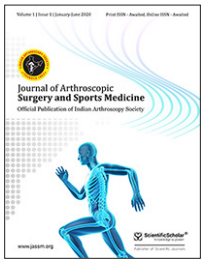

Original Article

Accuracy of magnetic resonance imaging for meniscal body tear in anterior cruciate ligament-deficient knees compared to anterior cruciate ligament-intact knee

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ABSTRACT

Objectives: This prospective case–control study was conducted with primary aim to compare the value of magnetic resonance imaging (MRI) in terms of accuracy, sensitivity, specificity, positive predictive value, and negative predictive value for the detection of meniscal tear in anterior cruciate ligament (ACL)-deficient and ACL-intact groups. The secondary aim was to identify if the sensitivity and accuracy differ if the MRI is older than 3 months from the time of surgery.

Materials and Methods: There were 255 patients enrolled into this study out of which 207 fulfilled the inclusion criteria. Among 207, 138 underwent surgery within 1 month of MRI, 30 had 1–3 months delay, and 39 cases underwent surgery more than 3 months after their MRI. Among 167 patients who underwent surgery within 3 months of MRI, 97 had ACL tear and 71 had intact ACL.

Results: The overall sensitivity for lateral meniscus tear (68.2%) is significantly lower than the medial meniscus tear (92.9%). The sensitivity of MRI for medial meniscus tear in ACL-deficient knee is lower than ACL-intact knees (90% vs. 96.2%, $P = 0.3$). Similarly, the sensitivity is significantly lesser for lateral meniscus tear in ACL-deficient knee compared to ACL-intact knee (50% vs. 83.3%, $P = 0.009$). The sensitivity of MRI for both the lateral and medial meniscus tear decreased if the MRI performed 3 months before the surgery.

Conclusion: Patients with ACL-deficient knee have to be counseled for intraoperative detection of lateral meniscus tear as the sensitivity of MRI for lateral meniscus tear in ACL-deficient group is low. Similarly, if the MRI is more than 3 months old from the time of surgery, we recommend to repeat the MRI as the sensitivity decreases significantly.

Keywords: Magnetic resonance imaging, Accuracy, Meniscus, Anterior cruciate ligament deficiency

INTRODUCTION

The presence of meniscal tear is crucial for surgical decision in anterior cruciate ligament (ACL) deficient knee.[1] Because of high sensitivity (over 90%) of magnetic resonance imaging (MRI) for meniscal tears detection, it is considered as the gold standard investigation for meniscal pathologies.[2-6] Both patients and physicians believe that the pre-operative MRI is highly accurate in detecting the concomitant injuries to the meniscus.[7] However, MRI results are not always consistent with arthroscopic findings and it does not guarantee a complete detection.[8] Some studies have emphasized lower sensitivity and specificity of MRI for the

detection of meniscal lesions if it is associated with ACL injuries.[8-10]

There are still controversies on which meniscus, lateral, or medial are culprit for this low sensitivity. Several factors are described as cause of high false-negative and false-positive rate of MRI.[10-15] In acute ACL tear scenario, Nam *et al*.[11] reported a lower sensitivity of MRI for medial meniscus tear and cause being the hemarthrosis. Whereas, others reported low sensitivity and positive predictive value (PPV) of MRI for lateral meniscus tear. De Smet and Graf mentioned arterial pulsation artifact as a possible cause of false-negative report, especially for tears in posterior horn.[16] Similarly, others cited shorter radius of curvature of lateral meniscus, presence of popliteus tendon, and meniscofemoral ligaments of lateral meniscus as the cause of low accuracy of MRI for the detection of lateral meniscus pathologies.[8,16] Unfortunately, most of these studies were either retrospective or did not have a control arm. In addition, patients with ACL injuries may sustain a meniscal tear in the interval between MRI and arthroscopy, which may decrease the apparent sensitivity of MRI.[17-19] However, to the best of our knowledge, there are no studies conducted to identify the time limit from where the sensitivity of MRI starts decreasing.

We hypothesized that, even with advancement in training and MRI facilities, the sensitivity of MRI for detecting lateral meniscus tear is low in ACL tear setting and an MRI older than 3 months from the time of injury is less useful. This prospective case–control study was conducted with the aim to compare the value of MRI in terms of accuracy, sensitivity, specificity, PPV, and negative predictive value (NPV) or detection of meniscal tear in ACL-deficient and ACL-intact groups. The secondary aim of this research was to identify, what is the time duration from MRI to surgery when the sensitivity starts falling.

