Knee Dislocations and Multiligament Injuries

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Abstract

Multiligament knee injuries (MLKIs) are more than 60 times less common than ACL reconstructions in the practice of sports surgeons, but the estimated incidence is still 0.072 events per 100 person-years. Their potential to cause serious short-term and long-term consequences such as persistent instability with functional limitations, chronic pain and stiffness, and accelerated post-traumatic osteoarthritis underscores the importance of understanding and expert management of this severe and career-threatening injury in athletes. This chapter addresses prevention techniques for multiligament knee injuries, particularly in skiing and other pivot sports to create a safer sports environment. We will also discuss acute treatment and review surgical principles and techniques for the repair and reconstruction of injured ligaments. Special attention will also be given to the postoperative rehabilitation and return to sports after MLKI.

Keywords

Multiligament · Knee dislocation · Prevention · Rehabilitation · Reconstruction

Introduction

The terms “knee dislocation” and “multiligament injury of the knee” are often used interchangeably. A knee dislocation is usually a total malalignment of the tibia in relation to the femur, usually involving the rupture of three or more stabilizing ligaments (Wascher et al. 1997). This is often accompanied by rupture of both cruciate ligaments, and sometimes there is also a grade III injury on the medial or lateral side. However,

Table 1 Schenck anatomic classification system for knee dislocation and multiple ligament knee injury

Type		Description
KD1		Knee dislocation with either cruciate intact
KD2		Bicruciate injury with collaterals intact
KD3	KD3M	Bicruciate injury with medial sided ligaments injury
	KL3L	Bicruciate injury with posterolateral ligaments injury
KD4		Bicruciate injury with both collateral ligament injury
KD5		Peri-articular fracture dislocation

cases of knee dislocations in which one of the cruciate ligaments was still intact have also been documented (Shelbourne et al. 1992). Although knee dislocations often result in multiligamentous injuries of the knee, it is important to note that not every multiligamentous injury of the knee is due to a knee dislocation.

Multiligament knee injuries (MLKIs) have traditionally been defined as involving at least two of the four major knee ligaments, namely, the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL) (Mook et al. 2009). More recently, the classification has been expanded to include posterolateral corner (PLC) and posteromedial corner (PMC) injuries (Schenck 2003). The widely used classification system for dislocated knees, described by Schenck in 1994 (Table 1), is based on the anatomic patterns of the torn ligaments. This classification system offers several advantages, including the ability to identify the affected ligaments and facilitate treatment planning.

Incidence

MLKIs are considered rare, as shown by a recent study using a large population database that estimated an incidence of 0.072 events per 100 person-years (Makaram et al. 2023). The incidence of MLKI is approximately 0.02–0.20% of all orthopedic injuries. To put this in perspective for the sports surgeon, one study found that anterior cruciate ligament (ACL) reconstruction was 60 times more common than MLKI reconstruction (Sobrado et al. 2022). However, it should be noted that these numbers may be underestimated due to cases of spontaneous knee reduction and missed injuries, leading to possible underreporting of MLKI cases. Bilateral knee dislocations occur even less frequently than unilateral injuries, and only sporadic case reports are found in the literature (Sonnery-Cottet et al. 2019).

Multiligament knee injuries (MLKIs) can be caused by various types of injuries, but the vast majority are due to high-energy trauma, such as motor vehicle accidents (52%) (Sabesan et al. 2015). About one-third of MLKIs are due to sports injuries. Knee dislocations in sports have been reported in soccer, wrestling, rugby, American soccer, kabaddi, long jump, skating, cycling, skiing, gymnastics, climbing, motor sports, and extreme adventure sports.

The data from the United States suggest that knee dislocations are increasingly occurring in extreme sports, with an estimated incidence of 29.12 knee dislocations per 1 million person-years (Sabesan et al. 2015). The highest incidence is in the 10–19-year-old age group, with males more commonly affected. Among sports, skiing has the highest incidence. In a study (Koehle et al. 2002) that focused on snow sports, knee dislocation was found to be the most common injury resulting in admissions in the state of Victoria, with a higher prevalence in males aged 15–29 years. There was an increasing incidence of these injury types during the study period from 2007 to 2012, although the use of protective equipment led to a decrease in other injury types. Among snow sports, skiing also accounted for the majority of knee dislocation cases. In other snow and ice sports, such as snowboarding, ice hockey, and skating, the rate of knee dislocation is lower, generally less than 4% (Koehle et al. 2002).

It is widely recognized that contact sports tend to produce more severe injuries than noncontact sports. Larger and stronger athletes today can amplify the force of collisions, possibly increasing the frequency of such contact injuries (Skendzel et al. 2012). However, there is a lack of comprehensive studies on the incidence of knee dislocation (Braaten et al. 2023). Most of the data we have on this topic is sourced from isolated case reports (Moreno et al. 2022).

Implications

Multiligament knee injuries (MLKIs) can have profound and life-altering consequences that impact various aspects of a person's well-being. These injuries are associated with accelerated progression of posttraumatic osteoarthritis, which can lead to chronic pain, functional limitations, and decreased quality of life. In addition, MLKI can result in an individual's inability to return to work or participate in sports, which has significant psychological and socioeconomic consequences for them.

