Strong Agreement Between Magnetic Resonance Imaging and Radiographs for Caton–Deschamps Index in Patients With Patellofemoral Instability

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Purpose: To compare the measurements of the Caton–Deschamps index on preoperative magnetic resonance imaging and radiographs of patients undergoing operative management of patellar instability. Methods: Patients who underwent primary medial patellofemoral ligament reconstruction and/or tibial tubercle osteotomy between January 2015 and November 2019 were assessed. Caton–Deschamps indices were measured by 3 independent reviewers on both radiographs and magnetic resonance imaging. Intra- and interclass correlation coefficients and a Bland–Altman analysis were calculated to assess inter-rater reliability and measurement agreement between radiographic and magnetic resonance imaging. Results: Seventy-two patients (73 knees) were identified. The average Caton–Deschamps index was 1.23 ± 0.18 on radiograph and 1.26 ± 0.18 on magnetic resonance imaging. Strong inter-rater reliability was observed between reviewers for both radiographic and magnetic resonance imaging Caton–Deschamps indices (intraclass correlation coefficients 0.700 and 0.715, respectively). Pooled observer measurements revealed a moderate agreement between radiographic and magnetic resonance imaging for patella to tibia distance, weak agreement for patellar articular cartilage distance, and strong agreement for the Caton–Deschamps index (intraclass correlation coefficients 0.687, 0.485, and 0.749, respectively). Bland–Altman analysis demonstrated a mean difference in Caton–Deschamps index of −0.03 ± 0.15 (95% limits of agreement: −0.29 to 0.23) between radiographic and magnetic resonance imaging, meaning that Caton–Deschamps indices were on average 0.03 lower on radiographic than on magnetic resonance imaging. Conclusions: The Caton–Deschamps index has strong agreement between radiographic and magnetic resonance imaging in patients undergoing patellar stabilization surgery. Either modality can be reliably used to preoperatively assess patellar height. Level of Evidence: Level IV, diagnostic case series.

Patellar instability is a common condition found in sports medicine offices, with an incidence of 23 per 100,000 persons in the general population and 148 per 100,000 persons in adolescents aged 14 to 18 years. Recent years have seen an increase in patellar instability, as 86.0 children per hospital were reported with patellar dislocations in 2016 compared with only 14.5 children per hospital in 2004. The etiology of patellar instability is multifactorial, with many patients having predisposing anatomic factors that alter the
biomechanics of the patellofemoral joint, including trochlear dysplasia, limb malalignment, and patella alta.3-10

Patients with patella alta have a 4-fold increase in recurrent patellar dislocations compared with control patients.11 This is due to the fact that the patella does not engage in the trochlear groove until a high knee flexion angle in patients with patella alta, thereby increasing the risk of instability.10,12,13 Hence, measurement of patellar height is an important technique for evaluating the risk of patellar instability and determining subsequent treatment options.11,14-16 There are a number of methods to radiographically measure patellar height, including the Insall–Salvati (IS), modified Insall–Salvati (MIS), Caton–Deschamps Index (CDI), and Blackburne–Peel (BP).17-20 A meta-analysis performed by Smith et al.20 evaluated the reliability and validity of various patellar height measurements, finding good reliability and validity for 7 different methods with no method standing out as clinically superior.

Yue et al.21 investigated IS, MIS, CDI, and BP measurements on both lateral radiographic and magnetic resonance imaging (MRI) in patients with lateral patellar dislocation and compared these measurements with a control group. The authors found that the patellar height of the lateral patellar dislocation group was measured greater on MRI than radiograph for all 4 measurements, and patellar height was also greater on MRI in the control group for CDI and BP ratios.21 Furthermore, Verhulst et al.22 investigated intra- and inter-rater reliability on radiographs, computed tomography, and MRI in 48 patients presenting with patellar instability. Interestingly, the CDI showed good reliability on radiographs, moderate reliability on computed tomography, and poor reliability on MRI.22 However, in a 2017 study that included a survey of the members of the International Patellofemoral Study Group, consensus established the CDI as the preferred method for measuring patellar height.23 The CDI has been considered the most functional assessment of patellar height and provides great clinical advantage due to the prevalence of lateral radiographs and the simplicity of CDI measurement.24 Also, unlike the IS ratio, CDI is not affected by concomitant tibial tuberosity abnormalities, allowing for a more universal clinical application.

