Hamstring Allograft Anterior Cruciate Ligament Reconstruction in the Skeletally Immature Patient

Jerome J. Da Silva, MD, FRCSC and Bernard R. Bach Jr, MD

Abstract: Reconstruction of the anterior cruciate ligament (ACL) remains the most appropriate treatment for adolescent patients who are ACL deficient. This article reviews the indications for adolescent ACL reconstruction, potential risks, and the technique for allograft reconstruction.

Key Words: anterior cruciate ligament, adolescent, allograft, knee ligament, over the top

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HISTORICAL PERSPECTIVE

In the last 20 years, there has been an increase in the literature pertaining to the management of a skeletally immature patient with anterior cruciate ligament (ACL) injuries. With increasing involvement of children in sports, an increase in ACL injuries in this population has been reported.1 In a survey of members of the Herodicus Society and the ACL Study Group, Kocher et al2 reported that the members studied a mean of 5.8 pediatric patients with ACL injuries annually. In addition, 78% of those surveyed stated that they had performed an ACL reconstruction on a skeletally immature patient within the previous year.

Historically, ACL reconstruction in skeletally immature patients has been discouraged because of the theoretical risks of damage to the growth plate. However, the case series data available in the literature have not supported a significant pattern of leg length discrepancy or angular deformity caused by ACL reconstruction in adolescent patients.3-10

Controversy still exists between nonoperative management and surgical reconstruction of these patients based on the potential risks of both treatment options. Nonsurgical treatment risks an unstable knee and further damages the meniscal structures and articular cartilage. Anterior cruciate ligament injuries in adolescents behave similarly to those injuries in adults; chondral and meniscal injuries are common. Operative reconstruction risks potential damage to the growth plate. Previous research has shown that 21% to 100% of pediatric patients with ACL injuries will have a concomitant meniscal injury.11,12,15,16 In addition, there is a risk of exacerbating initial injury or new meniscal damage if the knee remains chronically unstable.5,15,16 Growth plate arrest after ACL reconstruction, although a concern, has only been infrequently reported.17-18 Furthermore, the treatment of physical arrest is soft tissue interposition, and for this reason, hamstring tendon grafts have been recommended as the graft of choice in patients with open growth plates.19

INDICATIONS/CONTRAINDICATIONS

Indications for ACL reconstruction in skeletally immature patients are similar to those in an adult. There is, however, more need for counseling and compliance, as the adolescent population places high demands on their knees with their daily activities. This can lead to further knee damage as previously mentioned. Anterior cruciate ligament reconstruction can be viewed as more urgent in an adolescent compared to that in an adult. Clinical ACL insufficiency is the main indication for ACL reconstruction. Other considerations include patient activity level, KT-1000 (MEDMetric, San Diego, Calif) maximal manual side-to-side differences of greater than 3 mm, associated repairable meniscal tears, and multiligament injury association.13,15,17

Contraindications to physeal-sparing ACL reconstruction include medical comorbidities precluding surgical intervention, a stiff knee that does not have normal motion, and closed growth plates. In adolescents who have finished growing earlier than their peers and have closed their growth plates, standard adult-type ACL reconstruction can be performed.

PREOPERATIVE PLANNING

In a skeletally immature patient, preoperative planning is important. An accurate assessment of bone age and remaining growth assists in the planning process and guides the decision making for graft choice. In a patient who is very close to skeletal maturity, using an adult reconstructive technique would be acceptable. In a patient who has significant remaining growth based on bone age, using a physeal sparing or adolescent ACL technique is more appropriate. Each child has a unique rate of growth, and especially in males, there can be significant variation of remaining growth among subjects of the same age. Therefore, numerical age alone cannot solely guide decision making regarding a skeletally immature patient who is ACL insufficient.

