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Criteria-Based Management of an Acute Multistructure Knee Injury in a Professional Football Player: A Case Report

Traumatic knee injuries that involve multiple ligamentous structures, coupled with significant soft tissue involvement, can be extremely difficult to manage.[3,5,7,9,14,15,20,22,26,31-33] As the severity of a knee injury increases, so does the probability that a patient will experience greater difficulty achieving full preinjury range of motion (ROM).[7] Individuals with these type of injuries, when operated on immediately after the episode of trauma, may be at greater risk for developing arthrofibrosis.[7,20,22,26] The loss of normal knee ROM after an injury or multiple ligament reconstruction is a potentially serious and critical complication to the uninhibited restoration of normal lower extremity function. Noyes et al[20] stated that a loss of preinjury knee ROM continues to be one of the most frequently reported complications following knee surgery. Anterior cruciate ligament (ACL) reconstruction performed in the acutely injured knee, prior to the resolution of swelling, pain, and the normalization of motion, has been shown to place an individual at a greater risk for the development of postoperative knee motion complications.[24] This is especially true for combined injuries of the anterior cruciate and medial collateral ligaments.[26] Arthrofibrosis, which causes marked postoperative knee motion complications, poses significant challenges to both patient management and the overall course of postoperative rehabilitation.

STUDY DESIGN: Case report.

BACKGROUND: Joint stiffness, also called arthrofibrosis, remains the primary complication following any reconstructive knee surgery. Acute anterior cruciate ligament surgery, performed with concomitant multiple ligamentous repair and/or reconstruction, further increases the likelihood of developing impaired knee motion following surgery. The purpose of this case report is to present a criteria-based approach to the postoperative management of a multiligament knee injury.

CASE DESCRIPTION: A 25-year-old male professional football player sustained a contact injury to his right knee while making a tackle during a regular season game in 2007. He underwent an acute anterior cruciate ligament reconstruction, with concomitant posterolateral corner repair, biceps femoris/iliotibial band repair, lateral collateral ligament repair, and a medial meniscocapsular junction repair. He completed 17 weeks of a multiphased rehabilitation program that emphasized immediate range of motion, low-load long-duration stretching, therapeutic exercise, neuromuscular reeducation/perturbation training, plyometrics, and sport-specific functional drills. Electrical neurostimulation was implemented during the early stages of rehabilitation to control postoperative pain and to promote a steady progression of therapeutic exercise activity.

OUTCOMES: The patient was cleared to begin sport-specific activity 7 months after major multistructure reconstructive knee surgery. He began the 2008 season on the physically-unable-to-perform list, but was activated midseason and played in every game thereafter. During the 2009 and 2010 seasons, he played all regular season games and all playoff games as a starter, and continues to start as a defensive cornerback in the National Football League.

DISCUSSION: This case report highlights the clinical decision-making process and management involved in an acute multiple ligamentous knee injury/reconstruction.

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KEY WORDS: *ACL, anterior cruciate ligament, arthrofibrosis, posterolateral corner*

Arthrofibrosis of the knee complex is defined as the loss of motion in both flexion and extension, when compared to the normal contralateral side.[6,7,9,20,22] Primary arthrofibrosis is caused by an exaggerated inflammatory response to an injury or surgical procedure, followed by the production of fibroblasts and an increase in extracellular matrix protein deposits.[29] Jackson et al[15] hypothesized

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that arthrofibrosis is the result of an immune response in which T-cell activation plays a significant role in a cascade of events, resulting in cell activation and early proinflammatory fibrogenic cytokine production.

In the most severe cases, dense scar tissue invades the peripatellar recesses, suprapatellar pouch, intercondylar notch, and articular surfaces of the knee joint. Thick, dense scar tissue in the infrapatellar region may lead to patella infera, patellar entrapment, and permanent limitations in knee ROM.[9,14,15,17,20,22,27,31] In some cases, there is a localized formation of scar tissue on the anterior aspect of the tibia at the site of the original footprint of the ACL, referred to as a cyclops lesion.[15] These lesions have been implicated in the loss of knee extension following ACL reconstruction.[15]

Recent clinical research has demonstrated the efficacy of reconstructing the acutely torn ACL in athletes.[1,2] Even as the outcomes of reconstructive procedures become more predictable, orthopaedic surgeons and physical therapists realize that joint stiffness remains the single most common complication following these forms of surgical interventions.[5-7,14,26] Complications from knee arthrofibrosis can prolong the rehabilitative process, jeopardize achieving a full functional outcome, and possibly result in long-term disability. Additionally, chronic loss of motion often leads to tibiofemoral and patellofemoral joint articular cartilage degeneration and the formation of osteoarthritis.[5] Shelbourne and Gray[24] have reported that even a loss of 3° to 5° of knee extension can lead to knee osteoarthritis.

Two of the most common factors related to the development of arthrofibrosis are knee dislocations and major concurrent operative procedures, such as the reconstruction of other knee ligaments and complex meniscal repairs, performed in conjunction with ACL reconstruction.[5,20] Despite the risk of arthrofibrosis, early operative intervention, when possible, has been advocated in cases of multiple capsular ligament injuries that involve the lateral and posterolateral structures of the knee, where acute primary repair and augmentation procedures are required to adequately address the injured knee.[20,21] When required, the reconstructive and repair procedures of concomitantly torn ligaments, capsular structures, and menisci should be performed in a manner that allows for the implementation of immediate postoperative knee motion to minimize the risk of arthrofibrosis.[1,3,7-9,14,20-22,25-27,31-33]

The current literature describes a wide range of approaches to the postoperative treatment following ACL reconstruction; however, concomitant ligamentous and capsular injury coupled with an acute ACL reconstruction presents a unique challenge.[5,20,21,25-27,31-33] Implementing a rehabilitation protocol that emphasizes minimizing postoperative swelling, restoring of full knee ROM, progressive quadriceps strengthening, neuromuscular/proprioceptive balance training, perturbation training, agility training using multiplanar functional movement patterns, and plyometrics has been shown to be successful in the rehabilitation of athletes following ACL reconstruction.[18,25-27,32,33] The risk of arthrofibrosis, with its associated quadriceps weakness, abnormal gait mechanics, and progressive loss of function, may introduce overwhelming complications into the recovery of an athlete trying to return to the rigors of high-level sport. Therefore, patients who have undergone an acute ACL reconstruction in conjunction with concomitant ligamentous procedures require a specific postoperative rehabilitation regimen that includes an earlier emphasis on ROM, passive knee extension, and patellar mobility to counteract the potential for developing motion complications.

