

Prevention and Management of Post-operative Complications Following ACL Reconstruction

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Published online: 14 July 2017
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Abstract

Purpose of Review The goal of this paper is to review the current management and prevention of post-operative complications after anterior cruciate ligament (ACL) reconstruction. Trends in rehabilitation techniques will be presented, in addition to suggestions for interventions and expected milestones in ACL reconstruction recovery. **Recent Findings** ACL reconstruction protocols have evolved to more of a criterion-based progression rather than a tissue-healing time frame. Given the evolution of ACL surgical reconstruction techniques and rehabilitation protocols, the risk of post-operative complications can arise both early and late in the recovery process. This paper will discuss the role of preventative measures as it applies to the post-operative patient with ACL reconstruction.

Summary Short-term complications following ACL reconstruction include infection and deficits to knee motion and strength, whereas long-term complications include secondary ACL injury to either the involved or contralateral knee and lack of ability to return to high-level sports following this procedure. Future research should continue to address the multifactorial causes of secondary ACL injury and limited ability of patients to return to high level activities.

Keywords ACL reconstruction · Rehabilitation · Return to sport

Introduction

There are an estimated 200,000 anterior cruciate ligament (ACL) reconstructions annually in the USA [1–3], with recent trends showing an increase in the incidence of ACL tears and subsequent reconstructions through epidemiological data [4]. Surgical reconstruction of the ACL is designed to restore the normal anatomy and biomechanics of the knee joint to allow individuals to return to their previous sport or work activity. Rehabilitation following this procedure should safely progress the athlete through a staged approach based upon established guidelines while minimizing complications. It is important to consider the goals of the patient throughout the rehabilitation to process in order to incorporate specific functional and sport-specific activities as appropriate. Frequent and consistent communication between the surgeon, rehabilitation team, and patient will provide for a safe and efficient recovery process.

Rehabilitation Protocols

Detailed post-operative ACL reconstruction rehabilitation protocols have previously been published elsewhere [5–8]. Specific details regarding exercises and timing is beyond the scope of this paper, and it is recommended to consult these references for additional content. Early ACL reconstruction protocols were primarily based on the time frames of biological tissue healing [5] but have evolved to follow a criterion-based program [8, 6, 7]. The benefit of criterion-based guidelines is that they maximize the speed of a patient's progress

This article is part of the Topical Collection on *ACL Rehab*

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through the use of subjective and objective measures of impairment and level of function, while insuring that healing tissues are protected by establishing minimum time frames based upon current knowledge of the pace of biological repair [6•]. Staged benchmarks are required to be met before advancing to the subsequent stage of rehabilitation. Within each stage, goals are to be met which range from minimal criteria of range of motion (ROM) and strength presentation to functional assessment through measures such as hop testing comparing the involved to the uninvolved limb. The utilization of patient self-report outcome measures should be included in an on-going manner throughout rehabilitation to document a patient's self-perception of progress, confidence and readiness for advancing activity.

Typical post-operative ACL reconstruction rehabilitation protocols stages include (1) an early post-operative phase, which focuses on addressing knee range of motion (ROM) deficits, initiating knee strength and control, minimizing pain and effusion, and normalizing gait; (2) a strengthening and neuromuscular control phase, which includes the progression of lower extremity functional strength, and enhancement of balance and neuromuscular control; (3) an advanced strengthening phase, which progresses the patient into plyometrics, agility activities, running and early sport-specific training; and with (4) a final phase focusing on continued strengthening and neuromuscular control with emphasis towards return to sport activities. Appropriate decision-making by the rehabilitation team based upon pre-determined criteria in these protocols is required to optimize outcomes and allow for a safe return to sport. Therapists should consider any concomitant injuries and surgeries, such as meniscal involvement, articular cartilage defects or bony realignment procedures as these may delay how quickly a patient will progress through the post-operative rehabilitation stages.

