Diagnosis and Management of Knee Dislocations

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Abstract: An acute knee dislocation is an uncommon injury, with a high rate of associated vascular and neurologic injuries as well as potentially limb-threatening complications. High-energy trauma is the most common cause of an acute knee dislocation, although lower-energy injuries, such as those sustained during athletic competition, are increasing in incidence. Injuries to the popliteal artery and common peroneal nerve are relatively common, requiring a high index of suspicion and complete neurovascular examination in a timely fashion. All cases of suspected knee dislocation should have an ankle-brachial index performed, reserving arteriography for those with an abnormal finding. Initial management consists of closed reduction, if possible, and application of a hinged brace or external fixator. Definitive management remains an area of controversy, although anatomic surgical repair or reconstruction is favored by most surgeons to help optimize knee function. Most patients treated for a knee dislocation can expect to return to their daily activities, but with less predictable returns to sporting activities.

Keywords: knee; dislocation; ligament injury; vascular injury

Introduction

Acute knee dislocation is an uncommon diagnosis in orthopedics, with a high rate of associated injuries and potentially limb-threatening complications. The reported incidence is < 0.02% of musculoskeletal trauma, although this is likely an underestimate because of an unknown number of spontaneous reductions shortly after injury. Reports of long-term instability and pain are common following a diagnosis of knee dislocation. Although management principles have progressed over the past 20 years, optimal treatment of these injuries remains controversial. Few high-level evidence studies are available to help guide management. The low incidence and heterogeneous nature of the injury makes randomized controlled trials difficult to facilitate. A basic knowledge of the topic, with particular attention to physical examination and initial management, will allow the treating physician to manage a patient with a knee dislocation appropriately, with a potentially reduced risk of complications. This article reviews the epidemiology, diagnosis, management, and outcomes of acute knee dislocations.

Mechanism of Injury

Historically, motor vehicle collisions have been cited as the most common cause of acute knee dislocations. More recently, lower-energy injuries, such as those sustained during athletic competition, have been reported as an increasingly common cause (Figure 1). The combination of modern athletes being stronger, faster, and larger than those in the past, with the increasing popularity of extreme-type sports, in which high-speed collisions and falls from great heights are more frequent, likely account for this finding. Another likely contributing factor is that a larger proportion of individuals are maintaining athletic endeavors into older age. Morbidly obese patients may have a higher incidence of knee dislocation with low-energy injuries, as the physiological stress on the knee is increased exponentially compared with nonobese patients.

Classification

Several classification systems have been previously used to describe knee dislocations, although no system has been demonstrated to be prognostically significant. The first system, developed by Kennedy in 1963, describes the direction of displacement of the dislocated tibia with respect to the femur. This system is useful in that it helps guide closed reduction based on the direction of dislo-
However, its overall utility is limited because it does not identify specific sites of soft tissue pathology. Other classification systems have grouped dislocations based on the energy imparted at the time of injury (high, low, ultralow) or the period of time from injury to management (acute vs chronic), with 3 weeks being the division point.\(^{14-17}\) The anatomic classification system, developed by Schenck\(^{18}\) and subsequently modified by Wascher et al.,\(^{2}\) is the most widely accepted. This classification stratifies knee dislocations based on the ligaments that have been injured, presence of fracture, and associated vascular or neurologic injury (Figure 2). In addition to the classification systems described previously, the definitive description of a knee dislocation should include whether the injury is open or closed and the period of time since the injury occurred.

**Associated Injuries**

The clinical sequelae of a knee dislocation, namely multiligamentous knee injury, usually consists of disruption of \(\geq 3\) of the 4 major ligaments of the knee.\(^{19}\) Anterior is the most common direction of dislocation, closely followed by posterior. Although a hyperextension-type mechanism can cause the knee to dislocate,\(^{13}\) the more common reason is an exaggeration of the pivot-shift mechanism. The anterior cruciate ligament (ACL) resists anterior translation of the tibia with respect to the femur and is more often disrupted with an anterior dislocation. The posterior cruciate ligament (PCL) resists posterior translation of the tibia with respect to the femur and is more often disrupted with a posterior dislocation. However, the ACL and PCL are almost universally torn in combination with a knee dislocation. There are isolated reports of knee dislocation with \(\geq 1\) intact cruciate ligament,\(^{20,21}\) although this is extremely rare. Varus and valgus forces may predispose to disruption of the lateral collateral ligament (LCL) and medial collateral ligament (MCL), respectively, although these structures are rarely injured in isolation. Rotational mechanisms for knee dislocation have been increasingly recognized, with structures on the posterolateral and posteromedial corners of the joint being the primary site of injury.