These factors are all uniquely illustrated in this case, in which a professional athlete sustained a devastating multistructure right knee injury that could have potentially ended his National Football League (NFL) career. The purpose of this case report is to present a criteria-based approach to the postoperative management and rehabilitation of an acute multiligament knee injury, that was designed to minimize the potential development of motion complications.

CASE DESCRIPTION

THE PATIENT, A 25-YEAR-OLD PROFESsional football player, sustained a right knee injury during a regular season game on November 4, 2007, while attempting to make a tackle from his defensive cornerback position. The mechanism of injury was a fall onto an extended knee, with the combined application of a varus force. The team orthopaedic physician and the athletic trainer immediately made a diagnosis of ACL tear and posterolateral instability. Magnetic resonance imaging showed evidence of a lateral ligament complex tear, avulsion of the iliotibial band and biceps femoris, rupture of the posterolateral capsule, grade 2 medial collateral ligament sprain, rupture of the medial meniscocapsular junction, torn popliteus muscle belly, complete ACL tear, and a partial posterior cruciate ligament tear. Given the extensive nature of this injury, the patient was immediately referred for a surgical consult.

The physical examination, performed 3 days following the injury, revealed no damage to the peroneal nerve. However, there was significant laxity (3+) evident during varus stress testing of the right knee at both 0° and 30° of knee flexion, when compared to the contralateral side. The patient exhibited a positive Lachman test with a soft endpoint, and mild valgus laxity (1+) during stress testing at both 0° and 30° of knee flexion. Posterior drawer testing revealed a firm endpoint without laxity. Passive ROM of the involved knee was 57° of flexion, with an extension deficit of 9° (0°-9°-57°). ROM of the uninjured knee was 7° of hyperextension and 145° of flexion (7°-0°-145°). Given the severity of the injury, immediate surgical intervention was recommended to appropriately address the posterior-lateral corner injury, in combination with the other damaged structures.

Operative Findings and Procedures

After receiving informed consent, the patient was taken to the operating room on November 8, 2007, 4 days following his injury. Examination under anesthesia revealed a positive Lachman test, 3+ anterior drawer test, stable posterior drawer test, 3+ laxity with varus stress at both 0° and 30° of knee flexion, and good stability with valgus stress testing in both full extension and 30° of flexion.

Standard arthroscopic portals were created and an arthroscopic examination was performed, which revealed a complete ACL tear and a complete tear of the posterior aspect of the medial meniscal capsular junction. There was also a liftoff opening visually evident in the posterolateral aspect of the knee.

Following the arthroscopic examination, an open reconstruction of the lateral and posterolateral structures of the knee began. A curved incision was made laterally between the femoral condyle and the fibula. Upon splitting the skin and subcutaneous tissue, it became evident that there had been a complete stripping of the posterolateral structures away from both the tibia and fibula. The biceps femoris and iliotibial band had both been completely avulsed off of the tibia and fibula. The popliteus muscle had suffered both a muscle belly tear and an avulsion of its tendon from the femoral condyle. The peroneal nerve was located and inspected. There was no evidence of injury to the nerve, and it was carefully protected throughout the remainder of the procedure.

The end of the popliteus tendon was isolated and whipstitched with MaxBraid sutures, so that it could be reattached later in the procedure. The popliteus muscle belly was anatomically repaired with 2.0 Dacron sutures. An Innovasive anchor (DePuy Orthopaedics, Inc, Warsaw, IN) was placed into the posterolateral aspect of the tibia, and the popliteus muscle belly was securely tied down to the anchor in this location.

The lateral collateral ligament had also been avulsed from both the tibia and fibula. After being identified, both ends were whipstitched with MaxBraid sutures and reattached anatomically and secured via Innovasive anchors.

Next, the sleeve of posterolateral soft tissues was reattached to both the tibia and fibula via a total of 4 Innovasive anchors. Two additional anchors were used to advance these tissues further distally, then the entire area was reinforced to the capsule and retinaculum with Dacron sutures. At this point, another Innovasive anchor was placed in the femoral epicondyle, and the popliteus tendon was tied down over the anchor. Splits in both the iliotibial band and the biceps femoris-iliotibial band junction were also repaired.

Next, the arthroscope was reintroduced in the knee joint, the ACL stump was debrided, and an adequate notchplasty was performed. Then, the large posteromedial capsular junction tear was repaired using a loop suture tied to the meniscus and capsule via a sliding-knot technique. Finally, an ACL reconstruction was performed using an ipsilateral bone-patellar tendon-bone autograft. Fixation of the graft was accomplished using two 9 × 25-mm BioRCI screws, 1 in the femoral tunnel and 1 in the tibial tunnel.

The wounds were copiously irrigated, the incisions closed, and the patient placed in a hinged postoperative knee brace locked in 30° of knee flexion. He was then transferred to the postanesthesia care unit in stable condition, where immediate cryotherapy with Game Ready (CoolSystems Inc, Alameda, CA) vasopneumatic compression was initiated to control postoperative swelling.

