19 Management of the Stiff ACL Reconstruction

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Case Presentation

An 18-year-old female who is a collegiate lacrosse player presented 3 days after injuring her right knee during a game in which she pivoted and felt a "pop" in her right knee. Physical examination revealed an antalgic gait and a right knee effusion with 10–75 degrees of range of motion (ROM). On presentation, 30 cubic centimeters (cc) of serosanguineous fluid was aspirated from the knee. Weight-bearing plain radiographs were noncontributory. The patient was referred for magnetic resonance imaging (MRI) and physical therapy to regain motion and begin strengthening and modalities to decrease pain and swelling. MRI revealed a complete mid-substance ACL tear and a tear of the posterior horn of the lateral meniscus (Fig. 19.1). There was no sprain/injury of the medial collateral ligament (MCL). Surgery was provisionally scheduled 19 days after her injury.

Fig. 19.1 Pre-operative MRI of presented case

The patient underwent a right knee arthroscopic-assisted ACL reconstruction with a bone-patellar tendon-bone autograft and meniscus repair 19 days after her injury. She tolerated the procedure well without complications and was prescribed hydrocodone/acetaminophen post-operatively. She was made partial weight-bearing in a hinged brace orthosis. Post-operative

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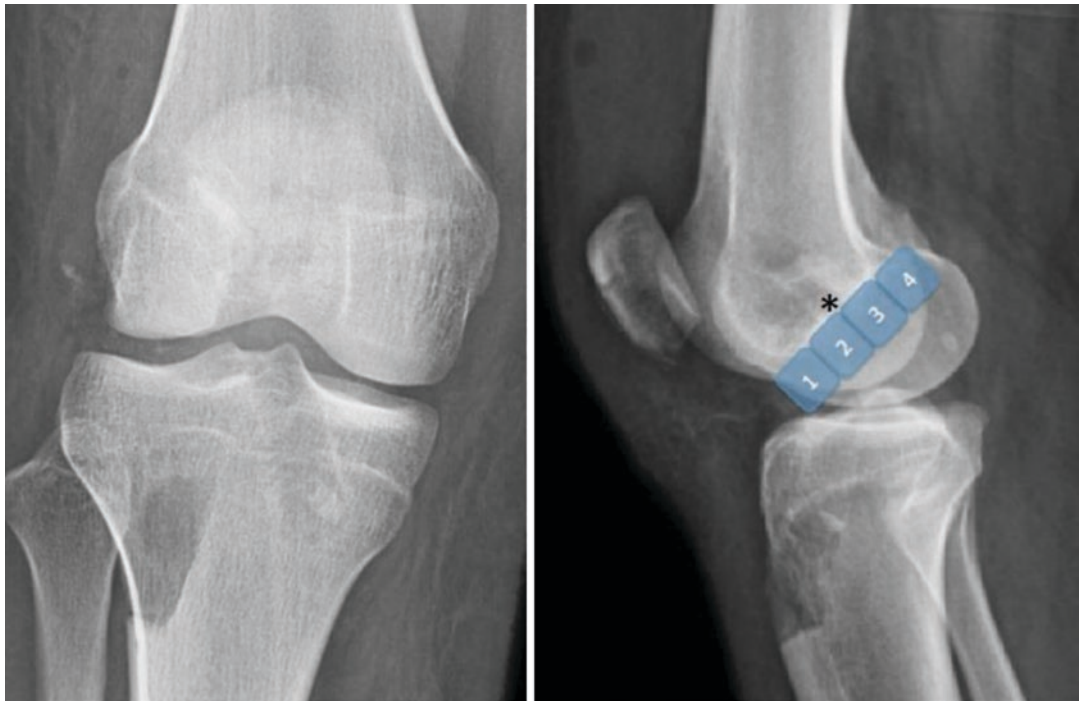

Fig. 19.2 Post-operative radiographs of presented case. The asterisk denotes the femoral tunnel position on the lateral view and illustration of radiographic quadrant method for identification of the anatomic site for femoral insertion of the graft during ACL reconstruction. It is noted that the femoral tunnel placement may be slightly anterior; however, the authors acknowledge that this is not a true lateral radiograph

radiographs were performed (Fig. 19.2). Upon evaluation of the radiographs, it was suggested that the femoral tunnel was placed slightly anterior to the normal anatomic site using the radiographic quadrant method [1]. She presented to the emergency department on post-operative day (POD) 3 with complaints that her pain was not under control. She was discharged home after workup revealed no evidence of infection or thromboembolic disorders.

