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Research Article

Diagnostic Accuracy of MRI Evaluation of Patellar Position According to the Physeal Line in Pediatric Patients

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Abstract

Aim: Abnormal positioning of the patella, of which the superior position is defined as patella alta (PA), whereas the inferior position is defined as patella baja (PB). Most of the measurements of patellar position evaluations are time-consuming. In this study, we aimed to examine the diagnostic accuracy of visual evaluation of the patellar position according to the physeal line and to determine the inter- and intraobserver agreement of this evaluation in MRI examinations.

Material and Methods: Knee MRI examinations performed between 2019-2021 with different knee symptoms and prediagnoses were retrospectively analyzed in this study. As a reference test, Insall-Salvati Ratio was calculated by the following formula: Tendon length/patellar length. Two visual evaluation methods were used; physis line to the patella (PLP) and physis line to patellar joint cartilage (PLC).

Results: Three hundred and sixty consecutive children aged 60-215 months were included in the study. There was excellent an agreement of both intra- and interobserver on PLP and PLC for two observers ($\kappa > 0.800$, for all). When we evaluated intra- and interobserver agreements according to groups, almost perfect agreements were detected ($\kappa > 0.750$, for all). Diagnostic accuracy for both two observers on the visual evaluation of PLP was almost perfect (Sensitivity 95.5%, specificity 87.2% for observer 1, and Sensitivity 94.7%, specificity 87.2% for observer 2), and on the PLC evaluation was also good (Sensitivity 89.3%, specificity 82.9% for observer 1, and Sensitivity 88.1%, specificity 85.5% for observer 2).

Conclusion: Even though direct radiography is used in the diagnosis of PA and PB, it has been shown that MRI can also be used in pediatric patients in daily practice. Instead of the time-consuming measurements used in MRI, it may be kept in mind to use these methods in our study for practical and accurate diagnosis.

Keywords: MRI, insall-salvati ratio, patella alta, patella baja, agreement, pediatric patients

INTRODUCTION

The vertical position of the patella, of which the superior position is defined as patella alta (PA), whereas the inferior position is defined as patella baja (PB), is clinically important. Abnormal patella positioning leads to anterior knee pain and patellar dislocation (1,2). Patellar dislocation is associated with patellar chondromalacia and joint effusion (3–5).

Several methods are used in defining the patellar position; however, the Insall-Salvati ratio (ISR) is the most commonly used method. ISR is the ratio of patellar tendon length to patella length and determines the position of the patella in lateral knee radiography with the knee in 30° flexion (6). The use of ISR in other imaging modalities, including computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography (US) in determining patellar position in children and adults has been reported in the literature (7-10).

MRI enables and eases the measurements of non-ossified cartilage components in children, compared to radiographs in which ossification is necessary to measure patellar tendon length and patellar height (1). ISR is the most accepted technique since it is not dependent on the

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degree of knee flexion and applicability in MRI (1,11). So, ISR can be applied to MRI despite position differences (11). In most age groups, PA is defined as a ratio bigger than 1.2, and PB is defined as lower than 0.8 (12).

MRI is an imaging method that can be used for various reasons in children, and the abnormal patellar position, which is one of the causes of knee pain, has been shown to be evaluated with MRI. Most of the measurements of patellar position evaluations are also time-consuming. For these reasons, we aimed to examine the usability of visual evaluation of the patellar position according to the physeal line instead of ISR measurement in MRI evaluations and to test the intra- and interobserver agreement of this evaluation.

MATERIAL AND METHOD

Knee MRI examinations performed between 2019-2021 with different knee symptoms and clinical history were retrospectively analyzed in this study. Three hundred and sixty consecutive children aged 60-215 months were included in the study. Five years old was determined as the lower age threshold for inclusion because patellar ossification starts at this age (15). Patients with closed physeal line but not discernible, patients with bipartite patella, patella fracture, prominent suprapatellar fluid, patellar dislocation, and anterior cruciate ligament rupture were excluded from the study. Malatya Turgut Özal University Ethical Commitee, Decision ID:2022/129)

