J Orthop Spine Trauma. 2020 September; 6(3): 57-60. DOI: http://dx.doi.org/10.18502/jost.v6i3.4966

Educational Corner

Anterior Cruciate Ligament Reconstruction in Skeletally Immature Patients

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Received: 27 February 2020; **Revised:** 01 May 2020; **Accepted:** 23 July 2020

Keywords: Anterior Cruciate Ligament; Arthroscopy; Child; Athletic Injuries

Citation: Rezaei Dogahe R, Vosoughi F, Mortazavi SMJ. **Anterior Cruciate Ligament Reconstruction in Skeletally Immature Patients.** *J Orthop Spine Trauma* 2020; 6(3): 57-60.

Background

In the past, anterior cruciate ligament (ACL) injury was considered to be rare in children. However, as the participation of children and adolescents in professional sports has increased recently, the rate of ACL injury has risen. Mall et al. demonstrated that among individuals aged less than 20 in the United States, the incidence of ACL injury has surged from 12.22 in the year 1994 to 17.97 per 100000 in the year 2006. It is estimated that 1360490 sport injuries have occurred during the year 2017-2018 among high school athletes in the Unites States. Knee injuries accounted for 14% of high school athletic injuries in this study. Most susceptible knee tissues for injury were reported to be medial collateral ligament (MCL), patellar tendon, knee meniscus, and ACL, respectively (1).

Female soccer and male football were the most common sport activities associated with the ACL injury. The injury to the ACL may occur as a result of player to player contact, jumping, or during swift change in the athlete's direction or speed (2).

During managing a child with ACL injury, the physician will face a therapeutic dilemma. Surgical options carry a risk of injury to the growth plates placed around the knee joint, while conservative therapies are associated with a long term risk of knee cartilage damage and degenerative joint diseases. In this paper, we aim to delineate the concept and the management options available for treating a skeletally immature patient with ACL injury.

History and Physical Examination

The signs and symptoms of the ACL injury in children are similar to those is adults. Children may feel a clicking sound after the injury. Additionally, they may develop hemarthrosis within 6-12 hours following the trauma. Hemarthrosis following acute knee injury is an important clue suggesting structural knee injury and is associated with ACL deficiency in 65% of cases (3).

As joints and tissues have more laxity in children compared to adults, interpretation of the physical examination should be more cautiously performed and it is recommended to compare the results of each examination maneuver on both sides. The medial and lateral knee joint lines, patellar tendon, and tibial tubercle should be carefully palpated. Decreased range of motion (ROM) of the affected knee suggests a possible additional damage to the joint cartilage or meniscus. The collateral ligaments of the knee should be evaluated with varus/valgus stress test both in full extension and 30-degree flexion of the knee. The ACL integrity can be evaluated with Lachman test. In this test, anterior moment is inserted to the tibia while the knee is flexed by 30 degrees. Anterior translation of the tibia during the test suggests ACL injury. Since surgical management of ACL injury in children may be associated with growth plate injury related complications like limb length discrepancy, the patient should be searched for any limb length discrepancy or knee deformity prior to any clinical intervention (3).

Imaging

Anteroposterior, lateral, and sunrise view of the injured knee help to evaluate the growth plates around the joint and rule out any possible bone fracture. The three hip-knee-ankle joints standing X ray view shows the skeletal alignment and reveal angular deformities of the knee joints. In addition, the posteroanterior radiography of the left hand is used to analyze the ossification centers of the hand and estimate the skeletal age. Magnetic resonance imaging (MRI) can help evaluate the integrity of the ACL, meniscus, and knee collateral ligaments. It has a 95% sensitivity and 88% specificity in detecting pediatric ACL injury. In children with a locked knee, an acute MRI is warranted to assess the presence of a displaced bucket handle meniscal tear or an osteochondral injury that may need prompt surgical treatment (3-5).

Maturity Assessment

Maturity assessment is important as it provides a clue on whether the patient's growth plates are closed, and therefore help the surgeon to adopt the best management option. In general, a younger skeletal age is accompanied by higher operative risk of growth disturbances. The assessment can be performed based on the evaluation of secondary sexual characteristics of the participant (Tanner classification). Moreover, estimation of the skeletal age by using the patients' left hand PA radiograph according to the Hospital for Special Surgery (HSS) method is another useful way for maturity assessment (3).

Nonoperative Treatment

No consensus has been reached on the best method of treatment for a torn ACL in children and adolescents. Nonoperative and operative management are two therapeutic options. The nonoperative approach can lead

to instability, meniscal tears, and degenerative changes. In contrast, operative treatment might damage the adjacent physis causing leg length discrepancy or angular deformity (6).

