Diagnosis and Treatment of Posterior Cruciate Ligament Injuries

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Posterior cruciate ligament (PCL) injuries are less common than other knee injuries and may result in a spectrum of symptoms and disability. The predictive factors that may determine which patients with isolated PCL lesions will develop knee pain and degenerative arthritis have yet to be identified. As such, the optimal treatment algorithm for these patients remains a matter of debate. This article provides a concise review of the anatomy and function of the PCL, as well as an overview of diagnostic methods and treatment options for patients with PCL injuries.

Introduction

Isolated injuries of the posterior cruciate ligament (PCL) and combined ligamentous injuries of the knee involving the PCL are far less common than other derangements of the knee. Consequently, there has been substantially less research directed at delineating the natural history and directing the management of these injuries. However, a mounting body of biomechanical and clinical evidence has underscored the importance of this ligament in knee stability and function. The PCL acts as the primary restraint to posterior tibial translation, and insufficiency has the potential to result in instability, arthrosis, pain, and deterioration of function. Presently, it is unclear which patients with a PCL-deficient knee will develop chronic symptoms and which will return to their preinjury level of activity without significant impairment. Moreover, there is ongoing debate as to the optimal method of PCL reconstruction in symptomatic individuals. The current literature lacks appropriately powered randomized trials comparing various reconstructive techniques with one another and with nonoperative management. This paucity of data has prompted clinical investigation into the long-term natural history of the PCL-deficient knee, as well as retrospective and prospective comparisons of contemporary treatment options.

This article provides the clinician with guidelines regarding the evaluation, diagnosis, and management of PCL injuries. In addition, it provides a critical review of the basic science and clinical studies that have been published on this topic over the past 2 years. Upon completion of this review, the reader should be able to identify historical data and physical examination maneuvers that are suggestive of PCL injury, describe the utility of radiographic imaging and MRI in diagnosing acute and chronic PCL injuries, and understand contemporary surgical indications and the rationale underlying available reconstruction techniques.

Anatomy and Function

The PCL originates from the lateral border of the medial femoral condyle and inserts approximately 1 cm below the joint line in a depression between the posterior aspects of the medial and lateral tibial plateaus [1]. The ligament consists of two functional components: an anterolateral and a posteromedial bundle. The anterolateral bundle is larger in cross-sectional area and tightens in knee flexion and becomes lax in extension. Conversely, the posteromedial bundle is smaller and becomes tight in knee extension and deep knee flexion. Together, the anterolateral and posteromedial bundles act as the primary restraint to posterior translation of the tibia, with the collateral ligaments and the posterolateral corner (PLC) acting as secondary restraints. Additionally, the PCL acts as a secondary restraint to varus and external rotation forces, primarily resisted by the lateral collateral ligament and PLC, respectively. Combined injuries to the PCL and PLC can result in significantly greater posterior tibial translation and external rotation than isolated injuries to either structure. It is important to appreciate the interdependence of these structures on knee stability when treating patients with combined ligament injuries, as their integrity will have implications for surgical management.

Epidemiology

The relative paucity of PCL injuries and subtlety of symptoms have made it difficult to collect accurate epidemiologic data concerning the incidence and prevalence of these injuries. The incidence of PCL injuries varies widely in the literature and has been reported to be as low as 3% in the general population to as high as 37% of all patients presenting with knee hemarthroses in a major trauma center [2,3,4•]. In a recent retrospective review, Schulz et al. [5] studied the mechanism of injury in 587 patients with confirmed PCL insufficiency. In this review, vehicular trauma (45.3%) and injury from sporting activities (39.9%) were the main causes of PCL lesions, with the remaining 12% resulting from other activities. Of the patients evaluated in this study, 47.5% had sustained combined ligament injuries. Other investigators evaluating the etiology of sports-related injuries have found that activities involving high contact forces (eg, football, soccer, or rugby) may result in a relatively higher risk of PCL injury than noncontact sports; however, the overall incidence of PCL injury in athletes remains low [6–11]. Parolie and Bergfeld [12] demonstrated a 2% incidence of asymptomatic PCL injury in collegiate football players participating in the NFL predraft examination, underscoring the fact that individuals may continue to participate in high-level competitive athletics in the face of PCL laxity. This further illustrates the difficulty in establishing the prevalence of this injury.

Despite the lack of studies regarding the epidemiology of PCL injury, the available data suggest that there are two distinct cohorts of patients who sustain PCL injuries: athletes involved in contact sports and individuals involved in high-energy trauma. The former is less common and typically occurs in isolation, whereas the latter is seen with greater frequency and usually occurs in conjunction with injury to other capsuloligamentous structures of the knee. Improved imaging techniques and an evolving understanding of PCL injury may further delineate its true extent in various patient cohorts and its impact on long-term knee function.