Early Post-operative Complications

Knee joint infection post-operatively is rare, but can occur, so vigilance is encouraged by the surgical and rehabilitation team should any concerns arise. Gobbi et al. [9] reported an infection rate of 0.37% after ACL reconstruction, with an onset time of infection from surgery ranging between 7.5 and 61.7 days. The clinical presentation of an infection in this population may include the presence of an acutely swollen and painful knee joint, limited knee ROM, sudden increase of pulsatile knee pain, rapidly increased and persistent effusion, incisional drainage, local erythema, warmth, intermittent fever (usually over 38 °C) and hyperemia with serous or purulent discharge [9]. Again, the value of open communication between the surgeon and rehabilitation team is important when signs of potential infection are present in a post-operative patient.

Formal physical therapy is often initiated between 3 to 10 days after surgery. At discharge immediately following ACL reconstruction surgery, the patient is often instructed in the use of crutches for ambulation with weight-bearing as tolerated in addition to the use of ice to manage pain and swelling. The use of a post-operative knee brace may or may not be utilized based on the preference of the surgeon. For the early post-operative rehabilitation phase, one of the primary goals of physical therapy is to improve knee ROM. It is recommended that the patient obtain full passive and active knee extension range of motion within the first 2 weeks [6•]. Failure to achieve full knee extension ROM can have a significant long-term impact on pain, gait and function, with arthrofibrosis as a potential complication. Arthrofibrosis is an inflammatory response which results in joint fibrosis and restricted knee motion [10], which can occur following knee surgery, trauma or immobilization [11]. Prevention of knee joint stiffness and potential arthrofibrosis should be a primary goal early post-operatively [12]. Patient education is crucial to carryover the home exercises designed to address knee extension ROM, with the frequency of physical therapy sessions established to maximize early return of full knee extension ROM. It is important to recognize that even a loss of less than 5 degrees of knee extension ROM can lead to long-term patellofemoral pain issues, quadriceps strength deficits and a bent-knee gait abnormality [13, 14]. Sample exercises and interventions for improving knee extension ROM are presented in Table 1. Appropriate dosage of these exercises should be considered in terms of frequency, duration and intensity. Lack of progress with knee extension ROM may warrant an increase in the dosage of the intervention; whereas worsening of knee pain, swelling and ROM would warrant a decrease in dosage, particularly intensity. For individuals who exhibit knee extension ROM, the incorporation of low-load long-duration stretching is advocated to assist with improving extension motion.

The loss of knee flexion ROM post-operatively tends not to be a major issue as with the loss of knee extension. For knee flexion ROM, general goals are to achieve active and passive motion to 90° at week 1, 100° at week 2 and 120° at week 3 [6•]. Full knee flexion ROM should be achieved by 6 weeks. Table 2 describes some potential exercises to address knee flexion ROM loss. Patients with concomitant knee surgical procedures are often delayed in the recovery of knee flexion motion. In a systematic review by Wright et al. [16], they found no substantial advantage for the use of a continuous passive motion device in the early post-operative phase based on six randomized controlled trials.

The inclusion of serial casts, drop-out casts and or daily physical therapy may further address loss of motion for those individuals not responding to traditional interventions [17, 18]. Additional conservative measures may include joint aspiration, nonsteroidal anti-inflammatory drugs, and oral

Table 1 Exercises to address knee extension range of motion loss

Exercises/interventions	Considerations
Prone knee hangs	Use contralateral leg or ankle weights for overpressure if needed
Heel props	Use manual overpressure or weight on thigh for overpressure if needed
Manual therapy	Patella mobilizations, tibiofemoral glides, overpressure, soft tissue mobilizations, scar massage
Neuromuscular electric stimulation in knee extension with the electrodes placed on the vastus medialis distally and vastus lateralis proximally (with 2.75 × 5 in electrodes)	2500 Hz, 75 bursts per second, 2-s ramp-up and ramp down time, 10 s on, 50 s off, for 10 to 12 min at an intensity of maximum tolerance/discomfort [15]
Splint	Drop-out cast, static or dynamic splint

corticosteroids. For patients who fail to regain functional and symmetrical knee ROM, operative procedures may include manipulation under anaesthesia, arthroscopic lysis of adhesions and or soft tissue release [11]. Following any additional surgical procedure, formal physical therapy is initiated within the first several days to maximize knee ROM and assist with carryover of motion obtained in surgery.

