Anterior Tibial Translation Sign: Factors Affecting Interpretation of Anterior Cruciate Ligament Tear

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Objective: *To demonstrate factors that can affect interpretation of ACL tear using anterior tibial translation sign and to compare the cut-off value of anterior tibial translation sign in the present study with previous studies.*
Material and Method: *This was a retrospective descriptive research study. The authors included all patients who underwent both MRI and arthroscopy of the knee in King Chulalongkorn Memorial Hospital from January 2002 to March 2010. Anterior tibial translation distance was measured. For patients with intact ACL, tests for correlation between anterior tibial translation distance and demographic data were performed. For patients with ACL tear, a receiver operating characteristic (ROC) analysis was performed in order to determine the best cut-off value for an anterior tibial translation sign.*
Results: *One hundred seventeen patients were enrolled in this study and classified as follows: intact ACL (n = 58), partial ACL tear (n = 19), and complete ACL tear (n = 40). Anterior tibial translation distances for each subgroup were 1.5, 5.0, and 7.6 mm, respectively. Significant mean distance differences for each pair of subgroups were found. No significant correlations between anterior tibial translation distance and sex, height, and weight were found. There was, however, a significant correlation between anterior tibial translation distance and age. For diagnosis of partial and complete ACL tear, cut-off distances of 3.5 mm and 5.5 mm provided the best accuracy, respectively.*
Conclusion: *There is correlation between anterior tibial translation distance and age. The authors may possibly imply that, using anterior tibial translation distance in young age group patients for diagnosing ACL tear may increase the false-positive rate. The authors introduce a cut-off distance of 3.5 mm to classify patients as having intact ACL or ACL tear.*

Keywords: *Anterior cruciate ligament (ACL), Anterior tibial translation, Arthroscopy, Magnetic resonance imaging (MRI)*

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The anterior cruciate ligament (ACL) is a major ligament of the knee. Its origin and insertion are at posteromedial aspect of the lateral femoral condyle and anterolateral aspect of the anterior tibial spine, respectively. Its function is to prevent anterior translation and internal rotation of the tibia, with respect to the femur. Most common causes of ACL tear are actions involving deceleration, twisting, or jumping[1]. Early and accurate diagnosis of ACL tear is important, because ACL tear may lead to instability of the knee.

The diagnosis of ACL tear is based on clinical history and examination. However, presentation can mimic meniscal and other ligamentous injuries. The anterior drawer test and the Lachman test are commonly used diagnostic methods. The sensitivity of these two tests for acute ACL injury is approximately 22.2-70% and 80-87%, respectively. The specificity of both tests exceeds 90%[2]. Limitation in an acute injury setting is often due to swelling of the affected knee.

Magnetic resonance imaging (MRI) has been reported to be accurate in helping make the diagnosis of complete ACL tear[3]. In most reports, a diagnosis of ACL tear is based on sagittal images that show a disrupted ACL. Direct signs of ACL tear include failure to visualize the ACL, wavy contour of the ACL, discontinuity of the ACL, high signal intensity of the ACL on T2-weighted images, and thickening of the ACL[3,4].

Although MRI is accurate, false-positive and false-negative results still occur. Indirect signs of complete ACL tear have been recommended as an added method for improving diagnostic accuracy. The presence of indirect signs support the diagnosis with high specificity, but the sensitivity of these indirect signs is relatively low[3]. These indirect signs can be classified as both qualitative and quantitative signs.

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Due to the clearly defined objective criteria of quantitative signs, the authors reviewed only the quantitative indirect signs of complete ACL tear. These included anterior tibial translation sign, ACL-Blumenstaat line angle sign, ACL angle sign, posterior cruciate ligament (PCL) angle sign, PCL bowing ratio sign, and uncovered meniscus sign[3-7]. Of these, we decided to study the anterior tibial translation sign in detail, due to its uncomplicated measurement and simple correlation with the function of ACL.

