ACL Reconstruction in Children Using Growth Plate Sparing Techniques

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Background

Although previously considered rare in the pediatric population, recent work has found that 1-3.4% of children presenting for management of a knee injury are diagnosed with an ACL rupture.[1] In fact, the incidence of ACL rupture in pediatric patients has increased substantially.[2-4] With over 100,000 reconstructions annually in the United States[4] and a significant proportion attributable to children and adolescents, effective management of ACL ruptures in the skeletally immature is an important topic. Surgical techniques to address ACL insufficiency in these patients include primary repair, extra-articular tenodesis, transphyseal reconstruction, partial transphyseal reconstruction, and physeal-sparing reconstruction

Considering Physeal-Sparing Reconstruction

When ACL reconstruction is considered in a pediatric patient, the surgeon must decide if a physeal-sparing method is appropriate. This decision is based upon the patient's skeletal development and anatomic constraints. While patients nearing skeletal maturity may be managed with transphyseal techniques (as indicated in Figure 1), patients with substantial growth remaining (>2 years until skeletal maturity) may be good candidates for physeal-sparing techniques.

Choosing the Right Physeal-Sparing Approach

After choosing physeal-sparing ACL reconstruction, one must decide upon the most appropriate method. Several techniques are described in the literature, but there are two main approaches: the extraphyseal Iliotibial Band Reconstruction (ITBR) and All-Epiphyseal Reconstructions (AERs). While the ITBR uses no bone drilling, AERs use horizontal-oblique bone tunnels or sockets placed wholly within the epiphyses without crossing adjacent growth plates. Each approach has its own risks and benefits.

Although the ITBR is appropriate for any patient with open growth plates and significant growth remaining (Figure 1), we use it most commonly for prepubescent (Tanner Stage 1-2) children with a great amount of skeletal growth remaining. These patients generally have a small amount of epiphyseal bone stock, precluding all-epiphyseal tunnel placement. We use all-epiphyseal reconstruction in prepubescent and pubescent adolescents who have >2 years of skeletal growth and several inches of height growth remaining. Several variables, including provider experience, influence the decision to perform one procedure rather than the other in an adolescent patient where either is reasonable. In patients with less than two years of skeletal growth remaining, we prefer transphyseal reconstruction with care to only place soft tissue (no bone or screw) at the level of the growth plate.

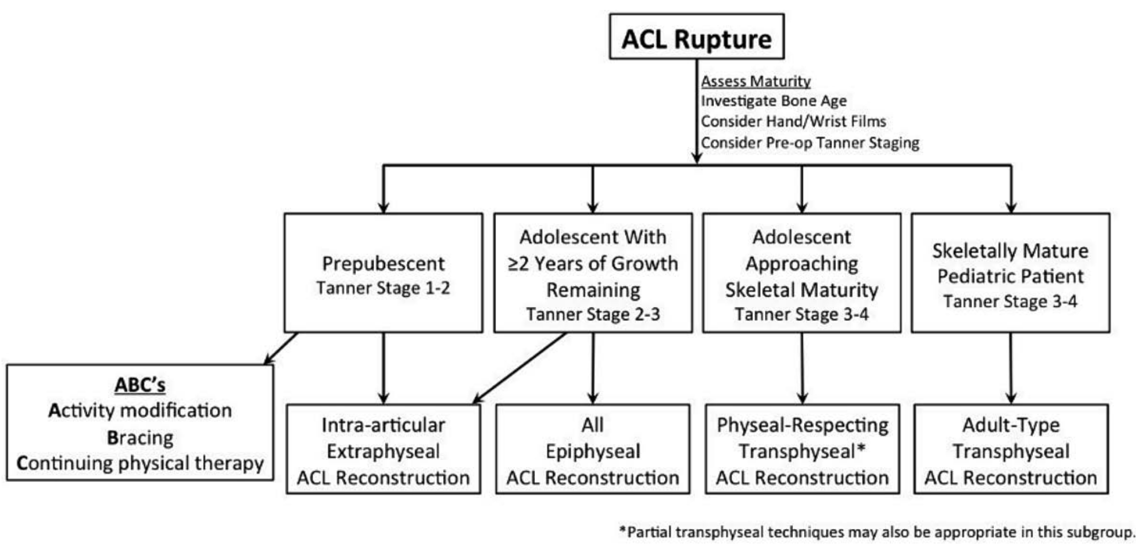

Figure 1. Algorithm for the treatment of ACL tears in pediatric patients. The lower panel illustrates which techniques are appropriate based upon the patient's developmental status.

