Passive Posterior Tibial Subluxation on Routine Knee MRI as a Secondary Sign of PCL Tear

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1. Introduction

Posterior cruciate ligament (PCL) tears can have deleterious long-term consequences and therefore surgical repair has become a more widely utilized treatment option. In the setting of multiligament injuries, arthroscopy for other injuries may reveal occult PCL tears. In the setting of isolated PCL tear where arthroscopy is not performed, PCL tears that are missed clinically might only be detected on MRI. However, discontinuity of the PCL is not always seen on MRI. Therefore, various indirect signs have been invoked to diagnose PCL tears. Several indirect signs of PCL tears have been suggested, including posterior cruciate ligament thickness, ligamentous laxity, and increased intrasubstance signal [1]. The posterior drawer test is the most accurate clinical test to diagnose PCL tears; however, posterior subluxation often cannot be elicited with this maneuver in the acute setting due to soft tissue swelling and pain [2]. The purpose of this study is to determine if there is significant passive posterior translocation of the tibia relative to the femur in patients with isolated PCL tears on routine knee MRI with passive extension without manipulation or weight bearing. Additional work in a larger cohort may better address the accuracy of this finding.

2. Materials and Methods

2.1. Study Participants.

Institutional review board approval was obtained. The institutional database for two orthopedic surgeons was searched retrospectively for PCL tears with arthroscopically intact ACL over a 3-year period. Only patients with preoperative MRI were included in the study. A total of 11 patients fulfilled these criteria. For the control group, 22 knee MRI studies were obtained from scans over a one-month period of patients without clinical history or arthroscopic or MRI evidence of ligament injury.
2.2. Imaging Methods. All images were performed on a 1.5 T magnet, using our institutional standard knee MRI protocol. Sagittal PD and fat suppressed T2-weighted fast spin-echo imaging, coronal T1-weighted and fat suppressed T2-weighted fast spin-echo imaging and axial T2-weighted fat suppressed FSE imaging sequences were acquired. Images were obtained with the knee in passive extension. Measurements were performed from the sagittal PD images using the method described by Vahey et al. [2, 3]. Measurements were performed in the midmedial and midlateral compartments independently by two musculoskeletal fellowship trained radiologists for all patients and 18 of 22 controls. On the sagittal image, a tangential line was drawn posterior to the femoral condyle, and another similar line was drawn posterior to the tibia plateau. Perpendicular measurements of the relative anterior or posterior translation were made (Figure 1) for each knee.

2.3. Statistical Analysis. Statistical analysis using SPSS (Version 20, IBM Corp.) first examined intraclass correlation coefficient of each measurement for assessment of agreement between readers using a two-way random analysis of absolute agreement with a confidence interval of 95%. Group comparison of midmedial and midlateral compartment measurement differences between knees with PCL tear and normal control knees was ascertained by using a nonparametric Mann-Whitney U test. For all analyses, differences were considered to be significant when the P value was less than 0.05.

