Isolated Posterior Cruciate Ligament Injuries of the Knee

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Abstract: Isolated injuries of the posterior cruciate ligament (PCL) are rare in comparison to other ligamentous knee injuries, resulting in a lack of evidence-based literature regarding their treatment. Although consensus exists regarding the nonoperative management of asymptomatic grade I injuries, the treatment of high-grade symptomatic PCL insufficiency remains a matter of debate. A variety of reconstructive procedures have been advocated on the basis of biomechanical data, however, the clinical benefit of these anatomic reconstructive techniques have yet to be conclusively proven in randomized trials. This article attempts to provide the treating physician with a concise overview of the etiology and diagnosis of isolated PCL injuries as well as an objective review of contemporary surgical treatment options and outcomes as reported in the current literature.

Key Words: isolated posterior cruciate ligament injury, posterior cruicate ligament, single-bundle reconstruction, double-bundle reconstruction, tibial inlay

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Isolated posterior cruciate ligament (PCL) injuries represent a clinical dilemma for the treating physician. Although the natural history, management options, surgical outcomes, and rehabilitation protocols have been thoroughly described for injuries of the anterior cruciate ligament (ACL) and collateral ligaments of the knee, there is no general consensus on the treatment of isolated PCL injuries, nor is there a significant body of evidence-based data to guide clinical management. This is likely a result of the relative paucity of isolated PCL injuries relative to other sports-related knee trauma and the overall heterogeneity of outcomes after these injuries. Although some patients remain asymptomatic and are able to return to full athletic participation, others demonstrate significant disability and progressive arthrosis of the knee joint. Currently, no prognostic factors have been clearly identified that can accurately predict which patients will experience chronic posterior tibial instability and persistent pain. Moreover, no randomized trials have been undertaken to directly compare the outcomes of operative and conservative treatment modalities, or among the outcomes of different operative techniques.[1] Accordingly, the indications for surgical reconstruction in cases of isolated PCL injury remain a subject of debate. In the absence of substantial level I or level II evidence, this article will attempt to provide a focused review of the literature that will aid in the evaluation and diagnosis of PCL injuries and will also provide treatment recommendations predicated on the patient's symptoms, physical exam findings, and the outcomes as described by current studies of this complex problem.

EPIDEMIOLOGY

The reported incidence of PCL injuries demonstrates significant variability among study populations. Fanelli et al conducted a prospective analysis of the incidence of PCL injuries in patients presenting to a regional trauma center with acute hemarthrosis of the knee (level I).[2,3] In this cohort, PCL injuries were present in 38% of cases. Trauma patients represented 56.5% of these injuries whereas 32.9% were sports related. Isolated PCL injuries were rare (3.5%), whereas 96.5% of PCL injuries occurred in combination with other ligament injuries. The authors concluded that trauma patients had a higher incidence of PCL injuries than did athletes, and that this difference was likely due to the high energy mechanisms underlying trauma-related knee injuries. Schulz et al[4] retrospectively reviewed the injury mechanism of 587 patients with confirmed PCL insufficiency and found that athletic injuries represented 40% of this cohort, with the greatest number of these injuries resulting from contact sports (level II). Of the patients evaluated in this study, 47.5% had sustained combined ligament injuries. Conversely, the reported incidence of PCL injuries in the general population has been found to be lower (3%) than the aforementioned figure relating to sports and trauma-involved study cohorts.[5]

Despite the fact that a large proportion of PCL injuries result from athletic activity, the actual prospective incidence and distribution of PCL injury in various sports remains unknown. Data from retrospective studies have demonstrated a low incidence of PCL injuries in athletes, with injuries occurring more frequently in sports involving high contact forces.[4,6–14] Parolie and Bergfeld[8] described the outcomes of 25 athletes with isolated PCL injures who had undergone nonoperative management (level IV). The activity most frequently associated with PCL injury in this group was football, followed by

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baseball, skiing, and soccer. The investigators also found a 2% incidence of chronic, asymptomatic, PCL insufficiency among collegiate football players at the annual National Football League predraft examination, suggesting that high-level athletes can continue to participate in contact sports with a PCL-deficient knee.[8,15] The retrospective sports-specific incidence of PCL injury has been reviewed for hockey, soccer, handball, wrestling, and rugby, and has been found to range from 1% to 4%.[6,9,10,12,14]

Although no prospective studies have been identified which quantify the true incidence of PCL injury in the athletic population, these data suggest that participation in sporting activity predisposes athletes to isolated PCL injury,[8,11] and that these injuries occur more frequently in sports which subject the knee to high contact forces. Moreover, isolated injuries of the PCL sustained by athletes are infrequent in comparison to the combined ligamentous injuries sustained in high-energy trauma, and this relative paucity may prove problematic when attempting to design prospective studies to evaluate the outcomes of treatment for isolated PCL insufficiency.