Examinations were performed with MRI, 1.5-T system (SIEMENS Magnetom Amira, Germany), and slice thickness was 3 mm. Visual evaluation and measurements were done on T1-weighted sagittal sequences. The location of the patella was assessed visually according to the femoral distal epiphysis line. Two different visual assessment methods were used; the line from the physis to the patella (PLP) and the line from the physis to the articular cartilage (PLC). In the PLP method, an imaginary line is drawn from the central apex of the physeal line to the patella in the section where the longest axis of the patella is observed in sagittal MRI. This imaginary line was considered "normal" if it corresponded to the middle 1/3 of the patella length, "PB" if it corresponded to the upper 1/3, and "PA" if it corresponded to the lower 1/3 (Figure 1). In the PLC method, an imaginary line is drawn from the central apex of the physeal line to the patellar cartilage in the section where the longest axis of the patella is observed in sagittal MRI. This imaginary line was considered "normal" if it corresponded to the middle 1/3 of the patellar cartilage length, "PB" if it corresponded to the upper 1/3, and "PA" if it corresponded to the lower 1/3 (Figure 2). MRI evaluations were performed blind to the symptoms of patients.

Visual evaluations were performed by two pediatric radiologists two times within four weeks period. Each researcher was blinded to the previous self-evaluation results and the other researcher's results. Measurements of ISR were performed by one pediatric radiologist and used for comparison with visual assessments.

Figure 1. PLP method a normal patellar position, imaginary physeal line to the patella (1) and imaginary patellar length (2)

Figure 2. PLC method a normal patellar position, imaginary physeal line to the patella (1) and imaginary patellar cartilage length (2)

For ISR calculation, patella length (PL), the longest craniocaudal length of the patella, and patellar tendon length (TL) from the lower patellar pole to insertion on the tibial tuberosity from the dorsal side were measured in MRI (Figure 3). If the patellar tendon origin on the lower patellar pole or insertion on tibial tubercle was in a different sagittal sequence, the patellar tendon origin was marked, then the sequence was changed to distal insertion, and measurement was terminated on this sequence. ISR was computed by the following formula: TL/PL. If ISR was between 0.8 and 1.2 defined as "normal"; if smaller than 0.8 defined as "PB"; and if larger than 1.2 defined as "PA" (12). The inter-observer and intra-observer variability and agreement of ISR measurements and observers' visual evaluation were statistically evaluated.

Figure 3. ISR calculation; the longest craniocaudal length of patella length (PL), patellar tendon length (TL), imaginary physeal line. Astral = Tongue-like extension on the inferior patellar without articular surface

Statistical Analysis

Statistical analysis was performed with SPSS Statistics (version 24.0; IBM Corp., USA) and Jamovi (version 1.6.23.0). The normality of data was assessed with Shapiro Wilk Test. ANOVA test was used in the analysis of continuous variables between groups. The Bonferroni test was used for post-hoc analysis. Kruskal-Wallis test and Chi-Square test were used in the analysis of categorical variables. Pearson and Spearman correlation tests were used in correlation analysis. Cohen's kappa test was used in intra- and interobserver reliability analysis. The power of interobserver reliability was defined as follows: slight if $\kappa \leq 0.20$; fair if $\kappa = 0.21$ to 0.40; moderate if $\kappa = 0.41$ to 0.60; substantial if $\kappa = 0.61$ to 0.80; and almost perfect if $\kappa = 0.81$ to 1.00 (13). Specificity, sensitivity, positive predictive value (PPV), and negative predictive value (NPV) were assessed for diagnostic accuracy, validity, and reproducibility. $p<0.05$ was accepted as statistically significant.