The patient was seen on POD 12 without concerns, and an evaluation revealed an otherwise routine post-operative course. On POD 37, she complained that her knee was increasing in stiffness, and on exam her ROM was 15–75 degrees (Fig. 19.3). At this time, the patient was fitted for a dynamic-hinged brace that allowed dynamic progressive stretching, started on nonsteroidal anti-inflammatory drugs, and instructed to continue aggressive physical therapy. Possible arthroscopic adhesiolysis in the future was discussed. At 9 weeks post-operatively, the patient's ROM improved to 5–115 degrees after aggressive physical therapy. At 15 weeks post-operatively, the ROM of her right knee was 10–130 degrees compared to 0–155 degrees on

Fig. 19.3 Demonstrating lack of extension on POD 37 of presented case

the contralateral leg. She was instructed to continue aggressive physical therapy and to wear a static extension brace. At 17 weeks post-operatively, the patient's ROM was 10–135 degrees, and she continued aggressive physical therapy. At 21 weeks post-operatively, her ROM improved to 5–140 degrees and was able to achieve near full extension with physical therapy. The patient continued to participate in physical therapy.

The potential problems that may raise concern as to the patient's development of post-operative stiffness following ACL reconstruction include the following:

1. Pre-operative loss of extension
2. A short interval from time of injury to time of surgery (19 days)
3. Increased perioperative pain
4. A concomitant meniscus repair
5. A non-anatomical anterior femoral tunnel (Fig. 19.2)

This chapter addresses these potential problems associated with the presented case and appropriate treatment strategies.

Introduction

ACL injuries remain one of the most frequently injured ligaments that require surgery. With about 120,000–150,000 primary reconstructions being performed annually in the United States, the incidence of revisions will likely continue to increase [2, 3]. One of the primary goals of ACL reconstruction is to recreate native biomechanics of the knee while also restoring symmetric ROM [4]. Arthrofibrosis following primary ACL reconstruction is a well-defined complication with an incidence of 4–38% [5–8]. Patient-reported stiffness can be more common following revision ACL reconstruction when compared to primary ACL reconstruction [9]. Significant etiologic variability exists regarding the precise causes, ideal rehabilitation protocol, and optimal treatment. If not recognized, post-operative arthrofibrosis causing loss of motion can be more debilitating than an ACL-deficient knee [8]. Decreased knee ROM may lead to quadriceps atrophy, increased patellofemoral forces with loss of patellar mobility, patellar tendon shortening, and eventual articular cartilage damage [10–13]. Therefore, it is important to properly identify these patients early in the post-operative period to manage loss of motion appropriately.

Definition and Classification

Loss of motion remains one of the challenging complications faced by orthopedic surgeons following ACL reconstruction. While there is lack of clear evidence on the definition of arthrofibrosis, there is a consensus that arthrofibrosis requiring surgery is based upon a clinical limitation in knee ROM compared to the contralateral side that is symptomatic and refractory to non-operative treatment [8]. Arthrofibrosis has been previously defined as "abnormal proliferation of fibrous tissue in a joint with an unclear etiopathogenesis that leads to loss of motion, pain, muscle weakness, swelling, and functional limitation" [14]. Clinically it is identified as a loss of motion in comparison to the contralateral extremity [15]. Shelbourne et al. classified this loss of motion into four separate types. Type 1 is a <10 degree extension loss and normal flexion. Type 2 is a >10 degree extension loss and normal flexion. Type 3 is a >10 degree extension loss and >25 degree flexion loss with a tight patella. Type 4 is a >10 degree extension loss, 30 degrees or more flexion loss, and patella infera with marked patellar tightness [15]. A simpler classification of arthrofibrosis was proposed by Mayr et al., who defined it as abnormal scar tissue within at least one compartment that caused restricted ROM [16]. Asymmetric motion of the operative leg compared to the contralateral knee should be noted clinically and addressed appropriately.

