25 Anterior Cruciate Ligament—Tibial Avulsion

Elizabeth C. Truelove, Conor I. Murphy, Jeremy M. Burnham, Jan S. Grudziak, Volker Musahl, Joshua Pratt, and Rory McHardy

25.1 Description

Tibial spine or eminence avulsions, primarily a pediatric orthopaedic injury, are synonymous with anterior cruciate ligament (ACL) injuries. The attachment site of the ACL to the tibia is larger and more secure than its femoral site, making tibial-sided avulsions a rare subtype of ACL injury. While plain radiographs are often normal in ACL injuries without a second fracture, tibial avulsion injuries can be apparent on plain films with the presence of a tibial eminence fracture. These injuries often occur in children with incomplete ossification of the tibial spine predisposing to it avulsion fracture rather than ACL failure. High-energy trauma with hyperextension, valgus, and external rotation forces less commonly result in these injuries in adults. Tibial avulsions have traditionally been classified according to the system described by Meyers and McKeever, with surgical intervention indicated for any amount of fracture displacement (Types II, III, and IV).

25.2 Key Principles

As with nearly all orthopaedic injuries, the key principles in treating tibial avulsion ACL injuries are patient history, physical examination, appropriate imaging, preoperative planning, and intraoperative preparedness. Thorough understanding of the anatomy is vital. Two prominences exist within the tibial eminence: the medial and lateral elevations. The ACL inserts onto the tibia at the medial elevation. The medial and lateral menisci also insert anteriorly at the tibial eminence, which may complicate repair of tibial eminence avulsions due to interposition at the fracture site. Special attention must be paid to the width, location, and status of the physis on radiographic analysis (Fig. 25.1) as this will inevitably affect treatment and fixation.

A thorough physical exam must be performed to evaluate for any concomitant injuries. Examination in combination with review of appropriate radiographs guides indications for advanced imaging. Direct trauma is typically the cause of tibial avulsion injuries, whereas ACL tears are usually secondary to noncontact trauma. Computed tomography identifies concomitant bony injuries such as a tibial plateau fracture or tibial tuberosity injury, while magnetic resonance imaging (MRI) is required to evaluate associated soft tissue anatomy (Fig. 25.2). Both imaging modalities may help to clarify the precise features of the injury as some avulsions have a substantial bony component while others are primarily cartilaginous. When there is no concern for other osseous injuries, MRI can generally provide adequate characterization of the injury while avoiding excessive radiation exposure in children.

Surgical treatment primarily incorporates either suture or screw fixation of the avulsion. Occasionally, temporary percutaneous Kirschner wires are utilized, although this is not the preferred fixation method as they lack long-term stability and must be later removed. The anatomical components of the avulsion will help dictate fixation methodology. Cartilaginous avulsions are more amenable to suture fixation, whereas larger bony avulsions will tolerate screw fixation. When operative management is appropriate, the treatment algorithm must include consideration of the patient’s skeletal maturity and remaining skeletal growth through the proximal tibia physis. Anatomic reduction is best achieved under direct visualization and often requires retracting the medial meniscus, which can be torn or entrapped in the fracture.

25.3 Expectations

Establishing realistic expectations with the patient based on the severity of injury, need for surgical intervention, and his or her preoperative level of activity or competition is necessary. Traditionally, patients have good functional outcomes regardless of operative technique. Loss of motion, specifically loss of extension, is the most common complication. This stiffness can be further exacerbated by arthrofibrosis, which is more common after surgical intervention compared with nonoperative treatment. The patient must understand that manipulation under anesthesia

![Fig. 25.1 Preoperative anteroposterior (AP) and lateral radiographs of the right knee of Patient A showing a displaced tibial eminence avulsion injury.](image1)

![Fig. 25.2 Preoperative T1 coronal and turbo spin echo (TSE) sagittal magnetic resonance imaging (MRI) cuts of the right knee of Patient A showing an intact anterior cruciate ligament (ACL) and avulsion of the entire tibial eminence.](image2)
may be required if postoperative mobility is not regained or postoperative rehabilitation protocols are not followed.

In the pediatric population with ACL tibial avulsion injuries, the physeal may be disrupted during surgery. This can potentially lead to growth arrest of the proximal tibia resulting in leg length discrepancy, and although uncommon, it must be discussed with the patient and parent or guardian. Lastly, resultant ACL laxity may persist despite surgical treatment. Postoperative laxity is not always a direct outcome of surgical intervention. More often, the etiology is secondary to nonrecoverable strain and plastic deformation of the ACL at the time of injury secondary to a high amount of tension prior to failure of the tibial eminence. This laxity is often subclinical and has limited impact on functional outcomes, but at times, it may require that the patient undergoes delayed ACL reconstruction.