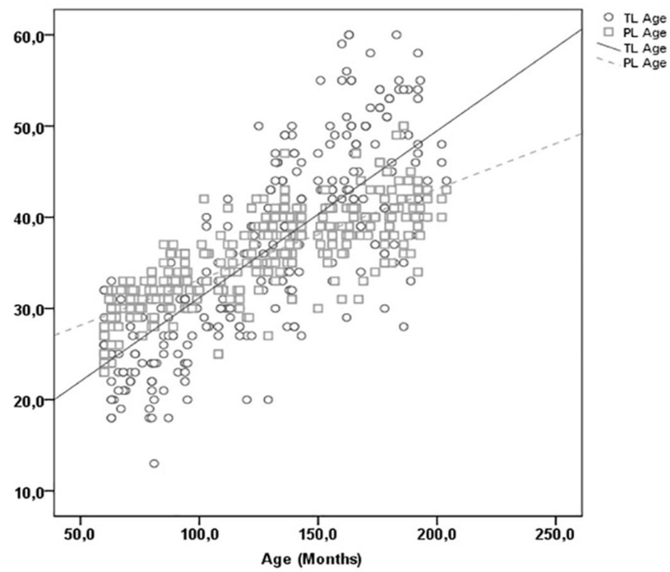

Figure 4. Relationship between patella and tendon length and age

RESULTS

Children were divided into three groups according to age: group 1: 60-107 months, group 2: 108-143 months, and group 3: 144-215 months. Age, gender, PL, TL, ISR, PA, and PB data are given in Table 1. TL, PL, ISR, and PA were found to increase with age, while PB decreased with age.

Table 1. Demographic parameters of the study population

	Group 1 (n = 120)	Group 2 (n =120)	Group 3 (n =120)	*p* value
Age, mounth	79.1±13.6	128.6±10.6	173.6±13.8	<0.001
Gender, male (n, %)	67 (55.6%)	63 (53.4%)	64 (54.2%)	0.941
Tendon length (mm)	26.8±4.9	36.7±6.2	44.9±7.2	<0.001
Patellar length (mm)	31.0±3.4	36.6±3.8	39.9±3.5	<0.001
ISR	0.87±0.16	1.01±0.16	1.13±0.21	<0.001
PA (n, %)	3 (2.4%)	19 (16.4%)	42 (35.0%)	<0.001
PB (n, %)	42 (33.9%)	8 (6.9%)	3 (2.5%)	<0.001

ISR = Insall-Salvati ratio, PA=Patella alta, PB=Patella baja, TL= Tendon length, PL=Patellar length

A positive correlation was found between age with PL and TL (r=0.795, p<0.001 and r=0.800, p<0.001, respectively).

Table 2. Intra- and interobserver variability of values according to the patella and cartilage measurements

Factor	Intraobserver aggreement (Kappa)	Interobserver aggreement (Kappa)
PLP		
Observer#1	0.965	0.931
Observer #2	0.930	
PLC		
Observer#1	0.944	0.880
Observer #2	0.891	

PLP = Physis line to patella, PLC = physis line to patellar joint cartilage

Intra- and interobserver agreements of values PLP and PLC are shown in Table 2. There was an almost perfect agreement of both intra- and interobserver on PLP and PLC for two observers.

Excellent agreement was detected when we evaluated intra- and interobserver agreements according to groups. With increasing age, intra- and interobserver agreements in PLC were lower than in PLP; however still well and acceptable (Table 3).

When sensitivity, specificity, and positive and negative predictive values of PLP and PLC were evaluated (Table 4), high values were detected for validity and reproducibility.

Table 3. Intra- and interobserver variability of the groups of values according to the patella and cartilage measurements

Factor	Intraobserver aggreement (Kappa)	Interobserver aggreement (Kappa)
Group 1		
PLP		
Observer#1	0.930	0.947
Observer #2	0.982	
PLC		
Observer#1	0.981	0.893
Observer #2	0.965	
Group 2		
PLP		
Observer#1	0.978	0.933
Observer #2	0.909	
PLC		
Observer#1	0.863	0.786
Observer #2	0.758	
Group 3		
PLP		
Observer#1	0.982	0.897
Observer #2	0.879	
PLC		
Observer#1	0.951	0.901
Observer #2	0.885	

PLP = Physis line to patella, PLC = Physis line to patellar joint cartilage

Table 4. Sensitivity, specifity, positive and negative predctive values of the patella and cartilage measurements

	Patella				Cartilage			
	Sensitivity	Specifity	PPV	NPV	Sensitivity	Specifity	PPV	NPV
Observer #1	95.5%	87.2%	93.9%	90.3%	89.3%	82.9%	91.6%	78.9%
Observer #2	94.7%	87.2%	93.9%	88.7%	88.1%	85.5%	92.6%	77.5%

PPV = Positive predictive value, NPV = Negative predictive value

DISCUSSION

The main findings of our study are as follows: i) TL, PL, ISR, and PA increased with increasing age while PB decreased, ii) Both intra- and interobserver agreements of values according to the patella and cartilage measurements had excellent results, (iii) when this agreement was assessed according to groups we found perfect agreement, highly usable in terms of validity and reproducibility.