Patients typically do not handle loss of extension as well as a flexion deficit [17]. A loss of 5° of extension can lead to abnormal forces in the knee joint. This can cause increased joint loading, quadriceps weakness, and patellofemoral pain [18]. A recent definition for loss of extension following

ACL reconstruction is a difference of greater than 5° loss of extension compared to the contralateral knee [10]. In addition, this seemingly minimal lack of motion can have long-term effects on patient outcomes. A study by Shelbourne et al. with 10-year follow-up found a loss of as low as 3° of knee extension leads to adverse results on both subjective and objective measurements [19]. These adverse outcomes were significantly greater in association with concurrent meniscal and/or articular cartilage procedures.

When evaluating a patient to determine their ROM after undergoing ACL reconstruction, another important consideration is whether the presentation is acute or chronic. Patients should be monitored closely in the acute post-operative period to ensure adequate rehabilitation and that motion is regained. Many rehabilitation programs consist of a combination of ROM and quad strengthening to prevent both weakness and ROM loss [10, 17, 20]. Despite the quantity of research regarding ACL reconstruction, there remains no definitive time period defining ROM loss post-operatively. Noll et al. of motion following ACL reconstruction at initial post-op visit up to 12 compared knee extension range weeks. They found a statistically significant correlation with loss of extension at 4 weeks post-op compared to 12 weeks [17]. Another study found that 48% of patients with a loss of extension at 4 weeks post-operatively eventually underwent an arthroscopic lysis of adhesions [10]. It is important for clinicians to identify an asymmetric ROM early in the rehabilitation phase (within 4 weeks) to ensure adequate motion is restored to prevent poor patient outcomes.

Risk Factors and Etiology

Risk factors for loss of ROM include preoperative stiffness. One of the major focuses prior to undergoing ACL reconstruction is "prehab." Physical therapy is prescribed after injury but before surgery with a goal to regain similar side-to-side ROM prior to surgery. Patients who did not have full extension at the time of surgery were at a statistically significant higher risk for loss of extension after ACL reconstruction [10]. Having symmetric side-to-side ROM preoperatively is an important checkpoint for any patient undergoing ACL reconstruction.

Timing of ACL Reconstruction

Historically timing between initial injury and surgery has always been a debate. Previous studies have found a significant relationship in postoperative complications, including stiffness, in patients who undergo ACL reconstruction more acutely [10, 16, 21]. These studies found an increased risk for arthrofibrosis in patients who had surgery less than 3 weeks from time of injury. There is recent literature, however, showing that timing may not be a factor in the development of arthrofibrosis. Deabate et al. performed a meta-analysis of multiple randomized control trials, which showed ACL reconstruction within 3 weeks of injury had no influence on stiffness and other complications [22]. Another systematic review found similar results, with no difference in clinical outcomes in patients undergoing ACL reconstruction within 3 weeks of injury compared to delayed surgery [23]. Undergoing ACL reconstruction acutely may not have as much of an impact on stiffness post-operatively as previously believed.

Associated MCL Injury

Patients with an ACL injury requiring reconstruction that also have a MCL injury may be at higher risk of post-operative stiffness requiring surgery, regardless of whether the MCL injury is treated non-operatively or operatively [24]. In a prospective study, Noyes et al. showed that 22% of patients with MCL repair during ACL reconstruction lost ROM after surgery which was significant when compared with ACL reconstruction alone [25]. Patients should be counseled about post-operative stiffness and potential increased reoperation risks if there is an associated MCL injury in patients also undergoing ACL reconstruction. In addition, delaying ACL reconstruction until MCL healing occurs is an important consideration.

Graft Choice

Surgical reconstruction graft choice and harvest morbidity have a potential impact on post-operative ROM. While bone-patellar-tendon bone (BTBP) and hamstring tendon autografts remain the most popular autograft choices, others such as quadriceps tendon autografts and allografts such as Achilles tendons and tibialis anterior tendons are commonly used [26]. A prospective analysis comparing BTBP and hamstring autograft found no significant difference in outcomes related to stiffness [27]. They did, however, find a higher incidence of "cyclops" lesions in the hamstring group, although this had no statistically significant impact on ROM. In several studies, no significant differences have been found in post-operative ROM comparing bone-patellar-tendon bone and hamstring autograft [28, 29]. Huleatt et al. found a higher incidence rate of manipulation under anesthesia and/or lysis of adhesions in patients with a quadriceps tendon autograft compared to other graft types [30]. In the pediatric population, studies have bone bone-patellar-tendon bone tendons to have a higher incidence of stiffness compared to hamstring autograft [31]. Additionally, graft size may have an impact on arthrofibrosis following ACL reconstruction. Su et al. found a 3.2 times increase in odds of arthrofibrosis with an increase in graft diameter by 1 millimeter (mm) in their cohort of 1121 patients [32]. Graft choice and size can play a significant role in ROM-related outcomes following ACL reconstruction.