Physeal-Sparing Surgical Techniques

Iliotibial Band Reconstruction (ITBR)

The combined intra-articular and extra-articular ACL reconstruction using auto genous iliotibial band graft is a tunnel-free reconstruction.[5,6] In this procedure, a mid-substance slip of the iliotibial ban d (ITB) is brought through the "over-the-top" position around the lateral femoral condyle and then through the "over-the-front" position under the intermeniscal ligament to form a new ACL (Figure 2). This non-anatomic reconstruction provides satisfactory knee stability, with the extra-articular portion of the ITB graft providing extra rotational joint stability.[7]

Surgical Technique

1. Examination Under Anesthesia and Diagnostic Arthroscopy

The patient is prepped and draped in the supine position with a tourniquet in place and the lateral thigh generously exposed. It is useful to map anatomic landmarks using a skin marker (Figure 3A-B). After anesthetic induction, an examination is performed to confirm ACL insufficiency. A diagnostic arthroscopy through standard anteromedial and anterolateral portals is performed. The ACL stumps are debrided and meniscal pathology is addressed.

2. Lateral Incision

Next, a longitudinal incision is made over the lateral aspect of the distal thigh, centered over the ITB, beginning at the joint line, and extending proximally 6-8 cm (Figure 3C). The underlying ITB is exposed and a periosteal elevator is used to separate it from the subcutaneous tissues, extending proximal to the skin incision for about 10 cm to free the entire length of the future graft. The ITB's anterior and posterior extents are identified and may be marked (Figure 3D).

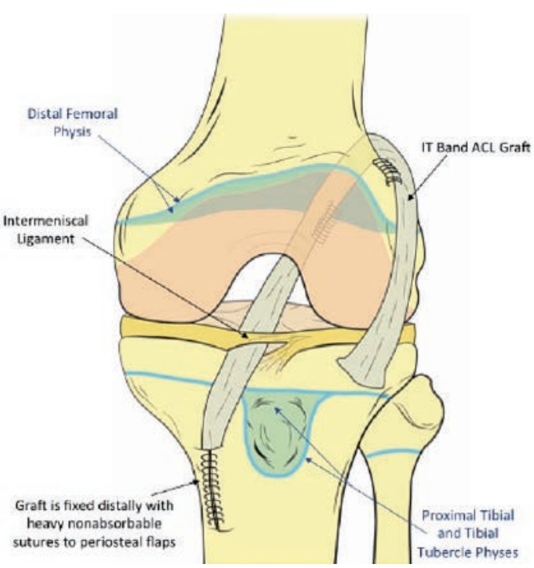

Figure 2. Schematic drawing of the IT band reconstruction technique demonstrating the use of the mid-substance slip of the IT band looped posterolaterally over the lateral femoral condyle, through the joint, and under the intermeniscal ligament to form a new ACL.

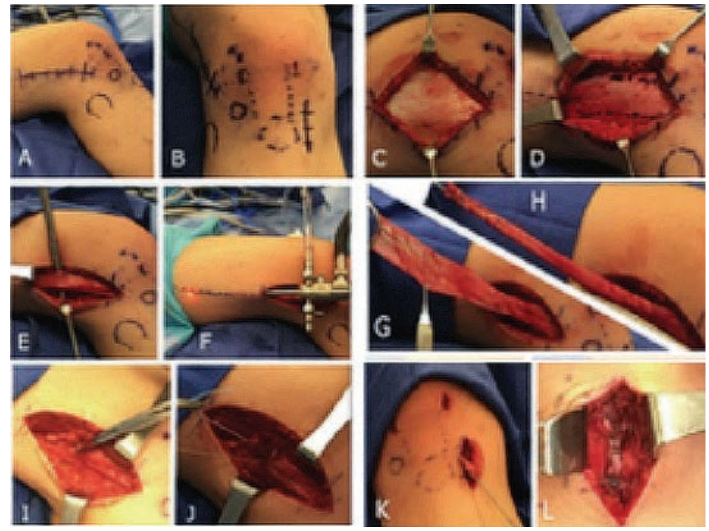

Figure 3. (A-B) Right knee prior to ITBR with anatomic landmarks. **(C-D)** Exposure and identification of the ITB. **(E-F)** Division of the ITB. **(G-H)** Preparation of the ITB graft. **(I-J)** After the graft has been pulled through the joint, it is sutured into the femoral periosteum at the insertion of the intermuscular septum. The graft lies in the "over-the-top" position. **(K-L)** The graft is fixed distally in a metaphyseal trough and sutured to the adjacent periosteum.