Multiple time-consuming measurements and proportional calculations are required for methods used to evaluate the patellar position in daily practice. ISR is the most sensitive and reproducible method to rule out PA, and the most widely used method in clinical settings for all age groups (14,15). Verhulst et al. (11) showed that, although radiography and CT have high reliability, only ISR has an acceptable agreement between radiography and MRI. It has been demonstrated that the ISR value calculated on MRI and radiographs can be used interchangeably, regardless of the threshold value used (6,7). Kurowecki et al., in their comparative study of 49 pediatric patients with unfused growth plates, demonstrated a strong association between ISR and PA derived from MRI and radiographs in children ages 7.5 years and older (7). In this observational study, when compared with ISR, visual inspection, according to the physis line for detection of abnormal patellar localization, may be used as a sensitive and specific method with high validity and reproducibility.

It is known that MRI is safer than radiography imaging, because direct X-ray contains ionizing radiation and stochastic effects of X-ray especially in children. It has been also stated that MRI may be more accurate in determining the ISR due to the inclusion of non-ossified cartilage in the true patellar length measurement, but the ratio could potentially be kept higher (7). However, in the present study, ISR was found to be lower in younger patients, contrary to the previous studies (7,10). In the comparison study of Kurowecki et al., the age of inclusion of the patients was 7.5 years, while in our study, this value was five years. Including a smaller age group in the present study and including non-ossified components in measurements may result in higher PL measurements. Smaller TL in small age groups may lead to lower ISR values (7). In our study, the youngest age of the patients was five years old. We think that the inclusion of the younger age group in the study, and the longer PL measurement due to the inclusion of components that will ossify with age in the measurement, and the shorter TL due to younger age may be possible reasons for these small ISR values. Among the possible reasons for this, we think that the non-ossifying cartilage segments are included due to the evaluation of patellar height with MRI in ISR, and that the denominator is kept partially constant in this proportional calculation. At the same time, the numerator (TL) increases with age (Figure 4). However, large-scale randomized studies are needed to support our results.

It has been stated that another important factor in determining the patella height is the position of the articular surface of the patella relative to the trochlear cartilage (16,17). Biedert et al. aimed to describe a new method of measuring patellar height using the true articular cartilage on MRI and found that measurements of the articular cartilage congruence can help define an underlying pathology of patellar height (16). In our study, we found that with our visual method, which can detect patellar pathology faster and more accurately in patients undergoing MRI scans, both inter- and intraobserver agreement are almost perfect, and this method has high validity and reproducibility with high specificity and sensitivity rates. It has been stated that since the relationship between ISR and cartilage surface change may also differ due to changes in patella type, this may underestimate the incidence of PA or overestimate PB (18). Although we had high rates for both in our study, we think that the specificity and sensitivity values of cartilage assessments are relatively lower than patellar assessments, and this is due to the shape difference of the patella (Figure 3).

There were some limitations of our study. First, in this retrospective study, the entire extended knee position in MRI could not be fixed, where 30° flexion is a standard position in knee radiography. Another possible confounding factor in determining patellar tendon length on MRI is that not all patellar tendons are straight and appear retractile. The other is that our study was done without knowing the patient's clinical history.

CONCLUSION

To the best of our knowledge, our study is the first to visually evaluate patella localization relative to the physeal line with MRI. Although direct radiography is used in the diagnosing PA and PB, which is the subject of this study, it has been shown that MRI can also be used in pediatric patients in daily practice. Instead of the time-consuming measurements used in MRI, it may be kept in mind to use these methods in our study for practical and accurate diagnosis. Large-scale randomized studies are needed to support our results.

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