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Posterior lateral meniscal overhang is associated with ACL tears: A retrospective case-control study

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ABSTRACT

Introduction: There have been several described imaging findings that correlate with anterior cruciate ligament (ACL) injuries. The investigators in this study observed a higher frequency of posterior translation of the lateral meniscus beyond the posterior border of the tibial plateau in patients with ACL tears. The purpose of this study was to assess the frequency and degree of posterior lateral meniscal overhang (LMO) of the lateral meniscus in patients with ACL tears compared to uninjured controls.

Materials and methods: Magnetic resonance imaging (MRI) was analyzed in 117 knees with ACL tears and compared to a control group of 89 knees without injury. Lateral meniscus diameter, LMO, knee flexion angle, and lateral tibial plateau diameter were measured and compared between the two groups. Exclusion criteria included displaced and macerated lateral meniscus tears, multi-ligamentous knee injuries, and periarticular fractures. Difference in mean lateral meniscal overhang between ACL injured and control groups was tested using a paired T-test (alpha = 0.01). Assumptions for normality and variance were tested prior to analysis.

Results: In patients with ACL tears, average LMO was significantly greater compared to the control group (0.95 mm vs. 0.08 mm; $p < 0.001$). Additionally, measurable LMO was found in 42.7 % of patients with ACL tears compared to 4.5 % uninjured knees ($p < 0.001$).

Conclusion: Patients with ACL injury show higher incidence of LMO compared to uninjured controls. Future studies are necessary to better understand its clinical significance.

1. Introduction

Anterior cruciate ligament (ACL) tears are very common orthopedic sports injuries with a reported prevalence of 43.5–74.6 per 100,0000 person-years, and numerous studies indicate that they are occurring at greater rates each year.[1–4] ACL tears commonly present with concomitant injuries to nearby structures, leading to a multitude of radiographic findings having been associated with them. Several secondary radiographic findings associated with ACL tears have been reported including contusion to the lateral femoral condyle and posterior tibial plateau, anterior tibial translation, increased posterior cruciate ligament curvature, and lateral femoral sulcus sign.[5–8]

The investigators of this current study recognized the association of posterior lateral meniscal overhang (LMO) on MRI with ACL tears, leading to formal investigation of both incidence and degree of LMO present in ACL deficient knees when compared to healthy controls. One previous study has been published regarding posterior lateral meniscus protrusion but had a limited number of patients.[9] The current study includes the largest series of patients to date when evaluating LMO in the setting of ACL tear. We hypothesized that knees with an ACL tear will exhibit a greater degree of and higher frequency of LMO on MRI compared to the control group.

2. Materials and methods

2.1. Eligibility criteria

After IRB approval and exemption, the institutional medical record

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at a university medical center was queried for patients who underwent a knee MRI. Knee MRIs of patients from January 2017 to April 2022 were collected, and patients with acute ACL injury were identified. Control knee MRIs were also collected in patients with no imaging abnormality as read by a fellowship-trained musculoskeletal radiologist. Patients were included if the surgeon recommended that the patient undergo ACL reconstruction. Patients were excluded if their ACL pathology did not warrant reconstruction, previous ACL reconstruction, an injury requiring posterior lateral corner reconstruction, ACL tibial spine avulsion, the presence of multiple ligamentous injury requiring reconstruction, mucoid or myxoid ACL degeneration, intra-articular fractures, septic joint, or an injury secondary to other trauma. Control knee MRIs were then reviewed in patients with no injury or other imaging abnormality. Additionally, MRIs with excessive movement or other artifacts were excluded.

2.2. Radiographic measurement

Magnetic resonance imaging was separately reviewed by 2 fellowship-trained musculoskeletal radiologists (CN, BE) for this study. Electronic measurements were taken by two fellowship-trained musculoskeletal radiologists and one senior orthopedic resident to determine Lateral Meniscal Overhang (LMO), Knee Flexion Angle (KFA), and Tibial Plateau Diameter. Measurements were recorded using Phillips iSite (Phillips, Cambridge MA).

LMO was determined by traversing sagittal frames laterally from the tibial eminence until the greatest degree of posterior meniscal overhang was observed. A line was drawn tracing the posterior tibial cortex on the frame with the largest degree of LMO (white line, Fig. 1). Then a line was drawn that spans from the superior to inferior aspect of the meniscus to find its overall height. This value for height was divided by two to find the meniscal center. Next, a line was drawn perpendicular to the posterior tibial cortical line through the center of the lateral meniscus to its posterior extent (yellow line, Fig. 1). This line was recorded as the lateral LMO. Lateral meniscus posterior horn anteroposterior length was measured in the same sagittal image at the meniscal center perpendicular to the posterior cortical line (red line, Fig. 1). This was recorded as lateral meniscus diameter.

