# Imaging Findings of Complications After Lateral Extra-Articular Tenodesis of the Knee: A Current Concepts Review

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**Background:** Despite successful anterior cruciate ligament (ACL) reconstruction, many patients continue to experience persistent anterolateral rotatory instability. Lateral extra-articular tenodesis (LET) is used to address this instability by harvesting a portion of the iliotibial band, passing it underneath the fibular collateral ligament, and attaching it just proximal and posterior to the lateral femoral epicondyle. Based on the most recent clinical evidence, the addition of LET to ACL reconstruction improves clinical outcomes, which has led to an increase in the use of this technique.

**Purpose:** To provide an overview of the postoperative complications of the LET procedure and their associated imaging findings, with a focus on magnetic resonance imaging (MRI).

**Study Design:** Narrative review.

**Methods:** In this scoping review, the authors reviewed available radiographic, computed tomography, and MRI scans of patients who experienced postoperative complications after ACL reconstruction with LET, in which the complication was determined to be from the LET procedure. Images were reviewed and subsequently described by an on-staff musculoskeletal radiologist.

**Results:** The authors found 9 different complications associated with LET: graft failure, hematoma, infection, chronic pain, tunnel convergence, fixation device migration, muscular hernia, peroneal nerve palsy, and knee stiffness. They supplemented these findings with radiographic evidence from 6 patients.

**Conclusion:** As extra-articular reconstruction techniques including LET become more popular among orthopaedic surgeons, it is important that radiologists and surgeons be adept at recognizing the normal imaging findings of LET and associated complications.

**Keywords:** lateral extra-articular tenodesis; LET; anterolateral rotatory instability; anterolateral rotatory instability; MRI; complications

Persistent anterolateral rotational instability of the knee despite successful anterior cruciate ligament (ACL) reconstruction continues to pose a challenge for many orthopaedic surgeons. High-level athletes who are intent on returning to sports are particularly at risk for anterolateral rotatory instability. This has led to renewed interest in the anterolateral complex (ALC) structures of the knee, which act as secondary stabilizers during internal rotation of the tibia. The ALC, made up of the anterolateral ligament (ALL), joint capsule, and Kaplan fibers (fibers between the femur and the iliotibial band [ITB]), has been shown in numerous biomechanical studies to control internal tibial rotation and thus affect the pivot-shift phenomenon.[11,37,81] As such, many orthopaedic surgeons have begun to use lateral extra-articular tenodesis (LET) as an adjunct to ACL reconstruction to restore this secondary stabilizer.

Lateral-based soft tissue reconstruction techniques to correct anterolateral rotatory instability were first introduced by Lemaire[43] in 1967, with multiple modifications thereafter.[1,2,16,34] With the development of intra-articular ACL reconstructions in the 1980s, these lateral-based reconstructions fell out of favor. However, renewed interest in lateral-based reconstruction techniques has grown because of the resurgence of evidence of persistent rotational laxity after modern ACL reconstruction procedures. In recent years, ALL reconstruction and LET (both Lemaire and modified Lemaire) have reemerged as the favored techniques to augment ACL reconstruction.[4,16,88] Not only has LET been shown to stabilize the outer aspect of the knee by improving the rotational stability, it also reduces the incidence of ACL graft failure.[21-23,59,68]

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In the past decade, magnetic resonance imaging (MRI) evaluation of the normal and injured ALL has been thoroughly characterized in the literature.[20,44,57,78,79] A recent review by Lôbo et al[44] furthered this body of research by describing the imaging evaluation of LET and ALL reconstruction techniques, along with the associated postoperative MRI findings after ALL reconstruction.

Previous studies have thoroughly reviewed the radiologic findings of both the normal and the injured ALC.[‖] The purpose of this study was to provide an overview of the postoperative complications of the LET procedure and their associated imaging findings. This will assist the radiologist and treating surgeon to better understand the radiologic findings associated with complications of the LET procedure in order to promptly identify and manage patients who experience complications after LET surgery.

## METHODS

In this scoping review, we evaluated complications associated with LET. After receiving ethics committee approval, we utilized our institutional picture archiving and communication software system, which caters to a single hospital system, and inspected postoperative ACL reconstruction images, identified by the key phrase "prior ACL reconstruction OR CPT code 29888," between 2010 and 2018 (CPT, Current Procedural Terminology). We additionally filtered for the presence of LET via the key phrase "lateral extra-articular tenodesis, ligamentous reconstruction/augmentation OR CPT code 27305." In addition, we requested 2 deidentified cases from outside of our institution to supplement our existing repertoire of LET-related complications. We reviewed the available radiographs, computed tomography scans, and MRI scans of patients who experienced postoperative complications after ACL reconstruction with LET. We then selected cases in which the complication was determined by a staff surgeon to be from the LET procedure. Images were reviewed by an on-staff musculoskeletal radiologist (J.J.).

We found 9 different complications associated with LET: graft failure, hematoma, infection, chronic pain, tunnel convergence, fixation device migration, muscular hernia, peroneal nerve palsy, and knee stiffness. These findings are supplemented by imaging studies from 6 patients.

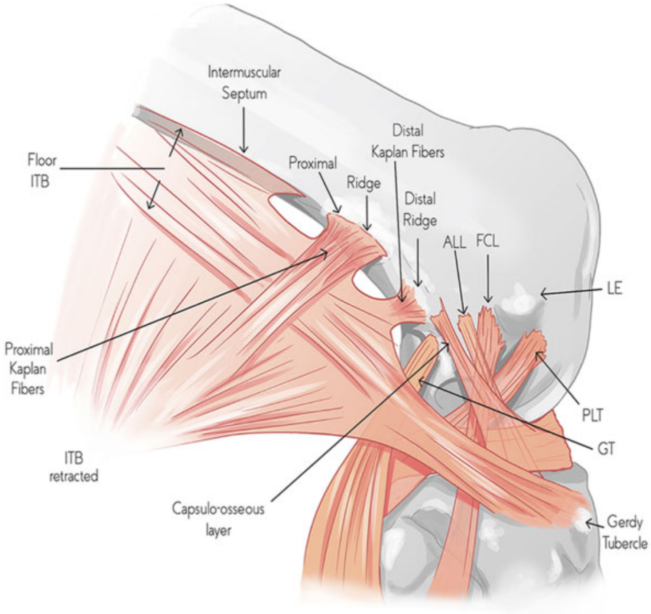

**Figure 1.** The anatomy of the anterolateral structures of the knee. ALL, anterolateral ligament; FCL, fibular collateral ligament; GT, lateral head of the gastrocnemius; ITB, iliotibial band; LE, lateral epicondyle; PLT, popliteus tendon.

## OVERVIEW

### Anatomy of the Lateral Knee

The lateral knee can be separated into 3 layers. Layer 1 consists of the fascia, including the ITB anterolaterally and the biceps femoris posterolaterally. Layer 2 consists of the retinacula and the aponeurosis of the quadriceps along with the lateral patellofemoral ligaments. Anteriorly, layer 1 fuses with layer 2 close to the patellar tendon. Layer 3 consists of the lateral surface of the joint capsule, the lateral collateral ligament, the fabellofibular ligament, coronary ligament and popliteus tendon. Beneath the ITB, the deep layer of posterior lateral joint capsule is subsequently divided into 2 laminae: a superficial laminae that encompasses the lateral collateral ligament and a deeper laminae that encompasses the fabellofibular ligament and arcuate ligament. The deep laminae passes along the lateral edge of the meniscus to form the coronary ligament.[9] The popliteus tendon passes through a hiatus in the coronary ligament to attach at the femur. The ITB has been described as having superficial, middle, deep, and capsulo-osseous

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[‖] References 3, 10, 24, 26, 28, 38, 41, 44, 67, 79, 83, 86.

