

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

Pinij Srisuwanporn MD*, Sittichai Wachiratarapadorn MD**, Roongroj Panyasakulwong MD**,
Banchong Thuntong MSc***, Sukorm Cheechareem MD*, Weera Precha MD*

* Department of Orthopaedics, Rajavithi Hospital, College of Medicine, Rangsit University, Bangkok, Thailand

** Fellowship in Sports Medicine, Department of Orthopaedics, Rajavithi Hospital,
College of Medicine, Rangsit University, Bangkok, Thailand

*** Biomedical Engineering, Rajavithi Hospital, Bangkok, Thailand

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

J Med Assoc Thai 2016; 99 (4): 394-9

Full text. e-Journal: <http://www.jmatonline.com>

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

Correspondence to:

Srisuwanporn P, Department of Orthopaedics, Rajavithi Hospital,
2 Phayathai Road, Ratchathewi, Bangkok 10400, Thailand.

Phone: +66-2-3548102

E-mail: pinij_sri@yahoo.com

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.

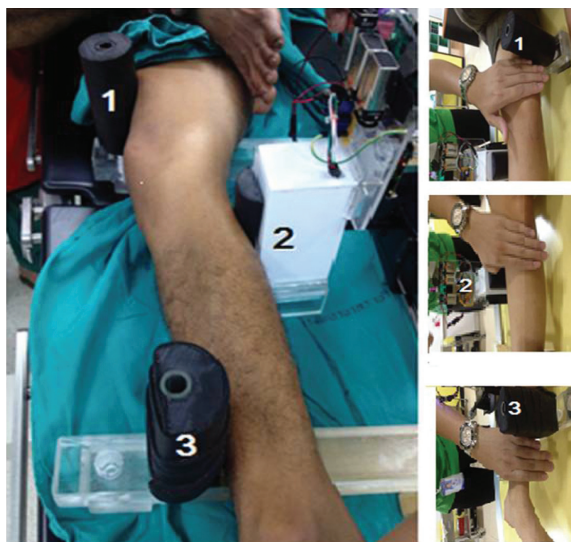


Fig. 1 The stress radiographic device and measure method. Position of post: 1) Proximal post put on one palm above of superior pole of patella bone at anterior side of thigh. 2) The pressure regulator post at behind proximal leg, one palm lower from inferior pole of patella bone. 3) Distal post put on one palm above ankle at anterior side of distal leg.

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

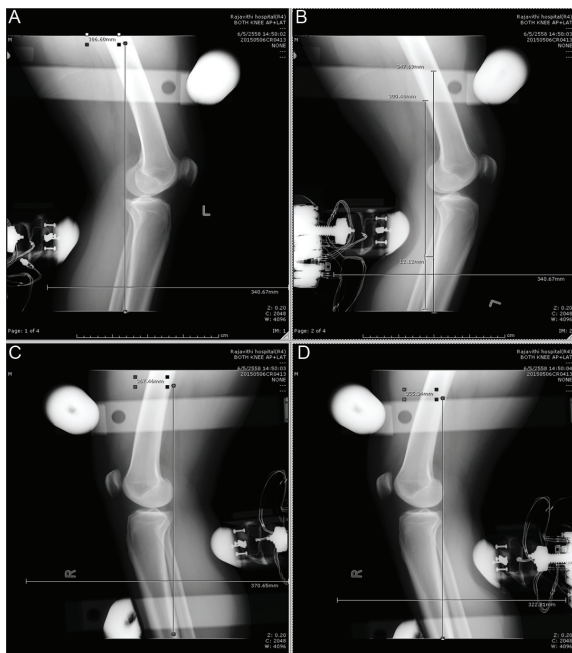


Fig. 2 Measurement anterior translation distance by anterior drawer of medial compartment (ADMC). A, B) Distance between pre and post stress anterior tibial translation in ACL tear 0, 12.12 mm. C, D) distance between Pre-stress anterior tibial translation in normal knee 0, 0 mm.

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 5.18 ± 5.03 mm, median 3.99 mm and min and max of 0 and 17 mm. The difference was statistically significant ($p < 0.001$).

In the normal-knee group, the post-stress displacement measurement had a mean value 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 ($p < 0.001$).

