

Original Article

Preoperative Patella Alta on Caton-Deschamps Index Is a Predictor of Outcome Following Isolated Medial Patellofemoral Ligament Reconstruction

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Purpose: The purpose of this study was to determine whether a preoperative Caton-Deschamps index (CDI) ≥ 1.30 , as measured by magnetic resonance imaging, is associated with rates of postoperative instability, revision knee surgery, and patient-reported outcomes in patients undergoing isolated medial patellofemoral ligament (MPFL) reconstruction. **Methods:** Patients who underwent primary medial patellofemoral ligament reconstruction (MPFLR) between 2015 and 2019 at a single institution were assessed. Only those with at least 2 year follow up were included. Patients who had undergone a previous ipsilateral knee surgery, concomitant tibial tubercle osteotomy and/or ligamentous repair/reconstruction at the time of MPFL reconstruction were excluded from the study. CDIs were evaluated by three investigators based on magnetic resonance imaging measurement. Patients with a CDI ≥ 1.30 were included in the patella alta group, while those with a CDI between 0.70 and 1.29 served as controls. A retrospective review of clinical notes was used to evaluate the number of postoperative instability episodes and revisions. Functional outcomes were measured by the International Knee Documentation Committee (IKDC) and 12-Item Short Form Health Survey (SF-12) physical and mental scores. **Results:** Overall, 49 patients (50 knees, 29 males, 59.2%) underwent isolated MPFLR. Nineteen (38.8%) patients had a CDI ≥ 1.30 (mean: 1.41, range: 1.30-1.66). The patella alta group was significantly more likely to experience a postoperative instability episode (36.8% vs 10.0%; $P = .023$) and was more likely to return to the operating room for any reason (26.3% vs 3.0%; $P = .022$) compared to those with normal patellar height. Despite this, the patella alta group had significantly greater postoperative IKDC (86.5 vs 72.4; $P = .035$) and SF-12 physical (54.2 vs 46.5; $P = .006$) scores. Pearson's correlation showed a significant association between CDI and postoperative IKDC ($R^2 = 0.157$; $P = .022$) and SF-12P ($R^2 = .246$; $P = .002$) scores. There was no difference in postoperative Lysholm (87.9 vs 85.1; $P = .531$). and SF-12M (48.9 vs 52.5; $P = .425$) scores between the groups. **Conclusion:** Patients with preoperative patella alta, as measured by CDI had higher rates of postoperative instability and return to the OR with isolated MPFL reconstruction for patellar instability. Despite this, higher preoperative CDI was associated with greater postoperative IKDC scores and SF-12 physical scores in these patients. **Level of Evidence:** Retrospective cohort study, Level IV

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Introduction

Nearly 150 out of 100,000 adolescents, ages 14-18 years old, will develop patellar instability.¹ Unfortunately, about one-third of people with a first-time patellar dislocation will experience a recurrent dislocation.² Several risk factors have been identified for recurrent patellar instability: patella alta, trochlear dysplasia, and elevated tibial tuberosity-trochlear groove (TT-TG) distance, all of which can negatively impact the biomechanics of the patellofemoral joint.²⁻⁵

Patella alta may place patients at a higher risk for instability because the patella does not engage in the trochlear groove until higher degrees of knee flexion.^{3,6,7} Ultimately, patients with patella alta are twice as likely to experience recurrent patellar dislocations.^{2,8} Various methods have been created to evaluate patellar height; however, the International Patellofemoral Study Group uses the Caton-Deschamps index (CDI) as the preferred method.⁹ The CDI is the distance from the anterior aspect of the tibial plateau to the inferior portion of the patella articular cartilage divided by the superior-inferior distance of the patellar articular cartilage.¹⁰⁻¹² Clinically, the CDI is a widely used tool to evaluate patella alta and patella baja and can help identify patients at risk for recurrent patellar dislocation.^{2,13,14} CDI can be measured with radiograph, computed tomography (CT), and magnetic resonance imaging (MRI), with varying reliability for each imaging modality across the literature.^{10,15}

