Accuracy of a New Stress Radiographic Device in Diagnosing Anterior Cruciate Ligament Tear

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Background: Anterior cruciate ligament (ACL) tears are clinically diagnosed by detection of anterior tibial translation on physical examination; however, this manual method of assessment is imprecise, subjective, and not reproducible. Recently a new instrument, a stress radiographic device (SRD), was produced to objectively measure these displacements.

Objective: To assess a new instrument, a SRD, in the measurement of anterior tibial translation in ACL-deficient knee compared to the healthy ACL knee.

Material and Method: The SRD was applied to 24 ACL-tear knees that were diagnosed by MRI as having complete ACL tears, and 24 healthy ACLs from the contralateral knee of each patient. Each knee was tested under a force 120 Newtons in a posterior to anterior direction to create anterior tibial translation at 20 degrees knee flexion. Side-to-side difference of anterior tibial translation (mm) was measured from radiographs.

Results: We studied 24 patients who had one knee with complete rupture of ACL diagnosed by MRI and the other with healthy ACL confirmed by clinical diagnosis. The mean anterior tibial translation before and after using the device was significantly lower in the healthy ACL group than in the ruptured ACL group. A stress radiographic device was used with a 4 mm side-to-side cut off point of difference of anterior tibial translation between pre- and post-stress displacement for diagnosis of complete rupture of anterior cruciate ligament. The sensitivity was 79% and specificity was 100%.

Conclusion: The new stress radiographic device is reliable and reproducible in diagnosis of complete rupture of anterior cruciate ligament.

Keywords: Anterior cruciate ligament tears, Anterior tibial translation, Stress radiographic device

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There are several ways to diagnose anterior cruciate ligament (ACL) tear, starting with history assessment and physical examination. Physical examination results in many diagnostic errors; for example, the force of examination and the analysis of results are often interpreted differently in each detector, affecting the consistency of these examinations(1-3). In cases of suspected anterior cruciate ligament tear, therefore, more than one method of examination should be utilized.

Magnetic Resonance Imaging (MRI) is the most reliable method for diagnosis of anterior cruciate ligament tear; however, it uses imaging alone and does not show ligament functional problems such as ligament elongation that causes joint laxity or partial tear, and it sometimes fails to find ligament or partial tear. Furthermore, MRI has limitations in postoperative ACL reconstruction because it is sometimes fails to detect tendon or ligament functional problems, and its results may be imprecise(4).

In order to reduce errors made in manual assessment of anterior tibial translation, the arthrometer was developed to replace this manual method. It can control the force (N) of the examination and measure tibial translation in millimeters, resulting in a higher level of accuracy(5). In Thailand, arthrometers are used only by the Faculties of Medicine in university hospitals and other large institutions(6).

The stress radiographic device was created to assess tibial translation and achieve more accurate measurement. It is superior to the arthrometer because it takes measurements directly from radiographs; this results in clearer definition and reduces errors caused by the presence of soft tissue and skin thickening(7). The radiograph is used as the document record and is
more useful than length of tibial translation record alone.

The stress radiographic device is very reliable and is widely used abroad, but it is very expensive to import into Thailand.

Between August 2014 and February 2015, a stress radiograph device was used in Rajavithi Hospital and in the Faculty of Applied Science of King Mongkut University of Technology, North Bangkok (Fig. 1). The present study was carried out in the seven months following the machine’s inception at the hospitals. It was first used on patients with anterior cruciate ligament tear because it is the most commonly-found incidence of knee ligament injury.

**Objective**

To assess the stress radiographic device in the measurement of anterior tibial translation in patients with anterior cruciate ligament tear.

**Material and Method**

The protocol of the present research was reviewed and approved by the Ethics Committee of Rajavithi Hospital (No.066/2558). Twenty-four patients were examined at Rajavithi Hospital between August 2014 and June 2015.

**Selection criteria**

Patients were included if they had been diagnosed by MRI as having one knee with complete ACL, and the other knee diagnosed as having healthy ACL after physical examination.

