

The Acutely Dislocated Knee: Evaluation and Management

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Abstract

Acute knee dislocations are uncommon orthopaedic injuries. Because they often spontaneously reduce before initial evaluation, the true incidence is unknown. Dislocation involves injury to multiple ligaments of the knee, resulting in multidirectional instability. Associated meniscal, osteochondral, and neurovascular injuries are often present and can complicate management. The substantial risk of associated vascular injury mandates that vascular integrity be confirmed by angiography in all suspected knee dislocations. Evaluation and initial management must be performed expeditiously to prevent limb-threatening complications. Definitive management of acute knee dislocation remains a matter of debate; however, surgical reconstruction or repair of all ligamentous injuries likely can help in achieving the return of adequate knee function. Important considerations in surgical management include surgical timing, graft selection, surgical technique, and postoperative rehabilitation.

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Traumatic knee dislocations are uncommon, accounting for <0.02% of all orthopaedic injuries.¹⁻³ These data likely underestimate the true incidence because an unknown percentage of knee dislocations spontaneously reduce and thus are not diagnosed during the initial evaluation. Mismanagement of such injuries can have devastating consequences, particularly in dislocations that involve limb-threatening vascular injuries. Therefore, despite the low reported incidence of knee dislocation, a basic knowledge of current evaluation and management concepts is essential.

Knee dislocation commonly involves injury to most of the soft-tissue stabilizing structures of the knee, resulting in multidirectional instability. Although knee dislocation can occur involving injury isolated to the anterior cruciate ligament (ACL) or posterior cruciate ligament (PCL), both of the cruciate ligaments are usually disrupted.^{4,5} Associated injuries

to the collateral ligaments, menisci, articular cartilage, and neurovascular structures can complicate the evaluation and treatment of the patient with a traumatic knee dislocation.

Historically, traumatic dislocation of the knee has been managed with prolonged immobilization, which has been associated with variable outcomes, including loss of motion, residual instability, and poor knee function.⁶⁻⁸ The goal of surgical management of acute dislocations is anatomic repair and reconstruction of all associated ligamentous and meniscal injuries.⁹⁻¹³ Surgical timing, graft selection, and surgical technique remain controversial. The use of allograft has become popular in multiligament knee surgery because of graft availability, decreased operating time, and decreased donor site morbidity in an already traumatized knee.^{9,12,13} Some advocate delayed surgery, but many others recommend early surgical repair or reconstruction

(within 3 weeks of injury).^{6,8,13,14} Most of the principles of evaluation and management of the patient with an acutely dislocated knee are well established;¹⁵ recent advances have centered on improvements in surgical technique.

Classification

Knee dislocation is temporally classified as acute (<3 weeks) or chronic (≥ 3 weeks).¹⁶ Anatomic classification is based on the position of the displaced tibia (ie, anterior, posterior, medial, or lateral) on the femur.² A

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rotatory knee dislocation involves a combination of these tibial displacement positions. Knee dislocations that spontaneously reduce before evaluation are classified according to the direction of instability.

Anterior dislocations are the most common, accounting for approximately 40% of all knee dislocations.¹⁷ Hyperextension is typically the mechanism of injury. Posterior dislocations represent 33% of all knee dislocations.¹⁷ The mechanism is usually high energy, such as the so-called dashboard injury sustained during a motor vehicle accident. Lateral and medial dislocations are less common, estimated at 18% and 4% incidence, respectively.¹⁷ The mechanism involves a violent varus or valgus load. Associated fractures are not uncommon. Rotatory knee dislocations, caused by a twisting force to the knee, are the least common type. Posterolateral dislocations, the most common type of rotatory knee dislocation, have a high incidence of irreducibility, in which case the medial femoral condyle buttonholes through the medial soft-tissue structures.¹⁸

Associated Neurovascular Injuries

Injuries to the popliteal artery can make knee dislocation a limb-threatening emergency. The reported incidence of associated popliteal artery injury is between 32%¹⁷ and 45%,¹⁹ with severity ranging from an intimal tear to complete transection. Because amputation rates vary in direct relation to the length of time to revascularization, immediate recognition of arterial vascular compromise is crucial. An amputation rate of 86% after a delay in revascularization of 6 to 8 hours has been reported.¹⁷ Damage to the intimal portion of the artery can be more insidious, with delayed vascular compromise presenting several days after the injury. Vascular injury must be assumed in all patients

with knee dislocation until it is proved otherwise by angiography.

Neurologic damage, ranging from a stretching of the nerve (neurapraxia) to complete transection (neuronotmesis), occurs in 16% to 40% of all knee dislocations; it is most common after posterolateral dislocations.^{6,20} The peroneal nerve is more often injured than the tibial nerve.²¹ Careful neurologic examination before any manipulation of the knee is mandatory, although it is often difficult to obtain, particularly in a trauma patient.

Evaluation

Initial assessment of the patient begins with a brief history that reviews the mechanism of injury and a directed physical examination that includes a thorough neurovascular evaluation of the injured extremity. The patient with a dislocated knee usually has a tremendous amount of pain, a large knee effusion, and overall swelling of the extremity. A spontaneously reduced knee dislocation can appear deceptively benign and can be over-

looked when evaluating a multiply traumatized patient. Thus, even with normal-appearing radiographs, a complete physical examination of the knee, including thorough neurovascular assessment, is essential for all victims of high-energy trauma. When substantial laxity of two or more of the major ligaments of the knee is found, a presumptive diagnosis of knee dislocation should be made.

The vascular examination includes manual palpation of the dorsalis pedis and posterior tibialis pulses and comparison with the uninvolved side. The ankle-brachial indices (ABI) determined with ultrasound is a more sensitive study that can help confirm the vascular status of the extremity. An abnormal result from any of these tests should prompt a vascular surgery consultation. However, a normal result from any of these tests does not exclude arterial injury. Normal pulses, a warm foot, and brisk capillary refill can be present with arterial injury. Therefore, any patient with a high suspicion of knee dislocation should undergo arteriography of the lower extremity (Fig. 1). The routine

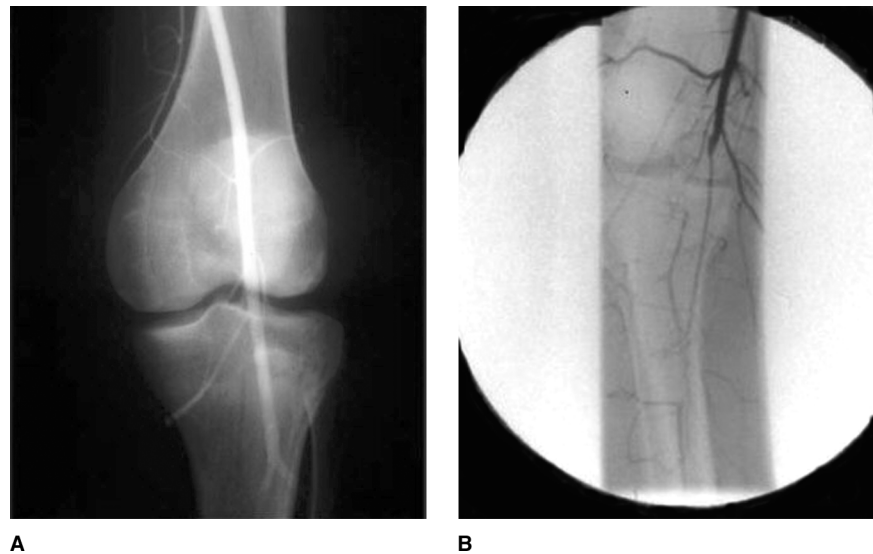


Figure 1 Anteroposterior arteriograms of an intact popliteal artery (A) and an injured popliteal artery (B) after acute knee dislocation and subsequent reduction. The artery shown in panel B was found to be transected at exploration.

