Technical Note

Reverse Ramp Lesion Repair in Patients With Meniscotibial Ligament Avulsion Injury: The Hidden AMRI

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Abstract: Lesions of the meniscocapsular junction and the meniscotibial ligament (MTL) of the posterior horn of the medial meniscus are common with knee ligamentous injuries and associated with residual rotational instability if left untreated. MTL avulsion from its tibial attachment has never been described among different types of meniscocapsular disruptions so far. Both diagnosis and treatment of such an injury can be challenging. This article describes a detailed technique and proposes an algorithm to appropriate management of this rare injury.

Initially described as longitudinal tears of the meniscocapsular junction (MCJ) of the posterior horn of the medial meniscus (PHMM), ramp lesions are increasingly being diagnosed at the time of anterior cruciate ligament (ACL) reconstruction (ACLR), with a reported prevalence reaching 40%.[1] In recent years, the anatomy of the MCJ has been further investigated, revealing a separate meniscotibial ligament (MTL) insertion on the PHMM, with utmost importance in ramp stability, and referred to as the posterior "belt" of the medial meniscus (Fig 1).[2-4] Injury to the MCJ, particularly to the MTL, may cause increased anterior translation and rotational instability in the setting of ACL injury.[2,5] Thus, repairing the MTL is crucial to restoration of knee kinematics.

Techniques for ramp repairs include all-inside devices, or more commonly using a suture hook repair through a posteromedial (PM) portal.[6] The aim is to fix the detached MCJ to the medial meniscus, with care to include the MTL, and ramp lesions are often repairable because the level of disruption is at the level of joint line, or in the midsubstance of the MTL.[7] However, in rare cases, the MTL can be avulsed from its tibial insertion 4 to 6 mm inferior to the joint line,[8] which makes both arthroscopic detection of the ramp lesion and its repair difficult with any suture technique. In such cases, repair of the MTL and MCJ using anchor fixation is more reliable in reducing the anteromedial rotatory instability (AMRI) and restoring knee kinematics.[5] To our knowledge, ramp repair using suture anchor fixation has been mainly evaluated in cadaveric studies with an open approach[2,5] and only recently described arthroscopically.[9]

This article describes an arthroscopic repair of MTL avulsion, or "reverse ramp" lesion, using suture anchor fixation. We also propose an algorithm to appropriate diagnosis and optimal repair of such injuries.

Surgical Technique

Tables 1 and 2 highlight technical tips to follow and pitfalls to avoid, in addition to advantages and disadvantages associated with this technique. Video 1 illustrates the surgical technique in a patient with an acute reverse ramp injury.

Patient Setup

The patient is placed supine on the operative table in a standard arthroscopy position. A lateral post is placed against the thigh, and a foot post is positioned to hold the knee at 90° of flexion. For external identification of

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Received October 11, 2023; accepted December 23, 2023.

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2212-6287/231475
https://doi.org/10.1016/j.eats.2024.102930