According to the Kocher et al., the partial ACL injury can be managed non-operatively. On exception, they recommended to treat patients surgically for ages more than 14 years old, having positive pivot test (grade B or worse), those with more than 50% ACL injury or damage to the posterolateral ACL (7).

Complete ACL injury responds poorly to nonoperative management predominantly due to noncompliance of pediatric patients and high level of their activity (6).

Surgical Treatment Options for Pediatric ACL Injury

1. Physeal-sparing Techniques

1a. Iliotibial Band (ITB) Reconstruction: Kocher et al. popularized ITB reconstruction (the modified MacIntosh procedure) (Figure 1). A combination of intra-articular and extra-articular stabilization is used in this method. This method is primarily indicated for patients at Tanner stage I or II. During this procedure, the middle one third of the ITB is transected proximally, transferred over the top of the distal femur to reach the tibia, then the graft is passed under the intrameniscal ligament on the tibia and is fixed to the periosteum of the proximal tibia (8).

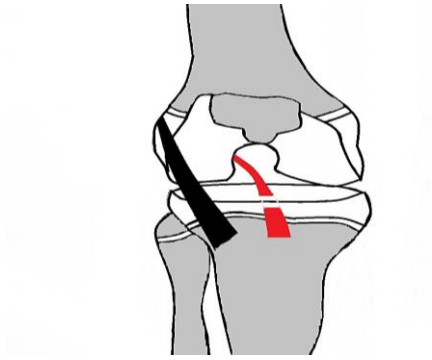

Figure 1. The Anterior Cruciate Ligament (ACL) reconstruction in a skeletally immature patient using iliotibial band (ITB)

1b. All-epiphyseal Technique: An all-intraepiphyseal technique was described by Anderson et al. and was performed for patients aged 13.3 years on average (Figure 2).

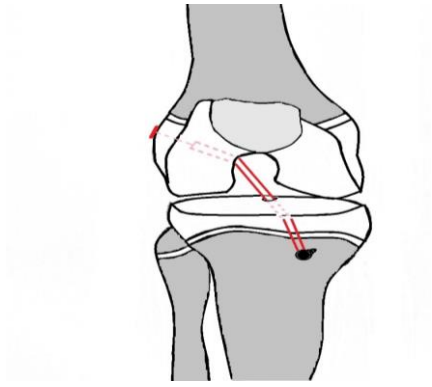

Figure 2. Anderson's technique [all-epiphyseal anterior cruciate ligament (ACL) reconstruction]

In this method, a graft of hamstring tendon is harvested and passed through the distal femoral epiphysis. The graft then is fixed with an EndoButton over the lateral femoral condyle. The remaining portion of the graft will be transferred through an intra-epiphyseal tibial tunnel. The ending distal part of the graft is placed on the tibia and fixed to the tibia with a screw distal to the proximal tibial physis (9). Alternatively, the distal end of the graft can be fixed to the tibia with an endobutton (double suspensory fixation) (Figure 3).

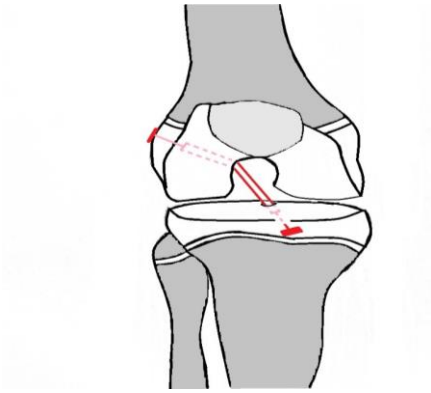

Figure 3. All-epiphyseal technique with double suspensory fixation with EndoButton

2. Partial Transphyseal Technique

The partial transphyseal technique is a combination of physeal-sparing technique and transphyseal procedures that are performed in adults. For this purpose, hamstring or bone-patellar tendon-bone grafts are used. Either the distal femoral or the proximal tibial physis is left intact to minimize the possibility of growth arrest. By using smaller bone tunnels (6 to 8 mm) and more vertical tunnels in this method, the injury to the physis is further decreased (10).

3. Complete Transphyseal Reconstruction

Complete transphyseal reconstruction is highly similar to the adult ACL reconstruction, with multiple changes including the use of smaller more vertical tunnels, placement of the hardware or bone blocks outside the physis zone, and application of metaphyseal fixation.

