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My Approach to Anterior Cruciate Ligament Injuries

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Anterior cruciate ligament (ACL) injury is among the most common problems encountered by orthopedic surgeons. However, the algorithm to optimally manage these pathologic conditions is still a topic of debate. We believe that accurate diagnosis, with specific attention to concomitant injuries, is crucial to management. Furthermore, individual patient goals and activity levels must be critically examined for appropriate treatment. Careful attention must be paid to technical factors that can predispose a graft to failure. When all these factors are considered, excellent short-term results can be attained, and athletes can return to sport at a high level.

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The incidence and prevalence of anterior cruciate ligament (ACL) injury has made it one of the most studied topics in orthopedics.[1] However, the inability to predict long-term degenerative changes, even with a technically well-performed reconstruction, has called the appropriate management of these pathologies into question. This article discusses our approach to ACL injury and other questions regarding the management of ACL-related pathology.

Diagnosis

An evaluation of patient history and physical examination are essential to a timely and accurate diagnosis of ACL pathology. There are several items of key information within the history to suggest an acute ACL injury. These injuries commonly occur during deceleration and cutting or twisting maneuvers. Often, patients will report sensing a "pop" within the knee. A postinjury effusion and a sense of instability when ambulatory are suggestive of ACL injury. Inability to ambulate after the injury is also suggestive. When patients report a locked knee, the question of concomitant meniscal pathology is raised.

Chronic ACL patients may report a remote history of injury. Usually, if the ACL does not heal, these patients may have giving-way episodes or may report that the knee feels like it is sliding during particular maneuvers. A classic description is the 2 fist sign, with the patient showing 1 fist sliding on the other to illustrate the sensation of giving-way in the knee. These episodes are precipitated by cutting, jumping, or stopping quickly.

The key points of the physical examination are the assessment of ACL competency and a thorough evaluation of other areas of the knee. ACL injury often occurs in combination with other injuries. In fact, one of the major reasons for failure of ACL reconstruction is a posterolateral corner injury that was not addressed. As such, a thorough examination of all knee ligaments is critical. The range of motion (ROM) is noted, as it could impede the examination and result in a missed ACL or posterior cruciate ligament (PCL) injury. Specific attention should also be paid to the medial and lateral joint line (to evaluate meniscal pathology), and to varus, valgus and rotatory instability to assess competency of the collaterals and posterolateral corner.

The examination of the acute ACL can be difficult at times because of the experience of pain and the presence of an effusion. A Lachman examination and anterior drawer and pivot shift tests are routinely performed. The Lachman should be performed at 20°-30° knee flexion. If performed closer to full extension, a false or pseudo endpoint may result. In a study from our institution, the pivot shift test was found to be dependent on hip abduction and tibial rotation.[2] However, it is often not feasible to perform a pivot in the acute setting because of pain and swelling. Even if it can be performed, the examiner will often have only one opportunity because of patient apprehension. Therefore, we usually reserve this test for the evaluation of chronic injuries.

The effusion may also limit a clinician's ability to accurately assess anterior translation on the Lachman and anterior drawer tests; however, the ability to detect an endpoint should be assessed and remain accurate. A comparison to the opposite uninjured knee is useful to note increased transla-

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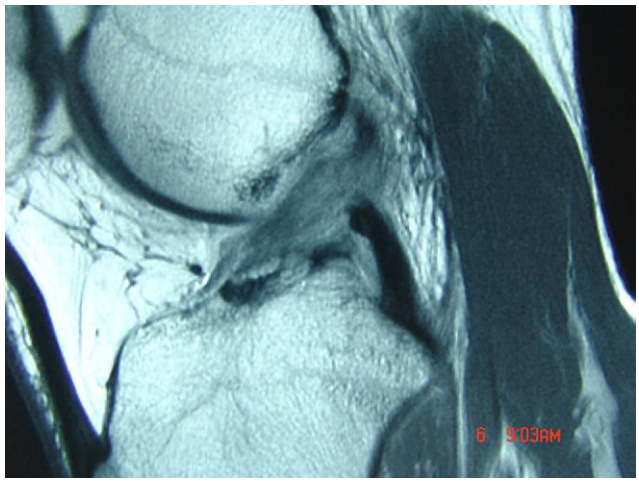

Figure 1 Sagittal MRI of a partially torn ACL with some fibers still in an appropriate orientation and a small bony avulsion of the femoral origin. (Color version of figure is available online.)

tion and the lack of an endpoint to the Lachman test. Despite a thorough physical examination, the diagnosis may still be questionable. This may be the case in partial ACL tears or revision settings where the endpoint may be soft. Other studies will become more useful in these situations.

