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Multiligament knee injury and dislocation in a 17-year old football player: clinical focus on rehabilitation exercise and return to sport

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Objective: *To highlight the rehabilitation exercises of a football player following surgical reconstruction of a multi-ligament knee injury (MLKI) with vascular compromise.*

Case Presentation: *A 17-year-old male high school football player sustained a traumatic MLKI requiring immediate limb saving surgery and subsequent tissue repair. Post-operatively, he engaged in an interdisciplinary phased and structured rehabilitation program with an emphasis on progressive loading, neuromuscular control and return-to-sport (RTS) readiness. At eight months post-op the athlete returned to a United States prepatory school where he transitioned to an external strength and conditioning program.*

Une lésion multiligamentaire et une luxation du genou chez un joueur de football de 17 ans : un focus clinique sur l'exercice de réhabilitation et le retour au sport.

Objectifs: *Pour mettre en évidence les exercices de réhabilitation d'un joueur de football à la suite d'une reconstruction chirurgicale d'une lésion multiligamentaire du genou avec un compromis vasculaire.*

Présentation de cas: *Un joueur de football au lycée âgé de 17 ans a subi une lésion multiligamentaire du genou traumatique nécessitant une chirurgie immédiate pour sauver le membre et une réparation tissulaire subséquente. Après l'opération, il a participé à un programme de réhabilitation structuré et interdisciplinaire en plusieurs phases, mettant l'accent sur le chargement progressif, le contrôle neuromusculaire et la préparation au retour au sport (RTS). À huit mois après l'opération, l'athlète est retourné dans une école préparatoire aux États-Unis où il a intégré un programme externe de force et de conditionnement.*

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Summary: *This case report illustrates the complexities and value of an interdisciplinary and individualized rehabilitation program in the early stages of MLKI recovery. Outcomes were positive through eight months, but there were limitations related to the continuity of care that prevented long-term follow up.*

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KEY WORDS: multiligament-knee-injury, rehabilitation, return-to-sport, sports medicine, chiropractic

Résumé: *Ce rapport de cas illustre les complexités et la valeur d'un programme de réhabilitation interdisciplinaire et individualisé dans les premières étapes de la récupération après une lésion multiligamentaire du genou. Les résultats étaient positifs pendant huit mois, mais il y avait des limitations liées à la continuité des soins qui ont empêché un suivi à long terme.*

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MOTS CLÉS : lésion multiligamentaire du genou, réhabilitation, retour au sport, médecine du sport, chiropratique

Introduction

The knee is a complex joint within the body and is often associated with several pathologies that present in chiropractic offices and clinics. These acute injuries are most commonly experienced in sport-related environments, often only resulting in short-term management, and rarely require any surgical intervention.[1] Conversely, more serious injuries of the lower limb, such as acute MLKIs or acute knee dislocations (KDs), rarely present within traditional chiropractic settings. MLKIs are defined as complete injury to two or more of the four major ligaments of the knee: the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL)/posteromedial corner (PMC), and lateral collateral ligament (LCL)/posterolateral corner (PLC)[2], or acute KDs. As a result of the complexity and rarity of MLKIs, management may present a challenge to clinicians. However, with the growing involvement of chiropractors in sports medicine and the on-field care of amateur and professional athletes, exposure to more extreme injuries to the knee complex will become more prevalent. Therefore, it is essential that when these situations do present into practice, those within the profession have the clinical tools necessary to implement effective and timely patient care.

Acute knee dislocations are considered medical emergencies due to the potential of vascular and neurological compromise to the lower limb that can result in long-term disability. MLKIs are often associated with KDs and neurovascular injury, typically affecting the popliteal artery (PA) and the common peroneal nerve (CPN).[1] However, based on the timing, mechanism of injury, and high likelihood of spontaneous reduction, the knee may or may not be in a dislocated position, which can mask the potential dangers of this pathology and delay appropriate treatment.[2] This is of concern because approximately 40% of MLKIs and KDs have some degree of CPN palsy or vascular injury.[1] MLKIs involving dislocation – with or without vascular injury – require close monitoring, timely reduction, and often surgical management to preserve leg function. This necessitates proper triage from the attending clinician to determine the need for immediate orthopaedic intervention, as surgical treatment has been shown to lead to better outcomes than non-operative care.[1]

Although surgical considerations for MLKIs with associated vascular compromise is outside the scope of chiropractic practice, there is an important on-field role to potentially recognize, stabilize, and refer these patients accordingly. While there is currently no standardized treatment algorithm for MLKIs, and no consensus regarding the optimal timing of surgery, reconstruction versus repair, graft choice, and pre-operative rehabilitation[1], chiropractors working in sport can become an essential part of the health care team with regards to pre-rehabilitation for future reconstructive surgeries, post-surgical rehabilitation, return to sport training, and patient education. Our initiative in this paper is to highlight a case of a post-surgical MLKI with vascular compromise that presented to a sports specialist chiropractor. A brief literature review outlining the clinical relevance of this pathology in the scope of conservative management will be provided to help identify barriers and goals when rehabilitating a complicated orthopaedic knee injury. In addition, this case report will highlight the paucity within the literature regarding the lack of specificity within current rehabilitation protocols with respect to the class of MLKIs with neurovascular compromise.

Case Presentation

A 17-year-old male wide receiver, competing in an elite college preparatory football program in the United States of America, sustained a severe and limb-threatening lower extremity injury while attempting to catch a pass in a game. Upon landing, his left knee went into hyperextension while experiencing a torsional force, resulting in a comminuted tibial plateau fracture and tibio-femoral joint dislocation. Some of the involved soft tissue injuries included complete tears to the PCL and both popliteus and biceps femoris tendons, a radial tear to the medial meniscus and partial tears to the LCL, gastrocnemius proximal heads and patellar tendon. After the on-field injury, he was rushed to a local emergency department where he underwent emergency fasciotomies (medial and lateral) to salvage his lower limb as he had developed injury and ischemia to the PA that required a left PA endarterectomy and patch angioplasty. At the time, no ligamentous reconstruction was performed. Radiographs following the left knee reduction and first surgeries are found in Figures 1 and 2. Two months after the initial injury, he returned to

Figure 1.
Lateral radiograph post left knee reduction and angioplasty. The arrow in this image is highlighting the tibial plateau fracture still evident following the emergency knee reduction and angioplasty.