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Ethical approval for this study was obtained from Jackson Memorial Hospital (reference No. 20170165).

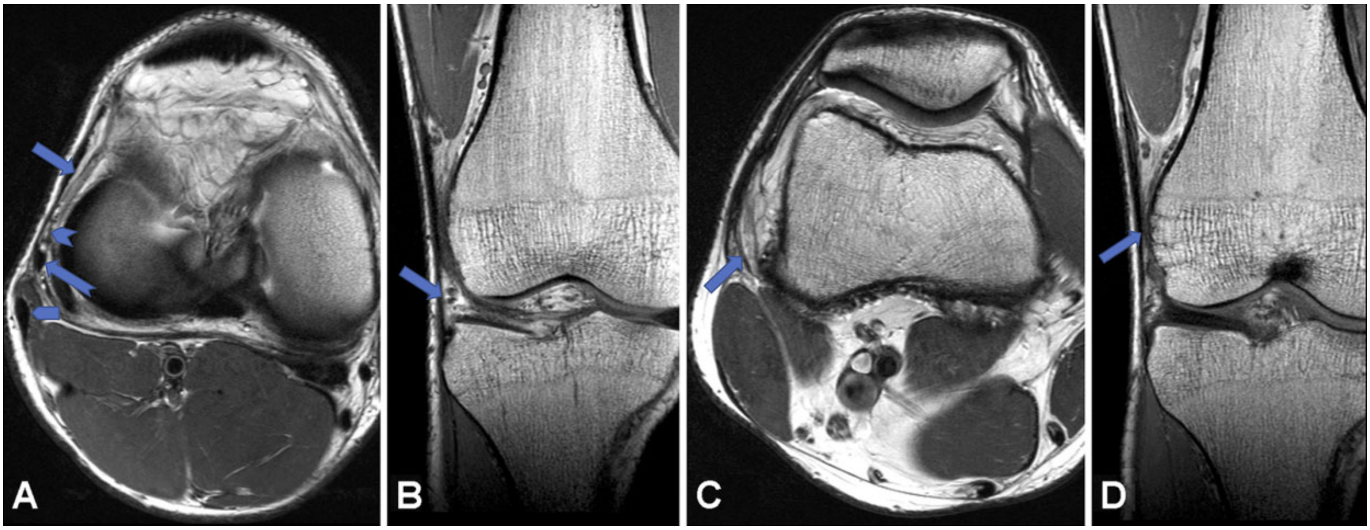

**Figure 2.** Proton density–weighted magnetic resonance imaging (MRI) appearance of normal anterolateral ligament (ALL) and related lateral structures. (A) Axial sequence demonstrating the inferior lateral genicular arteries (arrow), the ALL (arrowhead), the fibular collateral ligament (notched arrow), and the biceps femoris (pentagon arrow). (B) On a coronal MRI sequence, the ALL is identified (arrow). (C) Axial and (D) coronal sequences identifying the proximal Kaplan fibers (arrows) extending from the femur to the iliotibial band.

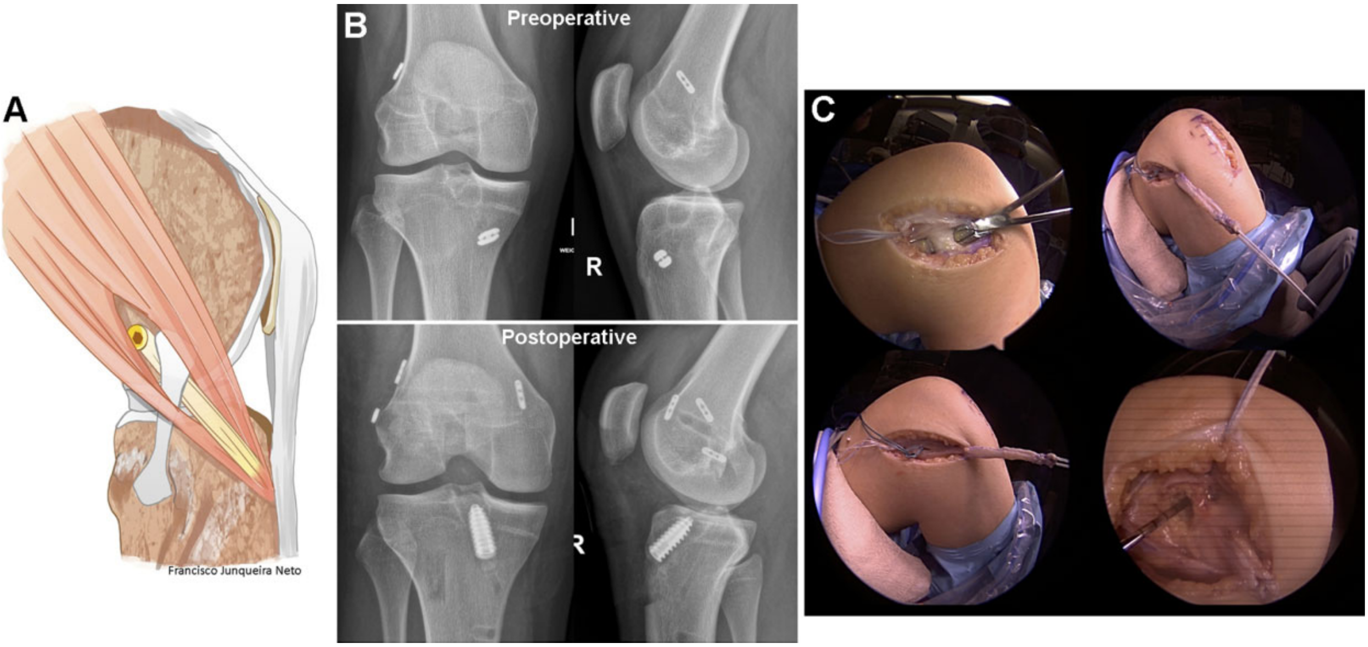

**Figure 3.** (A) Illustration of lateral extra-articular tenodesis using the modified Lemaire procedure. The midsubstance strip of the iliotibial band is seen coursing deep to the posterior cruciate ligament. (B) Pre- and postoperative radiographs obtained in a 14-year-old patient who underwent revision anterior cruciate ligament reconstruction via the transosseous tunnel technique with modified Lemaire lateral extra-articular tenodesis (LET) and lateral meniscal root repair. (C) Intraoperative images of the modified Lemaire LET procedure.

layers, which connect layers 1 and 3 as well as the distal femur in the proximal and posterior part of the lateral knee (Figure 1).[10,12]

Kaplan fibers are connections between the ITB and distal lateral femoral condyle. Structurally, Kaplan fibers are deep and posterior to the ITB. They are subsequently divided into proximal and distal components and anteriorly integrate into the ALC. The Kaplan fibers are located superior and posterior to the ALL. Originally described by the French surgeon Segond[74] in 1879 as a “pearly, fibrous

