Clinical and radiologic evaluation of the posterior cruciate ligament-injured knee

Ahmad Badri¹ · Guillem Gonzalez-Lomas¹ · Laith Jazrawi¹

Published online: 10 July 2018

© Springer Science+Business Media, LLC, part of Springer Nature 2018

Abstract

Purpose of review Accurate isolated PCL diagnosis continues to present a challenge. This article reviews the current literature regarding clinical and radiographic evaluation of PCL injuries.

Recent findings A thorough history to understand the mechanism of injury should begin any evaluation. Several clinical tests have been shown to effectively assess PCL laxity, with the posterior drawer test possessing the highest sensitivity and specificity. Any thorough exam should compare the contralateral, uninjured leg. If a PCL or multi-ligament injury is suspected, plain radiographs should be performed to avoid missing a fracture or avulsion. An MRI represents the current gold standard for diagnosing ligament injuries in the knee and should always be obtained in these cases. Due to the significant incidence of nerve injuries (25%) and vascular injuries (18%) with knee dislocations, any suspicion of neurovascular compromise necessitates further studies.

Summary A combination of a thorough clinical history and examination, followed by appropriate imaging optimizes PCL and multi-ligament injury evaluation.

Keywords Isolated posterior cruciate ligament · Multi-ligament · Clinical radiographic evaluation

Introduction

Isolated PCL injuries present less commonly than ACL injuries and can easily be missed if a careful exam is not performed. They may occur in the setting of athletic injuries or high-energy trauma and are commonly associated with multi-ligament knee injuries. The mechanism of injury is typically a posteriorly directed force on the tibia or knee hyperflexion with the foot plantar-flexed. Sports like rugby and football create a high energy collision environment that can generate this mechanism. Dashboard injuries, when the proximal tibia strikes the dashboard in the setting of a motor vehicle accident, also commonly lead to PCL injuries. Patients presenting with this history should be evaluated with a clinical suspicion for a potential PCL tear.

Clinical evaluation of the PCL

A thorough history and physical examination of the knee must always be conducted to evaluate the potential PCL injured knee. The history of the injury may be vague and an isolated PCL injury may be overlooked if associated injuries are present. Patients with a lower energy injury, on the other hand, may be able to recall details regarding its mechanism. A direct impact to the anterior aspect of the tibia with a flexed knee, a hyperextension injury, or rotational injuries with a valgus or varus stress can all produce PCL disruption [1]. Chronicity, pain, stiffness, or instability should be elucidated from the patient.

High-energy injuries often present with multi-ligament disruption, and patients may be unable to describe the mechanism. Some questions that can key into a high-energy injury include the following:

1. Was there an accident requiring emergency room services?
2. Was the knee dislocated, requiring a reduction (Fig. 1a, b)?
3. Was the foot cold at any time or was there loss of sensation in the foot?

This article is part of the Topical Collection on *PCL Update*

✉ Laith Jazrawi
laith.jazrawi@nyumc.org

¹ Department of Orthopedics. Division of Sports Medicine, NYU Langone Health, 333 East 38th Street, New York, NY 10016, USA

Fig. 1 **a** Lateral radiograph of anterolateral knee dislocation. **b** AP radiograph of an anterolateral knee dislocation

High-energy injuries should be treated with a high degree of suspicion for concomitant neurovascular injuries, both in the acute and subacute setting. Medina et al. found in a cohort of 862 patients with knee dislocations that 18% sustained vascular injuries. Of those with vascular injuries, 80% required a repair and 12% of those ended with an amputation. The authors also found that the incidence of nerve injuries after knee dislocation was 25%, the majority of which to the peroneal nerve [2•].

Physical exam

The physical exam begins with visual inspection of the entire leg and comparison with the contralateral leg. The clinician should pay attention to any skin changes, abrasions, lacerations, bruising, swelling, and/or effusion. In the setting of a PCL injury, ecchymosis and/or hematoma is commonly seen over the anterior tibia, especially when the mechanism consists of direct trauma on the anterior tibia with a flexed knee.