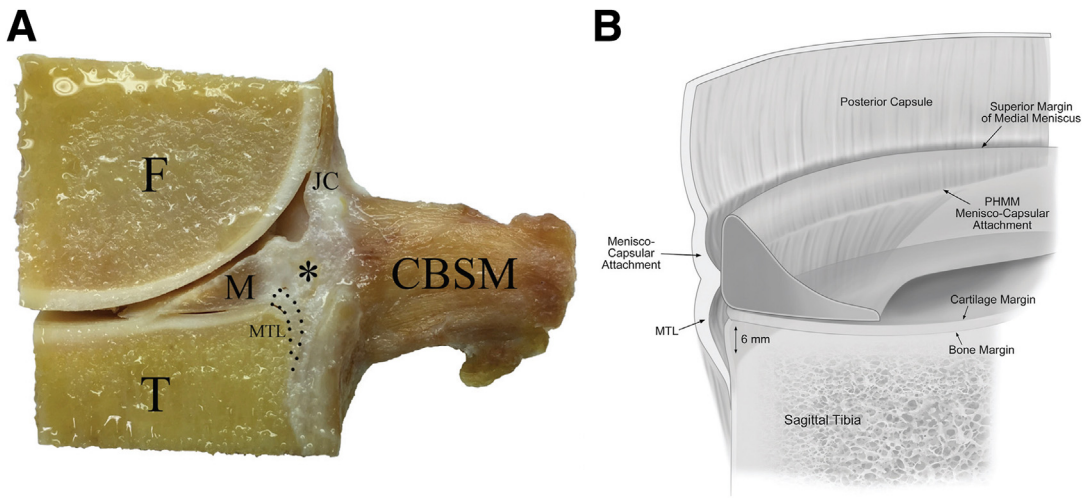

Fig 1. Sagittal cuts from the posteromedial corner of the knee. (A) Cadaveric view from Cavaignac et al.[3] showing detailed anatomy of the meniscocapsular junction and highlighting the meniscotibial ligament (MTL) attachment between the inferior portion of the posterior horn of the medial meniscus (PHMM) and the tibia (T). (B) Illustrative view proposed by DePhillipo et al.[8] showing the attachment of the MTL approximately 6 mm distal to the articular margin of the posterior medial tibial plateau. *Adipose tissue. (CBSM, capsular branch of the semimembranosus; F, femur; JC, joint capsule; M, medial meniscus.) (Reprinted with permission)

the PM portal, 2 lines are drawn as landmarks: the first is drawn at 3 finger breadths from the superior patellar pole, and the second is tangent to the tip of the inferior patellar border. The landmark for needle insertion is just posterior to the intersection of the 2 lines (Fig 2).

Reverse Ramp Lesion Detection

Injury Pattern

Ramp lesions are typically associated with ACL injuries, as part of rotational instability, with both AMRI and posteromedial rotatory instability (PMRI) being increased in the presence of a concomitant ramp lesion.[2,5,10] In the few cases of MTL avulsions that we have encountered in our practice, there was always a combined ACL and posterolateral corner (PLC) injury (Fig 3). The AMRI pattern is predominant in this multiligament injury, and we feel an excessive external tibial rotation is the driving force to cause the MTL avulsion from its tibial attachment, rather than the described reflex contraction of the semimembranosus tendon, secondary to anterior tibial translation during ACL injury, leading to a ramp lesion.[8,10]

Magnetic Resonance Imaging Findings

Although magnetic resonance imaging (MRI) can miss ramp lesion identification,[11] visualization of the MTL tibial attachment is important in the surgical decision-making. In cases with MTL avulsion, there is no fluid filling between the PHMM and the MCJ, as seen with a MCJ disruption. In addition, the anterior translation of the PHMM typically seen on the sagittal view with a ramp lesion is often not observed. On the contrary, there is anterior translation of the tibia in the medial compartment, compatible with the AMRI pattern. Bone bruising at the level of MTL tibial attachment can be seen in the acute setting. Attention should be paid to look for bone bruising and MTL avulsion 4 to 6 mm inferior to the tibial articular surface.[8,12] Thus, the combination of bone bruising, disruption of the MTL at its tibial attachment, and

Table 1. Pearls and Pitfalls

Pearls	Pitfalls
A more proximal PM portal makes working trajectory easier and therefore anchor implantation easier to achieve.	Avoid dissection beyond 6 mm inferior to the joint line, as this could injure the semimembranosus tendon attachments.
The use of a cannula through the PM portal is recommended for easier suture manipulation.	Avoid sliding off the posterior tibial cortex during anchor implantation.
A transseptal posterolateral view is preferred over a transnotch view.	Avoid using single-loaded anchors, as multiple fixation points are needed to reduce the tibial translation, and using more than 1 anchor can be challenging.
A lateral fluoroscopic view can help confirm the anchor is flush with the posterior cortex, due to limited visualization.	

PM, posteromedial portal.

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
Appropriate fixation of PHMM	Requires 6 weeks of protected weightbearing
Better rotational stability in the context of cruciate reconstruction	Additional surgical site morbidity related to the posteromedial working portal and dissection through the MCJ
AMRI reduction	Risk of injury to the saphenous nerve

AMRI, anteromedial rotatory instability; MCJ, meniscocapsular junction; PHMM, posterior horn of medial meniscus.

forward medial tibial plateau translation are signs highly suspicious of a reverse ramp lesion (Fig 4).