The anterior tibial translation sign is positive when the anterior tibial translation distance is more than 5 mm. With a 5-mm cut-off value, the sensitivity and specificity are 58-86% and 88-99%, respectively[4-6].

A meta-analysis, which included data from 9 studies, found significant menstrual cycle-related effect on anterior knee laxity in women. Laxity increased during the ovulatory or post-ovulatory phases of the cycle. Hormone level involvement was suspected to be the responsible factor for this association[8,9]. A study of school-aged children discovered a significant negative correlation between anterior knee laxity under an application force and age for both boys and girls. Girls also had higher mean values for anterior knee translation than boys of a similar age did. Additionally, a decrease in anterior knee laxity was observed relative to increasing BMI in some subgroups of the present study[10]. All of these studies were non-imaging studies and arthrometers were used for all measurements.

To our knowledge, no demonstrated factors have been introduced that can affect interpretation of ACL tear by imaging using the anterior tibial translation sign.

Material and Method

This was a retrospective descriptive research study. The authors included all patients who underwent both MRI and arthroscopy of the knee at King Chulalongkorn Memorial Hospital from January 2002 to March 2010. Patient data were collected from the hospital information system and the picture archiving and communication system (PACS). The following disease classification codes were researched from the International Classification of Diseases, 9th Revision Clinical Codification (ICD-9-CM): 80.26 (arthroscopy of the knee), 81.43 (triad knee repair; medial meniscectomy with repair of the anterior cruciate ligament and the medial collateral ligament), 81.45 (other repair of the cruciate ligaments), 81.46 (other repair of the collateral ligaments), and 81.47 (other repair of knee).

Patient clinical data were collected from in-patient records, including demographic data (e.g. age, sex, height, weight, and occupation). Patients were categorized into 1 of 3 subgroups based on arthroscopic findings, as follows: intact ACL, partial ACL tear, or complete ACL tear. We then reviewed patient diagnostic images from PACS and anterior tibial translation distances were measured. The means of the anterior tibial translation distances in each subgroup were calculated and the unpaired t-test for the mean difference of each subgroup was performed.

For patients with intact ACL, tests for correlation between the normal value of the anterior tibial translation distance and demographic data were performed, using unpaired t-test and Pearson correlation coefficient.

For patients with (partial or complete) ACL tear, a receiver operating characteristic (ROC) analysis was performed in order to determine the best cut-off value for the anterior tibial translation sign. In addition, a comparison was made between the cut-off value found in this study and the cut-off values reported in previous studies.

MRI protocols

All patients underwent a knee protocol MRI scan with the 1.5-Tesla Signa (GE Healthcare, Little Chalfont, United Kingdom) or the 3.0-Tesla Achieva (Philips Healthcare, Amsterdam, Netherlands) for the following planes and pulse sequences: Sagittal oblique-PD and FS T2WI; Coronal-T1WI, FS T2WI and GRE T2*WI; and, Axial-FS PDWI.

Measurement

Anterior tibial translation distance was defined as the distance between the most posterior cortex of the tibia and femur, obtained at the midsagittal plane of the lateral femoral condyle. Distance was measured with regard to a plane parallel to the long axis of the image[5]. Only one author was blinded to the related clinical data and arthroscopic findings. Interobserver reliability was assessed by intra-class correlation coefficient (ICC).

Results

Initially, 136 patients were included in this study. Nineteen patients were excluded for the following reasons: incorrect scanning plane (11 patients), post ACL reconstruction (5 patients), no available image on PACS (2 patients), and incomplete arthroscopic finding (1 patient). Minus exclusions, 117 patients were enrolled

in the study. These patients were classified, as follows: intact ACL (58 patients), partial ACL tear (19 patients), and complete ACL tear (40 patients).