To determine Knee Flexion Angle, the frame through the center of the knee of the T1 sagittal MRI was utilized. A line was drawn parallel to the posterior femoral cortex surface (red line, Fig. 2), and a second line parallel to the posterior tibial cortex (dark blue line, Fig. 2). The angle between these two lines was recorded as the Knee Flexion Angle (white arc, Fig. 2). Tibial Plateau Diameter was measured from anterior to posterior in the same sagittal image as the meniscal overhang by tracing the superior most subchondral bone (light blue line, Fig. 2). Meniscal overhang was measured from the edge of the tibial plateau at the height of the meniscal edge, to the posterior most aspect of the lateral meniscus (yellow line, Fig. 1).

$$\text{Meniscal Overhang Percentage} = (\text{LMO} / \text{Lateral Meniscal Diameter}) * 100$$

Equation 1

2.3. Statistical methods

Differences between group demographic variables were compared using two sample T-tests and Fisher exact tests, with Yates continuity correction, for continuous and categorical variables, respectively. Primary outcome of interest was lateral meniscal overhang (LMO) between ACL injured individuals, and non-injured controls. Statistical significance was set at alpha = 0.05 for outcomes of interest. The data is considered exploratory in nature, and familywise error rate control for multiple testing was not performed.

3. Results

A total of 500 MRIs were reviewed of patients with a history of acute ACL injury. After exclusion for prior surgery (170 cases), excessive movement and artifact (3 cases), and multi-ligamentous injury or other concomitant pathology (122 cases), the MRIs of 117 ACL tears and 88 of radiographically normal knees with intact ACLs were analyzed. There was no significant difference in age and race between groups. There were more females in the control group ($p = 0.001$, Table I).

There was a higher incidence of LMO in the ACL injury group, with 42.7 % exhibiting radiographically measurable LMO, compared to 4.5 % in uninjured control knees ($p < 0.001$). Of the ACL injured subjects with lateral meniscal overhang, the mean overhang was 2.2 mm. Meniscal diameter was significantly greater in the ACL injured group (mean: 9.64 mm) compared to control group (mean: 8.85 mm, $p < 0.001$). Lateral tibial plateau diameter was larger in the control group (mean: 35.1 mm) compared to the ACL injured group (mean: 32.7 mm, $p < 0.001$) (Table I).

When the ACL injured patients were separated by those with and without meniscal overhang, there was no difference in demographic characteristics between groups (Table II). Significantly higher proportions of male patients were found to have LMO compared to females ($p = 0.039$, Table II). Similarly, tibial plateau diameter differences approached but did not attain statistical significance between the aforementioned groups ($p = 0.08$, Table II).

4. Discussion

This study evaluated posterior LMO on MRI as a radiographic entity in ACL injured patients. The most important finding in this study is that knees with ACL injuries exhibit a greater degree of LMO compared to

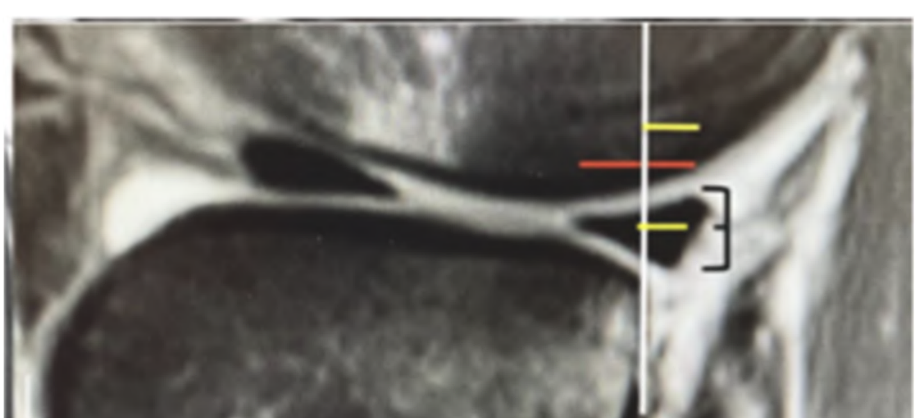

Fig. 1. Meniscal overhang measurement landmarks.

