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Osteochondral Avulsion Fracture of the Anterior Cruciate Ligament Femoral Origin in a 10-Year-Old Child: A Case Report

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Objective: To describe the case of a 10-year-old football player who sustained a comminuted osteochondral avulsion fracture of the femoral origin of the anterior cruciate ligament (ACL) via a low-energy mechanism.

Background: In children, both purely cartilaginous and osteochondral avulsion fractures have been described; most such ACL avulsions are from the tibial eminence. In the few previous case reports describing femoral osteochondral avulsion fractures, high-energy injury mechanisms were typically responsible and resulted in a single fracture fragment.

Differential Diagnosis: Femoral osteochondral avulsion fracture at the ACL origin, femoral cartilaginous avulsion fracture at the ACL origin, midsubstance ACL tear, meniscal tear.

Treatment: Sutures and a button were used to repair the comminuted fragments. Postoperatively, a modified ACL reconstruction rehabilitation program was instituted.

Uniqueness: Most injuries of this nature in youngsters are caused by a high-energy mechanism of injury, result in an osteochondral avulsion fracture of the tibial eminence, and involve a single fracture fragment.

Conclusions: Although they occur infrequently, ACL femoral avulsion fractures in children can result from a low-energy injury mechanism. Identifying the mechanism of injury, performing a thorough physical examination, and obtaining appropriate diagnostic studies will enable the correct treatment to be implemented, with the goal of safely returning the athlete to play.

Key Words: injury mechanisms, knee injuries, pediatric injuries

Avulsion injuries of the anterior cruciate ligament (ACL) in the pediatric population are well recognized in the orthopaedic literature, dating back to the early 20th century. In children, ligamentous structures are stronger than their associated physeal insertion sites, making them prone to avulsion fracture injuries.[1–8] Both purely cartilaginous and osteochondral avulsion fractures have been reported, with the latter occurring more frequently,[9] and most ACL avulsions occur at the tibial eminence.[1,4,5] Of the prior 7 case reports of femoral osteochondral avulsion fractures,[10–14] the majority occurred secondary to high-energy mechanisms, such as skiing or motor vehicle accidents. In addition, a review of the literature revealed all femoral avulsions to involve a single fracture fragment.[9–15]

We present the unique case of a 10-year-old boy who sustained a comminuted osteochondral avulsion fracture of the femoral origin of the ACL via a low-energy athletic injury mechanism.

CASE REPORT

A 10-year, 11-month-old boy sustained an injury to his right knee during a football game in September 2007. Although the patient and family members could not recall the specific mechanism of injury, the patient did recall being tackled by an opposing player while running with the ball down the sideline. His knee gave way, he noted severe pain, and he was unable to continue playing. Despite appropriate icing over the following hours, the parents noted significant swelling of the right knee.

Initial physical examination 3 days later revealed a moderate right knee effusion without ecchymosis or deformity. Tenderness was elicited with palpation of the posterolateral corner and the medial aspect of the knee. Passive range of motion (ROM) was measured as 10° short of full extension to 90° of flexion. The Lachman test was positive with no end point (as compared with a solid end point of the contralateral knee), but pivot shift and McMurray tests could not be performed because of patient guarding.

Magnetic resonance imaging (MRI) of the right knee demonstrated a large lateral femoral condyle contusion with a disruption of the ACL near its femoral origin (Figure 1). A multilevel effusion was noted, consistent with a lipohemarthrosis that suggested bony involvement (Figure 2). To better delineate the bony injury, a computed tomography (CT) scan was obtained (Figure 3), which revealed a comminuted fracture of the posteromedial aspect of the lateral femoral condyle at the proximal ACL attachment within the intercondylar notch. With these findings, surgical fixation of the fracture fragment was planned.

Examination under anesthesia again showed a significant effusion and a positive Lachman test with a grade 1 pivot shift. Diagnostic arthroscopy confirmed a femoral avulsion of the ACL with multiple bone fragments still attached to the femoral portion of the ligament without intrasubstance injury (Figure 4). The patellofemoral joint, medial and lateral compartments, menisci, articular cartilage, and other ligaments appeared intact, healthy, and appropriate for the patient's age.

