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Diagnostic evaluation of posterior cruciate ligament injuries

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Abstract The posterior cruciate ligament is one of the most controversial issues in sports medicine. There is no consensus in the literature with respect to its incidence, natural history, and treatment indications. Injury evaluation is often underestimated, with the result of misdiagnosed injury or wrong treatment. This contribution reviews the principles of diagnostic evaluation of posterior cruciate ligament injuries.

Keywords Posterior cruciate ligament · Diagnosis · Evaluation

Introduction

It has been shown that posterior cruciate ligament (PCL) injuries account for 3% [14] to 37% [4] of all ligamentous knee injuries in an outpatient setting and a traumatic setting, respectively. Successful treatment of PCL injuries depends on an early and accurate diagnosis. This requires a complete history, meticulous physical examination, and additional instrumental studies as suggested by the patient's clinical presentation.

Clinical evaluation

A thorough history and physical examination are essential in accurately diagnosing a PCL injury. It is important to bear in mind that a patient with a PCL-deficient knee does not usually present with specific symptomatic complaints. Rarely is there an awareness of ligamentous injury at the moment when the PCL is torn. In contrast to injuries to the anterior or medial collateral ligament, the patient does not feel a "pop" or "tear" indicative of ligamentous disruption. The isolated PCL injury is often more subtle, and the patient is usually unable to recall the exact mechanism of injury. Patients with PCL injuries most often report vague symptoms, such as unsteadiness or discomfort. During the acute phase of injury a patient's complaints may include a mild to moderate effusion, pain in the back of the knee, and pain with kneeling. Instability may be present during rapid direction change, but instability is more likely to be reported in cases of combined PCL and patellar lateral subluxation injuries. In the subacute or chronic phase of injury the patient may experience vague anterior knee pain, pain with deceleration and descending stairs, and pain with running at full stride. Pain tends to be progressive over time and usually localizes to the patellofemoral and medial compartments.

Regardless of whether the injury is due to sports activity or a motor vehicle accident the mechanism remains fairly constant: posterior force on the proximal tibia. In motor vehicle accidents this is commonly known as the dashboard injury. High-energy mechanism often causes additional ligamentous damage to the PCL-injured knee, which leads to severe peripheral damages. A PCL injury from sports activity can occur when an athlete falls to the ground with the knee flexed and the foot plantarflexed, causing the proximal tibia to strike the ground first. Hyperflexion of the knee produces commonly isolated injuries in the athletes [5], and it frequently results in proximal avulsion of the PCL from the femur with adjacent periosteum that can be surgically treated with an early repair with good functional result [13]. Other mechanism of injury includes hyperextension of the knee and forceful valgus or varus stress combined with leg rotation.

Patients with acute isolated PCL injury do not complain commonly with severe instability or pain, while combined ligament injury produce more severe symptoms resulting from the high-energy trauma. Patient with chronic lesion often complain mild disability with retropatellar pain due to the increasing contact surface [22] and instability in the case of posterolateral and/or posteromedial involvement. Therefore a thorough physical examination is imperative for suggesting the best treatment.

Testing for a PCL injury in acute settings is frequently difficult. The presence of blood effusion, skin abrasion, concomitant injuries, and/or pain may adversely effect the clinical evaluation, which suggests rescheduling the clinical examination within the next 2 weeks. As soon trauma symptoms settle down, a complete clinical examination should be run to rule out a PCL involvement.

Rubinstein et al. [18] assessed the accuracy of PCL injury diagnosis. The posterior drawer was the most sensitive test (90%) and highly specific (99%). The biomechanical basis for this test is that the maximum posterior translation of the tibia on the femur occurs between 70° and 90° of knee flexion with PCL deficiency. The examiner sits on the patient's foot to prevent sliding and has the patient relax his thigh muscles. The test is carried out with the patient supine, knee flexed at 90°, and foot flat on the table.