In the setting of an acute knee dislocation, any intra-articular or surrounding extra-articular structure can sus-
tain injury. In particular, injuries to the popliteal artery and peroneal nerve are relatively common.\textsuperscript{22–24} Intra-articular and periarticular fractures can also complicate management.

The popliteal artery is estimated to sustain injury in 10% to 40% of knee dislocations, with anterior or posterior mechanisms being the most common.\textsuperscript{25} The popliteal artery’s predisposition to injury is due to fibrous tethering both proximally at the adductor hiatus and distally at the soleus arch (Figure 3).\textsuperscript{26} These anatomical features not only limit the excursion of the popliteal artery, but also cause it to be in an anatomically vulnerable position, in close proximity to the posterior knee joint capsule, separated only by a thin layer of adipose tissue. In addition, poor collateral vascular flow proximal to the trifurcation of the popliteal artery contributes to the susceptibility of the lower leg to inadequate distal perfusion. The severity of an arterial injury lies on a continuous spectrum, progressing from vasospasm, to intimal tear, to frank transection. Vasospasm should never be used as an explanation for dysvascularity; rather, an alternative cause should be sought. Many vascular injuries are non-flow-limiting intimal tears that rarely progress to flow-limiting lesions.\textsuperscript{27–29} With respect to flow-limiting lesions, some evidence suggests that a vascular injury resulting in > 8 hours of arterial occlusion substantially increases the risk of the patient requiring an above-knee amputation.\textsuperscript{30} Many surgeons will use 6 hours as their threshold for performing vascular reconstruction, as procedures performed at > 6 hours have substantially higher complication rates.\textsuperscript{31}

The incidence of nerve injury associated with knee dislocation is 10% to 35%, although there is wide variation in reported series.\textsuperscript{32,33} The peroneal nerve is the nerve most commonly injured. Analogous to the anatomy of the popliteal artery, the common peroneal nerve is constrained proximally at the fibular neck and distally at the intermuscular septum by fibrous arches that limit its excursion potential. In addition, the peroneal nerve may be inherently predisposed to hypoxic injury compared with other peripheral nerves because of its precarious blood supply and lack of intraneural vessels in the region of the fibular neck.\textsuperscript{34} In contrast with vascular injuries, where displacement of the knee occurs in the sagittal plane, the mechanism resulting in neurologic injury usually occurs in the coronal plane, resulting in tension being placed on the peroneal nerve. This mechanism may also help explain the higher incidence of associated fibular head fractures in the setting of peroneal nerve injury. Injury to the tibial nerve has also been reported in association with knee dislocation, although it is quite rare.\textsuperscript{1}

Periarticular fractures frequently occur in the setting of knee dislocation. These may occur in the patella, tibial plateau, supracondylar femur, or in association with a ligamentous injury causing an avulsion-type injury (most commonly a fracture of the fibular head) (Figure 4). These fractures rou-
Physical Examination

Physical examination of a patient with a suspected knee dislocation should take place shortly after the injury is sustained. These patients have often sustained multisystem trauma and should be assessed using the Advanced Trauma and Life Support protocol as a priority (Figure 5). Following initial resuscitation, a focused examination of the lower limb should begin with inspection to exclude any evidence of open injury, gross malalignment, ecchymosis, blisters, or skin mottling. Open injuries occur with an incidence of between 19% and 35%, and have greater surgical urgency and overall higher complication rates.36,37 The presence of a “dimple sign” overlying the medial femoral condyle frequently represents buttonholing of the medial femoral condyle through the anteromedial joint capsule following a posterolateral rotatory injury mechanism (Figure 6). This is an important physical finding, as it can be a predictor of a dislocation that is irreducible by closed methods.38–40

The physical examination continues with an assessment of the vascular status of the affected limb. Hard signs of vascular injury, such as active hemorrhage, expanding hematoma, and distal ischemia, should alert the treating physician to the need for immediate vascular imaging. Soft findings of vascular injury, such as limb color and capillary refill, have been described for vascular assessment; however, their reliability and clinical utility remain unclear.41 The options for vascular assessment include: physical examination alone, physical examination with measurement of ankle-brachial index (ABI), or routine arteriography. In all cases, the physician should palpate for the presence of both the dorsalis pedis and posterior tibial pulses. Although there is evidence to suggest that the presence of normal distal pulses exclude clinically significant
vascular injury with 100% sensitivity, we strongly advocate that an ABI be performed in any patient suspected of having a knee dislocation. The ABI is measured with a Doppler ultrasound probe by measuring the systolic pressure in the affected leg at a level just proximal to the ankle and dividing this value by the systolic pressure in the ipsilateral arm (Figure 7). An ABI value of 0.9 has been shown to be a reliable marker of normal arterial patency; however, this measurement may be less reliable in patients with peripheral vascular disease with vessel calcification. Further investigation with arteriography or imaging with vascular reconstruction is warranted in the setting of an abnormal physical examination and an ABI of < 0.9.