To assess bone age, we obtain anteriorposterior hand radiographs from all adolescent patients and compare them with the Greulich and Pyle atlas.22 Adolescent girls will usually stop growing at the skeletal age of 14, whereas adolescent boys will stop growing at 16.5 years. When appropriate, we also use patients’ height compared with their parents’, secondary sexual characteristics (Tanner level), and in adolescent girls, the onset of menarche. In adolescent girls, a growth spurt precedes the onset of menarche and, in general, they will grow for 2 years from the onset of menses. In addition, if a growth arrest would occur, it may take up to a year to manifest itself; hence, if there is less than 1 year of predicted remaining growth, we generally will perform our adult ACL reconstruction.

If we determine that a patient has significant remaining growth, we discuss the options that are available for reconstruction. Many of these adolescents are quite petite, and in those circumstances, we discuss and recommend allograft hamstring...
tissues. It is our opinion that we will have superior-quality tissue for reconstruction and have minimal surgical intervention that might not be tolerated in a young child. Specific informed consent is obtained from families regarding allograft tissues. We have used the same not-for-profit tissue bank since 1986.

Our preoperative imaging routine in this patient population includes knee radiographs, the posteroanterior views of the hand for skeletal age, and, frequently, a magnetic resonance imaging to evaluate for meniscal pathology or to assess the extent of a bone contusion.

**TECHNIQUE**

In the preoperative holding area, the operative extremity is signed by both the patient and the surgeon. The consent is reviewed with the parents, and antibiotics are initiated (first-generation cephalosporin).

General anesthesia is used in the operating room. Once the patient is anesthetized, an examination under anesthesia is performed as a final confirmation of the diagnosis. Both Lachman and pivot shift examinations are performed (Figs. 1 and 2). Once the Lachman and the pivot shift tests confirm the diagnosis, the graft is thawed.

The patient is positioned supinely on the operative table. The contralateral leg is placed in a gynecological stirrup, and the operative leg is placed in an arthroscopic leg holder with a padded tourniquet around the thigh. The foot of the bed is flexed to allow the operative leg to hang at 90 degrees. The waist of the bed is also slightly flexed to eliminate lumbar extension and reduce traction on the femoral nerve during surgery (Fig. 3).

Diagnostic arthroscopy is first performed using an anterolateral viewing portal, an anteromedial instrument portal, and a superomedial outflow portal. Once the articular surfaces of all 3 compartments are inspected and the menisci are examined, the fat pad and medial plica are decompressed. We perform this routinely in ACL reconstructions feeling that this reduces postoperative stiffness.

**Graft Preparation**

The graft is prepared on the back table. Two hamstring tendons are prepared independently. A FiberLoop suture (Arthrex, Naples, Fla) is used on each end of the 4 limbs of the graft. The graft is then sized and placed in a damp sponge until insertion.

**Limited Notchplasty**

Notch preparation is performed using the arthroscopic shaver. The ACL stump is debrided to reveal its footprint. Residual soft tissue is debrided off the lateral wall from the anterior to the posterior aspect, and the over-the-top position is identified. A notchplasty is generally not performed.

**Tibial Tunnel**

An incision is made on the anteromedial aspect of the proximal tibia to drill the tibial tunnel. The pes anserinus and tibial tubercle are used as landmarks. A 1.5- to 2-cm incision is made along the border of the pes anserinus, which is also approximately 1 thumb breadth medial to the tibial tubercle. Dissection is made down to the periosteum.

A tibial drill guide is used to position the intra-articular position of the guide pin. The guide is set at a 55-degree angle. This steep angle is used to minimize injury to the tibial growth plate. Accurate tibial guide pin placement is performed by closely observing and adhering to 3 parameters: (1) the posterior aspect of the tibial ACL footprint; (2) five millimeters lateral to the medial tibial spine; and (3) seven millimeters anterior to the posterior cruciate ligament. The guide is placed through an accessory inferomedial portal with the aiming stylet placed...
where the tibial tunnel will enter the joint. This portal is made through a separate transpatellar tendon portal. Placing the tibial drill guide through this inferomedial portal allows excellent mobility of the aiming device and allows for easier medial-to-lateral (ie, oblique) orientation of the aimer than when it is placed through the standard medial portal (Fig. 4).