Postoperative Rehabilitation

The first week following any knee ligament reconstruction represents a critical period in the patient's rehabilitation. Essential interventions implemented at this stage of the process are structured toward controlling knee joint swelling and pain, regaining appropriate voluntary quadriceps contraction, initiating immediate knee motion, and maintaining adequate limb elevation.[32,33]

The rehabilitative plan of care immediately after surgery emphasized the restoration of knee ROM, focusing on full passive knee extension and patellar mobility. Strategies to reduce swelling, postoperative pain management techniques, and an immediate exercise program to promote voluntary muscle activation, designed to retard atrophy and control forces placed on the healing ACL graft and posterolateral corner of the knee, were also outlined with the patient. The criteria-based rehabilitation program designed to manage this patient is outlined in the **APPENDIX**.

For the first 2 weeks after surgery the patient did not bear weight on his surgical leg, to protect the healing posterolateral corner repair from undo forces. The patient wore a postoperative hinged knee brace locked in 30° of flexion at all times, except during his rehabilitation sessions, for the first 10 days following surgery. After 2 weeks of non-weight bearing, the patient was advanced to weight bearing as tolerated, while ambulating for the next 2 weeks with the brace locked in full extension. Adequate quadriceps control for ambulation was achieved 6 weeks following surgery, at which time the brace was unlocked for general activity and the patient's weight-bearing status was progressed to full, unassisted ambulation.

The patient began physical therapy 2 days following surgery. During the first treatment session, his knee flexion passive ROM (PROM) was limited to 30°, and he demonstrated difficulty performing quadriceps setting exercises and passive patellar mobilization secondary to pain and nausea. The patient could not be treated over the next 2 days because of continued nausea. During this time, cryotherapy, compression, and elevation were used to control postoperative edema and pain. The use of a continuous passive motion device for knee ROM was also implemented for 60 minutes per day in conjunction with these interventions, during the time the patient was unable to rehabilitate. On day 4 postsurgery, the patient's right knee ROM was 48° of flexion and 4° short of full extension (0°-4°-48°).

One week following surgery, the patient's right knee ROM demonstrated an extension deficit of 2° and 92° of knee flexion (0°-2°-92°). PROM of his contralateral knee was 7° of hyperextension to 139° of flexion (7°-0°-139°). Therefore, the injured knee lacked 9° of passive knee extension to be symmetrical with the uninvolved side. After surgery, full passive knee extension must be obtained as quickly as possible to avoid excessive fibrous tissue proliferation within the intercondylar notch and posterior capsular contracture.[15,22] Passive patellar mobility, passive knee ROM, stationary cycling, and electrical muscle stimulation to the quadriceps were performed to improve ROM and initiate quadriceps activation to minimize muscular disuse atrophy. Additionally, active assisted ROM and low-load long-duration (LLLD) stretching into extension was performed in 12-minute bouts, repeated 4 to 6 times daily.

Gradual improvements in ROM, patellar mobility, and strength occurred over the subsequent 3 postoperative weeks. However, 4 weeks postsurgery, the patient began to experience intense pain in his right knee during routine exercises that had previously been nonpainful. This pain was described as a sharp, throbbing sensation along the medial aspect of his right knee during both end range flexion and extension motions passively. The pain was localized along the medial retinaculum, capsule, and medial collateral ligament of the right knee. At this stage, the patient's flexion ROM was 110°, while extension remained unchanged from his 1 week postsurgery measurement (0°-2°-110°). Rehabilitation efforts continued to focus on restoring ROM and limb symmetry.[5] Numerous electrophysical agents (cryotherapy, laser, ultrasound, iontophoresis, and phonophoresis) were used in an attempt to alleviate pain and discomfort with only minimal short-term relief. Rehabilitative interventions focusing on full passive knee extension were emphasized, including LLLD stretching, light ROM, and patellofemoral joint mobilizations. The overpressure program utilized a specially designed device, the Extensionator (ERMI, Atlanta, GA), which imparts an LLLD extension stretch across the knee joint (**FIGURE 1**).[25,26,32,33] Over the next 2 weeks, pain continued to be the primary factor limiting ROM and exercise progression.

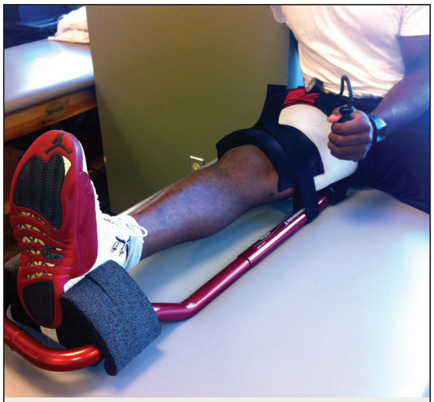

FIGURE 1. Patient performing a low-load long-duration stretching exercise.

Due to his progressive pain intolerance and tenderness to palpation with manual PROM and patellar mobilization, interactive neurostimulation was introduced into the treatment regimen approximately 6 weeks following surgery. The InterX 5002 unit (Neuro Resource Group, Plano, TX) is suggested as a noninvasive electrical stimulator for the treatment of acute posttraumatic and chronic intractable pain during therapeutic exercises. The device is designed to recognize increased areas of cutaneous sympathetic activity by measuring skin impedance. The waveform utilized by the device allows for the delivery of stimulation through small, closely spaced electrodes. This configuration allows treatments to reach a current amplitude that is 4 to 5 times higher than that which can be tolerated with most other electrical stimulation devices, without any associated muscular contractions.