Evaluation and Classification

History

The initial evaluation of any patient presenting with knee pain or acute knee trauma should include a comprehensive history. Patients involved in high-energy trauma who present in the acute period with knee pain and swelling should be considered at high risk for a PCL injury in addition to other capsuloligamentous injuries. These patients will often present with a hemarthrosis, inability to bear weight, instability, and decreased range of motion. In such cases, the physician must consider the possibility of a knee dislocation and, accordingly, rule out injury to the neurovascular structures of the lower leg [1]. The most common mechanism of injury to the PCL in motor vehicle accidents is a posterior-directed blow to the proximal tibia often described as a “dashboard injury”; however, other force vectors are often involved and, consequently, multiligament injury is often the result.

The most common mechanism of PCL injury in athletes is a posterior-directed blow to the proximal tibia with the knee in flexion and the foot plantar flexed. However, hyperflexion or hyperextension in the presence or absence of a posterior-directed tibial force has also been implicated as injury mechanisms [6,13–15]. Low-energy unidirectional force typically results in isolated injury and, accordingly, patients often present with subtle, nonspecific complaints. Acutely, patients may report stiffness, swelling, moderate pain in the back of the knee, or pain with deep knee flexion including squatting or kneeling. In contrast to anterior cruciate ligament (ACL) ruptures, patients do not usually report a “pop” and may not recall notable trauma. In many cases, the injured athlete is able to continue his/her sport and medical attention is not sought acutely. Many of these patients may not appreciate any disability initially but develop symptoms over time. Patients who present in the chronic phase of isolated PCL injury may complain of anterior knee pain, difficulty with negotiating stairs, pain with sprinting or deceleration, or instability [15].

Physical examination

A thorough examination of the knee should include an assessment of the patient’s overall lower extremity alignment and gait. Subtle varus alignment, external rotation, and varus thrust may be present in a chronic PCL- or PLC-deficient knee. Palpation of the knee can reveal a mild effusion in the acutely injured knee or no effusion with more chronic injuries. When assessing the ACL, the examiner must be aware of the normal relationship of the tibia relative to the femur, in which the medial tibial plateau lies approximately 1 cm anterior to the medial femoral condyle with the knee flexed 90°. Failure to recognize the posterior position of the tibia in the PCL-deficient knee may result in a falsely positive anterior drawer test and a pseudopositive Lachman’s test. The collateral ligaments should also be assessed with varus and valgus stress testing at 0° and 30° of knee flexion, and the menisci should be assessed via palpation and McMurray’s test.

The most accurate test for assessing PCL integrity is the posterior drawer test. This test is performed with the patient supine, with the hip flexed to 45°, the knee flexed to 90°, and the foot in neutral position. Both hands are placed behind the subject’s proximal tibia and a posterior-directed force is applied to the tibia, assessing the position of the medial tibial plateau relative to the medial femoral condyle. It is important to realize that with a PCL injury, the tibial plateau will sublux posteriorly in this position. Thus, the examiner must first reduce the tibia by pulling anteriorly. This is followed by applying a posterior-directed force. The magnitude of posterior translation is assessed and this measurement is used to grade the degree of laxity. Posterior displacement of 0 to 5 mm is designated a grade I injury, 5 to 10 mm a grade II injury, and greater than 10 mm a grade III injury. Grade

Table 1. Physical examination findings in the posterior cruciate ligament–deficient knee

Mild effusion
Resting posture of the tibia posterior to femoral condyles
Positive posterior drawer test
Positive dial test at 30° and 90° (in conjunction with posterolateral corner injury)
Positive reverse pivot shift test

III injuries typically represent combined injuries, and in the presence of this degree of laxity, special attention should be paid to the other capsuloligamentous structures of the knee. Another useful test for assessing the presence of a PCL injury is the Godfrey test, or posterior sag test, in which the knees and hips of the patient are flexed to 90° and the examiner suspends both of the legs parallel to the examination table. In the PCL-deficient knee, the tibia will sag down below the level of uninjured side. This finding may be appreciated in both acute and chronic PCL insufficiency. The quadriceps active test can also corroborate the presence of a PCL injury. This is also performed with the subject supine and the knee flexed to 90°. The examiner stabilizes the foot, and the subject is asked to slide the foot down the table. Contraction of the quadriceps muscle results in an anterior shift to the tibia in the PCL-deficient knee. A shift greater than 2 mm is considered positive for PCL insufficiency.