Figure 1. A, B, On magnetic resonance imaging, sagittal views of the knee reveal a disrupted anterior cruciate ligament; a tear or possibly an avulsion fracture was suspected. A large amount of high-intensity signal fluid is also visible in the suprapatellar pouch. C, Significant marrow edema is seen in the lateral femoral condyle and posterior tibia (note fibula location). Open physes are readily appreciated. A, Proton-dense, fat-suppressed image. B, C, T2-weighted, fast-recovery, fast spin echo, fat-suppressed images.

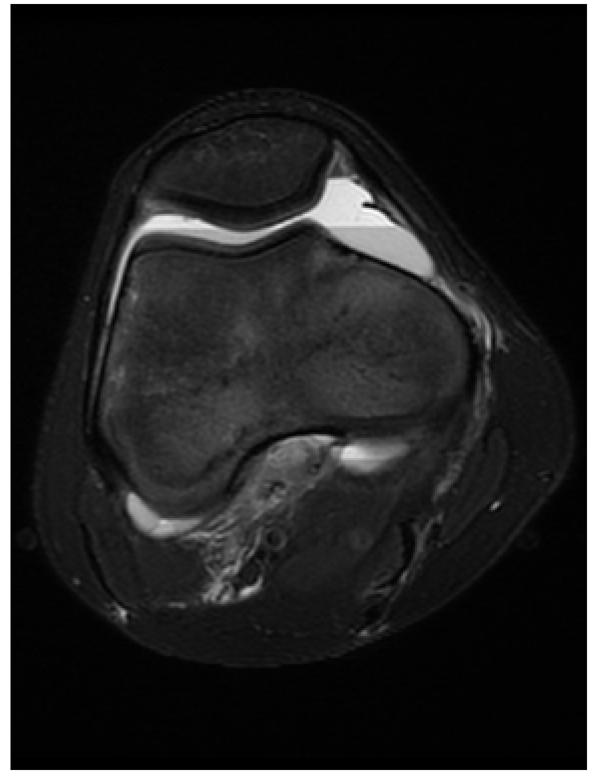

Figure 2. Axial T2-weighted magnetic resonance image demonstrates lipohemarthrosis with 2 fluid-level demarcations and heterogeneous signal intensity within the bone marrow of the distal femur (fast-recovery, fast spin echo, fat-suppressed image).

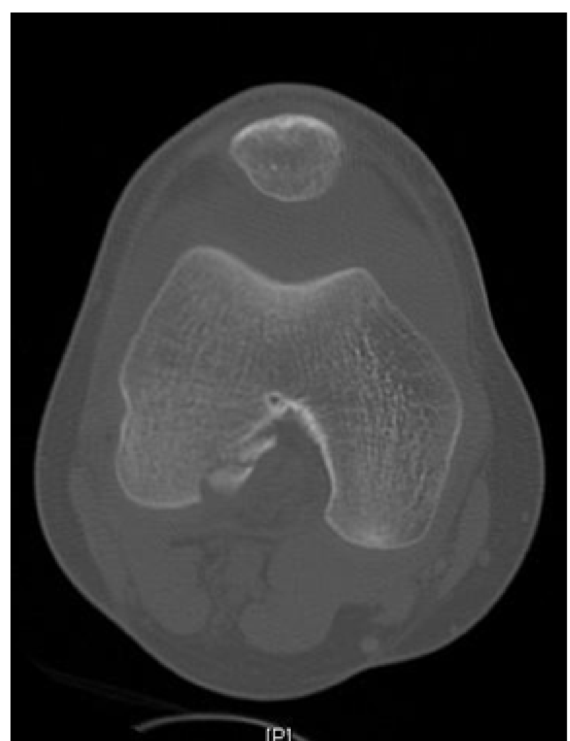

Figure 3. Axial computed tomography image shows comminuted femoral avulsion fracture from the lateral portion of the intercondylar notch. A large knee effusion is forcing the patella away from the femoral groove.

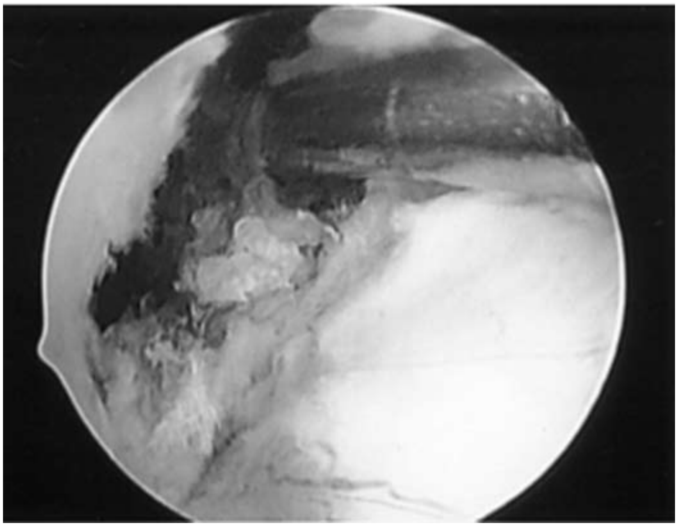

Figure 4. Intraoperative arthroscopy confirms femoral avulsion fracture. The probe is penetrating subchondral bone.