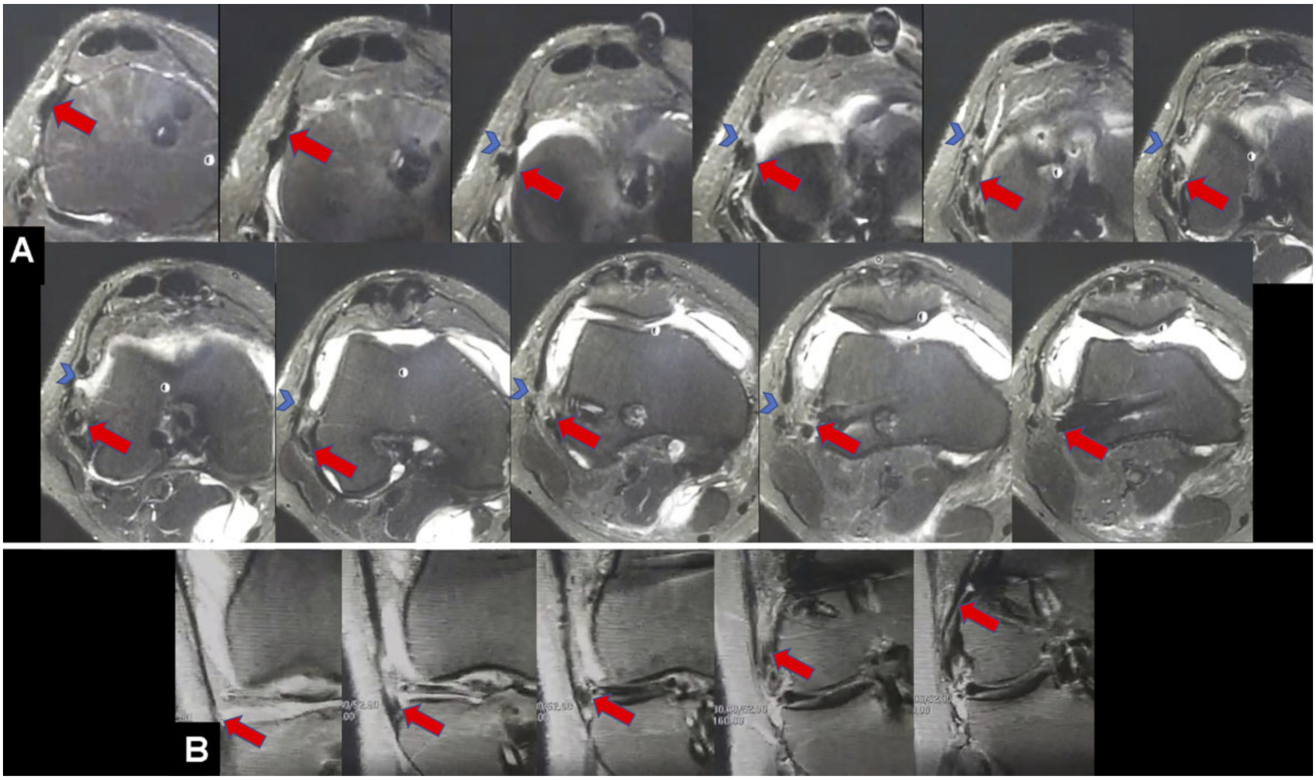

**Figure 4.** (A) Axial proton-density fast-spin sequences from distal to proximal demonstrating the normal magnetic resonance imaging appearance of the modified Lemaire lateral extra-articular tenodesis procedure. Images show the graft (arrows) extending from the Gerdy tubercle in the proximal tibia to the lateral femoral condyle. Note the defect in the iliotibial band secondary to graft harvesting (arrowheads). (B) Coronal proton-density fast-spin sequences from distal to proximal demonstrating the iliotibial band (arrows) extending from the proximal tibia to the lateral femoral condyle.

band," the term "anterolateral ligament" was first utilized by Terry et al[83] in their 1986 cadaveric study and was later used by Claes et al[11] in 2013 in a similar cadaveric study. Claes et al[11] described a distinct oblique ligament that arose from the prominence of the lateral femoral epicondyle (LFE), slightly anterior to the origin of the fibular collateral ligament. It has been identified as an extracapsular ligament with a "fanlike" femoral attachment.[15] The femoral attachment site is variable according to current literature, varying from anterior and distal to the LFE to more proximal and posterior.[13,15,62] It courses anterolaterally to the proximal tibia, where it attaches to the periphery of the middle third of the lateral meniscus, midway between the Gerdy tubercle and the tip of the fibular head, and usually 5 to 10 mm below the lateral tibial plateau joint line.[10,39,62] It lies proximal and posterior to the popliteal tendon, enveloping the inferior lateral genicular artery and vein,[11] and deep to the ITB.[39] The average length and thickness of the ALL are 35 to 40 mm and 1 to 3 mm, respectively[10,25,62,87]; the width ranges from 4 to 11 mm at the origin on the LFE, narrows to 4 to 8 mm at the midpoint, and fans out again to 11 to 12 mm at its broad insertion distally.[10,11,13,62] The ALC includes the deep layers of the ITB, Kaplan fibers, anterolateral capsule, and ALL. The ALC is situated near the LFE, and its insertion is inferior to the tibial articular surface posterior to the Gerdy tubercle.[13,62]

## Preoperative MRI Evaluation of the ALC

In general, the anterolateral structures of the knee are best visualized on proton density–weighted fat-saturated MRI sequences, with normal ligaments and tendons appearing as well-defined low–signal intensity structures.[41] When these structures are injured, discontinuity and/or laxity may be noted. In addition, T2-weighted sequences help to highlight concurrent interstitial and localized edema by appearing as increased signal within the damaged structures. LaPrade et al[41] assessed the accuracy of MRI in identifying intact versus injured structures in 20 posterolateral knees using a spin-echo T2-weighted sequence with 3-mm slices and a T1-weighted sequence with 2-mm slices; the ALL and its associated lesions were accurately identified 95% of the time using both techniques. Since then, studies have assessed the appearance of the ALL on MRI scans, with the identification rate ranging from 51% to 100%.[24,66] In particular, Monaco et al[57] found only fair agreement ($\kappa = 0.23$) among 3 investigators when differentiating between partial and complete ALL/capsule tears, illustrating the limitations of MRI.

Another proposed reason for the discrepancy in ALL identification between MRI scans and cadaveric dissection in these studies is the use of MRI protocols with thin slices.[57] This method has the advantage of improving spatial resolution,