A thorough neurovascular exam should always be performed and documented. Capillary refill as well as palpation of both the dorsalis pedis and posterior tibial pulses should be performed on both lower extremities and compared. If signs of delayed capillary refill, absent or unequal pulses, or a cold extremity are found, then further vascular studies and consultation with a vascular surgeon may be required. If pulses are asymmetrical or there is any suspicion for potential arterial injury (especially with a high energy mechanism), ankle-brachial index (ABI) studies should be performed immediately. An ABI < 0.9 necessitates further vascular evaluation with

a CT angiogram. Furthermore, a sensory and motor assessment of the peroneal and tibial nerves should be performed. If a patient presents with a knee that dislocated and is subsequently reduced, the neurovascular examination should occur before and after the reduction and documented as such. Notably, a “dimple” over the medial aspect of the knee indicates an irreducible knee dislocation that may require open reduction. This sign represents buttonholing of the medial femoral condyle through the anteromedial joint capsule or entrapment of the adductor magnus tendon [3].

Examination of both the injured and the uninjured knee provides useful clinical information. Active and passive range of motion is assessed. Inability to actively extend the leg may be due to rupture of the extensor mechanism or meniscal pathology if the patient is unable to obtain terminal extension. Knee flexion of at least 90° is required to carry out a conclusive examination of the PCL [4•]. In the setting of an isolated PCL tear, motion should be regained in physical therapy and stability tested once the knee can flex past 90° [4•]. Knees with bicruciate disruption in addition to a collateral ligament injury will often present with laxity in valgus or varus with the knee in extension. Varus laxity in hyperextension can indicate a disruption of the PCL and PLC. Laxity in hyperextension and valgus can indicate concomitant damage to the medial collateral ligament and capsular structures [4•].

There are several special tests for examination of the PCL described in the literature with varying sensitivities and specificities. Shelbourne et al. [5], in a blindly randomized study, attempted to quantify the accuracy of these special tests. The study consisted of sports medicine fellowship-trained orthopedic surgeons that were asked to blindly identify PCL-

deficient knees, using ACL-deficient knees and normal knees as controls. The authors found that although there was a 96% examination accuracy in diagnosing PCL injuries, disagreement about the grade of the injury existed in 19% of the cases. While we will focus only on PCL-specific special tests within this chapter, a full knee examination should be performed on all patients to assess for combined ligament injuries.

The posterior drawer test is considered the most accurate test for PCL diagnosis [6]. It is performed with the patient supine on the examination table with the hip flexed 45° and the knee flexed to about 90°. The examiner places their thumbs on the joint line and examines the relationship of the femoral condyles and the tibial plateau (Fig. 2a). If the tibia lies posterior to the condyle at baseline, there is a high likelihood that the PCL is torn. The examiner applies a posteriorly directed force on the proximal tibia with the thumbs palpating the relationship of the tibia and femur (Fig. 2b). Tibial displacement of 0–5 mm with the tibia anterior to the femoral condyles represents a grade 1 injury. Tibial displacement of 5 to 10 mm or if the tibial plateau is aligned with the femoral condyles anteriorly represents a grade 2 injury. Tibial plateau displacement posterior to the femoral condyles (greater than 10 mm) represents a grade 3 injury with likely associated posterolateral corner injury [7].

The Quadriceps active test is performed with the patient lying supine and the hip flexed to 45° and knee flexed to about 90°. If the knee is posteriorly subluxated in this position (Fig. 3a) and the patient voluntarily activates their quadriceps, the tibia will translate anteriorly (Fig. 3b). With an intact PCL, the activation of the quadriceps against resistance will cause the tibia to paradoxically translate slightly posterior. Daniel et al. [8] reported that using the quadriceps active test led to an

accuracy of 98% in 42 cases of acute and chronic PCL tears. Shelbourne's study coincided in demonstrating a 97% specificity but 54% sensitivity of this test.