use of arteriography in this setting is justified by the relatively low morbidity of the test, the high incidence of popliteal artery injury, and the potentially devastating consequences of delay in diagnosis.^{20,22-24}

A complete neurologic examination also must be performed, including an evaluation of motor and sensory function in the distribution of the tibial and peroneal nerves. The portions of the examination requiring patient cooperation are often difficult to obtain and should be accurately documented. Progressive deterioration of neurologic function raises the suspicion of an impending compartment syndrome or ischemia.

The examination of knee stability should be done only after survival of the limb is ensured. It should be done as gently as possible to avoid iatrogenic injury. Thorough evaluation of all ligaments can be difficult to obtain because of the associated pain. The most sensitive test for determining ACL deficiency is the Lachman test, performed with the knee held in 20° to 30° of flexion.²⁵ The most sensitive test for detecting PCL injury is the posterior drawer test, performed with the knee in 90° of flexion.²⁶ To accurately assess the PCL, the normal step-off of the medial tibial plateau in reference to the medial femoral condyle must be determined. The collateral ligaments are assessed by applying stress in the coronal plane at both full extension and 30° of knee flexion.

Standard radiographs are obtained to evaluate the direction of dislocation, characterize associated osseous injuries (ie, fracture or avulsion), and confirm reduction (Fig. 2). Initial radiographs should be obtained immediately after a prompt evaluation of the patient. Magnetic resonance imaging (MRI) can be used to characterize associated soft-tissue and occult osseous injuries only after the patient has been acutely stabilized (Fig. 3). MRI is helpful in developing a surgical plan.

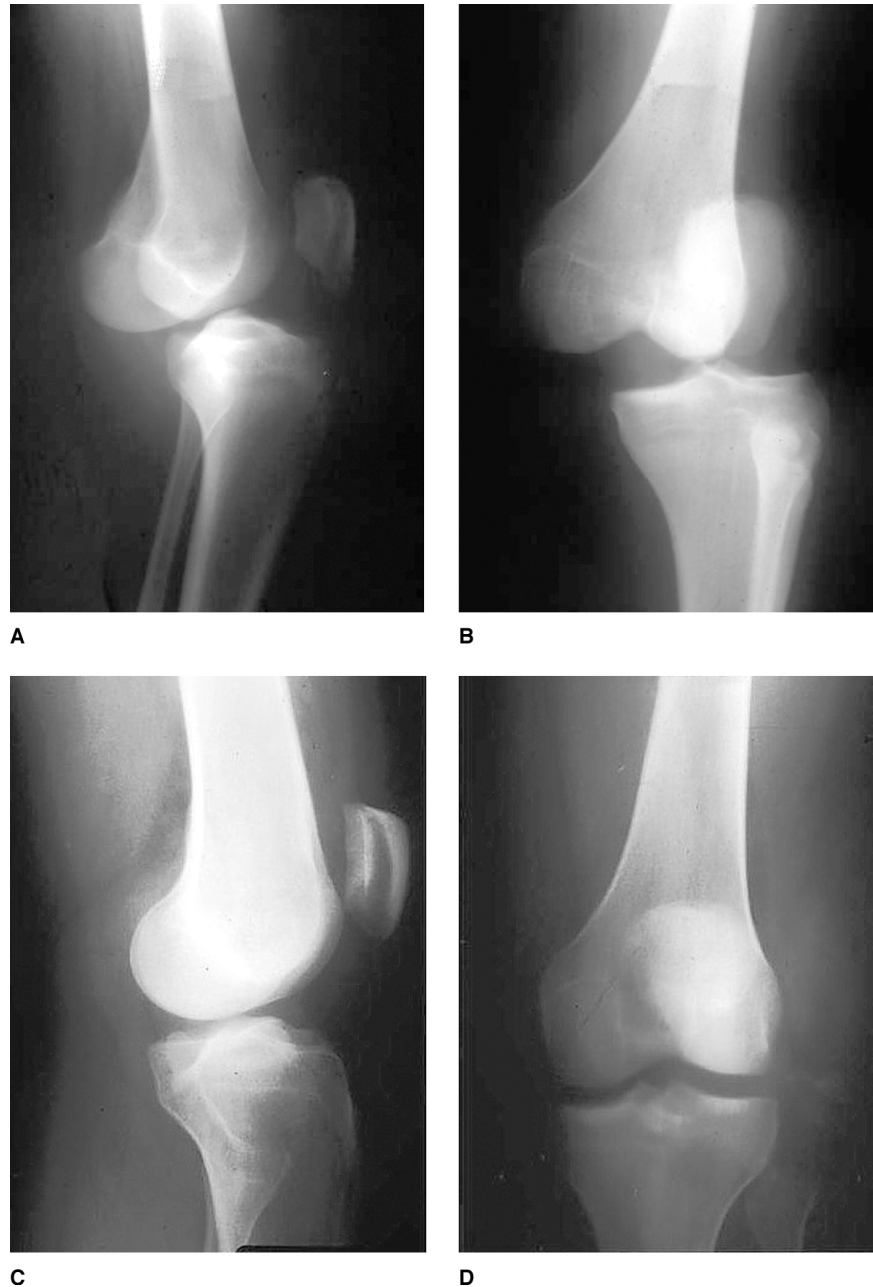


Figure 2 Anteroposterior (A) and lateral (B) radiographs of a posterolateral knee dislocation in a patient who sustained a twisting injury to the left knee while playing basketball. Anteroposterior (C) and lateral (D) radiographs of the same knee after closed reduction under conscious sedation and placement in a long leg plaster splint.

