Review Article

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Assessment and Decision Making in Acute Knee Dislocation

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Abstract

The traumatic knee dislocation (KD) is a complex condition resulting in injury to more than one ligament or ligament complexes about the knee. Most of the time, KDs result in injury to both cruciate ligaments with variable injury to the collateral ligament complexes. However, there are rare presentations of a single cruciate and collateral ligament injury that present with the tibiofemoral joint dislocated. With the use of the term multi-ligamentous knee injuries (MLKI), it is important to understand that not all MLKIs are KDs. Knees can present in a wide spectrum of severity; from frank dislocation of the tibiofemoral joint to a spontaneously reduced KD, either with or without neurovascular injury. The initial evaluation of these injuries should include a thorough patient history, physical exam and imaging, with particular attention to vascular status which has the most emergent treatment implications. Multiple classification systems have been developed for KDs, with the anatomic classification having the most practical application.

Keywords: Knee dislocation (KD), Multi-ligament knee injury, Assessment, Classification

Introduction

The understanding of knee dislocations (KD) has continued to change and improve over the past few decades. Once rare, these injuries are becoming increasingly recognized and an area of specialized interest to orthopaedic practitioners who have experience treating these patients. KD's were once rare enough that it was surprising to see more than one during the career of an orthopedic surgeon [1]. Rates are now 0.02-0.2% of all orthopedic injuries [2]. The causes for this increase in frequency are multifactorial and include higher exposures to trauma, decreased mortality from trauma due to improved care and safety measures, an increase in extreme activities and sports, and increased awareness by clinicians [2, 3]. Additionally, the increasing trend of ultra-low-velocity KDs are attributed to the rise in obesity [4]. Wascher et al. showed that up to 50% of KDs present with the tibiofemoral joint in a reduced position which may contribute to a higher incidence than previously published [5]. Recognition of the spontaneously reduced KD has improved, likely leading to even higher numbers than previously seen in the literature. It is important to remember that the incidence of neurovascular injury in spontaneously reduced KDs is the same as those that present dislocated. Typically, KDs result in injury to both cruciate ligaments with variable injury to the collateral ligament complexes. Very rarely, KD may occur with single cruciate injuries combined with collateral involvement; it is important to understand that not all MLKIs are KDs.

Classification systems serve many purposes and many factors contribute to their utility. A classification system should direct the decision-making process, especially in surgical management, and also convey the severity of the injury. In general, systems should be simple and reproducible. This also aids in both communication among providers and overall acceptance of its utilization. Knee dislocations have been classified by position, energy of the injury, pathophysiology, or the injured anatomic structures. Here we will review the initial evaluation of the dislocated knee, review the attributes of standard classification systems, and discuss management in general terms.

Initial Evaluation

As noted previously, KDs can present in a reduced or frankly dislocated position. Obtaining a thorough history including the mechanism and timing of injury, an accurate physical examination, and pertinent imaging studies can allow for appropriate management and reduce the risks associated with these devastating injuries. The clinician must understand that one half of all KDs will present reduced and early recognition requires a clinical exam, especially looking for the presence of a swollen knee in all trauma patients.

History

These injuries are frequently the result of a high energy mechanism such as a motor vehicle collision; however, they can also be seen in sporting injuries or with simple mechanisms such as a fall from standing in the morbidly obese population (ultra-low-velocity KD). The treating physician should have a high index of suspicion when evaluating the patient, particularly in a polytrauma setting or in the morbidly obese patient. The time elapsed since the injury occurred and whether there is

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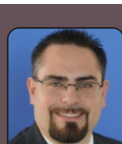
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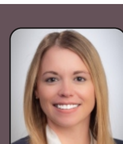
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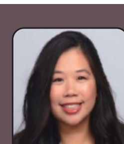
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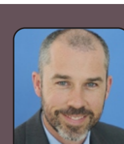
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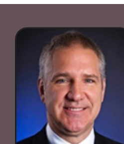
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Figure 1: AP radiograph of a knee fracture-dislocation.