3. Results

In total, there were 22 individuals (10 male, 12 female) who met inclusion criteria for normal controls without ligamentous injury and 11 individuals (7 male, 4 female) with PCL tear and an intact ACL on arthroscopy. There was no statistically significant difference in age, sex, or laterality between groups as shown in Table 1. Initial MRI evaluation, arthroscopy findings, and average midmedial and midlateral compartment tibial translation for patients with PCL tear are listed in Table 2. At the time of MRI imaging, 3 of the PCL tears were acute (up to 6 weeks after injury), 1 was subacute (6 weeks to 3 months after injury), and 7 were chronic (greater than 3 months after injury). Five of the 11 PCL tears were precipitated by fall or athletic injury and 6 were the result of MVA.
Diagnosis of posterior cruciate ligament tears is becoming more important as more indications for surgical reconstruction arise [1]. Indications for reconstruction include solitary PCL tears in young active individuals and patients with bony avulsion injuries, high-grade PCL tears, and PCL tears associated with other ligamentous injuries [4]. Patients with chondromalacia of the patella, meniscal derangement, quadriceps atrophy, or degenerative changes may benefit from PCL reconstruction as well [5]. Motor vehicle accidents and sports injuries account for the majority of PCL tears. Sports injuries are more likely to produce isolated PCL tears. Over 50% of tears present more than one year after injury [6]. Isolated PCL tears have a high propensity to result in cartilage damage, which is reported to occur in the medial compartment in 80% of patients and in the patella in 50% of patients by 5 years following the initial injury [7]. The PCL acts as the primary restraint to posterior translation of the tibia [8]. Passive sagittal laxity in the medial compartment resulting from isolated chronic PCL tear with fixed posterior subluxation of the medial tibial plateau, has been proffered as an explanation for the increased incidence of osteoarthritis in the medial compartment seen in these patients [9]. Functional integrity of the ligament has been clinically determined by posterior tibial translation, graded with the knee flexed at 90 degrees [10]. Swelling, hemorrhage, and multiligamentous injury may obfuscate assessment on physical exam [11]. Arthroscopically, laxity of the ligament to probing is diagnostic. At examination, posterior translation in the midmedial compartment ranges from 7.6 to 12.3 mm at 30° and 90° of flexion, respectively [12]. Posterior translation of the tibia is not seen under normal physiologic, resting conditions. MRI studies have also confirmed no significant posterior subluxation of the normal knee in passive extension [3]. In fact, posterior translation of the tibia is occasionally not seen during physical exam in patients with known PCL tears [13]. This has been attributed to significant swelling about the knee joint, hemorrhage, and an intact arcuate complex. MRI diagnosis can be obfuscated due to the fact that the majority of PCL tears retain some degree of passive flexion and would not be contralateral to anterior translation from concomitant ACL tear and would not be seen in normal knees. In a study of normal knees, mean anterior (-) and posterior (+) translation of the knee measure 0.3 mm ± 0.5 mm (±2 standard errors) in the midmedial compartment [3]. Our normal reference data was consistent with that of Vahey et al., and, in the cohort with intact ligaments, tibial translation measured 0.09 mm ± 1.53 mm in the midmedial compartment. This method has been applied previously to ACL tear with 58% of patients having torn ACLs reported to show an anterior translation of the tibia relative to the femur of at least 5 mm [3].

Evaluation of anterior-posterior girth of the vertical segment of the PCL, as proposed by Rodriguez Jr. et al., can be problematic in the acute setting, as edema and heterogeneity of signal may make it difficult to discern the anterior and posterior boundaries of the PCL [1]. This may be a significant problem in using this method, since abnormal intrasubstance signal or fluid signal was observed in all 34 cases [1]. When measurements of ligament girth were performed on the basis of consensus by three musculoskeletal radiologists also not independently, interobserver reliability and reproducibility of their findings have not been established. The difficulty in obtaining measurements in the acute setting with edema may have manifested as poor interobserver reliability if all three radiologists had rendered measurements independently. In normal practice, three radiologists do not read each single MRI and the ability to translate their results into routine practice is unclear and may not be reproducible in a single reader setting. In the acute setting, posterior translation of the tibia may be more easily measured than ligament girth.

