Intrinsic Healing of the Anterior Cruciate Ligament in an Adolescent

Deren Bagsby, MD, George Gantsoudes, MD, and Robert Klitzman, MD

Abstract

The anterior cruciate ligament (ACL) is an important ligamentous stabilizer of the knee. The natural primary healing potential of the ACL has been shown to be extremely poor.

We report the case of a 12-year-old boy who was involved in a motor vehicle collision and sustained a grade IIIB open tibial fracture, distal fibula fracture, medial and lateral meniscus tears, avulsion fracture of the femoral metaphysis, and anterior and posterior cruciate ligament tears. Because of delayed union of his tibia fracture, treatment of the ligamentous injuries was postponed to 16 months after initial injury. However, magnetic resonance imaging at that time showed complete healing. At 20 months, the patient returned to competitive hockey. Based on this case, we believe there is some natural primary healing potential within the ACL.

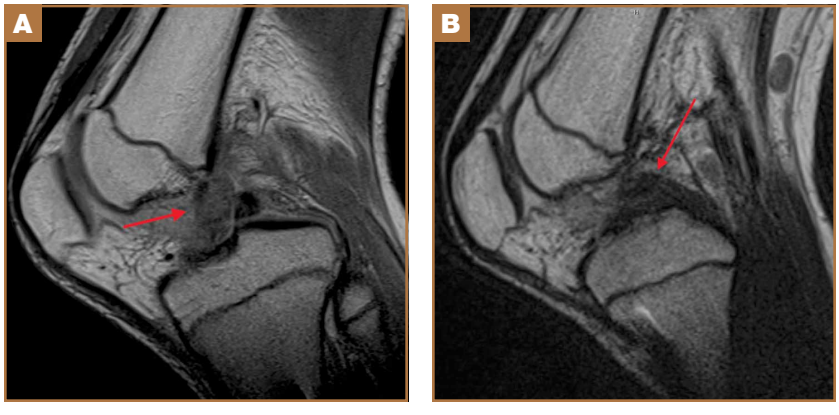
The anterior cruciate ligament (ACL) restrains anterior translation of the tibia on the femur and controls rotation of the knee. The natural primary healing potential of the ACL has been extremely poor in clinical and experimental studies, and primary suture repair has not provided stability to the joint in most patients.[1-8] This has led surgeons to reconstruct the ACL, rather than to attempt nonoperative treatment. Anterior cruciate ligament reconstruction is recommended to help patients maintain activities that place shear and torque forces on the knee or to ameliorate persistent pain due to instability.[9] Reconstruction of the ACL in adults is one of the most common procedures performed by orthopedic surgeons. However, reconstruction in the ACL-deficient adolescent remains a controversial subject, with debates surrounding operative timing and surgical technique.

This case report presents a skeletally immature patient who suffered a complete traumatic rupture of his ACL, which intrinsically healed. The patient had a protracted treatment course, complicated by an open tibial fracture with delayed union. He responded to a progressive rehabilitation program and has made a good functional recovery. Review of the literature has demonstrated limited evidence of intrinsic ACL healing, none of which has been shown to occur in a skeletally immature patient. The patient's mother provided written informed consent for print and electronic publication of this case report.

Case Report

A 12-year-old boy was brought to our level I trauma center by ambulance after being hit by a car while riding a motorized scooter. He presented with a grade IIIB open tibial fracture and a distal fibula fracture of his left lower extremity and was taken to the operating room that night for irrigation and débridement, percutaneous fixation of the fibula, and intramedullary flexible nail fixation of the tibia. On postoperative day 1, he had increasing pain and, once his splint was removed, his compartments were found to be very tense. He was taken emergently to the operating room for 4 compartment fasciotomies of the left lower extremity with wound vacuum-assisted closure (VAC) placement. This was changed on hospital day 4 and was removed with definitive closure on day 7. Examina-

Figure 1. Sagittal T1-weighted magnetic resonance imaging showing complete rupture of the (A) anterior cruciate ligament (arrow) and (B) posterior cruciate ligament (arrow).



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tion under anesthesia prior to the final wound VAC change was performed given the patient's complaints during physical therapy. This showed anterior and posterior ligamentous instability of the knee, and he was placed in a knee immobilizer. He was discharged on hospital day 11.

