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Physeal-Sparing Anterior Cruciate Ligament Reconstruction For Skeletally Immature Knee: A Case Report

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ABSTRACT

Introduction : ACL injuries are common in the knee and often caused by non-contact sports or dynamic valgus knee movements. There has been an increase in competitive sports at younger ages, resulting in higher levels of competition and greater recognition of sports injuries by coaches and specialists. **Case Report :** Patient is a 14 year old woman with the initials RNF came to the emergency room of the hospital with complaints of pain in the right knee accompanied by a feeling of instability after suffering an injury while playing football with the mechanism of injury: when the patient was running and was about to change direction by supporting her right leg, suddenly the patient felt pain and there was a sound in the right knee area. After history, physical examination, and supporting test, diagnosis was made as complete ACL tear and surgery was planned in the form of ACL reconstruction using the physeal sparing technique. **Discussion :** The risk of ACL damage is greater in young and active individuals. The physeal-sparing technique is a relatively safe approach with few complications. It reduces knee pain at the donor site and lowers the risk of nerve damage. This method also reduces the risk of joint damage after physical activity. Young athletes who returned to sports after ACL reconstruction showed a much higher rate of injury, with a 30 to 40 times greater risk of ACL injury compared to uninjured youth. Effective communication among patient and specialist therapeutic is crucial for a successful surgery and safe return to sports and daily activities. **Conclusion :** Full ACL reconstruction using a physeal-sparing technique in young patients is a safe method that protects the growth plate and avoids the complications. However, further research is needed to determine the long-term effectiveness of this approach in treating ACL injuries in young patients.

Keywords: Physeal-sparing technique, anterior cruciate ligament, reconstruction, skeletally immature knee, pediatric

INTRODUCTION

ACL injuries are common in the knee and often caused by non-contact sports or dynamic valgus knee movements. There has been an increase in competitive sports at younger ages, resulting in higher levels of competition and greater recognition of sports injuries by coaches and specialists.[1] Skiing, soccer, basketball, and football have the highest risk of ACL injury.[2] Shea et al. 12 found ACL wounds accounted for 6,7% of all damage cases and 30,8% of knee wounds in soccer players aged 5 to 18 in the US.[3] Young female athletes are more prone to ACL injuries due to their smaller intercondylar notches, smaller and looser tendons, and greater knee valgus angle.[4] Untreated ACL insufficiency can result in instability, meniscus damage, chondral damage, osteoarthritis, and decreased activity levels. Previous data suggests that 21-100% of pediatric patients have both a meniscal injury and an ACL injury.[5] However, the actual rate is often underestimated due to a lack of well-designed studies on the frequency of ACL injuries in children and adolescents, especially in developing countries. Most studies only focus on surgical patients and overlook those who do not undergo surgery. A study by Beck et al. showed an increasing rate of ACL tears in pediatric patients over the past 20 years.[6,7]

ACL tear treatment modality in children has uncertain outcomes. The ACL reconstruction is anatomically positioned on the tibial side and the femoral position is isometric but in the end it lacks rotational control. There is a risk of physeal damage with tibial fixation and potential development disturbances with femoral fixation due to tying effects or harm to the perichondrial ring. ACL injuries in young patients are treated with nonoperative methods like braces, physical therapy, and daily activities changes.[8] These approaches are temporary until the child reaches skeletal maturity, at which point standard ACL reconstruction can be safely done. There is a better understanding of the results seen with nonoperative

treatment and delayed surgery in preadolescent patients, leading to recent recommendations for earlier surgical intervention. One strategy developed is the "Physeal-sparing" procedure.[9,10]

Currently, there is no strong evidence to suggest that ACL reconstruction can predict the likelihood of developing joint pain. However, research indicates that leg length inconsistency and leg angle deviation are less common after ACL reconstruction in young individuals. Additionally, initial ACL tears are often associated with cartilage and meniscus injuries, which are the primary cause of stiffness[11]. However, no consensus has been reached regarding the optimal surgical approach to accurately replicate the biomechanics of the local ACL structure and 78% of specialists surveyed had performed ACL reconstruction in skeletally young patients, but yet no standardized procedure exists.[12]