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 $11.63 \pm 4.70/3.02 \pm 2.70$ mm and a difference of $6.42 \pm 3.31/4.39 \pm 1.31$ 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

Table 1. Demographic data

Characteristics	Number	Percentage (%)
Age (years)		
Mean \pm SD	26.79 \pm 7.87	
Min-max	18-46	
Gender		
Female	3	12.5
Male	21	87.5
Mechanism of injury		
Non-contact sport	9	37.6
Contacts sport	10	41.6
Vehicle accident	5	20.8
Lachman's test		
Grade 0	1	4.2
Grade 1	6	25.0
Grade 2	11	45.8
Grade 3	6	25.0

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

	Normal (n = 24)		Rupture (n = 24)		p-value
	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Pre-stress	1.43±2.04	0.00 (0-7.00)	5.18±5.03	3.99 (0-17.00)	<0.001*
Post-stress	3.02±2.70	2.68 (0-8.80)	11.63±4.70	10.85 (4.30-22.04)	<0.001*
Difference	1.39±1.31	1.26 (0-3.74)	6.42±3.31	6.71 (1.04-14.00)	<0.001*

ACL = anterior cruciate ligament

p-value from Wilcoxon signed ranks test, * Significant at $p < 0.05$

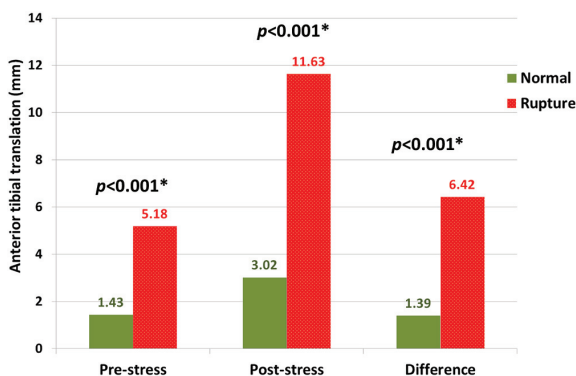


Fig. 3 Comparison displacement distance between ACL tear group and normal knee group.

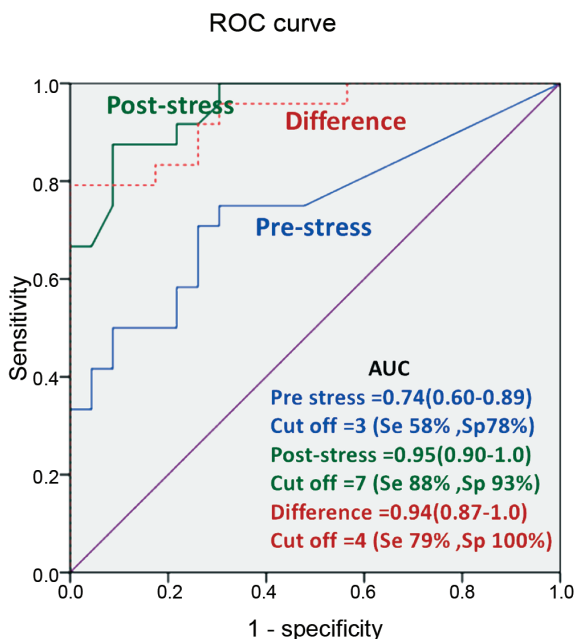


Fig. 4 ROC cure for calculate cut off point.

of the ACL-tear knees compared with normal knee using the ADMC method of $10.8 \pm 3.1 / 3.3 \pm 2.0$ 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 $5.8 \pm 4.9 / 1.07 \pm 3.5$ 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 $5.9 \pm 5.25 / 2.17 \pm 1.28$ mm.

Statistical calculation of cut-off points for optimal sensitivity and specificity in screening for ACL tear found that post-stress ADMC measurement 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

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

1. Benvenuti JF, Vallotton JA, Meystre JL, Leyvraz PF. Objective assessment of the anterior tibial translation in Lachman test position. Comparison between three types of measurement. *Knee Surg Sports Traumatol Arthrosc* 1998; 6: 215-9.
2. Iversen BF, Sturup J, Jacobsen K, Andersen J. Implications of muscular defense in testing for the anterior drawer sign in the knee. A stress radiographic investigation. *Am J Sports Med* 1989; 17: 409-13.
3. van Eck CF, van den Bekerom MP, Fu FH, Poolman RW, Kerkhoffs GM. Methods to diagnose acute anterior cruciate ligament rupture: a meta-analysis of physical examinations with and without anaesthesia. *Knee Surg Sports Traumatol Arthrosc* 2013; 21: 1895-903.
4. Bari AA, Kashikar SV, Lakhkar BN, Ahsan MS. Evaluation of MRI versus arthroscopy in anterior cruciate ligament and meniscal injuries. *J Clin Diagn Res* 2014; 8: RC14-8.
5. Highgenboten CL, Jackson AW, Jansson KA, Meske NB. KT-1000 arthrometer: conscious and unconscious test results using 15, 20, and 30 pounds of force. *Am J Sports Med* 1992; 20: 450-4.
6. Laoruengthana A, Pattayakorn S, Chotanaputhi T, Kosiyatrakul A. Clinical comparison between six-strand hamstring tendon and patellar tendon autograft in arthroscopic anterior cruciate ligament reconstruction: a prospective, randomized clinical trial. *J Med Assoc Thai* 2009; 92: 491-7.
7. Margheritini F, Mancini L, Mauro CS, Mariani PP. Stress radiography for quantifying posterior cruciate ligament deficiency. *Arthroscopy* 2003; 19: 706-11.
8. Lee YS, Han SH, Jo J, Kwak KS, Nha KW, Kim JH. Comparison of 5 different methods for measuring stress radiographs to improve reproducibility during the evaluation of knee instability. *Am J Sports Med* 2011; 39: 1275-81.
9. Lerat JL, Moyon BL, Cladiere F, Besse JL, Abidi H. Knee instability after injury to the anterior cruciate ligament. Quantification of the Lachman test. *J Bone Joint Surg Br* 2000; 82: 42-7.
10. Garcés GL, Perdomo E, Guerra A, Cabrera-Bonilla R. Stress radiography in the diagnosis of anterior cruciate ligament deficiency. *Int Orthop* 1995; 19: 86-8.
11. Beldame J, Bertiaux S, Roussignol X, Lefebvre B, Adam JM, Mouilhade F, et al. Laxity measurements using stress radiography to assess anterior cruciate ligament tears. *Orthop Traumatol Surg Res* 2011; 97: 34-43.
12. Panisset JC, Ntagiopoulos PG, Saggin PR, Dejour D. A comparison of Telos stress radiography versus Rolimeter in the diagnosis of different patterns of anterior cruciate ligament tears. *Orthop Traumatol Surg Res* 2012; 98: 751-8.