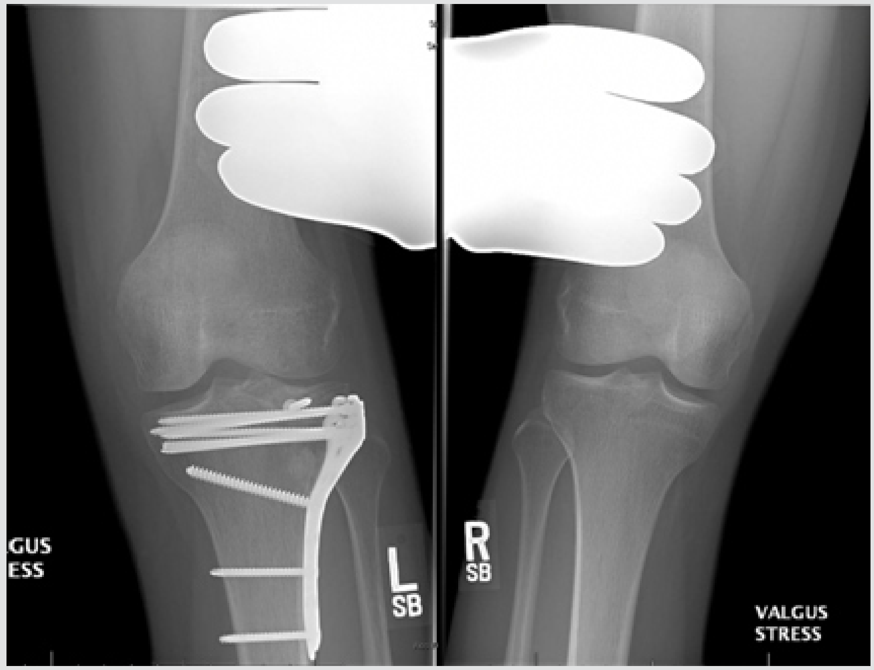

Figure 2: Valgus stress radiographs of the injured (A) compared to uninjured (B) knee demonstrating medial compartment gapping and associated medial-sided knee injury.

any history of an abnormal vascular examination prior to arrival at the treating institution are critical data that will help determine the need for advanced vascular imaging, treatment and limb salvage.

Physical Examination

Even in the era of MRI, the most important part of the initial evaluation of the KD is a thorough physical exam. KDs occur in polytrauma patients and, therefore, examination of the patient's head, abdomen, chest, and extremities should be completed. Life-threatening intracranial, thoracic, abdominal injuries, and cardiovascular collapse should take precedence over ligamentous treatment of KDs. Initially, the knee should be assessed for obvious deformity including medial skin furrowing that may indicate a posterolateral KD, open wounds, range of motion, and extensor mechanism function. Ruptures of the extensor mechanism can often be palpated, and recognition of these injuries is critical prior to planning surgical treatment [6]. A thorough knee exam should be completed including a Lachman exam to assess anterior cruciate ligament (ACL) stability, posterior drawer test to assess posterior cruciate ligament (PCL) stability, varus and valgus tests at 0° and 30° to assess fibular collateral ligament (FCL) and medial collateral ligament (MCL) stability, respectively, and dial test to assess posterolateral corner (PLC) stability. Since an accurate Lachman exam needs to be completed at 20° of flexion, one way to make it relatively painless is to place the examiner's knee or a bolster under the patient's thigh. This technique is called a stabilized Lachman [7]. The quadriceps active test can be used to examine PCL integrity [8]. The patient is asked to actively contract their quadriceps muscle while supine with the knee flexed to 90°. The examiner evaluates for anterior shift of the tibia, 2mm or more. Lastly, varus and/or valgus stress in full extension with gross opening is often indicative of a bicruciate and collateral ligament injured knee.

The neurovascular exam is the most critical aspect of evaluating KDs. A delay in vascular injury diagnosis can lead to compartment syndrome and/or amputation in up to 20% of patients [9]. The rate of popliteal artery injury varies depending on the study, ranging from as high as 64% to as low as 3.3% in the largest North American study of 8050 KDs [10-13]. The vascular exam should include palpation of the dorsalis pedis and posterior tibial pulses. A lack of symmetry in pulses is highly sensitive for vascular injury, as is an expanding popliteal