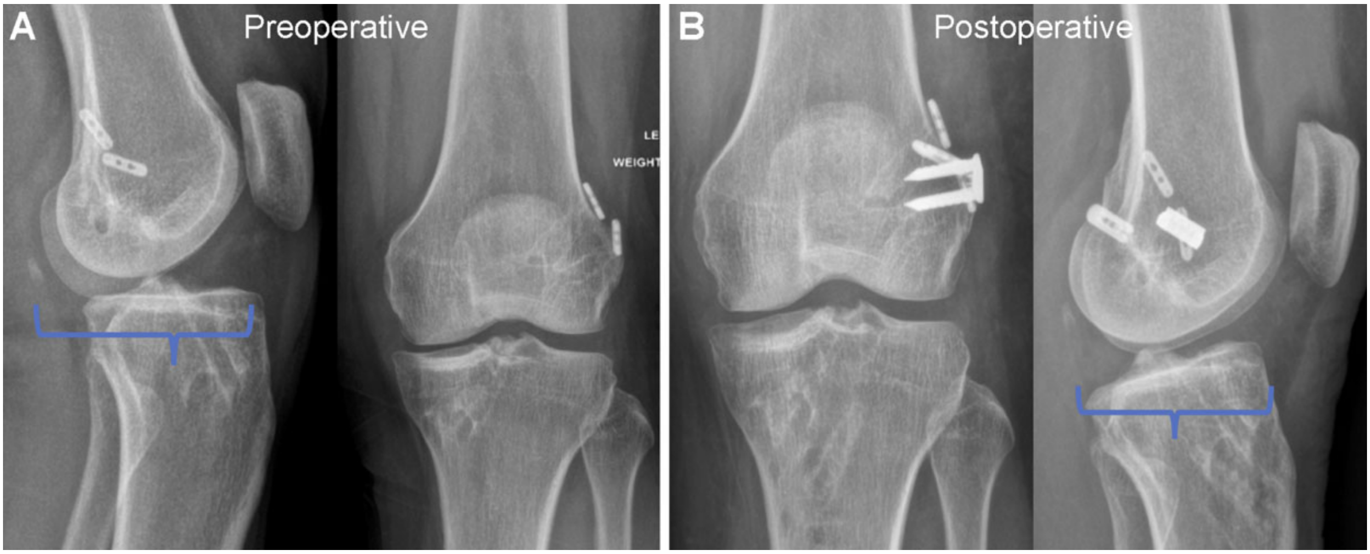

**Figure 5.** Pre- and postoperative radiographs obtained in a patient who underwent revision anterior cruciate ligament (ACL) reconstruction with lateral extra-articular tenodesis (LET). (A) Preoperatively, the patient reported anterior lateral rotary instability due to double-bundle ACL graft failure, which is illustrated via anterior subluxation of the tibia on a lateral radiograph (asymmetric bracket). (B) After revision ACL reconstruction with LET secured using a staple, reduction of prior anterior tibial translation was obtained (symmetric bracket).

thereby reducing partial volume effect; however, this protocol may not be widely utilized in clinical practice because of the increased scan duration required. MRI scans may also be helpful in identifying associated injuries, including Segond fractures, medial collateral ligament tears, medial and lateral meniscal tears, posterolateral corner injuries, and bony contusions.[11,14,24,62,86] Barrera et al[3] found a statistically significant association between injury to the ALL and other concomitant lateral structures, supporting the concept that the ALL works synergistically with regional lateral structures to provide rotation support to the knee. Although debate still exists on the reliability of detecting ALL injury, MRI has been shown to be a reliable technique for identifying the native ALL in most studies.[88] On MRI scans, the ALL appears as a distinct thin, linear, low-signal band on proton-density sequences and is best identified in the coronal plane[26,27,66] (Figure 2).

The coronal plane sequences can also help to identify the meniscal and tibial insertions of the ligament.[26,38,83] Lôbo et al[44] described the ALL as having 3 discrete portions originating from the LFE, meniscus, and tibia. Multiple studies have reported variation in identification of the femoral attachment on MRI scans, with debate centering around the presence or absence of ALL attachment to the lateral meniscus.[36,62,66,83] Khanna et al[36] described the radiographic anatomy of the capsulo-osseous layer of the ITB, demonstrating on MRI scans that the distal insertion could be reliably identified but varied at the proximal femoral origin. The lateral inferior genicular vessels can be reliably used as a landmark by which to identify the bifurcation point of the ALL.[27,83] In a radiographic landmark study, Helito et al[28] evaluated the femoral and tibial attachments of the ALL, comparing radiographic parameters to anatomic dissection in cadaveric specimens. They found that the ALL origin was radiographically along the Blumensaat line approximately 47.5% ± 4.3% (Mean ± SD) of the time. On anteroposterior radiographs, the distance from the ALL to the posterior intercondylar line measured 15.8 ± 1.9 mm, and the tibial attachment was 7.0 ± 0.5 mm below the articular line.[26,29,65]

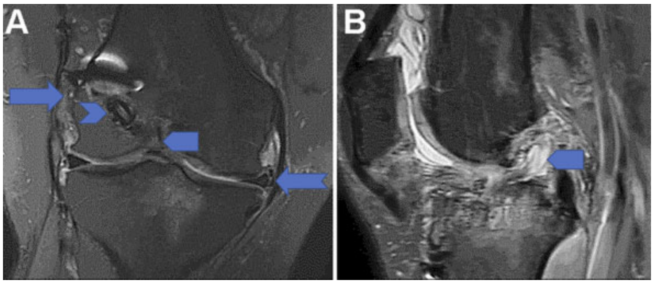

**Figure 6.** (A) Coronal and (B) sagittal proton-density fat-saturated magnetic resonance imaging sequences demonstrate full-thickness tear of the lateral extra-articular tenodesis at the femur (regular arrow), with concomitant anterior cruciate ligament (ACL) graft failure seen on the sagittal sequence (pentagon arrow in images A and B). Arrowhead in panel A delineates the ACL femoral tunnel on the coronal sequence. There is concomitant medial meniscal peripheral vertical tear with extrusion of the body into the medial gutter (notched arrow).

## LET Procedure

In the 1967 LET procedure, Lemaire[43] described using a strip of the ITB to laterally reinforce the knee. This was

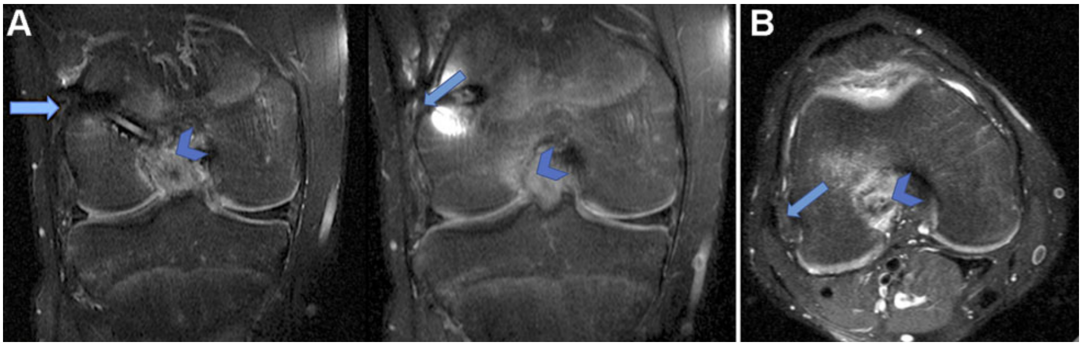

**Figure 7.** (A) Coronal and (B) axial proton-density fat-saturated magnetic resonance imaging sequences demonstrate a partial-thickness tear of the lateral extra-articular tenodesis graft proximally at the femoral attachment (arrows), as well as anterior cruciate ligament graft failure (arrowheads).