Common surgical procedures indicated for patients with patellar instability include medial patellofemoral ligament (MPFL) reconstruction with or without a tibial tubercle osteotomy.¹⁶⁻¹⁹ These procedures may treat patellar instability by reconstructing the static stabilizer of the patella and/or adjusting the position of the patella, leading to improved patellar biomechanics and tracking.^{3,16,17} A recent systematic review demonstrated that patients with patella alta and normal patella height will report satisfactory outcomes across the 9 most common patient-reported outcome instruments after isolated MPFL reconstruction.²⁰ MPFL reconstruction has been shown to decrease the CDI by about 0.09-0.20, although nearly 5% of patients will require a revision surgery for recurrent patellar instability.^{18,21,22} While the CDI on a lateral radiograph has been used as a predictive tool to identify patients at risk for recurrence,²² no association has been found between preoperative CDI and postoperative functional outcomes.^{23,24}

The purpose of this study was to determine whether a preoperative $CDI \geq 1.30$, as measured on an MRI, is associated with rates of postoperative instability, revision knee surgery, and patient-reported outcomes in patients undergoing isolated MPFL reconstruction. The authors hypothesized that preoperative patella alta

would not significantly affect postoperative outcomes or risk of recurrence.

Methods

This investigation was approved by the Institutional Review Board of Thomas Jefferson University. Charts of patients who underwent isolated MPFL reconstruction between January 2015 and November 2019 were reviewed retrospectively. Only patients who had at least 2 years of follow-up were included. Patients who had undergone a previous ipsilateral knee surgery, concomitant tibial tubercle osteotomy and/or ligamentous repair/reconstruction at the time of MPFL reconstruction were excluded from the study. In addition, patients with a TT-TG distance >20 mm, who were candidates for tibial tubercle osteotomy, were also excluded. Patient charts were reviewed to confirm that a proton density MRI of the knee was obtained 3 months prior to surgery. After confirmation, operative reports were reviewed to confirm isolated MPFL reconstruction. All surgeries were completed at the same institution. Surgical indication and technique were identical between the surgeons involved in this study. Indications for surgery included a history of recurrent patellar dislocation without malalignment. MPFL reconstruction procedures were accomplished with patellar fixation of a semitendinosis allograft with suture anchors, with care taken to achieve anatomic fixation. Femoral fixation was achieved with an interference screw at Schottle's point with tension applied at 30° of knee flexion with the lateral edge of the patella in line with the lateral edge of the lateral femoral condyle.

Three independent reviewers, including an attending sports medicine surgeon (M.E.B.), a sports medicine surgical fellow (M.W.), and a research assistant (R.W.P.) measured the CDI on MRI images for all included patients. The technique previously described by Askenberger et al.²⁵ was used to measure the CDI on MRI, using the sagittal PD slice with the greatest patellar length to measure patella-to-tibia distance and patellar articular cartilage distance (Fig 1). Patients with a $CDI \geq 1.30$ were included in the patella alta group, while those with a CDI between 0.70 and 1.29 served as controls. Measurements between the three reviewers were averaged prior to data analysis.

Preoperative and postoperative instability episodes and revision knee surgery were collected from physician chart notes. Patients were also contacted to complete a RedCap (Vanderbilt University, Nashville, TN) follow-up questionnaire featuring the number of postoperative instability episodes, subsequent knee surgery, International Knee Documentation Committee (IKDC) survey,²⁶ Lysholm score,²⁷ and Short Form 12-Item

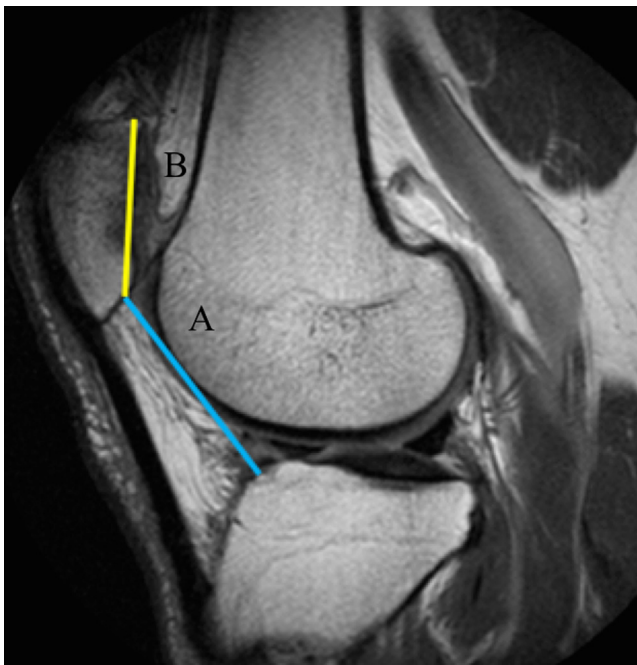


Fig 1. Caton-Deschamps Index (CDI) measurement from sagittal MRI slice with the greatest length of the patella. The CDI equals the distance from the distal aspect of the patellar articular cartilage to the anterosuperior corner of the tibial joint surface (blue line in A), divided by the length of the cartilaginous articular surface (yellow line in B).