CASE PRESENTATION

Patient is a 14 year old woman with the initials RNF came to the emergency room of the hospital with complaints of pain in the right knee accompanied by a feeling of instability after suffering an injury while playing football with the mechanism of injury: when the patient was running and was about to change direction by supporting her right leg, suddenly the patient felt pain and there was a sound in the right knee area. After this incident, the patient was unable to continue playing. When a physical examination was carried out, on local status in the form of look, feel, move, and a special test for the right knee was carried out upon arrival, the Look (L) results were obtained in the form of swelling, no deformity was found, and no visible wounds on the outside. In Feel (F), no neurovascular disturbance (NVD) was found, but the ballotement examination showed positive results so it was continued with aspiration and the findings obtained were haemarthrosis of 100cc. In the movement (M) examination, it was found that the patient in an antalgic gait, and in the range of motion (ROM) examination of the knee, the results showed that

the ROM was limited with -10' extension and 80' flexion. Apart from that, the patient also underwent special tests in the form of a positive Lachman test, a positive anterior drawer test, and a negative pivot test. The valgus and varus tests at 0' and 30' showed negative results. Based on the history and examination, the patient received initial medical treatment, cold compresses for 20 minutes every 2 hours and entered the pre-operation physiotherapy program for 2 weeks. Follow-up of the patient's development after 2 weeks was continued with supporting imaging examinations (MRI) of the knee with the results: bone marrow edema and bone bruises on the lateral condyle of the posterior tibial bone and lateral aspect, fluid collection in the retropatella to suprapatella, and complete ACL tear. So the diagnosis was made for this patient as complete ACL tear and surgery was planned in the form of ACL reconstruction using the physeal sparing technique.

PROCEDURAL TECHNIQUE

Under anesthesia and nerve block, the patient was placed lying down on a table. They received a single dose of antibiotics before surgery and a tourniquet was applied. A 5 cm × 10 mm × 5 mm hamstring (semitendinosus and gracilis) tendon auto-graft was collected using a minimally invasive method and prepared for an physeal sparing ACL reconstruction. The ends of the tendon were extended by 15 mm using a fiber loop with fiber tag and attached to an ACL tight rope. Arthroscopic knee examination revealed a complete tear of the ACL. The tear and debris was cleaned up and the femoral and tibial footprints were identified. Both menisci appeared normal, and the cartilage was unremarkable. Despite the osteochondral injury shown on MRI on the horizontal femoral condyle, the cartilage remained stable and did not need further surgical attention. Under arthroscopic vision, a guidewire was placed in the femoral impression of the ACL using a 7mm FlipCutter to create a 1.5-2cm femoral tunnel. Sutures were pulled through the femoral condyle for later graft placement. The penetration was ensured to be completely epiphyseal.

A guidewire was inserted from the proximal tibia into the back of the tibial ACL using a 6 mm FlipCutter to create 1.5cm tibial tunnel. The procedure was done again under arthroscopic control for precise placement. Sutures were placed in the tibial tunnel and then retrieved alongside back of the knee through the arthroscopic entry. Finally, the graft was flexed around 20 degrees. An arthroscopic final check and debris was done, wounds were closed, and a brace was applied to the leg.

Post-surgery protocol included early mobilization and weightbearing were encouraged. The child had the freedom to wear the brace or evacuate as desired. Closed chain exercises were started soon after surgery with special precautions for the weakened quadricep ligament. Physiotherapy carried out from day 2 after surgery, followed by a guided exercise program. Return to high-impact activities or competitive sports allowed after 9 months.