**Exclusion criteria**

Patients who:
1. Had other tendon injury
2. Had severe knee pain and were difficult to examine
3. Had knee swelling and inflammation
4. Had injury for less than 6 weeks
5. Refused to participate in the study

Examination was performed in a lateral decubitus position with the knee flexed at 20 degrees (Lachman’s test), putting one post at the anterior side of the thigh of the distal leg and another post at the posterior side of the proximal leg, which was connected to a pressure regulator. A force of 120N was applied at the proximal leg; this force is the recommended value used for testing subjects and causes displacement of the knee without severe pain (Fig. 1).

Patients were tested twice, first on the knee with ACL tear, and then on the normal one. Assessments were made and recorded for five parameters using radiographs (Fig. 2).

1. Pre-stress anterior tibial translation in normal knee
2. Post-stress anterior tibial translation in normal knee
3. Pre-stress anterior tibial translation in ACL-tear knee
4. Post-stress anterior tibial translation in ACL-tear knee
5. Difference (length of tibial translation from pre- to post-stress measurement)

Measurement of anterior translation distance was carried out by anterior drawer of medial compartment (ADMC) (8,11).

**Statistical analysis**

Statistical analyses were performed using SPSS version 17.0 software.

- Descriptive Statistics were used to describe the personal characteristics of participants in terms of percentage, mean, standard deviation, median, minimum, and maximum value.

- Inferential Statistics were employed to compare mean anterior tibial translation in the two groups using Wilcoxon Signed Ranks test, and a
value of $p<0.05$ was considered significant. Anterior tibial translation cut-off points for predicting ACL tear were found using ROC Curve, and their sensitivity and specificity for screening for ACL were calculated.

### Results

The 24 patients had a mean age of 26.79±7.89 (min-max 18-46 years), were mainly male gender 21(87.5%), and had injury caused by: non-contact sports 9, contact sports 10, and traffic accident 5. Lachman’s test showed grade 0 = 1 (4.2%), grade 1 = 6 (25%), grade 2 = 11 (45.8%), grade 3 = 6 (25%), as displayed in Table 1.

In the normal-knee group, the pre-stress displacement measurement had a mean of 1.43±2.04 mm, median 0 mm and min and max of 0 and 7 mm. In the ACL-tear group, the pre-stress displacement measurement had a mean of 11.63±4.70 mm, median 10.85 mm and min and max of 4.30 and 22.04 mm, and the difference was statistically significant ($p<0.001$).

The mean pre-stress and post-stress displacement measurement (difference) in the normal knee group was 1.39±1.31 mm, with median 1.26 mm and min and max of 0 and 3.74 mm. In the ACL-tear group, the mean pre-stress and post-stress displacement measurement (difference) was 6.42±3.31 mm with median 6.71 mm and min and max of 1.04 and 14.00 mm. The difference was statistically significant ($p<0.001$) (Table 2, Fig. 3).

Calculations for cut-off values in ROC curve were made using pre-stress and post-stress measurements and difference of displacement. Pre-stress displacement at cut-off point 3 mm had a sensitivity of 58% and specificity of 78%. Post-stress displacement at cut-off point 7 mm had a sensitivity of 88% and specificity 93%. Distance of pre-stress and post-stress displacement (difference) at cut off point 4 mm had a sensitivity of 79% and specificity of 100% (Fig. 4).

### Discussion

In the present study, it was found that the displacement in the ACL-tear group was significantly higher than in the normal-knee group, with post-stress displacement of 11.63 ±4.70/3.02±2.70 mm and a difference of 6.42±3.31/4.39±1.31 mm. Lerat et al. (9) studied 125 ACL-tear and 180 normal knees using stress film with passive drawer, putting a weight of 9 kg at the thigh. They found post-stress displacement displacement measurement had a mean of 11.63±4.70 mm, median 10.85 mm and min and max of 4.30 and 22.04 mm, and the difference was statistically significant ($p<0.001$).

In the normal-knee group, the post-stress displacement measurement had a mean of 3.02±2.70 mm, median 2.68 mm, and min and max of 0 and 8.80 mm. In the ACL-tear group, the post-stress displacement measurement had a mean of 11.63±4.70 mm, median 10.85 mm and min and max of 4.30 and 22.04 mm, and the difference was statistically significant ($p<0.001$).