Figure 2.
Anterior-posterior radiograph post-left knee reduction and angioplasty.

his permanent residence in Canada, where he underwent a secondary multiligament reconstructive knee surgery to repair the PCL, medial meniscus and PLC of his left knee (Figures 3 and 4). Immediately following reconstruction, he was given an initial rehabilitation protocol from his surgeon to complete (Table 1). At six weeks post-operative, he was referred to a sports specialist chiropractor for consultation and rehabilitation at the recommendation of his surgeon. In addition to helping facilitate a return to full range of motion (ROM) and strength in the surgical knee, the surgeon requested a focused strength and conditioning program to help the patient get back to his performance goals in a timely manner. The primary goal of the patient was to return to football at a high level, with aspirations of playing NCAA Division I.

A multimodal plan of conservative care was designed that included exercise, manual therapies, joint mobilizations and therapeutic modalities (microcurrent, transcutaneous electrical nerve stimulation [TENS], electroacupuncture) to help facilitate and optimize tissue healing and are highlighted specifically in stages 3-5 of Table 1 with relevant clinical findings (> 6 weeks post-operative care). These were included to meet the targets of the post-surgical rehabilitation plan and address the signifi-

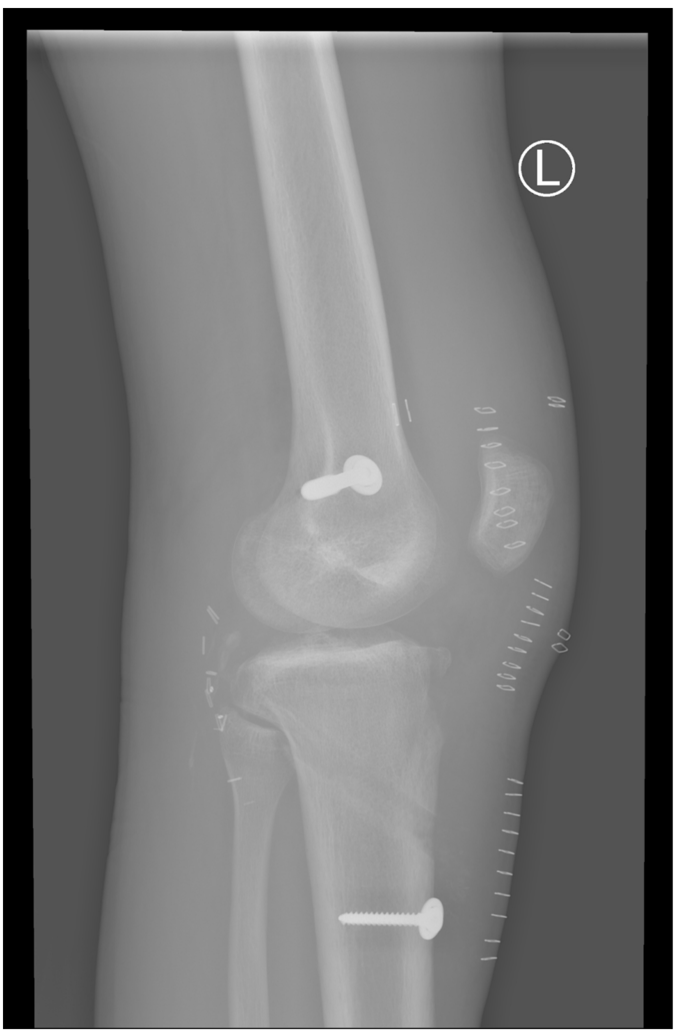

Figure 3.
Lateral radiograph post left knee multiligament reconstruction.

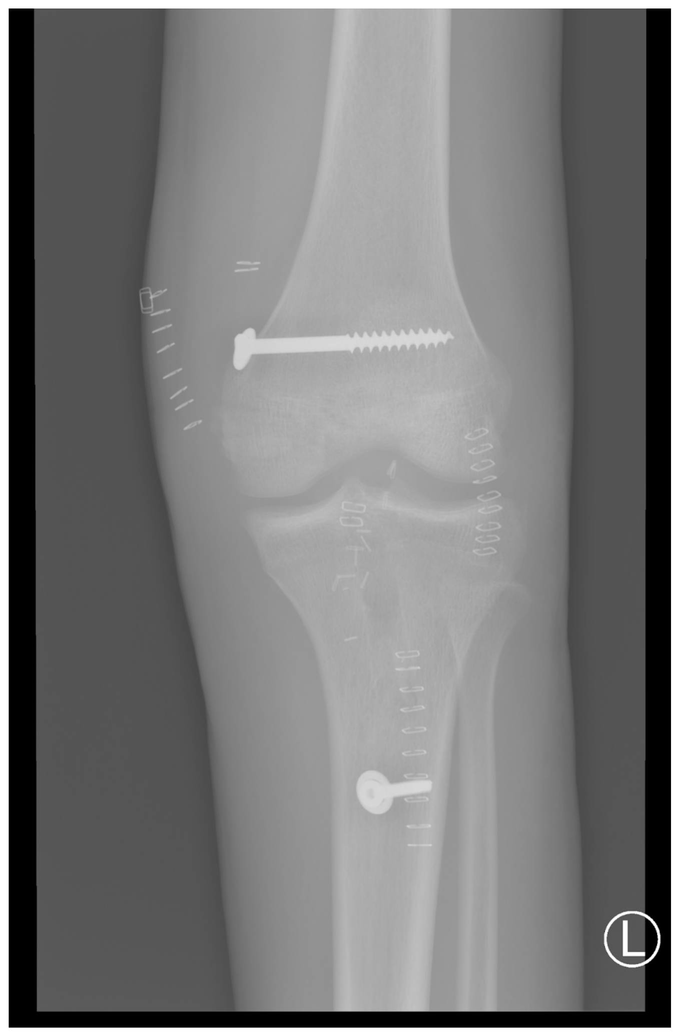

Figure 4.
Anterior-posterior radiograph post left knee multiligament reconstruction.