In the presence of significant posterior laxity of the tibia, the examiner should suspect injury to the PLC. These structures can be assessed by evaluating external rotation of the tibia on the femur. Testing is performed with the patient positioned prone or supine while an external rotation force is applied to both feet with the knee positioned at 30° and then 90° of flexion. The degree of external rotation is measured by comparing the medial border of the foot with the axis of the femur, and this measurement is compared with the contralateral limb. When compared with the uninjured side, an increase of 10° or more of external rotation at 30° of knee flexion, but not at 90°, is suggestive of an isolated PLC injury. Increased external rotation at both 30° and 90° of knee flexion suggests a combined PCL and PLC injury. The reverse pivot shift test is another common maneuver for evaluating for a combined PCL injury. To perform this test, the patient is supine and the knee is held, initially, in 90° of flexion. The examiner then externally rotates and extends the knee. When positive, an anterior shift of the tibia will occur at approximately 20° to 30° of flexion as the iliotibial band pulls the subluxated tibia forward. When this test is positive, it usually signifies injury to the PCL and another capsuloligamentous structure, usually the PLC. The key components of the physical examination are outlined in Table 1.

Imaging

All patients presenting with a knee injury should undergo routine radiography. In the acute setting, anteroposterior and lateral views should be obtained to evaluate for fractures and/or dislocation. When evaluating the knee in the setting of a chronic PCL injury, the examiner should obtain weight-bearing anteroposterior images in neutral and flexion as well as lateral and Merchant views of the patella. The Merchant view is obtained with the knee flexed to 45° and x-ray cassette supported at the patient's ankle. The beam is aimed at approximately 60° superior to inferior as to be tangential to the patella.

These plain radiographs may reveal subtle changes including posterior sag of the tibia, or degenerative changes of the medial and patellofemoral compartments, which can be present in chronic insufficiency. Recently, stress radiography has been suggested as a potentially reliable method of grading PCL injury. Schulz et al. [16] retrospectively reviewed the results of stress radiographs using a Telos device (Telos Corp., Griesheim, Germany) in 1041 consecutive patients with PCL injuries. The data suggested that posterior tibial displacement in excess of 8 mm was indicative of complete insufficiency of the PCL, whereas tibial displacement exceeding 12 mm suggested additional injury of secondary restraining structures of the knee. The authors concluded that instrumented stress radiography is a useful method for objectively determining the amount of posterior tibial displacement of the knee in adults with a PCL injury. However, it should be noted that this technique is used primarily for research purposes and is not routinely used for clinical evaluation.

In numerous studies, MRI has proven to be an accurate method of diagnosing acute PCL injury (Fig. 1) [17–19]. In a large, prospective multicenter study, MRI was found to demonstrate 99% accuracy in diagnosing the presence of PCL injury, which was confirmed via arthroscopy [18]. However, the accuracy of this imaging modality in detecting chronic PCL deficiency appears to be less reliable. Two recent studies cited the capacity of the PCL to regain continuity and assume a normal appearance on MRI as early as 6 months following injury, substantially reducing the sensitivity of this test [20,21]. However, this appearance on MRI does not necessarily correlate with improvement in clinical examination. In light of this, the importance of the history and physical examination in diagnosing chronic PCL insufficiency cannot be overemphasized.

Management

Natural history and nonoperative management

Due to the relative paucity of PCL lesions in the general population and the spectrum of disability that is observed in the PCL-deficient knee, the true natural history of this injury is largely unknown. Parolie and Bergfeld [12] reported good results at an average follow-up of 6.2 years (range, 2.2–16 years) with nonoperative management

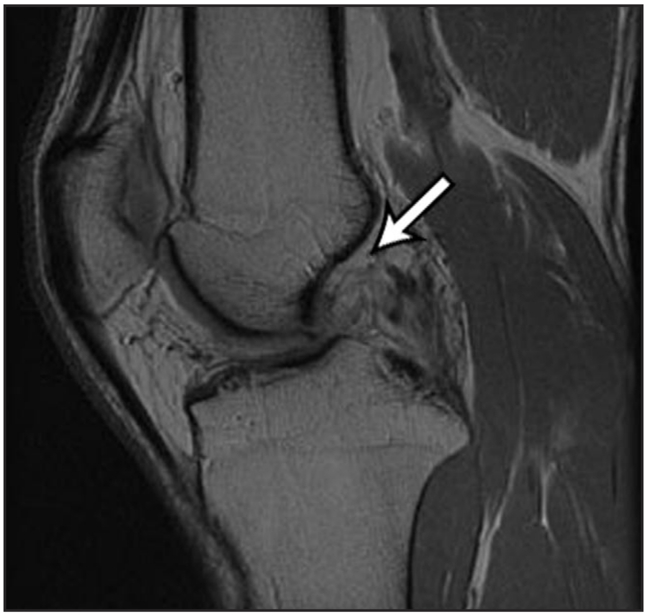

Figure 1. This T2-weighted MRI demonstrates a chronic grade III tear of the posterior cruciate ligament (PCL). The proximal stump of the PCL is indicated by the *arrow*.