### Table 1. Demographic data

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Number</th>
<th>Percentage (%)</th>
</tr>
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<tbody>
<tr>
<td><strong>Age (years)</strong></td>
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<tr>
<td>Mean ± SD</td>
<td>26.79±7.87</td>
<td></td>
</tr>
<tr>
<td>Min-max</td>
<td>18-46</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
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<td></td>
</tr>
<tr>
<td>Female</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>Male</td>
<td>21</td>
<td>87.5</td>
</tr>
<tr>
<td><strong>Mechanism of injury</strong></td>
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<td></td>
</tr>
<tr>
<td>Non-contact sport</td>
<td>9</td>
<td>37.6</td>
</tr>
<tr>
<td>Contacts sport</td>
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<td>41.6</td>
</tr>
<tr>
<td>Vehicle accident</td>
<td>5</td>
<td>20.8</td>
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<td><strong>Lachman’s test</strong></td>
<td></td>
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<tr>
<td>Grade 0</td>
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<td>4.2</td>
</tr>
<tr>
<td>Grade 1</td>
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<tr>
<td>Grade 2</td>
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<td>45.8</td>
</tr>
<tr>
<td>Grade 3</td>
<td>6</td>
<td>25.0</td>
</tr>
</tbody>
</table>

Fig. 2 Measurement anterior translation distance by anterior drawer of medial compartment (ADMC). A, B) Distance between pre and post stress anterior tibial translation in ACL tear 0, 12.12 mm. C, D) distance between Pre-stress anterior tibial translation in normal knee 0, 0 mm.
of the ACL-tear knees compared with normal knee using the ADMC method of 10.8±3.1/3.3±2.0 mm. In the study by Garces et al(10), 47 ACL-tear and 69 normal knees were examined using a stress radiographic device Telos®, at a force of 137 Newtons, it was found that post-stress displacement measurements using ADMC in the ACL-tear group compared with the normal-knee one were 5.8±4.9/1.07±3.5 mm. Beldame et al(11) studied 70 ACL-tear and 144 normal knees using a stress radiographic device Telos®, at a force of 250 Newton, they found that the post-stress displacement measurement by ADMC in the ACL-tear knees compared with normal ones was 5.9±5.25/2.17±1.28 mm.

Statistical calculation of cut-off points for optimal sensitivity and specificity in screening for ACL tear found that post-stress displacement measurements using ADMC at 7 mm had a sensitivity of 88% and specificity of 93%. Lerat et al(9) found that a cut-off point of post-stress displacement ADMC at 6 mm had a sensitivity of 87% and specificity of 90%. Pansies et al(12) found that a cut-off point of post-stress displacement ADMC at 5 mm had a sensitivity of 80.9% and specificity of 81.8%. A cut-off point in difference measurement of 4 mm using a stress radiographic device Telos® at a force of 250 Newtons had a sensitivity of 59.4% and specificity of 90.6%.

The present study had several limitations. MRI is the gold standard, but it has limitations in diagnosing ACL-tear knees in casts, and sometimes it is necessary to compare its results with arthroscopy, which is the gold standard technique. Arthroscopic findings are more reliable than MRI, but in the present study only 10 patients underwent arthroscopic examination. Diagnosis for normal knee by group history and physical examination carried a high risk of erroneous results. Diagnosis should be made by MRI, but it is an expensive method for ruling out normal knee.

**Conclusion**

The new instrument, the stress radiographic device, has a high level of sensitivity and specificity. Although it has limitations in detecting problems with tendon and ligament function, it can be used to

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### Table 2. Distance of displacement measure of ACL tear group and normal knee group

<table>
<thead>
<tr>
<th></th>
<th>Normal (n = 24)</th>
<th>Rupture (n = 24)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Median (min-max)</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Pre-stress</td>
<td>1.43±2.04</td>
<td>0.00 (0-7.00)</td>
<td>5.18±5.03</td>
</tr>
<tr>
<td>Post-stress</td>
<td>3.02±2.70</td>
<td>2.68 (0-8.80)</td>
<td>11.63±4.70</td>
</tr>
<tr>
<td>Difference</td>
<td>1.39±1.31</td>
<td>1.26 (0-3.74)</td>
<td>6.42±3.31</td>
</tr>
</tbody>
</table>

ACL = anterior cruciate ligament

*p*-value from Wilcoxon signed ranks test, * Significant at *p*<0.05
compare pre- and post-operation results where other devices have limitations.