cant scarring left from the emergency fasciotomies and arterial repair. In stage 3 (weeks 6-12) the goals were to reduce pain and swelling, work towards full knee ROM, improve muscle strength and control while being mindful to protect the surgical grafts. Manual soft tissue therapies began in this stage involving the muscles of the lower extremity and scar tissue mobilization was prioritized for full patellar and tibiofemoral joint ROM. Modalities such as neuromuscular electrical stimulation (NMES) and electroacupuncture (low frequency stimulation, 2-4 Hz)[3] were used to help facilitate quadriceps activation. Instrument assisted soft tissue therapy, cross friction soft tissue therapy and high frequency electroacupuncture (210-270 Hz) were used to aid in scar mobility.[4] During this stage, the patient was seen twice a week where all of the passive treatment was completed prior to ending in the gym with exercise.

The goals of stage 4 (3-6 months) progressed to full patellar and tibiofemoral joint ROM and increasing strength and control of the lower extremity. Closed chain exercise and proprioception training was initiated at month 3 as detailed in Table 1. Many of the manual therapy techniques and modalities previously mentioned in weeks 6-12 were used here to maintain ROM and function of the lower limb.

During stage 5 (>6 months) goals were aimed to optimize knee ROM and strength while initiating a return to sport program. Whole body (compound) movements were utilized here to help integrate the affected left lower limb in more functional athletic movements and demands. In addition to Table 1 outlining the surgeon's recommendations with the detailed treatment therapies, Table 2 outlines the supplementary strength and conditioning program that was initiated.

Although there were several components in this plan of care, the purpose of this case is to highlight the complexity of the decision-making in MLKIs within the context of rehabilitation exercise. As such, the discussion will draw on how a clinician must evaluate several variables to optimize knee healing in the context of exercise program design in a high-performance athlete. Some of the variables that will be discussed are timelines for healing, functional anatomy of the knee, what movements are prioritized, and novel approaches to augment clinical outcomes.

Table 1.
Surgeon instructed post-operative physical therapy following multiligament reconstruction

Weeks 0-3. Goals: Decrease pain and swelling, protect surgical grafts, optimize early range of motion, initiate early muscle activation and strength

Category	Protocol Details
Weight Bearing	Touch weight bearing
ROM Goals	0-70° (prone)
Stability Precautions	No varus/valgus stress Protect posterior tibial sag
Bracing	ROM brace Locked at 0-70° flexion
Patellar Mobilizations:	Patellar Mobilizations: Multi-angle (cranial/caudal/medial/lateral glides) Positions: 0° , 30° , 60°

Category	Protocol Details
Local Modalities	Ice – 20 min every 2 hours Therapeutic ultrasound Interferential current/TENS – 20 min with therapy
Neuromuscular Electrical Stimulation (NMES)	Left quadriceps (full extension) – 20 min every 2 days
Strengthening	Quad sets (with NMES) Straight leg raises (SLR) – if full extension is achieved

Weeks 3-6. Goals: Reduce pain and swelling, protect surgical grafts, optimize early range of motion, initiate early muscle activation and strength

Category	Protocol Details
Weight Bearing	Partial weight bearing (25-30%) if full extension is achieved in brace
ROM Goals	0-90° (prone)
Stability Precautions	No varus/valgus stress Protect posterior tibial sag
Bracing	ROM brace Locked at 0-90° flexion
Patellar Mobilizations	Multi-angle (cranial/caudal/medial/lateral glides) Positions: 0° , 3° , 60°
Local Modalities	Ice – 20 min every 4 hours Therapeutic ultrasound Local scar massage Interferential current/TENS – 20 min with therapy
Muscle Stimulation (NMES)	Quads (full extension) – 20 min every 2 days
Strengthening	Quad sets (with NMES) Straight leg raises (SLR) – if full extension is achieved

Weeks 6-12. Goals: Reduce pain and swelling, protect surgical grafts, work towards full knee range of motion, regain muscle strength and control

Category	Protocol Details
Weight Bearing	Partial weight bearing, transitioning to weight bearing as tolerated over 2 weeks (protected in ROM brace)
ROM Goals	0-115° (transition to supine)
Stability Precautions	No varus/valgus stress

Category	Protocol Details
Case Clinical Findings: VAS PROM	Week 6: VAS 6/10 Week 12: VAS 2/10 Week 6: Extension 0°; Flexion 90° Week 12: Extension 0°; Flexion 135°
Bracing	ROM brace Unlocked while ambulating
Manual Therapies	Soft tissue therapy: directed towards the lower extremity (gluteals, quadriceps, hamstrings, gastrocnemius, soleus, extensor and peroneal muscles) Scar mobilization/treatment: • Instrument assisted soft tissue therapy • Cross friction • Electroacupucture (high frequency stimulation 210-270 Hz) Patellar Mobilizations: • Multi-angle (cranial/caudal/medial/lateral glides) • Unrestricted ROM
Local Modalities	Ice – post-therapy Electroacupuncture (low frequency stimulation, 2-4 Hz) directed towards the left quadriceps, hamstrings, peroneals
Muscle Stimulation (NMES)	Quads (full extension) – 20 min every 2 days Quads (30-0° closed chain) – 8-12 weeks
Strengthening	Quad sets (with NMES) Straight leg raises (SLR) – if full extension is achieved Open chain quads (no resistance) – 60-30° Closed chain quads – no deep flexion >60° (8-12 weeks) Open chain hamstring (eccentric, no resistance) – 60-10° (8 weeks) Hip abduction – standing, gravity eliminated
Proprioceptive Exercises	8-12 weeks
Cardio/Endurance	Stationary bike (no fixation of the distal chain)

3-6 months. Goals: Work towards full knee range of motion, regain muscle strength and control.