A medial parapatellar arthrotomy was performed. Suture repair was carried out using #2 MaxBraid (Biomet, Inc, Warsaw, IN) rather than screw fixation because of the comminution of the fragments. The sutures were passed through 2 parallel holes angled from the isometric point of the ACL attachment and through the physis, exiting through the lateral metaphysis of the distal femur. The sutures were tied over a button. Intraoperatively, the Lachman test was negative, confirming appropriate fixation of the native ligament.

Postoperatively, a slightly modified ACL reconstruction rehabilitation program commenced. Initially, a knee immobilizer was applied in full extension with the foot flat; weight bearing was permitted with crutches for 6 weeks while bony union progressed. The patient was then transitioned to a hinged knee brace, advanced to full weight bearing as tolerated, and started on a formal rehabilitation regimen. Both active and passive ROM was encouraged via heel and wall slides, active-assisted flexion, patellofemoral joint mobilization, and cycling on a stationary bicycle. Strengthening progressed with isometric to isotonic to partial and then to full ROM isokinetic exercises and, finally, to sport-specific strength training activities. He began using a double-upright brace at 4 months, when fracture consolidation was noted on radiographs, and eventually a functional knee brace (worn only with strenuous activities) at 1 year postoperatively. At 24 months after surgery, he had no pain, instability, or activity limitation. He had resumed participation in all desired athletic events, including baseball, basketball, and football. Physical examination demonstrated full and symmetric ROM, normal Lachman and pivot shift tests, and symmetric stability to varus and valgus stresses. Knee radiographs were normal, without any signs of epiphyseal irregularity (Figure 5).

DISCUSSION

Most ACL injuries in the pediatric population result from osteochondral avulsion fractures of the tibial eminence.[1,4,5] Recent reports[16–18] suggested that midsubstance tears in youths are not uncommon and are increasingly likely as the child ages from preadolescence to adolescence. Although osteochondral avulsions from the femoral attachment site of the ACL are uncommon, clinicians must be aware of these injuries in order to recognize them quickly and begin immediate appropriate treatment. Anterior cruciate ligament osteochondral avulsion fracture treatment focuses on bony union rather than a reconstructed ligament, so prompt diagnosis and management are essential because a delay could lead to malunion. Additionally, failing to diagnose the ACL-deficient knee will undoubtedly lead to knee instability and, as noted by Millett et al,[19] increase the incidence of associated knee injuries (eg, medial meniscus tears).

A review of the literature reveals 2 cases of cartilaginous[9,15] and 5 osteochondral[10–14] avulsion fractures from the femoral origin of the ACL. As did our patient, the 7 previously documented patients underwent operative intervention for the avulsions. All 5 osteochondral avulsions resulted from high-energy mechanisms, including snow skiing (both children were 11 years old),[11,13] falling from motorized moving vehicles (patients were 12 and 13 years old),[12,14] and falling from the monkey bars while getting a leg caught in the rungs (7-year-old child).[10] Although our patient's injury resulted from what Rice[20] identified as a lower-energy mechanism (ie, prepubertal athletics), it yielded a similar result. Treatment for injuries resulting from the 2 mechanism types is similar, and medical personnel caring for pediatric athletes should be aware that even low-energy mechanisms can result in an ACL-deficient knee.