The reverse pivot shift test is performed with the patient supine and the hip flexed. The knee is brought from flexion to extension. Starting with the knee flexed, the foot is externally rotated and a valgus stress is applied to the knee as it is extended. A positive test occurs when the displaced tibia is reduced at about 20° of knee flexion. Similar to the quadriceps active test, the reverse pivot shift has a high specificity (95%) but a low sensitivity (26%) [5].

The dial test is important to assess for posterolateral corner injury as well as PCL injury. This test can be performed either supine or prone, although prone may be easier. Regardless of patient position, the test is performed at both 30 and 90° of knee flexion. The feet are externally rotated and compared to each other. A test is considered positive if the examiner identifies greater than 10° of rotational asymmetry compared with the uninjured leg. If the asymmetry is seen only at 30°, then this is consistent with an isolated PLC injury. If the asymmetry occurs at 30° and 90°, the test is consistent with a concomitant PLC and PCL injury.

Imaging studies

In patients with a suspected PCL injury, bilateral standing AP, lateral, tunnel, and sunrise view radiographs are obtained. These should be evaluated for any concomitant fractures, avulsion injuries, osteoarthritic changes, and subtle or gross joint incongruence. Full leg length hip to ankle x-rays should be obtained to assess the patient's mechanical axis. In cases of

Fig. 2 **a** Posterior drawer test. Note the placement of the thumbs on the proximal tibia to readily estimate for posterior tibial translation. **b** Notice the posterior translation of the tibial plateau on the femoral condyles. This is considered a positive posterior drawer

Fig. 3 **a** The tibia is posteriorly subluxed in relation to the femur. **b** As the patient contracts the quadriceps muscle, the tibia is translated anterior and reduced

confirmed malalignment, a corrective osteotomy may be required, especially in the context of a chronic rupture.

On the AP radiograph and tunnel view, avulsion fractures of the tibia may be identified. Axial radiographs have been described which are taken with the knee in 70° of flexion and the beam directed in a similar manner as the skyline view. When this view is performed bilaterally, the tibial silhouette will appear to be posteriorly subluxed in comparison to the contralateral leg. On the lateral radiograph, the tibia may often appear posteriorly subluxed (Fig. 4). A reverse second-type fracture, reported by Hall [9], may also present in PCL ruptures with associated medial meniscal tears. It is described as a cortical avulsion off the medial rim of the medial tibial plateau [9]. In chronic PCL-deficient knees, the radiographs may show degenerative changes in the patellofemoral and medial compartment [10].

Stress radiographs can be obtained for suspected multi-ligamentous knee injuries (Fig. 5). Laprade et al. [11] demonstrated that an increase in lateral compartment distance of

approximately 2.7 mm on varus stress radiograph when compared to traditional AP radiograph is indicative of isolated fibular collateral injury. If lateral compartment distance increases to 4 mm, the clinician should be suspicious of a grade 3 PLC injury [11]. Stress radiography can also be used to assess posterior laxity in PCL injuries. Several techniques have been proposed to simulate a posteriorly directed force. Some of these techniques include using devices to quantify posterior subluxation (e.g., Telos stress device), having the patient contract their hamstrings under fluoroscopy to assess for posterior translation, having the patient kneel during a lateral radiograph, obtaining a gravity view, or an axial view (sunrise view). In a comparative controlled clinical study, it was shown that although the Telos device had the lowest rotational error of all techniques, it was comparable to the kneeling view in measuring tibial translation [12]. The authors concluded that the kneeling view was a reliable alternative to quantifying posterior displacement in a PCL injured knee [12].

Fig. 4 Lateral radiograph demonstrating posterior translation of the tibia on the femur in a patient with a grade 3 PCL injury

MRI

MRI has become the gold standard in the diagnosis of PCL tears. MRI can identify meniscal, ligamentous, tendon, cartilaginous, and bony injuries, which distinguishes it from other imaging modalities.