The electrical stimulation waveform is impedance sensitive and is used to identify areas of low impedance.[11] These areas are considered to be the optimal locations for the most effective application of electrical stimulation.[12,17,19,28] The low impedance of the skin over painful locations is produced by an increase in the galvanic or sympathetic skin response.[11,16,28,30] Several authors have reported that these locations correlate to myofascial trigger points,[16,17,19,28] acupuncture points,[17,19,28,30] and localized sympathetic tissue changes.[12,13] Melzack[12] demonstrated that treating major nerve branches, trigger points, and secondary areas along an associated dermatome, in addition to the area of pain, with high-amplitude stimulation provided the most effective and sustained pain relief when compared to lower amplitude treatment delivered only at the point of pain. The current utilized in this device produces an interactive and constantly changing waveform, which prevents adaptation to the stimulation being applied.[11] Treating painful areas at higher current intensities has been shown to cause greater nerve inhibition and, therefore, enhanced pain relief.[17,19,28] Implementing various frequencies in the treatment approach has also been shown to release endogenous opiates, which can further enhance the effectiveness of the treatment for pain relief.[12] Clinically, the device is scanned over the skin to identify areas of low impedance, then applied over these targeted areas for 10- to 30-minute treatment durations.

Interactive neurostimulation was initially used for treatment while performing passive knee flexion (**FIGURE 2**). Prior to the first treatment, the patient reported a pain rating of 8 to 9 on a 0-to-10-point visual analog scale. Following the initial neurostimulation treatment, the patient reported that his perceived pain level had decreased to 3 or 4 out of 10. Given these results, which could have been partially related to a placebo effect, the patient was provided with a similar portable device (InterX1000, Neuro Resource Group, Plano, TX) for home usage. He was instructed to use the unit during times of discomfort for 10 to 30 minutes, mirroring the treatment durations performed in the clinic.

The patient reported using interactive neurostimulation 2 to 4 times daily, for durations of 10 to 30 minutes, when away from the clinic. After 4 days of using interactive neurostimulation while performing passive knee flexion, it was also incorporated as part of the overpressure program using the Extensionator device. A moderate reduction in pain to 2 out of 10 was observed, along with an immediate gain in knee extension of 5° during its initial use. After 2 weeks of interactive neurostimulation with both the clinic and portable devices, 8° of total motion improvement (6° flexion, 2° extension) was noted. Interactive neurostimulation might have contributed to the patient's neuromodulation of pain and improved his tolerance for ROM and patellar mobility activities. During this time, rehabilitation continued to focus on patellar mobilization, overpressure into knee extension, contract-relax techniques for improved knee flexion ROM, PROM on an isokinetic device, stationary cycling, and the use of a mechanical passive knee flexion device.

The neurostimulation eventually became part of the patient's regular isotonic strength program. Neurostimulation was used while the patient performed various exercises, including stationary cycling (**FIGURE 3**), leg presses, and wall squats. The patient had previously complained of medial knee pain with the above-mentioned exercises and was able to perform the exercises with less discomfort after interactive neurostimulation treatments. Overall, his pain was reduced to a level of 2 to 3 on a 0-to-10 visual analog scale, demonstrating a significant decrease in discomfort with exercises that previously had been very painful.

This program was continued from week 6 to week 14 postsurgery. During this time, the rehabilitation program emphasized a progression of knee ROM, particularly extension, strength, balance/proprioception, neuromuscular control drills, and reduction of knee joint edema and pain. The rehabilitation program emphasized alternating the treatment focus every other day. Three days per week the patient performed strengthening exercises, while on alternating days focused on agility and neuromuscular control drills. ROM and manual stretching activities were utilized during each treatment session. The ROM activities were highlighted by 3 sessions of manual passive knee flexion and prone quadriceps stretching, and 2 sessions of LLLD stretching into extension. Manual patellar mobilization was performed in all directions prior to LLLD stretching. Specific exercises during this phase of the program included leg presses, wall squats, forward lunges, front and lateral step-downs, agility exercises (forward/backward/lateral cone stepovers, sports cord, front and lateral step-downs on foam, and lunges onto an unstable surface such as a tremor box), and balance exercises (tilt board squats, single-leg stance on a tilt board with perturbations, single-leg stance on foam with ball catches, and BOSU squats). Interactive neurostimulation was used prior to treatment during PROM and stretching exercises to control pain.

FIGURE 2. Neurostimulation applied during passive knee flexion.

The patient left the clinic at the end of his 17th postoperative week, at which point his PROM was 1°-0°-128° and side-to-side thigh circumference was 2.5 cm smaller on the involved side, when measured 20 cm above the knee joint line. At this stage, he returned to his team for further evaluation and to continue his rehabilitation program with the athletic training staff. The patient's ROM progression during his postoperative course of care is detailed in **TABLE 1**. Five months after surgery, the patient returned to our clinic for a follow-up appointment demonstrating knee ROM of 4°-0°-136°. After treatment modification and progression, his knee extension improved to 6° of hyperextension. In comparison, ROM of the uninvolved extremity was 7°-0°-146°. At this time, the patient was cleared to begin a running program for cardiovascular training and was told that he could begin limited straight-ahead field drills after 1 month of light pain-free jogging. However, cutting drills would not be allowed for another 2 months.

FIGURE 3. Neurostimulation applied while riding the Uni-Cam Bicycle.

The patient returned for re-evaluation and functional testing 7 months after surgery. At that time he reported that he had been participating in alternating days of strength training workouts and agility/sport-specific drills on the field. The sport-specific training included a variety of running drills and some slow cutting activities performed at 50% effort. His running program consisted of forward and backward running, side shuffles, carioca, 4-corner cone drills, backward running with directional changes, and forward running with 45° cutting. Subjectively, he reported that his knee had been feeling satisfactory and that he felt as if he was ready to begin individual drills during the team's off-season workouts. The patient had 138° of knee flexion and 5° of hyperextension (5°-0°-138°). There were still reports of mild pain in the posterior aspect of the knee at end range flexion, rated as 3 to 4 on a 0-to-10 pain scale. Overall, the patient rated his knee at this time to be 80% of normal.