(SF-12) survey. Patients also received up to five follow-up phone calls to encourage survey completion.

Statistics

Descriptive statistics including mean, range, and standard deviation, were calculated. The Wilcoxon rank sum test was used to compare continuous variables among the 2 groups with nonparametric data, while the Student's *t*-test was used to compare continuous variables among 2 groups with parametric data. The Fischer exact test was used to compare categorical data. Interrater reliability was assessed by calculating intraclass

correlation coefficients (ICC) for continuous data. The ICC scores were interpreted as follows: a score of 0-0.50 indicates weak reliability, 0.51 to 0.70 indicates moderate reliability, and a score of 0.71 to 1.00 indicates a strong reliability. Linear regression was used to determine the association between preoperative patellar height and postoperative outcomes. All *P* values less than .05 were considered statistically significant. All statistical analyses were performed with R Studio (version 3.6.3, Vienna, Austria).

Results

Forty-nine patients (50 knees) were available for quantitative analysis. Included patients were operated on by 16 fellowship-trained orthopedic surgeons, with two surgeons accounting for 27 (55.0%) of the included patients. The patella alta group was composed of 19 patients, while the control group was composed of 30 patients (Table 1). The patella alta group was significantly younger than the controls ($P < .001$), although there was no difference regarding sex ($P = .237$) or mean follow-up time ($P = .333$) between the groups. Linear regression showed a negative association between age and postoperative IKDC ($R^2 = .191$; $P = .011$) and Short Form 12- Physical scores ($R^2 = .164$; $P = .016$).

The mean CDI of the patella alta group was 1.41 ± 0.10 (range: 1.30-1.66), while the mean CDI of the control group was 1.16 ± 0.09 (range: 0.95-1.29), ($P < .001$). There was strong interrater reliability for the measurement of patella-to-tibia distance, articular cartilage distance, and CDI between each independent investigator (Table 2).

Patient-reported functional outcomes were available for 14 (73.7%) patients in the patella alta group at a mean follow-up of 2.8 ± 0.6 years (range: 2.1-3.6) and 22 (73.3%) patients in the control group at a mean follow-up of 3.2 ± 0.9 years (range: 2.1-5.3) (Table 3). The patella alta group was found to have significantly greater postoperative IKDC ($P = .035$) and SF-12P

Table 1. Baseline Characteristics of Included Patients According to CDI on MRI

	Patella Alta <i>n</i> = 19	Controls <i>n</i> = 30	<i>P</i> Value
Age at surgery, years	16.4 ± 2.8 (11.9-23.8)	24.9 ± 9.6 (14.0-48.7)	< .001*
Sex			
Male	9 (47.4)	20 (66.7)	.237
Female	10 (52.6)	10 (33.3)	
Laterality			
Right side	5 (26.3)	13 (43.3)	.037*
Left side	14 (73.7)	17 (56.7)	
Preoperative Dislocations	2.6 ± 2.2	2.0 ± 1.4	.243
Follow-up, years	2.8 ± 0.6 (2.1-3.6)	3.2 ± 0.9 (2.1-5.3)	.333
CDI	1.41 ± 0.098	1.16 ± 0.094	<.001*

Data are presented as the means \pm SD or *n* (%). CD, Caton-Deschamps; CDI, Caton-Deschamps Index; MRI, magnetic resonance imaging.

*Indicates statistically significant difference at $P < .05$.

Table 2. Reliability of Each CD Measurement Between the Three Independent Investigators

	ICC Value	95% CI	Agreement
Patella-to-Tibia Distance	0.906	0.842 – 0.943	Strong
Articular Cartilage Distance	0.752	0.655 – 0.829	Strong
CDI	0.715	0.612 – 0.800	Strong

CI, confidence interval; ICC, intra-class correlation coefficients; CD, CD, Caton-Deschamps; CDI, CD, Caton-Deschamps Index.