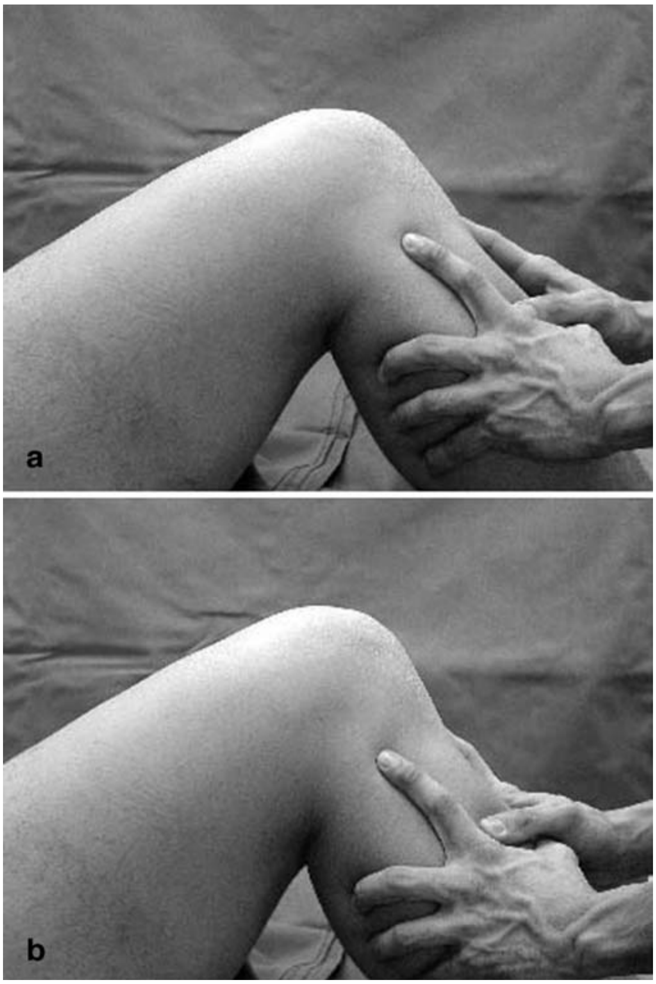

Fig. 1a, b Posterior drawer test. Note the already decreased tibial step-off in the neutral position (**a**), with the tibial plateau almost flush with the femoral condyles. Applying a posterior directed force (**b**) the sag is more visible

The step-off test can be easily performed before assessing posterior subluxation with the posterior drawer test. With the knee flexed at 90° the medial tibial plateau normally lies approximately 1 cm anterior to the medial femoral condyle. This starting position, or step-off, is usually reduced in the PCL-deficient knee, and it can easily be felt by running the thumb or index finger down the medial femoral condyle toward the tibia. The posterior translation is graded according to the amount of posterior subluxation of the tibia. Tibial translation between 1 and 5 mm is considered a grade I injury. The tibial condyle translates posteriorly with the tibia remaining slightly anterior to the femoral condyle. A grade II injury exists when posterior tibial translation is between 5 and 10 mm, and the tibia is flush with the femoral condyles. Further posterior subluxation is considered a grade III injury (Fig. 1). This is seen when the tibia translates greater than 10 mm posterior to the femoral condyles. Moreover, Parolie and Bergfeld [16] have found the posterior drawer test with the knee at 90° in neutral position and internal rotation helps differentiate between isolated and combined PCL and capsuloligamentous injury in a PCL-deficient knee clinically.

Additional tests commonly used to evaluate the PCL include the posterior sag test, the quadriceps active test, and Whipple-Ellis test. For the posterior sag test the patient is supine and the hips and knees are held in 90° of flexion. The clinician lifts the heels of the patient and makes a side-by-side comparison of the position of the tibia from a lateral view. Gravity causes the tibia in the PCL-deficient knee to rest in a posteriorly subluxated position compared to the intact knee. For the quadriceps active test the patient is supine position, the hip and knee are positioned in 90° of flexion, and the foot is held in a neutral position. In this position the tibia in a PCL-deficient knee is posteriorly subluxated. Voluntary quadriceps contraction anteriorly reduces the posteriorly subluxated tibia. Whipple and Ellis [28] described a test with the patient prone and the knee flexed at approximately 70°. PCL insufficiency is demonstrated by grasping the lower leg with one hand and posteriorly displacing the tibia by pushing on the tibial tubercle with the other. This test allows accurate clinical evaluation while avoiding quadriceps contraction, which may interfere with the examination. Moreover, if there is an associate damage of posterior capsular structures, the foot moves during this test medially or laterally.