Every patient undergoes a standard set of radiographs, including anteroposterior (AP), lateral, and merchant views of the knee. These can be useful to help determine alignment, arthritic changes, and a Segond fracture, which is virtually pathonomonic for ACL injury. We also perform magnetic resonance imaging (MRI) of the knee with fat suppressed and proton density-weighted and specific cartilage sequence imaging. The fat-suppressed images will usually reveal the effusion, and characteristic subchondral fracture pattern at the middle third of the lateral femoral condyle and the posterior third of the lateral tibial plateau indicate whether excess translation has taken place.

The cartilage specific sequences allow inspection of the articular cartilage and meniscus. Our specific protocols allow for quantifying the dimensions of a cartilage injury and the amount of ACL torn. They also characterize fiber orientation. For example, if the fibers are more horizontal or wavy, the ligament is less likely to be competent. This is often seen on the sagittal images. It is also important to pay close attention to the coronal images, which can show an injury at the origin and insertion of the ACL. Subtle findings such as the visualization of the entire lateral collateral ligament (LCL) on one coronal image are indicative of ACL injury. The LCL lies in an oblique orientation from its origin to insertion and should be seen on several coronal cuts. If seen on 1 image, this finding demonstrates anterior translation of the tibia relative to the femur.

Surgical Indications

The decision to proceed with ACL surgery is multifactorial. First and foremost, ACL insufficiency must be demonstrated. Patient history, physical examination, and MRI findings all play an important role. In some cases, particularly in those with a partial tear, the ability to assess ACL competency is less clear. Furthermore, in a small fraction of cases, the ACL may scar down and preclude the need for reconstruction. In these cases, an examination under anesthesia may be particularly helpful. If the patient has a 2+ pivot and 2B Lachman, the knee is unstable, and the patient will likely have giving-way episodes with athletic activity. The 2B Lachman indicates an anterior translation of 6-10 mm without an endpoint. We would proceed with surgery in such cases. In light of equivocal findings, we have used 50% as a cut-off for whether to reconstruct these injuries, depending on level of activity. Often, an arthroscopic Lachman examination will help to quantify exactly how much translation the knee has. The surgeon can also visualize the amount of tension in the remaining ACL. There have been few studies to help predict the natural history of partial ACL tears. Noyes et al reported that 38% of their partial ACL tears went on to complete ACL deficiency when treated conservatively.[3]

Partial ACL injury occurs particularly in women with some osteoporosis. These are proximal avulsions that, if still oriented in a straight line (Fig. 1) on the sagittal MRI, have the potential to heal over 8-12 weeks. Anecdotally, we have observed that about 80% of these will be able to function with a low-grade partial tear (Fig. 2). However, the other patients will either become symptomatic or reinjure the knee, completing the tear. We have had to reconstruct about 20% of those initially managed nonoperatively for a partial ACL injury caused by repeated giving-way episodes or inability to return to play at a similar level. These are among the most difficult decisions to make without clear guidelines. In practice, we are guided by the history and physical requirements (including level of activity), examination under anesthesia arthroscopic evaluation of the ligament, and the goals of the patient.

If the presence of an ACL tear is more definitive, the question of whether the patient needs ACL reconstructive surgery arises. We base our recommendations on the particular needs

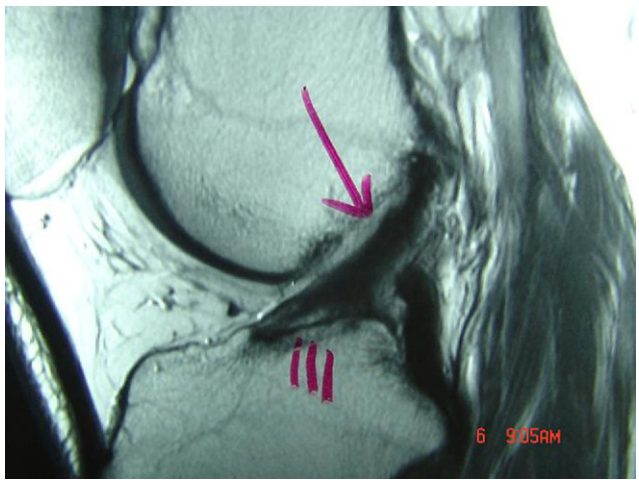

Figure 2 Sagittal MRI of patient in Fig. 1, 1 year later, demonstrating healing of the fragment and ligament. (Color version of figure is available online.)