of isolated PCL injuries, with most patients returning to sport. In this retrospective study, no correlation was noted between degree of laxity and subjective satisfaction or return to sport. In a long-term retrospective review of outcomes in patients with isolated PCL injuries, Shelbourne and Muthukaruppan [22••], using modified Noyes survey and International Knee Documentation Committee subjective knee surveys, evaluated subjective results in 215 nonoperatively managed patients at a mean of 7.8 years after injury (range, 1–18 years). In 146 patients with four or more serial evaluations, total scores were consistently excellent for 40% of patients and good for 10% of patients, with no correlation observed between grade of laxity and mean score. The authors concluded that subjective scores were independent of grade of laxity and did not deteriorate over time [22••]. Conversely, other authors have found that patients with PCL insufficiency are at increased risk for meniscal tears, articular cartilage injury, and patellofemoral/medial compartment arthritis [1,23,24]. Moreover, none of the data derived from these retrospective studies has identified predictive factors that help to identify patients who will develop intra-articular pathology or subjunctive symptoms related to either instability or pain. Specifically, the development of degenerative joint disease does not correlate with grade of injury [25,26].

The conflicting retrospective data regarding the natural history of isolated injury have led to significant controversy regarding the indications for surgical reconstruction of the PCL. Currently, there are no clinical data to suggest that contemporary reconstruction techniques can improve knee stability in low-grade (I/II) PCL injury or improve outcomes in this cohort of patients [1,27]. As such, isolated, low-grade PCL injuries are often treated nonoperatively with a regimen that includes protected weight-bearing in the acute stage followed by structured rehabilitation focused on improving quadriceps strength. Collectively, the current literature suggests that most of these patients will return to sport; however, an unknown proportion will eventually develop arthrosis and knee pain that may limit function.

In 2005, Peccin et al. [28] conducted a review of the PCL literature. No randomized or quasirandomized controlled studies meeting the selection criteria were identified. The authors concluded that future research should include randomized, controlled trials of acute isolated PCL injuries, or PCL injuries when combined with other ligament injuries of the knee, treated operatively and conservatively. Adequate numbers of patients and an objective methodology for patient evaluation must be used in future studies of these interventions to determine the long-term outcomes.

Surgical management

In light of the present data, the indications for surgical reconstruction of the PCL remain a matter of debate. Most surgeons advocate reconstructing the PCL when it is injured in conjunction with the ACL, PLC, or medial collateral ligament [1]. In cases of isolated acute PCL insufficiency, the decision to proceed with surgical reconstruction is influenced by the patient's degree of laxity, symptoms, and demands on the knee. Moreover, there are a variety of surgical techniques that may be employed to reconstruct the PCL. Again, there are no well-designed, randomized trials comparing the relative efficacy of these methods in regard to reducing clinical laxity or improving subjective knee function. Therefore, the selection of a technique is often predicated on surgeon and patient preference, as well as the available surgical resources, rather than evidence-based guidelines. The most common reconstruction strategies use a single- or double-bundle graft of autologous or allogenic tissue (hamstring, Achilles tendon, patellar tendon) that is passed through a tibial tunnel or secured to the tibia via a bone inlay technique.

In single-bundle tibial tunnel PCL reconstruction, the graft is passed through a tibial tunnel that exits through the PCL footprint and enters a femoral tunnel placed in the position of the anterolateral bundle of the native PCL on the medial femoral condyle [1,29]. Contemporary single-bundle PCL reconstruction was first proposed and described by Clancy et al. [23], who reported the results of 23 patients who underwent single-bundle autologous bone-patellar tendon-bone replacement. Ten patients who were treated for acute injuries reported good to excellent functional results, whereas in the setting of chronic PCL instability, the overall results were graded as good or excellent in 11 of 13 patients. However, subsequent studies have had good subjective results despite unsatisfactory objective results [30–32].