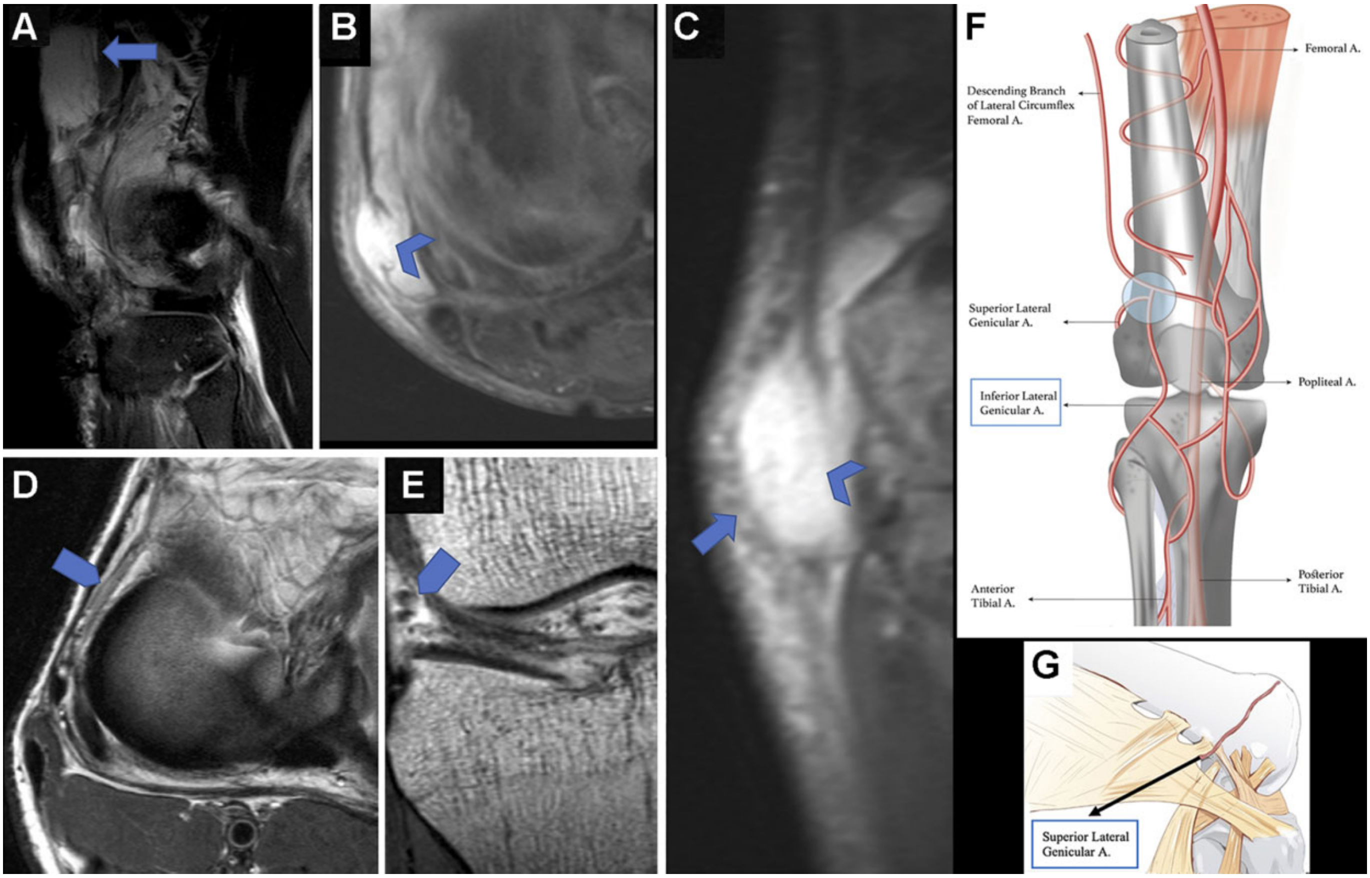

**Figure 8.** Postoperative magnetic resonance imaging scans demonstrating a hematoma secondary to a lateral inferior genicular artery injury from graft harvesting. (A) Sagittal T2-weighted proton-density fast-spin (B) axial and (C) coronal sequences demonstrate a hematoma (arrows) extending from lateral to the vastus lateralis down to the level of the insertion of the iliotibial band, insinuating into the surgical defect at the graft donor site (arrowheads). Proton-density (D) axial and (E) coronal sequences demonstrate the normal anatomy of the lateral inferior genicular artery (pentagon arrows). (F and G) Illustrations demonstrating the blood supply of the knee are provided for reference. A, artery.

accomplished by routing the ITB graft through bone tunnels located around the insertion of the distal Kaplan fibers and suturing it back to itself, while preserving the distal attachment. Since that time, numerous modifications to this technique have been described,[2,6,16,40,45,49,52,93] including modifications in graft choice, fixation, and tibiofemoral

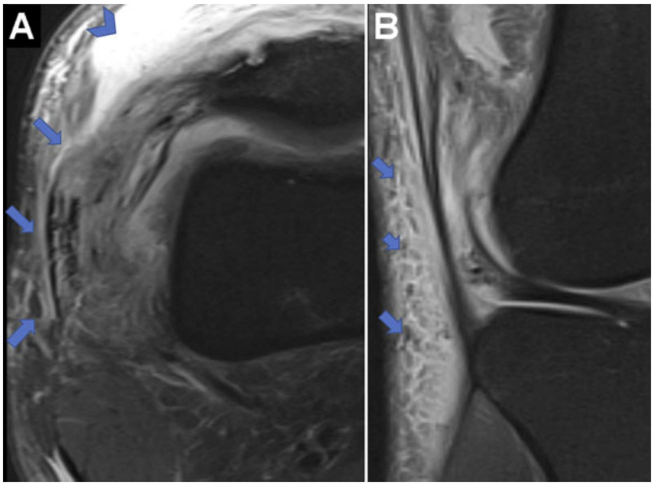

**Figure 9.** (A) Axial and (B) coronal proton-density magnetic resonance imaging sequences demonstrate soft edema surrounding the iliotibial (IT) band (arrows) consistent with cellulitis and deep tissue infection involving the IT band and an associated prepatellar abscess (arrowhead).

positioning for lateral tenodesis and more recently with the development of anatomic ALL reconstruction techniques (Figure 3). For instance, the Zarins and Rowe approach[93] uses the semitendinosus tendon, the Benum approach[6] uses the lateral one-third of the patellar tendon, and the approach of Marcacci et al[52] uses the semitendinosus and gracilis tendons rather than a segment of the ITB for the graft. Newer techniques use a surgical staple, suture anchor, or interference screw to secure the graft to the LFE.[20,40,63] Despite these adaptations, all LET procedures continue to preserve the native ITB attachment distally at the Gerdy tubercle and route the graft posterolateral to the LFE, while ALL reconstruction techniques re-create a proximal tibial attachment site as well. To date, no clinical studies that demonstrate that one technique is superior to another have been performed.[34]

## Normal Imaging Appearance After LET

On postoperative images of patients who underwent combined ACL intra-articular reconstruction and LET using the ITB as a graft, one should expect to see a gap on both the coronal and the axial planes of MRI corresponding to the central portion of the ITB that was harvested (Figure 4). Care should be taken to follow the graft through multiple slices on the coronal plane, as the graft courses obliquely.[44] At the Gerdy tubercle, there will be no fixation device. However, femoral fixation via interference screws, suture anchors, or staples proximal and posterior to the LFE should be visualized.

## COMPLICATIONS AND ASSOCIATED IMAGING FINDINGS

Complications are infrequent in ACL reconstruction, most often involving early postoperative wound hematoma, implant removal secondary to loosening, impingement, painful hardware, intra-articular infection, instability in the absence of rerupture, and ACL rerupture. Grassi et al reviewed 11 clinical studies[¶], including their own, and reported 59 complications (8%) in 742 patients. Beyond the complications reported above, temporary peroneal nerve palsies, stiffness, superficial infection, lateral muscular hernias, and staple pullout have also been reported in the literature.[23,88,91] In a multicenter study by Louis et al[46] of 349 patients who underwent combined ACL-LET reconstruction, the authors attributed <3% of the 10.5% late complication rate to the lateral extra-articular reconstruction. Of note, the overall complication rate is generally very low in combined ACL-LET reconstructions, confirming the safety and justifying the addition of extra-articular procedures when reconstructing the ACL.[23,46,91] The 9 most frequent complications, with associated images, are described below.