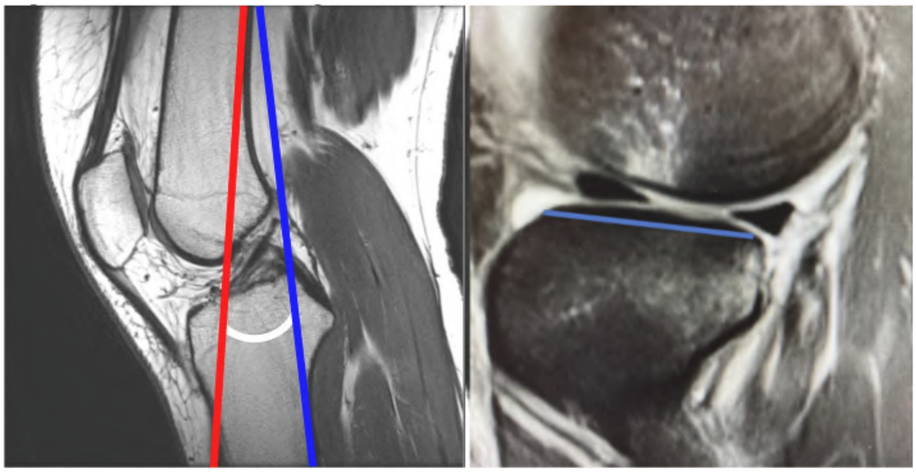

Fig. 2. Meniscal overhang measurement.

Table 1
Characteristics of patients with ACL injured knees vs controls.

	ACL Injury (n = 117)	Control (n = 88)	P-Value
Age (SD)	30.4 (11.4)	30.5 (10.2)	0.95
Sex (%)			
Male	54 (46.6)	21 (23.9)	**0.001**
Female	62 (53.4)	67 (76.1)	
Race (%)			
Caucasian	54 (46.6)	44 (50.0)	0.108
African American	45 (38.8)	38 (43.2)	
Asian	10 (8.6)	1 (1.1)	
Hispanic/Latino	3 (2.6)	4 (4.6)	
Native American	1 (0.8)	0	
Declined/Refused	4 (3.4)	1 (1.1)	
Knee Flexion Angle (degrees, SD)	7.5 (4.6)	9.8 (4.8)	**<0.001**
Incidence of LMO	42.7 %	4.5 %	**<0.001**
Lateral meniscal overhang (mm)	0.95	0.08	**<0.001**
Meniscal diameter (mm)	9.6	8.9	**<0.001**
Lateral tibial plateau diameter (mm)	32.7	35.1	**<0.001**

Table 2
Subjects with ACL tears with and without meniscal overhang.

	LMO (n = 49)	No LMO (n = 66)	P-Value
Age (SD)	31.6 (12.3)	29.9 (11.3)	0.44
Sex (%)			
Male	17 (34.7)	36 (54.5)	0.039
Female	32 (65.3)	30 (45.5)	
Race (%)			
Caucasian	26 (39.4)	28 (42.4)	0.495
African American	26 (30.3)	25 (37.9)	
Asian	2 (3.0)	7 (10.6)	
Hispanic/Latino	1 (1.5)	2 (3.0)	
Native American	0	1 (1.5)	
Declined/Refused	0	3 (4.5)	
Knee Flexion Angle (°, SD)	7.2 (4.7)	7.8 (4.5)	0.49
Tibial Plateau Diameter (mm, SD)	32.1 (3.3)	33.3 (3.8)	0.08

knees without injury. To our knowledge, this is the largest study evaluating this as a correlative imaging finding with ACL tears.

There are many secondary imaging findings in patients with ACL tears, including LMO. These findings can likely be attributed to the many concomitant injuries often found in these patients and the change in knee stability and kinematics. Relative to the distal femur, the proximal tibia translates anteriorly in ACL insufficient knees. This likely explains the finding of lateral meniscal overhang as the meniscus remains situated around the distal femur as the proximal tibia translates anteriorly. McDonald et al. showed greater than 6 mm of anterior tibial translation in 16.2 % and 25 % of acute and chronic ACL injuries, respectively.[10] The lateral meniscus covers between 75 % and 93 % of the lateral tibial plateau. In contrast to the medial meniscus, the lateral meniscus is less firmly attached to the tibia at its anterior and posterior horns and to the joint capsule. This allows for the lateral meniscus to have greater mobility which accommodates the increased translational and rotational motion of the lateral femoral condyle on the lateral tibial plateau.[11]