One of the biggest problems with MLKI is the potential for neurovascular injury. If neurovascular injuries are not promptly diagnosed and appropriately treated, they can lead to serious complications, including ischemia, nerve dysfunction, and limb-threatening conditions. A recent study (Everhart et al. 2018) based on the analysis of registry data shed light on the additional challenges faced by patients with MLKI. It showed that a significant proportion (28%) of MLKI patients required at least one additional surgical procedure following their initial treatment. In addition, a significant number (22%) underwent multiple subsequent surgical procedures. A multidisciplinary approach involving orthopedic surgeons, physical therapists, and other healthcare professionals is essential to optimize outcomes and improve long-term prognosis for those affected by MLKI.

Prevention of MLKI in Sports

Prevention in Skiing

Skiing has the highest incidence of knee ligament injuries among extreme sports, and numerous studies have focused on reducing these injuries in skiing. It is important to understand the mechanisms that lead to knee ligament injuries in skiing. There are three common mechanisms associated with these injuries (Ettlinger et al. 1995):

- Valgus external rotation sequence: Falling forward while catching the inside edge of a ski results in injuries to the anterior cruciate ligament and sometimes the anterior cruciate ligament.
- Boot-induced anterior drawer mechanism: Landing from a jump with the knee extended puts pressure on the boot-binding complex, causing the tibia to move forward on the femur.
- Phantom foot mechanism: When falling backward between skis with knees bent and hips below knee level, the inside edge of the downhill ski digs into the snow and exerts a force of internal rotation on the overbent knee.

The tight binding between the foot and the ski, combined with the above movements, is a major contributor to knee injuries while skiing. The technology used in the development and adjustment of ski bindings therefore offers the possibility of reducing such injuries and increasing safety.

Binding Design

Despite the association between knee injuries and binding failures, current ski bindings are still not capable of addressing the above injury patterns. Numerous studies have consistently found a correlation between knee injuries and the inability of bindings to release properly. In the event of a fall, the risk of lower extremity injury increases significantly if one ski fails to release, and it increases further if both skis remain attached (Natri et al. 1999).

Conventional ski bindings have only a limited release system with two release modes that respond to twist or forward lean. They do not have a release option for lateral twist at the heel or backward tilt. Newer "multirelease" bindings offer additional release modes, including upward release at the toe. However, these advances have not resulted in a reduction in ACL injury rates. The efforts to develop more practical electronic bindings with wider release options have been unsuccessful (Natri et al. 1999).

Bindings, Maintenance, and Fitting

Ski binding adjustment and maintenance play a critical role in injury prevention. Standards from organizations such as DIN (German Institute for

Standardization), ASTM (American Society for Testing and Materials), and ISO (International Organization for Standardization) guide the process (Finch and Kelsall 1998), using binding release force and tibial plateau width or weight-based approaches. Specialized testing equipment is required for proper adjustment, as relying only on the scale marked on the bindings is not sufficient, especially for older or cheaper models and children's skis. In a study (Goulet et al. 1999) of ski injuries in children, it was found that incorrect ski adjustment increases the risk of injury by 2.1 times. Children are especially at risk because equipment is passed down and may not work properly. Promoting the use of testing equipment, proper equipment selection, and maintenance are therefore critical to reducing ski injuries, especially among children. Another important factor is that children's equipment often does not fit properly or is poorly adjusted. Children's bindings may not be properly adjusted for the shorter boot lengths and softer material.

Ski Design and Adoption

Ski design has a tremendous impact on reducing knee injuries. Short carving skis have been shown to be a risk factor but are still commonly used. Their use is still associated with anterior cruciate ligament (ACL) rupture, which is the most common diagnosis of knee injury with an incidence rate of 15.8–16.7% (Wölfel et al. 2003). In addition, abrasion of ski boot soles potentially increases the risk of ligament injury in both male and female recreational skiers (Posch et al. 2019), and designers are striving to address this issue. Ruedl et al. (2022) have shown that interventions such as reducing ski length, reducing ski tip width, reducing rear standing height, and maintaining a lower-standing height ratio could reduce the likelihood of knee ligament injuries. Although there have been advances in the ski equipment industry over the past few decades, there is still much room for research into fine-tuning equipment to minimize injuries and implementing research findings.

Experience

Skier experience is closely related to ski injuries, with less skilled and less experienced skiers having a higher risk of injury. Experienced skiers are thought to be less likely to fall and, when they do fall, do so in a less dangerous manner. Goulet et al. (1999) conducted a study of ski injuries in children and found that a higher skill level was associated with a lower risk of injury. However, the study did not provide conclusive evidence of a clear benefit of formal ski training in preventing injury.