To accurately diagnose a PCL injury by MRI, a combination of T1- and T2-weighted images should be obtained in the axial, coronal, and sagittal planes of view. Unlike the ACL, the PCL has low signal on both T2 and proton density-weighted images and therefore lacks the striations normally visualized in the intact ACL. The PCL is readily visualized in the sagittal plane on a T2-weighted image (Fig. 6) but can also easily be followed on both the axial and coronal views. The position of the knee during the scan is typically in extension so the PCL appears curved and lax, whereas the ACL is taut and straight.

PCL injuries can be partial or complete (Fig. 7) and may present as avulsions or intra-substance tears. Bony avulsions usually occur off the tibial insertion and, commonly, the PCL will be retracted with the bony fragment attached. Additionally, peel-off lesions from the femoral attachment can be readily visualized. This is important to distinguish as the presence of an

Fig. 5 Varus stress view demonstrating significant gapping at 0° of flexion, indicating compromise to the lateral structures of the knee as well as bicruciate injury

avulsion can change the course of management. It is also imperative to look for concomitant meniscus tears, which do not occur in conjunction with PCL injuries as commonly as they present with ACL tears. [13]. In contrast to ACL bone bruising, which usually appears posteriorly on the tibia, the location of bone bruising with PCL injury is typically on the anterior tibia [13].

MRI does have some limitation, as it provides only a static representation of the injury and does not assess dynamic

Fig. 6 Intact PCL on sagittal MRI T1 sequence

dysfunction. A chronic injury may therefore appear as an intact PCL on MRI, and yet the knee may be clinically unstable. Furthermore, variable image quality may produce unreliable studies, such as those seen with low magnet-strength MRI.

Ultrasound

Ultrasound is a fast, inexpensive, and noninvasive imaging modality which may be used in either an inpatient or outpatient setting. On ultrasound, the PCL is best visualized with the patient in the prone position and the knee in extension. The transducer is placed along the posterior longitudinal plane of the PCL. A normal PCL is seen as triangular in shape, narrower proximally and wider distally. Proximally, it can be followed up to its deep attachment on the lateral aspect of the medial femoral condyle. A torn ligament will appear discontinuous, redundant, or non-visualized [13]. This modality, although limited in capacity, may be used to evaluate avulsions, as well as posterolateral and posteromedial corner injuries. However, disadvantages to ultrasonography are operator dependent results and limited reproducibility when compared to MRI [13].

Computed tomography

The value of CT in evaluation of isolated posterior cruciate ligament tears or multi-ligament injuries is somewhat limited when MRI is available. A few studies have demonstrated CT diagnosis of ligament injuries in the setting of a tibial plateau fracture. Kode et al. [14] found that in a study of 22 patients with tibial plateau fractures, 68% were accurately diagnosed

Fig. 7 T1-weighted image showing a complete midsubstance PCL rupture with posterior translation of the tibia on the femur

with ligament ruptures. Similarly, Gardner et al. [15] found that in his series of 103 patients, 77% were diagnosed with ligament ruptures on CT. When comparing CT results followed by MRI findings, Mui et al. [16] showed that CT demonstrated an 80% sensitivity and 98% specificity for torn ACL, whereas PCL tears had a sensitivity of 67% and specificity of 100%. In 2% of cases, CT diagnosis of intact cruciate ligaments was reversed by MRI, which appeared as partial or complete tears [16]. In diagnosis of PCL avulsions, CT may be helpful for preoperative planning to assess the size of the bone and amount of displacement.