Measurement of the CDI can be determined on both radiographs and MRI.25 Lateral knee radiographs are often taken in a weight-bearing position with the knee at 30° of flexion, whereas MRI is taken with the patient in the supine position with the knee in extension. Variability in knee positioning and imaging modality...
may affect patellar height and CDI measurement. While previous studies have examined the inter-rater reliability of the CDI for measurement of patellar height, the agreement between measurements from radiographs and MRI remains unclear. Evaluating the reliability and agreement between imaging modalities can help determine the clinical applicability of each modality, potentially allowing clinicians to simply use standard-of-care imaging instead of requiring further imaging. The purpose of this study was to compare the measurements of the CDI on preoperative MRI and radiographs of patients undergoing operative management of patellar instability. The null hypothesis was that there would be no difference in CDI between imaging modalities.

**Methods**

Study approval was obtained from the institutional review board (study #19E.938 was exempt from Jefferson University institutional review board review on December 19, 2019). A list of all patients who underwent medial patellofemoral ligament reconstruction (MPFLR) and/or tibial tubercle osteotomy (TTO) from

| Table 1. Baseline Characteristics of Included Patients |
|------------------------------------------------------|
| **Characteristics** | **Patients** |
| Female sex (% female) | 41 (56.9%) |
| Age at surgery, y | 25.4 ± 11.1 (11.9-56.3) |
| Surgical procedure | |
| MPFLR only | 49 (67.1%) |
| TTO only | 5 (6.8%) |
| Both MPFLR and TTO | 19 (26.0%) |
| Laterality | |
| Right | 29 (39.7%) |
| Left | 44 (60.3%) |

NOTE: Sex, surgical procedure, and laterality presented as n (%), and age at surgery presented as mean ± standard deviation (range). MPFLR, medial patellofemoral ligament reconstruction; TTO, tibial tubercle osteotomy.
January 1, 2015, to November 30, 2019, were obtained from the medical records of a single institution. Patients with both a preoperative 30° standing lateral radiograph and a sagittal proton density—weighted MRI from within 3 months of surgery were included in the study. Patients were excluded from the study if they did not undergo MPFLR and/or TTO, or if they underwent a previous ipsilateral knee surgery. In addition, patients were excluded if they were without both a preoperative radiograph and MRI, or if imaging had occurred greater than 3 months before surgery.

Patient sex, age, laterality, and procedure date were collected from clinical records. Three independent reviewers, including an attending sports medicine surgeon (M.E.B.), a sports medicine clinical fellow (M.L.W.), and a trained research assistant (R.W.P.), measured the CDI on radiographic and MRI images for all included patients. To measure the CDI on radiograph, the technique previously described by Caton et al.22,27 was used, as the ratio of the distance between the anterosuperior point of the tibial plateau and the distal pole of the patellar articular surface to the articular surface length of the patella (Fig 1). The CDI on MRI was determined via the technique described by Askenberger et al.,28 with the sagittal slice showing the greatest length of the patella (through the central part of the patellar facet) used for sagittal measurements of patellar height (Fig 2).

Inter-rater reliability and agreement between measurement modalities (radiographs and MRI) was determined by calculating the intraclass correlation coefficient (ICC).22 The ICC scores were interpreted as follows: a score <0.50 indicating weak reliability, 0.50 to 0.69 indicating moderate reliability, and a score of 0.70 to 1.00 indicating strong reliability. Inter-rater reliability was evaluated for both distance (patella to tibia distance and patellar articular cartilage distance) measures of the CDI, as well as the CDI itself, on both MRI and radiographs. Since strong inter-rater reliability was observed, data from the 3 investigators were pooled for an overall assessment of MRI versus radiograph agreement. This pooled assessment of MRI versus radiograph was performed with ICCs and Bland–Altman 95% limits of agreement. The Student t test was used to examine the difference in mean CDI on radiographs and MRI, with statistical significance set at .05.