Table 2. Clinical studies comparing contemporary methods of posterior cruciate ligament reconstruction

Study	Comparison	Study type	Patients, *n*	Mean follow-up, *mo*	Outcome difference*
Houe and Jorgensen [36]	Single- vs double-bundle	Prospective, nonrandomized cohort	6 single-bundle	35 (range 25–51.5)†	None
			10 double-bundle		
Wang et al. [37]	Single- vs double-bundle	Prospective, nonrandomized cohort	19 single-bundle	41.0 (range, 26–71)	None
			16 double-bundle	28.1 (range, 24–37)	
Seon and Song [38]	Transtibial tunnel vs tibial inlay	Retrospective, case series	21 transtibial	31.8 (range, 24–58)	None
			22 tibial inlay	35.9 (range, 24–80)	
MacGillivray et al. [39]	Transtibial tunnel vs tibial inlay	Retrospective, case series	13 transtibial	75 (range, 29–181)	None
			7 tibial inlay	57 (range, 24–85)	

*Difference in outcomes, either subjective or objective.
†One average reported for both groups.

It has been suggested by biomechanical data that double-bundle reconstruction may provide a theoretical advantage because it attempts to reconstruct both the anterolateral and posteromedial bundles of the PCL, thereby restoring knee stability through a complete range of knee flexion [33,34]. When using this technique, two grafts or a split graft are passed through the tibial tunnel and fixed in separate femoral tunnels representing the anterolateral and posteromedial positions on the medial femoral condyle. Three recent retrospective comparisons have not demonstrated any clinical advantage to this method of reconstruction in regard to laxity, functional outcomes, or radiographic changes between the two techniques (Table 2) [35–39]. Moreover, a recent biomechanical investigation by Markolf et al. [40] demonstrated that a single anterolateral graft best reproduced the normal PCL force profile following reconstruction. However, knee laxities were 1 to 2 mm greater than normal between 0° and 30° of knee flexion. The addition of a second posteromedial graft reduced laxity in this flexion range but did so at the expense of higher forces in the posteromedial graft. This is potentially of concern because higher graft forces could cause elongation of this bundle, resulting in failure of this component of the reconstruction. Another biomechanical study by this group demonstrated very small changes in mean laxity following isolated cutting of the posteromedial bundle of the native PCL at 0° and 10° of flexion in the cadaveric knee, whereas laxity remained unchanged at other knee flexion angles [41]. The results of these studies have called into question the biomechanical rationale underlying double-bundle reconstruction.

The tibial inlay technique also provides a potential technical advantage during PCL reconstruction. With this technique, the graft is directly attached to the posterior tibia using a trough created at the native footprint of the PCL [1]. This graft positioning obviates the acute angular turn that is encountered with passage of a graft through a tibial tunnel. It has been suggested that this “killer turn” results in graft wear and elongation, with some cadaveric studies supporting this hypothesis [42–44]. Yet, recent clinical comparisons between tibial inlay and transtibial tunnel fixation have failed to demonstrate a subjective or objective advantage of either reconstructive technique in short- to mid-term follow-up (Table 2) [38,39].

Further clinical studies are required to determine whether either the double-bundle or tibial inlay methods of reconstruction demonstrate clinical superiority to the single-bundle transtibial technique, which is a less time-consuming and technically less demanding procedure.

Conclusions

PCL injuries, although less common than other knee injuries, can result in significant disability in both the athletic and trauma populations. The examining physician must possess a high index of suspicion for isolated or combined PCL injury when examining any patient with a high-energy injury or an athlete who complains of mild symptoms related to seemingly trivial trauma. The physical examination must be used to differentiate between ACL and PCL insufficiency as well as isolated and combined injuries. MRI may help corroborate the diagnosis, but this modality may not prove sensitive in the setting of chronic PCL injury.

For mild injuries (grade I and II), physical therapy focused on strengthening quadriceps and avoiding unopposed hamstring contraction will usually render good results in most patients; however, some individuals will have persistent symptoms or develop pain and arthrosis with time. Currently, there are no available criteria to predict which patients with mild injury will have a poor outcome following nonoperative therapy. Moreover, there is no definitive evidence that surgery improves the natural history of mild PCL insufficiency. In patients with severe symptomatic laxity (grade III) or combined injury, surgical reconstruction is necessary. Single-bundle reconstruction through a tibial tunnel has had variable results, but outcomes appear to be improving with improved surgical techniques and more defined patient selection. Although newer methods of reconstruction may possess certain theoretical biomechanical advantages over single-bundle repair, there is not enough evidence to endorse their clinical superiority. Further studies are necessary to define the natural history of the PCL-deficient knee and determine optimal surgical technique for patients requiring reconstruction.

Disclosure

The authors disclose no extramural sources of support or conflicts of interest in the preparation of this manuscript.

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