Once the guide pin is appropriately positioned, the knee is hyperflexed, and the pin is tapped up to engage the femoral notch (Fig. 5). This holds the pin securely during drilling. The pin is then overdrilled with a cannulated reamer to match the size of the prepared graft (Fig. 6). This is often 6 to 7 mm. The tunnel is plugged with a rubber stopper, and a shaver is used to remove osteochondral fragments from the intra-articular opening of the tibial tunnel. A chamfer reamer and a curved hand rasp are used successively to smooth the posterior edge of the tunnel's proximal opening. This provides a smooth posterior surface, which the graft will lie against (Figs. 7A–C). This scope can then be placed up the tibial tunnel to visualize and document the open growth plate (Fig. 8).

Femoral Over-the-Top Approach

The over-the-top technique requires a second incision. This is made on the lateral aspect of the distal thigh. The incision length is 2 cm. Dissection is made down to the iliotibial band. The iliotibial band is incised longitudinally. The intermuscular septum is then identified, and the vastus lateralis is reflected off the septum anteriorly. A Z retractor can then be placed beneath the vastus and over the femur, retracting the soft tissues anteriorly. The periosteum is incised well above the growth plate to avoid injury. The posterolateral femoral condyle and posterior aspect of the notch can then be palpated.

Once the incision and dissection is complete, the over-the-top position can be established. This is performed with the arthroscope in the inferomedial portal. The Shepherd's hook (a j-shaped guide passer with an eyelet at its tip) is placed through the inferolateral portal hugging along the lateral intercondylar wall to the over-the-top position. With the knee in flexion to relax the posterior neurovascular bundle, the Shepherd's hook is pushed through the capsule and delivered anterior to the intermuscular septum (Figs. 9–11). With the hook delivered, a #5 Tycron suture is attached and pulled back into the knee joint out through the inferolateral portal. A grasper is then inserted up the tibial tunnel to grasp the suture and deliver it out through the tibial tunnel. The suture is now positioned such that one end is out the lateral thigh incision in the over-the-top position and the other end out the tibial tunnel (Figs. 12 and 13). It will function as a suture passer for the hamstring graft.

Graft Passage and Fixation

The 2 prepared grafts are passed by attaching them to the Tycron suture distally and pulling them up through the tibial tunnel, exiting the over-the-top position (Figs. 14A, B and 15).
Fixation is achieved on both the femur and tibia using barbed Richards staples (Richards, Memphis, Tenn). These are placed distant from the growth plate to avoid injury. On the femur, a pants-over-vest technique is used on the lateral aspect of the femur. The knee is then cycled, and the graft is tensioned manually with the knee in 15 degrees of flexion. The graft is then fixed to the tibia distal to the tunnel using small and extra small Richards staples. These are impacted sufficiently to try and reduce their prominence.

The arthroscope is then reinserted to check the graft position throughout a full range of motion. Incisions are irrigated and closed with subcuticular closure. A sterile dressing and a continuous cooling unit are applied. Over this, a drop-lock brace is applied and locked in full extension. Early motion and progression to full weight bearing is allowed.

POSTOPERATIVE MANAGEMENT

Our postoperative management protocol is the same for our adolescent population as it is for our adult population. The postoperative rehabilitation protocol that we use has been previously described in detail.\textsuperscript{21} Postoperatively, the patient’s knee is stabilized in a hinged knee brace (Fig. 16). The brace is locked in extension for weight bearing and sleeping. Otherwise, the brace can be unlocked to allow flexion. This brace is used for the first 4 to 6 weeks postoperatively to provide comfort and assist in achieving full extension. Most patients will require crutches for 7 days; however, some will not need them at all. Initially, particular emphasis is directed at achieving full extension of the knee. Heel slides, prone heel hangs, straight leg raises, and patellar mobilization are initiated on the day of the surgery. By 2 weeks, the rehabilitation program is progressed to include toe raises, closed chain quadriceps exercises, hamstring curls, and stationary bicycling. A stretching routine is also started, including weight-bearing stretching of the gastrocnemius and the soleus. By 8 to 12 weeks postoperatively, the patient is allowed to begin jogging. By 4 to 6 months postoperatively, the patient is selectively allowed to begin sport-specific rehabilitation and gradual return to athletic activities using their functional ACL brace. Patients are seen in the office at 6-week intervals postoperatively until 6 months and then at 9 and 12 months.