MECHANISM OF INJURY

Patients with isolated PCL injuries often present with vague symptoms and subtle clinical findings. Accordingly, certain mechanisms of injury must escalate the physician's index of suspicion for PCL disruption when evaluating the injured athlete. The most common mechanism of isolated PCL injury is the application of a posteriorly directed force to the proximal tibia with the knee in flexion.[16] This mechanism is commonly seen in sports such as football when an opponent attempts to tackle the ball carrier and strikes the proximal tibia during high knee flexion. Another commonly described mechanism is the athlete who falls on a flexed knee with the foot in plantar flexion, striking the proximal tibia to the ground first.[15,17] Finally, hyperflexion or hyperextension in the presence or absence of a posteriorly directed tibial force have also been implicated in the genesis of PCL injury.[11,18] Schulz et al[4] report that the most common injury pattern reported by athletes with PCL insufficiency was a direct fall on a flexed knee (level IV). However, many patients (51.6%) were unable to recall the specific injury mechanism, underscoring the assertion that this injury often goes unrecognized by patients in the acute period.

The mechanisms underlying combined ligament injuries involving the PCL are usually a combination of posteriorly directed force applied to the tibia in conjunction with a valgus, varus, or torsional moment. These combined forces may result in injury to the ACL, medial collateral ligament, lateral collateral ligament, posterior capsule, or the posterolateral corner (PLC).[2]

CLINICAL EVALUATION

A comprehensive history is mandated for all patients presenting with complaints related to the knee. The details of the initial injury should be obtained to determine the magnitude of energy exchange during the event and, consequently, the potential extent of injury to stabilizing structures of the knee. The physician must be mindful that the majority of injuries to the PCL involve other ligamentous injuries and that higher velocity trauma may be more likely to result in combined injury. Patients may present with a spectrum of symptoms that relate to the extent of injuries to surrounding structures. Patients with isolated PCL injury rarely report an audible "pop" or tactile "tear" as is common in ACL rupture. Furthermore, many individuals may be unaware that they have sustained an injury and will continue participation in athletic activities. Patients who present in the acute period may complain of mild to moderate pain in the back of the knee, stiffness, swelling, or pain with deep knee flexion including squatting or kneeling. Rarely do patients with isolated PCL insufficiency complain of gross instability. Rather, these patients often describe a vague sense of discomfort that may be difficult to localize. A substantial effusion, as well as significant pain and loss of motion should alert the examiner to the presence of concomitant structural knee injury. Some patients may not appreciate any initial disability but develop symptoms over time. These patients who present in the chronic phase of isolated PCL injury may complain of anterior knee pain, difficulty with ascending or descending stairs, or pain with sprinting or deceleration.[15]

The physical exam represents the cornerstone of diagnosis for PCL insufficiency and is essential in determining the scope of injury as well as the presence of subtle dysfunction of other structures, particularly the PLC. The physical exam should include an evaluation of the patient's gait and overall weight-bearing alignment. Tibia vara, external rotation, and genu recurvatum may be signs of a PCL-deficient or PLC-deficient gait caused by posterior subluxation of the lateral tibia, although the patient may also assume a bent-knee gait to avoid terminal extension of the tibia.[19] On palpation, patients may have a mild effusion and lack 10 to 20 degrees of terminal flexion as compared to the uninjured knee.[20] The medial collateral ligament and lateral collateral ligament should be palpated and subjected to valgus and varus stress testing at both 30 degrees of flexion (to evaluate collateral integrity) and full extension (to evaluate posteromedial and posterolateral structure integrity).[21] Examination of the ACL should be performed with the understanding that in the presence of PCL injury, the anterior drawer test may be falsely positive. Therefore, it should be underscored that in the uninjured knee, the medial tibial plateau lies approximately 1 cm anterior to the medial femoral condyle, and that anterior and posterior translation should be compared to the uninjured side.