Diagnostic Arthroscopy

Diagnostic arthroscopy is performed through the anterolateral portal. The PHMM is first assessed with anterior probing. In a ramp lesion, probing often reveals anterior hypermobility of the PHMM. On the contrary, when the MTL is avulsed from its tibial insertion, anterior probing often does not reveal any instability. Lifting of the PHMM also does not reveal any MTL midsubstance disruption. Although the medial meniscus may look normal on examination, testing of rotational instability is key to reverse ramp examination to detect an AMRI pattern. With the knee in 20° to 30° of flexion, external rotation of the tibia often reveals meniscotibial mismatch, as the tibia translates forward while the PHMM remains in place due to the avulsed MTL, as highlighted in Figure 5. A transnotch view is then established to explore the posteromedial compartment; with the knee held in a semiflexed position and with a slight valgus load, the scope is driven through the notch beneath the posterior cruciate ligament fibers. At this point, the knee is positioned flexed at 90° to examine the posteromedial compartment. With MTL avulsion, the superficial aspect of the MCJ does not reveal any abnormalities as well, including partial rupture, or scarring from earlier tears. The PM working portal is then established to introduce a probe to further assess the MCJ and confirm its continuity. Using the landmarks in Figure 1 is a reliable technique to avoid multiple skin penetration and decrease soft tissue injury. This is in contrast to a standard ramp lesion, where this step often reveals signs of injury, suspicious for MCJ or MTL tear. Due to limited visualization, examination with tibial rotation is key to detect instability. A standard ramp lesion is often associated with PMRI, as internal rotation of the tibia is exaggerated due to disruption of the MCJ and/or midsubstance tearing of the MTL. In fact, this maneuver often helps with ramp lesion visualization and can reveal some of the hidden lesions.[4,7,10,13] In MTL avulsions, on the contrary, tibial internal rotation is often stable, but there is instability with external rotation compatible with the AMRI pattern, despite the integrity of the medial collateral ligament (MCL) and the posterior oblique ligament. At this point, combining the normal meniscal findings and the AMRI pattern on examination is highly suspicious for a reverse ramp injury.

Reverse Ramp Lesion Repair

Combining MRI findings and arthroscopic examination, MTL avulsion is now confirmed. A transseptal approach is recommended at this point for better

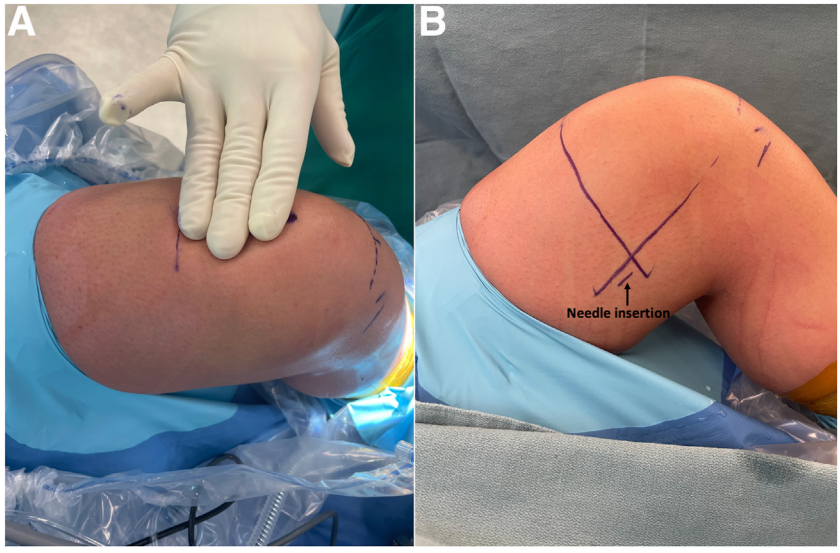

Fig 2. Superior (A) and medial side (B) views of a left knee positioned in 90° of flexion, showing skin landmarks for the external identification of the posteromedial portal. (A) The first line is drawn at 3 finger breadths from the superior patellar pole. (B) The second line is tangent to the tip of the inferior patellar border. The landmark for needle insertion is just posterior to the intersection of the 2 lines.