An instrumented knee laxity test was performed using a KT2000 (MEDmetric Corporation, San Diego, CA). There was a 3.0-mm side-to-side difference in anterior translation at maximal force, with the surgical knee having greater displacement. There was a 1.0-mm posterior translation differential at 30 lb (13.6 kg) of force. The total difference in combined anterior and posterior translation at 30 lb (13.6 kg) of force was only 1.0 mm, representing adequate passive stability of the repaired and reconstructed structures. Numerous studies have shown that a difference of 3 mm of translation or less correlates positively with improved functional outcomes in patients following ACL reconstruction.[23,25,26] The uninvolved thigh had a greater circumference measured at both 10 and 20 cm superior to the knee joint line. The circumference of the knee joint itself was 1.5 cm greater on the involved limb when compared to the uninvolved side. This information was noted for future use to see if hypertrophy of the involved limb would continue.

A Biodex (Biodex Medical Systems, Shirley, NY) knee extension/flexion isokinetic strength assessment was also performed during this re-evaluation.

TABLE 1 Passive Range of Motion*

	Involved Knee	Uninvolved Knee
Preoperative	0-9-57	7-0-145
Postoperative day 4	0-4-48	
Postoperative day 7	0-2-92	7-0-139
Postoperative week 4	0-2-110	7-0-143
Postoperative week 8	0-0-114	
Postoperative week 17	1-0-128	7-0-145
Postoperative week 20	4-0-136	7-0-146
Postoperative week 28	5-0-138	7-0-146

**Data are in degrees, with the first number indicating knee extension beyond 0° (hyperextension), the second number knee extension deficits, and the third number knee flexion.*

The test results indicated that there was a 29.3% knee extension strength deficit at 180°/s and a 19.1% deficit at 300°/s. Hamstring testing demonstrated a 7.8% deficit on the involved side at 180°/s and a 14.8% deficit at 300°/s (**TABLE 2**). The patient's peak torque-body weight ratio for the involved side was 75.0%, which was 29.3% less than that of the uninvolved side. For this individual, the typical goal of a peak torque-body weight ratio from 60% to 65%, when tested at 180°/s, did not apply. Hamstring-quadriceps ratio was 81.5% for the involved extremity, compared to 62.5% for the uninvolved side (**TABLE 3**). Finally, the patient had an acceleration time of 30 milliseconds bilaterally at 180°/s for knee extension, but the acceleration time was 40 milliseconds for the uninvolved side and 50 milliseconds for the involved side at 300°/s. This 10-millisecond difference represents a 20% deficit in acceleration time on the involved side (**TABLE 3**). These findings led us to believe that more explosive exercises should be incorporated into this patient's program to improve the acceleration of his involved limb.

Seven months after surgery, the patient was cleared to begin sport-specific training activities that focused on football-related drills. All contact activity was still prohibited. The patient was instructed to gradually progress the amount and intensity of sport-specific on-field drills, while wearing a functional ACL brace. Additionally, he was given clearance to gradually begin cutting and deceleration activities.

The patient returned to his team to continue his training program and the activity progression plan that had been outlined. The objective was the gradual advancement in volume and intensity of sport-specific activities over the next 2 months, while continuing to perform strengthening exercises under the supervision of the team's strength and conditioning coach. Recommendations were that he would be able to begin training camp in July 2008 (8 months postsurgery), but that full-speed sport-specific drills and overall practice participation would be restricted. The patient was advised to gradually return to full practice over the course of training, wearing a functional performance brace. His ability to return to participation would be based on his functional abilities on the field, physical examination of his knee, and his subjective reports.

OUTCOMES

The patient began participating in team drills during the 2008 NFL training camp. Although he had been medically released to return to competitive football participation, the team ultimately decided to take a more conservative approach, placing him on the physically-unable-to-perform list

TABLE 2	Peak Torque as a Percent of the Uninjured Side at 7 mo Postsurgery		
	Involved Leg	**Deficit Goal**	**Deficit**
Quadriceps at 180°/s	29.3% deficit	<20%	9.3%
Hamstrings at 180°/s	7.8% deficit	<10%	+2.2% stronger
Quadriceps at 300°/s	19.1% deficit	15%	
Hamstrings at 300°/s	14.8% deficit	0%	

TABLE 3	Hamstrings-Quadriceps Ratio and Acceleration Time		
	Involved Leg	**Uninvolved Leg**	**Goal**
Hamstring-quadriceps ratio at 180°/s	81.5%	62.5%	66%-72%
Acceleration time at 180°/s	30 ms	30 ms	20-25 ms
Acceleration time at 300°/s	50 ms	40 ms	30-40 ms

to begin the 2008 season. This allowed him additional time to reacclimate to the speed of his position, the game of football, and the demands required to be an effective player in the NFL. The patient was removed from the physically-unable-to-perform list midway through the 2008 season and thereafter played in every game that season. He participated in all 16 games during the 2009 season as a starter, without functional performance limitations or subjective complaints of knee pain or dysfunction. He finished the 2009 season ranked fourth on his team in total tackles and was chosen as an alternate member for the NFL Pro Bowl Game. He played the entire 2010 season as a starting defensive back in the NFL, without any limitations or setbacks related to his surgical knee.

DISCUSSION

Patients who sustain multiple ligamentous and joint capsular injuries are at an increased risk for developing motion impairments. These injuries are usually the result of high-velocity trauma that can produce profound swelling, intense pain, hematomas, and scar tissue formation that is normally addressed prior to the consideration of acute capsular repair or ligamentous reconstruction. The prevalence of knee ROM complications increases when a primary ACL reconstruction is performed with concomitant soft tissue and collateral ligament procedures, within the first 2 to 4 weeks following an injury, prior to the resolution of pain, swelling, as well as the restoration of motion and normal gait mechanics.