MATERIALS AND METHODS

After taking approval from the Institutional Review Committee of B&B Hospital, this prospective case–control study was planned. Informed written consent was obtained from patient for using their data for research maintaining patient confidentiality. Cases were enrolled between September 1, 2019, and March 15, 2020. All the patients who have at least 1.5 Tesla MRI of their knee and scheduled for arthroscopy procedure within the study period were included in this study.

All MR images were reported for the presence of meniscal pathology by one of our institution's fellowship-trained musculoskeletal radiologists. If the MRI was done outside of our institution, rereporting of MRI was done by our radiologist. Predesigned proforma was prepared for individual patient and MRI reports were recorded with respect to status of ACL, medial meniscus, lateral meniscus, root tear, RAMP lesion, and cartilage injuries.

Arthroscopically, a tear was considered if meniscus required some surgical intervention (meniscectomy or repair). Incomplete meniscus tears that were <5 mm and stable with arthroscopic evaluation and probing were left alone. Intrasubstance degeneration and Grades 1 and 2 tear of meniscus were considered as no tear. If MRI reported a partial tear of meniscus and during arthroscopy, there was no tear or scar of healing, they were considered as false negative.

All the arthroscopies were performed by three senior authors (AJ, NS, and BB). While performing arthroscopy, everybody followed a standard 9-step protocol of diagnostic arthroscopy. Step (1) Examination of patellar facet cartilage; (2) lateral gutter and meniscus; (3) medial gutter and meniscus. Then, an anteromedial portal was created and fat pad removed to have better visualization of intercondylar notch. Then, the remaining steps were followed: (4) ACL; (5) modified Gillquist maneuver was performed to examine the Ramp lesion; (6) both the superior and inferior surfaces of medial meniscus were inspected using probe. If posterior horn visualization was difficult, piecrusting of MCL was done to visualize entire meniscus; (7) medial femoral and tibial cartilage was inspected; (8) both the surfaces of lateral meniscus were examined using prob by putting leg in figure of four position, and finally, (9) lateral femoral and tibial cartilage was inspected. The injury reported by MRI is doubly confirmed or disproved in arthroscopy by at least two of the senior authors. All the findings of arthroscopy were recorded into the same proforma where the MRI findings were recorded with specific mention of medial and lateral meniscus tear.

There were 255 patients who fulfilled the inclusion criteria [Figure 1]. Multiligament injuries (18 cases) and four incomplete data were excluded. There were 23 root tears and 3 RAMP lesions. Since MRI sensitivity of root and RAMP lesion is extremely low in our country and may decrease the overall sensitivity of meniscal body tears, they were also excluded from the study. Remaining 207 cases were divided into two groups: Those who were operated within 3 months of MRI (168 cases) and more than 3 months of MRI (39 cases). Considering our hypothesis that if the MRI is older than 3 months, because of increased risk of new tear, the sensitivity of MRI will be even lower. Hence, these 39 cases were not included in calculation of MRI accuracy. A total of 168 cases (MRI within 1 month of surgery [n = 138] and 1 month–3 months of surgery [n = 30]) were further divided in to ACL-deficient group (n = 97) and ACL-intact group (n = 71). The sensitivity, specificity, PPV, NPV, and accuracy were calculated for both the groups and compared with each other [Figure 1].

Following definition was used to determine true positive, true negative, false positive, and false negative cases. True