Initial Management

The vascular status of the limb must be determined quickly and managed appropriately. If the limb is obviously ischemic, the knee should be re-

duced immediately through gentle traction-countertraction with the patient under conscious sedation. The limb should then be stabilized in a long leg splint. If pulses are restored with the reduction, postreduction ra-

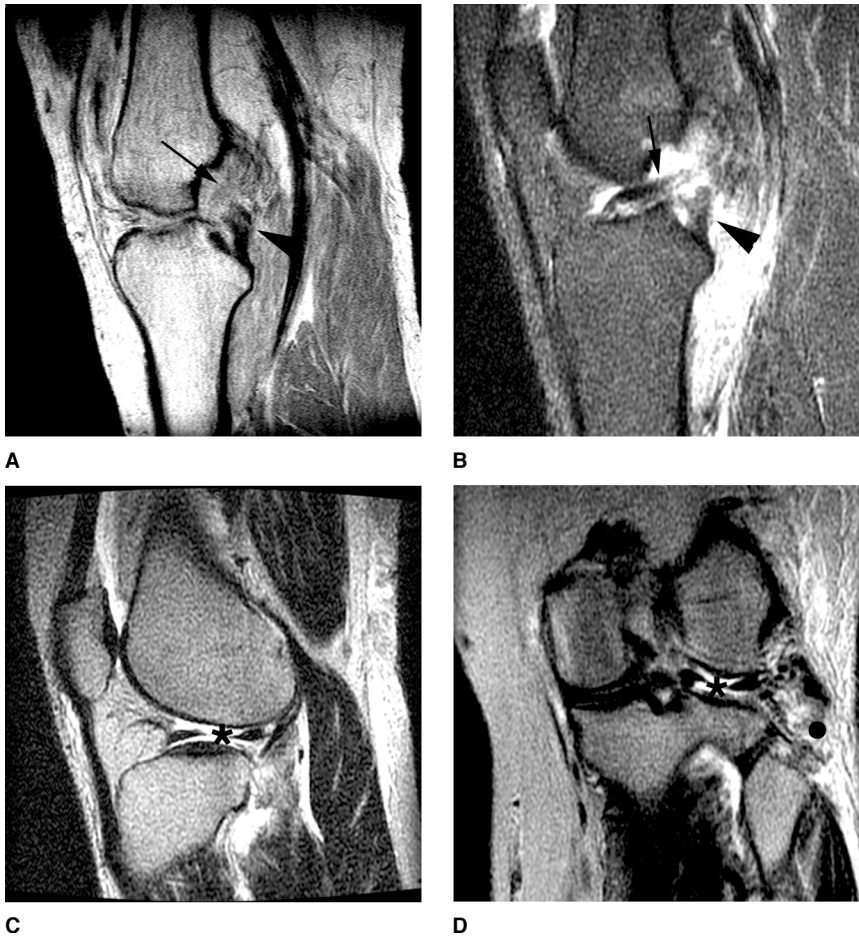


Figure 3 T1-weighted (A) and T2-weighted (B) sagittal MRI scans of the left knee of a patient who sustained a twisting injury from stepping in a hole during a softball game. The images show disruption of both the anterior (arrow) and posterior (arrowhead) cruciate ligaments. C, T1-weighted sagittal image showing an injury to the lateral meniscus (asterisk), which appears to be elevated off the lateral tibial plateau. D, T2-weighted coronal image showing injuries to the lateral meniscus (asterisk) and posterolateral corner (solid circle). The fibular head appears comminuted, and there is no identifiable lateral collateral ligament, biceps femoris tendon, or popliteus tendon.

diographs and a formal angiogram should be obtained. If the limb remains ischemic, the patient requires emergent surgical exploration and revascularization in the operating room. More rigid stabilization can be applied in the form of external fixation that spans the knee joint, with pins in the femur and tibia. The external fixator supplies sufficient rigidity to maintain reduction but allows good access to the knee and leg for serial neurovascular examinations.

When there is no vascular compromise, radiographs should be obtained

and the knee is promptly reduced. A gentle reduction maneuver is preferable, avoiding extreme deformity of the limb to minimize the likelihood of iatrogenic vascular injury. Adequate sedation is important. The specific reduction technique depends on the direction of the dislocation, but the most important element is distractive force. After reduction, a repeat neurovascular examination is done and radiographs are obtained. As with all cases of knee dislocation, angiography should be done to rule out vascular injury.

Emergent Surgery

Emergent surgery is indicated in patients with vascular injury, compartment syndrome, open injury, or irreducible dislocation. Patients with a popliteal artery injury require emergent intervention by a vascular surgeon. Input from the orthopaedic surgeon concerning the location of future incisions can help optimize reconstructive efforts. Saphenous vein grafting and fasciotomies are often required after revascularization. Even without vascular compromise, a compartment syndrome is a surgical emergency. Despite the presence of a knee dislocation, prompt diagnosis and management of a compartment syndrome is mandatory for successful resolution.

In open knee dislocation, the standard principles of wound management prevail, including initial irrigation and débridement, with serial débridements as needed as well as intravenous antibiotics and adequate soft-tissue coverage. Early ligament reconstruction is contraindicated with an open wound. In some instances, soft-tissue coverage problems may delay ligament reconstruction for several months.

Irreducible dislocations are uncommon, but they require prompt surgical reduction to avoid prolonged traction on the neurovascular structures. Although ligament reconstruction can be done at the time of open reduction, it is preferable to delay definitive reconstruction to allow for complete knee imaging, planning, and resource mobilization.

During emergent surgery on a dislocated knee, however, it is acceptable to perform simple repairs as they are encountered in the surgical exposure. Use of excessive foreign material, including suture, should be avoided in open injuries, and additional incisions solely for reconstruction should not be done. In almost all circumstances, definitive ligament reconstruction should be delayed for sev-

eral days to allow limb swelling to subside. With vascular injury, time is required to ensure that the vascular repair is adequate.

Definitive Management

The management of multiligamentous knee injuries has not been well studied and remains controversial. Definitive conclusions are difficult to make because of the relative infrequency of these injuries, the many combinations of ligamentous and meniscal injury patterns, the varied treatment approaches, and the numerous methods of outcomes assessment. Before the mid 1970s, nonsurgical management consisting of closed reduction followed by immobilization was common.^{2,7,27,28} Results tended to vary with the duration of closed treatment: longer periods of immobilization resulted in stable but stiff knees, whereas brief periods led to excellent motion but greater instability.^{6,7,29,30} Unfortunately, no prospective study compares surgical with nonsurgical management options for this type of injury. With recent advances in knee ligament surgery, however, surgery is often recommended for the patient with knee dislocation.^{8,9,13,15,29-32} The goal of surgery is to improve stability, retain motion, and achieve knee function that allows the patient to perform daily activities.

Nonsurgical Management

Although used frequently in the past, closed reduction and cast immobilization is now indicated only for patients who are elderly or sedentary or who have debilitating medical or post-traumatic comorbidities.^{7,33} Those who initially undergo a trial of nonsurgical management often require surgical intervention later to address problems with knee function, including loss of motion or persistent instability. Poor outcome after nonsurgical manage-

ment of knee dislocation is well documented.^{7,8,34}

Nonsurgical management begins with 6 weeks of immobilization in extension. The form of immobilization depends on several clinical factors; choices include a cast, brace, external fixator, or transarticular Steinmann pin. If vascular repair was done, a cast or brace should not be used in order to avoid circumferential pressure on the limb. External fixation can provide more protection to the vasculature. For the extremely obese patient, immobilization often is not possible with a cast or brace alone. Therefore, external fixation is a viable option for the extremely obese patient.