Assessment of neurological function requires testing of both the common peroneal nerve and tibial nerve. Both the sensory and motor functions of these peripheral nerves must be evaluated because they can be affected independently. This evaluation can be difficult when patient compliance has been compromised by head injury or intoxication. Proper documentation of neurologic status is particularly important when a knee joint reduction maneuver is planned.

A complete examination (though sometimes difficult to perform in the acute setting) includes assessment of the ligamentous structures of the knee, particularly the ACL, PCL, MCL, LCL, posterolateral, and posteromedial corners. Ideally, the assessment is performed only once and in a gentle fashion so as not to induce pain or further injury. Although optimally performed by a surgeon with expertise in multiligament knee reconstruction, this may not be practical for a patient who is initially managed by an emergency department physician.

The most sensitive test for ACL injury is the Lachman test, and the most sensitive test for PCL injury is the posterior drawer test. In the case of a combined ACL/PCL injury, the drawer tests may be difficult to interpret and one must pay particular attention to the step-off between the medial tibial plateau and medial femoral condyle. Competency of the MCL and LCL are assessed by imparting a valgus and varus force, respectively, to the knee. This is best accomplished with the knee first in full extension followed by 30° of flexion. Comparison with the contralateral limb is useful for identifying pathologic laxity. The final component in assessing the soft tissue of the knee involves a test evaluating the competence of the extensor mechanism. This may be accomplished by direct palpation or a straight leg elevation test. Although injuries to the extensor mechanism are rare, the high morbidity associated with loss of active knee extension necessitates early recognition and treatment (Figure 8).

To complete the physical examination, the fascial compartments of the lower leg should be palpated because compartment syndrome may occur with or without concomitant vascular injury. In the setting of an obtunded or noncompliant patient with abnormally tense compartments, consideration should be given to invasive compartment pressure measurement.
Investigations

Following clinical diagnosis, closed reduction, and immobilization of a knee dislocation, adjunctive imaging should be obtained. Routine radiographs help to identify the direction of dislocation and the presence of associated fractures. The role of computed tomography (CT) in the evaluation of knee dislocation continues to evolve. The ability to clearly define the nature of associated fractures and the option of performing concomitant CT angiography has increased its utility, especially in cases of suspected vascular injury. Moreover, CT angiography requires only antecubital venous cannulation, whereas traditional arteriography requires femoral artery cannulation, and is also associated with a higher complication rate.

The role of arteriography, whether performed preoperatively or intraoperatively, remains a source of controversy (Figure 9). Previous management algorithms recommended routine arteriography in all cases of knee dislocation; recently, however, benefits to this approach have been proven to be limited. In addition, the potential risks to the patient and resource-intensive nature of the procedure have caused many physicians to explore other options.

Magnetic resonance imaging (MRI) is of utmost importance in the management of knee dislocation, although it should not be undertaken until the patient has been stabilized and initial management is complete. The ability of MRI to identify associated ligament, tendon, and meniscal injury is unparalleled compared with other imaging modalities. Furthermore, the specific site of ligament injury (proximal/distal) can be clearly defined, which can impact the need for surgical treatment. The accuracy of MRI for detecting the extent or site of soft tissue pathology in the setting of knee dislocation has been demonstrated to be between 85% and 100%. This range is significantly higher than the accuracy of physical examination, which is between 53% and 82%.

Initial Management

The goals of initial management of knee dislocations are to recognize and treat limb-threatening injuries and subsequently maximize long-term joint function, particularly related to motion, stability, and strength. Specific treatment depends on the exact nature of the injury, systemic status of the patient, and presence of concomitant injuries. Associated vascular injury, open injury, compartment syndrome, irreducible dislocation, or grossly unstable dislocation requires emergent surgical management.