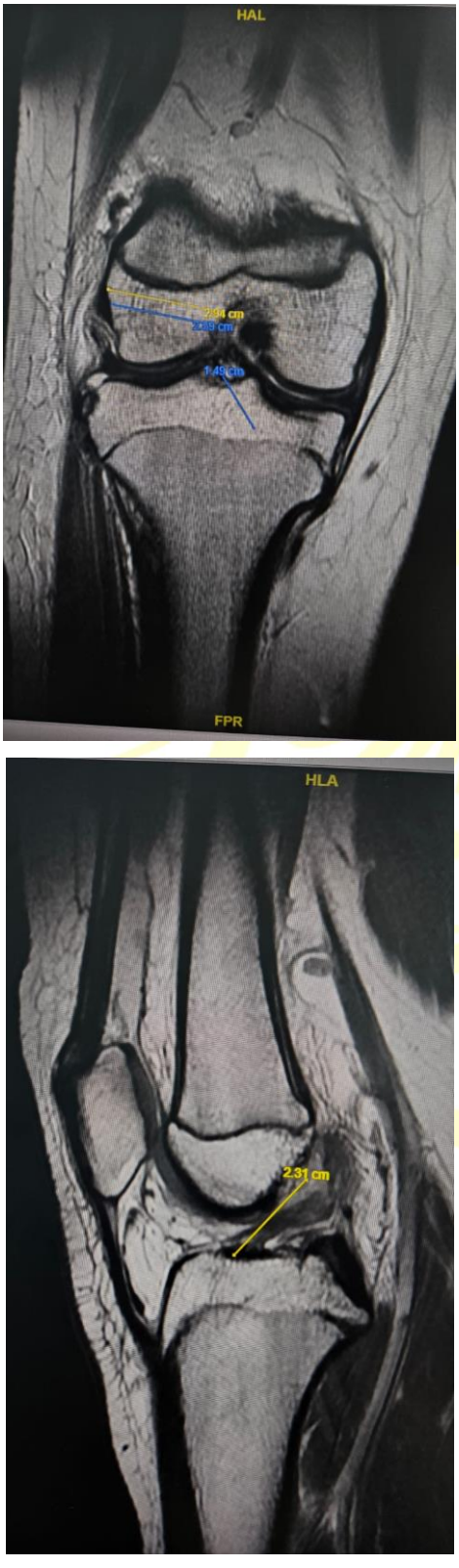

Figure 1. MRI Examination

DISCUSSION

The anterior cruciate ligament (ACL) is one of 4 important ligament connecting the femur to the tibia. Its main functions are to resist internal rotation and shear forces, protect the meniscus during jumping and slowing down, and provide input to the thigh muscles. It also helps in maintaining strong quadriceps muscles. The ACL is typically 32 mm long and 9 mm wide. Although it is an intra-articular structure, it is considered extra-synovial due to surrounding synovial folds. The ACL is supplied by the tibial nerve and blood vessels, but it lacks blood supply and cells. Disruption of the synovial lining prevents the ACL from receiving necessary nutrients and healing processes, making recovery impossible. ACL tears are usually diagnosed clinically using the Lachman and pivot tests. However, MRI is necessary for further analysis and to confirm the diagnosis. According to a study, the sensitivity and specificity of MRI for identifying ACL tears in children are reported to be 95% and 88%, respectively.[13]

Tibial eminence fracture in children are generally more common than ACL tears. However, recent evidence trend suggests that ACL rupture could also occur frequently.[14] Increased sports participation at a young age has led to a higher rate of ACL tears in young patients. However, managing ACL injuries in young patients is still a controversial topic.[15] The Olympic Committee organized an international expert group of physiotherapists and orthopedic specialists from the US and Europe who specialize in treating pediatric ACL injuries. They recommend surgical treatment with ACL autograft reconstruction for acute ACL fracture if it is associated with another injury. Conservative management with high-quality rehabilitation is recommended for those patients without additional wounds as a long-term or short-term choice for delayed ACL reconstruction. It is also noted that children who undergo ACL reconstruction after failed nonsurgical administration may have more meniscal and chondral wounds compared to those who undergo early ACL reconstruction due to repeated instability, especially if the child receives inadequate or no recovery.[16]

A comprehensive study by Vavken et al. examined treatment of ACL tears in patients with juvenile bones. This report summarizes data from 12 articles on conservation treatment and natural history, including a comparison of 6 studies on conservation treatment versus surgical treatment. It includes data on 476 patients. They found that konservative treatment is not effective for individuals suffering from meniscus and cartilage damage, leading to the suggestion that surgery should be considered as the fisrt option for young patients, as it produces better clinical outcomes in terms of stability and prevention of further injuries.[17] Study from Seil and Robert conducted 17 clinical studies on ACL injuries in children and their treatment outcomes. They found that conservative management led to knee instability in 91%, while ACL reconstruction resulted in only 14% patient experiencing instability. A study by Ramski et al. found that children or youth who had non-

surgical or deferred ACL reconstruction were 33,7 times more likely to be clinically unsteady and 12 times more likely to have an average meniscus injury than those who had early surgery.[19]

Current recommendation is against for primary repair for ACL tears in young patient. However, there has been renewed interest in recent times for repairing acute rupture of the ACL. Nevertheless, ACL reconstruction is still the preferred surgical treatment. Unity determination depends on variables and operator inclination. It can be an allograft or autograft. Autografts commonly include bone-patella tendon-bone (BPTB), hamstring, and quadriceps ligament. Allografts are not recommended for younger and more active patients due to a higher rate of ACL rupture. The ultimate tensile load (UTL) of the native ACL is about 2160 N, the quadriceps tendon graft is around 2353 N, the BPTB is about 2977 N, and the quadripled hamstring autograft is the highest at around 4000 N.[20,21] BPTB autograft is preferred for adults wanting to quickly return to sports due to faster bone integration, but it also leads to higher donor site discomfort and increased risk of patellar fracture. In young patients, BPTB autografts are typically avoided due to the risk of physeal compromise.[22]