The ideal flexion angle in which to immobilize the dislocated knee has not been well studied. The ACL-deficient knee is more stable in flexion, and the PCL-deficient knee more stable in full extension. Knee flexion of 30° to 45° is usually sufficient. Irrespective of the angle selected, maintaining a reduced tibiofemoral joint is essential. Nonsurgical management demands frequent radiographs, especially in the first few weeks, to ensure that the joint remains in the reduced position. Immobilization is followed by rehabilitation with progressive motion in a brace. Initiation of light running is highly variable, with most patients reaching this point at 6 to 8 months.

Surgical Management

Most authors currently recommend surgery for acute knee dislocation.^{8,9,13,15,29-32} Controversies persist regarding surgical timing, surgical technique (ie, which structures to reconstruct or repair), graft selection, and rehabilitation. Generally, simultaneously repairing both the ACL and PCL as well as any grade III collateral or capsular injuries is the most reliable method of restoring ligamentous stability, knee motion, and overall knee function.

Timing

When there is no need for emergent surgery, surgical intervention should be delayed until adequate perfusion of the limb is ensured and all factors have been optimized to allow safe surgical repair. Delaying surgery for 10 to 14 days offers several advantages. It allows for a period of vascular monitoring and the resolution of acute inflammation and soft-tissue swelling. Range of motion (ROM) and quadriceps muscle tone will partially return, potentially reducing the risk of postoperative arthrofibrosis.¹⁰ Various degrees of healing occur. The capsule heals quickly and may allow an arthroscopically assisted approach that minimizes the extent of dissection.

Delaying surgery beyond 3 weeks, however, results in excessive scarring of the collateral ligaments and posterolateral structures that may preclude their repair. If surgery must be delayed beyond 3 weeks, it may be prudent to wait until full ROM is established and to consider late reconstruction only if the patient develops residual laxity and functional instability.

Procedure

The patient is positioned supine on the operating table with a well-padded tourniquet applied to the upper thigh; the tourniquet is not inflated during the procedure unless necessary. A sandbag, on which the foot is rested when the injured knee is flexed, is secured to the operating table at the level of the midthigh. A lateral post is placed at the level of the tourniquet to prevent lateral movement of the flexed leg. The setup should permit the knee to be taken through a full ROM. A Doppler ultrasound is used to confirm the distal pulses at the beginning and end of surgery.

After appropriate patient positioning, an examination under anesthesia is performed. It is important to completely define all ligamentous in-

juries and ROM. Special attention is paid to the collateral ligaments because injuries to these structures generally determine which surgical incisions are used. The contralateral knee is used for comparison. Proposed skin incisions are marked and injected with 0.5% bupivacaine with epinephrine.

To decrease the amount of surgical dissection, arthroscopic techniques are used as much as possible. However, it is not always possible or safe to use arthroscopy in the acute setting because of capsular disruption. Sufficient capsular healing (approximately 2 weeks) is needed to maintain joint distension and avoid iatrogenic compartment syndrome. The procedure is begun using gravity inflow. The thigh and calf must be palpated intermittently throughout the procedure to monitor fluid extravasation. If extravasation is noted, the arthroscopic technique is abandoned and the remainder of the surgery is done with an open technique. In this situation, the arthroscope can still be valuable in a dry field because it can improve visualization as the procedure is done through miniarthrotomies.

Approach

The pattern of injury dictates the surgical approach. The two most common combined injury patterns include either the ACL, PCL, and medial collateral ligament (MCL), or the ACL, PCL, lateral collateral ligament (LCL), and posterolateral structures. Less commonly, the PCL is intact or is only partially disrupted and does not require reconstruction.^{5,35} The pattern of injury determines placement of the skin incisions. Some authors advocate the use of a midline incision, which provides limited access to the collateral ligaments and can be complicated by skin sloughing over the patella. The medial and lateral hockey stick incisions described by Hughston and Jacobson³⁶ and Muller,³⁷ when separated by at least 10 cm, minimize the risk of skin necrosis and

wound breakdown while providing satisfactory exposure.

Repair Versus Reconstruction

The decision to repair or reconstruct a torn ligament depends on several factors. Most cruciate injuries in knee dislocations are midsubstance tears that are not amenable to successful surgical repair.^{37,38} Some surgeons reconstruct midsubstance tears of the cruciate ligaments with allograft. Successful repairs can be done in cases of bony avulsion,^{39,40} either by using nonabsorbable sutures passed through small drill holes tied over a cortical bridge of bone or by achieving screw fixation, depending on the size of the associated bone fragment.

For the MCL and posterolateral structures, primary surgical repair in the acute setting (<3 weeks) yields satisfactory results. During this time, avulsions or intrasubstance tears of the MCL may be directly repaired. Similar intrasubstance tears of the LCL also can be repaired but may need to be supplemented with allograft tissue. Beyond 3 weeks, scar formation and soft-tissue contracture limit the success of primary ligamentous repair, often making reconstructive procedures necessary.

The articular cartilage and menisci should be inspected arthroscopically to define pathology not appreciated on physical examination or in imaging studies. Peripheral meniscal tears are repaired directly; central or irreparable meniscal lesions are débrided to a stable rim while preserving as much meniscus as possible.

Graft Selection and Preparation

Several different grafts may be used for reconstruction. Depending on the extent of injury, autograft tissue may be obtained from the ipsilateral or contralateral extremity. However, allograft tissue has advantages over autografts in knees with multiple ligament injuries. The use of allograft tissue eliminates graft site morbidity, decreases dissection time, and reduces the num-

ber and extent of incisions in an already traumatized knee.^{12,41,42} Allograft use also decreases intraoperative tourniquet time, postoperative pain, and postoperative knee stiffness.⁴¹ Disadvantages of allograft tissue compared with autograft tissue include greater cost, risk of disease transmission, and delay in graft incorporation and remodeling.^{43,44}

Bone-patellar tendon-bone (BPTB) allograft is recommended to reconstruct the ACL. The BPTB graft provides adequate strength and rigid bony fixation at both the tibial and femoral attachment sites. Use of cylindrical bone plugs 11 mm in diameter × 25 mm in length with an 11-mm tendon width is preferred. To facilitate graft passage, two no. 5 nonabsorbable sutures are placed in both the patellar and tibial plugs through drill holes. For PCL reconstruction, Achilles tendon allograft can be used alone or in combination with an ipsilateral hamstring tendon as an autograft for a single-bundle or double-bundle technique, respectively. Achilles tendon allograft is effective for PCL reconstruction because of its cross-sectional area and calcaneal bone plug that allows rigid bony fixation at the femoral attachment site. Compaction pliers and a rongeur are used to size the central portion of the calcaneal bone plug to a diameter of 11 mm and a length of 25 mm. Two no. 5 nonabsorbable sutures are placed in the bone plug. The tendinous end of the graft is tubularized with a double-armed no. 5 nonabsorbable suture using a baseball whipstitch, which prevents the graft from "balling up" during graft passage. The LCL is reconstructed with an Achilles tendon allograft with a 7- or 8-mm-diameter calcaneal bone plug. Alternatively, the BPTB allograft remaining from the ACL graft may be used for the LCL reconstruction. Either tibialis anterior tendon allograft or ipsilateral hamstring tendon autograft can be used to reconstruct the popliteofibular ligament. These grafts are prepared to a diameter of 7 mm and secured with

a no. 2 nonabsorbable suture using a whipstitch on both ends.