Numerous physical examination maneuvers have been described to aid in the identification of PCL injury. The posterior drawer test is performed with the subject supine, the hip flexed to 45 degrees, the knee flexed to 90 degrees, and the foot in neutral position. With the

examiner sitting on the subject's foot, both hands are placed behind the subject's proximal tibia and with the thumbs on the anterior tibial plateau, a posteriorly directed force is applied to the tibia, assessing the position of the medial tibial plateau relative to the medial femoral condyle. Posterior tibial translation is measured and assigned 3 grades of injury (Table 1). In a double-blinded, randomized study, Rubinstein et al[22] reported that the posterior drawer test was the most sensitive (90%) and specific (99%) test for identifying PCL injuries (level I). When stratified by grade, the sensitivity was lower for grade I (70%) versus grade II and III (97%) injuries. It is important to note that this study only included patients with chronic PCL tears, and the results should not be generalized for patients after acute injury. Other authors have reported the sensitivity of the posterior drawer test between 51% and 91%.[23–25]

The posterior sag test (Godfrey test) is performed with the hip flexed to 45 degrees and the knee flexed to 90 degrees with the foot resting on the examination table. When the PCL is disrupted, the tibia may seem to sag posteriorly and the tibial tubercle will be less prominent than that of the uninjured contralateral knee. This test has a reported sensitivity of 79% and specificity of 100% (level I).[22]

The quadriceps active test is performed with the subject supine and the knee flexed to 90 degrees. The examiner stabilizes the foot, and the subject is asked to slide foot down the table. Contraction of the quadriceps muscle in the PCL-deficient knee results in an anterior shift to the tibia. A shift greater than 2 mm is considered positive for PCL disruption. This maneuver has a reported sensitivity of 54% and specificity of 97% (level I).[22]

PLC injuries are common in the setting of PCL insufficiency, and many tests can be used to evaluate the PLC. However, their sensitivity and specificity are not well delineated, and accordingly, only one will be described. The Dial test is best performed with the patient positioned prone while an external rotation force is applied to both feet with the knee positioned at 30 degrees and then 90 degrees of flexion. The degree of external rotation is measured by comparing the medial border of the foot with the axis of the femur. Because of the wide variability of external rotation possible at these positions, it is essential to compare the results with the contralateral side. A side-to-side difference greater than 10 degrees is considered abnormal. An increase of 10 degrees or more of external rotation at 30 degrees of knee flexion, but not at 90 degrees, is suggestive of an isolated PLC injury. Increased external rotation at both 30 degrees and 90 degrees of knee flexion suggests a combined PCL and PLC injury. At 90 degrees of flexion, the intact PCL should become taught, acting as a secondary restraint to external rotation of the tibia. If there is a concomitant PCL injury, increased external rotation will also be present at 90 degrees of flexion.

TABLE 1. PCL Injury Classification

Injury Grade	Position of Tibial Plateau Relative to Medial Femoral Condyle	Posterior Translation of Tibial Plateau Relative to the Uninjured Knee (mm)
I	Anterior	0 to 5
II	Flush	6 to 10
III	Posterior	> 10

IMAGING

Plain radiographs are mandated in the assessment of PCL injuries, and should include weight-bearing anteroposterior views at neutral and 45 degrees of flexion, as well as lateral and merchant patellar views. Plain x-ray may assist in demonstrating posterior sag of the tibia or avulsion fractures on the lateral view, and the presence of osteoarthritis may be noted in the neutral and flexion weight-bearing views.[26] Some authors have advocated lateral stress views as an adjuvant to diagnosing PCL tears.[27,28] Hewett et al[27] retrospectively evaluated 21 patients with partial or complete PCL tears using stress radiography and compared the results with KT-1000 (Medmetric Corp, San Diego, CA) measurements and physical exam (level IV). The authors concluded that stress radiographs were more accurate than KT-1000 arthrometer measurements in diagnosing PCL tears, with > 8 mm of posterior translation indicating complete rupture. Schulz et al[28] also found stress radiography to be a useful adjuvant method to evaluate posterior laxity in patients with PCL lesions. However, they caution that the reproducibility of stress radiography may be influenced by multiple variables, most importantly tibial rotation. Overall, stress radiography seems to be a reproducible means of evaluating posterior tibial translation and maybe useful for the longitudinal evaluation of patients with PCL-deficient knees. However, no level I, II, or III evidence exists to support its efficacy in diagnosing PCL rupture.