Early biomechanical studies of the ACL's function revealed the ligament to be taut from full extension to 20° of flexion and again from 70° to 90° of flexion, with a period of relaxation occurring between 40° and 50°. Additionally, increased ACL tension was found throughout the knee arc of motion with tibial internal rotation.[21] Boden et al[22] noted that most ACL injuries occurred at footstrike with the knee close to full extension. Subgroup analysis showed that noncontact mechanisms consisted primarily of sudden decelerations with a landing motion or a planned change of direction, whereas contact mechanisms typically consisted of a valgus collapse of the knee.[22] Multiple authors[23,24] have shown that the ACL's role in anterior tibial translation resistance during deep knee flexion is aided by other surrounding soft tissues (eg, medial collateral ligament), but the common perception is that it acts in near isolation for such resistance near full extension. Even though our patient did not recall the exact mechanism of injury, this biomechanical understanding may help us reconstruct the probable mechanism. Upon tackling our patient, whose injured foot may have been planted, his opponent probably created an internal tibial rotation or valgus force (or both) while the patient's knee was near full extension, causing enough tension to tear most ACLs. However, because the patient was skeletally immature, his ACL was stronger than its associated physeal insertion site, making him prone to an avulsion fracture.

The role of MRI in ACL avulsion fractures has not been studied well to date.[25] Secondary signs of an avulsion fracture, such as a complex hemarthrosis (eg, hemarthrosis or lipohemarthrosis) (Figure 2) can aid in the diagnosis. Stanitski et al[17] demonstrated that hemarthroses were associated with ACL tears 63% of the time. Moreover, Prince et al[26] showed that complex effusions seen on MRI correlated highly with avulsion fractures (66% of hemarthroses and 100% of lipohemarthroses). Other modalities for identifying ACL avulsion fractures, such as CT, have shown promising results. Griffith et al[27] retrospectively evaluated ACL tibial avulsion fractures and showed that only 48% were visible (ie, fracture margins fully delineated) on radiographs, whereas 100% were visible on CT.

Figure 5. Two-year postoperative follow-up radiographs. A, Anteroposterior, B, lateral, and C, notch views of the injured knee show well-healed anterior cruciate ligament femoral avulsion fracture, with appropriate trabecular remodeling and excellent alignment of the femur on the tibia in both planes.

Additionally, fragment orientation was better distinguished on CT, including an inverted fracture fragment initially thought to be a tibial avulsion fracture. Although an MRI is an appropriate diagnostic test for most ACL injuries, CT proved to be a key preoperative planning tool for our patient, affecting the specific method of fixation.

Postoperative rehabilitation is integral to the overall success of ACL reconstructive surgery. Stanitski[28] noted that rehabilitating the entire lower extremity using isometric, isotonic, and isokinetic exercises contributed to rapid improvement, and modifying the devices or equipment may be necessary for children, given their size (eg, too small for certain machines) or understanding (eg, unable to comprehend proper equipment use). The literature is scarce for rehabilitation regimens after ACL osteochondral avulsion fracture. Our postoperative rehabilitation protocol mimicked that for a bone–patellar tendon–bone ACL reconstruction regimen because both procedures require bony union before significant stress can be placed on the attachment site. The one difference resides in the fixation construct; rather than being able to augment the ACL reconstruction in a bone–patellar tendon–bone graft with another device (eg, interference screw), we had to rely on physiologic healing, which has a time-dependent rate-limiting step. Therefore, we adjusted our patient's postoperative course by immobilizing the knee in full extension for 6 weeks, until bridging callus was identified radiographically.

Criteria for full weight bearing without crutches started with satisfactory pain management and freedom from patellofemoral pain but included quadriceps muscle control, quadriceps and hamstrings cocontractions, and the ability to perform a straightleg raise with an extension lag of less than 2°. Return to full activity has usually been restricted until full ROM was achieved, with restoration of quadriceps-hamstrings strength ratios on concentric and eccentric isokinetic testing and performance of sport-specific tasks at full speed.[28] Our criteria required subjective freedom from pain, stiffness, and giving way with activities of daily living, rehabilitation activities, and sport-specific agility drills. Objectively, the patient had to demonstrate full active and passive ROM and no quadriceps extension lag. Comparison testing of the contralateral lower extremity using isokinetic dynamometer, KT 1000 (Medmetric Corporation, San Diego, CA), and functional sport-specific testing must be within 90% of that in the healthy extremity.

Although ACL avulsion fractures of the femoral attachment are rare in the pediatric population, particularly during low-energy sports such as football, prompt diagnosis is essential. Identifying a relevant mechanism of injury, examination findings consistent with a knee effusion and a positive Lachman test, and obtaining appropriate diagnostic studies will expedite suitable treatment. When surgical fracture fixation is accomplished, the postoperative rehabilitation regimen provides the ideal environment for reconditioning with the goal of eventual unhindered return to play.

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