Demographic data

Mean ages of each subgroup were as follows: 41.8 [18-75] years for patients with intact ACL, 33.1 [16-50] years for patients with partial ACL tear, and 30.4 [15-58] years for patients with complete ACL tear. Within the intact ACL subgroup, 31 patients were males and 27 females. In the partial ACL tear and complete ACL tear subgroups, only 1 and 3 patients were females, respectively.

Anterior tibial translation distance

Anterior tibial translation distances (mean $\pm$ SD [range]) of each subgroup were, as follows: 1.5$\pm$3.6 [-7.8- 9.9] mm for patients with intact ACL, 5.0$\pm$2.8 [0.6-11.0] mm for patients with partial ACL tear, and 7.6$\pm$3.0 [2.4-15.7] mm for patients with complete ACL tear (Fig. 1-3).

Statistically significant difference in mean distances (mean difference $\pm$ SD) for each pair of subgroups were found, as follows: 3.5$\pm$1.0 mm (95% CI: 1.5-5.5, $p = 0.0007$) for intact ACL vs. partial ACL tear; 2.6$\pm$0.8 mm (95% CI: 1.0-4.3, $p = 0.0036$) for partial ACL tear vs. complete ACL tear; and, 6.1$\pm$0.7 mm (95% CI: 4.8-7.4, $p<0.0001$) for intact ACL vs. complete ACL tear.

Almost perfect agreement in the measurement for anterior tibial translation distances was found (ICC = 0.991).

Correlation between distance & demographic data

Correlation between anterior tibial translation distance and demographic data was tested. However, this correlation was tested only in the intact ACL subgroup because of this subgroup being associated with the least number of confounding factors.

Sex

Anterior tibial translation distances (mean $\pm$ SD [range]) were, as follows: 1.2$\pm$3.9 [-7.8-8.3] mm for males and 1.9$\pm$3.2 [-3.5-9.9] mm for females. No statistically significant difference for distance between males and females was found ($p = 0.4965$).

Height & weight

Correlation between anterior tibial translation distance and height and weight was tested by Pearson correlation coefficient (r). For anterior tibial translation distance and height, no correlation was found (r = -0.0037). Similarly, for anterior tibial translation distance and weight, no correlations were found (r = 0.1108).

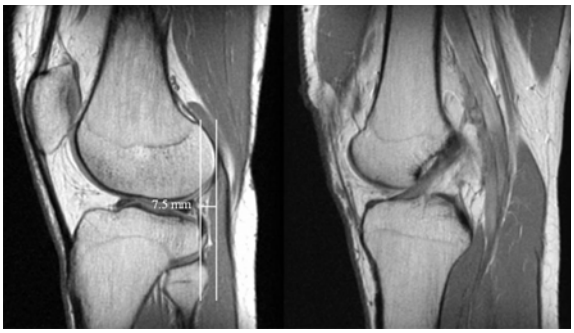

Fig. 1 A 28-year-old man with intact ACL. Sagittal MR image of the knee through the midpoint of the lateral femoral condyle shows an anterior tibial translation distance of 7.5 mm: a false positive result for the 5-mm cut-off value.

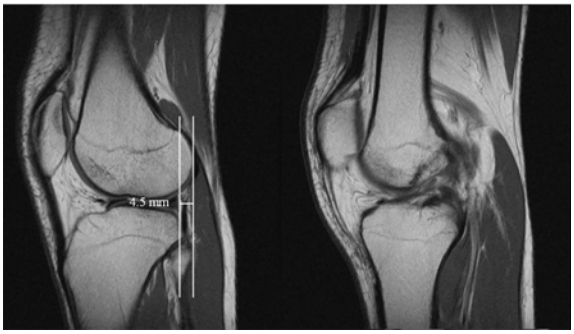

Fig. 2 An 18-year-old man with partial ACL tear. Sagittal MR image of the knee through the midpoint of the lateral femoral condyle shows an anterior tibial translation distance of 4.5 mm, with signs of deep lateral condylepatellar sulcus also being noted.