of the patient. More specifically, we do not have an age cutoff. If a patient is active in pivoting sports such as basketball or soccer, surgery will be recommended. Similarly, surgery will be recommended in an aggressive skier who skis more than 50 days a year. We have performed ACL reconstructive surgery for these reasons in patients older than 60 years. By contrast, an older patient who likes to run straight ahead or perform other activities where pivoting does not play a role may not need ACL reconstructive surgery. However, if a patient continues to complain of giving-way postinjury, we will recommend ACL surgery to protect the meniscus. Studies have shown a high risk of meniscal injury in the ACL-deficient knee in active patients.[4-6] This is another example where concomitant pathologies must be considered. For example, if a patient has a large peripheral meniscal tear that is amenable to repair, we will recommend ACL surgery to protect the repaired meniscus. Similarly, if there is concomitant collateral or PCL injury, we would be more aggressive in recommending surgery to enhance the overall stability of the knee.

Timing of Surgery

Once the decision for surgical intervention has been made, the next issue to address is the appropriate time for the surgery. In our opinion, it is safe to proceed with ACL surgery when the knee has full ROM. Several studies have shown an increased incidence of arthrofibrosis when knee surgery is performed on an urgent basis.[7-9] We believe that in such cases, the second insult, the surgery, may be synergistic with the initial injury. If the cascade of inflammatory mediators released into the intra-articular milieu is not allowed to taper before the surgery, this can have an adverse effect on the outcome. Therefore, we prefer to have the patient undergo physical therapy before surgery and perform ROM activities to enhance mobility as well as modalities to decrease swelling.

If the patient has a concomitant medial collateral ligament (MCL) injury, we will also proceed more slowly.[10,11] In a grade 3 MCL injury, the ligament will often scar down and become competent, particularly if it is torn off the femoral origin. In this situation, we recommend delaying ACL reconstruction for 6 weeks. This is usually sufficient to allow the MCL to heal and restore ROM to the knee. At the time of surgery, a diagnostic arthroscopy is performed. When the medial compartment is entered, a valgus stress is placed upon the knee. A 3-mm probe is then placed in the medial compartment, and the amount of opening is assessed arthroscopically. If the patient continues to open greater than 7-8 mm, the MCL still lacks the ability to resist valgus stress, and concomitant MCL reconstruction is considered.

Surgical Technique

Before surgery, an examination under anesthesia is performed. If the patient has a 2B Lachman and 2+ pivot shift, the operation is performed and the graft is harvested first. If the examination is equivocal, a diagnostic arthroscopy is performed. A superolateral outflow portal is established in addition to the standard medial and lateral portals. During arthroscopy, careful attention is paid to documenting and addressing all other intra-articular pathology. Careful assessment of the ACL, specifically, looking for an empty wall sign upon inspection of the origin and insertion and assessing the ability of the ACL to take up load, is critical.[12]

If the decision to proceed is made, the graft is then harvested. With respect to graft selection, we use Bone-Patella Tendon-Bone (BTB) in young, active patients who perform contact sports. Hamstrings may stretch more (1 mm) than BTB but can be useful if adequate in size. Despite quadrupling the hamstring, grafts can still be small (<6 mm), and an alternative should be used. Allografts are typically used for patients older than 30 years and for revisions. For allografts, we typically choose the Achilles tendon. Notchplasty may be performed. Most acute cases will not need bone removal. Care is taken to remove an appropriate amount of tissue to allow for adequate visualization of the footprint. However, we are mindful not to remove an excessive amount of bone on the lateral femoral condyle, as this will change the center of rotation of the knee once the graft has been positioned. An ACL guide is placed in the middle of the ACL footprint on the tibia. A guide wire is then placed through the guide, and a reamer is used to drill the tibial tunnel to the appropriate size. A shaver is used to remove all debris from the tunnel opening. For the femoral tunnel, the site for drilling is marked on the femur, and if it can be reached from the tibial tunnel, it is drilled. If not, then an alternative is used, such as drilling

