Original Article

Correlation between a Stress Radiographic Device and MRI in Posterior Cruciate Ligament Tears

Cheecharern S, MD[1], Panyasakulwong R, MD[2], Laksawut S, MD[1], Lorpongpaiboon C, MD[2], Thuntong B, MSc[3], Srisuwanporn P, MD[1], Precha W, MD[1]

[1] Department of Orthopedics, Rajavithi Hospital, College of Medicine, Rangsit University, Bangkok, Thailand

[2] Fellowship in Sports Medicine, Department of Orthopedics, Rajavithi Hospital, College of Medicine, Rangsit University, Bangkok, Thailand

[3] Biomedical Engineering, Rajavithi Hospital, Bangkok, Thailand

Background: The posterior cruciate ligament (PCL) is the primary restraint to posterior tibia translation, which is difficult to determine by physical examination because manual assessment is imprecise, subjective, and not reproducible. The stress radiographic device (SRD) was developed to objectively measure these displacements.

Objective: To assess the accuracy of SRD and determine correlations between the results of SRD and magnetic resonance imaging (MRI) in PCL tear and healthy PCL.

Materials and Methods: Forty-nine knees with MRI-confirmed diagnosis of PCL-tear or healthy PCL were examined. The SRD was applied with a 90-newton posterior force in the 90 degrees knee flexion position. The present study determined the distance of the most posterior part of the medial femoral condyle and the tibia plateau that was projected perpendicular to the medial tibia articular line from lateral radiography (posterior femoral-tibia distance, PFTD).

Results: The present study examined 49 knees, 25 healthy PCLs and 24 complete-tear PCLs diagnosed by MRI. The mean PFTD measured by the stress radiograph was 15.78±4.65 mm (range 6.68 to 25.02 mm) in PCL tears and 2.42±2.32 mm (0 to 7.07 mm) in healthy PCLs, and these figures were significantly different. There was a strong correlation between the results obtained from the SRD and those found using MRI in diagnosing PCL tear. Using the SRD with a 9 mm cut-off point of PFTD for diagnosis of complete rupture of PCL, the accuracy was 97.96%, sensitivity 95.83%, specificity 100%, PPV 100%, and NPV 96.15%.

Conclusion: The SRD is a useful tool for diagnosis of PCL tear with high levels of accuracy (97.96%), sensitivity (95.83%), and specificity (100.00%). The SRD is highly reliable and reproducible, and the results obtained using SRD and MRI have a strong correlation in diagnosis of PCL tear. The SRD is cheap and easy to use with simple radiography. Therefore, it is an appropriate tool for use in screening for diagnosis of PCL-tear knees.

Keywords: Posterior cruciate ligament tears, Posterior tibia translation, Stress radiographic device

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The posterior cruciate ligament (PCL) is the primary restraint to posterior tibial translation. An injured PCL knee has greater posterior tibia translation than that of a healthy PCL knee, as well as less stability and more functional disability, resulting in an inability to take part in physical activities at a normal level.

PCL deficiency knee examinations need to be performed by experienced doctors. They usually involve posterior translated position (posterior sagging) and may be mistakenly diagnosed as anterior cruciate ligament (ACL) insufficiency[1]. They need to be carried out thoroughly to confirm diagnosis[2].

Magnetic resonance imaging (MRI) is the method considered to be the most reliable in diagnosing PCL tear, which is shown by the shape of the PCL; however, MRI has limited use in post-operative PCL reconstruction because the material used in repairing the ligament can interfere with the imaging process and yield inaccurate results[3-5].

To reduce the errors that commonly occur in manual assessment of posterior tibial translation, the

Correspondence to:

Cheecharern S.

Department of Orthopedics, Rajavithi Hospital, 2, Phaya Thai Road, Ratchathewi, Bangkok 10400, Thailand.

Phone: +66-2-3548102

Email: sukrom@gmail.com

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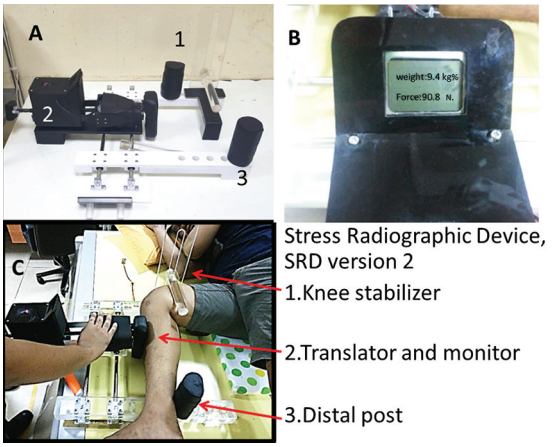

Figure 1. The Stress Radiographic Device (SRD), version 2. (A) The SRD with body, knee stabilizer (proximal post), distal post, translator and (B) monitor. (C) The SRD and the translator are applied with a 90-newton force posterior translation on the anterior surface of the tibia and 10 cm below the joint line.