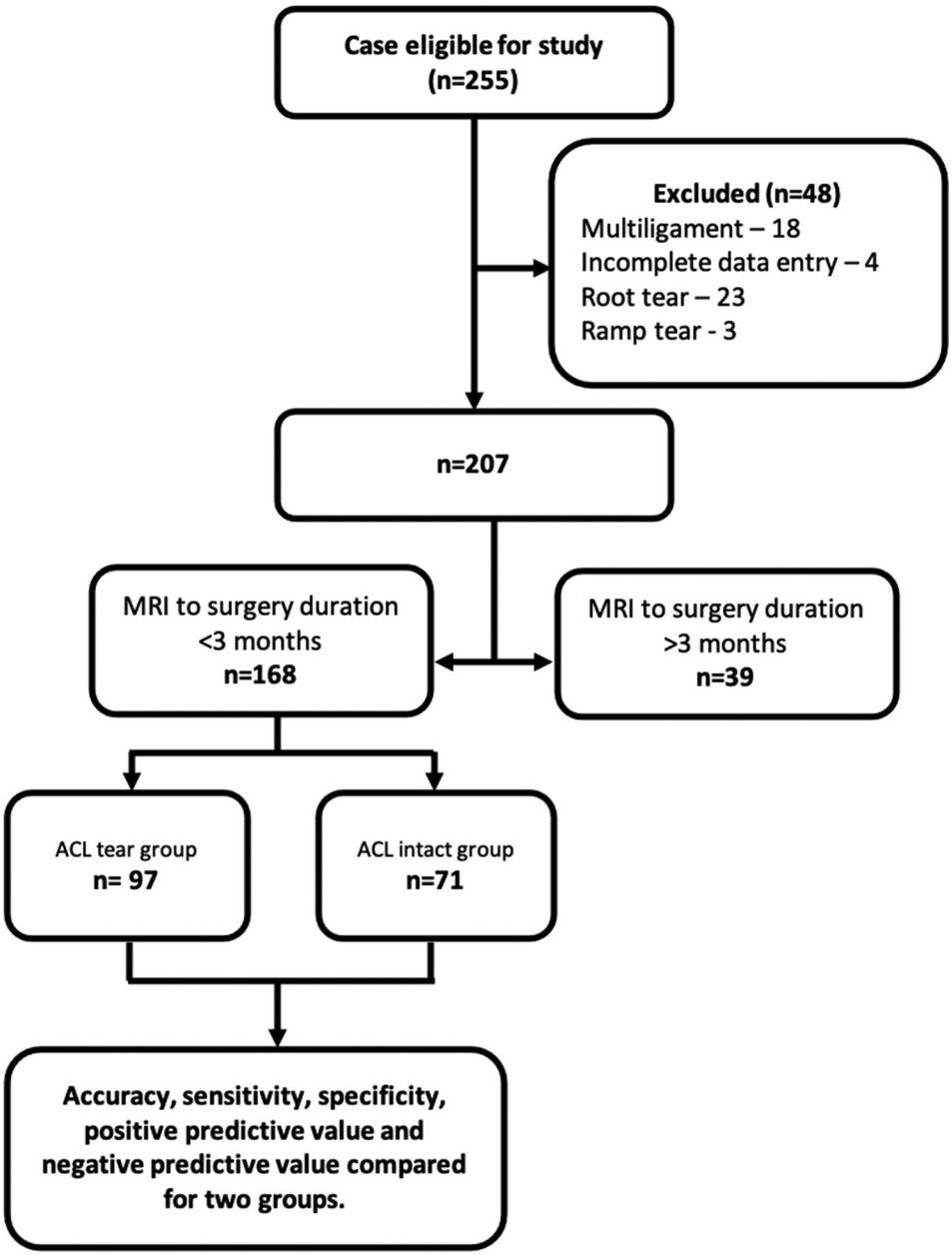

Figure 1: Flowchart of methodology for cases selection and group division.

positive = MRI and arthroscopy both report tear; True negative = MRI and arthroscopy both report no tear; False positive = when MRI reported tear and there was no tear in arthroscopy; and false negative = when MRI reported no tear and there was tear in arthroscopy. The statistical variables are defined as follows: Accuracy = Number of true positive + Number of true negative/number of all cases; sensitivity = Number of true positive/Number of true positive + Number of false negative; specificity = Number of true negative/Number of true negative + Number of false positive; PPV = Number of true positive/Number of true positive + Number of false positive; and NPV = Number of true negative/Number of true negative + Number of false negative.

The data were entered into SPSS software for Windows (version 16.0; SPSS, Chicago, IL). The level of significance was set at $P < 0.05$, and Chi-square and Student's t-test were used to calculate the significant value when appropriate.

RESULTS

The overall mean age of the patients was 33.6 ± 10.7 ranging from 16 to 62 years. Among 168 patients, there were 100

Table 1: Comparison of parameters in ACL-deficient and ACL-intact groups.