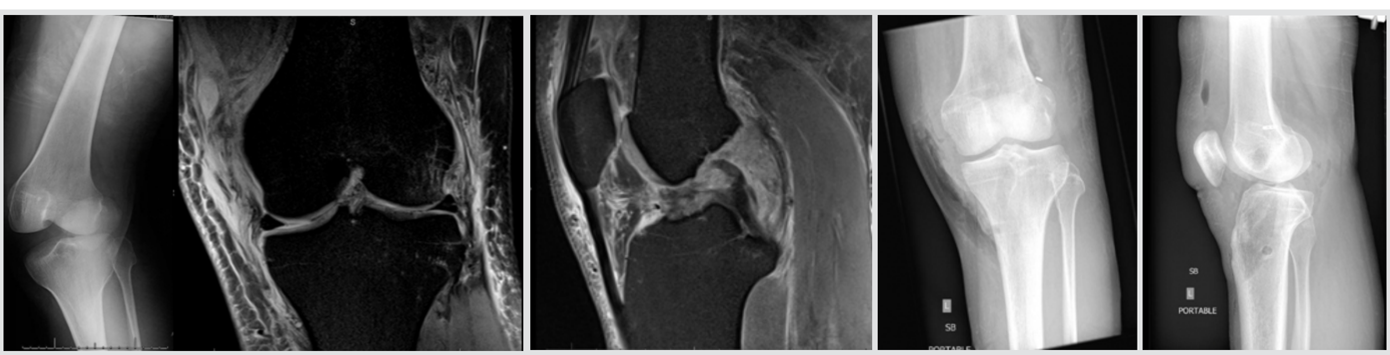

Figure 3: (A) AP radiograph of a KDI-M (ACL/MCL injury). , (B) Coronal and (C) sagittal MRI images demonstrating the ACL and MCL injuries. (D) AP and (E) lateral radiographs post-ACL reconstruction with hamstring autograft and MCL reconstruction with hamstring allograft plus posterior medial capsule/posterior oblique ligament imbrication.

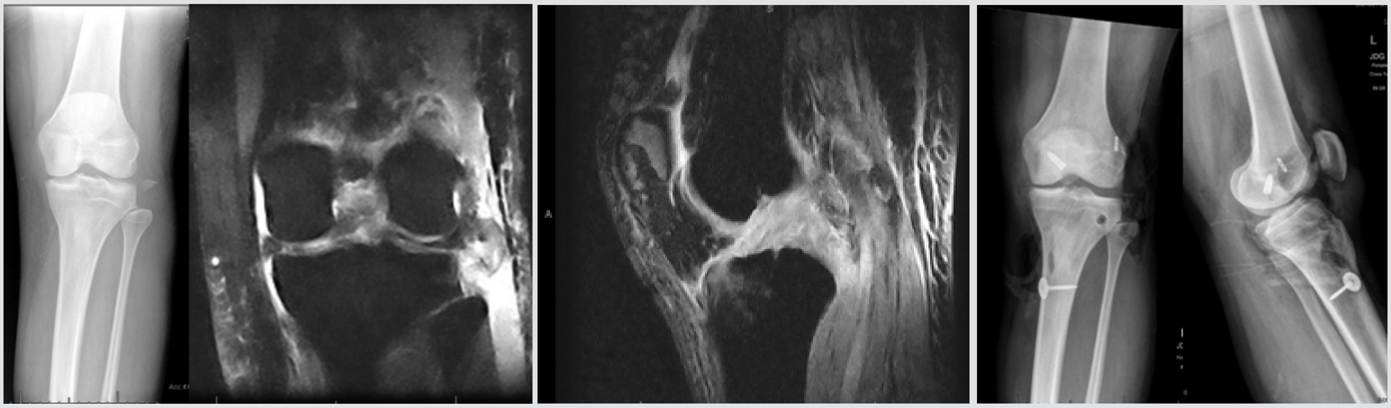

Figure 4: (A) AP radiograph of a KDIII L injury with proximal fibula fracture. Magnetic resonance imaging showing coronal (B) and sagittal (C) images in the setting of a KDIII L injury. AP (D) and lateral (E) post-operative radiographs following ACL reconstruction with hamstring autograft, double bundle PCL reconstruction with allograft, and LaPrade-type posterolateral corner reconstruction with allograft.

hematoma [14]. In addition, ankle-brachial indices (ABIs) should be obtained and documented. The patient with 1) history of abnormal vascular exam at any point in time after injury, 2) asymmetric pulses (monitored over 48 hours), or 3) ABI less than 0.9 requires advanced imaging such as duplex arterial ultrasonography, CT angiography, or angiography to determine the need for vascular intervention [15-16]. In the presence of clinical ischemia, vascular exploration/reconstruction should not be delayed secondary to delays in imaging studies. Lastly, ultra-low-velocity KDs have a very high risk of neurovascular injury noted about 40% of the time. In other words, KDs from incidental falls in obese patients must be carefully evaluated for a nerve or popliteal artery injury [4].