($P = .006$) scores. There was no significant difference in postoperative Lysholm ($P = .531$) and SF-12M ($P = .425$) scores between the two groups. Linear regression showed a significant positive association between preoperative CDI and postoperative IKDC ($R^2 = .159$; $P = .022$) and SF-12P ($R^2 = .248$; $P = .002$) scores (Table 4). There was not a significant association between preoperative CDI and postoperative Lysholm ($R^2 = .041$; $P = .321$) and SF-12M ($R^2 = .002$; $P = .780$) scores.

Seven (36.8%) patients in the patella alta group experienced at least 1 postoperative instability episode during the follow-up period compared to only 3 (10.0%) patients in the control group ($P = .023$). In the patella alta group, 5 patients experienced just 1 postoperative instability episode, and two patients had 2 instability episodes. In the control group, the three patients experienced 3, 5, and 10 instability episodes.

The patella alta group was significantly more likely to undergo a subsequent procedure following initial MPFL reconstruction compared to the control cohort ($P = .019$). Five (26.3%) patients in the patella alta group underwent a subsequent procedure, which included three revision MPFL reconstructions and two chondroplasties. One patient (3.0%) in the control group underwent a second procedure for lysis of adhesions.

Discussion

Patients in the patella alta cohort were found to have significantly higher postoperative functional outcome scores, despite an increased rate of instability episodes and subsequent surgery. Therefore, the authors rejected their hypothesis that preoperative patella alta, as measured by the CDI on MRI, would not significantly

Table 4. Strength of Regressions Between the Caton-Deschamps Index (CDI) and Various Postoperative Outcomes

Dependent Variable	Beta Estimate	95% Confidence Interval	Correlation Strength	P Value
IKDC	52.2	8.2 – 96.2	Moderate	.022*
SF – 12P	30.2	11.6 – 48.8	Moderate	.002*
Lysholm	15.5	–16.0 – 47.0	Weak	.321
SF-12M	4.0	–21.8 – 28.8	None	.780

IKDC, International Knee Documentation Committee; SF-12 P/M, 12-Item Short Form Health Survey Physical/Mental.

*Indicates statistically significant difference at $P < .05$.

affect postoperative outcomes. The presence of preoperative patella alta on lateral radiographs has been shown to correlate with risk for recurrent patellar dislocations after isolated MPFL reconstruction in prior studies.^{2,8,20} Hiemstra et al. reported that patella alta has no effect on quality-of-life outcomes based on the Banff Patellofemoral Instability Instrument score (BPII).²⁴ However, this radiographic measurement has not previously been associated with other postoperative functional outcomes, such as the IKDC, Lysholm score, or the SF-12, following isolated MPFL reconstruction.

Previous studies have examined the correlation between the CDI and patient-reported outcomes following MPFLR. Hiemstra et al.²⁴ examined 136 patients at 2 years following isolated reconstruction and found no association between preoperative patella alta on lateral radiographs ($CDI \geq 1.2$) and postoperative Banff Patellofemoral Instability Instrument scores. Similarly, Allen et al. evaluated 28 patients and reported that while female sex was associated with worse IKDC and Kujala scores, a $CDI \geq 1.2$ was not an independent risk factor ($P = .21$ and $P = .56$, respectively).²³ The present study suggests that CDI on MRI may be more valuable in assessing clinical outcomes, as patients with a higher preoperative CDI were found to have significantly greater postoperative IKDC and SF-12P scores compared to the control cohort at final follow-up. The IKDC and SF-12P scores of the patella alta group in this study were similar to those reported in the literature, as Erickson et al.²⁸ reported a mean IKDC score of 83.2 and VR-12 physical score of 56.4 at 2 years following isolated MPFL reconstruction. The functional outcomes of the control cohort in the present study, however, were lower than expected. The likely

Table 3. A Comparison of Postoperative Functional Outcome Scores Between Patella Alta and Controls

	Patella Alta $n = 14$	Controls $n = 22$	P Value
IKDC	86.5 ± 12.6 (79.3-93.8)	72.4 ± 23.6 (61.0-83.8)	.035*
Lysholm	87.9 ± 11.6 (80.1-95.7)	85.1 ± 10.7 (79.1-91.0)	.531
SF-12P	54.2 ± 5.1 (51.1-57.2)	46.5 ± 10.2 (42.0-51.1)	.006*
SF-12M	48.9 ± 14.5 (40.2-57.7)	52.5 ± 8.6 (48.7-56.3)	.425

Data presented as the mean ± standard deviation (95% confidence interval). IKDC, International Knee Documentation Committee; SF-12 P/M, 12-Item Short Form Health Survey Physical/Mental.