Category	**Protocol Details**
Weight Bearing	As tolerated
ROM Goals	Full ROM No varus/valgus stress
Case Clinical Findings: VAS PROM	6 months: VAS 1/10 6 months: Extension 0°; Flexion 150°
Bracing	Custom ACL/PCL brace
Local Modalities	Ice – post-therapy (as needed) Electroacupuncture (low frequency stimulation, 2-4 Hz) directed towards the left quadriceps, hamstrings, peroneals
Manual Therapies	Soft tissue therapy: directed towards the lower extremity (gluteals, quadriceps, hamstrings, gastrocnemius, soleus, extensor and peroneal muscles) Scar mobilization/treatment: • Instrument assisted soft tissue therapy • Cross friction • Electroacupucture (high frequency stimulation 210-270 Hz) Patellar Mobilizations: • Multi-angle (cranial/caudal/medial/lateral glides) Unrestricted ROM
Muscle Stimulation (NMES)	Quads (30-0° closed chain): ¼ squat holds
Stretching	ITB stretching – not for PCL/LCL
Strengthening	Open chain quads (no resistance) – 90-30° Open chain quads (light resistance <10 lbs) – 90-30° Closed chain quads – no deep flexion >60° Open chain hamstrings (eccentric, <10 lbs) – 60-10° Open chain hamstrings (eccentric, <10 lbs) – 90-10° Hip abduction (standing) – gravity eliminated
Proprioceptive Exercises	Single leg balance, ¼ to full Y-balance reaches
Cardio/Endurance	Stationary bike (no fixation of distal chain)

After 6 months. Goals: Work towards full knee range of motion, work towards full muscle strength and control, initiate a return to play program

Category	**Protocol Details**
Weight Bearing	As tolerated
ROM Goals	Full ROM
Bracing	Custom ACL/PCL brace
Local Modalities (as needed, varied per session)	Ice – post-therapy Electroacupuncture (low frequency stimulation, 2-4 Hz)
Stretching	ITB Stretching – not for PCL/LCL
Manual Therapies	Soft tissue therapy: directed towards the lower extremity (gluteals, adductor magnus, iliopsoas, quadriceps, hamstrings, gastrocnemius, soleus, extensor and peroneal muscles)
Strengthening	Closed chain quads – no deep flexion >60° Open chain hamstrings (eccentric, <25 lbs) – 60-10° Open chain hamstrings (eccentric, <25 lbs) – 90-10° Hip abduction (standing) – gravity eliminated Hip abduction (side-lying) *Table 5a: Initiated at 6 months
Proprioceptive Exercises	*Table 5a: Initiated at 6 months
Cardio/Endurance	Stationary bike (no fixation of distal chain) Pilates
Return to Sport Progression (surgeon criteria)	Running – 6 months Cutting/pivoting – 6-8 months Sports – <1 year
Restrictions (surgeon criteria)	No stationary bike/spin with distal chain fixed (until >6 months) No spin/bike with free flywheel (until > 4 months) No open chain hamstring (first 6 weeks) No plyometrics (until 8-12 months) No sports (until 1 year) No yoga (if not previously a sport/hobby until >1 year)

ROM: range of motion; Deg: degrees; TENS: Transcutaneous electrical nerve stimulation; NMES: Neuromuscular electrical stimulation; SLR: straight leg raise; ACL: anterior cruciate ligament; PCL: posterior cruciate ligament; LCL: lateral collateral ligament; MCL: medial collateral ligament; ITB: iliotibial band; Lbs: pounds; PNF: proprioceptive neuromuscular facilitation; KB: kettlebell; DB: dumbbell; BFR: blood flow restriction; CW: clockwise; CCW: counterclockwise; RDL: Romanian deadlift; 2L: two legs; 1L: one leg; KD: knee dislocation

Table 2.
Strength and conditioning protocol (>6 months)

Mobility Work

Exercise	Sets	Reps	Weight
Askling Extender's (patient laying supine, stabilizing thigh at 90 degrees hip & knee flexion, perform slow knee extensions until the point before pain)	3	12	N/a
Prone assisted knee flexion holds	2	3-4	N/a
Hip flexor split-stance proprioceptive neuromuscular facilitation (PNF) holds	2	3-4	N/a
Cat-camels	2	10-15	N/a
Hip 90/90 PNF holds	2	4-5	N/a
Scar/patellar mobilizations	N/a	3 minutes	N/a
Isometric 2-leg/single-leg hamstring bridge holds	3	4-5	N/a

*Pick minimum of 4 off of mobility/neuromuscular list

Neuromuscular Control

Exercise	Sets	Reps	Weight
Single Leg balance +/- BOSU, Wobble board	3	60 seconds	N/a
Single leg clock squats	10	1/leg	N/a
Y-balance reaches	3	10	N/a
Kettlebell Arm Bars	2	12	>10 lbs
Front Plank Shoulder Taps	3	10-12	N/a
McGill Modified Curl Up	3	15	N/a
Dead Bug	3	20	N/a

Workout A

Exercise	Sets	Reps	Weight
Goblet Squat KB/DB +/- BFR therapy	3	15	>45 lbs
Eccentric SL hamstring curls 3:1 T	3	12	Ankle weight
2L or SL glute bridge	3	10	N/a
DB/KB carry (reps as steps/side)	3	15	>10 lbs
Bear Crawl (reps as steps/side)	3	15	N/a
2L (SL) Hamstring curl on ball	3	12	N/a
DB/KB squat to single arm press	3	10	>15 lbs
Eccentric (3:1) lateral step down	3	12	>15 lbs