### Results

After we screened inclusion and exclusion criteria, a final cohort of 72 patients (73 knees) was available for quantitative analysis (Fig 3). There were 41 female (56.9%) and 31 male (43.1%) patients evaluated, with a mean age of 25.4 years (range, 11.9-56.3 years) (Table 1).

Patella to tibia distance and patellar articular cartilage distance were longer on radiograph than on MRI for each observer, although the difference was not statistically significant (P = .200) (Table 2). The average CDI was 1.23 ± 0.18 (95% confidence interval 1.20-1.25) on radiograph and 1.26 ± 0.18 (95% confidence interval 1.24-1.28) on MRI. There was moderate inter-rater reliability for the measurement of patellar

### Table 2. Average Caton—Deschamps Index (CDI), Patella to Tibia Distance, and Patellar Articular Cartilage Distance, Among Each Investigator for Radiographs and MRI

| Variable                  | Investigator 1 | Investigator 2 | Investigator 3 | Total (n = 219) |
|---------------------------|----------------|----------------|----------------|-----------------|
| CDI                       | 1.23 ± 0.16    | 1.20 ± 0.19    | 1.25 ± 0.18    | 1.23 ± 0.18     |
| (1.19-1.26)               | (1.16-1.24)    | (1.21-1.29)    | (1.20-1.25)    | (1.24-1.28)     |
| Patella to tibia distance, mm | 43.33 ± 6.05 | 43.36 ± 6.46 | 43.64 ± 6.68 | 43.44 ± 6.37 |
| (41.95-44.72)             | (41.87-44.84)  | (35.76-42.11)  | (42.60-44.29)  | (39.16-40.54)  |
| Patellar articular cartilage distance, mm | 35.44 ± 3.72 | 36.35 ± 3.59 | 35.05 ± 3.08 | 35.61 ± 3.50 |
| (34.59-36.29)             | (35.52-37.17)  | (34.35-35.76)  | (35.15-36.08)  | (31.42-32.33)  |

*NOTE. Data presented as mean ± standard deviation (95% confidence interval). MRI, magnetic resonance imaging.*

### Table 3. Inter-rater Reliability of Each Caton—Deschamps Index (CDI) Measurement Between Three Investigators

| Variable                  | Investigator 1 | Investigator 2 | Investigator 3 | Total (n = 219) |
|---------------------------|----------------|----------------|----------------|-----------------|
| CDI                       | 0.923          | 0.906          | 0.752          | 0.713           |
| Patella to tibia radiograph | 0.890-0.949  | 0.842-0.943   | 0.561-0.776   | 0.594-0.788     |
| Patella to tibia MRI      | 0.842-0.943   | 0.655-0.829   | 0.612-0.800   | Strong          |
| Articular cartilage radiograph | 0.561-0.776 | Moderate      | Strong         | Strong          |
| Articular cartilage MRI  | 0.655-0.829   | 0.594-0.788   | Strong         | Strong          |
| CDI radiograph            | 0.890-0.949   | 0.842-0.943   | 0.561-0.776   | Strong          |
| CDI MRI                   | 0.842-0.943   | 0.655-0.829   | 0.594-0.788   | Strong          |

*ICC, intra-class correlation coefficient; MRI, magnetic resonance imaging.*


Table 4. Intra-rater Agreement Between Radiographs and MRI

| Investigator | Variable               | ICC Value | 95% Confidence Interval | Agreement |
|--------------|------------------------|-----------|-------------------------|-----------|
| Investigator 1 | Patella to tibia        | 0.659     | 0.033-0.861             | Moderate  |
|              | Articular cartilage distance | 0.575     | 0.000-0.824             | Moderate  |
|              | CDI                     | 0.797     | 0.694-0.867             | Strong    |
| Investigator 2 | Patella to tibia        | 0.700     | 0.391-0.840             | Strong    |
|              | Articular cartilage distance | 0.015     | 0.001-0.032             | No true agreement |
|              | CDI                     | 0.543     | 0.321-0.700             | Moderate  |
| Investigator 3 | Patella to tibia        | 0.615     | 0.020-0.834             | Moderate  |
|              | Articular cartilage distance | 0.383     | 0.000-0.696             | Weak      |
|              | CDI                     | 0.593     | 0.422-0.723             | Moderate  |

CDI, Caton–Deschamps index; ICC, intraclass correlation coefficient.