The tibiofemoral relationship can also be checked by the posterior sag test. This is performed with the hip and knee flexed at 90° and usually produces a more obvious sag in a PCL-deficient knee for the effect of gravity force. If a PCL injury is present, active contraction of the quadriceps muscle performed when the patient's knee is flexed 60° to 90° visibly and palpably eliminates the posterior sag. The dynamic posterior shift test has been described by Shelbourne et al. [19]. Starting from the same position of the posterior sag test, the examiner extends the knee slowly. If the PCL is torn, the posteriorly subluxated tibia suddenly reduces with a visible and palpable jerk as the knee approaches full extension.

The reverse pivot shift test helps identify posterolateral rotatory instability due to associated injuries of posterolateral structures. In this test the patient is supine, and the examiner stands on the side of the injured leg. One hand is placed on the lateral aspect of the knee, with the other hand grasping the foot and rotating the tibia externally and causing posterior subluxation of the lateral tibia plateau when posterolateral instability is present. The test starts from a flexed position while maintaining foot externally rotated as the knee is gradually extended.

The external rotation thigh foot angle test can be performed with the patient either prone or supine at 30 and 90° of knee flexion. Differences in external rotation between the two feet are indicative of posterolateral compartment involvement (Fig. 2). Increased external rotation at 30° and 90° indicates a combined posterolateral and PCL injury, while that at 90° indicates only an isolated PCL insufficiency. Recently a rotational laxiometer has been developed by Dr. Beacon for measuring internal or external tibial rotation. Despite this effort its use remains experimental. Unfortunately no other methods are available for accurately quantifying knee rotation. We routinely use intraoperatively a device designed to assess the joint's widening (Fig. 3) and consequently the degree of peripheral damage, but its use is still far from being validated.

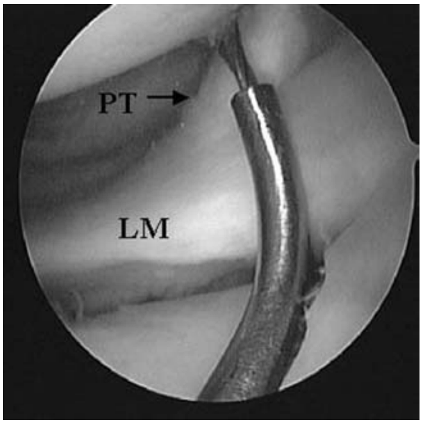

Fig. 3 Arthroscopic view of the external compartment in a left knee. The joint space is measured with a special device, which helps in identifying abnormal joint widening, as in this PCL/posterolateral capsule combined injury. *PT* Popliteus tendon, *LM* lateral meniscus

Because it is important to accurately measure the posterior translation of the tibia to select a proper treatment, instrumental devices such as the KT-1000 (MedMetric) or Rolimeter (AirCast) have been developed as adjuvant tools. Use of KT-1000 in quantifying posterior translations has been described by Daniel et al. [2], and more recently looking for the anteroposterior translation at 70° of knee flexion. Unfortunately the KT-1000 is less accurate for detecting PCL insufficiency [9] than anterior cruciate ligament deficiency; no data are available for the PCL with the Rolimeter.

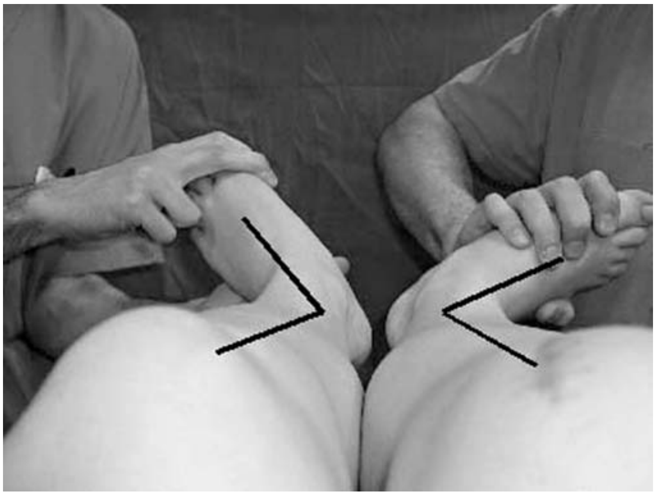

Fig. 2 External rotation thigh foot angle test performed at approximately 30° of knee flexion in this revision of PCL/posterolateral capsule deficient knee