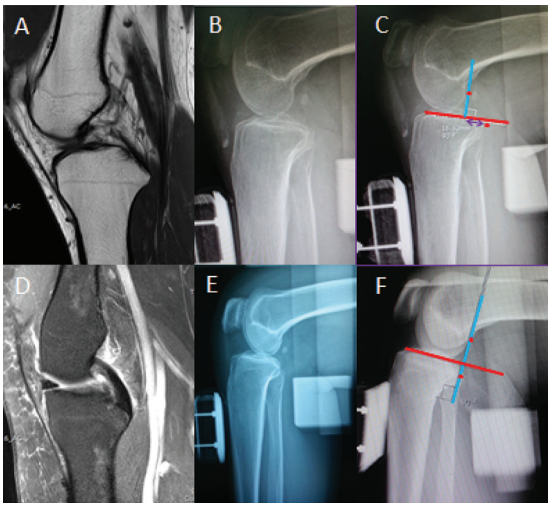

Figure 2. The MRI images show complete rupture of PCL (A) and healthy PCL (D). The posterior stress radiography in the 90 degrees knee flexion position with SRD shows posterior tibia translation of 16.50 mm distance (B, C) while no posterior tibia translation is seen in healthy PCL (E, F). The measurement of the distance of the most posterior contour of the medial femoral condyle and medial tibia plateau projected perpendicular to the medial tibia articular line (medial-medial method, MM method) in the 90 degrees of knee flexion position.

arthrometer was developed[6]. This device can control the force (in newtons) of the examination and measure tibial translation in millimeters, resulting in more accurate measurement[1,7,8]. The distance of translation can indicate the efficacy of PCL function and help in deciding whether there is a need for surgery.

The stress radiographic device (SRD) is reliable, results in few mistakes, and is widely used abroad. In August 2014, Rajavithi Hospital and the Faculty of Applied Science of King Mongkut University of Technology, North Bangkok used an SRD for the first time in Thailand, as published in J Med Assoc Thai. This device was used with patients with ACL tear and found to have high sensitivity, specificity, and accuracy; however, prior to the present study, it had not been used with PCL-tear patients[9]. The distance of posterior translation measurement varies according to the degree of knee flexion, and in the present study, PCL-tear patients were tested using a 90-degree knee flexion position to determine sensitivity, specificity, and accuracy of diagnosis and the correlation between the SRD and MRI in PCL tear[1].

Materials and Methods

The protocol of the present research was reviewed and approved by the Ethics Committee of Rajavithi Hospital (No.211/2558). The patients, diagnosed by MRI as 25 PCL-tear knees and 25 healthy PCL knees, were examined at Rajavithi Hospital between December 2015 and June 2016. Informed consent forms were obtained. Examination was performed in a lateral decubitus position with the knee flexed at 90 degrees. A 90-Newton posterior direction force was applied at the proximal leg 10 cm below the joint line (Figure 1). This force is the recommended value used for testing subjects and causes displacement of the knee without severe pain. Measurement of posterior translation distance was taken using the medial-medial method (MM method)[10]. From the reference line (articular surface of medial tibial plateau), perpendicular lines were drawn tangentially to the most posterior contour of the medial femoral condyle and the most posterior contour of the medial tibial condyle. The distance between these two points was then measured (Figure 2).

Selection criteria

Patients included were those diagnosed by MRI as having one knee with complete PCL tear and the other with healthy PCL, and had no previous PCL surgery. Some healthy PCL knees had medial patellofemoral ligament (MPFL) tear, patella-femoral arthritis, meniscal injury or other defects but were diagnosed by MRI as normal PCL. Patients had previous PCL surgery, severe knee pain and would be difficult to