Preskiing Instructions

Recent studies have shown the effectiveness of preski instruction in preventing ski injuries. Ettlinger et al. (1995) developed an education program to prevent ACL injuries that resulted in a remarkable 62% decrease in ACL injuries at ski resorts whose employees participated in the program. The program used video analysis, flip charts, and workbooks to raise awareness of injury mechanisms and provided guidelines for minimizing the risk of injury from falls. Similarly, Jłrgensen et al. (1998) found that injury incidence decreased by 30% among Danish skiers who watched a safety video before their ski trip. These studies highlight the potential of targeted instructional programs that focus on injury prevention techniques for skiing. While general ski instruction may not always prevent injuries, tailored programs that address specific injury prevention methods show promising results.

Conditioning

Proper conditioning is generally recommended as an effective measure to prevent skiing injuries. Strengthening muscles helps stabilize joints during falls, while improving flexibility and mobility can reduce both the frequency and severity of injuries. Natri et al. (1999) indicate that increased muscle strength can reduce the stress on the ACL during internal rotation of the tibia. In addition, exercise has been shown to have positive effects on maintaining bone density, which may help prevent fractures, particularly in older adults. Although further research is needed to explore the specific effects of ski-specific training programs on injury prevention, it is generally recommended that all skiers complete a preseason conditioning training program that includes both strength and endurance components, with an emphasis on the legs and back.

Modifying Ski Behavior

Promoting responsible skiing behaviors and avoiding fatigue are key to preventing injuries on the slopes. Certain activities such as high-speed cruising, tree skiing, and big jumps are known to be more prone to injury. Traditional measures such as signage and controls have proven ineffective, especially with younger skiers (Tarazi et al. 1999). To target this age group, a certification system similar to that used in martial arts or scuba diving (SCUBA) could be introduced, requiring participants to acquire certain skills and achieve certain categories before being allowed to enter certain slopes. This would encourage safer participation in higher-risk activities. Group skiing has also been identified as a factor in skier behavior, with school-organized groups facing higher risk for injury. Modifying school programs by increasing the number of instructional and supervised segments while decreasing free ski time can create a safer environment. In addition, school-based education about the Alpine Code of Responsibilities can promote responsible behavior and reduce injuries among school program participants.

Prevention in Soccer and Pivoting Sports

Most studies of soccer players focus on injuries to the ACL because they are the most common compared to multiligament knee injuries. However, the principles should still be applicable. Neuromuscular risk factors, such as poor landing mechanics and leg asymmetry, contribute to an increased risk of lower limb injuries, including ACL and multiligament knee injuries. Tests to determine these risk factors include assessment of leg dominance and measurement of hip external rotation strength. A difference of 15% or more between dominant and nondominant limbs predicts future injury, while an asymmetry of more than 4 cm in the anterior portion of the Y-balance test increases the risk of injury. Low hip external rotation strength values (less than 18% of body weight) are associated with lower extremity and back injuries. Dynamic stability deficits and altered neuromuscular firing during movements such as cutting or landing further increase injury risk for male youth soccer players.

We can apply the studies on injury prevention to strategies for preventing knee injuries involving multiple ligaments in pivoting sports. Evidence supports the effectiveness of exercise-based interventions such as neuromuscular warm-up (NMT) programs in reducing soccer-related injuries. A systematic review (Hanlon et al. 2020) found that several exercise-based injury prevention programs for youth players reduced injury rates by up to 46%. The 11+ Warm-Up program has shown a 30–47% reduction in overall injury rate, a 39–44% reduction in lower limb injury rate, a 55% reduction in overuse injury rate, and a 52% reduction in knee injury rate. The 11+ Kids program has also been effective in reducing injuries in younger players. The Knee Injury Prevention Program (KIPP) has shown the potential to reduce noncontact lower extremity injuries and overuse injuries in young female soccer players. The International Olympic Committee's "Get Set" app and associated website provide detailed instructions for conducting NMT warm-up programs, including the 11+ program.

Prophylactic Bracing

Prophylactic braces for knee injuries are becoming increasingly popular, especially in high-speed sports such as motocross (Lazzarini et al. 2023) and collision sports such as football (Table 2). Made by a variety of manufacturers, these braces are designed to protect the knee from excessive stress while maintaining the athlete's full range of

Table 2 Summary of strategies to prevent multiligamentous knee injury

	Specific strategies described in literature	General strategies
Skiing	Equipment—Binding design, maintenance, and fitting; ski design Modifying ski behaviors Preskiing instructions	Understand injury mechanisms in various sports Individualized neuromuscular training programs General strength and conditioning
Soccer	Neuromuscular training Injury prevention warm-up programs	
Motocross	Prophylactic bracing	
Contact sports	Prophylactic bracing	

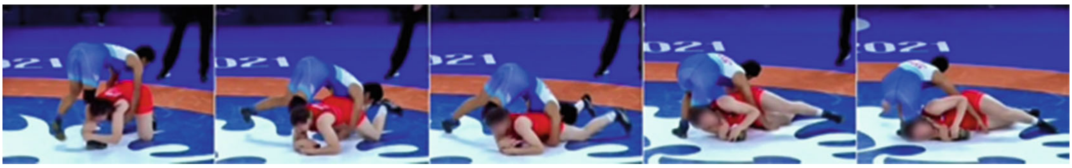

Fig. 1 Sports knee dislocations are more common in combat and contact sports like wrestling. A video analysis of the injury, if available, is useful to confirm the diagnosis of dislocation along with expected injury pattern, especially in athletes with spontaneous reduction

motion. They usually consist of two rigid frames attached to the thigh and lower leg and connected by a polycentric hinge. According to a study by Boden et al. (2000), 28% of ACL injuries are due to contact between players, while 72% occur without such interaction.