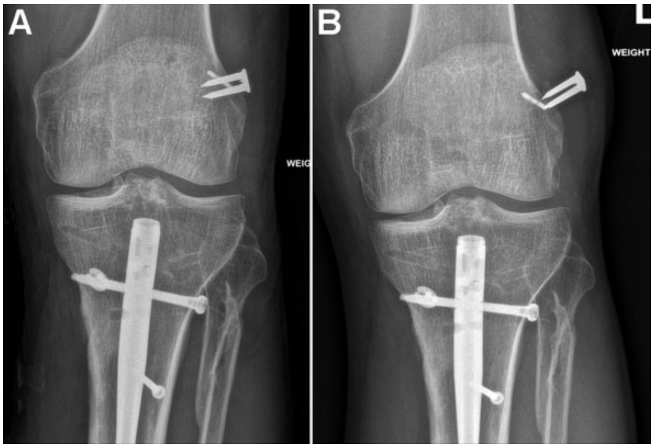

**Figure 10.** Anteroposterior radiographs of a combined tibial intramedullary nail and lateral extra-articular tenodesis procedure with staple fixation at (A) 1 month and (B) 3 months postoperatively. Staple pullout at the lateral femoral epicondyle proximal fixation site is seen in panel B.

## Graft Failure

A review of the literature places the failure rate for primary ACL reconstruction at 3% to 5% and that for revision ACL reconstruction at 15% to 20%.[71,75] Many have blamed higher failure rates on residual rotatory laxity, which has been supported by numerous biomechanical studies.[11,37,81,91] The aim of adding the LET procedure to ACL reconstruction is to decrease this rotational laxity and thus reduce graft failure rates, which has been borne out in clinical studies.[23,59,93] In grafts that do fail after combined ACL-LET reconstruction, complete or partial tear of the LET graft may contribute to this failure.[23] To date, complete or partial failures of the LET graft have only be described from the femoral attachment site, with no described failures or avulsion fractures from the Gerdy

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[¶] References 1, 9, 19, 23, 42, 46, 50, 55, 68, 91, 92.

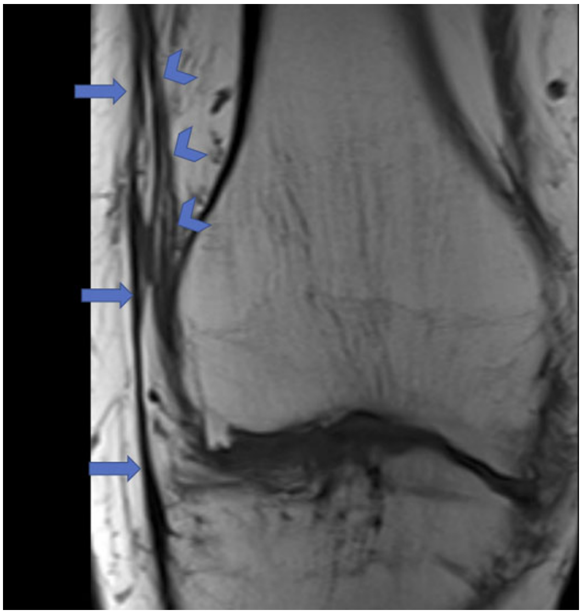

**Figure 11.** Postoperative coronal proton-density magnetic resonance imaging scan demonstrates diffuse low–signal intensity scarring (arrowheads) involving the iliotibial band (arrows) and its Kaplan fibers along the anterolateral aspect of the proximal femur in this patient with arthrofibrosis that resulted in persistent knee stiffness after a lateral extra-articular tenodesis procedure.

tubercle.[23,60,61,69,91] A recent review found an overall ACL-LET reconstruction failure rate of 3.6%, ranging from 1.6% to 16%.[1,9,19,22,23,55,68] Even without a complete or partial tear of the ACL, LET graft elongation secondary to the absence of postoperative isometry has been identified as a cause of early failure.[23,61,76] It has been hypothesized that if the joint is overconstrained, this can result in LET elongation and eventual failure,[18,37] which then can result in a residual grade 2 pivot shift, deemed an ACL revision failure in some patients.[68] When reviewing postoperative images, reviewers should take care to scrutinize the LET graft in relation to ACL integrity for evidence of these abnormalities (Figures 5–7).

## Hematoma

Given the close proximity of the lateral inferior genicular vessels to the LET graft site, injury during dissection can cause bleeding and result in hematoma formation in the lateral soft tissues (Figure 8).

Wound hematoma is one of the most frequent complications described, with a reported incidence of 5% to 10%.[23,42,46,55] Mirouse et al[55] reported 3 cases (10%) of harvest-site hematoma, none of which required surgical drainage. Panisset et al[61] described a postoperative hematoma rate of 6%, with only 0.4% requiring evacuation of hemarthrosis; however, there were no reported complications specific to extra-articular reconstruction during the first month after surgery. It is important for radiologists to differentiate between hematoma sites, as postoperative hematoma from an ACL graft rupture typically occurs at the suprapatellar pouch and may dictate more immediate surgical intervention as compared with a hematoma caused by the LET.[17]

## Infection

The infection rate is extremely low after ACL-LET reconstructions, with a case rate of 0.2% to 5% reported in the literature.[8,61,80] Risk factors include a history of diabetes, allograft and hamstring graft, and high-level sports activity.[8,80] A majority of infections reported are superficial wound infections at the ITB tenodesis site (Figure 9) that were successfully treated with a single course of oral antibiotics.[67]

Although rare, some studies have found an association between LET during ACL reconstruction and an increased risk of septic arthritis.[35,72]

## Chronic Pain

In a retrospective series of 80 patients with 4-year follow-up who underwent bone–patellar tendon–bone ACL reconstruction via the modified MacIntosh procedure, the authors reported that 40% of patients experienced chronic pain and swelling associated with the LET procedure.[60] More recently, however, in a large prospective series by Panisset et al,[61] 592 combined ACL-LET reconstruction cases were evaluated for short- and medium-term complications. The study found that 1.4% and 0.8% of patients reported femoral-site pain and 0.4% and 0.6% reported tibial-site pain at 3 and 6 months, respectively. These authors clarified that this pain was specific to the extra-articular reconstruction but progressively resolved in all except for 1.7% of patients with impingement requiring fixation material ablation (Figure 10). This lateral pain generally resolved within 1 year.[22] Implant removal because of pain has been reported in 0% to 21.5% of patients, with staples being the most common fixation device requiring removal.[1,22,91,92]

However, the removal of tibial Evolgate screws,[19] femoral staples,[91] and other fixation devices[46] has also been described. The removal of fixation devices has not been reported to affect final clinical outcome.[21,23,92]

## Stiffness

One concern raised regarding the LET procedure is the potential overconstraint of the lateral compartment of the knee.[7,32] Authors have previously suggested that the addition of this lateral constraint may lead to an increased risk of lateral compartment osteoarthritis.[16,64,73] Two cadaveric studies showed that the “screw home mechanism” of knee motion could be disrupted by the addition of the LET procedure.[18,73] However, this concern has been disproven in large clinical studies and meta-analyses, which have shown no correlation between the addition of LET to ACL reconstruction and the risk of lateral compartment osteoarthritis.[51,88,92] Instead, the only correlation that has been