Standard radiographic examination

After a thorough history and physical examination it is essential to perform baseline plain radiography, although this not very helpful in evaluating an acute PCL injury, it must be obtained to rule out avulsion fracture at the PCL tibial insertion and other associated fractures. Hall and Hochman [7] have described the "medial Segond fracture," which is a medial capsular avulsion found in conjunction with PCL tear [3]. In cases of chronic PCL instability it is necessary to obtain weightbearing anteroposterior (45° knee flexion), lateral, and Merchant radiographs to assess degenerative changes, especially of the medial and patellofemoral compartments.

Stress radiography

Considering the limitations with clinical examination and arthrometry testing, stress radiography is a relatively simple, noninvasive, and reproducible method for measuring compartment knee motion. This allows accurate skeletal displacement measurement, reduction in errors from soft tissue interposition, and the possibility of obtaining reproducible data, which is extremely helpful for follow-up purposes. Moreover, the lateral stress radiograph technique allows specific quantification of the internal and external compartments instability, which theoretically aids in diagnosis of combined peripheral injuries.

In 1977 Jacobsen [10] published one of the first studies on stress radiographic measurements of posttraumatic knee instability. He stated that stress radiography, even with its limitations, shows high accuracy in diagnosing knee injuries. Stäubli and Jakob [24] refined the stress radiographic technique in the early 1990s and concluded that posterior stress radiography is a valuable adjunct in determining the amount of compartmental subluxation after acute ligament injury. Since then other techniques differing in the amount of applied radiation, knee flexion angle, and measurement methods have been presented to provide a simple, reliable, and economic method for identifying PCL insufficiency. Unfortunately, few studies have examined the value of stress radiography in the PCL-deficient knee.

Stress radiography can be divided into two group techniques according to the type of force applied: the manual and the instrumented technique. Stress radiography of the knee may be performed by using a manual technique in which a posteriorly directed force is produced by the examiner using gravity or muscle contraction. A manual force technique with examiner-applied force was proposed in the early 1980s and consists of an force applied downward on the tibia of approx. 200–300 N (25–30 kg), reproducing the posterior drawer test. Although this technique is simple and easy to perform, it is no longer widely used due to the lack of standardized applied force, errors in knee flexion angle and tibial rotation, and radiation exposure. In the early 1990s Chassaing et al. [1] described a technique based on hamstring contraction. Dynamic radiography is performed with the patient in the lateral decubitus position and the knee flexed at 90°. The hamstring contraction causes marked posterior displacement of the proximal tibia (Fig. 4). Axial stress radiography has been described by Puddu et al. [17]. The radiography is performed with the patient supine, the knee flexed at approximately 70°, and the X-ray beam angled superiorly. The resulting image is evaluated based on the location of the tibia in relation to the femur as compared with the contralateral, normal side (Fig. 5). An axial press producing an 18-kg force ground directed, could better reproduce the maximum posterior translation achievable. Shino et al. [21] recently described the gravity sag view, which is a lateral radiograph taken in the same position when the posterior sag sign is observed. The patient is placed supine with both hips flexed at 45° and both knees kept upright at 90° of flexion, with an X-ray cassette placed upright between the knee. The X-ray beam is projected perpendicularly from the lateral to the X-ray cassette so that the tibia-femur step-off is easily displayed on the film. The kneeling view has been described by Osti and Bartelett [15] and is based on the principle that a patient in the kneeling position applies a direct force which subluxes the tibia posteriorly. The X-ray cassette is placed between the legs with precise projection of the X-ray beam so that posterior displacement may be calculated.