	ACL-deficient group (*n*=97)	ACL-intact group (*n*=71)	*P*-value
Mean age ± standard deviation	31.77±9.3	36.18±12.03	0.01
Sex distribution			
Male	76	45	0.03
Female	21	26	
Difference in time from MRI to surgery			
<1 month	81	57	0.59
1–3 months	16	14	
Medial meniscus			
Tear	30	26	0.4
No tear	67	45	
Lateral meniscus			
Tear	22	22	0.2
No tear	75	49	

MRI: Magnetic resonance imaging, ACL: Anterior cruciate ligament

meniscal tear, 56 medial, and 44 lateral. Arthroscopically, 97 had ACL tear and 71 had ACL intact, hence, the ACL-deficient group consisted 97 patients and ACL-intact group had 71 patients. The mean age of patients in ACL-intact group was higher compared to ACL-deficient group ($P = 0.01$). The male-to-female ratio was also significantly different in comparable groups. However, difference in time from MRI to surgery, medial meniscus and lateral meniscus distribution in both the groups were comparable. There were 30 and 26 medial meniscus tears in ACL-deficient group and ACL-intact group, respectively. Similarly, there were 22 lateral meniscal tears each in both ACL-deficient and ACL-intact groups [Table 1].

The overall sensitivity, specificity, PPV, NPV, and accuracy of MRI for the detection of meniscal tear were 92.9%, 86.4%, 77.9%, 96%, and 86.6%, respectively. For lateral meniscus, the sensitivity and specificity of MRI were 68.2% and 86.3%, respectively. Although accuracy of MRI for medial and lateral meniscus was similar (88.6% vs. 81.5%), the sensitivity was significantly higher for medial meniscus (92.9%) compared to lateral meniscus (68.2%). Similarly, the PPV was moderately low for both the medial and lateral meniscus (77.9% and 63.8%) [Table 2].

The accuracy of MRI for the detection of medial meniscus tear was similar in ACL-deficient and ACL-intact groups, 88.6% and 88.7%, respectively. The comparison of MRI sensitivity, specificity, PPV, NPV, and accuracy between ACL-deficient and ACL-intact groups for medial meniscus was similar. The sensitivity of MRI for detecting medial meniscus tear was 90% in ACL-deficient group compared to 96.2% in ACL-intact group [Table 3].

Similarly, the accuracy of MRI for the detection of lateral meniscal tear was also comparable for ACL-deficient and ACL-intact groups, 77.3% and 87.3%, respectively. However, the sensitivity and PPV were significantly different between ACL-deficient and ACL-intact groups for lateral meniscus ($P = 0.009$ for sensitivity and $P = 0.064$ for PPV) [Table 4].

Table 2: Overall sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MRI for medial and lateral meniscus.

	Medial meniscus	Lateral meniscus
True positive	53	30
True negative	96	107
False positive	15	17
False negative	4	14
Sensitivity	92.9%	68.2%
Specificity	86.4%	86.3%
Positive predictive value	77.9%	63.8%
Negative predictive value	96%	88.4%
Accuracy	88.6%	81.5%

MRI: Magnetic resonance imaging

The mean time from imaging to surgery was 21.1 ± 102.4 days (range 3–254 days). In a subgroup analysis for value of MRI in different time frame, the 207 cases were divided into three groups: Less than 1-month group (n = 138); 1–3 months group (n = 30); and more than 3 months group (n = 39), based on time gap between MRI and surgery.

The sensitivity, specificity, PPV, NPV, and accuracy of MRI were compared for both the menisci in these time frames. The sensitivity significantly reduced if there was time elapse between MRI and surgery which was more than 3 months [Table 5]. Out of 39 cases in more than 3 months period, 5 cases of medial meniscus tears were misdiagnosed (3 false negative and 2 false positive) by MRI. Similarly, there were five false-negative MRI reports for lateral meniscus. All of these tears were longitudinal tears located in the posterior horn.

Table 3: Comparison of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MRI for medial meniscus.

Parameters	ACL-deficient group	ACL-intact group	*P*-value
True positive	27	26	
True negative	59	37	
False positive	8	7	
False negative	3	1	
Sensitivity	90%	96.2%	0.352
Specificity	88%	84%	0.549
Positive predictive value	77.1%	78.8%	0.870
Negative predictive value	95.1%	97.4%	0.584

MRI: Magnetic resonance imaging, ACL: Anterior cruciate ligament

Table 4: Comparison of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MRI for lateral meniscus.