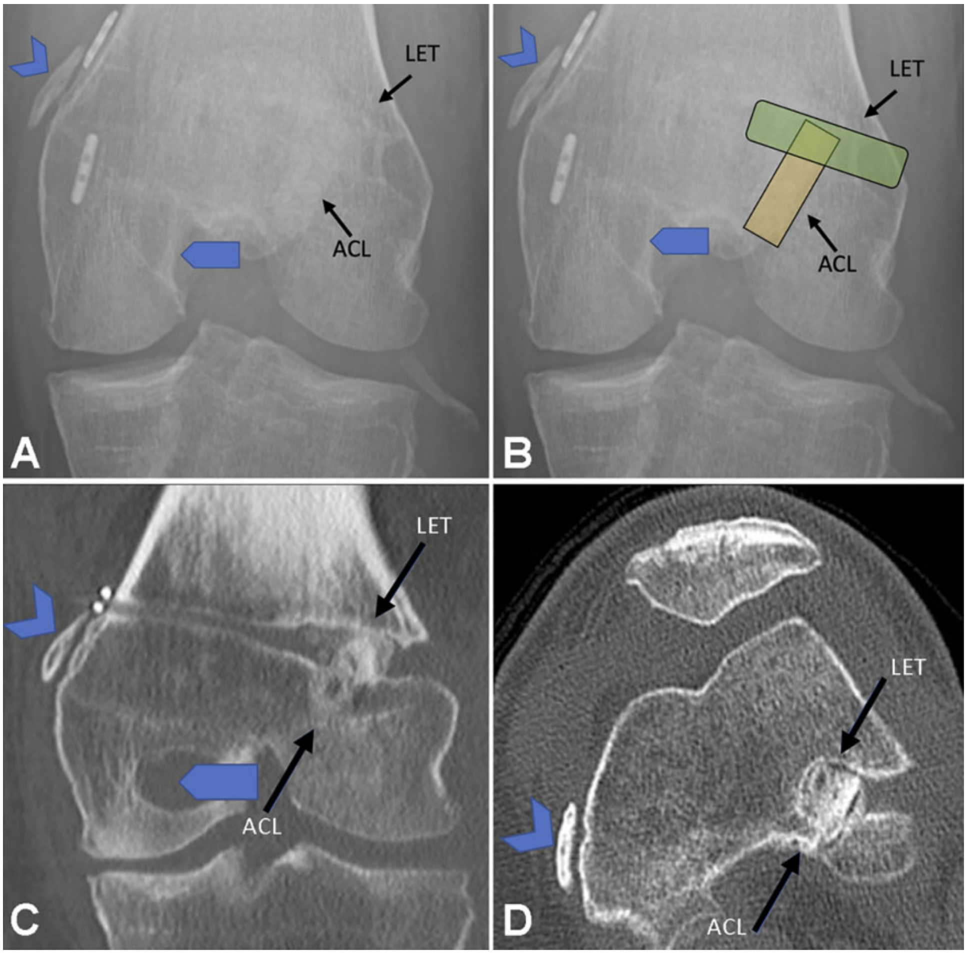

**Figure 12.** Multiligament reconstruction seen on (A and B) anteroposterior radiographs and (C) coronal and (D) axial computed tomography images. The pentagon arrows indicate the posterior cruciate ligament reconstruction tunnel, arrowheads indicate a chronic Pellegrini-Stieda lesion from a prior medial collateral ligament injury, and thin black arrows indicate the site of the tunnel for lateral extra-articular tenodesis (LET) and the anterior cruciate ligament (ACL) reconstruction. In panel B, tunnel positions are indicated for the LET tunnel (green rectangle) and for the femoral tunnel of the ACL reconstruction (orange rectangle).

consistently associated with compartment degeneration is meniscectomy, more commonly involving the medial rather than lateral compartment.[64,88,90]

Appropriate positioning of the knee during fixation of the graft to the LFE is essential to avoid overconstraining the knee. If the LET procedure is performed while the knee is placed in too much flexion, it may lead to excessive tightness of the knee in extension, and the patient can experience stiffness and loss of range of motion.[7,51] Internal rotation of the knee can also be inadvertently overconstrained. Prior techniques relying purely on extra-articular reconstructions for the treatment of ACL tear placed the knee in external rotation at the time of fixation, which led to overconstraint. Modern techniques emphasize neutral tibial rotation at the time of fixation of the LET to decrease this risk.[7,48,63] Stiffness and loss of motion may also be due to arthrofibrosis within the anterolateral knee, as seen on MRI scans (Figure 11).

However, stiffness in the postoperative setting must be interpreted with caution, as countless studies have reported flexion stiffness in 2.5% to 17.6% of patients after an ACL reconstruction, a rate that does not significantly differ from that in patients with combined ACL-LET reconstructions.[61,71,75,82] Conversely, overrestraint of the lateral compartment can also lead to an extension deficit, usually between 3° and 5°, which has been reported infrequently in the literature.[9]

## Tunnel Convergence

As different LET procedures have gained popularity, tunnel conflicts (eg, tunnel convergence, tunnel collision, or lateral wall blowout) have been cited by multiple studies as a complication during combined ACL-LET reconstruction[56,77] (Figure 12). This is because the femoral LET position is located in close proximity to the femoral tunnel position in ACL reconstruction, which is commonly applied at an oblique angle using an anteromedial portal.[5,63] In 2019, Jaecker et al[33] evaluated the risk of femoral tunnel convergence in a biomechanical study of 10 cadaveric knees comparing the

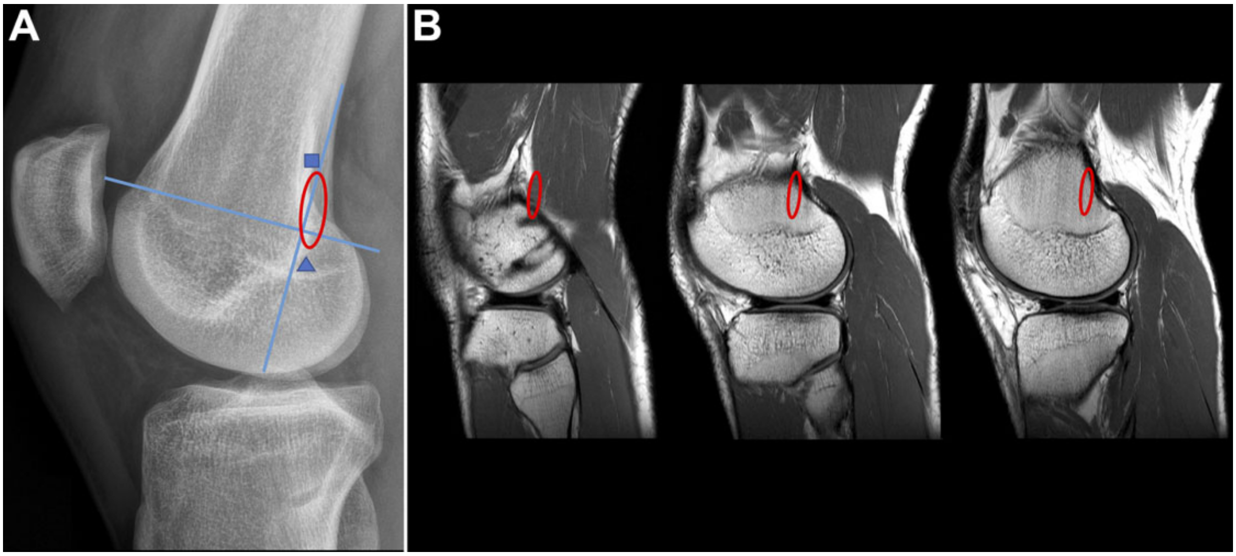

**Figure 13.** (A) Lateral radiograph and (B) non–fast spin proton-density sagittal magnetic resonance imaging scans demonstrating an ideal isometric femoral lateral extra-articular tenodesis graft attachment site and femoral tunnel position (red ellipses) located between the lateral femoral epicondyle (triangle) and Kaplan fiber attachment (square) point on the femur. Images adapted from Jaecker et al[33] and Slette et al.[76]