In most circumstances of acute knee dislocation without associated injury, initial management begins with closed reduction under conscious sedation. This is an opportune time to examine the knee and assess the pattern of ligament injury and extent of instability. Gentle traction-countertraction combined with deformity correction can provide an atraumatic reduction. In a patient with an acute knee dislocation who has undergone successful closed reduction and remains reduced with a normal ABI, a hinge brace combined with repeat physical examinations, including ABI measurement, should be performed approximately every 2 hours, and continued for a minimum of 48 hours. This approach will help to detect vascular lesions that develop in a delayed fashion. A second option for temporary stabilization of the knee is an external fixator. However, there are limited data to suggest that temporizing with an external fixator instead of a hinged knee brace ultimately results in decreased range of motion. Additional potential drawbacks of external fixation include bacterial infection via pin site contamination and violation of periarticular muscle groups.

Vascular injury in association with knee dislocation requires adjunctive investigations, such as CT or traditional angiography, and the involvement of a surgeon with specialty training in vascular reconstruction. Appropriate management often requires popliteal artery reconstruction with a contralateral
eral reverse saphenous vein graft. To facilitate maturation of the vascular reconstruction, the knee joint should be temporarily stabilized with an external fixator. When considering vascular reconstruction, time is an important factor because delay in management can be associated with higher rates of procedural failure and reperfusion injury, with the potential to cause systemic complications. When the dysvascular time period approaches 6 hours, one option is to temporize with vascular shunting while harvesting the contralateral saphenous vein graft. Fasciotomies of the lower leg should be considered when a revascularization has occurred > 6 hours postinjury or at any point when there is a clinical suspicion of a frank or evolving compartment syndrome.

The use of an external fixator is indicated with a knee dislocation when there is an associated vascular repair, open injury, fasciotomy, or grossly unstable reduction that cannot be maintained with the use of a hinged brace. A relative indication for use of an external fixator is patient obesity, which often causes intolerance or fitting difficulty of a hinged knee brace. The external fixator has 3 primary advantages compared with cast bracing: 1) it allows the soft tissues to be directly monitored, 2) it simplifies repeated vascular assessments, and 3) it facilitates transportation and mobilization of patients. Soft tissue monitoring is particularly important with open dislocations or the presence of fasciotomy wounds.

Application of a knee-spanning external fixator can be performed either directly anteriorly or laterally, with pins placed in both the femur and tibia. One disadvantage of placement of the pins anteriorly is the risk for quadriceps tethering, which can cause muscle dysfunction and compromised rehabilitation. Most surgeons apply the fixator in a biplanar orientation with pins placed laterally in the femur and anteromedially in the tibia. This pin configuration limits the degree of soft tissue violation, thereby decreasing the potential for pin site infection and subsequent loosening. The external fixator should be applied with the knee in full extension, or a slight amount of flexion if a vascular reconstruction has been performed. In the past there has been concern that placement of a knee-spanning external fixator increases compartment pressures, although this appears to be a transient occurrence with little to no increased risk of progression to compartment syndrome.

External fixation has been used for definitive management of knee dislocations, although chronic laxity can result and compromise outcomes. In the scenario of temporary external fixation, the surgeon must be aware of the balance between stiffness and laxity based on the amount of time the fixator is left in place. The external fixator is typically left in place for a total of 6 to 8 weeks. It is usually removed in the operating room after the patient has been given an anesthetic, which allows for a complete examination under anesthesia and possible knee manipulation.

An open-knee dislocation requires immediate and serial irrigation and debridement, antibiotic treatment, and definitive wound coverage, as guided by a plastic surgeon. This may delay definitive management and potentially compromise patient outcome, although the risk for infection and wound dehiscence preclude early definitive management.

An irreducible dislocation, often seen with a posterolateral mechanism, is managed with an urgent open reduction. Some have advocated immediate ligamentous repair in this situation, although this approach may increase the risk of arthrofibrosis.

**Definitive Management**

Over the past 50 years, the accepted definitive management of knee dislocations has undergone many changes. Although prolonged immobilization in a splint or hinged brace was a well-accepted treatment in the past, the current goal of definitive management is anatomic repair or reconstruction of the knee ligaments and menisci to facilitate a stable, pain-free, functional knee, with the avoidance of complications. Several factors must be considered when deciding on definitive management of a knee dislocation. Patient age, ability to participate in a rehabilitation program, and desired future functional activities all help to guide treatment.

The most recent advances in definitive management have been related to specific surgical techniques, which are beyond the scope of this article.