Cruciate Ligament Reconstruction

The details of reconstructing the ACL and PCL have been well described.⁴⁵⁻⁴⁸ The femoral and tibial insertions of the cruciate ligaments are identified arthroscopically. The femoral PCL tunnels are placed to reproduce the anterolateral bundle of the native PCL, whereas the ACL tunnels are placed in the center of its anatomic insertions (Fig. 4). In the setting of acute knee dislocation, a transtibial tunnel technique for PCL reconstruction is safer than the tibial inlay technique; the tibial inlay technique requires extensive soft-tissue dissection, and there is increased risk of vascular injury associated with the posterior approach. Some technique modifications are helpful for multi-ligament reconstruction after knee dislocation. One order of bicruciate reconstruction is outlined in Table 1.

Tibial and Femoral Tunnels

The PCL tibial tunnel is drilled first, with placement of a 15-mm offset PCL guide set at 50° through the anteromedial portal. The tip of the PCL guide is positioned in the distal and lateral third of the tibial PCL insertion site. A 1.8-mm guidewire is started 4 cm distal to the joint line and 2 cm medial to the tibial tubercle and placed under arthroscopic guidance using the PCL guide. The guidewire should exit through the tibial PCL footprint approximately 1 cm below the tibial plateau. Caution must be taken when passing the guidewire through the PCL tibial insertion site because of the close proximity of the neurovascular structures.

The ACL tibial guide is set to 47.5° and introduced through the anteromedial portal. A 1.8-mm guidewire is placed through the center of the ACL tibial footprint. It exits at least 2 to 3 cm proximal to the PCL guidewire to ensure that an adequate medial tib-

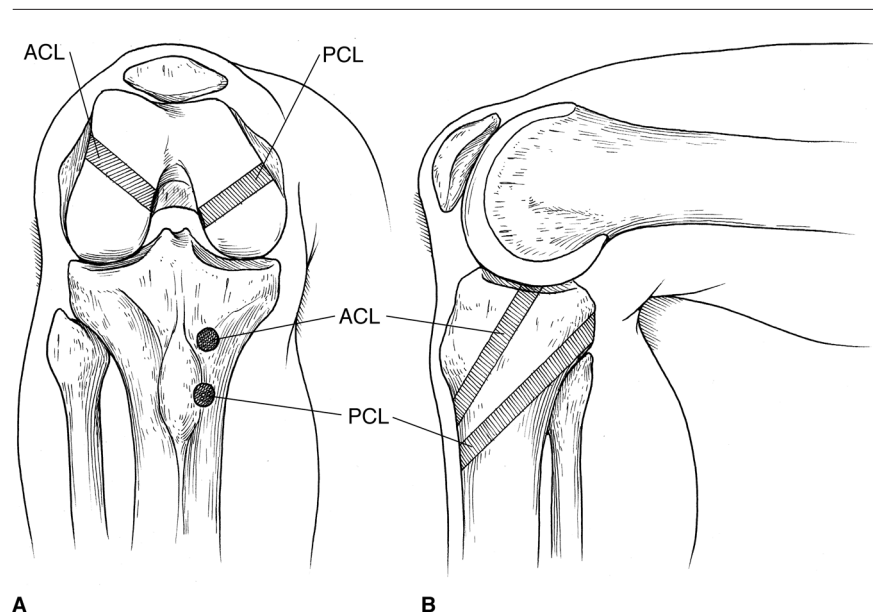


Figure 4 Anteroposterior (A) and lateral (B) views showing tunnel placement in combined PCL and ACL reconstruction.

ial cortical bridge remains after drilling. Because the PCL is absent, the posterior edge of the anterior horn of the lateral meniscus is used as a guide to the center of the tibial footprint of the ACL. The guidewire should be directed posterior to Blumenstaaf's line on the full extension lateral projection

to ensure proper placement of the ACL tibial tunnel. Intraoperative radiographs or fluoroscopy images are obtained to monitor guidewire placement (Fig. 5).

The PCL tunnel is drilled using a 10-mm compaction drill bit under direct arthroscopic control. A 30° arthro-

Table 1

Order of Bicruciate Ligament Reconstruction in the Dislocated Knee

Step 1	Drill tibial tunnels	PCL, then ACL
Step 2	Drill femoral tunnels	ACL, then PCL
Step 3	Graft passage and femoral fixation	Pass and fix PCL bone block into femoral tunnel through the anterolateral portal Pass tendinous portion of PCL graft into tibial tunnel Pass ACL graft through tibial tunnel and fix in femoral tunnel
Step 4	Collateral ligament repair	Secure extra-articular repairs or reconstructions
Step 5	PCL fixation: Tibia	Fix PCL graft on tibia at 90° of flexion with reproduction of anteromedial step-off
Step 6	ACL fixation: Tibia	Fix ACL graft on tibial side at full extension

ACL = anterior cruciate ligament, PCL = posterior cruciate ligament

(Adapted with permission from Cole BJ, Harner CD: The multiple ligament injured knee. *Clin Sports Med* 1999;18:241-262.)



Figure 5 Intraoperative lateral radiograph taken after placement of ACL (top wire) and PCL (bottom wire) tibial tunnel guidewires.

scope is placed through the posteromedial portal, and a curette is used to stabilize the Kirschner wire during drilling. The initial drilling is started by power and completed by hand to minimize the risk of plunging through the posterior tibial cortex. Although intraoperative fluoroscopy can be used, direct visualization provides better control. The PCL tibial tunnel is expanded to a diameter of 11 mm using dilators in 0.5-mm increments. The ACL tibial tunnel is then drilled using a 9-mm compaction drill bit and is expanded to a diameter of 10 mm using dilators in 0.5-mm increments.

The femoral tunnels are created in the opposite order: ACL, then PCL. The ACL femoral tunnel is drilled through the anteromedial portal with the knee in full flexion.⁴⁹ This is preferable to the more traditional transtibial technique because the location of the femoral tunnel is not constrained by the position or angulation of the tibial tunnel. The femoral tunnel can be placed more easily toward the wall

of the notch in the center of the anatomic insertion of the ACL, located 6 mm anterior to the posterior wall of the femur at the 10 o'clock position (right knee) or 2 o'clock position (left knee).⁵⁰ The guidewire is overdrilled with a 9-mm compaction drill to a depth of 25 to 35 mm, and dilators in 0.5-mm increments are used to expand the tunnel to a diameter of 10 mm. This technique can be demanding because visibility is limited with the knee in full flexion.