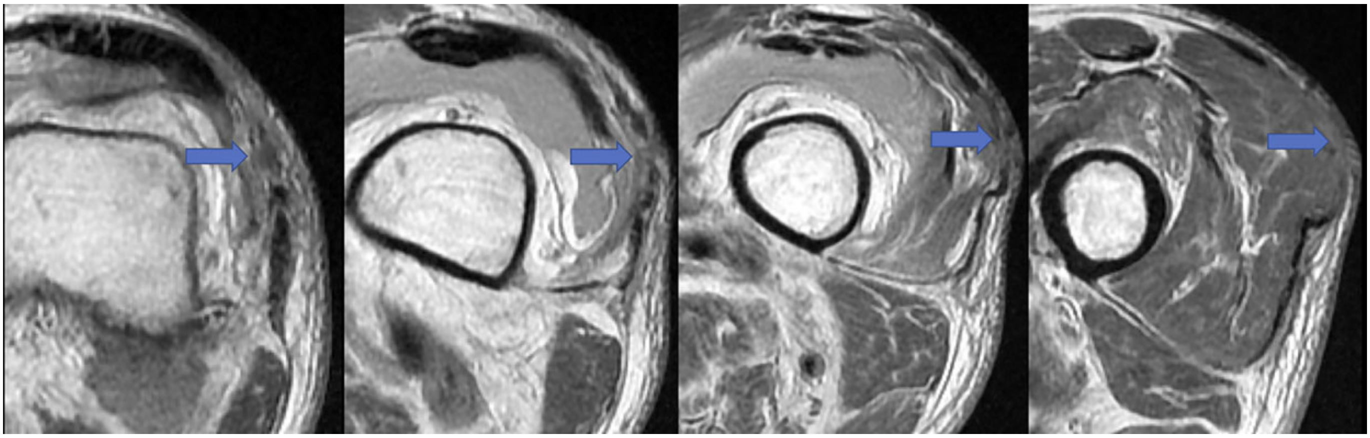

**Figure 14.** Proton-density axial magnetic resonance imaging scans demonstrate lateral herniation of the vastus lateralis muscle (arrows) due to harvesting of the iliotibial band graft too anteriorly.

Lemaire and MacIntosh positions. These authors found that tunnel convergence occurred frequently in combined ACL reconstruction and LET procedures using the Lemaire technique but did not occur when the more proximal MacIntosh technique was used. In the Lemaire technique, these tunnel convergences occurred directly at the lateral femoral cortex, which may result in poor graft fixation or injury to the fixation device.[32,33,40,89]

Nonanatomic tunnel placement has been cited frequently as the most common cause of surgeon-related primary ACL reconstruction failure and a cause of overconstraint of internal tibial rotation in LET.[58,70,75] Thus, it is essential to evaluate for both tunnel position and lysis on computed tomography or MRI scans.[70] Conventionally, the ACL reconstruction femoral tunnel position should be located at the intersection of the posterior femoral cortex and the lateral wall of the intercondylar notch, as posterior as possible without violating the posterior femoral cortex.[70,84] Jaecker et al[33] described an isometric femoral attachment area in LET procedures with reference to consistent radiographic reference lines, with results indicating that ideal femoral tunnel placement was posterior to the femoral cortex line and proximal to the posterior femoral condyle within a 10-mm distance. These tunnel guidelines took into account the ideal isometric attachment area as well as ensured avoidance of the Kaplan fiber attachments on the distal femur[33] (Figure 13). Measurements of tunnel width should be performed at the tunnel midpoint to assess for tunnel enlargement.

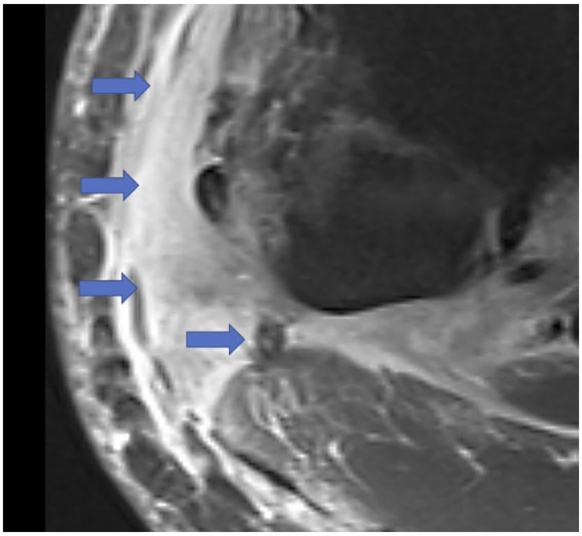

**Figure 15.** Proton-density axial magnetic resonance imaging sequence demonstrating edema within and surrounding an enlarged common peroneal nerve (arrows). Excessive traction on the nerve intraoperatively resulted in a temporary peroneal nerve palsy.

Tunnel enlargement due to suspensory fixation failure, immune response to graft, ganglion cyst formation, and exposure to toxic ethylene oxide and metal have been described in ACL reconstructions but have not been implicated as causes of tunnel enlargement and failure in LET reconstructions.[30,70] If there is concern for significant tunnel enlargement or convergence, computed tomography should be obtained for further evaluation, as MRI is susceptible to artifact and anatomic distortion from metallic hardware, often making accurate assessment of tunnel enlargement difficult.[31,53,70]

### Fixation Device Migration

The migration of graft fixation devices, including interference screws, staples, and adjustable cortical suspensory fixation devices, is another concern for surgeons after LET (Figure 10). Tendon–bone area contact is essential for fixation of the graft within the bone tunnel, which is initiated by Sharpey fibers.[54,85] Interference screws provide less tendon-bone contact because much of the tunnel is occupied by the screw itself compared with adjustable cortical suspensory fixation devices, which provide larger contact to promote healing inside the tunnel.[12,47] Additionally, intra-articular malposition of the fixation devices may lead to unstable fixation.[44] This complication has thus far been poorly characterized in the literature.

### Muscular Hernia in the Lateral Approach

If the ITB graft is harvested too anteriorly, the anterior compartment musculature, and particularly the vastus lateralis, can herniate laterally[46] (Figure 14).

In his review of 11 large clinical studies looking at combined ACL-LET procedures, Grassi et al[23] identified this infrequent complication that was generally asymptomatic and required no intervention. Additionally, Bernholt et al[7] warned that harvest of the ITB too far posteriorly can disrupt the Kaplan fibers, which may disrupt the ITB's most posterior attachment to the femur.

### Peroneal Nerve Palsy

In rare cases, short-lived peroneal nerve impairment has been reported after ACL reconstruction with LET.[23,40,46] The peroneal nerve is at risk during dissection down to the ITB if the dissection is carried too far posteriorly. When the ITB strip is harvested, excessive traction can be placed on the nerve, leading to temporary peroneal neuritis.[40] Postoperatively on MRI scans, thickening and irregularity of the common peroneal nerve at the level of the fibular neck on axial fat-suppressed T2-weighted images can be seen, with surrounding denervation edema (Figure 15).

## CONCLUSION

As extra-articular reconstruction techniques including LET become more popular among orthopaedic surgeons, it is important that radiologists and surgeons be adept at recognizing the normal imaging findings of LET and associated complications. We believe this review will assist the radiologist and treating surgeon to better understand the postoperative radiologic findings common to LET and be better equipped to identify patients who experience complications after LET surgery.

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