Posterior Cruciate Ligament: Current Concepts

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Introduction
Understanding of posterior cruciate ligament (PCL) injuries of the knee has increased in large part because of a better understanding of the anatomy and biomechanics of the PCL and the posterolateral corner. More careful clinical evaluation of injury to these structures has resulted in earlier diagnosis and treatment, with new surgical techniques increasing the possibility of improved results.

Anatomy
The PCL has two functional components, an anterolateral and a posteromedial bundle (Fig. 1). The anterolateral bundle, which is approximately twice the size of the posteromedial bundle, is taut in flexion, and the posteromedial portion is taut in extension.1 Two variable meniscofemoral ligaments (Humphry and Wrisberg) originate from the posterior horn of the lateral meniscus and contribute fibers to the PCL. The cross-sectional area of the PCL narrows midsubstance to approximately one third the area of its insertions.2

The posterolateral corner is perhaps best considered as consisting of superficial and deep structures. The superficial structures include the iliotibial band or tract (with the tract representing the distal third of the tendon near its insertion) and the biceps tendon. Deep structures include the lateral collateral ligament, capsular structures (midthird lateral capsular ligament, fabellofibular ligament, and posterior arcuate ligament), and the popliteus muscle complex (including the popliteofibular ligament)3 (Fig. 2).

Biomechanics
The PCL has an ultimate load of approximately 1,600 N and a stiffness of approximately 200 N/mm.4 The anterolateral portion of the ligament is stronger and stiffer than the other portions;1 therefore, reconstructing this component has been the focus of PCL reconstruction techniques. Isolated sectioning of the PCL and of the posterolateral corner (as secondary stabilizer) results in posterior translation of approximately 11 mm and less than 3 mm, respectively. Sectioning of both the PCL and the posterolateral corner, however, causes posterior translation of up to 30 mm, demonstrating the synergistic relationship between these structures.5-7 A similar effect on rotation occurs when the posterolateral corner (as primary stabilizer) and PCL (as secondary stabilizer) are sectioned individually and together.

In situ forces in the PCL increase from 36 N in full extension to 112 N at 90° of flexion.8 These forces are reduced with axial compression (as in weight bearing) and quadriceps loading, and increased with hamstring loading.9,10 In an intact knee, the popliteus muscle significantly reduces the in situ forces in the PCL.11 Sectioning of the PCL causes increased in situ forces in the popliteus and the meniscofemoral ligaments.8 PCL deficiency is associated with increased contact pressures and late arthritis of the medial femoral condyle and patella.12-15

Recent biomechanical studies of newer PCL reconstruction procedures have provided interesting information. The tibial inlay technique, in which the bone block of a graft is laid directly into a trough in the back of the tibia, results in less graft laxity with cyclic loading.16 A two-bundle technique, which includes a second femoral tunnel using a separate graft or a split graft, results in improved stability in both extension and flexion.17 Perhaps the best construct, at least from a biomechanical standpoint, would be a two-bundle inlay technique, with a split quadriceps tendon-bone graft. Clinical
results of these options will ultimately determine the best construct.

Combined PCL and posterolateral corner injuries are more common than initially believed, with up to 60% of significant PCL injuries having a combined posterolateral corner disruption. Failure to treat this associated injury results in undue tension in the PCL graft and may doom the reconstruction to failure.

Clinical Evaluation

Physical Examination

The mechanism of PCL injury is most commonly a posterior blow to the proximal tibia with the foot in plantar flexion. The foot position is important only because it changes the force vector. If the foot is dorsiflexed, the ground force contacts the patella and distal femur; with the foot plantar flexed, however, the ground force vector intersects with the proximal tibia. Other mechanisms of injury include hyperflexion and combined forces.

The posterior drawer test is the most sensitive and specific test for the diagnosis of PCL injuries. The test is done with the patient supine and the knee flexed 70º to 90º. Evaluation of the tibial starting point is key. The tibia normally has an anterior step-off of approximately 10 mm in this position. If there is posterior subluxation of the tibia (with a complete PCL injury), then the starting point may be even with or posterior to the medial femoral condyle. Displacement beyond this position with a posteriorly directed force on the tibia suggests a complete injury, and posterior displacement of the tibia more than 5 mm posterior to the femur suggests a combined injury (usually involving the PCL and the posterolateral corner). The quadriceps active test is done with the patient supine and the knee flexed. The patient is instructed to tense the quadriceps, and this action brings the posteriorly subluxated tibia anteriorly. The test can be useful in assessing the relative anterior and posterior instability in a knee with a chronic combined ACL and PCL deficiency.

The dial test for asymmetric external rotation is the most important test for posterolateral instability. The test can be done with the patient prone or supine (an assistant holds the knees together). Both feet are passively externally rotated and the thigh-foot angle is measured. Excessive external rotation (as compared with the opposite side) of more than 10º to 15º is considered pathologic. The test is done with the knee in both 30º and 90º of flexion. If the thigh-foot angle is increased at only 30º and not 90º, the patient has an isolated PCL injury. If, however, the thigh-foot angle is increased at both 30º and 90º, this indicates a combined injury to the posterolateral corner and PCL (confirmed with a posterior drawer test). Other tests for posterolateral corner injuries (especially combined injuries) include the posterolateral drawer and external rotation recurvatum tests (with the latter being most dramatic in ACL/PCL/posterolateral corner combined injuries). With all tests for posterolateral instability, it is critical to compare the results to the contralateral normal knee.