The presence of lateral meniscus posterior displacement has been described previously by Miller et al. when studying the prevalence of meniscal protrusion in degenerative arthropathy, internal derangement, and joint effusion. The study consisted of 132 total knee MRIs, which included 111 considered to be abnormal for either intra- or extra-articular injuries and 21 knees used as a control. Of the 111 injured knees, only 18 had ACL injury with 12 showing complete tears. Fourteen of these 18 ACL injuries showed anterior translation of the tibia relative to the femur. Six of these (50 % of the complete ACL tears) showed posterior protrusion of the lateral meniscus.[9] Their findings align with our current study. While Miller et al. did describe the presence of meniscal overhang in the setting of ACL injury, their study included knees with varying pathologies, with only a select few showing ACL injury and did not distinguish between an acute or chronic timeframe. In addition, they only described the prevalence of LMO and did not quantify or measure the degree of this finding.[9] Tung et al. similarly evaluated MRIs of 53 uninjured knees and 50 knees with complete ACL injuries to determine the sensitivity and specificity of primary and secondary signs of ACL injury.[12] The secondary signs included bone contusion, increased PCL curvature or bowing, and lateral meniscus posterior displacement relative to the tibial plateau which they termed the "uncovered lateral meniscus sign". They describe this lateral meniscus posterior displacement as a function of the anterior translation of the tibia. This was treated as positive if the posterior horn was intersected by a line drawn tangent to the posterior cortex of the lateral tibial plateau. They reported a positive uncovered lateral meniscus sign in 9 (50 %) of these patients which is similar to the number reported in our study.

Gentili et al. studied the sensitivity and specificity of the secondary MR findings in a collection of 54 patients with torn ACLs.[13] They found a mean lateral meniscus posterior translation of 3.05 mm in patients with ACL injuries, and 0.54 mm in patients with no ACL injury.[13] While our study agrees that meniscal overhang in ACL deficient knees is greater than in knees with intact ACLs, our study included a greater number of patients and found a smaller average distance of overhang in the ACL injured group (0.95 mm vs 3.05 mm) and in the group with an intact ACL (0.08 vs 0.54 mm). Differences between the measured average overhang may be attributed to the exclusion of patients with multi-ligamentous injury and concomitant injuries, which was done to isolate the effect that the ACL has on LMO.

While the significance of LMO in patients with ACL injuries is unknown, this radiographic anomaly is one that we have found to be associated with ACL tears. It may correlate with increased rotatory instability and higher grade pivot shift as this has been shown with increased tibia anterior translation.[14] Prior literature has implicated rotational instability associated with lateral meniscus tears as a potential risk factor for subsequent ACL injury.[15] This elevated risk of ACL injury associated with a torn lateral meniscus has been show to persist after ACL reconstruction.[16] This highlights the necessity of identifying and repairing lateral meniscal tears during ACL reconstruction, as it may function as a secondary knee stabilizer by minimizing the pivot shift.[17] Some literature has even suggested intraoperative measurement of pivot shift prior to ACL reconstruction to evaluate for rotatory insufficiency that may need correction.[18]

Further research is necessary to understand the clinical utility of LMO in the setting of an ACL tear and its correlation with outcomes after standard ACL reconstruction.

This study is not without limitations. The study was retrospective in nature and is susceptible to the biases of any retrospective study. The retrospective nature of this study made it impossible to control the positioning of patients during imaging, and it is possible that knee flexion angle, leg positioning during MRI, meniscal pathology, and other variables may play a role in the magnitude of meniscal overhang. However, these issues are somewhat mitigated by the fact that this is an imaging study conducted at a single academic center with standardized protocols for imaging. Although our sample size was somewhat small, it is the largest sample size used to describe this anomaly to date and specific exclusion criteria was set to minimize the effects that additional knee pathologies might have on findings. Finally, because this was an imaging study only, we were unable to evaluate any clinical implications.

5. Conclusion

On MRI, knees with ACL injuries tend to have a greater degree of and more frequent LMO. Future studies are needed to evaluate the clinical significance of such findings.

Ethical statement

This retrospective case-control study was approved by the University of Alabama at Birmingham Institutional Review Board: Study Number 300009561. The authors of this manuscript agree that this work represents honest and original research.

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Guardian and patient consent

This was a retrospective case-control study, and therefore a parent/guardian consent is not applciable

IRB approval

University of Alabama at Birmingham Institutional Review Board Study Number 300009561.

Declaration of competing interest

The authors have no relevant conflicts of interests to report.

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