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Middle patellar tendon to posterior cruciate ligament (PT–PCL) and normalized PT–PCL: New magnetic resonance indices for tibial tubercle position in patients with patellar instability

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ABSTRACT

Background: To demonstrate whether the distance between the middle point of the patellar tendon and posterior cruciate ligament (PT–PCL) calculated on a single axial MR image could be an alternative measure to tibial tubercle–PCL (TT–PCL) distance for TT lateralization without the need of imaging processing. To show that normalization of PT–PCL (nPT-PCL) against the maximum diameter of the tibial plateau may help to identify patients with patellar instability (PI).
Methods: MR scans of 30 patients (13 females, age 32 ± 13 years) with known PI and 60 patients (31 females, age 39 ± 19 years) with no history of PI were reviewed. Two operators calculated TT–PCL, and PT–PCL nPT-PCL. Intraclass correlation coefficient, Student's *t*-test, Receiver Operator Characteristic curves, Spearman's Rho and McNemar's test were used.
Results: Interobserver reproducibility was 0.894 for PT-PCL for TT-PCL (95% CI = 0.839–0.930) and 0.866 for TT-PCL (95% CI = 0.796–0.912). The PT–PCL was 23.5 ± 3.8 mm in patients and 20.0 ± 2.7 mm in controls ($P < 0.001$). The TT–PCL was 22.9 ± 3.9 mm in patients and 20.5 ± 2.7 mm in controls ($P = 0.002$). Correlation between the PT–PCL and TT–PCL was $R = 0.838$, $P < 0.001$. The PT–PCL had 66.6% (95% CI = 0.542–0.790) diagnostic yield. The nPT–PCL was significantly higher in patients (0.302 ± 0.03) than controls (0.271 ± 0.03; $P < 0.001$) with 73.9% (95% CI = 0.628–0.851) diagnostic yield.
Conclusion: The PT–PCL correlated with TT–PCL, with 66.6% diagnostic yield. The nPT–PCL may represent an additional index, with 73.9% diagnostic yield.

1. Introduction

Patellar instability (PI) is a major knee problem, with an incidence of about 5.8 per 100,000 people. It mainly affects young and active people. Females in their second decade of life are affected more than males [1,2].

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About 15–44% of first time patellar dislocations will recur after conservative treatment, and about 50% will have knee pain with restricted physical activities [1,2]. The main predisposing factors for first or recurrent patellar dislocations include trochlear dysplasia, patella alta, tibial tubercle lateralization, and femorotibial malrotation. Magnetic resonance imaging (MRI) is considered to be a reliable diagnostic modality for identifying risk factors of chronic PI and assessing joint damage caused by patellar dislocation [3].

The tibial tubercle (TT) position is critical for patellar stability as it should normally be located vertically below the femoral sulcus. Excessive TT lateralization determines an increase in lateral patellar tracking and lateral joint contact pressures, with decreased patellar stability [4,5]. The TT to trochlear groove (TG) (TT–TG) distance is the standard method for assessing the lateral position of the TT. It was originally described by Goutallier et al. on axial radiographs, and then applied by Dejour et al. on computed tomography (CT) images [4,6]. However, the position of the tibia relative to the femur changes during flexion, resulting in a changing TT–TG distance as a function of knee flexion [7]. Furthermore, in a patient with an extremely dysplastic trochlea, it could be difficult to identify its deepest point, which makes the TT–TG value less reliable or even unreliable [8]. An increase in the TT–TG distance is not always due to TT lateralization, but it can be due to medialization of the deepest point of the trochlea, medial rotation of the femur, or lateral rotation of the tibia. In all cases, the exact pathology and the need for TT realignment could not be determined by that measurement alone [8].

In 2012, Seitlinger et al. proposed the TT to posterior cruciate ligament (PCL) (TT–PCL) distance as an alternate measure with which to independently evaluate the lateral position of the TT, by assuming that not all patients with a pathological TT–TG distance (≥20 mm) have TT lateralization [9]. The TT–PCL distance has been demonstrated to be highly reproducible [10].

One of the technical drawbacks of TT–TG and TT–PCL distances is the need for subsequent image reformat on a separate workstation to get superimposed axial images of the tibia at TT level on the axial images obtained through the TG (TT–TG) or PCL (TT–PCL), respectively. This is time-consuming and potentially prone to errors in clinical practice.

Thus, the current study's aim was two-fold: (1) to demonstrate whether the distance between the middle point of the patellar tendon (PT) and the PCL (PT–PCL) calculated on a single axial MRI could be used as an alternate measure for TT lateralization without the need for further imaging processing and (2) to show whether normalization of PT–PCL against the maximum diameter of the tibial plateau may serve as an index for differentiating patients with PI.

2. Materials and methods

2.1. Study population

Institutional Review Board approval was obtained, and patients' consent was waived for this retrospective work. This study reviewed MRI knee scans of a consecutive series of 30 patients (13 females, 17 males, age 32 ± 13 years (mean ± standard deviation)) who were specifically sent to the current institution by a pertinent orthopedic surgeon to evaluate a known episode of previous single or multiple patellar dislocations. As a control group, 60 consecutive patients (31 females and 29 males, age 39 ± 19 years) who presented at the institution for knee MRI for reasons other than patellar conditions were included. This excluded patients with history of previous patellar instability or patellofemoral chondropathy who had an increased rate of patellofemoral malalignment compared to healthy controls [11]. Patients and controls who previously underwent knee surgery were also excluded from the current study.

2.2. Image acquisition protocol

MRI scans were performed using one of two 1.5 T MR systems (Espree or Avanto, Siemens Medical Systems, Erlangen, Germany) equipped with dedicated knee coils. Patients were positioned supine in the gantry with 15° knee flexion. The imaging protocol included: sagittal T1-weighted (time of repetition (TR) = 600–610 ms, time of echo (TE) = 8–15 ms) and proton density (PD) fat suppressed sequences (TR = 2800–3100 ms, TE = 30–40 ms); coronal T2-weighted (TR = 3900–4000 ms, TE = 90–110 ms) and PD fat suppressed sequences (TR = 2500–2900 ms, TE = 20–30 ms); and axial T2 weighted (TR = 4500–5500 ms, TE = 80–110 ms) and PD fat suppressed sequences (TR = 2100–3500 ms, TE = 25–35 ms). Field of view was 160 mm for the sagittal images, and 180 mm for the coronal and axial images. Slice thickness was three millimeters, slice gap was about 3.6 mm, matrix was 384 × 384 pixels for the sagittal images, and 448 × 448 pixels for the coronal and axial images. The current study used T2-weighted axial MR images for measurements.

2.3. Image analysis

Image analysis was performed separately by one musculoskeletal radiologist with >10 years' experience in musculoskeletal imaging, and one radiology resident with >3 years' experience in musculoskeletal MR for all patients included in the analysis. The analysis was performed using dedicated picture archiving and a communication system workstation (Sectra Workstation IDS7, version 15.2.12.72; Sectra AB, Linköping, Sweden).

2.4. TT–PCL calculation

The TT–PCL distance was calculated according to Seitlinger's criteria [9]. In brief, on two superimposed axial images, including the TT and the root of the PCL, the TT–PCL distance was defined as the mediolateral distance between the midpoint of the PT insertion on the TT and the medial border of the PCL root at its tibial insertion. The distance was calculated parallel to the dorsal

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