Although this type of injury is commonly seen in the general orthopaedic population, an injury of this magnitude in a high-level professional athlete is somewhat unusual and its potential functional limitations could be devastating. The authors of this case report expect patients who have had acute ACL reconstructions to return to premorbid, unrestricted activities, but there are studies reporting that a professional football player's career may be altered or shortened secondary to ACL surgery.[4] Athletes have a poor tolerance for minor deficits in knee flexion ROM, because these can adversely affect performance in running, agilities, and jumping. Cosgarea and associates[6,7] have reported that deficits greater than 10° of knee flexion were associated with decreased running speed. Our patient exhibited an 8° loss of flexion compared to the uninvolved side when he started his running program at 7 months. Fortunately, he did not complain of pain or exhibit impairments related to running. We believe that a loss of flexion is a concern when returning patients to high-level functional sporting activities such as running. Deficits in knee flexion PROM should be addressed and treated with respect to limb symmetry when returning patients to sport.

The surgical procedure is one critical step toward a patient's successful recovery; following an acute multiligamentous repair, the appropriate surgery must be coupled with a well-designed rehabilitation program. The program implemented should focus on restoring motion, improving functional muscle strength, and, when possible, encouraging early weight bearing. Rehabilitation has changed substantially regarding knee injuries, especially ACL reconstructions, since the early 1990s. Former rehabilitation principles following primary ACL reconstruction focused on periods of immobilization, protected ROM guidelines, and a delayed return to sport. There is agreement in the literature regarding immobilization and its deleterious effects on knee motion, patellar mobility, and articular cartilage deterioration. Current rehabilitation procedures have transitioned into immediate motion exercises,[8] early progressive weight bearing,[32] functional exercises,[18,32,33] and neuromuscular/proprioceptive principles[18,32,33] that reestablish dynamic stability faster, while doing no harm to the healing soft tissues and osseous structures. However, publications demonstrate a wide discrepancy among authors regarding the treatment of combined multiple ligamentous injuries that develop knee joint stiffness.

There is no consensus on intervention time in the postoperative period and the treatments that would be most efficacious in restoring lost knee motion and patellar mobility. It is imperative that clinicians and healthcare providers comprehend that any acute injury can lead to an exaggerated response in pain, swelling, scar tissue formation, and ultimate loss of motion, which can improve as symptoms resolve, because knee joint stiffness may be due to histological mechanisms other than arthrofibrosis.

The patient in this case report represents a situation in which a multiligamentous injury, coupled with immediate surgical intervention, resulted in postoperative arthrofibrosis, as described by Shelbourne.[27] The rehabilitation approach utilized in this patient's treatment incorporated principles of both an accelerated isolated ACL program and modifications of our combined multiple ligament reconstruction repair protocol secondary to the nature of his injury and the combined surgical procedures. Patients who typically follow our accelerated program exhibit better strength, less patellofemoral complaints, and an earlier return to sport. Patients usually demonstrate good patellar mobility, 90° of knee flexion PROM, full knee extension PROM, and initiate proprioceptive training during the second postoperative week.

The patient in this case report was not able to achieve these 2-week postoperative milestones; therefore, interactive neuromuscular electrical stimulation was implemented as an adjunct therapy to assist in decreasing pain to regain ROM and tolerate therapeutic exercise. Recognition of early postoperative motion loss following a major ligament reconstruction requires rehabilitative adaptations and constant modification based on the patient's host tissue, healing response, and subjective complaints. The goal of most rehabilitation protocols related to primary ACL reconstruction is to resolve extension deficits by 4 weeks after surgery. We believe that the first 2 to 4 weeks following ACL surgery is a critical time to establish homeostasis within the knee.[10] The use of electrical stimulation in conjunction with therapeutic exercise assisted in the incorporation of functional activities such as single-leg balance and cone drills. These closed kinetic chain exercises helped enhance neuromuscular control of the knee and hip through dynamic movement. Strengthening of the hip and knee is integral to reestablishing functional stability of the lower extremity. A gradual progression of applied loads during the patient's postoperative course was implemented based on his decreased pain response with the use of electrical stimulation. This allowed for an increase in functional ability, progressing the patient to transitional drills designed to challenge the neuromuscular control system for sport-specific activity, and preparation for an eventual return to sport.

The rehabilitation approach for the patient in this case report was atypical, combining principles of postoperative ACL rehabilitation with timely alternative clinical decision making, to progress an elite athlete through a complicated postsurgical situation. The decision to perform acute multiligamentous reconstruction, coupled with the development of knee joint stiffness, could have resulted in profound functional deficits that could have ended this patient's career. A progressive motion and therapeutic exercise program, paired with the physical therapist's knowledge of complex ligamentous reconstruction techniques, offers insight regarding proper management of this unique situation. A modality such as electrical stimulation as an adjunct treatment can be a powerful tool to promote successful rehabilitative outcomes related to multiple ligament reconstructions. The use of sensory stimulation to decrease the excitability of cutaneous nerve endings has shown promise in assisting the restoration of knee ROM and improved functional outcomes. ◉

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APPENDIX

REHABILITATION PROGRAM FOR MULTILIGAMENT INJURY

Preoperative Phase

Goals
- Diminish inflammation, swelling, and pain
- Restore normal range of motion (gradual knee extension)
- Restore voluntary muscle activation
- Provide patient education to prepare patient for surgery

Brace:
- Elastic wrap or knee sleeve to reduce swelling

Weight bearing:
- As tolerated with or without crutches

Exercises:
- Ankle pumps
- Passive knee extension (gradual progression)
- Passive knee flexion to tolerance
- Straight leg raises (3-way extension, flexion, abduction), pillow squeezes
- Quadriceps setting
- Closed kinetic chain exercises: mini-squats, lunges, step-ups

Muscle stimulation:
- Electrical muscle stimulation to quadriceps during voluntary quadriceps exercises (4 to 6 hours per day)

Neuromuscular/proprioception training:
- Eliminate quadriceps avoidance gait
- Retro-stepping drills