Concomitant Procedures

It is common for additional procedures to be performed concomitantly with ACL reconstruction. Often an ACL tear is associated with meniscal injury, articular cartilage damage, or other intra-/extra-articular ligament pathology. Huleatt et al. found an increased rate of arthrofibrosis in patients who underwent concomitant procedures at the time of ACL reconstruction [30]. They found an increase in incidence of manipulation under anesthesia (MUA) and lysis of adhesions (LOA) from 3.7% in isolated ACL reconstruction to 5.2% with additional procedures. A similar study found an increase of 1.8–8.0% compared to 0.3–0.5% in MUA/LOA in patients with multiple procedures done simultaneously compared to isolated ACL reconstruction, respectively [33]. Noyes et al. showed that in patients who underwent MCL repair during ACL reconstruction, there is an increased risk of arthrofibrosis [25]. Associated pathology that is addressed with ACL reconstruction clearly plays a role in motion restriction post-operatively.

Tunnel Position

Position of both femoral and tibial tunnels in ACL reconstruction is a critical part in the success of the operation. Restoring normal knee kinematics and biomechanics through an anatomic ACL footprint is a goal of every ACL reconstruction. Therefore, positioning the tunnels as close to their anatomic location as possible should be the objective for all surgeons. Intercondylar roof impingement is a leading cause of extension loss related to graft position post-ACL reconstruction [34, 35]. A tibial tunnel too anterior can lead to impingement on the intercondylar notch and loss of extension [35]. In addition, Maak et al. reviewed femoral tunnel position and its relationship to impingement [36]. They found that creating a femoral tunnel as close to the center of the ACL footprint had lower rates of impingement as opposed to higher and/or more anteromedial placement. A femoral tunnel placed too anterior may result in graft/notch impingement and result in loss of flexion and extension.

Impingement against the native PCL can also be a cause of post-operative stiffness. This can lead to a mechanical block in flexion. If the tibia tunnel is placed too posteriorly, the graft is more likely to impinge on the PCL during flexion [37].While this may lead to a mechanical block, it can also cause pain with flexion and secondarily lead to loss of motion in the rehabilitation period. This apparent proprioceptive pain can be caused by a vertical "high noon" femoral tunnel placement and lead to a reflex loss of extension [38]. Tunnel position during the index procedure remains a key factor in preventing stiffness after ACL reconstruction.

Other Risk Factors

Other clinical factors have been shown to lead to arthrofibrosis in the post-operative ACL reconstruction period. Post-operative infection remains a relatively less common but potentially devastating complication following ACL reconstruction. The incidence of infection after ACL surgery is reported to be less than 1% [39]. Infection and/or hematoma was found to be an independent risk of stiffness following ACL reconstruction [30]. As seen with risk for initial ACL tear, females are also seemingly at increased risk for developing arthrofibrosis following reconstruction [30]. Additionally, it has been suggested that patients below the age of 18 also are associated with higher rates of stiffness in the post-operative period [30]. Tourniquet use may also have an influence on post-operative ROM. A recent study found increased tourniquet time to have an increased risk of return to the operating room for motion loss following ACL reconstruction [11].

Non-operative Management

Aggressive non-operative management of stiffness following ACL reconstruction is critical, and therefore early diagnosis is essential in the post-operative period. There should be an immediate focus on adequate pain control that starts at surgery with a planned pre-emptive multi-modal protocol. A supervised physical therapy program beginning on post-operative day 1 is important to ensure adequate early motion and stretching. Static or dynamic splinting methods may be helpful as an adjunct, and there may be a role in oral corticosteroids and/or biologics in the post-operative period to prevent stiffness.