It is also important to carefully observe a patient’s gait. A varus thrust gait, during which the knee shifts into varus during foot strike with associated lateral compartment opening, is common in patients with chronic posterolateral corner deficiencies. Patients may attempt to compensate by walking with a flexed knee gait with the foot in internal rota-
tion. If these gait abnormalities are associated with an underlying varus alignment of the knee, a bony procedure (osteotomy) should precede any soft-tissue reconstruction.

**Imaging**

Plain radiographs are first carefully evaluated for avulsion fracture, medial Segond fracture,27 fibular head avulsion (arcuate sign),28 posterior sagging on the lateral view, lateral joint space widening, and, in skeletally immature patients, physeal injuries. Standing flexion weight-bearing views are mandatory, especially for chronic injuries, to evaluate for medial compartment chondrosis and to assess limb alignment. Nuclear imaging (bone scans) may be useful to detect early arthritis; however, the clinical implications are unclear. MRI is said to be 100% sensitive and specific in detecting PCL injuries.29 Its primary benefit is in the evaluation of combined injuries and in surgical planning. Posterolateral corner structures also can be seen with MRI,30 however, there is significant variability in the interpretation of images. Stress radiography can be extremely beneficial and may prove to be the best way of assessing clinical results. A lateral radiograph with a posterior force allows direct measurement of posterior tibial translation.31

**Diagnostic Arthroscopy**

Although the diagnosis should be clear before surgery is begun, direct and indirect arthroscopic signs of PCL injury have been described.32 Direct signs include torn fibers, hemorrhage, decreased tension, and laxity. Indirect signs include "sloppy ACL" (ACL pseudolaxity from posterior displacement of the tibia), degenerative changes in the patellofemoral and medial compartments, and altered contact points. The sight of a ruptured PCL often is not as dramatic as seeing the "stump" of a torn ACL, because PCL injuries commonly occur in what has been described as zone II, which is hidden by the ACL.33

Arthroscopic findings associated with posterolateral corner injuries, such as an unexpected amount of lateral opening during arthroscopic examination of the lateral compartment (drive-through sign), are also important to recognize.34 The popliteus tendon origin on the femur should be inspected to determine if there is an avulsion off the femur or if it is injured (Fig. 3).

**Treatment**

Although some low-grade, isolated PCL injuries may do well without surgery, more severe and combined injuries have a worse outcome.35,36 Shelbourne and associates37 reported good results (mean Noyes score, 84.2; mean Lysholm score, 83.4) with nonsurgical management of isolated PCL injuries, but only patients with grade 2 laxity or less were included in the study group. Isolated PCL injuries with less than 10 mm of laxity (flush with the medial femoral condyle) can be treated with extension splinting, quadriceps rehabilitation, and progressive activity. Nonsurgical treatment of chronic PCL-injured knees includes quadriceps strength training, activity modification, and careful follow-up.

Although most surgeons agree that PCL bony avulsion injuries38 and severe combined PCL injuries require surgical intervention, the best management of more severe isolated PCL injuries

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**Table 1**

**Principles of Reconstruction**

| Identification and treatment of all pathology |
| Protection of the neurovascular structures |
| Accurate tunnel placement |
| Recreation of anatomic graft insertion sites |
| Strong graft material |
| Minimal graft bending |
| Appropriate tension of the graft |
| Secure primary and (if necessary) backup |
| graft fixation |
| Structured postoperative rehabilitation |
| program |

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remains controversial. Many or even most severe "isolated" PCL injuries may in fact be combined PCL/posterolateral corner injuries requiring combined reconstruction techniques. Other associated knee injuries such as meniscal tears and acute chondral injury also may benefit from surgical intervention.

Combined ligamentous injuries are best treated within 2 weeks of the injury. Combined ACL/PCL injuries represent a functional knee dislocation and all of the precautions taken in the presence of these injuries (including thorough neurovascular examination and studies) are appropriate.

The principles of reconstruction of PCL injuries are outlined in Table 1. The goal of PCL reconstruction is to reproduce the normal anterior tibial step-off and to restore the restraint to posterior displacement (Fig. 4). Likewise, the goal of posterolateral corner reconstruction is to restore injured structures. Hamstring grafts have been found to be very effective for this purpose. Although there are a variety of procedures described for posterolateral corner reconstruction, a two-tailed (through the fibula neck and tibia posterior to anterior) reconstruction is preferred. (Fig. 5).

Postoperative rehabilitation principles deserve special emphasis. Patients are initially placed in a brace locked in extension. Protected (prone) range of motion negates the effect of gravity and reduces the incidence of postoperative stiffness. Quadriceps rehabilitation is emphasized and hamstrings rehabilitation is de-emphasized during the early postoperative period.

References


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17. Harner CD, Januszke MA, Kanamori A, Yagi...