Discussion

This study found strong agreement between CDI measurements from radiographs and MRI. Both imaging modalities also showed strong inter-rater reliability between 3 independent investigators. Overall, this study suggests that both imaging modalities can be reliably used for measuring patella alta with the CDI.

Current literature has shown inconsistent results regarding the reliability of measuring CDI, as CDI measurements have ranged from poor to excellent on radiograph and MRI. The discrepancy of reported inter-rater reliability may be attributed to several factors, such as differences in identification of bony landmarks, radiographic measurements amongst observers, criteria used for categorizing patellar height, and the statistical methods implemented for classifying reliability in prior studies. While other measurements of patellar height offer alternatives to the CDI (IS, MIS, BP, patellofemoral index, sagittal patellofemoral engagement, and patellar articular overlap), some of these measurements do not have as well-established ranges of normal, may be affected by tibial tuberosity abnormalities, and are not as commonly used in a clinical setting.

Despite strong agreement for the overall CDI ratio between radiograph and MRI, weak agreement was found between MRI radiographs for articular cartilage distance measurement. The inter-rater reliability presented in this current study suggests that clinicians can more accurately assess articular cartilage distance using MRI as opposed to radiograph, potentially due to the ability to visualize the articular cartilage on MRI. Due to poor visualization of the patellar articular cartilage on radiograph, clinicians may only estimate the true length of the cartilage resulting in imprecise and inconsistent measurements.

Decreased intra-rater agreement between MRI and radiograph may be partly attributed to the greater length of the patella and articular cartilage measured on radiograph compared with MRI. This finding is supported by similar reports in previous literature. In contrast, there are other sources of error from MRI that should not be ignored. MRI intra-rater reliability is highly dependent on not only the experience of the
observer but also on the sagittal MRI slice chosen during measurement. While the mid-sagittal slice is the most commonly used, Verhulst et al. argues that this slice infrequently provides the maximal measurement in regard to the length of the patella and articular cartilage in patients with patellar instability. The findings of the present study are important due to its implications on surgical planning in patients diagnosed with patella alta. After failure of nonoperative management, patients undergoing MPFLR with patella alta are sometimes considered for a concomitant distalizing TTO to help with stability. While radiographs have traditionally provided visualization of the bony integrity and calculation of the CDI, MRI allows for visualization of not only bony, but also ligamentous and cartilaginous structures of the knee. The results of the current study suggest that MRI can provide a reliable CDI in addition to superior visualization of the structural integrity of the knee. While these results are encouraging, further examination of the reproducibility of the CDI on MRI is warranted due to the disagreements within existing literature.

Limitations
Radiographic imaging was of varying quality and therefore may have resulted in imperfect measurements. Also, lateral views of the knee are commonly taken with the knee in 30° of flexion, but the amount of flexion could have varied among radiographs. To control for variability, 3 independent observers conducted measurements on all radiographic images. The differences in the experience of the observers may have led to measurement inconsistencies; however, all were trained in measuring CDI on both MRI and radiographs as described. Lastly, the CDI was calculated from radiographic images of patients who had undergone MPFLR and/or TTO, which likely skewed the data towards an average CDI larger than the general population. This may have led to increased reliability; however, measurement of CDI is most applicable to this patient population, so this effect is reflective of clinical applicability.

Conclusions
The CDI has strong agreement between radiograph and MRI in patients undergoing patellar stabilization surgery. Either modality can be reliably used to preoperatively access patellar height.

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