It is also extremely important for treatment planning and prognosis to assess both the peroneal and tibial nerve motor and sensory function pre-operatively. The rate of peroneal nerve palsy in association with KDs has been reported to be between 25% and 40% [17-19]. Partial nerve injuries have a better prognosis for recovery and function compared with complete nerve injuries [20]. However, since many KDs occur in polytrauma patients it is not always possible to get an accurate exam. Nonetheless, when utilizing observation of pulses as a tool in ruling out vascular injury, the presence of any neurological abnormality about the knee precludes the use of observation and secondary studies must be obtained.

Figure 5: Coronal MRI image of a KDV involving a lateral plateau fracture and MCL injury.

Imaging

After appropriate physical exam, plain radiographs of the knee should be obtained to assess for fractures and tibiofemoral alignment (Fig. 1). Repeat plain films should be obtained after an attempted reduction maneuver to rule out irreducible knee dislocations and to identify any bony avulsions or fractures which are often difficult to see on initial radiographs of a dislocation. After successful reduction, distraction can often be seen on plain films of a KD. Up to 9% of KDs have been shown to also have instability at the proximal tibiofibular joint [21] and palpation on examination as well as a satisfactory lateral radiograph are critical to rule out the easily missed proximal tibiofibular dislocation.

Plain films are useful in evaluating rim or joint surface fractures and avulsion fractures of the ACL, PCL, popliteofibular ligament, iliotibial band, and Segond-type injuries. Magnetic resonance imaging (MRI) should be routinely obtained once the patient's overall condition allows, even if an external fixator has been placed. MRI is very useful in diagnosis and treatment of KDs when used in combination with plain films and a thorough physical exam. This study can evaluate which structures are injured as well as the degree of injury [22-23]. Stress radiography is also a useful tool and can be used to identify cruciate, posterolateral, and posteromedial corner injuries and also compare side-to-side differences to further assess the integrity of ligaments [24] (Fig. 2). (Table 1)

Even with a stabilized Lachman exam and other advanced techniques, a thorough ligamentous exam is sometimes only possible with an exam under anesthesia (EUA). Without patient guarding and feedback, a side-to-side comparison can be made of the functional integrity of injured structures. Ligaments that demonstrate injury on an MRI in the acute setting may be functionally intact and may not require surgical intervention. Cruciate and capsular injuries can heal by the time surgery occurs since polytrauma patients often have other more pressing injuries that can delay ligamentous reconstruction. An EUA at the time of surgery is the best way to assess these structures functional integrity [25]. PCL and collateral injuries are often clinically intact despite having an MR read as injured. The best approach is to utilize MR examination in conjunction with a thorough clinical exam.

Position Classification

Kennedy described the position classification system for KDs. His system is based on the position of the tibia in relation to the femur at the time of dislocation [26]. It requires clinical or radiographic evidence of a knee dislocation. Five described dislocation types are: anterior, posterior, medial, lateral, and rotatory. Additionally, rotatory dislocations are subclassified as anteromedial, anterolateral, posteromedial, and posterolateral.

The position classification system has been in use for many years, but some limitations have been noted. The classification of tibiofemoral position is beneficial for identifying possible associated injuries such as vascular or nerve injury. Both anterior and posterior dislocations have been associated with increased likelihood of coexisting popliteal artery injury [1, 26]. All KDs, however, can have neurovascular injuries, regardless of the tibiofemoral position upon presentation, and the physician must always maintain a high index of suspicion. The position system is also beneficial for planning a reduction maneuver, but most dislocations reduce easily with longitudinal traction. Reductions are often performed by first responders even before any radiographs are obtained. The position system proves most beneficial when identifying a posterolateral KD. The posterolateral KD is unique because it is frequently irreducible by closed means. The medial soft tissue structures can become incarcerated in the joint as the medial femoral condyle perforates the joint capsule [25, 27-28]. This creates the classic "furrowing" of the posterolateral KD as the articular surface of the distal femoral condyle is outlined over the medial aspect of the knee. This alerts the orthopaedic surgeon to the high likelihood of irreducibility by closed means and requires prompt open reduction. Left unreduced, the pressure from the condyle can lead to necrosis of, either or both, skin and medial structures. To compound the severity of this injury, the posterolateral dislocation frequently has an accompanied peroneal nerve injury as the nerve is stretched between its tethered points.

The most significant limitation of the position system is the inability to classify the spontaneously reduced KD, once again, making at least half of all KDs unclassifiable. A clinician may fail to recognize a multi-ligament knee injury as a KD which requires careful assessment and monitoring of the limb's vascular status. Failure to recognize a neurovascular injury in the reduced KD can easily result in loss of limb.