Workout B

Exercise	Sets	Reps	Weight
DB Chest Press on ball	3	15	>30 lbs
Inverted (TRX/bar) row	3	15	3:1 tempo
Step Ups (front/lateral)	3	10	>10 lbs
Stir-the-pot on ball	3	15	CW/CCW
KB swing (modify for knee pain)	3	15-20	>20 lbs
BOSU Squat Holds +/- BFR	3	12	>15 lbs
Kickstand or 2L elevated heel squat	3	20	Light weight
SL RDL +/- KB	3	12	~10 lbs

Workout C

Exercise	Sets	Reps	Weight
Front or Back Squat +/- BFR	3	15	>bar weight
Bird dog single arm row	3	12	>10 lbs
Static lunge (front/lateral/back) BFR	2	12	>bodyweight
Deadlift (Conventional or RDL)	3	10	>bar weight
Eccentric heel raises (drops)	3	12-15	3:1 tempo
Monster walks	3	15-20	N/a
Push up-plus on BOSU	3	15	N/a
Plank track on bench (front/sides)	3	45 seconds	N/a

Plyometrics and Cardiovascular Training

Exercise	Sets	Reps	Weight
Line jumping (2L>SL): front/back/side	2	30s	N/a
Cariocas, figure 8's, ladder drills			N/a
Box jumps	3	10-12	N/a
Stationary bike			N/a
Skipping (2L and SL)	3	1 minute	N/a

ROM: range of motion; Deg: degrees; TENS: Transcutaneous electrical nerve stimulation; NMES: Neuromuscular electrical stimulation; SLR: straight leg raise; ACL: anterior cruciate ligrament; PCL: posterior cruciate ligament; LCL: lateral collateral ligament; MCL: medial collateral ligament; ITB: iliotibial band; Lbs: pounds; PNF: proprioceptive neuromuscular facilitation; KB: kettlebell; DB: dumbbell; BFR: blood flow restriction; CW: clockwise; CCW: counter-clockwise; RDL: Romanian deadlift; 2L: two legs; 1L: one leg; KD: knee dislocation

Discussion

Clinical presentation

The disruption of the primary and secondary stabilizers of the knee through various mechanisms of injury results in varying presentations and patterns of MLKIs. These injuries typically occur via high-energy mechanisms, and ultimately require a thorough physical exam to assess the extent of injury and determine the presence of secondary complications such as arterial or nerve involvement.[2] While 50% of KDs spontaneously reduce, it is crucial to identify KDs and have them reduced in order to mitigate morbidity. Moreover, it is recommended to assess patients presenting with MLKIs using the Adult Trauma Life Support principles, a trauma care method focused on treating the greatest threat to life first, and initiating the indicated treatment without a definitive diagnosis, or detailed history.[5] After following such procedures and principles, it is paramount to assess the neurovascular system to identify possible associated vascular or nerve injury. Data has shown that delayed treatment of vascular injury increases the probability of compartment syndrome and/or amputation by 20%.[2] Clinical examination of the vascular status of the limb alone using pedal pulse is often not sufficient or reliable enough to identify subtle vascular injury, and it is recommended to proceed with further examinations such as the ankle brachial pressure index (ABI) and potential referral for an arteriogram. This emphasizes the importance of appropriate triage and assessment of MLKIs to prevent further complications. In the case presented, the on-field medical team was able to execute the appropriate steps needed to rush the patient to the hospital. Evaluation in the emergency department determined significant vascular compromise in the injured limb, which ultimately led to a medial and lateral fasciotomy, a left popliteal artery endarterectomy, and patch angioplasty to help save his leg.

Imaging

In addition to a comprehensive physical examination, diagnostic imaging is required to assess the direction of dislocations, integrity of bones, and other signs pointing to the extent of injury and location. Radiographs are the first line in assessment, followed by magnetic resonance imaging (MRI) to assist in the diagnosis of MLKIs and creation of a specific treatment and rehabilitation plan.[6] The MRI aids in evaluating meniscal involvement, intraosseous contusions, possible fractures, capsule tears, specific ligament involvement, and determining the amount of graft that would possibly be needed for reconstruction[6]. The selective use of arteriography is shown to be a safe and prudent practice following knee dislocation. Arterial examination should include palpation and ABI evaluation of the dorsal pedis and posterior tibial arteries. ABI scores of <0.9 have been shown to have a sensitivity, specificity and positive predictive value of 100% for identifying vascular injuries in KDs.[7] Asymmetry in pulses, or an ABI below 0.9 in the injured limb would warrant immediate referral for an arteriogram.[1] In the absence of these findings, patients should be admitted for careful observation[6]. In the case presented, the severity of the injury required all the aforementioned diagnostic imaging to help triage intervention and aid in the management of the lower extremity ischemia.

Sports chiropractors are well positioned to manage the immediate triage of these injuries during on-field management, as their advanced training in musculoskeletal diagnosis and emergency care allows for rapid assessment, stabilization, and decision-making in high pressure environments. Understanding the role of imaging in MLKIs improves a clinician's ability to recognize or confirm clinical red flags, identify cases requiring immediate intervention and referral to ensure prompt and appropriate care. Additionally, the utilization of imaging provides clinicians with an accurate diagnosis that will drive clinical decision making during the rehabilitation process. Given the confirmed injuries to the tibial plateau, meniscus, PCL and PLC, many factors needed to be considered in terms of when and how to prioritize loading in the knee. These details can be found in tables 1 and 2, and will be discussed more in the following sections.