Conclusion

PCL injuries occur in a variety of clinical settings. High-energy injuries must be differentiated from low-energy injuries and may require a more extensive evaluation. A thorough history and physical exam, including a careful neurovascular evaluation, is paramount. The most accurate physical exam test for the PCL is the posterior drawer test, however other special tests may aid in diagnosis. Plain radiography, ultrasound, and computed tomography all have clinical value, but MRI remains the gold standard imaging modality for identifying these tears and their associated injuries.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance

1. Kannus P, Bergfeld J, Järvinen M, Johnson RJ, Pope M, Renström P, et al. Injuries to the posterior cruciate ligament of the knee. *Sports Med.* 1991;12(2):110–31.
2. Medina O, Arom GA, Yerasosian MG, Petrigliano FA, McAllister DR. Vascular and nerve injury after knee dislocation: a systematic review. *Clin Orthop Relat Res.* 2014. **a study of 862 patients with**

knee dislocations, 18% sustained vascular injuries and 25% had nerve injuries. Given the significant incidence of neurovascular injuries in this population, examiners should have a high suspicion and low tolerance to obtain advanced imaging if the exam is questionable.;472:2621–9.

3. Braun DT, Muffly MT, Altman GT. Irreducible posterolateral knee dislocation with entrapment of the adductor magnus tendon and medial skin dimpling. *J Knee Surg.* 2009;22(4):366–9.
4. Devitt BM, Whelan DB (2015) Posterior cruciate ligament injuries. <https://doi.org/10.1007/978-3-319-12072-0>. **A patients limited motion should not hinder the clinician from doing a comprehensive physical exam. If an exam cannot be completed accurately because of pain or stiffness than advanced imaging should be obtained and patient reexamined after better motion is achieved.**
5. Rubenstein RA, Shelbourne KD, JR MC, CD VM, Rettig AC. The accuracy of the clinical examination in the setting of posterior cruciate ligament injuries. *Am J Sports Med.* 1994;22(4):550–7.
6. Miller MD, Cooper DE, Fanelli GC, Harner CD, LaPrade R. Posterior cruciate ligament: current concepts. *Instr Course Lect.* 2002;51:347–51.
7. Sekiya JK, Whiddon DR, Zehms CT, Miller MD. A clinically relevant assessment of posterior cruciate ligament and posterolateral corner injuries. Evaluation of isolated and combined deficiency. *J Bone Joint Surg Am.* 2008;90(8):1621–7. <https://doi.org/10.2106/JBJS.G.01365>.
8. Daniel DM, Stone ML, Barnett P, et al. Use of the quadriceps active test to diagnose posterior cruciate-ligament disruption and measure posterior laxity of the knee. *J Bone Joint Surg.* 1988;70A:386–91.
9. Hall FM, Hochman MG. Medial second-type fracture: cortical avulsion off the medial tibial plateau associated with tears of the posterior cruciate ligament and medial meniscus. *Skeletal Radiol.* 1997;26:553–5.
10. Boynton M, Tietjens B. Long-term follow-up of the untreated isolated posterior cruciate ligament-deficient knee. *Am J Sports Med.* 1996;24:306 1.
11. LaPrade RF, Heikes C, Bakker AJ, Jakobsen RB. The reproducibility and repeatability of varus stress radiographs in the assessment of isolated fibular collateral ligament and grade-III posterolateral knee injuries. An in vitro biomechanical study *J Bone Joint Surg Am.* 2008;90(10):2069–76.
12. Jung T, Reinhardt C, Scheffler S, Weiler A. Stress radiography to measure posterior cruciate ligament insufficiency: a comparison of five different techniques. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:1116–21.1.
13. Peterson DC, Thain LMF, Fowler PJ (2001) Imaging of the posterior cruciate ligament.
14. Kode L, Lieberman JM, Motta AO, Wilber JH, Vasen A, Yagan R. Evaluation of tibial plateau fractures: efficacy of MR imaging compared with CT. *Radiology.* 1994;163:141–7.
15. Gardner MJ, Yacoubian S, Geller D, Suk M, Mintz D, Potter H, et al. The incidence of soft tissue injury in operative tibial plateau fractures. A magnetic resonance imaging analysis of 103 patients. *J Orthop Trauma.* 2005;19:79–84.
16. Mui LW, Engelsohn E, Umans H. Comparison of CT and MRI in patients with tibial plateau fracture: can CT findings predict ligament tear or meniscal injury? *Skelet Radiol.* 2007;36(2):145–51.