Table 1. Demographic data

Characteristics	Diagnosis by MRI, n (%)		p-value
	PCL tear	Healthy PCL	
Samples (knees)	24 (100)	25 (100)	
Sex (male:female)	17 (71.0):7 (29.0)	12 (48.0):13 (52.0)	0.104
Site of knee (left:right)	12 (50.0):12 (50.0)	11 (44.0):14 (56.0)	0.674
Age (years), Mean±SD (min-max)	32.63±12.54 (17 to 56)	32.96±9.41 (16 to 51)	0.09
Causes of injury			
None	0 (0.0)	13 (52.0)	
Vehicle accident	16 (66.6)	2 (8.0)	
Sport injury	6 (25.0)	9 (36.0)	
Occupational injury	1 (4.2)	1 (4.0)	
Home injury	1 (4.2)	0 (0.0)	

MRI=magnetic resonance image; PCL=posterior cruciate ligament; SD=standard deviation

examine, knee swelling or inflammation, an injury less than two weeks ago, or refused to participate in the present study were excluded.

Statistical analysis

Quantitative variables were presented as mean ± standard deviation (SD) while comparisons between them were using Student's t-test. Qualitative variables were reported as number (percent), and comparisons between independent groups were using Chi-squared tests. A p-value smaller than 0.05 was considered statistically significant. A ROC curve was generated by plotting the sensitivity against 1–specificity, and the area under the curve with 95% confidence intervals (CI) was calculated. The optimal cut-off points for the SRD were selected based on the ROC curve analysis. Sensitivity, specificity, positive predictive values, and negative predictive values were calculated using a 2×2 table of the collected data[11].

Results

The present study examined 49 knees, of which 25 had healthy PCL and the other 24 had PCL tear as diagnosed by MRI. There was no significant difference between mean age, gender, or site of knee (Table 1). The causes of PCL tear were vehicle accident in 66%, sports injury in 25%, injury from work in 4.2%, and fall at home in 4.2%. The reason for MRI investigation in the healthy PCL knees were non-trauma (patellar plica disease, patella-femoral arthritis, and osteochondritis dissecan) in 52%, sports injury in 36%, vehicle accident in 8%, and meniscal injury from work in 4%.

Physical examination in the PCL-tear knee group, showed five knees (21%) with grade 2 posterior drawer test (PDT) and 19 knees (79%) with grade 3. In the healthy PCL knee group, 24 knees (96%) had grade 0 and one knee (4%) had grade 1. The PCL-tear knee group consisted of 22 knees (91.7%) that had a positive Dial test and two (8.3%) that had a negative Dial test. All knees in the healthy PCL group had negative Dial tests (Table 2).

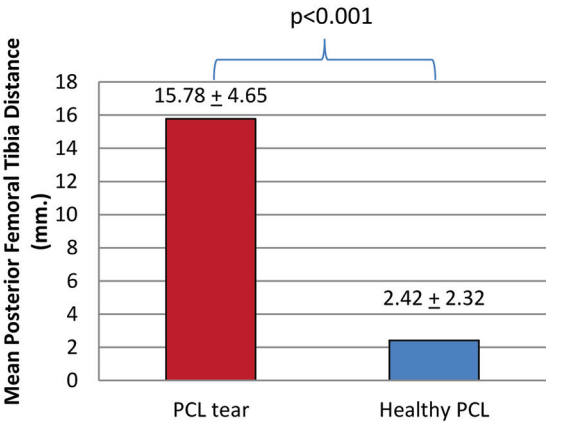

Figure 3. The comparison of mean posterior femoral-tibia distance by stress radiography with SRD in PCL tear and healthy PCL diagnosed by MRI.

The posterior femoral tibia distance (PFTD) measured by stress radiography with SRD showed mean PFTD of 15.78±4.65 mm (range 6.68 to 25.02 mm) in PCL-tear knees, and mean PFTD of 2.42±2.32 mm (range 0 to 7.07 mm) in healthy PCL knees. The mean PFTD of PCL-tear knees was significantly greater than that of healthy PCL knees (Figure 3).

The Optimal cut-off point was 9 mm. The SRD revealed a sensitivity of 95.83%, specificity of 100%, accuracy of 97.96%, positive predictive value of