Functional anatomy of the knee joint

The knee joint relies on a combination of different passive and dynamic stabilizers to maintain joint congruency and function. The four primary stabilizing ligaments include the ACL and PCL, which help control anterior and posterior translation, respectively, while providing critical proprioceptive input.[8,9] The MCL stabilizes against valgus forces, and the LCL resists varus stress and assists in rotational control. Additional support is provided by the posterior oblique and arcuate ligaments, in addition to the dynamic stabilizers of the knee's such as the quadriceps, hamstrings and pes anserine complex. The knees menisci further contribute to stability by providing improved joint congruency, load distribution and shock absorption.[10]

The MCL, which is a key medial stabilizer, consists of three layers: superficial, deep, and capsular.[11,12] Its primary function is to resist valgus stress and external rotation, with additional contributions from the semimembranosus, quadriceps and pes anserine muscles.[13] Similarly, the PCL and LCL work in conjunction to limit posterior translation and external rotation. The popliteofibular ligament and popliteus muscle play important roles in stabilizing the PLC, with the popliteus actively resisting external rotation forces.[14] While a PCL rupture can be functionally compensated for by secondary stabilizers like the quadriceps, damage to the PLC significantly increases instability, often requiring surgical intervention.[15,16]

Neurovascular structures within the knee, particularly the PA, tibial and CPN, are at high risk during severe knee trauma. The PA, constrained by the adductor magnus, is vulnerable to injury, with vascular compromise being a critical concern.[17] The CPN due to its superficial location over the fibular head is especially susceptible to traction and rupture in high-energy type dislocations, often resulting in poor recovery rates.[18] In this case, rupture of the PA required limb-saving surgery, with rehabilitation focused on restoring circulation and mitigating motor and sensory deficits[17-19] through the use of gentle ROM, electrical stimulation and neuromuscular re-education (Table 1).

Understanding the functional anatomy of the knee joint is crucial for clinicians in guiding rehabilitation and treatment decisions following MLKIs. Each ligament and stabilizing structure of the knee plays a specific role in controlling excessive movement in any given direction, being anterior, posterior, medial, lateral or rotational instability. Identifying the primary instability pattern, and the associated structures allows clinicians to tailor rehabilitation protocols to protect healing structures while promoting compensatory support from the secondary stabilizers. In cases of an injured PCL, the quadriceps complex and popliteofibular ligament can provide important posterior and rotational stability of the knee[15], influencing early rehabilitation exercises to help avoid any excessive posterior tibial translation. In complex cases where multiple structures are compromised, rehabilitation exercises must balance controlled loading to promote the healing of injured tissues while aiding in restoring strength, neuromuscular control and joint proprioception. This was particularly important in the case presented as complete tears occurred to the PCL and structures of the PLC. This was further made vulnerable by partial tears to supporting musculature of the knee joint. As a result, following the healing of the tibial fracture (6-8 weeks), early rehabilitation focused on regaining dynamic stability by encouraging muscular co-contraction without compromising joint congruency and graft integrity (Table 1: Weeks 6-12 and 3-6 months). By having a comprehensive understanding of the functional anatomy of the knee, it ensures a progressive return to function of the knee while minimizing the risk of any instability-related complications.

Rehabilitation for MLKI

MLKIs represent a large spectrum of injury pathology, evidently being less common than single ligament knee injuries. This provides a challenge in developing a consensus regarding diagnosis, and more importantly, management of these injuries. Post-operative rehabilitation and RTS protocols following multiligament knee reconstructions remain complex and individualized, specifically for high-level athletes.[20, 21] Existing literature emphasizes the need for structured rehabilitation strategies that balance early mobility with the protection of reconstructed ligaments to optimize functional outcomes.[20, 21] Key components of MLKI rehabilitation includes progressive weight-bearing, controlled ROM, neuromuscular re-education and gradual RTS.[20, 21] There is however, significant variability in rehabilitation timelines, bracing suggestions/requirements, and specific criteria for reintegration into sport, further highlighting the continued challenges in standardizing care. The importance of early mobilization and challenges in establishing definitive protocols was highlighted by Monson *et al*.[20]

An initial period of restricted weight-bearing, controlled ROM exercises, and progressive strengthening were central to the rehabilitation plan of our patient, and incorporated elements highlighted in recent expert consensus statements[21], as well as the article by Monson *et al*.[20] Given his goal of competing in NCAA Division I football, the rehabilitation strategy was designed using current best practices and individualized considerations for the patient's return to high-performance sport (see Tables 1-2).

The findings from Monson *et al*. suggest early mobilization improves stability, ROM and functional outcomes when compared to prolonged immobilization.[20] The overall rehabilitation strategy focused on progressing from weight bearing restrictions and ROM limitations, to dynamic strengthening and proprioceptive exercises, in line with current evidence advocating for early mobility for functional recovery. These steps were necessary for early fracture healing and allowing sufficient time to protect the PCL graft and other compromised passive tissues of the knee joint. Additionally, the use of a custom ACL/PCL brace for protection during high-impact activities was mandated, consistent with expert consensus recommendations to brace for the first 18 months to safeguard the knee during the rehabilitation process[21]. For this patient, progression through rehabilitation stages was guided by defined criteria including minimum ROM milestones (Table 1). The patient met early phase targets within the expected timeframes, however delayed neuromuscular activation due to nerve involvement slightly prolonged the transition into dynamic loading and closed chain strengthening. Throughout the rehabilitation program, adherence to the brace was maintained and stage progression was carefully monitored to ensure graft protection and gradual functional improvements.

For this patient, RTS was staged with running anticipated at 6 months, cutting and pivoting at 6-8 months, and full participation in sport expected within 1 year from the injury date. These milestones reflect the best practices outlined in the literature, but have been tailored to the patient's specific needs and goals.[20, 21]

Stages and pacing for rehabilitation

The rehabilitation process in MLKIs is complex due to the nature of tissue damage, the need for careful protection of reconstructed ligaments, and the risk of complications including stiffness, instability, and muscle atrophy. Rehabilitation in these cases must be carefully paced to avoid exacerbating underlying issues while promoting healing and recovery.

