

# Identifying Patients With Patella Alta and/or Severe Trochlear Dysplasia Through the Presence of Patellar Apprehension in Higher Degrees of Flexion

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**Background:** Recurrent patellar instability is frequently treated surgically with reconstruction of the medial patellofemoral ligament (MPFL). Patients with significant patella alta, trochlear dysplasia, and/or an elevated tibial tubercle–trochlear groove (TT-TG) distance may benefit from a concurrent bony procedure such as tibial tubercle osteotomy or trochleoplasty. The indications to perform such procedures are traditionally based on imaging criteria but remain controversial. Patellar apprehension is common in patients with patellar instability but typically resolves in higher degrees of knee flexion.

**Hypothesis:** The persistence of patellar apprehension at greater than 60° of knee flexion is associated with patella alta, an increased TT-TG distance, and trochlear dysplasia.

**Study Design:** Cross-sectional study; Level of evidence, 3.

**Methods:** A total of 76 patients with recurrent patellar instability were prospectively identified in a sports medicine clinic. Patellar apprehension was evaluated in each patient. Apprehension was defined as the patient reporting that the patella felt unstable to lateral patellar translation. Apprehension was first assessed at full knee extension and repeatedly assessed as the knee was flexed in 10° intervals, as measured using a goniometer. The degree of flexion at which patellar apprehension disappeared was recorded. Plain radiographs and magnetic resonance imaging (MRI) scans were obtained for all patients. Patellar height was assessed with the Caton-Deschamps (CD) index, and trochlear morphology was assessed through measurements of the sulcus angle and depth on MRI and classified using the Dejour classification system. Imaging measurements of patients in whom apprehension resolved by 60° of knee flexion were compared with measurements for those with apprehension that persisted deeper into flexion.

**Results:** Apprehension resolved by 60° of flexion in 56 patients and persisted into deeper flexion in 20 patients. The patients with a delayed resolution of apprehension demonstrated a higher CD index; elevated TT-TG distance; increased sulcus angle; decreased sulcus depth; and higher incidence of Dejour type B, C, or D dysplasia (all  $P < .05$ ). Of the 20 patients with a delayed resolution of apprehension, 18 had either Dejour type B, C, or D dysplasia or a CD index of at least 1.30. A delayed resolution of apprehension was present in 11 of the 16 patients with Dejour type B, C, or D dysplasia.

**Conclusion:** Overall, 90% of patients with significant patella alta and the majority of patients with high-grade trochlear dysplasia demonstrated patellar apprehension that persisted beyond 60° of knee flexion. Additionally, 90% of patients with persistent apprehension had significant patella alta and/or trochlear dysplasia. Further work is needed to evaluate the utility of these findings to inform surgical decision-making in this population.

**Keywords:** patellar instability; apprehension; physical examination; patella alta; trochlear dysplasia

Patellar instability is a relatively common knee condition, with an incidence of 23.2 per 100,000 person-years in a young, athletic population.<sup>19</sup> First-time patellar dislocations are typically amenable to nonoperative management;

however, recurrent dislocations may occur in 30% to 50% of patients.<sup>13,14</sup> The medial patellofemoral ligament (MPFL) serves as a key soft tissue restraint to lateral patellar translation,<sup>9</sup> and its reconstruction has become the mainstay of treatment for recurrent patellar instability.<sup>21</sup> The recurrent dislocation risk after isolated MPFL reconstruction in appropriately selected patients is as low as 1% to 3%.<sup>22</sup>

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While reconstruction of the deficient MPFL is critical to patellar instability treatment, it has long been known that anatomic factors including trochlear dysplasia, patellar height, and tibial tubercle–trochlear groove (TT-TG) distance are key risk factors for patellar instability.<sup>8</sup> Failure to assess these factors and address them when indicated may result in an increased recurrent dislocation risk after MPFL reconstruction alone.<sup>20</sup> A key and ongoing question for surgeons treating patellar instability is determining when additional treatments beyond isolated MPFL reconstruction are necessary. Classically, indications for bony procedures such as tibial tubercle osteotomy or trochleoplasty are based on imaging modalities.<sup>8</sup> Patients with patella alta as defined by a Caton-Deschamps (CD) index of greater than 1.2 may be candidates for tibial tubercle distalization,<sup>8</sup> those with severe trochlear dysplasia may be candidates for trochleoplasty,<sup>2</sup> and those with an elevated TT-TG distance may benefit from tibial tubercle medialization.<sup>8</sup> These indications remain controversial, and several recent studies<sup>4,10,15,18,24</sup> have demonstrated good outcomes of isolated MPFL reconstruction in patients with some anatomic risk factors.