Table 2. The results of physical examination and stress radiography

Physical examination	Diagnosis by MRI, n (%)		p-value
	PCL tear	Healthy PCL	
PFTD (mm), Mean±SD (min-max)	15.78±4.65 (6.68 to 25.02)	2.42±2.32 (0 to 7.07)	<0.001
PDT			
Grade 0	0 (0.0)	24 (96.0)	<0.001
Grade 1	0 (0.0)	1 (4.0)	
Grade 2	5 (21.0)	0 (0.0)	
Grade 3	19 (79.0)	0 (0.0)	
Dial test			<0.001
Positive	22 (91.7)	0 (0.0)	
Negative	2 (8.3)	25 (100)	
Varus stress test			
Grade 0	0 (0.0)	18 (72.0)	<0.001
Grade 1	2 (8.3)	5 (20.0)	
Grade 2	16 (66.7)	2 (8.0)	
Grade 3	6 (25.0)	0 (0.0)	
PDT-dial test (mm), n (PFTD, Mean±SD)			<0.001
0/-	0	24 (2.28±2.25)	
0/+	0	0	
1/-	0	1 (5.90±0.00)	
1/+	0	0	
2/-	1 (6.68±0.00)	0	
2/+	4 (12.16±3.38)	0	
3/-	1 (13.26±0.00)	0	
3/+	18 (17.23±4.08)	0	

MRI=magnetic resonance image; PCL=posterior cruciate ligament; PFTD=posterior femoral-tibia distance; PDT=posterior drawer test; PDT-dial test=posterior drawer test grade 0, 1, 2, 3 and negative dial test (-), positive dial test (+); SD=standard deviation

Table 3. The diagnosis of PCL tears by stress radiographic device

Screening test by SRD	Diagnosis by MRI, n		Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
	PCL tear	Healthy PCL					
PFTD			95.83	100	100	96.15	97.96
≥9 mm	23	0					
<9 mm	1	25					

SRD=stress radiographic device; MRI=magnetic resonance image; PCL=posterior cruciate ligament; PPV=positive predictive values; NPV=negative predictive values; PFTD=posterior femoral-tibia distance

100%, and negative predictive value of 96.15% in diagnosis of PCL tear (Table 3). The area under the curve was 0.998 (0.992 to 1), p<0.001 (Figure 4). There was a high correlation between distance of posterior femoral tibia measured by stress radiography with SRD and the results from MRI (Figure 4).

Discussion

The SRD is reliable, reproducible, and results in few errors. PCL tear was diagnosed when the PFTD was 9 mm or more measured by stress radiograph with the SRD. The results revealed high sensitivity (95.83%), specificity (100%), accuracy (97.96%), positive predictive values (PPV) (100%), and negative predictive values (NPV) (96.15%). The results of the PFTD measured by stress radiography with SRD and the results of PCL tear found by MRI were strongly correlated.

Posterior tibia translation distance measured by radiography with SRD was greater in knees with positive dial tests than in those with negative ones. The present study found positive dial test grade 2 in

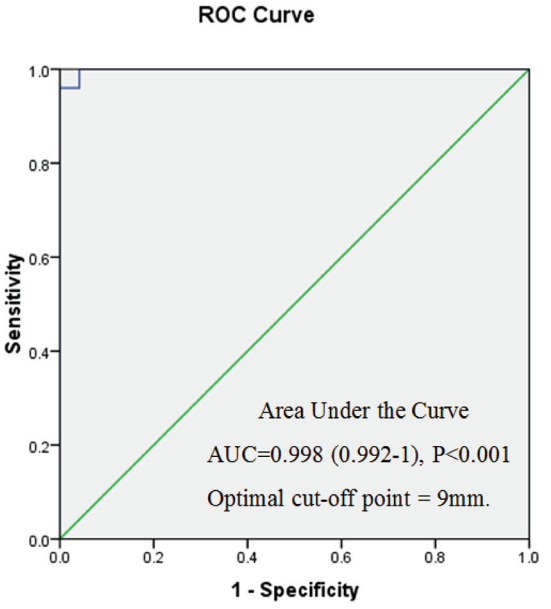

Figure 4. The ROC curve.

three knees. The authors performed the dial tests in the 90-degree knee flexion position. A positive dial test in 90 degrees knee flexion position signifies PCL tear and injury to the posterolateral complex (PLC), which is the secondary restraint to posterior tibia translation. Results from stress radiography are not reliable in establishing a definite differentiation between isolated and combined PCL lesions.

The SRD makes accurate diagnoses of PCL tear, is easy to use, and renders few mistakes. It has become widely used in screening for suspected PCL-tear knees and is used to compare pre- and post-operation states where other devices have limitations.

MRI has become accepted as a reliable method of diagnosing PCL tear, yielding a high sensitivity and specificity in diagnosing severity of injury, shape, size, location of ligament, meniscus, intra-articular structure, and other aspects of the pathology of the knee[1,11-13]. The present study used MRI as the gold standard diagnostic test for PCL tear.