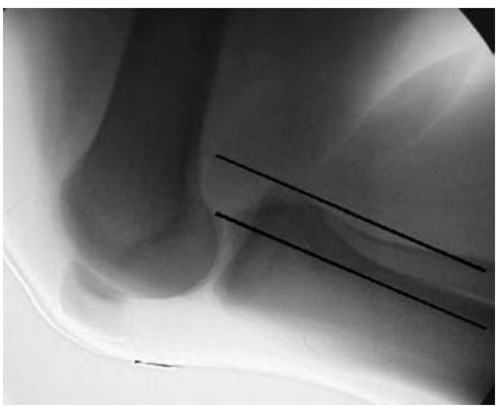

Fig. 4 Active stress radiography obtained with the hamstring contraction in this grade III right PCL-deficient knee. Posterior displacement is measured as the distance in millimeters between the tangents of the posterior tibial condyle and the posterior femoral condyle

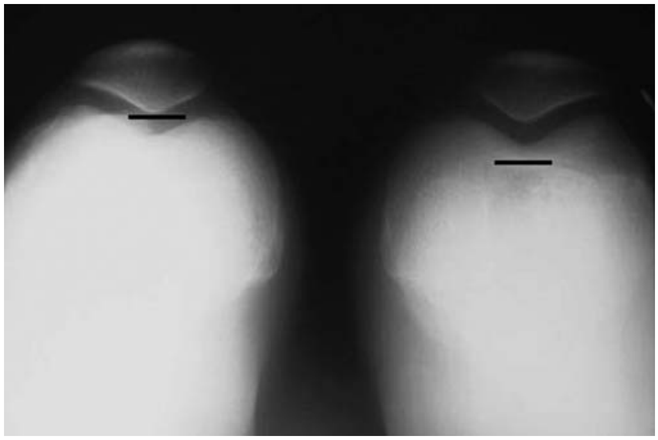

Fig. 5 Axial view according to Puddu et al. [17] showing a right PCL deficient knee

The use of instrument-applied stress force allows reproduction of the technique when applying equal tibial forces at different times through the load arm. One of the first reports of instrumented technique was presented by Staübli and Jakob [23], who modified their previous manual technique with application of the Telos stress testing device (Telos, Weterstadt, Germany). This device consists of a load arm fixed to a metallic frame that can be shifted proximally and distally. The arm is supplemented by a load system which allows immediate visualization of the applied force. The knee is maintained at approximately 20° of flexion, which according to the authors allows a reduction in the knee rotation visible with the knee flexed more than 70°. Hewett et al. [8] in 1997 compared stress radiography with the posterior drawer test. A 89-N posterior load was applied using the X-stress device (SAMO, Bologna, Italy), with the knee flexed at approximately 70°. Average posterior translation of 12.2 mm was found in complete PCL tears and 1.4 mm in intact knees. Furthermore, the results underlined the superiority of stress radiography over the posterior drawer test or KT-1000.

Stress radiography allows long-term measurement reproducibility, which is extremely helpful for follow-up purposes. Recently the use of stress radiography has been advocated for identifying the fixed posterior subluxation, which is seen in the patients with a posterior sag not reduced applying an anterior load [26]. This condition should be recognized before the PCL reconstruction to prevent early overloading and failure of the graft.

To quantify translation of the tibia landmarks on both femur and tibia are chosen and the distance between these points are then measured on radiographs taken with stress. Recently it has been suggested that either the knee rotation or flexion can affect the measurements. Therefore the use of fluoroscopy is proposed, while using of bone central axis as landmarks has been recommended to reduce those technical errors [29].

We believe stress radiography is the only method which shows almost exact amounts of tibial translation. Stress radiography performed with the knee flexed at 90° allows more precise staging of the injury [12], therefore we suggest using this knee flexion angle for better quantifying the PCL insufficiency. Recently Strobel [25] found that a side-to-side difference less than 10 mm, obtained with the Telos device, is indicative of an isolated PCL tear with no peripheral structure involvement.

Magnetic resonance imaging

The PCL, by virtue of its size and low signal intensity, is well visualized by magnetic resonance imaging (MRI), and its entire course may be detected on a single sagittal image. On coronal images the posterior portion of the PCL is seen in the intercondylar notch, adjacent to the lateral aspect of the medial femoral condyle. The meniscofemoral ligaments of Humphry and Wrisberg are often seen immediately and are situated anterior and posterior to the PCL, respectively (Fig. 6).