Further limiting the position system's utility, the classification system does not direct the physician in surgical decision making. No information is portrayed that could assist in the placement of surgical incisions, the need for bony fixation, or the number of grafts required. This system does not express easy or thorough communication between physicians regarding what structures need to be addressed with surgical reconstruction. The classification does have historical importance when discussing KDs and is most useful with regard to the posterolateral KD, but the system is deficient for current management of these injuries.

Energy of Injury Classification

Knee dislocations have also been classified by velocity or energy, based on mechanism of injury. Initially high and low energy dislocations were identified [29-31]. Motor vehicle/motorcycle accidents, automobile versus pedestrian, and falls from height are common causes of high energy KDs while low energy dislocations often occur in athletic activities [32]. In 2010, Azar and colleagues described a new group of morbidly obese patients with ultra-low-velocity knee dislocations that occurred during activities of daily living [33]. (Table 2)

A majority of KDs fall into the high energy category. Therefore, there are often concomitant multi-system injuries that may take precedence over the KD. Caring for these patients often involves a coordinated team effort between orthopedic surgeons, trauma surgeons, vascular surgeons, and emergency physicians. Life threatening intra-abdominal or intra-thoracic injuries should be prioritized, as should vascular injuries due to the increased probability of amputation if the limb is avascular. Patients with KDs and concomitant severe intracranial trauma may not be able to participate in rehabilitation immediately. Therefore, a delay in ligamentous reconstruction may be warranted to avoid stiffness. Patients with closed head injuries and concomitant KDs have been found to have higher rates of heterotopic ossification [34]. This has been shown to correlate with the Injury Severity Score with a score of 26 being 100% sensitive and 97% specific with a positive predictive value of 86% [35].

Low energy KDs occur most commonly during sporting events or falls from a height of 5 to 10 feet [36]. They encompass approximately 33% of all KDs, occurring most often in males aged 15 to 29 years [37]. These are injuries that are most suited for early surgical reconstruction.

Ultra-low-velocity KDs are a newer entity that should not be overlooked. Commonly they occur in patients with a BMI over 48 kg/m2 and these patients have a high rate of perioperative complications, including neurovascular injury [38]. They have become more prevalent with the increasing rates of obesity in the United States and can easily be missed. The 40% risk of associated neurovascular injury with an obesity related KD makes this factor the most important characteristic. Lastly, non-operative management of ultra-low-velocity KDs has a high failure rate and they should be managed aggressively with either external fixation, ligament repair or reconstruction.

There are limitations to classifying KDs based on energy. Energy of injury itself is not well defined and sometimes does not easily fall into one of the three categories. Many sporting

Table 1. Stress radiographic differences in collateral/cruciate ligament injuries.

Ligamentous Injury (Stress View)	Radiographic Gap
MCL (Valgus Stress)	3.2mm
FCL (Varus Stress)	2.7mm
PLC (Varus Stress)	4.0mm
PCL (Kneeling Stress View)	8-11mm
ACL (Anterior Drawer)	5mm absolute, 2mm compared to uninjured side

Table 2. Energy of Injury classification

Energy of Injury Classification	
High-energy KD	MVC, peds vs auto, falls from height, polytrauma
Low-energy KD	Athletes in sports, falls
Ultra-low-velocity KD	Morbid obesity, high rate of peroneal nerve and popliteal artery injury

Table 3 Anatomic/Schenck classification

KDI - Single cruciate injury, variable collateral injury	ACL or PCL injury
KDII - Bicruciate injury, collaterals intact	ACL and PCL torn
KDIII - Bicruciate injury with one collateral torn	Bicruciate, either medial or lateral injury
Subsets M or L: ie., KDIII-L	
KDIV - All 4 ligaments injured	ACL, PCL, medial, and lateral structures torn
KDV - Fracture dislocation	Stannard's addition:
	V.1 = single cruciate injury
	V.2 = bicruciate injury
	V.3 = both cruciates and one collateral injured
	V.4 = both cruciates and collaterals injured

C = arterial injury, N = nerve injury, M = medial injury, L = lateral injury events such as skiing may fall into low or high velocity injuries, while motor vehicle accidents can occur at low or high speeds. One may argue that the energy from a downhill skier's crash may be higher than a car hitting a tree at a low speed. This classification system does not always give an accurate idea of prognosis. While high energy KDs have a higher rate of vascular injury compared to low energy dislocations, ultra-low-velocity dislocations have also been found to have high rates of neurovascular compromise. Additionally, this system does not readily identify injured structures, making it less useful in surgical planning as well as communication between providers.