25.4 Indications

The most common classification system for these fractures was described by Meyers and McKeever in 1959. Type I injuries are nondisplaced or minimally displaced and best treated in a cast or splint with the knee in extension or slight flexion. Type II avulsions are those with superior displacement of the anterior aspect of the fracture with an intact posterior hinge, whereas type III injuries have complete detachment of the fragment. These are further divided into type IIa injuries, those in which only the ACL insertion is involved, and type IIb injuries, with avulsion of the entire tibial eminence. Some also describe type IV lesions with fracture comminution.

Surgical treatment is indicated in all displaced fractures. This includes irreducible Type II injuries and all Type III and IV avulsions. Traditional management of Type II tibial avulsion injuries, or those hinged open anteriorly, includes an attempt at closed reduction by fully extending the knee. However, this is often unsuccessful in practice, as hyperextension of the knee will mechanically tension the ACL with a resultant net force potentially distracting the fracture.

25.5 Contraindications

Surgical management is not indicated for nondisplaced avulsion fractures. In addition, if the patient sustains a high-grade injury to the ACL itself, surgical fixation of the avulsion fracture is generally not adequate.

25.6 Special Considerations

The surgeon must prepare for both open and arthroscopic management of this injury. Although arthroscopic management should be attempted first and is the current standard surgical intervention, some injuries may not be amenable to an isolated arthroscopic approach, thus requiring greater surgical exposure through an open approach. Open surgical management can lead to issues such as soft tissue damage and a delay in rehabilitation due to appropriate time allotment for surgical incision healing. Arthroscopic treatment allows for direct visualization,atomic intra-articular reduction, and the ability to address any other concomitant soft tissue injuries with minimal dissection.

Instrumentation for both suture fixation and screw fixation should be available in the operating room. In the pediatric population, it is often difficult to accurately assess the full extent of bony injury due to varying stages of ossification of the involved structures. Preoperative planning for the approach and fixation method may consequently be revised intraoperatively as initial imaging and physical exam are limited diagnostically compared to direct visualization of the injury in the operating room.

25.7 Special Instructions, Position, and Anesthesia

Supine patient positioning with the hip and knee flexed on a flat, radiolucent table is preferred. Conversion to open technique, should the need arise, is more easily performed with the patient supine as opposed to positioning the leg in a circumferential leg holder past the break in the table with the distal end dropped down. Furthermore, fluoroscopic examination of the knee after screw fixation is more feasible with supine positioning on a radiolucent table. Lastly, if the surgeon prefers postoperative immobilization with cylindrical casting, this is again logistically simplified with supine positioning.

The surrounding intra-articular soft tissues must be assessed arthroscopically prior to reduction and fixation. Often, the anterior horn of the medial meniscus or the intermeniscal ligament is interposed in the fracture site in displaced fractures and acts as a block to reduction (Fig. 25.3). Final fixation and tightening prior to mobilization of the entrapped medial meniscus may result in further damage to the meniscus.

Meticulous anatomic reduction and initial fixation are paramount. The avulsed tibial fragment can be diminutive, preventing multiple attempts at fixation and purchase as one could potentially cause further comminution. Bailout options are limited in the setting of a severely comminuted avulsed fragment.

Fig. 25.3 Arthroscopic view through the anterolateral portal of Patient B showing medial meniscus entrapment within the tibial eminence avulsion fracture bed.
25.8 Tips, Pearls, and Lessons Learned
The typical pathogenesis of tibial avulsion injuries is traumatic, and patients will likely be in pain secondary to an acute hemarthrosis. Definitive management can often be delayed until 7 to 14 days after an injury, as immediate operative intervention before this window can be complicated by diminished visualization due to the hemarthrosis. Furthermore, allowing the acute inflammatory phase of this injury to resolve can decrease extravasation of arthroscopy fluid into the bone intraoperatively. During this waiting period, advanced imaging studies can be obtained while swelling and inflammation subsides.

Tensioning of the ACL and fixation can be difficult. During final tensioning, a posteriorly directed force on the tibia should be applied in order to shorten the distance between the ACL origin and its insertion on the tibial eminence. Over-reduction or countersinking the avulsed fragment within the fracture bed can help offset postoperative ligamentous laxity caused by plastic deformation of the ACL, as well. Nonreversible strain of the ACL prior to tibial eminence failure and avulsion is thought to be the cause of residual laxity after anatomic reduction and fixation. By countersinking the avulsed fragment within the fracture bed, adequate tensioning of the repaired ACL will limit postoperative laxity without overconstraining the joint.

25.9 Difficulties Encountered
If operative intervention is attempted arthroscopically, it can often prove challenging to achieve the appropriate trajectory for screw insertion. It is thus imperative that preoperative planning include deliberate portal placement and potentially the use of accessory portals to achieve adequate fixation.

When management is attempted through an open technique, the exposure must allow for direct visualization of all necessary structures. This can be difficult if the patient has preexisting patella baja or has had any prior surgeries that could lead to anterior scar tissue.

Finally, with either arthroscopic or open fixation, the surgeon has to be cognizant of any lateral meniscus involvement in addition to the medial meniscus and specifically address the anterior root of the lateral meniscus if it is an aspect of the injury complex.