There is a paucity of level I or II evidence regarding surgical management of knee dislocations. Although research continues, many areas of treatment remain controversial. The most controversial areas relate to repair versus reconstruction, acute versus delayed treatment, arthroscopic versus open treatment, and the use of allografts. Most orthopedic surgeons agree that the majority of multiligament knee injuries should be treated in highly specialized trauma centers possessing the facilities and experience to manage patients with complicated orthopedic injuries.

The rationale for surgical management of knee dislocations is primarily derived from retrospective studies comparing conservative and surgical management.
of 132 knee dislocations demonstrated improved motion and functional outcome scores in surgically treated knees.72 However, there were no differences with respect to stability and return to work.

Most surgeons prefer to delay surgery in the majority of cases for 10 to 14 days. This latency period allows for swelling to decrease, quadriceps function to improve, and partial healing of the knee joint capsule. Surgery performed before the 3-week mark has shown better clinical stability and increased functional outcome scores when compared with delayed surgery.73–75 Moreover, complications from scar tissue formation are more commonly seen in a delayed repair. Capsular healing allows an arthroscopic technique to be used for cruciate ligament reconstruction with a decreased risk of iatrogenic compartment syndrome. Ideally, the ACL and PCL are reconstructed arthroscopically, and the posterolateral and posteromedial corners, MCL, and LCL are repaired in an open fashion.76

When available, the use of allografts has gained widespread acceptance in the setting of multiligament knee reconstruction. Common allograft selections include the Achilles tendon and the tibialis anterior tendon. The advantages of allograft use include decreased donor site morbidity, shorter operative times, and increased availability. However, concerns remain with respect to disease transmission, although the cited rate of transfection is extremely low.77 Several studies have shown overall good results with allograft reconstruction (Figure 10).78,79

### Rehabilitation

Optimization of postoperative outcomes following knee reconstruction requires a focused rehabilitation program with a coordinated effort from a multidisciplinary team. Several formal rehabilitation protocols have been published showing consistently good results.80,81 Patient compliance is placed at a premium to ensure increased mobility with minimal risk of failure. Some basic rehabilitation principles include an initial period of non-weight bearing, closed-chain exercises early to decrease the shear forces across the knee, and quadriceps strengthening prior to hamstring strengthening. Postoperative management of elite athletes presents additional challenges, such as increased pressure to return to sport early and subsequent exposure of the knee to supraphysiologic loads.

The process of rehabilitation should be tailored to the individual patient based on the pattern of injury and specifically reconstructed or repaired ligaments. General guidelines include: range of motion exercises at 2 weeks, full weight bearing at 4 weeks, return to sedentary work at 4 to 6 weeks, and return to heavy labor at 6 months. Finally, sporting activities should be restricted until approximately 9 to 12 months following reconstruction.82

### Patient Outcomes

It is difficult to draw definitive conclusions in regards to outcomes following knee dislocations because of the relative rarity of the injury and the variability of the specific injury pattern, operative technique, graft selection, and rehabilitation protocol.83 Patients who sustain a knee dislocation have decreased range of motion, increased instability, greater pain, and lower functional outcome scores compared with uninjured age-matched controls.84,85 Risk factors for poor outcome include: open injury, delayed definitive reconstruction, vascular injury, and nerve injury.86 In addition, higher-energy injuries portend a poorer prognosis when compared with lower-energy injuries.87

Elite athletes who sustain knee dislocations represent a special subset of patients. Expectations for a full return to sporting activities at the same competitive level must be tempered by the treating physician. A recent review of elite athletes with knee dislocations demonstrated a 79% return to sport, with only 33% of athletes returning to the same pre-injury competitive level.88 Overall, most authors would agree that the majority of patients treated for a knee dislocation can expect a return to their activities of daily living, with varying degrees of functional loss based on the severity of injury, success of reconstruction, and the presence of associated vascular, neurologic, or open injury.

### Summary

Acute dislocation of the knee is an uncommon diagnosis with the potential for limb-threatening complications. Con-
comitant injuries to the popliteal artery and peroneal nerve are relatively common and necessitate a high index of suspicion. An appreciation of these associated injuries and appropriate initial management can minimize the risk for devastating sequelae. Initial management consists of focused and repeated physical examinations, atraumatic reduction, appropriate investigations, and temporary stabilization. In addition, the need for vascular reconstruction, open reduction, and external fixation are dictated by the specific injury. Definitive management continues to evolve, with the overall goal of providing a stable and pain-free functional knee. In the absence of severe soft tissue trauma, early anatomic reconstruction combined with a dedicated physiotherapy program provides acceptable results in terms of pain and instability; however, few patients return to a high level of physical function.

Conflict of Interest Statement


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