Although this technique is usually performed in adolescence (little to no remaining growth), some studies propose its use in younger patients with immature skeletal development (11).

Which Graft (Allograft or Autograft) Is a Better Choice for ACL Reconstruction?

The most common graft is quadrupled hamstring graft. Alternatively, a quadriceps tendon graft can be used. To prevent injury to the apophysis of the tibial tuberosity, harvesting the patellar tendon should be avoided in children with open physes. Despite use by some surgeons, due to poor clinical outcomes (12), allografts are not indicated in most cases of pediatric ACL reconstruction (13, 14).

Approach to Treatment

Complete ACL ruptures are managed surgically even in the very young patients. In prepubescence (Tanner stages I and II; bone age: boys ≤12 years and girls ≤11 years), a physeal-sparing intraepiphyseal technique using autogenous quadrupled hamstring tendons is preferred. In adolescence with remaining growth (Tanners stages III or IV; bone age: 13-16 years for boys and 12-14 years for girls), a complete transphyseal reconstruction is favorable. In adolescence with closing physes (Tanner stage V; bone age: boys > 16 years and girls > 14 years), classical ACL reconstruction is preferred (Figure 4) (2).

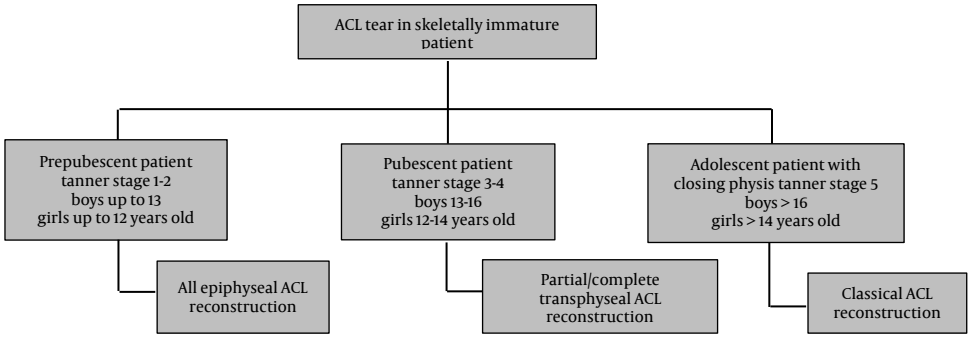

Figure 4. Approach to anterior cruciate ligament (ACL) injury in a skeletally immature individual

Postoperative Management

Patients are placed in knee brace for 6 weeks. After a transphyseal technique, patients are restricted to toe touch weight-bearing for 4 weeks.

For the first 3 months after reconstruction, progressive rehabilitation is used which includes ROM, closed chain quadriceps and hamstring strengthening, and patellar mobilization. At 3 months, the patient can start straight-line running and plyometric exercises. Pivoting activities and sports are only allowed at approximately 6 to 9 months after the surgery, preferably using an ACL brace during such activities for the first 2 years (2).

Case Presentation

A 12-year-old boy referred to our clinic with a chief complaint of knee pain and giving way from 3 months ago after a soccer injury. Past medical history and drug history were negative. In physical examination, there was a 10-mm displacement in the anterior drawer test (ADT) and 11-mm displacement in the Lachman.

The pivot shift test was 1+. Both the posterior drawer test (PDT) and McMurray test were negative. The MRI confirmed tearing of the ACL without any meniscal and chondral injuries.

After discussing all the management options with the patient and his parents, surgery was selected. Due to open physis in both proximal tibia and distal femur, we used all-epiphyseal technique.

After general anesthesia, the patient was placed in supine position. First, the hamstring autograft was harvested from the affected side. The following diagnostic arthroscopy showed no chondral and meniscal injury. Then, distal femur and proximal tibia all-epiphyseal tunnels were made.

The autograft hamstring tendon was passed through the distal femoral epiphysis and fixed with an EndoButton over the lateral femoral condyle.

In the end, the knee was positioned in a near full extension, and the free end of the graft was moved through the intra-epiphyseal tibial tunnel and was fixed with EndoButton while appropriate tension was applied. During 2-year follow-up, we observed no limb length discrepancy (LLD), growth disturbances, or functional instability (Figure 5).

Figure 5. An intraepiphyseal anterior cruciate ligament (ACL) reconstruction using double suspensory fixation was applied in our patient (upper photos). After the operation, he recovered uneventfully and gained full knee extension and flexion in his follow up visits (lower photos).

Conflict of Interest

The authors declare no conflict of interest in this study.

Acknowledgments

None.

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