Cryotherapy/elevation:
- Apply ice 20 minutes of every hour, elevate leg with knee in full extension (knee must be above heart)

Patient education:
- Review postoperative rehabilitation program
- Review instructional video (optional)
- Select appropriate surgical date

Immediate Postoperative Phase (Day 1 to Day 7)

Goals
- Gradual passive knee extension
- Diminish joint swelling and pain
- Restore patellar mobility
- Gradually improve knee flexion
- Reestablish quadriceps control
- Restore independent ambulation

Postoperative Day 1

Brace:
- Brace/immobilizer applied to knee, locked in full extension during ambulation

Weight bearing:
- Two crutches, weight bearing as tolerated

Exercises:
- Ankle pumps

APPENDIX

- Overpressure into passive knee extension
- Active and passive knee flexion (90° by day 5)
- Straight leg raises (flexion, abduction), pillow squeezes
- Quadriceps isometric setting
- Hamstring stretches
- Closed kinetic chain exercises: mini-squats, weight shifts

Muscle stimulation:
- Use muscle stimulation during active muscle exercises (4 to 6 hours per day)

Continuous passive motion:
- As needed, 0° to 45°/50° (as tolerated and as directed by physician)

Ice and elevation:
- Ice 20 minutes out of every hour and elevate with knee in full extension

<u>Postoperative Day 2 to 3</u>

Brace:
- Brace/immobilizer, locked in full extension for ambulation and unlocked for sitting, etc

Weight bearing:
- 2 crutches, weight bearing as tolerated

Range of motion:
- Remove brace to perform range-of-motion exercises 6 to 8 times per day
- Perform frequently to regain knee motion

Exercises:
- Multiangle isometrics at 90° and 60° (knee extension)
- Knee extension 90°-40°
- Overpressure into extension (knee extension should be at least 0° to slight hyperextension)
- Emphasize restoring knee extension
- Patellar mobilization
- Ankle pumps
- Straight leg raises, pillow squeezes
- Mini-squats and weight shifts
- Quadriceps isometric setting

Muscle stimulation:
- Electrical muscle stimulation to quadriceps (6 hours per day)

Continuous passive motion:
- 0° to 90°, as needed

Ice and elevation:
- Ice 20 minutes out of every hour and elevate leg with knee in full extension

<u>Postoperative Day 4 to 7</u>

Brace:
- Brace/immobilizer, locked at 0° extension for ambulation and unlocked for sitting, etc

Weight bearing:
- 2 crutches, weight bearing as tolerated

Range of motion:
- Remove brace to perform range-of-motion exercises 6 to 8 times per day, knee flexion 90° by day 5, approximately 100° by day 7

Exercises:
- Multiangle isometrics at 90° and 60° (knee extension)
- Knee extension 90°-40°
- Overpressure into extension
- Patellar mobilization (5 to 8 times daily)
- Ankle pumps
- Straight leg raises, pillow squeezes
- Mini-squats and weight shifts
- Standing hamstring curls
- Quadriceps isometric setting
- Proprioception and balance activities

Neuromuscular training/proprioception:
- Open kinetic chain passive/active joint repositioning at 90° and 60°
- Closed kinetic chain squats/weight shifts

Muscle stimulation:
- Electrical muscle stimulation (continue 6 hours daily)

Continuous passive motion:
- 0° to 90°, as needed

Ice and elevation:
- Ice 20 minutes of every hour and elevate leg with knee full extension

Early Rehabilitation Phase (Week 2-4)

<u>Criteria to progress to phase 2</u>

1. Quadriceps control (ability to perform good quadriceps setting and straight leg raise)
2. Full passive knee extension
3. Passive range of motion, 0°-90°
4. Good patellar mobility
5. Minimal joint effusion
6. Independent ambulation

<u>Goals</u>
- Gradual increase to full passive knee extension
- Gradually increase knee flexion
- Diminish swelling and pain
- Muscle control and activation
- Restore proprioception/neuromuscular control
- Normalize patellar mobility

<u>Week 2</u>

Brace:
- Continue locked brace for ambulation

Weight bearing:
- As tolerated (goal is to discontinue crutches 10 to 14 days postoperation)

Passive range of motion:
- Self-range-of-motion stretching (6 to 8 times daily), emphasis on maintaining full, passive range of motion

Exercises:
- Muscle stimulation to quadriceps with exercises
- Isometric quadriceps sets
- Straight leg raises (4 planes)
- Leg press (0°-60°)
- Knee extension 90°-40°
- Half-squats (0°-40°)
- Weight shifts
- Front and side lunges
- Uni-Cam bicycle (low-intensity cycling)
- Proprioception training

APPENDIX

- Overpressure into extension
- Passive range of motion, 0° to 105°
- Patellar mobilization
- Well leg exercises
- Progressive resistance extension program; start with 1 lb (0.5 kg), progress 1 lb (0.5 kg) per week

Proprioception/neuromuscular training:
- Open kinetic chain passive/active joint repositioning 90°, 60°, and 30°
- Close kinetic chain joint repositioning during squats/lunges
- Initiate squats on tilt board

Swelling control:
- Ice, compression, elevation

Week 3

Brace:
- Discontinue locked brace (some patients use range-of-motion brace for ambulation)

Passive range of motion:
- Continue range-of-motion stretching and overpressure into extension (range of motion should be 0° to 100°/105°)

Exercises:
- Continue all exercises as in week 2
- Passive range of motion, 0°-105°
- Bicycle for range-of-motion stimulus and endurance (emphasize range of motion on bike)
- Pool walking program (if incision is closed)
- Eccentric quadriceps program 40°-100° (isotonic only)
- Lateral lunges (straight plane)
- Front step-downs
- Lateral stepovers (cones)
- Progress proprioception drills, neuromuscular control drills
- Frequent bouts of range-of-motion exercises