In motocross sports, it was found that riders who did not use braces had a significantly higher incidence of anterior cruciate ligament and medial collateral ligament injuries than riders who used braces. However, the biomechanical study by Hacker et al. (2018) found that the effect of a brace varies depending on the direction and intensity of impact and can be beneficial, detrimental, or neutral. For contact sports where lateral or medial impacts are common, a brace could be beneficial, whereas sports where rotational knee motion or frontal impacts occur could be safer without a brace.

Field and Acute Management

MLKI caused by high-energy trauma must be assessed according to Advanced Trauma Life Support principles (Pardiwala et al. 2022). It is important to note that 50% of knee dislocations spontaneously resolve before initial medical evaluation, and because there is a strong association between knee dislocations and MLKI, any MLKI should be treated as a knee dislocation until proven otherwise. Acute assessment can be difficult, as it depends on the patient's ability to relax and the physician's ability to accurately identify endpoints. In chronic MLKI, patients often have persistent pain, a sense of instability, especially with twisting and jerking movements, and may have mild knee effusion.

Field Management

Pardiwala et al. (2022) published clinical practice guidelines for the management of MLKI, which provide a framework for clinicians in such cases. Athletes may present on the field with a deformed knee or with a knee that has spontaneously reduced after dislocation. A video analysis of the injury is useful to diagnose and confirm knee dislocations in athletes with spontaneous reduction (Fig. 1). Injuries that occur in contact sports, martial arts, and high-speed sports such as gymnastics and skating should always be treated with suspicion because they may be spontaneously reduced knee dislocations that can be associated with neurovascular complications. Any trauma from motorsports or extreme sports should first be treated according to standard ATLS protocols to identify and treat other injuries such as concussions and head injuries. If the limb is visibly deformed, it should be carefully realigned. Often, this action alone can restore the joint to its proper position. It is critical not to attempt any formal realignment of the joint in the field (Pardiwala et al. 2022) without first reviewing the radiographic status of the knee. Regardless of reduction status, the limb should be temporarily splinted to avoid further soft tissue injury and neurovascular compromise en route to the nearest hospital.

Acute Management

During evaluation in the emergency department, the assessment of the vascular and neurologic status of the limb is critical, and immediate radiography is recommended to confirm the diagnosis, determine the nature of the knee dislocation, and detect associated fractures. After reduction, a comprehensive examination is performed under anesthesia to assess ligament stability. Specific tests such as the Lachman test, posterior sag and drawer test, valgus and varus stress test, and dial test are sufficient in the acute situation, and excessive manipulation of the knee should be avoided.

If the knee is stable, full extension immobilization using a long knee brace is recommended, but temporary external fixation may be required for very unstable knees. In certain cases, flexion immobilization may be required to prevent anterior tibial subluxation in anterior knee dislocations or posterior tibial subluxation due to a damaged posterior capsule (Seroyer et al. 2008).

After reduction, adherence to a postreduction protocol is critical, including obtaining radiographs to confirm joint reduction, identifying avulsion fractures, and considering an MRI scan for soft tissue assessment and surgical planning. In certain cases, a CT scan may be useful for detailed characterization of fracture dislocations, and stress radiography may be considered to assess the extent of ligamentous laxity.

Associated Injuries

Vascular Injuries

The incidence of vascular injury in knee dislocations and MLKI is reported to be approximately 18% (Medina et al. 2014). The use of the ABI for routine vascular monitoring remains controversial. A meta-analysis performed by Barnes et al. (2002) found that the absence of a foot pulse had a sensitivity of 0.79 and a specificity of 0.91. In a case series, McDonough and Wojtys (2009) reported 12 cases of popliteal artery injuries in 72 knee dislocations. Interestingly, only four of these injuries were identified by physical examination before surgery, whereas five were identified by arteriography before surgery. In addition, three injuries were not detected by either physical examination or preoperative arteriography. Of note, the study did not use the ankle-brachial pressure index (ABPI).

The routine use of arteriography in all cases of knee dislocation is impractical, carries risks, and is costly. However, there is a substantial body of low-quality evidence (Nicandri et al. 2010) suggesting that clinical examination of foot pulses alone is insufficient for accurate diagnosis of vascular injury in MLKI (medial and lateral knee injuries). Several studies support the view that additional testing is needed, with the most commonly recommended approach being measurement of ankle brachial pressure index (ABPI). This consensus reflects general agreement among experts in the field.

For example, selective arteriography based on the ABPI has been shown to be effective in detecting vascular injury associated with knee dislocation (Fig. 2). Mills et al. (2004) reported in their study that an ABPI value below 0.9 has a sensitivity, specificity, and positive predictive value of 100% in detecting vascular injury in knee dislocation.