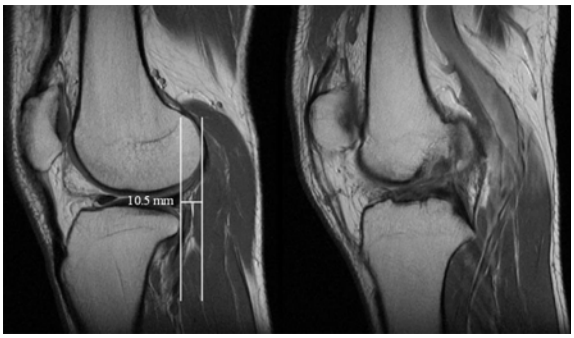

Fig. 3 A 39-year-old man with complete ACL tear. Sagittal MR image of the knee through the midpoint of the lateral femoral condyle shows an anterior tibial translation distance of 10.5 mm.

Age

Correlation between anterior tibial translation distance and age was tested by using Pearson correlation coefficient. No correlations were found (r = 0.0063). However, in subgroup analysis using 0 mm as the cut-off point (justification: to disregard the direction of anterior tibial translation distance), the following correlations between the anterior tibial translation distance and age were found: r = 0.5273 (moderate correlation, p = 0.0117) for distance ≤0 mm and r = -0.2768 and (slightly negative correlation, p = 0.0760) for distance ≥0 mm.

Diagnostic performance of anterior tibial translation sign

In discriminating intact ACL or partial ACL tear from complete ACL tear, a cut-off distance of 5.5 mm provides the best accuracy (82.1%), with sensitivity and specificity of 77.5% and 84.4%, respectively (Fig. 4).

In discriminating intact ACL from partial or complete ACL tear, a cut-off distance of 3.5 mm provides the best accuracy (78.6%), with sensitivity and specificity of 83.1% and 74.1%, respectively (Fig. 5).

Discussion

As previously described, a correlation exists between anterior tibial translation distance and age in patients in the intact ACL subgroup, in which a positive correlation was found for distances ≤0 mm and a negative correlation was found for distances ≥0 mm. This result corresponded with previous studies that used an arthrometer for measurements[10]. The authors may possibly imply that using the anterior tibial translation distance in young age group patients for diagnosing ACL tear may increase the false-positive rate. Additional studies that include a broader range of ages must be undertaken to further support this mild assertion.

In discriminating intact ACL or partial ACL tear from complete ACL tear, the best accuracy was found at the cut-off distance of 5.5 mm, with related levels of sensitivity and specificity of 77.5% and 84.4%, respectively. Previous studies that used a cut-off distance of 5 mm showed sensitivity and specificity of 58-86% and 88-99%, respectively; results that are comparable with the present study. The difference between these cut-off distances, however, is only 0.5 mm (5 mm and 5.5 mm). This difference was not significant due to the fact that its value is less than the measurement error (0.6 mm for median value).

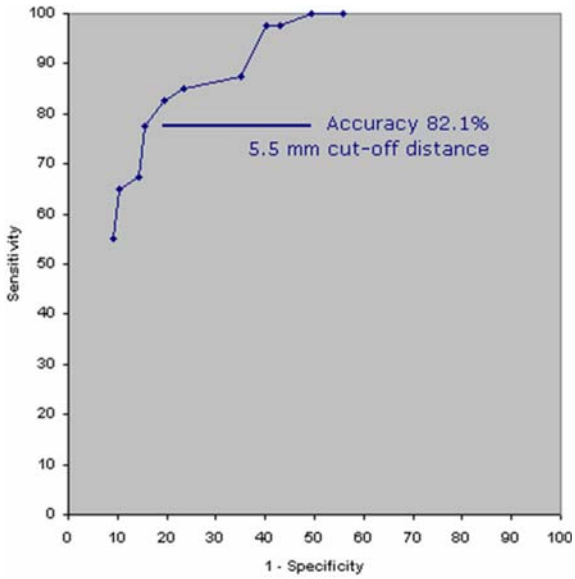

Fig. 4 ROC curve for discriminating intact ACL or partial ACL tear from complete ACL tear. A cut-off distance of 5.5 mm provides the best accuracy (82.1%); sensitivity and specificity are 77.5% and 84.4%, respectively.