Lee et al reported on five measurement methods for determining the distance between the femoral condyle and the tibia plateau[10]. The study used the MM method to determine the distance of the most posterior medial femoral condyle and the most posterior medial tibia plateau, which was projected perpendicular to the medial tibia articular line from radiograph in the 90-degree knee flexion position. The method is very useful because it is easy, reproducible, and highly reliable.

Schulz et al reported 1,041 PCL tears. They concluded that posterior tibial displacement values in excess of 8 mm are indicative of complete PCL insufficiency[12]. Stress radiography is not suitable for a definite differentiation between isolated and combined PCL lesions. Additional injury to peripheral structures, particularly the posterolateral corner structure, has to be considered in association with tibial displacement values exceeding 12 mm. Margheritini et al evaluated a stress radiography device with active hamstring contraction[8]. The mean posterior tibial displacement for both isolated and combined PCL tear was 11.54 mm with Telos device and 11.48 mm with hamstring contraction.

Many studies have reported varied displacement measurements of posterior tibial translation of isolated cutting of PCL knee in different degrees of knee flexion positions. Girgis et al[14] reported posterior tibial displacement of 9.6 mm in the 90-degree knee flexion position and 1.2 mm in the full extension position. Ogata et al[15] reported posterior tibial displacement of 9.0 mm in the 90 degree knee flexion position and 0 mm in the full extension position, indicating isolated PCL tear, while combined PCL and PLC tear was determined by posterior displacement of 19.0 mm in the 90 degree knee flexion position and 6.1 mm in the full extension position. Grood et al[6] found posterior tibial translation of 11.4 mm in 90 degree knee flexion and 1.0 mm in the full extension position, indicating isolated cutting of PCL only, while posterior tibial translation was 21.5 mm in the 90-degree knee flexion position and 6.6 mm in full extension which is indicative of cutting of both PCL and PLC[6,16-19].

Rubinstein et al reported that the accuracy of PDT is 90% sensitivity and 99% specificity. The SRD has higher both sensitivity (95.83%) and specificity (100%) when compared with clinical examination by PDT[2].

MRI is the gold standard in the diagnosis of PCL tears. MRI can be used to identify meniscal, ligamentous, tendon, and bony injuries, which distinguishes it from other images. However, MRI still has some limitation. MRI only provides a static representation of the injury and does not evaluate dynamic dysfunction. A chronic injury may occur as an intact PCL on MRI, and the knee may be clinically unstable. In addition, quality of images may lead to unreliable studies as those seen with low magnet-strength MRI[20]. Due to the limited availability of MRI queue, patients may have to wait long times for MRI examination. To date, the present study was primarily comparing the accuracy with gold standard

as MRI for a specific stress radiographic technique or the magnitude of force applied during testing has been established for assessing PCL. This SRD is cheaper and may be an alternative technique for orthopedic surgeons. Additional comparative studies should be further explored to establish evidence-based data for more accurate, reliable, easy-to-use, and cost-effective stress radiography technique. Further studies should be planned to eliminate sources of bias by sufficient blinding between SRD and reference standards.

Limitation

In the present study, healthy PCL knees were diagnosed as osteochondritis, meniscus injury, anterior knee pain due to patellar plica or patella-femoral joint arthritis, and mild ACL sprain with normal PCL. These were not truly normal knee ligaments, therefore, this may be a weak point of the present study. The PFTD is dependent on the degree of knee flexion and rotation used when taking radiographs.

Conclusion

The SRD is highly reliable and reproducible. It is inexpensive and easy to use with simple radiographs, and it yields high accuracy (97.96%), sensitivity (95.83%), and specificity (100%). The results of SRD and MRI have a strong correlation in diagnosis of PCL tear. The SRD is a useful tool in screening for diagnosis of PCL tear.

What is already known on this topic?

Several studies have been searching for translation distance using SRD. The present study was of a new instrument, so the data collected should only be used as a guideline for research, and cannot be used as a unique reference tool for the new instrument. The authors have extended their study to complete the new instrument studies.

What this study adds?

The SRD was developed to measure PCL tear that is difficult to physically examine. The SRD is an alternative tool for diagnosis of PCL tear with high levels of accuracy, sensitivity, and specificity. The results obtained using SRD and MRI has a strong correlation in diagnosis of PCL tear. The SRD is inexpensive and easy to use with simple radiography. It is a suitable tool for use in screening for diagnosis of PCL-tear knees.

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Conflicts of interest

The authors declare no conflict of interest.

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