A two-incision technique for PCL graft tunnel placement with a separate femoral incision for outside-in drilling of the femoral tunnel can be used, but it is preferable to drill the femoral PCL tunnel through the anterolateral portal. With the scope in the anteromedial portal, the footprint of the anterolateral bundle of the PCL is easily visualized on the medial femoral condyle. A guidewire is then placed 7 to 10 mm from the articular surface within this footprint. A 10-mm compaction drill bit is used to drill the tunnel to a depth of 25 to 30 mm. Bone debris is removed, and the tunnel is dilated to a diameter of 11 mm using dilators in 0.5-mm increments. Double-bundle PCL reconstruction is not routinely done in acute knee dislocations.

Graft Passage and Femoral Fixation

The PCL graft is passed first. Using the two-incision transtibial tunnel technique for PCL reconstruction, the graft is passed from the femur to the tibia, and the calcaneal bone plug is secured on the femoral side with an interference screw (Fig. 6). Using the one-incision transtibial tunnel technique for PCL reconstruction, a long looped 18-gauge wire is passed retrograde into the PCL tibial tunnel and retrieved from the anterolateral portal with a pituitary rongeur. The no. 5 suture secured to the tendinous portion of the graft is passed into the joint using the looped 18-gauge wire through the anterolateral portal, then passed antegrade down the PCL tib-



Figure 6 Passage of the Achilles tendon allograft for PCL reconstruction using the two-incision technique. The Achilles tendon allograft is passed from the femur to the tibia to position the calcaneal bone plug in the femoral tunnel.

ial tunnel to exit on the anteromedial tibia. The calcaneal bone plug is passed through the anteromedial femur using a Beath needle placed through the PCL femoral tunnel to exit in the anteromedial thigh. A probe is used under arthroscopic guidance to facilitate passage of the calcaneal bone plug. The calcaneal bone plug is secured within the femoral tunnel using an interference screw. If interference screw fixation is not possible, a separate femoral incision is made, and the no. 5 nonabsorbable suture attached to the calcaneal bone plug is tied over a plastic button. The ACL graft is then passed retrograde from the tibial to femoral tunnel using a Beath needle and is secured on the femoral side with a 7 × 25-mm interference screw.

Final Fixation

The tibial sides of the grafts are not secured until after the collateral ligament injuries are addressed. Extra-

articular repairs or reconstructions are secured with slight internal rotation for posterolateral structures and with valgus force on the tibia for lateral collateral ligament repairs. Once collateral surgery is completed, the cruciate grafts are fixed to their respective tibial attachment sites. In contrast to isolated cruciate ligament reconstruction, cyclic loading of the grafts is not performed before final fixation. The tenuous repair or reconstruction of other injured structures of the knee precludes rigorous pre-tensioning of the cruciate grafts. Rather, the knee is taken through gentle ROM before final fixation to ensure that the reconstructed knee has not been captured. The PCL graft is tensioned and fixed to the tibia while reproducing the normal step-off of the medial tibial plateau in relation to the femoral condyle. The graft is fixed with a 10 × 30-mm bioabsorbable interference screw and/or a 4.5-mm AO screw with a soft-tissue washer with the knee held in 90° of flexion to recreate the anterolateral bundle. This reestablishes the central pivot of the knee. With the knee in full extension, the ACL graft is then secured with a 7 × 25-mm interference screw.

Medial Side Injury

For combined ACL-PCL-MCL injuries in which the medial side opens in full extension, a combined cruciate ligament reconstruction and MCL repair is performed. The MCL does not require repair if the knee does not exhibit a grade III MCL injury in full extension during the examination under anesthesia. In patients with grade III MCL injury, the cruciate tunnels are created arthroscopically before the medial side repair is done. In the acute setting with marked MCL insufficiency and extreme valgus laxity, arthroscopy may be impossible because of fluid extravasation. In such cases, a medial hockey stick incision and the arthroscope (without fluid) are used to guide tunnel placement.

For MCL repairs, a medial hockey

stick incision is made at the level of the vastus medialis muscle and is brought over the femoral epicondyle to the anteromedial tibia just medial to the patellar tendon (Fig. 7). The sartorius fascia is split and reflected to expose the MCL and capsule. Peripheral tears of the medial meniscus are repaired through this approach using nonabsorbable sutures; the MCL is repaired with nonabsorbable sutures and suture anchors. MCL and capsular avulsions are repaired anatomically with suture anchors, whereas intrasubstance MCL tears are repaired with no. 2 nonabsorbable sutures using a modified Kessler stitch.³⁷ In the chronic setting, reconstruction with a semitendinosus tendon or Achilles tendon allograft may be required in addition to repair. The repair or reconstruction is done with the knee in 30° of flexion. The knee is flexed and extended during repair to ensure that knee motion is not constrained. The cruciate ligaments are then fixed on the tibial side, as described, and the knee is braced in full extension.

Lateral Side Injury

After the cruciate ligament graft passage, a 12- to 18-cm curvilinear in-

cision is made over the lateral epicondyle. It begins midway between the fibular head and Gerdy's tubercle and then continues proximally over the lateral epicondyle, paralleling the posterior border of the iliotibial band (ITB) (Fig. 8). The peroneal nerve is identified and tagged with a vessel loop. It is easiest to locate the nerve proximally, posterior to the biceps femoris tendon, and trace it distally to its entrance into the anterior compartment of the leg. The nerve is carefully evaluated and is usually released as it passes around the fibular neck. If a nerve injury is present preoperatively, the extent of damage is noted. A formal neurolysis is usually not done, but the fascial bands at the entrance to the anterior compartment of the leg are released if a neurologic deficit is present at the time of surgery.

All of the posterolateral structures are then systematically evaluated. In acute injuries, there may be significant stripping and detachment of both ligaments and tendons. The interval between the posterior edge of the ITB and the biceps femoris tendon is developed. The ITB insertion also can be partially released subper-

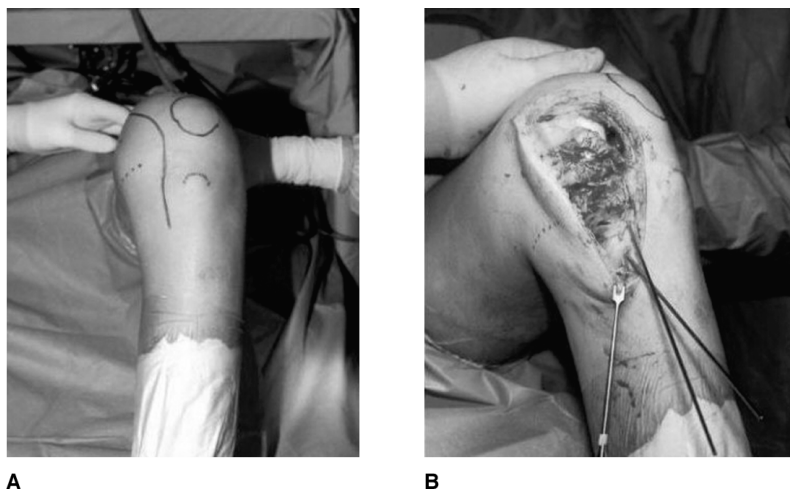


Figure 7 Medial approach to a knee dislocation involving injury of the ACL, PCL, and MCL. This patient also had an associated injury to the medial meniscus that required repair. **A**, Incisions for medial approach. **B**, Medial approach with guidewires present for drilling ACL and PCL tunnels and exposure of medial joint line for meniscus repair.