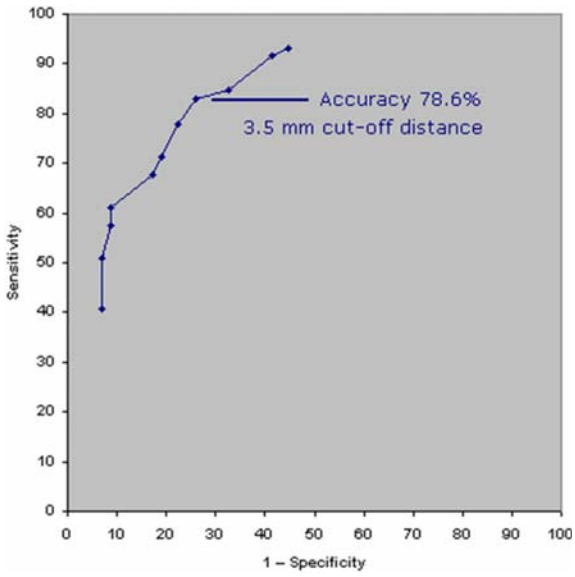

Fig. 5 ROC curve for discriminating intact ACL from partial or complete ACL tear. A cut-off distance of 3.5 mm provides the best accuracy (78.6%); sensitivity and specificity are 83.1% and 74.1%, respectively.

In discriminating intact ACL from partial or complete ACL tear, best accuracy was found at the cut-off distance of 3.5 mm, with related levels of sensitivity and specificity of 83.1% and 74.1%, respectively. No

previous study has reported this sign in the diagnosis of partial ACL tear.

The mean anterior tibial translation distance in intact ACL patients is 1.5 mm. Notably, no previous studies reported on this value. It may be implied that this value is the normal value of the anterior tibial translation distance. In the present study, however, intact ACL patients still have other knee conditions. In order to estimate normal value of the anterior tibial translation distance properly, the authors should enroll only healthy subjects with no associated conditions.

Four aspects regarding the limitations of this study were found. First, the ptesrnt study was performed in retrospective fashion; therefore, some clinical data and arthroscopic findings were or may have been incomplete. Second, there was an inadequate sample size (n = 58) in the intact ACL subgroup, which is only 70.0% (58/83) of calculated sample size. This occurred since we changed the gold standard (the optimal inclusion criteria for the intact ACL subgroup?) in order to classify patients as having intact ACL from MRI to arthroscopy. Third, patients with an acceptable degree of scanning plane error were not excluded. Finally, one of the two authors was not blinded to the arthroscopic findings (e.g. complete ACL tear, partial ACL tear, or intact ACL). However, the anterior tibial translation distance is an objective sign that has clear definition in the measuring process: therefore, only a mild degree of measurement bias can occur.

Further prospective study should be undertaken that enrolls more subjects, gathers more complete data, and identifies an optimal scanning plane. In addition all observers should be blinded for purposes of measuring the anterior tibial translation distance.

Conclusion

In patients with intact ACL, there is a correlation between anterior tibial translation distance and age. The authors may possibly imply that using anterior tibial translation distance in young age group patients for diagnosing ACL tear, increases the false-positive rate. The authors introduced a cut-off distance of 3.5 mm in classifying patients as having intact ACL or ACL tear (partial or complete tear) with associated sensitivity and specificity of 83.1% and 74.1%, respectively.

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Potential conflicts of interest

None.