Parameters	ACL-deficient group	ACL-intact group	*P*-value
True positive	11	19	
True negative	64	43	
False positive	11	6	
False negative	11	3	
Sensitivity	50%	83.3%	0.009
Specificity	85.3%	87.7%	0.701
Positive predictive value	50%	76%	0.064
Negative predictive value	85.3%	93.4%	0.173

MRI: Magnetic resonance imaging, ACL: Anterior cruciate ligament

DISCUSSION

There were two main findings of our study: (1) Lower sensitivity and PPV with MRI are more pronounced in lateral meniscus and ACL-deficient group compared to medial meniscus and ACL-intact group; (2) sensitivity and NPV significantly drop in MRI older than 3 months.

The overall incidence of meniscal tear in our study population (ACL-deficient and -intact groups) was 59.5% (100 tears out of 168). Although the meniscus tear rate ranges from 48 to 86% in ACL-deficient knee,[20-23] the incidence of meniscal tear in ACL-deficient group of this study was 57.7% (56 out of 97) which was similar to our previous study.[24] The meniscal tear rate was comparable to the ACL-intact group (61.97%) (44 out of 71). The distribution of medial and lateral meniscus tear in both ACL-deficient and -intact groups was statistically similar (P = 0.4 for medial and 0.2 for lateral meniscus). The mean time from MRI to surgery was also comparable ($P \geq 0.05$) between two groups. Although the mean age and sex distribution were significantly different in two groups ($P \geq 0.05$), indicating non-homogeneous groups, the main comparing parameters (meniscus tear and difference in time) were equally distributed. The significantly higher mean age in ACL-intact group is because of the indication of surgery. A population studies show that meniscal tears requiring treatment were 2–3 times more common in patients over 40 years than in those under 40 years.[25,26] Similarly, ACL tear is more common in male than in female which may have caused the disparity in sex distribution among two groups.[24,27,28]

The overall sensitivity of MRI for the detection of medial meniscus tear was 92.9% with specificity, PPV, NPV, and accuracy of 86.4%, 77.9%, 96%, and 88.6%, respectively. In contrast to this, the sensitivity and PPV were extremely low, 68.2% and 63.8%, respectively, but specificity and NPV remain similar to medial meniscus. Crawford *et al.*, in their systematic review, reported sensitivities of 91.4% and 76.0% for the medial and lateral menisci, respectively.[6] In another systematic review, the estimated sensitivity and specificity of MRI were 89% and 88%, respectively, for medial meniscal tears; and 78% and 95%, respectively, for lateral meniscal tears.[29] In another review study, they mentioned that sensitivity of MRI for medial meniscus ranges between 87 and 96% and sensitivity for lateral meniscus ranged between 70 and 92%. Existing literature consistently mentioned lower sensitivity of MRI for lateral meniscus compared to medial meniscus. Various reasons have been cited for this lower sensitivity such as arterial pulsation artifact,[16] shape of lateral meniscus, presence of popliteus tendon, and meniscofemoral ligaments near lateral meniscus which were some of the factor emphasized.[8] Sensitivity and specificity of MRI were found to have lower value for both the menisci in concomitant ACL injuries.

In this study, the sensitivity of MRI for medial meniscus was found to have higher in ACL-intact group compared to ACL-deficient group (96.2% compared to 90.0%), the difference was statistically not significant (P = 0.35). In contrast, Nam *et al.*,[11] in their study, found that the sensitivity of MRI in group with ACL injury was significantly lower than that in the ACL-intact group for both the medial and lateral menisci. This may be because, majority of medial meniscus tear in our cases were bucket handle meniscus tear in ACL-deficient group where Nam *et al.* mentioned that in their study, all the missed cases were longitudinal undisplaced tear of posterior horn of medial meniscus. However, De Smet and Graf[16] found similar results to ours with sensitivity of 97% for ACL-intact group and 88% for ACL-deficient group. Jee *et al.*[1] also found a sensitivity of 88% for medial meniscus in ACL-deficient knees. Medial meniscus is wider, less curved, and attached to the capsule all around, makes its anatomy simple in MRI compared to lateral meniscus. On top of that bucket handle tear is most common in medial meniscus compare to lateral meniscus, they are diagnosed easily.[16,24]

Table 5: Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of MRI according to time elapsed from MRI to surgery.