Patellar apprehension has long been cited as a physical examination finding that is correlated with the presence of patellar instability.<sup>11,16</sup> The classic test is performed by laterally translating the patella while in near full knee extension, and a positive test result is noted when the patient experiences apprehension that the patella could dislocate. Ahmad et al<sup>1</sup> described the moving patellar apprehension test in which the knee is flexed from 0° to 90° with a lateral force applied to the patella. Apprehension with this maneuver that is relieved with medial patellar translation through the same range of motion was noted to be a sensitive and specific test for the presence of lateral patellar instability.<sup>1</sup>

While the presence or absence of patellar apprehension is an important physical examination finding, the specific flexion angles at which patellar apprehension is present may also inform treatment decisions.<sup>17</sup> In higher degrees of knee flexion, osseous anatomy contributes more to patellar stabilization than the soft tissue restraints that are important near full extension.<sup>9</sup> A 2019 study by Zimmermann et al<sup>25</sup> described the reversed dynamic patellar apprehension test that contains elements of both the patellar apprehension test and moving patellar apprehension test. The test begins with the patient's knee flexed to 120°, which is then extended while the patella is simultaneously laterally translated by the examiner. The test is

stopped when the patient reports apprehension, and the angle at which this occurs is recorded with a goniometer. The authors noted the presence of apprehension in higher degrees of knee flexion to be associated with more severe anatomic risk factors for patellar instability.<sup>25</sup>

At our center, we have been using a similar dynamic patellar apprehension test to assess patients with recurrent instability to identify those with anatomy that may put them at risk for failure of isolated MPFL reconstruction. The aim of this study was to compare radiographic measurements of patellofemoral anatomy in patients with patellar apprehension that persists into knee flexion beyond 60° with those patients in whom apprehension resolves earlier in knee flexion. We hypothesized that the persistence of patellar apprehension at greater than 60° of knee flexion would be associated with patella alta, an increased TT-TG distance, and trochlear dysplasia.

## METHODS

A total of 76 patients with recurrent patellar instability and without radiographic evidence of osteoarthritis were prospectively identified in a sports medicine clinic. Included patients had sustained at least 2 prior patellar dislocations. Patients with obligatory dislocations and those who dislocated in flexion were excluded, as were any patients with associated fractures or ligament injuries beyond the medial patellofemoral complex. Informed consent was obtained along with institutional review board approval.

Patellar apprehension was evaluated by the senior author (R.A.M.) in each patient using the dynamic patellar apprehension test. The test was performed in the supine position with the hip and knee in neutral rotation. The test was performed beginning in full knee extension with the application of pressure to translate the patella laterally. Apprehension was defined as the patient reporting that the patella felt unstable to this lateral patellar translation. The assessment of apprehension in this manner was continued at 10° intervals of knee flexion using a goniometer. The degree of flexion at which patellar apprehension disappeared was then recorded. Patients were classified as having a delayed resolution of apprehension if resolution did not occur until beyond 60° of knee flexion. This value was chosen as a cutoff as it is similar to the mean flexion angle at which apprehension was noted to appear in the study by Zimmermann et al.<sup>25</sup> Ligamentous laxity was assessed utilizing the Beighton score in all patients.<sup>3</sup>

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Ethical approval for this study was obtained from The Ohio State University Biomedical Institutional Review Board (study No. 2016H0128).

Anteroposterior, lateral, and axial plain radiographs along with magnetic resonance imaging (MRI) scans were obtained for all patients. Patellar height was assessed with the CD index.<sup>5</sup> Trochlear morphology was assessed through measurements of the sulcus angle and depth on MRI as described by Charles et al.<sup>6</sup> Raters were instructed to choose the most proximal femoral axial slice on which the full width of the trochlea was covered with articular cartilage.<sup>23</sup> Trochlear morphology was also classified with the Dejour classification system.<sup>7</sup> The TT-TG distance was measured according to the method of Schoettle et al<sup>23</sup> on MRI. An elevated TT-TG distance was defined as greater than 16 mm.<sup>8</sup>

Statistical Analysis

Patient characteristics, ligamentous laxity, and radiographic measurements were compared between patients in whom apprehension resolved by 60° of knee flexion and those patients with apprehension that persisted deeper into flexion. Continuous variables were compared with unpaired *t* tests, and categorical variables were compared with Fisher exact tests. Sensitivity, specificity, and positive and negative predictive values for a delayed resolution of patellar apprehension in the detection of significant patella alta, trochlear dysplasia, and elevated TT-TG distance were determined. A power analysis based on the published standard deviation of the CD index in a previously reported patellar instability population<sup>10</sup> determined that a minimum sample size of 51 patients was required to provide 80% power to detect a difference in the CD index of 0.10 with an  $\alpha$  of 0.05.