In addition to stretching and manual therapy interventions, addressing knee effusion may also assist with gaining knee ROM and quadriceps muscle activation. Cryotherapy and knee compression through the use of a knee sleeve or compression wrap may assist to control post-operative knee joint swelling. Post-operative pain can be managed through the use of cryotherapy, analgesic medication or electrical stimulation. Post-operative rehab should be structured and gradually progressed without causing complications such as anterior knee pain or tendonitis [19].

Strength deficits are a common complication following ACL reconstruction, and rehabilitation should focus on this, regaining strength throughout the entire post-operative course of care. Early rehabilitation should address quadriceps femoris muscle activation. Assessment of this can be made through visible activation of the quadriceps with the knee in full extension, whereby the patella should be seen gliding superiorly. Inability to obtain full knee extension motion will confound the ability to obtain superior glide of the patella with the quadriceps set. Another milestone is the ability to perform an active straight leg raise against gravity without a lag, or inability to maintain complete knee extension with the knee straight. Often the ability to keep the knee in full extension for 10 to 30 repetitions without a lag is utilized as a benchmark for the discharge of the post-operative knee brace. The use of neuromuscular electrical stimulation (NMES) is recommended to

Table 2 Exercises to address knee flexion range of motion loss

Exercise	Considerations
Heel slides	Use towel or contralateral leg for overpressure
Bike	Use rocking motion for those who cannot complete full revolution
Wall slide	With patient supine and foot on the wall, use contralateral leg on top for overpressure or under to help support the involved leg
Manual therapy	Patella mobilizations, tibia-femoral glides, overpressure, soft tissue mobilizations, scar massage
Splint	Static or dynamic splint

be utilized with all patients following ACL reconstruction. The results of a recent systematic review found NMES improves quadriceps isometric torque, quadriceps peak torque, isokinetic knee extension strength, and led to a faster recovery of quadriceps strength [20]. Stimulation can be performed in full knee extension for patients with bone-patella-bone grafts and at 60° isometrically for patients with allografts or hamstring autografts. NMES is recommended to be applied at a high-intensity for it to be successful in improving quadriceps strength [16].

Late Post-operative Complications

Strength deficits, specifically to the quadriceps femoris musculature, is a major complication following ACL reconstruction as it can contribute greatly to functional limitations in addition to potentially leading to additional injuries of the lower extremities. It is also a deficit which can be minimized with appropriate strength training and neuromuscular rehabilitation techniques. Isometric quadriceps femoris strength deficits of greater than 15% have been shown to negatively affect knee joint loading patterns during bilateral landing [21]. In a recent research investigation, Schmitt et al. [22] reported that those individuals with quadriceps femoris strength deficits demonstrate altered landing patterns, including reduced peak knee external flexion moment, reduced peak vertical ground reaction forces and higher uninvolved limb peak loading rates. In addition to the functional asymmetries at the knee joint, landing mechanics of the trunk, hip and ankle joints may also exhibit compensatory loading alterations following ACL reconstruction [22]. Functional deficits in force development and absorption via vertical single leg jump height have been found to persist after ACL reconstruction [23].

Failure of the ACL graft has been to be reported as high as 12 to 24% [24, 25]. ACL reconstruction failure has been found to be related to patient age, sex, body mass index, time from surgery, graft size, meniscal integrity, tibial tunnel malposition and early return to sport [23, 26–30]. Parkinson et al.

[31] found that meniscal integrity was the strongest predictor of ACL reconstruction failure. Increased graft laxity was found in ACL reconstruction patients with medial meniscal deficiency [32], and a higher incidence of a residual pivot shift was reported in meniscal-deficient knees [33]. Greater stress through the ACL graft in meniscal-deficient knees may explain a higher graft failure rate [31].

Strength testing should be conducted throughout recovery to assess progress and to determine if milestones are met for advancement of function. In general, quadriceps and hamstring strength should be assessed through objective measures of hand held dynamometry or isokinetic dynamometry. Less than a 20–30% deficit compared to the uninvolved extremity is acceptable for progression into running and light plyometrics, and less than a 10% deficit on strength of the quadriceps and hamstrings is acceptable for progression into sport-specific skills and activities. A 1-repetition maximum leg press may be substituted if no isokinetic device is available [19].