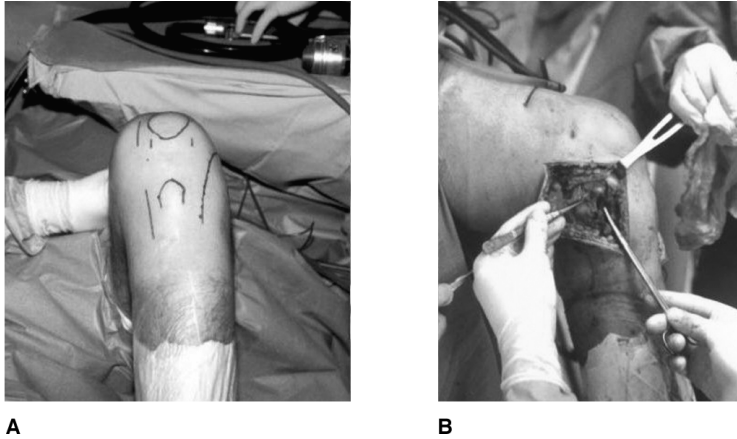


Figure 8 Lateral approach to a knee dislocation involving injury of the ACL, PCL, and LCL as well as the posterolateral structures. **A**, Incisions for combined ACL-PCL-posterolateral corner injury. **B**, Lateral exposure for repair of the posterolateral corner and LCL injuries. (Reproduced with permission from Cole BJ, Harner CD: The multiple ligament injured knee. *Clin Sports Med* 1999;18:241-262.)

ioestally from Gerdy's tubercle to increase exposure to the LCL and popliteus tendon insertions. All repairs and reconstructions are performed with the knee in 30° of flexion.

Peripheral tears of the lateral meniscus are repaired with nonabsorbable sutures, and capsular avulsions are fixed with suture anchors. Bony avulsions of the LCL or popliteus tendon are anatomically repaired. Achilles tendon allograft can be used for LCL reconstruction; a 7- to 8-mm bone block is fixed to the fibular head with a metal interference screw. The Achilles tendon allograft is secured to the lateral femoral epicondyle with suture anchors. The remaining LCL is meticulously dissected to preserve its proximal and distal remnants. These remnants are tensioned and sutured to the Achilles tendon allograft that has been secured to the lateral femoral condyle (Fig. 9).

If there is increased posterolateral rotation on the preoperative examination, the popliteus tendon and its various attachments are addressed. The location of injury determines the treatment method; femoral avulsions are repaired directly. A popliteofibular reconstruction is performed for

midsubstance injuries using hamstring autograft or tibialis anterior tendon allograft. A tunnel is created in the proximal fibula. The graft is passed deep to the LCL and placed into a closed-end tunnel at the ana-

tomous femoral insertion site of the popliteus tendon (Fig. 10). Its femoral attachment is then tied over a plastic button on the medial femoral cortex. The distal end is pulled through the tunnel created in the fibular head and tensioned with the knee in 30° of flexion. Fixation is achieved with a bioabsorbable interference screw placed in the fibular head tunnel. In patients who require combined LCL and popliteofibular ligament reconstruction, the distal end of the popliteofibular graft is brought posterior to anterior through a soft-tissue tunnel created at the insertion of the biceps femoris tendon.

Rehabilitation

Postoperative rehabilitation is critical to patient outcome. For the first 6 to 8 weeks, the primary goal is to decrease swelling and maximize quadriceps muscle firing.⁵¹ With primary repair, the initial fixation may be tenuous and vulnerable to failure if

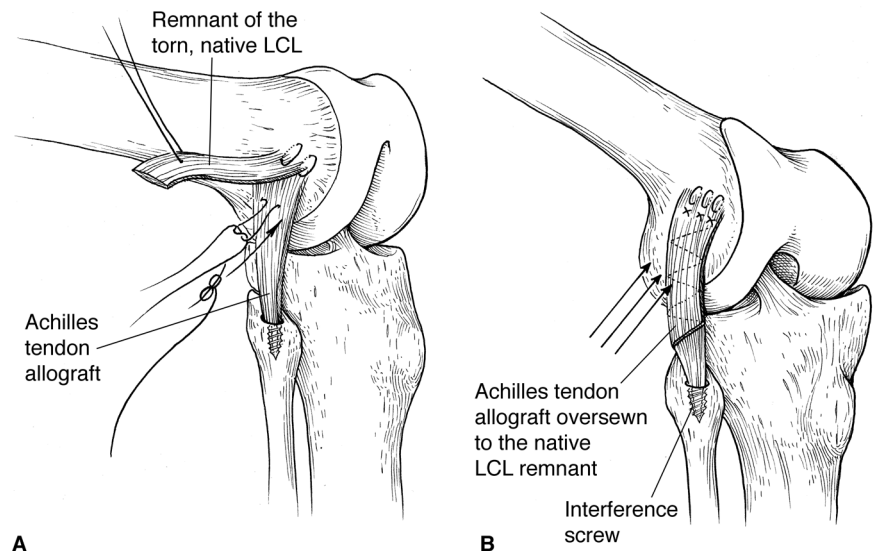


Figure 9 Reconstruction of the LCL. **A**, Calcaneal bone block of the Achilles tendon allograft is secured to the fibular head using an interference screw. The tendinous portion of the Achilles tendon allograft is sutured to the insertion of the native LCL. **B**, The tendinous portion of the Achilles tendon allograft is oversewn to the native LCL remnant. (Adapted with permission from Cole BJ, Harner CD: The multiple ligament injured knee. *Clin Sports Med* 1999; 18:241-262.)