*Indicates statistically significant difference at $P < .05$.

explanation for this difference was due to the discrepancy in age between the two groups. Although current literature has shown that a higher CDI is associated with a younger age of first patellar dislocation,^{24,29,30} the role of aging on functional outcomes after MPFL reconstruction is less clear.²²⁻²⁴ Importantly, Hiemstra et al.²⁴ demonstrated that older age at first dislocation is associated with lower patient-reported outcomes after MPFLR. Although the age at time of surgery was not associated with outcomes in their study, it is possible that the average age at the time of first dislocation in our patients was closer to the age of surgery than in their cohort, accounting for the findings in our analysis.

Studies have associated trochlear dysplasia, patella alta, and increased TT-TG distance as pathoanatomic risk factors that predispose to patellar instability.³¹⁻³³ Cregar et al. reported that, following MPFL reconstruction, elevated TT-TG distances >20 mm in conjunction with severe trochlear dysplasia incurred a higher rate of recurrent patellar instability; additionally, it was also found that trochlear dysplasia correlates to both increased postoperative instability and lower subjective PROs.³¹ Regarding the relationship between CDI and postoperative patellar instability, Sappey-Marini et al.²² examined predictive factors following isolated MPFL reconstruction in over 200 patients at a mean follow-up of 5.8 years. Preoperative CDI ≥ 1.3 on lateral radiographs, in addition to a positive J-sign, was found to be predictive of treatment failure, defined as postoperative patellar dislocation or surgical revision for recurrent patellar instability (OR, 4.9; 95% CI, 1.3-19.0; $P = .02$)²². These findings are further supported by Jaquith and Parikh, who reported a CDI > 1.45 as a risk factor for recurrent dislocations in younger patients. The findings of the present study indicate that utilizing MRI rather than radiography to measure patellar height does not limit its ability to predict treatment failure, as patients with a CDI ≥ 1.30 were significantly more likely to experience recurrent patellar instability and require a subsequent surgery following initial reconstruction compared to the control cohort. One advantage of using MRI for the evaluation of the CDI in patients with patellar instability is that it allows for greater visualization of the cartilage surfaces, in addition to the precise bony anatomy of the knee.¹⁵ Lateral radiographs have routinely been used to calculate the CDI in patients with patella instability, and a recent study reports that a strong agreement was found between CDI measurements from radiographs and MRI with both modalities being reliable for measuring patella alta with the CDI.¹⁵ However, studies have not found an association between patient-reported outcomes and CDI when measured on radiographs alone. The current study suggests that CDI measured on MRI may be able to predict patient outcomes following isolated MPFL reconstruction.

Limitations

The primary limitation of this study is that the patient groups were significantly different regarding age at the time of surgery. The patella alta group underwent surgery at a mean age of 16.4 years compared to 24.9 years in the control group. Selection bias likely contributed to the age discrepancy between the two cohorts, as current literature has shown that a higher CDI is correlated with a younger age of first patellar dislocation.^{24,29,30} In addition, preoperative functional outcome scores were not reported and, therefore, the CDI could not be used to assess magnitude of preoperative differences between the groups or overall improvement following isolated MPFL reconstruction. Additionally, postoperative functional outcome scores were only available for ~73% of the patients in each group leaving a small subset of patients unaccounted. The patella alta group had fewer patients in the subset than the control group. The retrospective design did not allow for quantification of the postoperative instability episodes in each patient. As a result, the disease severity, due to recurrent dislocations, could not be compared between groups. Trochlear dysplasia was not evaluated and, therefore, cannot be adequately evaluated in reference to outcome or recurrence. The present study also focused solely on isolated MPFL reconstruction and, therefore, the results cannot be generalized to other procedures geared toward treatment of patellar instability; however, excluding patients with elevated TT-TG distances does homogenize the population. We believe the observed significant differences noted between groups indicates that we were adequately powered to detect our main outcomes of interest in this analysis.

Conclusion

Patients with preoperative patella alta as measured by CDI had higher rates of postoperative instability and return to the OR with isolated MPFL reconstruction for patellar instability. Despite this, higher preoperative CDI was associated with greater postoperative IKDC scores and SF-12 physical scores in these patients.

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