Functional hop testing can be initiated at a minimum of 12 weeks post-operatively, should all staged goals be met including the patient achieving less than 20% deficit on strength testing of the quadriceps [6•]. Four hop tests are recommended including the single-leg hop for distance, triple hop for distance, crossover hop for distance, and 6-m timed hop [6•]. A deficit of less than 10% on all tests would provide additional objective data for progression into sport-specific activities.

The return-to-sport rates for patients following an ACL reconstruction have been reported to range between 63 and 65% returning to preinjury level of activity with 44–54% returning to competition [34, 35]. Altered contralateral hip strategy with limited motion and attenuating forces about the injured knee during gait has been noted in those who did not pass return to sport testing at 6 months [36]. Functional knee bracing may have some benefit via *in vivo* knee kinematics after ACL reconstruction; however, there is limited evidence that functional knee bracing decreases the rate of re-injury based on a systemic review of 15 studies [37].

Re-injury

Increased risk of a second ACL injury in addition to long-term cartilage degeneration has been found to be associated with having an ACL tear. The mechanism for a secondary injury is considered to be multifactorial [38•]. The highest risk of re-injury has been reported within the first 7 months of return to sport [39]. Second ACL injury rates have been reported to be as high as 24% in young, active individuals [25]. Younger age (<25 years) and return to high level of activity (cutting/pivoting sports) are associated with an increased risk secondary ACL injury [40].

Second ACL tears occur more frequently in the contralateral limb and may be related to asymmetrical loading [41]. Wright et al. [42] reported a 17.2% second injury rate, with 11.8% contralateral and 5.8% ipsilateral graft failure. A recent investigation reported that females has a 33.7% greater risk for contralateral ACL surgery compared to males [43]. Compensation from increased loading of the uninvolved limb may put the opposite extremity at increased risk [22].

Prevention

Prevention of ACL injuries should be considered during the rehabilitation process of individuals following ACL reconstruction. Given the fact that many ACL tears are non-contact in nature, these patients likely exhibit poor neuromuscular control and biomechanical deficits. In general, ACL prevention programs which include a combination of dynamic warm up, strengthening, agility, balance, and plyometric activities have been shown to have good short-term effectiveness [44–48]. These activities all involve elements of neuromuscular training, in addition to demonstrating the potential to reduce the number of ACL injuries. Prevention programs should include a variety of neuromuscular training techniques, as solely focusing on a single type of exercise in isolation has been shown to not be as effective for the prevention of ACL injuries [49]. The most effective dosage in these prevention programs was found to be 30 minutes twice a week during in-season training [49]. The incorporation of proximal control training exercises such as planks, side planks, sit-ups, push-ups, and upper body weight training was found to be related to greater ACL injury reduction in several studies [49]. A relative risk reduction of 73.4% has been reported when targeting neuromuscular control, strength, movement feedback, and balance [49]. Emphasis on biomechanical techniques and individualized feedback may aid in success of programs [50, 51].

Benjamise et al. [52•] noted limited long-term effectiveness of prevention programs, which is theorized to result from the difficulty with retention and transfer of the taught motor skills. The ability to learn and improve on motor tasks may be implemented through an internal focus or external focus of attention. An internal focus of attention would have the athlete focus on the actual movements themselves, such as providing cues to maintain their knee properly aligned over their second toe [52•, 53]. An external focus of attention would have the athlete focus on the movement effect and outcome of the movement, such as providing cues to keep their knee in line with a cone or other target (see Table 3) [52•, 53]. An external focus of attention may increase program compliance, enhance the efficiency of the athlete's skill acquisition, and better transfer the improved motor skill to the sport activity [52•]. The external focus may utilize a more unconscious or automatic process of control, whereas the internal focus may facilitate a

more conscious control of movement which is less than optimal for high level sport activities [52•]. The delivery and timing of feedback should also be considered in improving the effectiveness of motor learning in this population. In addition, perhaps some individuals will benefit from a combination of internal and external focus of attention to maximize effectiveness of carryover. Dual task challenges, such as memory recall, environmental stimulus (ball or partner perturbations), or direct visual perturbations prevention programs, can also enhance prevention programs through addressing neurocognitive and neurophysiological factors [54].