Pain Control

Non-operative treatment during the post-operative period after ACL reconstruction must be aimed at addressing the etiology for the individual patient. The fear of movement, or kinesiophobia, and pain catastrophizing are associated with decreased return to sport [40]. For stiff kinesiophobic patients, providers must ensure pain is properly controlled to facilitate adequate participation in physiotherapy in order to prevent stiffness. Pain therapy must be directed at achieving maximum therapeutic benefit while minimizing systemic side effects. In the author's experience, a single shot of intra-articular bupivacaine has been effective in treating immediate post-operative pain. Regional nerve blocks, specifically adductor canal blocks and femoral nerve blocks, are also frequently used in the management of pain in the immediate post-operative period. Abdallah et al. showed that adductor canal blocks and femoral nerve blocks are equally effective in treating pain; however, adductor canal blocks result in greater quadriceps strength which is essential for active participation in physical therapy [41]. It is also in the author's experience that use of IV acetaminophen and intra-articular injection of ketorolac are effective at treating pain associated with stiffness.

Physical Therapy

The primary goal of early physical therapy is to prevent joint stiffness and potential arthrofibrosis. Most surgeons initiate formal supervised therapy 1–10 days after ACL reconstruction. Patients are instructed to use crutches for ambulation with weight-bearing as tolerated. Many surgeons prefer the use of a post-operative knee brace. Ice is essential to manage swelling and pain. Ideally patients will obtain full active and passive ROM by 2 weeks post-operatively. Patient education is essential as home exercises are a key component of successful therapy. Special consideration should be paid to dosage of exercises with respect to frequency, duration, and intensity. Lack of progress signifies that a patient might require an increase in dose of physical therapy. In contrast worsening pain, loss of ROM, and swelling could demonstrate a need to decrease dosing of physical therapy. Bracing and in certain cases casting may serve as augments to physical therapy in patients with stiffness refractory to conventional physical therapy.

Casting and Dynamic Splinting

Serial casting and drop-out casting have been utilized as a non-operative treatment for arthrofibrosis following ACL reconstruction, although limited results have been reported only by case series [8, 15, 42–45]. This method of static splinting is explained by the theory of low-load long-duration stretching to improve knee extension in patients that do not respond to standard physical therapy interventions. Biologically, there is an increase in remodeling of periarticular connective tissue in response to stretch and stress relaxation through elongation [46]. Potential benefits of drop-out casting compared to serial casting are that it is less cumbersome and it provides the option of removing the cast to perform other functional activities [42]. In a systematic review of 13 patients treated by drop-out casting, there was a 6.2-degree improvement in extension which as a treatment option provided the greatest improvement of extension loss [8]. Casting has also been proposed to be significantly more cost-effective than dynamic splinting as a means of stretching to improve terminal extension [42].

Although dynamic splinting devices have been most frequently been described in the arthroplasty literature with varied success, there may be a role in patients with arthrofibrosis following ACL reconstruction [47]. Dynamic splinting capitalizes upon the "creep" mechanical property of tissue. By applying a constant force, typically through a spring-loaded coil, these splints gradually stretch tissue [48]. In the pediatric population, Pace et al. demonstrated in their retrospective study that there was an 84% improvement in knee ROM with dynamic splinting in patients with arthrofibrosis following ACL reconstruction or meniscal repair [49]. Additionally, 58% of these patients avoided the need for surgery.

Anti-Inflammatory Agents

Post-operative inflammation contributes to stiffness and the struggle to regain full ROM post-operative. Short-term low-dose oral corticosteroids are a viable option for non-surgical management of loss of ROM after ACL reconstruction. Rue et al. conducted a study to evaluate the effectiveness of treatment with a short course of tapered methylprednisolone in the early post-operative period for loss of flexion [50]. Their study included 252 patients who underwent primary ACL reconstruction of which 28 (11%) had early post-operative loss of ROM. Mean flexion deficit in these patients was of 31 degrees compared to contralateral side. The oral corticosteroid was initiated at an average of 6 weeks. Patients demonstrated a mean improvement of 29.2 degrees. Treatment with oral corticosteroids utilizing a short course of tapered methylprednisolone was correlated with a return to normal ROM in 78% of patients with early post-operative loss of flexion after ACL reconstruction. There were no associated complications or associated decrease in knee stability as measured using objective stability measurements.