Progressive Strengthening/Neuromuscular Control Phase (Week 4-10)

Criteria to enter phase 3
1. Active range of motion, 0°-115°
2. Quadriceps strength greater than 60% contralateral side (isometric test at 60° knee flexion)
3. Unchanged KT2000 test bilateral values (+1 mm or less)
4. Minimal to no joint effusion
5. No joint line or patellofemoral pain

Goals
- Restore full knee range of motion (0° to 145°)
- Improve lower extremity strength
- Enhance proprioception, balance, and neuromuscular control
- Improve muscular endurance
- Restore limb confidence and function

Brace:
- Unlocked for ambulation at 4 to 6 weeks, may use knee sleeve to control swelling/support

Range of motion:
- Self-range of motion (4-5 times daily, using the other leg to provide motion), emphasis on maintaining 0° passive extension
- Passive range of motion, 0°-125° at 4 weeks

KT2000 test:
- Week 4, 20 lb (9.07 kg) anterior and posterior test

Week 4

Exercises:
- Progress isometric strengthening program
- Leg press (0°-100°)
- Knee extension, 90° to 40°
- Hip abduction and adduction
- Hip flexion and extension
- Lateral stepovers
- Lateral lunges (straight plane and multiplane drills)
- Lateral step-ups
- Front step-downs
- Wall squats
- Vertical squats
- Standing toe calf raises
- Seated toe calf raises
- Biodex stability system (balance, squats, etc)
- Proprioception drills
- Bicycle
- Stair-stepper machine
- Pool program (backward running, hip and leg exercises)

Proprioception/neuromuscular drills:
- Tilt board squats (perturbation)
- Passive/active reposition open kinetic chain
- Close kinetic chain repositioning on tilt board

Week 6

KT2000 test:
- 20 lb (9.07 kg) and 30 lb (13.61 kg) anterior and posterior test

Exercises:
- Continue all exercises
- Pool running (forward) and agility drills
- Balance on tilt boards
- Progress to balance and ball throws
- Wall slides/squats

Week 8

KT2000 test:
- 20 lb (9.07 kg) and 30 lb (13.61 kg) anterior and posterior test

Brace:
- Discontinue use of hinged knee brace for general activity

Exercises:
- Continue all exercises listed in weeks 4 through 6
- Leg press sets (single leg) 0°-100° and 40°-100°
- Plyometric leg press
- Perturbation training
- Isokinetic exercises (90° to 40°) (120°/s to 240°/s)
- Walking program
- Bicycle for endurance
- Stair-stepper machine for endurance
- Biodex stability system

Week 10

KT2000 test:

APPENDIX

- 20 lb (9.07 kg) and 30 lb (13.61 kg) and manual maximum test

Isokinetic test:
- Concentric knee extension/flexion at 180°/s and 300°/s

Exercises:
- Continue all exercises listed in weeks 6, 8, and 10
- Plyometric training drills
- Continue stretching drills
- Progress strengthening exercises and neuromuscular training

Advanced Activity Phase (Week 10-16)

Criteria to enter phase 4
1. Active range of motion, 0°-125° or greater
2. Quadriceps strength 75% of contralateral side, knee extension flexor-extensor ratio 70% to 75%
3. No change in KT2000 values (comparable with contralateral side, within 2 mm)
4. No pain or effusion
5. Satisfactory clinical exam
6. Satisfactory isokinetic test (values at 180°/s)
   a. Quadriceps bilateral comparison 75%
   b. Hamstrings equal bilateral
   c. Quadriceps peak torque/body weight 65% at 180°/s (males), 55% at 180°/s (females)
   d. Hamstrings/quadriceps ratio 66% to 75%
7. Hop test (80% of contralateral side)
8. Subjective knee scoring (modified Noyes scoring system) 80 points or better

Goals
- Normalize lower extremity strength
- Enhance muscular power and endurance
- Improve neuromuscular control
- Perform selected sport-specific drills

Exercises:
- May initiate running program (weeks 10 through 12) if good quad control and range of motion
- May initiate light sport program (golf)
- Continue all strengthening drills
  - Leg press
  - Wall squats
  - Hip abduction/adduction
  - Hip flexion/extension
  - Knee extension 90°-40°
  - Hamstring curls
  - Standing toe calf
  - Seated toe calf
  - Step-downs
  - Lateral step-ups
  - Lateral lunges
- Neuromuscular training
  - Lateral stepovers cones
  - Lateral lunges
  - Tilt board drills

Week 14-16
- Progress program
- Continue all drills above
- May initiate lateral agility drills
- Backward running

Return-to-Activity Phase (Week 16-22)

Criteria to enter phase 5
1. Full range of motion
2. Unchanged KT2000 test (within 2.5 mm of opposite side)
3. Isokinetic test that fulfills criteria
4. Quadriceps bilateral comparison, 80% or greater
5. Hamstring bilateral comparison, 90% or greater
6. Quadriceps torque/body weight ratio, 60% to 65% or greater
7. Hamstrings/quadriceps ratio, 70% or greater
8. Proprioceptive test, 100% of contralateral leg
9. Functional test, 85% or greater of contralateral side
10. Satisfactory clinical exam
11. Subjective knee scoring (modified Noyes System) (90 points or better)

Goals
- Gradual return to full unrestricted sports
- Achieve maximal strength and endurance
- Normalize neuromuscular control
- Progress skill training

Tests:
- KT2000, isokinetic, and functional tests before return

Exercises:
- Continue strengthening exercises
- Continue neuromuscular control drills
- Continue plyometric drills
- Progress running and agility program
- Progress sport-specific training
- Running/cutting/agility drills
- Gradual return-to-sport drills

6-Month Follow-up
- Isokinetic test
- KT2000 test
- Functional test

12-Month Follow-up
- Isokinetic test
- KT2000 test
- Functional test