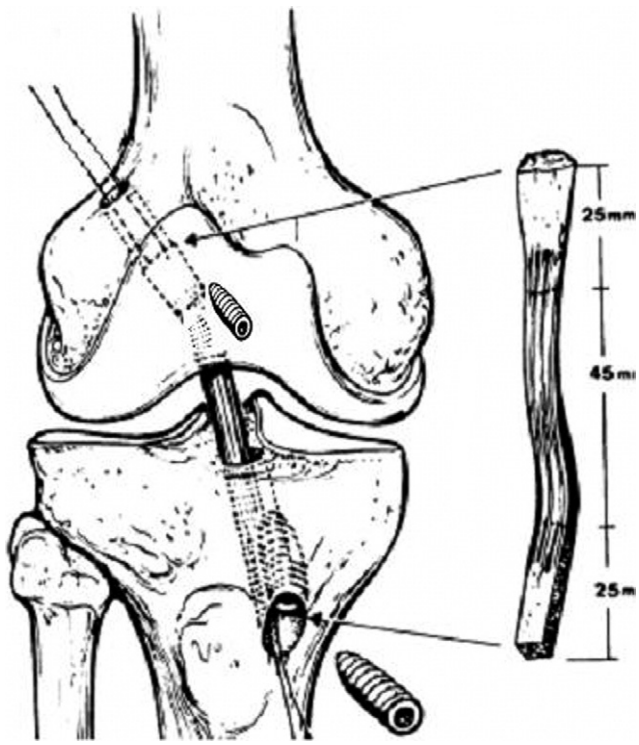

Figure 3 Illustration of completed BTB reconstruction with interference screw fixation on both the femur and tibia (adapted from O'Brien et al[13]).

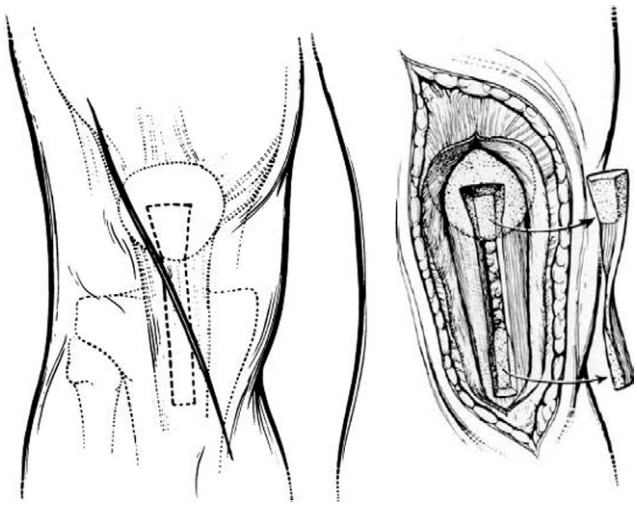

Figure 4 Illustration of the harvest of the central third of the patella tendon (adapted from O'Brien et al[13]).

from the anterior medial portal or using the retrodrill from an outside-in approach. To help control rotation, the entry site of this tunnel must be on the lateral femoral condyle wall (Fig. 3). For this, the drill needs to be at approximately 40° to the tibial plateau. In certain instances when this is not feasible from the tibial tunnel, the femoral tunnel is drilled from an anteromedial portal or a retrodrill is used.

In young, athletic patients, our preferred graft is the central third of the patella tendon (Fig. 4). Although clinical studies have not consistently shown an advantage in outcomes, we prefer this graft because of bony healing and predictable results.[14] In patients who kneel often, such as wrestlers, we recommend hamstring tendons because of the higher incidence of anterior knee pain and kneeling pain with BTB. We have secured these grafts on the femur with devices such as the EndoButton (Smith and Nephew, Andover, MA) or EZLoc (Biomet, Warsaw, IN). These were chosen for the strength inherent to cortical fixation. Anecdotally, we have had good experiences with these devices and few failures due to fixation. On the tibia, we use bioabsorbable screws. If the purchase of the screws was questionable intraoperatively, we augmented our tibia fixation with a plastic button.

At our institution, we have used allograft with increased frequency in patients older than 30. Lower morbidity, lack of a harvest site, and lower operative time make it an attractive option. However, concerns over quality control and infection and incorporation rates have been raised. We now use a certified distributor and have had good results with over 2000 allograft ACL reconstructions performed in the last 5 years. We use the Achilles tendon because of ease in shaping the bone block and a large cross-section of collagen in the tendon to function as the new ACL. A theoretic infection rate exists for viral infection. We have not had any seroconversions due to an infected graft to date. An investigation at our institution found similar rates of bacterial infection for allograft and autograft.[15] In fact, we had statistically higher rates of bacterial infection for hamstring autograft.