3. Prepping the ITB Graft

Parallel anterior and posterior longitudinal incisions are made at the distal ITB to mobilize a central slip of the tendon (Figure 3E). This should constitute 2/3 or more of the ITB's width. Dissection is carried distally to free the slip from the joint capsule and patellar retinaculum. Care must be taken to leave the graft attached to Gerdy's Tubercle. Proximally, the ITB divisions are extended beyond the skin incision using curved meniscotomes. Visualization can be improved using the arthroscope under the subcutaneous flap (Figure 3F). The ITB slip is freed at its proximal end through either the existing incision or a separate 1 to 2 cm counter incision on the lateral thigh. The proximal ITB slip is whip stitched with heavy nonabsorbable suture (Figures 3G-H). At this point, the free slip should measure 15-20 cm (varying with patient size). Suture ends should be cut and left long as tags to assist in graft passing.

4. Initial Passing of the ITB Graft

A curved Kelly-type clamp is extended through the anteromedial portal, through the joint, between the femoral condyles, carefully out through the capsule in a high posterior position, and into the lateral operative field. Arthroscopic viewing through the anterolateral portal can be of assistance in this step. Care should be taken to avoid damaging the perichondral ring when dissecting posteriorly. The ITB graft suture tags are secured with the clamp and carefully pulled out through the anteromedial portal. The clamp is disengaged, leaving the suture tags partially in the joint.

5. Anteromedial Tibial Incision and Final Graft Passing

A longitudinal skin incision of approximately 3 to 4 cm is made at the anteromedial tibia near the pes anserinus.

Dissection here is carried to the periosteum. A rasp may be placed through the incision and used to create a shallow groove in the tibial epiphysis posterior to the intermeniscal ligament. The clamp is then extended through the incision, under the intermeniscal ligament, and into the joint where it is used to secure the suture tags and guide the graft out through the tibial incision. As the graft is pulled into place, it assumes an "over-the-top" position around the lateral femoral condyle (Figure 3I) and an "over-the-front" position as it passes over the anterior tibia under the intermeniscal ligament.

6. Femoral Fixation

The leg is placed in 90° of flexion without lower leg rotation. With slack removed from the graft, mattress sutures are placed to secure its extra-articular portion to the periosteum on the posterior femur where the intermuscular septum attaches (Figure 3J).

7. Tibial Fixation and Closure

At the anteromedial operative site, the periosteum is incised in-line with the skin incision distal to the physis for approximately 3 cm. Some surgeons carry out this step under fluoroscopy to avoid injuring the growth plate. A shallow metaphyseal trough is made beneath the periosteal incision. With the knee in 20° of flexion and the graft extending into the medial tibial operative site, the free end of the graft is trimmed, tensioned, and seated into the trough (Figure 3K). Mattress sutures are used to secure the graft to the adjacent periosteum (Figure 3L). The knee is gently ranged, and skin incisions are closed.

8. Postoperative Management

The patient is initially restricted to 0-90° of knee flexion. They use crutches and are maintained in a hinged knee brace locked in extension for ambulation. Continuous passive motion can be useful in the early postoperative period. The patient is allowed to toe-touch weight-bear. After 2 weeks, full range-of-motion is allowed. At 6 weeks, the knee brace can be removed, and the patient enters a rehabilitation program.

All-Epiphyseal Reconstruction with All-Inside technique

AERs make use of horizontal-oblique tunnels that do not cross physes (Figure 4). The use of low-dose intraoperative fluoroscopy is recommended to ensure all-epiphyseal tunnel placement. Although 8-strand hamstrings autograft is preferred by the senior author, other graft types are used in various circumstances. Graft fixation can be achieved through a variety of approaches. All-epiphyseal cortical button fixation will be discussed here, but alternatives include interference screws and post constructs.

Surgical Technique

1. Examination Under Anesthesia and Diagnostic Arthroscopy

The patient is prepped and draped in the supine position, and an examination under anesthesia is performed. The senior author prefers to outline the lateral femoral condyle using a skin marker as seen in Figure 5A. The resulting circle is bisected into four quadrants, with proper femoral guide placement lying just anterior to the center of the circle. A diagnostic arthroscopy is performed, meniscus tears are addressed, and the ACL footprints are debrided. The graft is acquired, prepared, and placed on looped button constructs under tension using a graft board.

2. Femoral Gui de Placement

A pediatric-specific femoral targeting guide is set to 95° and placed at the femoral ACL footprint. Then, a 1-2 cm incision is made slightly anterior and distal to the lateral femoral epicondyle and dissection is carried to the periosteum. Using the g uide, a pin is placed through the incision, lateral to m edial, completely within the distal femoral epiphysis. The plac ement of the pin is checked via fluoroscopy to ensure that it avoids the undulating distal femoral physis.