The patient's vascular repairs and fasciotomies provide a unique aspect to the overall management. Typical fasciotomy incisions must extend along the full length of the affected segment of the limb which is necessary for thorough exploration of the affected musculature, as well as the major arteries and nerves in the area. In the rehabilitation of fasciotomies, typically a structured phase-based approach is important to optimize recovery and return function.[22] The outlined rehabilitation framework aligns with the recovery timeline of the patient in this case report, placing emphasis on early protection, progressive mobility, and gradual strengthening. Acutely post-operatively, PRICE principles play a role in minimizing swelling and post-operative complications. As healing continues, early ROM and soft tissue mobilizations can help maintain joint function, facilitating an easier transition to controlled resistance training, and proprioceptive and neuromuscular training in later stages.[22] Given the angioplasty and status of the PA, the surgeons involved in the management were consulted prior to using blood flow restriction therapy (BFR) to the lower limb in later stages of rehabilitation exercise.

Early rehabilitation phases, specifically in elite athletes, should focus on the prevention of common complications after knee trauma, including but not limited to joint stiffness and muscle atrophy. As highlighted in the literature, immobilization after MLKIs may result in decreased ROM, impaired joint stability, and delay recovery of muscle function, all of which can prolong rehabilitation and affect the athletes RTS.[20] Early mobilization within a controlled environment is the preferred approach, as it can accelerate recovery of function, specifically joint stability, and ROM.[21-23] This approach was closely followed with our patient. While the initial timelines were guided by the surgeon, early mobilization was initiated within the parameters and controlled passive ROM exercises and neuromuscular activation strategies began as soon as soft tissue integrity and vascular status allowed (Table 1).

The acute phase of 0-6 weeks post-op has a primary focus on protecting reconstructed ligaments and mitigating further damage, while restoring early function. The patient in this case was initially placed in a ROM brace with restricted weight-bearing, typical in the early phase of MLKI recovery. This allowed the patient to regain joint mobility while minimizing the risk of tissue compromise. During this initial period, prone knee ROM exercises with quadriceps activation should be initiated.[20, 21] These exercises aim to prevent joint stiffness, especially with PCL reconstruction, and ensure early quadriceps activation to avoid muscle atrophy and improve muscle and gait re-education.[24]

During the acute or tissue protection phase of rehabilitation, pain should be maintained below a 3/10 to prevent excessive stress on the healing tissues. Progression can occur as the pain and inflammation subsides, but any increase in symptoms lasting longer than 12-24 hours may indicate a premature overload of the tissues.[25] For patients recovering from PCL reconstruction, it is crucial to consider positions that place increased biomechanical stress on the compromised ligament. Hyperextension of the knee should be restricted for the first six weeks, and hamstring exercises should be avoided until week eight. This precaution is necessary due to the posterior tibial translatory forces that are exerted by the hamstrings in the absence of quadriceps co-contraction at 30 degrees of flexion.[20, 24, 25] The patient in this case also concomitantly sustained damage to their PLC and suffered a comminuted tibial plateau fracture. Rehabilitation considerations for these injuries do not differ from strategies described above, with an emphasis placed on early mobilization and graded exposure to load.[26-28] For early-stage rehabilitation (weeks 0-8) strengthening of the lower limb was limited to open-chain lower limb exercises to protect the osseous healing of the tibial fracture (Table 1). Additionally, clinicians should be mindful of the anchoring materials used during surgery, as soft tissue repairs secured with sutures are more susceptible to failure under early stress.[24]

As the patient progresses to the intermediate phase of post-operative recovery (6-12 weeks), rehabilitation can increase in intensity. Weight bearing can be advanced, and ROM goals expand to allow more functional movements. Surgeon clearance for weight bearing allowed for progression to both closed chain movements, and partial to full weight bearing (Table 1). The patient should begin integrating closed-chain exercises to strengthen the quadriceps while preventing excessive ligament stress.[21] In addition, the use of custom ACL/PCL bracing during higher-impact activities is important for protection of the surgically repaired tissues when transitioning to weight-bearing activities.[21] This stage additionally includes incorporation of proprioceptive exercise to regain neuromuscular control and improve proper movement patterns when returning to sport.

Advanced weight-bearing is defined as movements requiring greater eccentric control or a range of motion beyond 45 degrees of knee flexion.[24] These movements can begin as early as six weeks post-operatively, provided the patient has been cleared to bear weight without assistive devices. At this stage, a graded approach to weight-bearing load should be implemented.[20, 21-24] Initially, closed chain loading of the lower limb should not exceed 45 degrees of knee flexion. Advanced weight bearing was cautiously approached due to the tibial plateau fracture, and was initiated at week 8 (Table 1). Flexion beyond this point increases load on the PCL and activates the posterior stabilizers of the knee, whereas the ACL remains relatively unloaded.[29] While closed-chain movement was introduced at week 8 the patient was limited to a maximum range of motion of >60° of knee flexion. Tolerability of range was emphasized during the initial introduction of lower limb closed-chain loading (Table 1). Despite the patient in this case having full strength (graded 5/5 with manual muscle testing) in all isometric knee ROM at this stage, it was advised by the surgeon to proceed cautiously and avoid high knee flexion angles until week 12 post-operative given the complexity of the injury (Table 1).

The final phase (6-12 months post-operative) of rehabilitation should focus on sport-specific movements including cutting, pivoting, and sprinting. When introducing these higher intensity movements, it is crucial to monitor for signs of instability and discomfort. Through this phase, strengthening exercises should target functional muscle groups to help support dynamic movements. Plyometrics and complex sport-specific drills are to be incorporated gradually depending on the patient's recovery and status. RTS most importantly shouldn't be rushed and at this stage, management should include assessments of the patient's ability to perform high demand tasks and activities[20]. The integration of sport-specific movements programming (Table 2) was initiated at 6 months. The program included the following components: resistance, neuromuscular, cardiovascular, and mobility training.