Fear

Self-motivation, self-efficacy, and optimism were found to be associated with future knee pain, function, and return to sport following ACL injury [55]. Kinesiophobia, or fear of movement, may be negatively associated with self-perceived knee pain and function [56]. Including the use of Tampa Scale of Kinesiophobia (TSK-11) [57] will allow the rehabilitation team to identify those individuals with high fear of movement and thus warrant a modification to the therapeutic approach. Through delaying the progression through the protocol, providing education to improve patient self-efficacy, and incorporating neuromuscular re-education techniques such as perturbation training may benefit the patient who exhibits high fear [58, 59]. Kinesiophobia and pain catastrophizing are two psychological factors which have been shown to be strongly correlated with lack of return to sport [55].

Utilization

Utilization of physical therapy visits after ACL reconstruction is often a common topic of clinical debate, but there is minimal discussion of this in the literature. Given the current state of healthcare spending and increased need to maximize effectiveness of care, physical therapists should consider the frequency of visits across the rehabilitation time line following ACL reconstruction. Insurance coverage often dictates visit frequency, and therefore patient education should be emphasized throughout the recovery process. Physical therapists are in the prime position to appropriately determine the frequency of visits across the post-operative rehabilitation process. We suggest that pain, ROM, and quadriceps activation be the primary driver for visits early in the recovery. Patients with high pain, significant ROM loss, and poor strength and limited quadriceps activation would clearly benefit from multiple sessions per week of physical therapy. Whereas, those patients early in the post-operative rehabilitation phase who exhibit minimal pain, progressing ROM, and good quadriceps activation may benefit from weekly physical therapy for monitoring

Table 3 Examples of verbal instructions with internal and external focus of attention. Adapted from Benjaminse et al. [52•]

Exercise type	Instruction with internal focus	Instruction with external focus
Single-leg squat	Standing on one leg, slowly bend your knee while keeping your knee lined up over your 2nd toe.	Standing on one leg, slowly bend your knee towards the cone (cone placed anterior to knee to serve as a target).
Step-down	Standing on one leg, slowly lower yourself while keeping your knee lined up over your 2nd toe.	Standing on one leg, slowly bend your knee, keeping the outside part of the knee parallel with the wall.
Double-leg squat	Bend your knees and do not allow your knees to go forward over your toes.	Bend your knees and sit back as if you were going to sit into a chair.
Double-leg drop jump	Jump down (from a 30 cm box) and land with your feet shoulder width apart and keep your knees lined up over your 2nd toes.	Jump down (from a 30 cm box) and land on the markers on the floor and aim your toes and knees towards the cones.

and progression by the physical therapist. As the post-operative course progresses, the need for increased frequency of formal physical therapy may be necessary to address functional strength and neuromuscular control activities with an emphasis on proper movement patterns. In addition, an extended time frame of care may be warranted to ensure a safe progression into a running program and sport-specific activities, with optimal goals of achieving satisfactory results on return to sport testing.

Conclusions

In summary, ACL rehabilitation principals continue to evolve based on the findings of continued research. Both clinicians and surgeons should maintain appropriate dialogue to maximize a patient's safe rehabilitation and return to sport. Current protocols emphasize criteria for progression to the next phase rather than time. Both patient-reported and objective functional outcome measures should also be utilized for advancement. Early emphasis on extension ROM is essential, and if a patient has limited physical therapy benefits, consideration should be given to the possible need for higher visit frequency in the initial phase of recovery. Quadriceps strength is another key component of complication prevention, and NMES is recommended for all patients as it has been shown to assist in the restoration of quadriceps function. Re-injury rates are high, but fortunately, injury prevention programs have been demonstrating the ability to reduce ACL tears. Based upon our

review of the literature, if all of the recommendations outlined in this manuscript are followed, there is a high likelihood of a successful recovery with a low rate of complications.

Compliance with Ethical Standards

Conflict of Interest All authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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