RESULTS

We are currently in the process of publishing our clinical results using this technique. There are clinical results in the literature of similar techniques using a trans-physeal tibial tunnel, soft tissue graft, and an over-the-top technique on the femur.

Andrews et al\textsuperscript{4} reported on the use of a 7-mm fascia lata or Achilles tendon allograft through trans-physeal tibial drill holes and over-the-top positioning on the femur. At a mean follow-up
of 58 months, all 8 patients demonstrated symmetric closure of the growth plates, with no clinically significant limb-length discrepancy on orthoroentgenograms. The mean height increase postoperatively was 4.55 cm.

Lo et al reviewed ACL reconstruction in cases of extreme skeletal immaturity. From a larger series of 19 skeletally immature children who had undergone ACL reconstruction, 5 patients with evidence of wide open physes on plain radiographs were identified. The mean age was 12.9 years, with the youngest patient being 8 years or age. All cases used a transphyseal tibial drill hole, a soft tissue graft, and over-the-top femoral technique. At a mean follow-up of 7.4 years, no patient had a positive anterior drawer, Lachman, or pivot shift test. All patients had instrumented laxity side-to-side differences of less than 3 mm, and the mean was 1.0 (1.6) mm. Magnetic resonance imaging demonstrated that 4 tibial physes had closed in a symmetric fashion and 1 remained open. Orthoroentgenograms revealed no significant leg length discrepancy or angular deformity. The mean height gained postoperatively was 14.3 cm.

Bisson et al reported on 9 patients undergoing ACL reconstruction with wide open physes. The mean age for the group was 13 years, and the mean follow-up was 39 months. The technique used included soft tissue graft, tibial tunnel, and over-the-top graft passage on the femur. Seven patients reported excellent results and returned to full sporting activities. Two patients experienced traumatic failures of the ACL graft after returning to football. No patient had a clinically significant leg length discrepancy, angular deformity, or radiographic evidence of physeal injury.

POSSIBLE CONCERNS

The obvious concern that remains is the violation of the proximal tibial growth plate. Although the case series data available in the literature do not support any trend or significant pattern of leg length discrepancy or angular deformity, this theoretical risk needs to be discussed with the patient and the parents preoperatively. Another theoretical concern is the concern of graft stretching, attrition, and loosening with growth of the child. This concern is unsubstantiated in the literature, and can be argued with the opposing theory that as the child grows, the graft becomes tighter as it is stretched. There is also a
FIGURE 14. (A and B), Pull through technique is used to pull the
graft up through the tibial tunnel to the over-the-top position.

theoretical risk to the distal femoral physis with the passage of
the Shepherd’s hook and using staples near the growth plate. If
unsure of the location of the growth plate, intraoperative
fluoroscopy can be used to confirm its location to ensure proper
staple placement.

Many of the concerns surrounding the use of hamstring
graft in the adult population would translate into the pediatric
population. In addition, hardware prominence on the tibia is a
concern and may require subsequent removal.

Allograft risks including disease transmission are also
concerns, especially when treating the pediatric patient popula-
tion. These risks need to be discussed with families before
surgery.

FUTURE OF THE TECHNIQUE

Anterior cruciate ligament reconstruction in skeletally
immature patients will continue to evolve. There is a need for
good prospective clinical trials in this population, but the
infrequent incidence of pediatric ACL injuries and the concern
of meniscal injuries make the logistics of such a trial difficult.
Although the technique described in this paper provides very
good results, there remains room for improvement. Future
advances will likely focus on tibial fixation techniques with a
lower incidence of hardware irritation and over-the-top femoral
techniques without the need for a second incision.

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