Concomitant Pathologies

At the time of ACL surgery, other concomitant pathologies should be addressed. This includes but is not limited to meniscal tears, chondral injuries, and loose bodies. For meniscal tears, we have been fairly aggressive in repairing those tears that are amenable. Usually these occur in the acute setting in younger patients. Noyes and Barber-Westin showed that these types of tears tend to do well if repaired, even when they extend into the avascular zone.[16] They suggested, and we concur, that this may be due to the biological milieu of the knee joint after an ACL injury. However, in the chronic setting, this environment does not exist, and very often, the meniscus has become degenerative and is poorly suited to repair. We advocate menisectomy in these cases. Also, it clearly makes sense to fix the ACL concomitantly to protect the meniscus should one decide to perform the repair. We have had good results with all intra-articular devices, specifically the Fas T-Fix (Smith and Nephew, Andover, MA). We have used these in many professional athletes, and anecdotally, have had results similar to historic open procedures. We believe that there is less morbidity and similar outcomes. This does change the rehabilitation regimen when compared with isolated ACL reconstruction. We advocate crutches for 5 weeks and the use of a brace for 6 weeks.

We also recommend addressing articular cartilage injuries at the time of ACL reconstruction. In our experience, the microfracture technique has worked well for small lesions (<2 cm $\times$ 2 cm) in the setting of an acute ACL injury. Similar to the all intra-articular meniscal repair, we believe that this approach causes significantly less morbidity than its open counterparts (osteochondral autologous transplantation, OsteoBiologics Incorporated, San Antonio, TX) and takes advantage of a favorable intra-articular environment that will aid in healing. Although several studies have shown that the reparative bed is a mix of a hyaline and fibrocartilage, we have had some success in terms of return to play even in elite-level athletes.[17-19] With larger chondral lesions (>400 mm^2), results have been less promising, and other strategies must be explored.[20-22] These variables have also been demonstrated to have an impact on prognosis and return to sport.

Postoperative Rehabilitation

After surgery, we have generally placed patients in a Bledsoe brace locked in extension and made them partial weight bearing. We have advocated an aggressive rehabilitation program that begins immediately. In the first 2 weeks after surgery, the focus is on ROM, with an emphasis on full passive extension. We also stress the use of early straight leg-raise exercises to prevent quadriceps inhibition and the use of a bicycle.

In phase 2, we advance the patient to walking without a brace when a normal gait pattern is demonstrated. The ROM should be established during this time, and the patients' quadriceps control should make significant strides. Strengthening at this point involves leg press.

Phase 3 takes the patient from 6 weeks through the

3-month time point. At this point, the patient should be able to negotiate stairs without difficulty, and exercises may include squats, as well as proprioceptive training with balance platforms. The ROM should return to normal. Running is usually started around 4 months and should be pain free, and the patient should demonstrate good quad control and balance with a 0.2032 cm step-down test. Plyometric training may begin, as well as continued strengthening. Initially, we advocate close-chained exercises because of the potential increase in strain on the graft. At this point in rehabilitation, however, the patient may start open-chained exercises such as leg extension from 90° to 30°, as we do not want to stress the ACL graft with the terminal 30°.

There are many factors that can play a role in return to play: age of the patient, concomitant procedures, sport to which the patient would like to return, and individual response to rehabilitation. We have witnessed "quick healers" as well as those who have struggled postoperatively. As a general rule, we let patients return to sport at 6 months. This can be adjusted based on the patient's response to therapy and the clinical presentation of the knee. Several authors have recommended surrogate tests as a measure of ability to return. At our institution, we have used a hop test to assess lower extremity function to determine the ability to return.[23] We have found that a hop test with $>$ 85% limb symmetry is an appropriate measuring stick. However, the ultimate criteria rely more on lack of apprehension with sport-specific movements, close-to-normal strength of the affected limb, and flexibility to accepted levels of sports performance.

We have had success and return to sport of over 95% in our athletes with appropriate management and adequate rehabilitation after ACL injuries.[24,13] We have yet to fully understand the long-term sequelae of both the initial injury and the presence of a bone bruise, but in the short-term, it does not seem to be consequential. A functioning ACL has allowed for return to sport at a high level, which would not have been possible otherwise. In addition, the ACL helps to protect against meniscus tears that have a poor prognostic effect on arthritis in the knee. Ultimately, long-term studies will help to illuminate the natural history of the ACL reconstructed knee.

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