ความแม่นยำของเครื่องช่วยวัดข้อเคลื่อนทางรังสีใหม่ในผู้ป่วยเอ็นไขว้หน้าเข่าฉีกขาด

พินิจ ศรีสุวรรณภรณ์, ลีทธิชัย วชิรธราภาคร, รุ่งโรจน์ ปัญญาสกุลวงศ์, บรรจง ถันทอง, สุกรม ชีเจริญ, วีระ ปรีชา

ภูมิหลัง: การตรวจการเคลื่อนของข้อเข่าในผู้ป่วยที่มีเอ็นไขว้หน้าเข่าขาดโดยวิธีการตรวจร่างกายมีข้อผิดพลาดหลายอย่างจนนำไปสู่ความไม่น่าเชื่อถือ เครื่องช่วยวัดการเคลื่อนของข้อทางรังสีได้ถูกผลิตขึ้นมาใหม่เพื่อเพิ่มความน่าเชื่อถือในการวัด

วัตถุประสงค์: เพื่อศึกษาความแม่นยำของเครื่องช่วยวัดข้อเคลื่อนทางรังสีที่สร้างขึ้นใหม่ในผู้ป่วยเอ็นไขว้หน้าเข่าฉีกขาดเทียบกับข้อเข่าข้างปกติในผู้ป่วยรายเดียวกัน

วัสดุและวิธีการ: ผู้ป่วยทั้งหมดจำนวน 24 ราย โดยในผู้ป่วยในแต่ละรายจะมีเข่าข้างหนึ่งที่ถูกวินิจฉัยว่าเอ็นไขว้หน้าเข่าขาดหมดจากการเอกซเรย์คลื่นแม่เหล็กไฟฟ้าและเข่าอีกข้างจะถูกวินิจฉัยว่าเป็นเข่าปกติจากการซักประวัติและตรวจร่างกาย เข่าทั้งหมดนี้จะถูกนำมาวัดการเคลื่อนของข้อโดยใช้เครื่องช่วยวัดข้อเคลื่อนทางรังสี ซึ่งจะทำให้ข้อเข่าเคลื่อนไปด้านหลังโดยใช้แรงดันที่ 120 นิวตัน ในช่วงที่เข่าอยู่ในท่าองศา 20 องศา และวัดระยะการเคลื่อนข้อเข่าจากภาพฉายรังสี

ผลการศึกษา: เมื่อเปรียบเทียบเข่าข้างที่มีเอ็นไขว้หน้าเข่าขาดหมดจากการวินิจฉัยด้วยเอกซเรย์คลื่นแม่เหล็กไฟฟ้ากับเข่าข้างที่ปกติในผู้ป่วยจำนวน 24 ราย พบว่า ค่าเฉลี่ยของการเคลื่อนของข้อเข่าก่อนและหลังใช้เครื่อง ในกลุ่มที่ข้อเข่าปกติมีค่าเฉลี่ยที่น้อยกว่าอย่างมีนัยสำคัญทางสถิติ และเมื่อใช้ระยะการเคลื่อนที่ 4 มิลลิเมตร เป็นจุดตัดของระยะการเคลื่อนระหว่างก่อนและหลังใช้แรงดันในการวินิจฉัยการขาดหมดของเอ็นไขว้หน้า พบว่ามี *sensitivity* ที่ 79% และ *specificity* ที่ 100%

สรุป: เครื่องช่วยวัดข้อเคลื่อนทางรังสีที่สร้างขึ้นใหม่มีความน่าเชื่อถือในการวินิจฉัยในผู้ป่วยที่มีเอ็นไขว้หน้าเข่าขาดหมด