Magnetic resonance imaging (MRI) has been proven to be very accurate in diagnosing acute injuries of the PCL.[29–33] In a prospective multicenter study evaluating 1014 patients, MRI was found to demonstrate 99% accuracy in diagnosing the presence of PCL injury which was confirmed via arthroscopy (level I).[30] However, the authors did not comment on their ability to differentiate between partial and complete injury in the acute setting. The PCL is best evaluated on the T2-weighted sagittal images and is typically visualized in its entirety on a single image or more commonly on 2 consecutive sagittal images.[34] Primary signs of partial PCL injury include a high signal partially traversing the fibers of the PCL on T2-weighted images (Fig. 1), whereas a complete tear is represented by high signal completely traversing the fibers of the PCL on T2-weighted images (Fig. 2). Bone marrow edema may also be noted after isolated PCL injury and may be localized to the medial compartment or lateral compartment.[35] In the setting of chronic PCL injury, the accuracy of MRI has been found to be substantially lower.[7] Servant et al reviewed the MRI

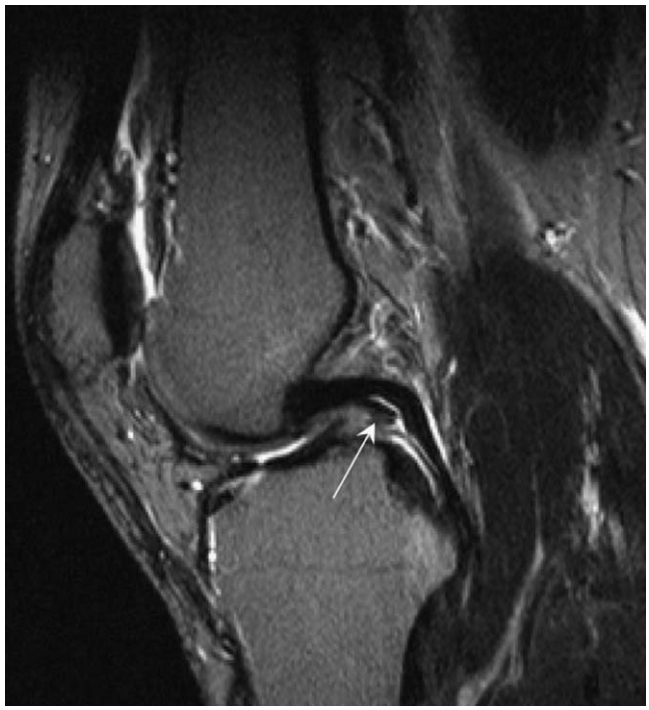

FIGURE 1. T2-weighted sagittal MRI demonstrating a partial tear of the PCL. Note the elongated posture of the ligament, the posterior position of the tibia relative to the femur, and the high signal intensity present in the ligament midsubstance (arrow). Normal low signal intensity is present in the remainder of intact PCL fibers.

FIGURE 2. T2-weighted sagittal MRI demonstrating complete rupture of the PCL. Complete disruption of the ligament is signified by diffuse high signal intensity present between the proximal and distal PCL remnants (arrow).

findings of 10 knees with a clinical and arthroscopic diagnosis of a PCL injury sustained at least 6 months previous to evaluation and found the accuracy of diagnosis in this cohort to be 57% (level IV).[36] It is important to note that PCL injuries can demonstrate radiologic healing and may regain a normal MRI appearance after initial injury.[37,38]

MANAGEMENT

Nonoperative Management

The management of isolated PCL injuries remains a matter of debate, largely due to the lack of prospective studies delineating the true natural history of the injury and the absence of randomized trials comparing the outcomes of current modes of treatment. Four prospective studies evaluating the outcomes of acute isolated PCL injuries have been identified for review. Shino et al[13] assessed 22 young athletes with acute, isolated PCL injury, 15 of whom were treated nonoperatively in the acute period. At an average follow-up of 51 months, one had developed symptoms due to a new medial femoral condyle cartilage lesion (level IV). The remaining 14 patients remained symptom free, and 11 were still participating in sports at their preinjury level. Radiography demonstrated no osteoarthritic changes in 8 of 9 patients who were available for evaluation. Fowler and Messieh[11] prospectively followed 13 patients for a mean of 2.6 years after acute PCL injury (level I). All patients were able to return to their previous level of activity and experienced no limitations with their injured knees. Subjective and functional ratings were all good; however, only 3 rated good and 10 fair when assessed objectively. Shelbourne et al[7] evaluated 133 patients with isolated PCL injury at a mean of 5.4 years (level I). Greater than half of all patients were able to return to their preinjury level of activity and no correlation was observed between objective and subjective scores and PCL laxity. Additionally, no correlation was found between grade of laxity and radiographic change, nor did the presence of degenerative changes significantly affect total scores.[7] In a long-term continuation of this study, Shelbourne and Muthukaruppan[39] evaluated the subjective outcomes of 215 nonoperatively managed patients with modified Noyes survey and the International Knee Documentation Committee (IKDC) subjective knee survey at a mean time of 7.8 years (mean score 85.6) and 8.8 years (mean score 82.7), respectively. In 146 patients with 4 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.[39] Parolie and Bergfeld[8] reviewed the outcomes of 25 athletes with isolated PCL injuries 6.2 years after injury (level IV). Seventeen patients (68%) were able to