The MRI morphology of the PCL depends on the degree of knee flexion and integrity of other intra-articular structures. During a standard examination with the knee in full extension the PCL has a convex posterior margin and becomes taut with knee flexion. Gross et al. [6] divided the PCL shape into three groups based on MRI appearance: (a) arcuate (88.2% of cases), (b) kinked (7.8%), and (c) U-shaped (4.0%). Variations in shape are not necessarily indicative of ligamentous injury. MRI accuracy ranges from 96% to 100% in diagnosis of complete acute PCL tears and may be useful for identifying associated injures. In the acutely injured knee MRI may be necessary for a proper diagnosis because swelling and patient guarding obscures the clinical examination. Signs of a complete PCL tears include: (a) failure to identify the PCL, (b) amorphous high intensity of PCL, and (c) visualization of PCL fibers with focal disruption of all visible fibers.

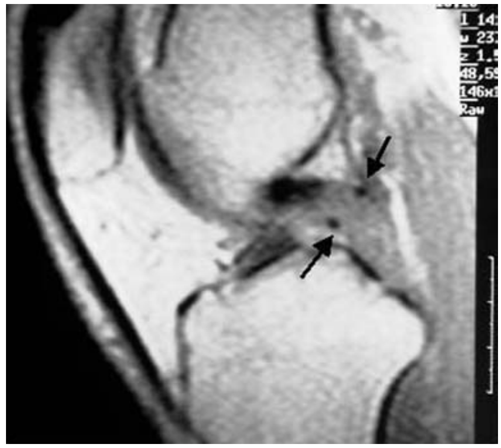

Fig. 6 Sagittal view of a grade III PCL injury, according to Gross classification [6]. Note in this T1-weighted images the two meniscofemoral ligaments

Different classifications of PCL injury on MRI have been proposed. Gross et al. suggested the following grading scale: grade 0, continuous low-intensity signal corresponding to the normal PCL; grade I, areas of increased signal within the ligament with intact borders (intrasubstance tear); grade II, areas of increased signal with one border intact (partial tear); and grade III, both borders torn (complete ligament disruption). Shelbourne et al. [20] proposed another grading system for PCL injuries: grade 1, edema on T2-weighted imaging without disruption of PCL fibers; grade 2, partial PCL disruption with fiber bridging present; grade 3, no bridging fibers present; and grade 4, no bridging fibers present and fluid or fat interposed between the two ends of the torn PCL. These classifications also have clinical significance, especially since the appropriate indications for acute PCL tears are still controversial.

The question remains as to which grade of PCL tear requires surgical treatment. Tewes et al. [27] have reported that 10 of 13 patients with complete PCL tears regain PCL continuity as seen on MRI. Therefore the potential for spontaneous healing may occur within the PCL. Shelbourne et al. [20] observed that 25 of 37 patients with differing grades of PCL injury regained or maintained continuity of PCL morphology with some alterations, especially elongation and angulation. No association was found between tear location or associated lesions and PCL healing at follow-up; however, a small correlation was found with lesion severity (grade 3 or 4). It appears that all partial PCL tears and most (86%) complete tears are able to regain continuity without surgery. Also, if MRI-evaluated PCL morphology is altered, functional outcome is not affected. Previous studies were not systematic, and clinical evaluation at the time of injury was unavailable. In a recently prospective, multicenter study [11] we found that all PCL lesions of grade II, according to Gross's classification, healed completely, while only some of the grade III improved morphologically and functionally. It seems that complete tear of the anterolateral and posteromedial bundle, combined with posterolateral injuries and complete meniscofemoral ligaments rupture are less likely to regain continuity and to reduce the posterior translation detectable by stress radiography.

Since spontaneous healing of a torn PCL is frequently observed, it is also possible to have a "morphologically intact" PCL in chronic injury. Atrophic changes are seldom seen and, in our experience, occur only in severe injuries with combined anterior cruciate ligament–PCL tears. Ligamentous redundancy may be the only finding in chronic lesions. Changes in signal intensity within the ligament may be observed in chronic lesions due to position-related changes in tension. For this reason one must be careful not to rely solely on MRI findings for diagnosis. All MRI images must be confirmed by clinical examination.

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