Therefore, it is our recommendation that patients with an ABPI score below 0.9 should undergo additional imaging studies, such as computed tomography angiogram (Halvorson et al. 2011), if the limb has adequate blood flow. The computed tomography angiogram when available in trauma centers should be used in cases where there is a suspicion of vascular injury in MLKI.

Fig. 2 Subclinical popliteal artery injury in a rugby player who sustained a KDIIIM sports knee dislocation. His distal pulses were palpable and ABI was 0.95. A routine preoperative CT angiogram detected the intimal injury to popliteal artery

Nerve Injuries

The prevalence of common peroneal nerve (CPN) injury after knee dislocations and MLKI is estimated to be as high as 40% [35]. The prognosis of CPN palsy depends on whether it is complete or partial, with complete palsy having a less favorable rate of functional recovery compared with partial palsy. Treatment options for CPN palsy due to knee dislocation include observation, neurolysis, nerve grafting, motor nerve transfer, and posterior tibial tendon transfer. Routine exploration and neurolysis of the CPN are usually performed during repair or reconstruction of the posterolateral corner. However, there is limited evidence to support the superiority of neurolysis over observation. A recent systematic review (Woodmass et al. 2015) recommended that posterior tibial tendon transfer be considered in patients with complete CPN rupture and in patients who did not improve within 3 months. This approach has shown promising results in achieving dorsiflexion of the ankle against gravity.

Meniscus and Chondral Injuries

Meniscal and cartilage injuries are commonly observed in MLKIs (medial and lateral knee injuries) (Fig. 3a–c). In a level I trauma center study, Moatshe et al. (2017b) found that meniscal injuries were present in 37.3% of cases and cartilage injuries in 28.3% of cases. It is important to

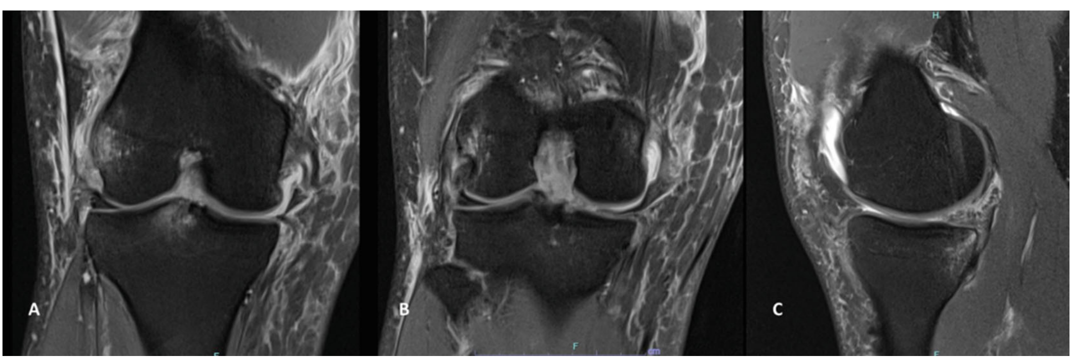

Fig. 3 (**a**–**c**) KD III M MLKI with a “floating meniscus” injury involving anterior and posterior root tears of the medial meniscus. It is important to identify and treat the complex meniscus tear in such cases to ensure a good clinical outcome

highlight that the presence of cartilage injuries and concomitant tears in the medial and lateral menisci has been associated with worse outcomes in MLKI. Therefore, it is critical to identify and treat these injuries simultaneously during surgical reconstruction or repair.

Treatment Rationale

Consensus on Surgical Treatment

The existing literature generally supports surgical treatment and postoperative functional rehabilitation for multiligament knee injuries. Nonoperative treatment may be considered in rare cases when advanced age, immobility, and comorbidities are present. Peskun and Whelan (2011) evaluated the outcomes of surgically treated patients from 31 studies and nonoperatively treated patients from 4 studies totaling 855 and 61 patients, respectively. The results of this study were in favor of surgical treatment in terms of functional outcomes, contracture, instability, and return to activity.

A recent systematic review (Makaram et al. 2023) also concluded that surgical treatment is generally preferred; patients who underwent surgery returned to work more quickly, were able to return to sports, and had better overall functional outcomes. It should be noted that the studies included in these reviews were of variable quality and did not include standardized assessment methods. In addition, important factors such as timing of surgery, surgical techniques, and rehabilitation protocols differed between studies, making a direct comparison between "surgical" and "nonsurgical" treatment difficult.

Timing and Staging of Surgery

There is an ongoing debate about the optimal timing of surgery for MLKI, with three approaches: **acute**, **staged**, and **delayed**. Acute surgery aims to restore normal knee kinematics by repairing or reconstructing all damaged ligaments within 3 weeks of injury. Delayed reconstruction is performed more than 3 weeks after injury when scarring and retraction of damaged structures prevent satisfactory repair. Staged reconstruction treats the extraarticular structures first, followed by cruciate ligament reconstruction once range of knee motion is restored.