return to sports at their preinjury level and 4 (16%) at a decreased level of performance. Overall, 80% of patients were satisfied with their knee function. Grade of posterior laxity as measured by KT-1000 did not correlate with satisfaction or ability to return to sports. However, quadriceps strength of the injured extremity seemed to be related to functional recovery. It is important to note that the aforementioned studies included few patients with grade III laxity, and that the overall satisfactory results should not be generalized to patients with more severe injury. Moreover, although numerous investigators have reported good results with nonoperative management, a significant incidence of knee pain and degenerative changes in the patellofemoral and medial compartments of the knee have been observed in some long-term studies.[40–42] Elevated contact pressures and abnormal kinematics observed in the PCL-deficient knee have been implicated in the development of these degenerative changes.[43,44]

Operative Management

The results of contemporary reconstruction of the PCL were initially described by Clancy et al[45] (level IV) who reported the results of 23 patients who underwent single-bundle autologous bone-patellar tendon-bone (BTB) autograft replacement with a transtibial tunnel technique. Ten patients who had reconstruction after acute PCL injury had static and functional results that were graded as good or excellent. Of the 13 patients for whom surgery was done in the setting of chronic PCL instability, the overall static and functional results were graded as good or excellent in 11. Mariani et al[46] retrospectively reviewed 24 patients after arthroscopic single-bundle PCL reconstruction with a BTB autograft for chronic PCL insufficiency (level IV). At a minimum follow-up of 2 years, they found that 25% of patients were normal and 21% of patients were abnormal or severely abnormal by IKDC criteria. Chen et al[47] retrospectively reviewed the outcomes of quadriceps tendon-patellar bone graft for PCL reconstruction at a minimum follow-up of 3 years (level IV). Twenty-nine patients with grade III PCL injury and marked instability underwent arthroscopic reconstruction. Twenty-four (83%) patients achieved good or excellent Lysholm knee scores and 25 (86%) patients had ligament laxity of less than 5 mm. The authors concluded that the quadriceps tendon autograft was an acceptable graft choice for PCL reconstruction. Sekiya et al[48] reported on the retrospective outcomes of 21 patients who had undergone arthroscopic single bundle PCL reconstruction using an Achilles' tendon allograft for isolated grade III injuries (level IV). In this review, only 57% of patients had normal or near normal knee function by IKDC assessment standards at an average follow-up of 5.9 years. Additionally, instrumented laxity examination revealed that only 62% of patients had less than 3 mm side-to-side difference in corrected posterior displacement.

The inconsistent results after arthroscopic single-bundle PCL reconstruction have been attributed to several technical obstacles. The placement of the tibial tunnel for PCL reconstruction requires that the exiting graft undergo an acute angular turn as it enters the joint. It has been suggested that this acute "killer turn" results in graft wear and elongation, with some cadaveric studies strongly corroborating this hypothesis.[49,50] However, other biomechanical studies have demonstrated only small differences in graft pretension, graft forces, or knee kinematics between tibial inlay and transtibial techniques.[51–54] Moreover, recent clinical comparisons between tibial inlay and transtibial techniques have failed to demonstrate the superiority of either reconstructive technique for treating isolated PCL insufficiency in short-term to mid-term follow-up.[55,56] Using a quadrupled hamstring autograft, Seon and Song[55] compared transtibial tunnel fixation with a tibial inlay technique using BTB autograft at a minimum 2-year follow-up (level III). Mean Lysholm scores for transtibial and tibial inlay groups were 91.5 and 93.5, respectively, however, this difference was not significant. Additionally, no significant difference was noted in instrumented posterior laxity testing with mean side-to side differences of 3.7 mm for the transtibial group and 3.3 mm for the tibial inlay group. MacGillivray et al[56] compared single-bundle endoscopic transtibial reconstructions with a tibial inlay technique and found that there were no significant differences in posterior drawer testing, KT-1000, functional testing, or Lysholm, Tegner, and American Academy of Orthopedic Surgeons (AAOS) knee scores at a minimum 2-year follow-up (level III). Although the tibial inlay technique has demonstrated distinct biomechanical advantages in the laboratory when compared to tibial tunnel techniques, these advantages have yet to be identified in clinical studies. However, it should be noted that the 2 clinic studies cited are retrospective case series. Further studies are warranted to determine whether the deleterious effects of the "killer corner" seen in vitro are observed in vivo.