25.10 Key Procedural Steps
25.10.1 Arthroscopic Technique
Standard arthroscopic portals for ACL reconstruction are used for tibial avulsion injuries. Typically, the anterolateral portal is used for visualization and diagnostic arthroscopy, the superomedial portal for outflow as needed, and the anteromedial portal for instrumentation and fixation.

The origin of the avulsion fracture should be debrided thoroughly down to a healthy subchondral base. All interposed tissues must be reduced from the fracture base and repaired as needed.

25.10.2 Open Reduction Internal Fixation
A medial parapatellar approach is the preferred open approach to tibial avulsion injuries. A midline or medial parapatellar skin incision will generally provide adequate access. Dissection is carried through the subcutaneous tissues and fat down to the retinaculum and medial border of the patella while leaving an adequate cuff of tissue to assist in repair upon closure. The patella and patellar tendon are then retracted laterally to allow access to the intercondylar notch, ACL, and tibial avulsion.

At this point, the avulsion base can be debrided and concomitant injuries addressed. After fixation, copious irrigation is necessary to flush all remaining intra-articular fragments and debris from the surgical site.

25.10.3 Suture Fixation
Suture fixation begins with a small incision just medial to the tibial tuberosity in order to properly seat the tibial drill guide. Suture fixation is achieved through two parallel transphyseal drill holes, one at the medial border and one at the lateral border of the tibial eminence avulsion. A tibial drill guide will orient the proper trajectory of the parallel drill holes, beginning just medial to the tibial tuberosity. The drill holes should be drilled with the oscillating function to avoid extensive damage to the physis. A suture is passed in an arthroscopic portal and through the base of the ACL as close to the tibial avulsion fragment as possible (Fig. 25.4). A suture passer is then inserted through each drill tunnel to pass the individual ends of the now secured tibial avulsion.

At the time of fixation, it is essential to confirm that the medial meniscus, lateral meniscus, or intermeniscal ligament is not entrapped in the fracture site blocking reduction. After confirmation, the ends of the suture are tied over a bony bridge at the tibial tuberosity to secure fixation.

Fig. 25.4 Arthroscopic view through the anterolateral portal of Patient C showing suture fixation from medial to lateral around the base of the anterior cruciate ligament (ACL) at the site of the tibial eminence avulsion.
25.10.4 Screw Fixation
Screw fixation is achieved over a guide pin directed through the base of the fragment into the epiphysis under fluoroscopic guidance (Fig. 25.5). The trajectory is from anterior to posterior and superior to inferior. Special care must be taken not to disrupt the physis or protrude through the posterior cortex of the tibia into the nearby neurovascular structures adjacent to the posterior cortex. A second guide pin may be utilized to maintain reduction if the fragment has sufficient bone stock for fixation.

Either a 3.5-mm, 4.0-mm, or 4.5-mm cannulated screw is passed over the guide pin. Final tightening of the screw must be confirmed on fluoroscopic examination to ensure proper trajectory and length. A second screw can be placed over the additional guide pin if possible.

25.10.5 Hybrid Fixation
Hybrid fixation combines both suture and screw fixation techniques (Fig. 25.6). Initially, the fracture is reduced and secured with suture fixation as described above. After tying the suture ends for final fixation, a 3.5-mm, 4.0-mm, or 4.5-mm cannulated screw is placed through the anterior base of the tibial eminence over a guide pin as described above.

Tibial avulsion injuries are generally seen in the pediatric population, and surgical management is required for any fracture displacement. Both arthroscopic and open techniques are utilized to reduce and fix the fracture with sutures, screws, or a combination. It is important to identify any associated soft tissue injuries both preoperatively with advanced imaging as indicated and intraoperatively with visualization and address these injuries as appropriate. Possible complications postoperatively include stiffness and ACL laxity, but the majority of patients have good functional outcomes.

25.11 Bailout, Rescue, Salvage Procedures
If adequate fixation of a tibial avulsion injury cannot be achieved or if fixation fails postoperatively, ACL reconstruction with either autograft or allograft is the recommended salvage procedure. Again, it is important to consider the age and skeletal maturity of the patient when planning for reconstruction, and any existing hardware in the tibia must be taken into account regarding bone tunnel placement.

25.12 Pitfalls
An inability to adequately reduce the fracture fragment can lead to difficulties intraoperatively and complications postoperatively. This is sometimes due to a failure to remove any entrapped anterior medial meniscus from the fracture site, reinforcing the importance of direct visualization and anatomic reduction. High-grade injury to the ACL itself would likely require a different surgical strategy than tibial avulsion fixation with suture or a screw. A missed intrasubstance injury to the ACL could lead to a worse functional outcome. Finally, one must take care to avoid iatrogenic injury to the cartilage, especially as most patients are pediatric. The articular surface of the patella can easily be damaged during screw insertion; thus, portal placement and the use of accessory portals as needed to obtain a safe trajectory must be emphasized.