RESULTS

The 76 participants enrolled in the study included 23 male (30%) and 53 female (70%) patients with a mean age of 20.8 ± 5.7 years. All patients had a history of recurrent lateral patellar dislocations, and none had undergone prior surgical procedures other than knee arthroscopic surgery without lateral retinacular procedures. The mean CD index for the cohort was 1.14 ± 0.14, and 10 patients (13%) had a CD index of at least 1.30. Trochlear dysplasia was defined as absent in 9 patients, while Dejour type A was classified in 51 patients, Dejour type B in 14 patients, Dejour type C in 1 patient, and Dejour type D in 1 patient. The mean sulcus angle was 159° ± 14°, and the mean sulcus depth was 2.2 ± 1.6 mm. The mean TT-TG distance was 14.5 ± 4.6 mm, and there were 30 patients (40%) with a TT-TG distance greater than 16 mm.

The angle at which apprehension resolved ranged from 30° to 80°, with a mean of 50° ± 13°. Apprehension resolved by 60° of flexion in 56 patients (74%) and persisted into deeper flexion in 20 patients (26%). There were no significant differences in patient sex, age, or Beighton score between the 2 groups (Table 1).

The patients with apprehension that persisted beyond 60° of flexion demonstrated a higher CD index; elevated TT-TG distance; increased sulcus angle; decreased sulcus depth; and higher incidence of Dejour type B, C, or D

TABLE 1  
Relationship Between Patient and Anatomic Risk Factors and Persistent Patellar Apprehension

	Angle at Which Apprehension Disappeared		P
	≤60° (n = 56)	>60° (n = 20)	
Age, y	20.3 ± 5.5	22.1 ± 6.2	.24
Sex, n (%)			.78
Male	18 (32)	5 (25)	
Female	38 (68)	15 (75)	
Beighton score, n (%)			>.99
<6	50 (89)	19 (95)	
≥6	6 (11)	1 (5)	
CD index	1.12 ± 0.12	1.20 ± 0.19	<b>.026</b>
Trochlear dysplasia, n (%)			<b>&lt;.001</b>
None or Dejour type A	51 (91)	9 (45)	
Dejour type B, C, or D	5 (9)	11 (55)	
Sulcus angle, deg	156 ± 12	168 ± 17	<b>&lt;.001</b>
Sulcus depth, mm	2.5 ± 1.5	1.3 ± 1.7	<b>.003</b>
TT-TG distance, mm	13.8 ± 4.0	16.7 ± 5.6	<b>.015</b>

<sup>a</sup>Values are shown as mean ± SD unless otherwise indicated. Bolded values indicate statistically significant differences (*P* < .05). CD, Caton-Deschamps; TT-TG, tibial tubercle–trochlear groove.

TABLE 2  
Sensitivity, Specificity, and Positive and Negative Predictive Values of Persistent Patellar Apprehension for the Identification of Anatomic Risk Factors<sup>a</sup>

	Sensitivity, %	Specificity, %	Positive Predictive Value, %	Negative Predictive Value, %
Patella alta (CD index ≥1.30)	90	83	45	98
High-grade trochlear dysplasia (Dejour type B, C, or D)	69	85	55	91
Elevated TT-TG distance (>16 mm)	40	83	60	67

<sup>a</sup>CD, Caton-Deschamps; TT-TG, tibial tubercle–trochlear groove.

dysplasia (all *P* < .05) (Table 1). Of the 20 patients with a delayed resolution of apprehension, 18 (90%) had either Dejour type B, C, or D dysplasia or a CD index of at least 1.30. Persistent apprehension was noted to have a high sensitivity (90%) for the detection of patients with a CD index of at least 1.30 and a specificity of greater than 80% for the detection of patients with a CD index of at least 1.30; Dejour type B, C, or D dysplasia; and a TT-TG distance of at least 16 mm (Table 2).

In our patient population, the positive predictive value of persistent apprehension was  $\leq 60\%$  for the detection of patients with a CD index of at least 1.30; Dejour type B, C, or D dysplasia; and a TT-TG distance of at least 16 mm. However, the negative predictive value of persistent apprehension was over 90% for the detection of patients with a CD index of at least 1.30 and Dejour type B, C, or D dysplasia (Table 2).