Various systematic reviews report conflicting results, with some favoring staged reconstruction (Mook et al. 2009) and others showing better results with acute surgery (Hohmann et al. 2017). The optimal timing remains controversial and should be guided by the patient injuries, medical condition, and availability of operating room as well as surgical expertise. Additional considerations to be considered include concomitant fractures or extensor mechanism injuries, which often may influence the decision to perform a single or staged surgery.

There is a lack of consistent terminology to describe "acute or delayed" surgery and "single or staged" surgery in the treatment of multiligament knee injuries (MLKIs) (Moatshe et al. 2017). There is also a lack of agreement in defining the critical time frame to distinguish between acute and delayed interventions. Some authors consider the acute phase to be within 3 weeks of injury, while others define it as within the first 6 weeks (Geeslin and LaPrade 2011).

A number of studies have documented satisfactory recovery of knee function, stability, and range of motion (ROM) using a staged approach. Ohkoshi et al. (2002) reported positive clinical outcomes after a two-stage reconstruction for MLKI, in which the PCL was reconstructed acutely within 2 weeks of injury, followed by reconstruction of the ACL and PLC 3 months later. Subbiah et al. (2011) also pointed out the advantage of deferring ACL reconstruction for further evaluation, suggesting that not all patients who do well without an ACL necessarily require reconstruction.

However, the concerns about staged surgeries come from a biomechanical perspective (Braaten et al. 2022). The worry is that the gap between surgeries might lead to the stretching of repaired or reconstructed grafts, given how the tension of one knee structure can depend on another. This potential stretching could increase the risk of early graft failure.

New data supports acute single-stage MLKI reconstruction, as evidenced by several recent case series (Goyal et al. 2021; Li et al. 2023) that document positive functional outcomes. LaPrade et al. (2019) in his series of 194 sports-related multiligament injuries demonstrated that single-stage knee ligament reconstructions, with immediate postsurgical rehabilitation, consistently led to better outcomes. This was true regardless of the specific ligament injury pattern.

A one-step surgical procedure for multi-ligament knee injuries might have several other benefits such as fewer complications, reduced reoperation rates, and cost savings, as opposed to a two-stage surgical approach (Lau et al. 2022). However, it is important to consider again the availability of operating room resources and surgeon's expertise in attempts to accomplish a three-knee ligament reconstruction in a single surgery setting.

Repair Versus Reconstruction

Another area of controversy in the management of ligament injuries in multiligament knee injuries (MLKIs) lies in whether to reconstruct or repair the damaged ligaments.

Cruciate Ligaments

Previous evidence seemed to favor reconstruction as a superior strategy to primary cruciate ligament repair. Mariani et al. (1999) indicated that patients who underwent cruciate ligament repair after knee dislocation were more likely to have a flexion deficit and posterior tibial instability and were less likely to regain their pre-injury level of performance. A meta-analysis conducted by Levy et al. (2009) found that patients who underwent autologous tendon reconstruction for cruciate ligaments had significantly better outcomes than patients who opted for suture reconstruction.

More recently, studies have been published supporting a primary cruciate ligament repair strategy. In a recent meta-analysis by Frosch et al. (2013), no significant difference was found when comparing the outcomes of suture repair and reconstruction of the ACL and PCL. With improved surgical equipment and skills, the suture repair of avulsed cruciate ligaments has been shown to be a viable treatment option. This helps to make use of the native ligaments of the patient, without having to harvest their tendons for autograft, potentially creating donor site morbidity. Additional allografts are also not required; therefore this leads to potential surgical cost savings.

Vermeijden et al. (2020) confirmed that arthroscopic primary PCL repair (Fig. 4) may be a beneficial treatment alternative for patients with proximal or distal avulsion-type tears, with the advantages of native tissue preservation, a less invasive procedure, and potentially shorter recovery time. This is especially true if the residual stump is >41 mm distal. In a review of 9 studies and 226 patients, Vandenrijt et al. (2023) reported that PCL repair had an overall failure rate of 5.6% (range 0–15.8%).

Fig. 4 MRI sagittal section showing a proximal PCL tear with sufficient residual stump >41 mm which was treated with primary PCL repair

The debate over single- or double-bundle reconstruction of the PCL continues. A recent meta-analysis (Migliorini et al. 2022) concluded that the available evidence does not support the double-bundle technique. Corsi et al. (2023) recommended considering tibial tilt when deciding on single- or double-bundle PCL reconstruction. They suggest that in patients with shallow inclination, double-bundle PCL reconstruction may be advantageous. This approach ensures a graft large enough to withstand forces, helps limit graft lengthening, and reduces the likelihood of failed reconstruction. However, the concern of a double-bundle PCL reconstruction is the increased risk of tunnel collision in MLKI surgery.

Collateral Ligament and Posterolateral Corner Injuries

Surgical intervention at the posterolateral corner (PLC) has been shown to be critical for achieving native knee stability and functionality (Fig. 5). This is especially true for grade III PLC injuries and combined PCL and PLC ruptures (LaPrade et al. 2022).