To more closely replicate the anatomy and kinetics of the native ligament, some authors have advocated double-bundle PCL reconstruction. Traditional single-bundle PCL reconstruction has focused on replacing the larger and stronger anterolateral bundle. However, some authors have proposed a major theoretical advantage to double-bundle reconstruction. These authors have reported that the double-bundle technique more accurately recapitulates both the anterolateral and posterolateral bundles of the PCL, and biomechanical studies have demonstrated that when used in conjunction with a transtibial tunnel, this technique can restore normal kinematics across the full range of knee flexion, versus single-bundle reconstruction which may only restore kinematics in the flexion arc of 0 to 60 degrees.[57–59] It could be argued that these observations are best explained by the methodology used in these studies. If these investigators had applied more graft tension to the single-bundle, perhaps they could have restored normal laxity as other authors have restored kinematics in vitro with a single-bundle reconstruction.[60] In a cadaveric

model comparing single-bundle and double-bundle tibial inlay reconstruction, Bergfeld et al[61] demonstrated that there was no statistical difference in translation between either of the reconstructions methods at any angle of flexion. Two clinical studies have compared the outcomes of single-bundle and double-bundle reconstruction. In one retrospective analysis, Houe and Jorgensen[62] evaluated 16 patients at a mean follow-up of 35 months and found no significant differences in Lysholm score, activity level, or graft laxity with reconstruction using a BTB graft in 1 femoral tunnel was compared with semitendinosus/gracilis grafts in 2 femoral tunnels (level II). Similarly, Wang et al[63] prospectively followed 35 patients for a minimum of 2 years to compared single-bundle and double-bundle PCL reconstruction with a hamstring autograft (level II). They found no significant difference in ligament laxity, functional score, or radiographic changes between the 2 groups. Further studies evaluating the long-term outcomes in larger cohorts of patients are needed to accurately compare the relative benefits of single-bundle and double-bundle techniques.

Treatment Recommendations

Despite the absence of randomized trials or systematic reviews addressing the treatment of isolated PCL injury, the existing literature can provide the treating physician with data that are useful in counseling the injured athlete and formulating a treatment plan tailored to the patient's activity-related needs. For those athletes sustaining acute isolated grade I or grade II PCL injuries, nonoperative management yields satisfactory subjective outcomes for the majority of patients, with most athletes returning to sport. Some patients will have chronic instability or pain, and may develop degenerative changes of the knee joint. However, these changes do not seem to be related to the grade of laxity, nor are there other known prognostic factors that can accurately predict which patients will develop these symptoms or progressive arthrosis. For those patients with acute or chronic grade III injuries and symptomatic instability, single-bundle, transtibial reconstruction seems to improve both subjective knee function and posterior tibial translation in the short-term. However, some patients may continue to demonstrate residual laxity, and there is no definitive evidence to suggest that PCL reconstruction significantly alters the natural history of the PCL-deficient knee. Furthermore, limited nonrandomized clinical comparisons have not demonstrated significant differences in the short-term subjective or objective outcomes for single-bundle versus double-bundle femoral fixation methods or tibial inlay versus transtibial techniques of tibial fixation. Further studies are warranted to evaluate these surgical methods in larger cohorts of patients over the long term.

SUMMARY

Isolated injuries of the PCL in the athletic population are relatively uncommon, and subsequently, evidence-based solutions to this complex problem are limited. Successful diagnosis of acute injury may aid in treatment, therefore a careful history and physical examination are essential for all athletes sustaining a knee injury. Certain mechanisms including hyperflexion or a fall onto a flexed knee should alert the examiner to the possibility of PCL injury. The posterior drawer sign and MRI serve as the most sensitive diagnostic tools available to the examiner for diagnosing this injury in the acute setting. As combined injuries are common, patients with suspected PCL injuries should also be assessed for concomitant ligamentous, chondral, or meniscal injuries. Most authors contend that symptomatic, high-grade PCL injuries warrant surgical intervention; however, limited clinical evidence exists as to the efficacy of various treatments in altering the natural history of the disease, and patients should be advised that restoration of stability and relief of clinical symptoms are less predictable than for other commonly performed reconstructive knee surgeries.

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