	<1 month (*n*=138) (%)	1–3 months (*n*=30) (%)	>3 months (*n*=39) (%)
Medial meniscus			
Sensitivity	91.8	100	76
Specificity	85	90.9	92.3
Positive predictive value	77.5	80	83.3
Negative predictive value	95	100	88.8
Accuracy	87.7	93.3	87.7
Lateral meniscus			
Sensitivity	63.6	90	54.5
Specificity	85.6	90	100
Positive predictive value	58.3	81.8	100
Negative predictive value	61.8	90	54.5
Accuracy	79.7	90	86.2

The sensitivity of MRI for lateral meniscus in our study was 50% for ACL-deficient group and it was 83.3% for ACL-intact group. When we performed a subgroup analysis in ACL-intact and ACL-deficient groups, the sensitivity in ACL-deficient group was significantly lower than ACL-intact group (P = 0.09). Similarly, the PPV was also significantly lower in ACL-deficient group (P = 0.06). However, the specificity and NPV in both ACL-deficient and ACL-intact groups were comparable. Lower sensitivity of MRI for lateral meniscus in cases of ACL injuries was reported by many authors.[1,8,9,11,30-32] Similar to our study, De Smet and Graf[16] found 69% sensitivity of MRI in ACL-deficient knee compared to 94% in ACL-intact group for lateral meniscus. Jee *et al*.[1] found the sensitivity of MRI for the detection of lateral meniscus as low as 62%. Lowest sensitivity of MRI to lateral meniscus (58%) was reported by Laundre *et al*.[33]

The relatively low sensitivity in our study was because of posterior horn tear of lateral meniscus in ACL-deficient group. Among the 11 false-negative cases, 10 tears were in posterior horn of lateral meniscus. Similarly, among 11 false-positive cases, 6 were around the popliteal hiatus which might have created a confusion in diagnosis. Similar to other studies, we found that most missed meniscal tears were located in posterior horn of lateral meniscus in ACL-deficient knees.[1,33] Lower sensitivity of MRI for diagnosis of lateral meniscus posterior horn tear could be because of complex anatomy of lateral meniscus, magic angle artifact, pulsation artifact, presence of popliteus tendon, and ligament of Wrisberg and Humphrey on the lateral side of the knee.[1] These fact and our low sensitivity of MRI for the detection of meniscus tear in ACL-deficient knee emphasize the fact that radiologist and surgeons must be careful in reading MRI, especially the lateral meniscus.

We hypothesized that the accuracy of MRI will be low if there is increase time gap between MRI and surgery. There are plenty of study mentioning increase in incidence of meniscal tear if the surgery is delayed by more than 12 weeks. Hence, considering this fact, the sensitivity should be lower because of false-negative reports, as the tear might have happened after the MRI and before the surgery. There were five false negative and no false positive for medial meniscus in more than 3 months group compared to three false negative and two false positive for medial meniscus. Although De Smet and Graf[16] did not find any change in sensitivity for either the medial or lateral menisci operated within 6 weeks of MRI examination or later, Dufka *et al*.[8] found that sensitivity, specificity, PPV, and NPV decrease for lateral meniscus as the time from imaging to surgery increased. However, sensitivity for medial meniscus tear remained relatively constant throughout the different time points. Our study demonstrates significantly lower sensitivity for both the medial and lateral menisci if the time gap between MRI and surgery was more than 3 months. This matches with the fact that longer the delay higher the chance of meniscal tear in ACL-deficient knee. Since, medial meniscus tear is more common in ACL-deficient knee and lateral meniscus is more common in ACL-intact knee, the sensitivity should decrease for both the knees if the time gap is sufficient enough. Our research also emphasizes the fact that if the MRI is older than 3 months, there is rational to repeat the MRI or counsel the patient adequately for higher false-negative reports.

One of the major limitations of our study was smaller sample size and non-homogenous group distribution. Although it is difficult to get a completely homogenous group in this type of study, a study with a larger sample size is recommended. Although, this was a prospective study and fellowship-trained surgeon has performed the arthroscopy and confirmed the findings of MRI. Arthroscopy also has its limitations and not all the tears are clearly visible in arthroscopy. This might have caused some increase in false-positive rate.

CONCLUSION

The diagnostic efficacy of MRI for lateral meniscus tear was significantly lower in ACL-deficient group compared to ACL-intact group. Radiologists and surgeons have to be more cautious in examining the lateral meniscus both in MRI and during arthroscopy. The sensitivity of MRI significantly decreases if the MRI is 3 or more than 3 months old from time of surgery. Hence, for appropriate planning, it is advisable to repeat the MRI if it is older than 3 months or adequately counsel the patient for high false-negative rate of MRI.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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