When comparing PLC repair and reconstruction, Stannard et al. (2005) had found a significantly lower failure rate of 9% with reconstruction of PLC injuries versus a failure rate of 37% in patients who received repair. Similarly, Levy et al. (2010) found a 6% failure rate in patients who underwent reconstruction versus a 40% failure rate in those who underwent repair (Fig. 6).

The more recent data from Westermann et al. (2019) which followed 34 patients who underwent combined ACL and PLC repair or reconstruction found no difference in functional outcomes for either repair or reconstruction group after 6 years. Similarly, Geeslin and LaPrade (2011) indicated that both repair and reconstruction techniques for the PLC can yield comparable results.

The injuries of the medial side of the knee are particularly important because they are most common in multiple ligament knee injuries (MLKIs). Isolated MCL injuries are often treated

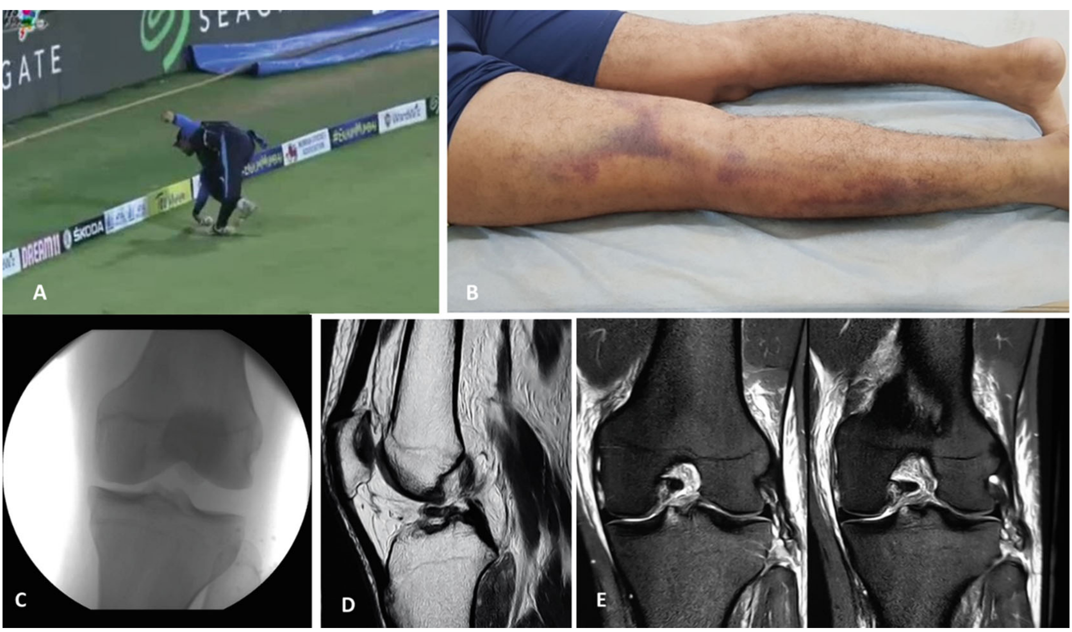

Fig. 5 (**a**) A young male cricketer sustained a knee dislocation with spontaneous reduction following a varus-hyperextension injury to his left knee while fielding; (**b**) severe ecchymosis is noted along the posterolateral aspect of the left knee and leg; (**c**) radiograph demonstrates severe laxity of the lateral knee ligaments; and (**d** and **e**) MRI confirms a KD III L type of injury with tears of the ACL, PCL, and PLC

Fig. 6 MRI coronal section showing a distal PLC avulsion that can be treated with an acute repair

Fig. 7 MRI coronal section showing a proximal MCL avulsion that can be treated with an acute repair

conservatively. However, when an MCL injury is part of an MLKI and is found to be unstable on examination under anesthesia (EUA), surgical repair (Fig. 7) or reconstruction is often required. MCL tears with invagination into the joint cause joint irreducibility and warrant open reduction (Fig. 8).

Rehabilitation of MLKI

Importance of Rehabilitation

While surgical treatment is indeed critical, it is equally important for surgeons to recognize that the postoperative rehabilitation phase is an integral and crucial step in achieving the best functional outcomes after MLKI. This process also includes the psychological preparation of the patient to return to his or her sport after a severe injury (Sheean et al. 2023).

Studies have shown that the efficacy of clinical outcomes and the ability to return to competitive sports after MLKI are largely dependent on the specifics and timing of the postoperative rehabilitation protocol. For example, Richter et al. (2002) showed that postoperative functional rehabilitation was the most important prognostic factor leading to a 63% return to sport rate.

It is important to recognize that return to high-level sports activities is challenging and not possible without a carefully planned rehabilitation protocol and personal motivation of the athlete. This was evident in a case described by DePhilipo et al. (2020) in which a 28-year-old female Olympian suffered an MLKI, underwent surgical reconstruction, and successfully returned to her Olympic-level sport.

Early Phase Rehabilitation

Postoperative rehabilitation in MLKI has received considerable research attention.