**What is already known on this topic?**

Several studies have been published of research into instruments for the measurement of the translation distance of ligaments using stress radiographic devices. The present study, however, was of a new instrument, so the data previously collected should only be used as a guideline for research, and cannot be used as a unique reference tool for the new instrument.

**What this study adds?**

This study examined the accuracy of a new stress radiographic device. The data obtained from this study is new data that can be used for consideration in development of the device and its use with patients in the future.

**Potential conflicts of interest**

None.

**References**


ความแม่นยำของเครื่องช่วยเคลื่อนทางรังสีใหม่ในผู้ป่วยฉีดเข้าข้าง

พิพิธ ศรีสุวรรณภรณ์, สิทธิชัย วชิรธาราภ, รุ่งโรจน์ ปัญญาสุทธิวงศ์, ธนาธร อัตนพงศ์, ศุภชัย ชีเจริญ, วีระ ปรีชาภูมิหลัง

ภูมิหลัง: การตรวจการเคลื่อนของข้อเข้าในผู้ป่วยที่มีเอ็นไขว้หน้าขาดโดยวิธีการตรวจร่างกายมีข้อดีดังหลักหลาอย่างยิ่งในสูติความแม่นยำเครื่องช่วยวัดการเคลื่อนของข้อเข้าวิธีใหม่เพื่อเพิ่มความหนาแน่นข้อมูลในการวินิจฉัย เนื่องจากความแม่นยำของเครื่องช่วยเคลื่อนทางรังสีที่สร้างขึ้นใหม่ในผู้ป่วยฉีดเข้าข้างมีการพัฒนาเพื่อทบทวน

วัตถุประสงค์: เพื่อศึกษาความแม่นยำของเครื่องช่วยเคลื่อนทางรังสีที่สร้างขึ้นใหม่ในผู้ป่วยฉีดเข้าข้างโดยเทียบกับข้อเข้าข้างในผู้ป่วยรายเดียวกัน

วิธีการ: ผู้ป่วยทั้งหมดจำนวน 24 ราย โดยในผู้ป่วยในแต่ละรายจะมีข้อเข้าหนึ่งที่ถูกวินิจฉัยว่ามีเอ็นไขว้หน้าขาดจากการเอกซเรย์คลื่นแม่เหล็กไฟฟ้าและข้อเข้าอีกข้อจะถูกวินิจฉัยว่าเป็นข้อเข้าปกติจากการซักประวัติและตรวจร่างกาย เอกซเรย์คลื่นแม่เหล็กไฟฟ้าจะใช้เครื่องช่วยเคลื่อนทางรังสีซึ่งจะทำให้ข้อเข้าเคลื่อนไปด้านหน้าโดยใช้แรงต้าน 120 หน่วยในช่วงที่ข้ออยู่ในท่า 20 องศา และวัดระยะการเคลื่อนของข้อเข้าจากภาพรังสี

ผลการศึกษา: เมื่อเปรียบเทียบข้อมูลที่ได้จากวินิจฉัยจากเครื่องช่วยเคลื่อนทางรังสีกับข้อเข้าช่าง推出的ผลที่ได้จากเอกซเรย์คลื่นแม่เหล็กไฟฟ้าในผู้ป่วยจำนวน 24 ราย พบว่าค่าเฉลี่ยของการเคลื่อนของข้อเข้าก่อนและหลังใช้เครื่อง ในกลุ่มที่ข้อเข้าปกติมีค่าเฉลี่ยที่น้อยกว่าอย่างมีนัยสัมพันธ์ทางสถิติ และเมื่อใช้ระยะการเคลื่อนที่ 4 มิลลิเมตร เป็นจุดตัดของการเคลื่อนที่ระหว่างก่อนและหลังใช้แรงต้านในการวินิจฉัยการขาดเด刍ของเอ็นไขว้หน้า พบว่า Sensitivity ที่ 79% และ Specificity ที่ 100%

สรุป: เครื่องช่วยเคลื่อนทางรังสีที่สร้างขึ้นใหม่มีความแม่นยำช่วยในการวินิจฉัยในผู้ป่วยที่มีเอ็นไขว้หน้าขาด

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