One kinematic study investigated posterior tibial translation on MRI [9]. Six patients with chronic, isolated PCL...
| Age | Sex | Timing   | Etiology               | Initial MRI evaluation | Arthroscopic findings                                                                 | Medial compartment translation | Lateral compartment translation |
|-----|-----|----------|------------------------|------------------------|---------------------------------------------------------------------------------------|-------------------------------|-------------------------------|
| 20  | F   | Acute    | Motor vehicle accident | Partial tear           | Complete PCL tear of AL bundle; partial of PM bundle; grade 1 medial femoral cartilage injury | −3.1                          | −1.6                          |
| 46  | M   | Acute    | Fall                   | High-grade partial tear | Intrasubstance tear of AL bundle; intact PM bundle                                      | 2.5                           | 0                             |
| 53  | M   | Acute    | Motor vehicle accident | Complete tear at tibial| Complete tear of the AL bundle                                                         | 8                             | 6.3                           |
| 17  | F   | Chronic  | Athletic injury        | High-grade partial tear| Complete PCL tear                                                                      | 1                             | −4.9                          |
| 21  | M   | Chronic  | Athletic injury        | Complete tear          | Complete PCL tear with no residual fibers                                              | 4.2                           | 2.1                           |
| 22  | M   | Chronic  | Athletic injury        | Complete tear          | Grades 2-3 PCL tear; grade 3 posterolateral corner rotatory laxity                     | 3.7                           | −1.8                          |
| 25  | F   | Chronic  | Motor vehicle accident | Complete tear          | Complete tear of PM bundle; partial tear of AL bundle; grade 2 chondrosis of inferior pole of patella | 0                             | 0                             |
| 28  | F   | Chronic  | Motor vehicle accident | High-grade partial tear| Near complete tear of AL with partial tear of PM bundle; grade 2 trochlear chondral injury | 3.3                           | −5.4                          |
| 30  | M   | Chronic  | Motor vehicle accident | Partial tear           | Intrasubstance PCL stretch injury; medial tibial plateau grade 1 softening; grade 2 medial collateral ligament injury | 5.7                           | 1.5                           |
| 42  | M   | Chronic  | Motor vehicle accident | High-grade partial tear| Grade 3 PCL tear; grade 3 posterolateral corner injury; medial meniscal fraying; grade 2 patellar chondral injury | 5.3                           | −2.5                          |
| 20  | M   | Subacute | Motor vehicle accident | Complete tear at tibial| Complete PCL tear of both AL and PM bundles                                             | 1.9                           | 0                             |

AL: anterolateral.  
PM: posteromedial.  

Tear were studied. Weight-bearing images were obtained at 0-, 20-, 45-, and 90-degree flexion and non-weight-bearing images were obtained at 90-degree flexion and again at 90-degree flexion with anterior and posterior drawer testing. Those investigators used the Iwaki method for measurements [15]. Their results were similar to ours. They found no statistically significant difference between normal knees and PCL deficient knees in the lateral compartment. In the medial compartment, an average difference of 10.1 mm of posterior tibial subluxation was seen between PCL deficient and normal patients in 90-degree flexion non-weight-bearing and an average of 8.2 mm was seen with drawer testing. Non-weight-bearing MRI exams showed a difference of 5.8 mm on average in posterior tibial subluxation between the PCL deficient patients and normal controls. Several important differences between our study and their study should be noted. We evaluated posterior subluxation on routine knee MRI under routine conditions with the knee extended without weight-bearing. In the study by Logan et al., the weight-bearing exams would require special scanners.
and non-weight-bearing scans require special maneuvers and manipulations which are not part of a routine scan [9]. In addition, their cases were chronic, where our cases were both chronic and acute. It is unclear if these maneuvers and stresses could be applied to an acute injury and could produce similar results. Also, their study does not have independent readers, and therefore interobserver reliability was not established.

Our study is the first to establish that posterior translation measurements are a valid indicator of acute or chronic PCL tear on MRI and a valid indicator of acute or chronic PCL tear on routine MRI with the knee routinely positioned in passive extension. This investigation constitutes the largest study to assess such MRI measurements for isolated PCL tear with routine MR imaging without maneuvers or weight-bearing. We provide evidence supporting that posterior tibial translation in the midmedial compartment is a promising indirect sign for isolated PCL tear on routine, clinical MRI imaging with excellent interobserver reliability. Such measurements can be obtained clinically and could be utilized to assist in prompt diagnosis and direct appropriate treatment.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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