Various surgical methods are available for ACL reconstruction in pediatric patients. These include physeal sparing techniques (All-epiphyseal and Over-the- top), combined intra-articular/extra-articular using autogenous iliotibial bands (ITB), and traditional transphyseal procedures commonly used in adults. Physeal-sparing ACLR, a combined procedure using autogenous ITB, reduces the risk of physical harm, also growth and developmental issues in young patients. This is achieved by avoiding tunneling and intraosseous fixation.[23] Kocher et al. found great results in 44 young patients (10 years old). The useful scores at the last follow-up were 96,7 ± 6,0 and 95,7 out of 100 on the International Knee Documentation Committee (IKDC) subjective knee assessment and Lysholm Knee Scoring Scale (LKSS),

respectively and the revision rate was low at 4,5%.[24] More research is needed to determine the results and recommendation of this strategy when performed with a stabilization method, including anterolateral ligament reconstruction.

The physeal-sparing strategy by Guzzanti et al. includes a small, centralized and vertical femoral tunnel combined with an offbeat proximal tibial tunnel. The hamstring autograft is connected distally, passed through the tibial and femoral tunnel, and settled to the femur proximal to the physis while the knee is at 30° flexion. Out of the 14 patients, 10 were asymptomatic and active in sports without any significant leg length or point variations from the normal skeletal development level.[32] Another method described by Anderson involves preserving the entire epiphyseal tunnel in the femur and tibia. Femur fixation was done with a washer and EndoButton, while tibia fixation was done with a post and suture distal to the pelvis. No failure found in 12 patients after 4.1 years of follow-up.[25]

Early and appropriate post-op care is crucial for successful recovery. The guidelines prioritize functional activities and stress the importance of education and home exercise programs (HEP). Regular reassessment is essential for ensuring HEP performance and improvements in ROM and quality. If the patient is worried about their ROM stability, clinicians should ensure proper HEP. The use of nonstop movement units at home can prevent arthrofibrosis, also provide bracing instruction to patients and caregivers for joint protection and enabling walking with a flexed knee. The specialist should recommend checking the brace regularly throughout the day to prevent it from loosening and shifting downwards, which may lead to loss of knee extension. Emphasize frequent exercise and cryotherapy.[26]

Consider the age and maturity of the patient for optimal management. Compliance may be a problem in child athletes. Patients and caregivers should be included in the recovery plan to ensure safety, movement adjustment, and proper use of support, as well as compliance with

the HEP. Clinicians should provide personalized care to ensure safety, correct technique with therapeutic exercises, and appropriate number of repetitions and sets. The child-specialist relationship is crucial for building the child's confidence in a rehab program. Specialists should be creative, identify motivators, set clear goals, and gain the patient's trust. The child's age and skeletal development affect the procedure used. Children under 14 have open growth plates that usually close by 17. The physeal-sparing strategy prevents growth plate injury but puts the unite in a nonanatomic position, increasing the risk of Genu recurvatum. A comparative study found more complications in the allepiphyseal group and precise distortion in the over-the-top group, also re-rupture rates were similar between groups. A larger meta-analysis by Wong et al. 45 articles on pediatric ACL reconstruction complications found that the proper surgical technique is more important than the specific reconstructive method to prevent repeated complications. The study found that the physeal-sparing procedure had fewer complications than the transphyseal procedure, but overall, there was no significant difference between the two methods.[26,27]

The all-inside physeal-sparing method using a hamstring tendon autograft is a safe and reliable option for the pediatric and adolescent patient undergoing ACL reconstruction. There is no graft transections, neurovascular injuries, secondary procedures for wound healing and closure, cosmetic concerns, or limitations in return to activity due to the incision.[28] The physeal-sparing strategy prevents postoperative complications associated with other methods and has shown promising results in a few case reports. High-quality restoration is crucial in managing ACL injuries, regardless of whether the child undergoes surgery or chooses non-surgical treatment. This reduces the risk of further damage to the joint after reconstruction. A recent survey found a higher rate of harm in young athletes returning to sports after ACL reconstruction, with a 30 to 40 times greater risk of ACL damage

compared to uninjured youth. Neuromuscular control is crucial, as athletes returning to sports after ACL reconstruction have a greater risk of subsequent ACL harm. The risk of ACL damage is higher in young and active individuals. Effective communication among specialists, physical advisors, and medical attendants is crucial for successful surgery and safe return to sports.[27]

CONCLUSION

Full ACL reconstruction using a physeal-sparing technique in young patients is a safe method that protects the growth plate and avoids the complications. However, further research is needed to determine the long-term effectiveness of this approach in treating ACL injuries in young patients.

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