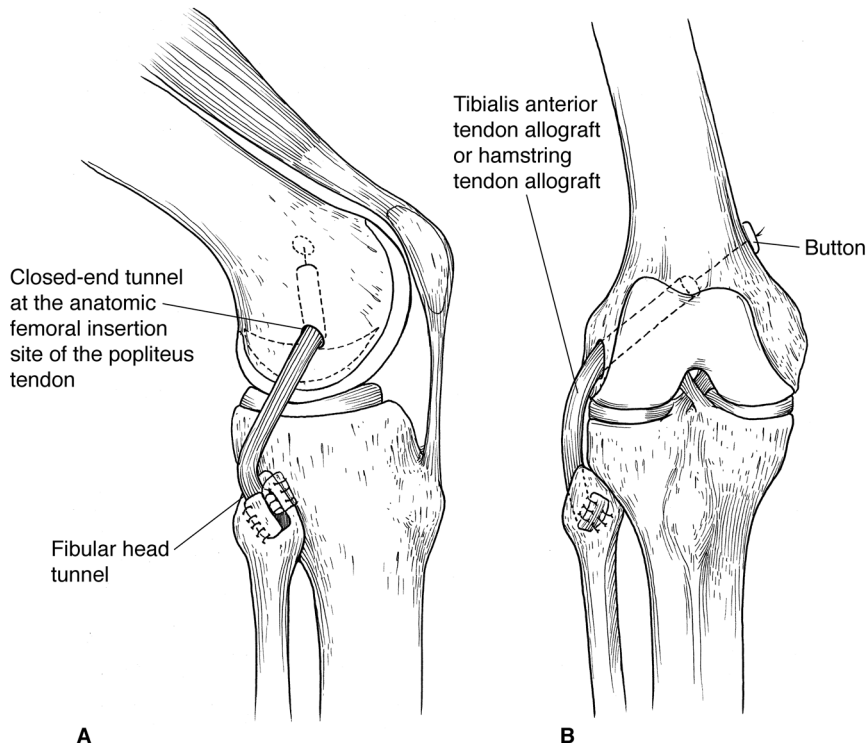


Figure 10 Lateral (A) and anteroposterior (B) views after reconstruction of the popliteofibular ligament. (Adapted with permission from Cole BJ, Harner CD: The multiple ligament injured knee. *Clin Sports Med* 1999;18:241-262.)

stressed too early. Therefore, the knee should remain in a brace locked in full extension for the first 4 weeks to provide maximum protection. Initial rehabilitation should focus on restoring full passive extension symmetric to that of the uninjured knee and restoring quadriceps muscle function such that the patient can perform a straight leg raise without a quadriceps lag. Exercises immediately after surgery include passive knee extension (avoiding hyperextension in patients with repair or reconstruction of the posterolateral structures), isometric quadriceps sets, and straight leg raises. High-intensity electrical stimulation may be used to improve quadriceps function.

Passive ROM is begun 2 to 3 weeks postoperatively with a physical therapist, preventing posterior tibial subluxation during flexion by applying an anterior force to the proximal tib-

ia. Active flexion is avoided for the first 6 weeks to prevent posterior tibial translation resulting from hamstring contraction. During this period, motion is limited to 90° of flexion. After 6 weeks, passive and active-assisted ROM and stretching exercises are begun to increase knee flexion. Knee flexion symmetric to that of the uninjured knee should be achieved within 12 weeks.

Quadriceps exercises are progressed to limited-arc, open-chain knee extension exercises as tolerated after 4 weeks. These exercises are performed only from 75° to 60° of knee flexion to prevent excessive stress on the reconstructed grafts. Open kinetic chain knee flexion is avoided for at least 3 months to prevent posterior tibial translation resulting from hamstring contraction. Closed-chain hamstring exercises should be avoided for the first 6 weeks after surgery.

Progression from partial to full weight bearing as tolerated is done over the first 4 weeks unless a lateral repair or reconstruction was performed. In those cases, patients must remain partial weight bearing and locked in extension for 8 weeks to protect the lateral structures. Once patients have regained good quadriceps control (approximately 4 weeks), the brace may be unlocked for controlled gait training. Patients generally require crutches for 6 to 8 weeks depending on ROM, strength, and ambulatory ability. The brace is usually discontinued at approximately 6 to 8 weeks after 90° to 100° of knee flexion is achieved. Gentle manipulation is required in patients who struggle to regain flexion (<90°) beyond 8 to 12 weeks. Running is permitted at 6 months if 80% of quadriceps strength has been achieved. Return to sports averages between 9 and 12 months. Patients may return to sedentary work in approximately 2 weeks and to heavy labor in 6 to 9 months.

Results

Studies that evaluate the results of surgical management of knee dislocation are limited in number and vary in regard to the involved ligamentous injuries, surgical technique, graft selection, outcomes assessment, and postoperative rehabilitation.^{9-12,42} Thus, it is difficult to draw conclusions regarding the efficacy of surgical treatment.

Harner et al⁵² recently reviewed the results of the protocol described above for surgical and postoperative management of knee dislocation with associated multiple-ligament injury. Forty-seven consecutive patients who presented with a spontaneously reduced or grossly dislocated knee between 1990 and 1995 were reviewed. Fourteen of these patients were not included in the study because of confounding variables that altered the treatment protocol: four open knee dislocations, five vascular injuries,

three patients treated with external fixation, one patient with a severe head injury, and one with a contralateral, below-the-knee amputation. The remaining 33 patients underwent treatment according to the protocol. Thirty-one of 33 patients were available for evaluation at a mean of 44 months after surgery. Nineteen patients underwent surgery <3 weeks after the initial injury (acute treatment). Twelve patients underwent surgery ≥3 weeks (average, 6.5 months) after the initial injury (chronic treatment). Three of four patients with injury to the common peroneal nerve had transient symptoms that resolved within 3 months after surgery; one had permanent symptoms necessitating a tendon transfer 9 months after surgery.

Clinical results were determined with a questionnaire and physical examination. The mean score on the Activities of Daily Living Scale of the Knee Outcome Survey was 91 points for patients with acute treatment and 84 points for patients with chronic treatment ($P = 0.07$).⁵² Patients in the acute group had a mean Knee Outcome Survey Sports Activities Scale score of 89, compared to a mean score of 69 in the chronic group ($P = 0.04$).⁵² Sixteen of the 19 acutely treated knees and 7 of the 12 chronically treated knees had an excellent or good Mey-

ers score. Improved stability was found in all patients on physical examination, with more predictable results in the acute group. No statistical difference in ROM was evident between patients treated acutely versus chronically. Four patients, all of whom were treated acutely, required manipulation under anesthesia because of postoperative stiffness.

These results are consistent with other reports of surgical management of knee dislocation with allograft reconstruction of the cruciate ligaments.^{9,11,12,42} The protocol used by Harner et al⁵² for the treatment of the knee with multiple ligament injuries seems to offer good functional outcome, ROM, and stability for most patients, particularly those treated within 3 weeks of initial injury. Most patients are able to perform daily activities without difficulty; however, return to high-demand sports activity is less predictable. Patients treated for a chronic injury are more likely to have functional limitations than are those treated within 3 weeks of initial injury.

Summary

Traumatic knee dislocation is relatively uncommon. Because of the severity of this injury and the potential for

devastating complications, however, it is necessary to understand the principles of evaluation and management of knee dislocation. Evaluation consists of a brief history, thorough neurovascular evaluation, ligamentous examination, and radiographic studies. Angiography should be used whenever knee dislocation is suspected to evaluate for the presence of a popliteal artery injury. Initial management includes prompt reduction and stabilization followed by reassessment of the neurovascular status of the limb and postreduction radiographs. Emergent surgery is indicated in patients with open dislocation, compartment syndrome, vascular injury, and irreducible dislocation.

Definitive management of the knee with multiple ligament injuries remains a controversial topic. Satisfactory results can be achieved with early reconstruction of both the ACL and PCL using allograft tissue along with allograft reconstruction of complete LCL injuries, repair or allograft reconstruction of injured posterolateral structures, and early repair of complete MCL injuries. Although technically challenging, adequate knee stability, ROM, and knee function can be obtained after anatomic repair or reconstruction and appropriate postoperative rehabilitation of the dislocated knee.

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