At 2-week follow-up, the patient was doing well, except that he was nonadherent with the knee immobilizer and unable to fully extend his left knee. On examination, a posterior drawer sign was noted; therefore, the patient was referred for magnetic resonance imaging (MRI) to evaluate his ligaments. His MRI, 9 weeks after injury, showed: (1) complete tears of both the anterior and posterior cruciate ligaments (PCLs) (**Figures 1A, 1B**); (2) medial meniscus and lateral meniscus tears; (3) 2.0-cm plate-like avulsion fracture of the posterolateral femoral metaphysis involving the insertion of the lateral head of the gastrocnemius muscle, fibular collateral ligament, and popliteus muscle (**Figure 2**); and (4) left posterior lateral tibial plateau contusion.

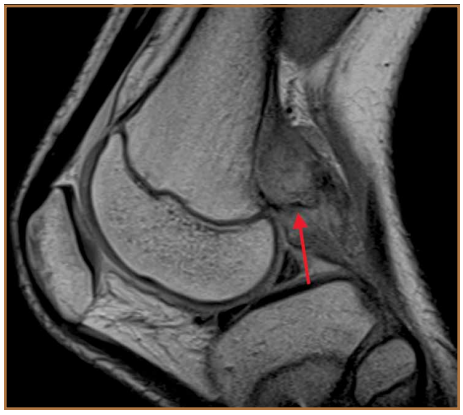

Figure 2. Sagittal T1-weighted magnetic resonance imaging showing plate-like avulsion fracture (arrow) of the posterolateral femoral metaphysis.

The patient was started on a 6-week course of physical therapy with active and active-assisted extension exercises. At follow-up approximately 3½ months after injury, he was found to have a 35° flexion contracture with pain at the end extension. Unfortunately, his tibial fracture showed minimal signs of healing, and the decision was made to delay surgical intervention on the knee until the tibial fracture had healed. He was given a knee orthotic to wear at night to help regain his knee extension.

Six months after injury, the patient underwent open removal of the avulsed bony fragment, posterior knee capsule release, and autograft of the delayed union tibial fracture. He was placed in a straight leg cast postoperatively and was discharged home on postoperative day 2. He transitioned to a knee immobilizer after 2 weeks. Six weeks after the last surgery, he had range of motion of 0° to 130°. Ligamentous examination at this time showed anterior and posterior drawer signs, positive Lachman test, and dial test with 90° of external rotation. He was placed in physical therapy for a total of 10 weeks to work on his quadriceps muscle strength and 15° extension lag.

On 13-month postinjury radiographs, the patient was noted to have adequate healing of his tibial fracture, and ligamentous reconstruction was discussed. At this time, the patient did not have any instability or pain in the knee. Examination demonstrated a very mild effusion of the left knee. Range of motion determined by goniometer was from -3° to 140°, and Lachman test was positive but with solid 2+ endpoint. He also had a positive posterior drawer sign with no endpoint, positive sag sign of his tibia, and positive active quadriceps test of the left leg. His dial test showed some increased external rotation at 90° but was equivocal at 30° when compared with the contralateral knee, demonstrating involvement of the posterolateral corner.

Sixteen months after injury, repeat MRI to further evaluate the posterolateral corner showed: (1) complete medial and lateral meniscal healing without evidence of residual or recurrent tear, and (2) interval healing of the remote ACL and PCL tears with intact insertions (**Figures 3A, 3B**). This scan showed an end-to-end continuous ACL with homogeneous signal and disappearance of the secondary signs. Physical examination at this time showed a very firm endpoint on Lachman test but some laxity with his posterior drawer. Given these findings, the patient was given a brace and continued in physical therapy to strengthen his quadriceps muscle. By 20 months after injury, he had returned to competitive hockey and had no complaints of pain or instability. His physical examination showed full range of motion in a ligamentously stable knee with firm endpoint. The patient's condition was unchanged at 29-month follow-up.

Discussion

There is a body of evidence that states a completely ruptured ACL does not heal.[3,6,10] In animal models, the ACL has been shown to have poor healing potential.[3,11] Some studies have