## DISCUSSION

The most important finding of this study is that patients with persistent patellar apprehension beyond 60° of knee flexion were associated with an increased patellar height, increased TT-TG distance, and more severe grades of trochlear dysplasia. The resolution of apprehension before 60° of knee flexion was a very strong indicator that the CD index was less than 1.30 and that there was no high-grade trochlear dysplasia (negative predictive value  $>90\%$  for each). A delayed resolution of patellar apprehension was noted to be very sensitive for the detection of patella alta and less sensitive for the detection of trochlear dysplasia and an elevated TT-TG distance. The specificity of delayed patellar apprehension was noted to be high for the detection of each of these anatomic factors.

The findings of this study demonstrate that the degree of flexion at which patellar apprehension resolves is a useful tool for surgeons when treating patients with patellar instability. The resolution of apprehension before 60° of knee flexion suggests with greater than 90% certainty that the CD index is less than 1.30, there is no high-grade trochlear dysplasia, and the TT-TG distance is less than 16 mm. In contrast, apprehension that persists deeper into flexion indicates the presence of patella alta, high-grade trochlear dysplasia, or both (90% of the time in this series). Surgeons should carefully scrutinize the imaging studies in these patients to identify the reason for a delayed resolution of apprehension and consider these findings in their surgical decision-making. The lack of any association between ligamentous laxity (as defined by a Beighton score of at least 6) and persistent apprehension in deeper flexion further suggests that this clinical examination finding is related to bony anatomy rather than soft tissue structures, but an evaluation of more patients with elevated Beighton scores would be desirable to confirm this finding.

While isolated MPFL reconstruction has become an increasingly common technique for the treatment of recurrent lateral patellar instability, indications for the addition of bony procedures such as tibial tubercle osteotomy and trochleoplasty remain unclear.<sup>12</sup> Commonly cited clinical thresholds for bony procedures include a TT-TG distance of greater than 16 mm or a CD index of greater than 1.2; however, the original surgical “a la carte menu” that established these criteria predates the surgical option of MPFL reconstruction.<sup>8</sup> There are few outcome studies of MPFL reconstruction evaluating the influence of TT-TG distance and patella alta on isolated MPFL reconstruction; however, several recent retrospective cohort studies<sup>4,10,15,18,24</sup> have demonstrated little influence of TT-TG distance and

moderate patella alta on the outcomes of MPFL reconstruction. These studies suggest that isolated MPFL reconstruction can be successful in cases with a higher CD index and TT-TG distance than previously thought. More work is needed in this area.

Prior work describing patellar apprehension tests have demonstrated these tests to be reliable indicators for the presence of patellar instability.<sup>1,25</sup> One previous publication by Zimmermann et al<sup>25</sup> investigated the association between patellar apprehension deeper in knee flexion and anatomic risk factors for patellar instability. They noted a correlation between the angle of knee flexion at which apprehension began and the severity of trochlear dysplasia, limb alignment (varus/valgus), and total number of patellofemoral instability risk factors present. Interestingly, they did not report a direct correlation between patellar height and apprehension angle. These authors did state that patients with apprehension present only near full knee extension (0° to 20°-30° of flexion) are likely good candidates for isolated MPFL reconstruction, while those with apprehension deeper in flexion may benefit from the addition of bony procedures. Our data support this line of reasoning, as patients with apprehension beyond 60° of knee flexion were noted to have a higher incidence of anatomic risk factors for instability.

There are several limitations of the current study. First, while the study evaluated the relationship between apprehension angle and anatomic risk factors for instability, this study did not examine persistent patellar apprehension in higher degrees of flexion as a predictor of outcomes after the surgical treatment of patellar instability. Further work is needed to clearly assess whether patients with apprehension deeper in flexion do indeed have poorer outcomes or an increased failure risk after isolated MPFL reconstruction. Moreover, the study did not evaluate limb alignment in the coronal plane or femoral version, both of which could influence outcomes. In addition, the dynamic patellar apprehension test was performed by a single examiner on a single occasion in each patient, precluding calculations of interrater and intrarater reliability for this measurement and limiting the generalizability of the study. The amount of lateral pressure of the patella to elicit apprehension was not standardized or measured but was felt by a single examiner to be relatively consistent through the study. Finally, because positive and negative predictive values are based in part on the incidence of anatomic factors in the study population, the positive and negative predictive values noted here may not be applicable to groups of patients with different characteristics. Strengths of this study include the prospective data collection, measurements of knee flexion angles with a goniometer, and inclusion of a relatively large series of patients with sufficient power to answer the study questions.

## CONCLUSION

Overall, 90% of patients with significant patella alta and the majority of patients with high-grade trochlear dysplasia demonstrated patellar apprehension that persisted

beyond 60° of knee flexion. Additionally, 90% of patients with persistent apprehension had significant patella alta and/or trochlear dysplasia. Further work is needed to evaluate the utility of these findings to inform surgical decision-making in this population.

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