Anatomic Classification (Schenck Classification)

Because the position classification system could not be used in 50% of patients, a new classification system for all KDs was needed in order to aid in diagnosis, treatment, and communication among medical providers. In 1994, Walker and Schenck described a classification of KDs based on the number and type of torn ligaments [39]. (Table 3) The anatomic structures of the knee were separated into 4 groups: the ACL, PCL, medial structures, and posterolateral structures. Medial structures encompass the MCL, posteromedial capsule, and posterior oblique ligament. The FCL, popliteofibular ligament, popliteus tendon, and posterolateral capsule all fall into the posterolateral structure group.

A thorough physical exam and appropriate imaging as described previously helps place knee dislocations into one of five major categories identified by Roman numerals in increasing order of severity. This system is based on clinical exam as opposed to imaging such that partial ligamentous injuries are sometimes seen on MRI but found to be functionally intact. KD I injuries are rarely described in the literature but are defined as a dislocated knee either clinically or on plain radiographs with either the ACL or PCL torn, along with a tear of the medial or lateral collateral ligament complex (Fig. 3) [40]. A KD II occurs when both cruciates are torn while the medial and lateral structures are intact. When both the ACL and PCL as well as one of the collaterals are torn the dislocation is defined as a KD III with the supplement of 'M' for medial and 'L' for lateral injuries(Fig. 4). KD IVs occur when all 4 structures are torn. In 1997, Wascher and colleagues added a fifth category, KD V, to include a KD with an associated periarticular fracture (Fig. 5) [5]. Stannard further subdivided KD Vs into 1- with a single cruciate tear, 2- with both cruciates torn, 3- with both cruciates and either the medial or lateral structures injured, and 4- with both cruciates and collaterals injured. Tibial spine fractures as well as other small avulsion fractures are defined as ligamentous injuries as opposed to true periarticular fractures. Nerve injuries are delineated by an 'N' while vascular injuries would be classified with a 'C' [41]. For example, a patient with ACL, PCL, and MCL laxity on exam as well as a cold leg that was found to have a popliteal artery injury would be defined as a KD III-M-C.

The anatomic classification system has advantages over the other classification systems. It does not require the patient to present with their knee actually dislocated and accommodates those that present spontaneously reduced. It assists in guiding treatment of these torn structures and allows for communication between treating providers. This system helps predict patient prognosis in that lower Roman numerals lead to a better prognosis than higher. There is a higher rate of vascular injury in KD IVs versus KD IIIs and this classification has been found to be predictive of return to work [16, 42]. One minor drawback of this classification system is that it does not have a category for extensor mechanism ruptures.

There has previously been discussion of the utility of the anatomic classification with regard to single cruciate injuries. It is important to remember that the anatomic classification is based on a thorough clinical exam, not imaging alone. Ligamentous insufficiency on clinical exam, regardless of appearance on imaging, requires treatment. Merritt et al. in their review of 138 KDs, were unable to classify single cruciate KDs based on MRI alone [43]. In contrast, Moatshe et al. had great success in describing 303 KDs using the anatomic system [44]. One rare injury pattern is the single cruciate KD with both MCL and LCL insufficiency. This is classified as a KD I-M-L; although a KDIV should be ruled out given the rarity of this injury. Furthermore, the KD classification predicts outcomes. The greater the number of ligaments involved, Schenck classification KD III & IV, the greater the need for eventual reconstruction. As a predictor, Everhart et al., noted that return to work is more likely with the KD injury being less than KDIV or KDV [42]. In a study by Cook et al., not only are revisions higher with KDIV injury patterns, but stiffness is more likely in the knee with three or more ligaments injured (>KDIII) and when surgery is performed within 3 weeks from injury [45]. In professional athletes, return to sport is higher in the next season with a KDIIIM (68%) versus a KDIIIL (37%). Return to preinjury level is also predicted by the KD system with KDIM having a higher return to preinjury function (44%) versus a KDIL (19%) [46].

Conclusions

Knee dislocations are severe injuries that can be clinically difficult to manage and are being recognized with increasing frequency. They sometimes require emergent surgery or revascularization. It is therefore essential to not only have a reproducible assessment algorithm, but also to have a reproducible and informative classification system to guide patient treatment. While the position and energy classifications give useful information, they do not aid in surgical planning and are not able to fully characterize every KD. The anatomic classification system helps guide treatment as well as conveys the severity of injury based on the injured structures. It also provides information on outcomes with the higher levels of classification having a lower functional outcome.

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