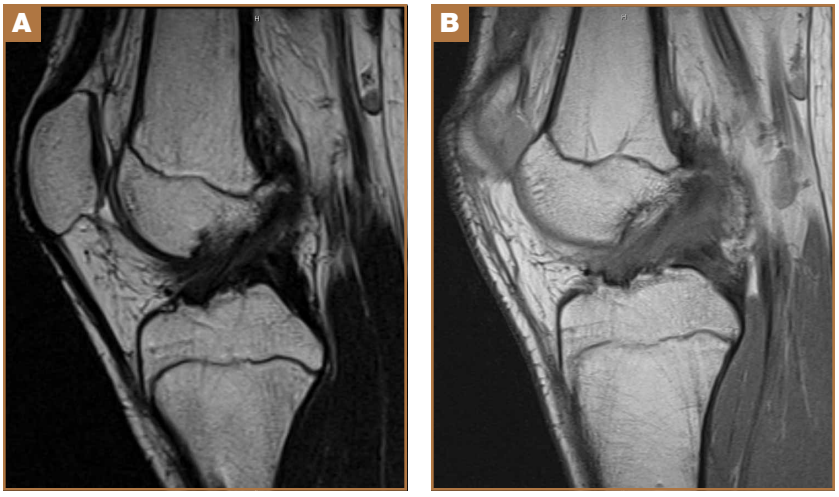

Figure 3. Sagittal T1-weighted magnetic resonance imaging showing (A) interval healing of the previous anterior cruciate ligament tear with (B) intact insertions.

suggested this is secondary to poor blood supply. Blood supply to the ACL is derived from a periligamentous, then endoligamentous, arterial network with a less vascularized area in the middle third of the ACL. Additionally, there is no blood supply from the tibia or femur, meaning the areas of attachment of the ligament are poorly vascularized.[12] With a minimal blood supply to the ACL, the supply of undifferentiated mesenchymal cells from the surrounding tissue during the initial healing process is limited. In vitro cell cultures of these cells have showed a reduced potential for proliferation and migration.[9] Cells of the ACL have a lower response to growth factors than human medial collateral ligament cells, further suggesting a decreased reparative capacity.[7] Joint fluid has been shown to inhibit the proliferation of these cells, further reducing their regenerative potential.[13] Additionally, biomechanical factors that alter signaling pathways, sites of ligament reattachment, and injury to proprioceptive structures have been shown to negatively influence the healing response.[14-18]

Review of the literature on healing of ACLs includes 2 case reports, totaling 3 patients, and 3 level IV therapeutic studies involving 74 patients total.[10,19-22] In most cases, the authors of these studies have indicated a nonoperative treatment protocol with bracing and a specific rehabilitation program. Malanga and colleagues[10] demonstrated that an ACL torn from its attachment on the femur, with the majority of the ligament in good condition and no compromise in the length, healed back onto the femur. Kurosaka and coauthors[20] described case reports of isolated distal or proximal midsubstance tears that have healed spontaneously. However, none of the patients described in the literature were under the age of 20 years.

Treatment for pediatric patients with open physes causes some debate. Nonoperative management of ACL deficiency in adolescents is generally not recommended because the continued instability of the joint leads to intra-articular injury, functional impairment, and joint degeneration.[23-25] A recent systematic review found only 1 study that showed no increase in secondary intra-articular injury when surgery was delayed until skeletal maturity.[26]

Our patient was a 12-year-old boy whose traumatic knee injury with multiple ruptured ligaments healed over the course of 20 months. It is likely that bracing associated with the patient's second surgery and delayed union of his tibial fracture allowed healing tissue to be protected from excessive stress until it remodeled with sufficient strength. Most would assume that healing would occur early, during the first 6 to 9 months; however, our patient regained his stability between 8 and 13 months. It is possible that the hostile healing environment of the ACL, including the low blood supply, poor response to growth factors, and biomechanical environment, as described previously, played a factor in this delay.[7,9,12,13]

It is important to recognize that our patient tore his ACL during a traumatic motorized scooter rollover collision, not the more common noncontact twisting injury. Additionally, given the patient's knee surgery that was performed 6 months after the initial injury, it is possible that intra-articular scar formation contributed to his healing capacity. While this patient did not undergo arthroscopy to visualize the tear in the ACL, or its reconstitution, recent evidence suggests that the accuracy of MRI in diagnosing pediatric ACL injuries is excellent.[27,28] The diagnostic accuracy with new MRI machines has sensitivity and specificity approaching 100%.[29] Additionally, the patient's subjective and objective improvements argue for a change in anatomy over a change in the quality of his examination.

Conclusion

The goal of ACL reconstruction in adolescents is to provide long-term stability to the knee while minimizing the risk of growth disturbance. This goal was achieved in our patient through the in situ healing of his ACL. Intrinsic reconstitution of a torn ACL is rare, and it is difficult to speculate which patients may have some healing potential. While this patient was an extreme example, his case demonstrated that protection of the knee from undue stress could favorably alter the environment of the knee to allow for healing of ACL tears. Such information could be valuable in managing select pediatric patients with open physes and ACL injuries nonoperatively, sparing them from the risks associated with surgical treatment. While we do not recommend nonoperative treatment for patients with acute tears of the ACL, we believe more investigation into the healing potential of the ACL, and potential pathways to augment this, is warranted.

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