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Anterior tibial translation sign: ปัจจัยที่มีผลกระทบในการแปลผลเพื่อวินิจฉัยการฉีกขาดของเอ็นไขว้หน้าในข้อเข่า

น้ำผึ้ง นำการุณอรุณโรจน์, ธีรชัย ชัยทัศนีย์

วัตถุประสงค์: *เพื่อแสดงถึงปัจจัยที่มีผลกระทบในการแปลผลเพื่อวินิจฉัยการฉีกขาดของเอ็นไขว้หน้าในข้อเข่าโดยใช้ anterior tibial translation sign และเพื่อเปรียบเทียบค่า cut-off ของ anterior tibial translation sign กับการศึกษาก่อนหน้านี้*

วัสดุและวิธีการ: *การศึกษาแบบบรรยายย้อนหลังโดยรวบรวมผู้ป่วยที่ได้รับการตรวจข้อเข่าด้วยเครื่องตรวจวินิจฉัยโรคด้วยคลื่นแม่เหล็กไฟฟ้าและได้รับการส่องกล้องในข้อเข่าในโรงพยาบาลจุฬาลงกรณ์ระหว่างเดือนมกราคม พ.ศ. 2545 ถึงเดือนมีนาคม พ.ศ. 2553 ทำการวัดค่า anterior tibial translation distance ในผู้ป่วยทุกรายโดยในกลุ่มผู้ป่วยที่ไม่มีการฉีกขาดของเอ็นไขว้หน้าในข้อเข่าจะหาค่าความสัมพันธ์ระหว่าง anterior tibial translation distance และ demographic data ส่วนในกลุ่มผู้ป่วยที่มีการฉีกขาดของเอ็นไขว้หน้าในข้อเข่าจะคำนวณหาค่า cut-off ของ anterior tibial translation distance โดยใช้ receiver operating characteristics curve*

ผลการศึกษา: *ผู้ป่วย 117 ราย แบ่งเป็นกลุ่มผู้ป่วยที่ไม่มีการฉีกขาดของเอ็นไขว้หน้าในข้อเข่า 58 ราย กลุ่มผู้ป่วยที่มีการฉีกขาดบางส่วนของเอ็นไขว้หน้าในข้อเข่า 19 รายและกลุ่มผู้ป่วยที่มีการฉีกขาดทั้งหมดของเอ็นไขว้หน้าในข้อเข่า 40 ราย ค่าเฉลี่ย anterior tibial translation distance ในแต่ละกลุ่มคือ 1.5, 5.0 และ 7.6 มิลลิเมตรตามลำดับ พบความแตกต่างของค่าเฉลี่ยที่วัดได้ในแต่ละกลุ่มอย่างมีนัยสำคัญไม่พบความสัมพันธ์ระหว่าง anterior tibial translation distance และ เพศ ส่วนสูง น้ำหนักของผู้ป่วยแต่พบความสัมพันธ์ระหว่าง anterior tibial translation distance และอายุอย่างมีนัยสำคัญ สำหรับการวินิจฉัยการฉีกขาดบางส่วนและการฉีกขาดทั้งหมดของเอ็นไขว้หน้าในข้อเข่าพบว่าค่า cut-off เท่ากับ 3.5 มิลลิเมตร และ 5.5 มิลลิเมตรตามลำดับจะมีความแม่นยำมากที่สุด*

สรุป: *พบความสัมพันธ์ระหว่าง anterior tibial translation distance และอายุของผู้ป่วยโดยสามารถสรุปได้ว่าการใช้ anterior tibial translation distance ในผู้ป่วยอายุน้อยเพื่อวินิจฉัยการฉีกขาดของเอ็นไขว้หน้าของข้อเข่านั้นอาจทำให้อัตราการเกิดผลบวกลวงสูงขึ้น อีกทั้งพบว่าค่า cut-off ของ anterior tibial translation distance ที่ 3.5 มิลลิเมตรจะช่วยแยกผู้ป่วยที่มีการฉีกขาดของเอ็นไขว้หน้าในข้อเข่าออกจากผู้ป่วยที่ไม่มีการฉีกขาด*