Intra-articular injection of anakinra, an interleukin-1 (IL-1) receptor antagonist, presents another viable option to reduce post-operative inflammation. Interleukin-1 is a key mediator of the inflammatory response and the maintenance of chronic inflammation. In a retrospective trial by Brown et al., they hypothesized that intra-articular anakinra would lead to sustained attenuation of chronic refractory arthrofibrosis and limited arthrofibrosis of the knee [51]. They reviewed eight patients who were injected with 200 mg of intra-articular anakinra. Six of these patients returned to prior activity levels and reported improvement in pain levels. Additionally, four of these patients reported an improvement in ROM between 20 and 45 degrees.

Operative Management

Aggressive management for the stiff knee following ACL reconstruction with arthroscopy, adhesiolysis +/− scar excision and/or notchplasty, and MUA has consistently been a gold standard in the operative management. Shelbourne et al. defined a classification system based on loss of motion

compared to the contralateral knee, which has since guided surgeons in the evaluation and treatment of arthrofibrosis [15]. Mayr et al. defined arthrofibrosis following ACL reconstruction as scar tissue within the knee that limited ROM [16]. There is a general consensus that arthrofibrosis requiring surgery is based upon a clinical limitation in knee ROM compared to the contralateral side that is symptomatic, persistent, and refractory to aggressive non-operative treatment [8].

Surgical Indications

Surgical indications include a loss of extension or asymmetric terminal flexion in a patient that has failed to improve with non-operative treatments. The etiology as to why stiffness has occurred must first be identified. Reasons may include primary arthrofibrosis, pain syndromes (such as complex regional pain syndrome), post-operative infection (especially within the first month), other associated ligamentous injuries, suboptimal post-operative rehabilitation (which may include inadequate patient compliance), tunnel malposition, and/or prior surgery.

Classically, timing for operative management of arthrofibrosis is within 3 months post-operatively and with a failure to progress during rehabilitation. This timing is based upon the clinical observation that the knee should be beyond the inflammatory state and that there must be a strengthening of the quadriceps muscles before proceeding with surgery [45].

Tunnel malposition rather than arthrofibrosis may be a cause of stiffness following ACL reconstruction. If the tunnel is anterior on the femur, the graft may impinge in extension and/or be stretched in flexion. If the tunnel is posterior on the femur, there will be laxity in flexion. If the tunnel is anterior on the tibia, there may also be graft impingement in extension. Lastly, as commonly seen in vertical tunnels, if the tunnel is placed posteriorly on the tibia, it will be stretched in extension, there will be laxity in flexion, and the graft may impinge on the posterior cruciate ligament (PCL). Careful analysis of the patient's anatomy and tunnel placement is therefore very important, and using computed tomography if needed to identify this may be necessary.

Surgical Management

Arthroscopic adhesiolysis is the most common technique used today; however, open or combined open and arthroscopic procedures may be necessary. Paulos et al. described an open technique for infrapatellar contracture syndrome which involves intra-articular and extra-articular release of lateral retinacular, hypertrophied fat pad, and the lateral and medial patellomeniscal ligaments [45]. Combined arthroscopic and open techniques have been described in which adhesions are lysed arthroscopically in the suprapatellar pouch, medial and lateral gutters, and intercondylar notch. If necessary, open releases of anterior extra-articular scar tissue and posterolateral and posteromedial capsule releases may be performed [52]. In addition to the need of open releases in cases of severe arthrofibrosis, there are instances that tibial tubercle osteotomy and fixation proximally may be necessary with patella baja [45].