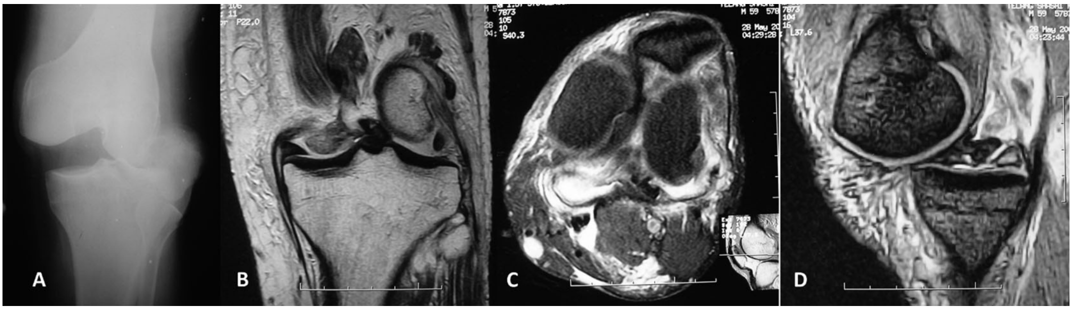

Fig. 8 Irreducible knee dislocation. (**a**) Prereduction AP radiograph reveals a posterolateral knee dislocation. (**b**–**d**) MRI reveals a complex knee dislocation in which the MCL has invaginated into the knee joint and the medial femoral condyle has button-holed through the medial capsule, preventing closed reduction

Hoit et al. (2021) compared early versus late physical therapy and found no significant difference in the need for postoperative manipulation under anesthesia (MUA) or patient-reported outcomes. Most authors also recommend initial nonweight-bearing for 4–6 weeks, followed by active mobilization and progressive weight-bearing, avoiding passive stretching (Lynch et al. 2017). A meta-analysis (Mook et al. 2009) found that most studies advocated early mobilization to improve stability, range of motion, and functional outcomes. However, there are differences in rehabilitation protocols, including loading status, type and duration of bracing, and timing of physical therapy initiation. The consensus on a specific rehabilitation strategy for MLKI has not yet been reached, but there is evidence that early physical therapy leads to better outcomes, and specific rehabilitation protocols, such as those described by Edson et al. (2011) and Monson et al. (2022), are consistently cited.

Late Phase Rehabilitation

Periodization involves dividing a training or rehabilitation program into smaller phases to create manageable segments. In the context of rehabilitation for multiple ligament knee reconstruction, phases can be structured to focus on muscular endurance, strength, and power and tailored to the patient's goals and expected time frame for return to activity. The duration of each phase depends on the overall rehabilitation program but should be at least 6 weeks. Once range of motion is restored, the focus shifts to building muscular endurance. This is followed by a transition to developing muscular strength and then muscular power. It is recommended that 3–4 training sessions be completed per week, with adequate recovery time between each session (Romeyn et al. 2008). Patients are advised to use a functional brace during sports or activities that expose their knee to potential risks. This practice should be maintained until completion of the postoperative recovery period (Barber-Westin and Noyes 2011).

Return to Sport Criteria

The rehabilitation process and return to sport schedule should be individualized, taking into account various factors such as age, BMI, sport type, and concurrent injuries. Studies have shown that the decision to return to sport is often based on subjective criteria, including regained stability, normal knee function, satisfactory stability, and near full range of motion and muscle strength (Barber-Westin and Noyes 2011). In some cases, objective criteria such as time after surgery, muscle strength, range of motion, and absence of effusion are also considered. However, there is a need for more standardized and objective criteria to assist in the decision-making process for return to sport.

Outcomes of MLKI in Athletes

Return to preinjury activity levels after knee dislocation reconstruction is not reliable and may be influenced by several factors. Mook et al. (2009) reviewed 24 retrospective studies at the time of surgery (acute, chronic, staged) and found rates of 89%, 100%, and 100% for return to work and 43.6%, 68.8%, and 90% for return to sports, respectively. Data regarding the return-to-sport rates for athletes after MLKI is not consistently available and often lacks comprehensiveness. However, available information suggests a return rate of 53%. Notably, this rate drops to 22% for competitive athletes (Everhart et al. 2018).

A relatively high prevalence of radiographic osteoarthritis has been observed in several studies, ranging from 23% to 87% (Sobrado et al. 2022) despite good functional outcomes. Factors associated with poor outcomes include high-energy trauma, medial injury repair, age greater than 30 years, concomitant cartilage injury, and combined medial and lateral meniscal tears.

Conclusion

The management multiligament knee injury (MLKI) sports requires specialized team management and expertise. There is still much work to be done in the prevention of such debilitating injuries in sports. This includes understanding of anatomy and the use of a connotation of surgical repair and reconstruction techniques. The ideal management, as shown by growing evidence, is early single stage repair and reconstruction of all injured ligaments, followed by early rehabilitation. The road to eventual return to competitive sports is long and difficult but not impossible.

Cross-References

► Structured Rehabilitation Considerations to Improve Outcomes After Complex Athletic Knee Injury

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