3. Tibial Guide Placement

Another targeting guide is set to 25-35° and placed at the tibial ACL footprint. A small anteromedial tibial incision is placed 1-2 cm medial to the tibial tubercle and carried to the periosteum of the proximal tibial epiphysis. Using the guide, a pin is placed through the tibial incision extending to the tibial ACL footprint. Care is taken to ensure that the pin does not violate the physis. Fluoroscopy is again used to confirm proper pin placement.

4. Drilling

Because ACL graft diameter drops with tensioning,[8] post-tensioning graft diameter is measured, and retro drilling tools are accordingly selected. The femoral retrodrill sleeve

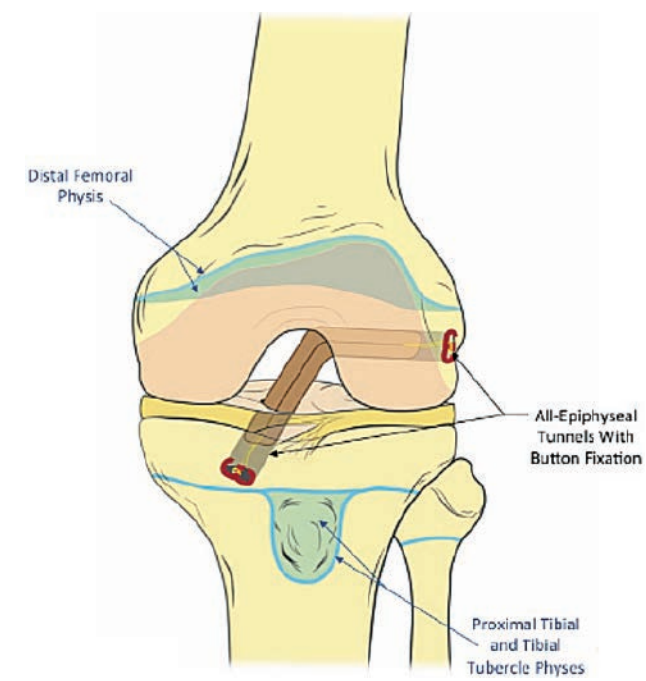

Figure 4. Schematic of an all-epiphyseal reconstruction with cortical button fixation

Figure 5. A left knee undergoing all-epiphyseal reconstruction. **(A)** The femoral guide is placed and the femoral guide pin is driven into the proximal ACL footprint. **(B)** The tibial guide is placed and another guide pin is driven into the distal footprint. **(C)** Intraoperative fluoroscopy or CT-scan confirms the epiphyseal placement of the guide pins.

is malleted over the guide pin to a depth-stop of 7-10 mm, and the pin is removed. The appropriate retrodrill is advanced through the sleeve into the joint, deployed, and used to drill a socket of approximately 20-25 mm in length in a retrograde fashion. The position of the retrodrill sleeve ensures that an adequate cortical wall is left intact. Tibial drilling is performed in an analogous fashion to form a socket of approximately 15-20 mm in length. The retrodrill sheaths are carefully removed. Arthroscopy can be used to evaluate the sockets and confirm their all-epiphyseal positioning.

5. Graft Shuttling, Fixation, and Closure

High-strength suture loops (shuttle sutures) are advanced through the guide pin holes. The graft (with attached sutures and femoral cortical button) is placed through the anteromedial portal into the joint. Using the shuttle sutures, the femoral side of the graft is pulled into the femoral tunnel. The femoral cortical button is advanced beyond the femoral cortical bone and flipped to rest on the lateral cortical bone of the distal femur. The tibial shuttle sutures are then used to retrieve the distal graft suture tags through the tibial pin hole. The knee is placed in full extension, and the tibial button is added to the exposed graft sutures. The construct is appropriately tensioned until there is no pathologic laxity in the knee. The tibial suture loop is tied to fix the graft length, and the tibial cortical button is flipped to engage cortical bone. The knee is ranged and checked for stability. The graft is evaluated arthroscopically before incisions are closed.

6. Postoperative Management

Continuous passive motion is used for 3 weeks postoperatively. For ambulation in the first 4 weeks, the patient wears a hinged knee brace locked in full extension and is restricted to toe-touch weight bearing. Physical therapy begins on post-operative day 5. Return to sport is allowed when strength and functional testing for the affected limb is equal to that of the contralateral limb—generally around 9 months postoperatively.

Conclusion

Physeal-sparing ACL reconstruction includes a varied set of operative techniques. The iliotibial band ACL reconstruction is non-anatomic and avoids physeal injury by having no bony tunnels or sockets. All-epiphyseal ACL reconstructions avoid physeal injury by placing bony tunnels wholly within the epiphyses. Both types of ACL reconstruction can provide preadolescent and adolescent children with stable knees, allowing them to participate in healthy fitness activities.

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