Today, most surgeons describe arthroscopic adhesiolysis combined with MUA as the most common surgical treatment for arthrofibrosis following ACL reconstruction (Fig. 19.4). *Author's (NAS) preferred surgical treatment*: A standard knee arthroscopy setup with a lateral post and tourniquet is used. A regional nerve block either femoral nerve or adductor canal block is performed, and a careful exam under anesthesia is utilized to better measure the patient's knee ROM which may have been limited by pain in the office. A well-padded thigh tourniquet is commonly utilized and then deflated following completion of all releases to ensure adequate hemostasis and to avoid postoperative hematomas. Diagnostic arthroscopy using a powered fluid irrigation pump is then performed followed by MUA as needed with the purpose of limiting chondrolysis. Then, intra-articular adhesions are lysed using a proprietary controlled radiofrequency temperature – monitored ablation in the suprapatellar pouch, medial and lateral gutters,

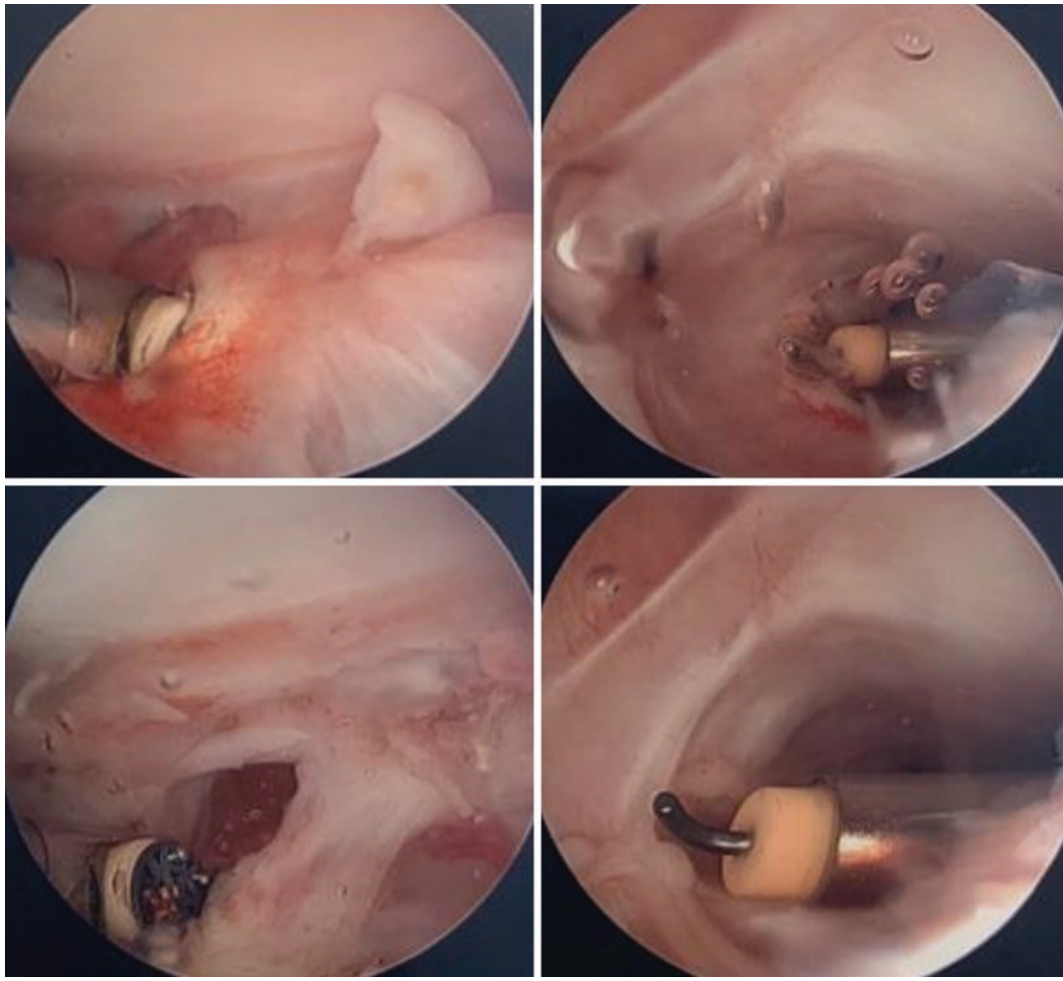

Fig. 19.4 Arthroscopic adhesiolysis for arthrofibrosis following ACL reconstruction

and intercondylar notch (Fig. 19.4). Accessory portals may also be utilized. Following precise intra-articular arthroscopic adhesiolysis, arthroscopic retinacular releases are performed under direct visualization, particularly if peripatellar fibrosis is pronounced. A MUA may then be gently performed which is often successful at gaining adequate extension and flexion. If there is lack of terminal extension, scar excisions, posterior capsular releases, and/or bony notchplasty may be also required. Open techniques may be utilized at this point if arthroscopic releases are found to be inadequate, but that is less commonly needed.