Currently, there is no defined or validated RTS protocol for MLKIs. However, ACL RTS testing includes a variety of objective measures, such as quadriceps and hamstring strength, single- and double-leg jumping performance, change of direction (COD) ability, and validated subjective questionnaires.[20, 30, 31] PCL RTS criteria share similarities with ACL RTS, as assessments focus on the athletes strength, endurance, and functional movement patterns to determine readiness for RTS. Limb function has been extensively studied in ACL injury literature, where functional hopping tests and isokinetic strength assessments are commonly recommended for RTS evaluation.[32] Additionally, single-leg hopping for time and the crossover hop test are valuable for assessing lower limb functional performance.[33] Traditional RTS testing for ACL injuries is typically conducted at three, six, and nine months post-injury.[34] Given the complexity of MLKIs and the potential soft tissue involvement, Monson *et al*.[20] proposed RTS metric testing at four, seven, and 10 months to better account for recovery timelines. Unfortunately, the subject returned to their respective collegiate team prior to completing RTS testing. In this case, steps were taken to prepare the athlete for sport readiness and testing preparedness with rehabilitation emphasizing unilateral strength, landing mechanics, and neuromuscular control of the lower limb (Table 2). Although the athlete was lost to follow-up prior to RTS testing, the utility of a proficient rehabilitation plan can be measured by its capacity to return an athlete to sport, therefore, discussing the implications and limitations of RTS testing is warranted.

The use of criteria-based testing aims to objectively clear athletes for RTS while minimizing the risk of reinjury. With 50% of ACL injuries occurring during single-leg landing or COD tasks[35], emphasis should be placed on unilateral loading mechanics. However, the validity of isolated objective performance measures in determining RTS readiness should be critically examined. In athletes with ACL reconstruction, asymmetrical joint mechanics have been observed despite symmetrical performance in jumping and COD tasks.[36, 37] These findings highlight the potential value of biomechanical assessment as an alternative measure of sport readiness, rather than relying solely on traditional performance metrics. As previously mentioned, the RTS battery testing is designed to clear an athlete's RTS while mitigating reinjury risk.[31] King *et al*. investigated reinjury rates in athletes following ACL reconstruction, assessing leg strength index (LSI) in the hamstring and quadriceps, jump height and length, and COD times.[38] Despite the findings from Kyritis *et al*.[31], where failure to achieve an LSI >90% increased reinjury risk, King *et al*.[38] demonstrated that even when this threshold was met, biomechanical abnormalities during jumping and COD tasks could still persist at the time of RTS. This suggests that the current standard of measuring symmetry may not be a strong predictor of sport readiness or reinjury risk mitigation.[38]

Although LSI was similar between the reinjury and non-reinjury groups in the study by King *et al*.[38], notable biomechanical differences were observed. In the sagittal plane during the double-leg drop jump, the reinjury group exhibited increased knee flexion, longer ground contact times on the surgical side, and a shorter vertical distance from the center of mass (COM) to the ankle. Additionally, during the COD tasks, the reinjury group demonstrated a less posterior COM position in planned COD movements and reduced anterior pelvic tilt during unplanned COD tasks. It has been suggested that a less posterior COM position is a strategy to reduce knee extensor moment during jumping and deceleration[38-41], and to decrease knee valgus moment during COD[39]. Interestingly, the study found no significant difference in knee valgus angle between the reinjury and non-reinjury groups, which contradicts previous reports identifying it as a risk factor for ACL reinjury.[38] These findings highlight the importance of movement context in the later stages of rehabilitation. A high-level rehabilitation professional understands the nuances of movement and the biomechanical compensations that may allow an athlete to meet objectively symmetrical RTS criteria while still exhibiting underlying deficits. This perspective may play a key role in mitigating reinjury risk[38] and represents a more comprehensive approach to both RTS and, more importantly, performance.

Limitations

This case report describes the rehabilitation process of a single patient that recovered from an MLKI, and the ability to generalize the findings from this case to a broader population is inherently limited due to the nature of a case report. While the rehabilitation plan was detailed, the observations and outcomes here are specific to this unique patient's injury pattern, surgical management, and access to care. Furthermore, continuity of care was disrupted at eight months postoperatively when the athlete returned to the United States preparatory school and transitioned to a different strength and conditioning program. As a result, we were unable to comprehensively track the patient's progress through the full rehabilitation timeline including the final return-to-play phases and decisions. Notably, the patient was red-shirted for his first year following the injury, while not competing in official games that season, he preserved eligibility while still training with the team. This allowed for a continued conservative progression and an extended recovery period, though the impact of this decision on long-term outcomes could not be fully assessed.

Follow-up appointments and treatments occurred periodically during school holidays, which limited the ability to document longitudinal functional outcomes in the late-stage rehabilitation process. Additionally, while there were efforts to incorporate a collaborative interdisciplinary approach to managing this patient, the change in care environments as well as providers meant that the later stage rehabilitation may not have followed the initially established plan of care which may have influenced the patients long-term recovery trajectory in ways that cannot be accounted for in the scope of this report.

Summary

This case highlights the continued challenges in MLKI rehabilitation, outlining the importance of individualized treatment plans that consider the patients recovery and their long-term functional goals. However, as highlighted in a recent consensus statement[21], studies vary significantly in their protocols and guidelines for specific MLKI injury patterns. While current protocols provide general guidance, significant variation in rehabilitation strategies and the lack of high-quality, large-scale evidence means more research is needed to refine protocols and improve outcomes for athletes returning to sport.

While the early stages of rehabilitation focus on protection of the surgical repairs, the latter stages of rehabilitation should focus on strength, conditioning, and normalizing biomechanics. It is also critical to evaluate the goals and expectations of the patient. This can become particularly challenging in high performance sport where timelines and expectations are scrutinized. With the limited body of RTS literature on MLKIs in athletes, this case provides value as it presents MLKI rehabilitation strategies implemented by a sports chiropractor past the stage of post-surgical protocol, with the objective of returning to a high-level contact sport.

In MLKIs, the level of tissue damage and reconstruction of multiple ligaments requires a cautious and structured rehabilitation approach. The patient in this case not only suffered ligament damage, but also a tibial fracture and arterial damage which further requires management of swelling, circulation and healing in his early stages of rehabilitation, and necessitate attention to limb health in managing swelling and promoting blood flow.

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