Shelbourne et al. described arthroscopic methods based on their classification system which may be helpful in guiding surgeons [15]. With the goal of achieving full extension, the hypertrophied "cyclops" lesion can be removed from the base of the ACL, anterior intra-synovial and extra-synovial scar tissue can be resected, and the graft may be "debrided." Also, a notchplasty and/or fibrotic capsule excision up to the vastus medialis and lateralis insertion to free the patella and patellar tendon completely may be required. MUA is again used after scar resection to achieve as much flexion as possible.

Lastly, during arthroscopic evaluation, revision ACL reconstruction may be considered at the index adhesiolysis or as a staged procedure if the graft is malpositioned. However, preoperative workup, computerized tomography scan evaluation, and confirmation of non-anatomic graft positioning in addition to patient

counseling are essential. Anterior fibers may also be resected with an anterolateral notchplasty at the time of arthroscopic adhesiolysis. It is the author's preference to perform a revision ACL reconstruction in a staged fashion if the graft is noted to be non-anatomic as a cause of stiffness and all else fails. This allows the patient to pursue post-operative rehabilitation after arthroscopic adhesiolysis with appropriate patient counseling. It is important to set realistic patient expectations.

Post-Operative Rehabilitation

Post-operatively, bracing and an immediate rehabilitation program are required to ensure success. This includes an emphasis on achieving adequate extension before aggressive measures are taken to improve flexion. This requires patient compliance and diligence with aggressive post-operative protocols. It is the author's preference to more recently not routinely use continuous passive motion (CPM) machines and to selectively use dynamic splinting only in cases where full extension is not achieved after arthroscopic adhesiolysis and MUA. To limit pain and swelling in the immediate post-operative period, regional anesthesia and intra-articular ketorolac, as well as cryotherapy compression cuffs, are routinely utilized. An opioid-limited, multimodal pain control regimen is prescribed including acetaminophen and nonsteroidal anti-inflammatory drugs (NSAIDs). More recently, we have had success with current pain management methodologies and the above protocol and have not found it necessary to routinely admit the patient overnight for epidural analgesia and continuous passive motion, given the desire to discharge the patient home on the same day as surgery and with adequate pain control.

Outcomes

Surgery generally can lead to a significant improvement in ROM post-operatively according to a recent systematic review [8]. The surgical outcomes of arthroscopic adhesiolysis reported by Shelbourne et al. were adequate, and patients showed improvements in ROM, mean stiffness, self-evaluation, functional activity, and Noyes knee scores [15]. Dodds et al. were the first who reported significant improvements both flexion and extension in 86% of patients treated with MUA who had persistent flexion or extension deficits after intra-articular ACL reconstructions [53].

Recent reports indicate that arthroscopic surgery for stiffness following ACL reconstruction does not affect patient function at 2-year follow-up. Worsham et al. reviewed 29 patients requiring surgery for loss of motion and compared them to matched controls [11]. They found no difference in time to release to play, level of participation, and subjective function scores. This was despite higher International Knee Disability Committee (IKDC) scores and single-legged hop testing in the control group, although not significant. This may be important as other authors found that patients following ACL reconstruction who had post-operative stiffness had significantly lower IKDC scores than those with normal ROM [54].

Regarding appropriate timing of operative intervention for arthrofibrosis, a recent study by Mayr et al. found that patients who underwent arthrolysis greater than 1 year after ACL reconstruction had more severe osteoarthritis and a lower IKDC score compared to those who underwent arthrolysis within 1 year [12]. This further emphasizes the importance of early diagnosis and aggressive management.

Conclusion

The keys to preemptive management for stiffness following ACL reconstruction include early diagnosis of loss of motion post-operatively with a defined etiology, aggressive non-operative treatments and surgical intervention with arthroscopic adhesiolysis, and MUA for failure of improvement after 3 months. Prevention of arthrofibrosis is critical, and we must educate patients, prescribe early motion, and work closely with physical therapists to improve perioperative rehabilitation. As

surgeons, we also must improve surgical techniques which include reducing harvest morbidity and optimizing anatomic tunnel placement.

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