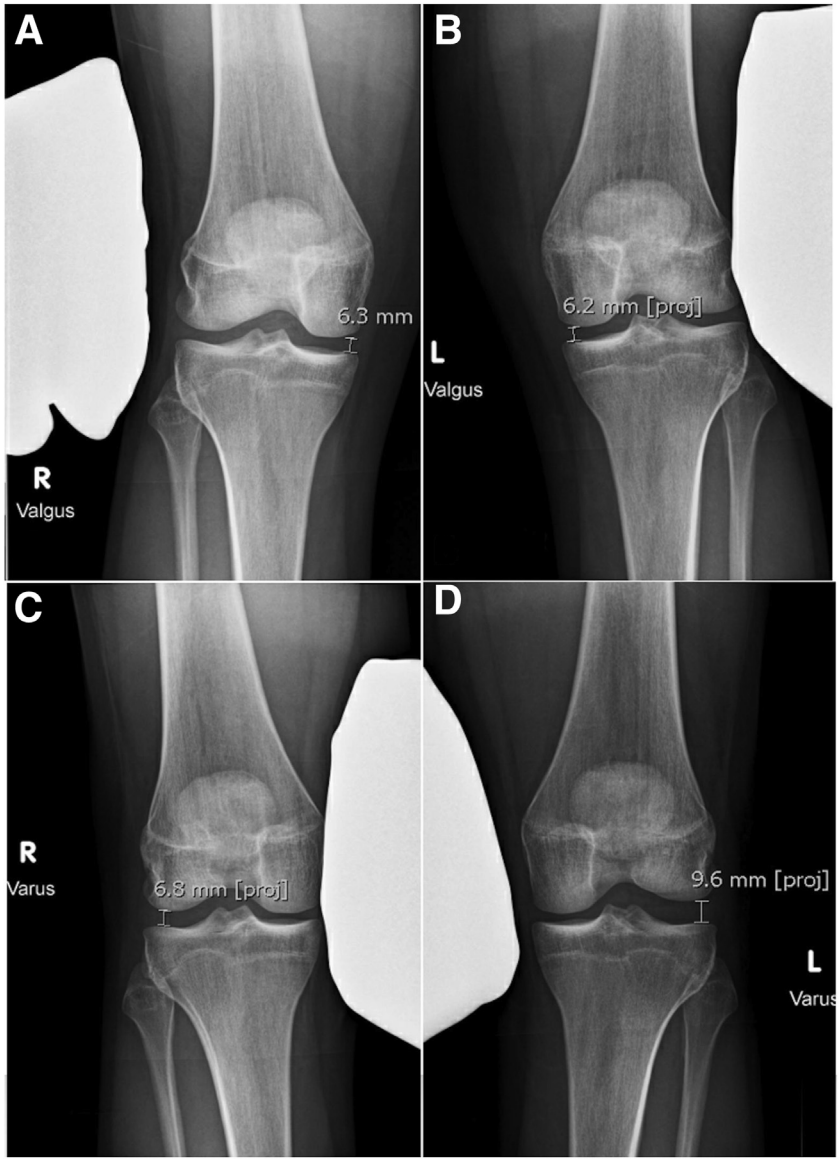

Fig 3. Bilateral knee preoperative stress views in a patient with left knee multiligament injury including combined anterior cruciate ligament and posterolateral corner (PLC) injury. Views A and B confirm an intact posteromedial corner with valgus stress. Views C and D demonstrate an unstable PLC on the left side with a side-to-side difference of 2.8 mm with varus stress.

visualization and easier suture manipulation. With the scope introduced through the posterolateral portal to establish a transseptal view, the probe is introduced through the PM portal. The MCJ is bluntly dissected toward the posterior tibial cortex, until the cortex is palpated. Recent anatomic studies confirmed the MTL tibial insertion is between 4 and 6 mm from the tibial articular surface and attaches approximately 7.7 mm medial to the center of the posterior meniscal root (Fig 1).[8] Keeping these measurements in mind, we aim toward that area from the PM portal. The trajectory angle should therefore be aiming medially and inferiorly (Fig 6A). The MTL can often be felt and elevated with the probe, which is another confirming sign of its avulsion injury. A working cannula is then introduced through the PM portal to facilitate the next steps. The MCJ is debrided using coblation in the trajectory previously created by the probe, in order to prepare for the repair, with care to avoid any extensive debridement of the normal MCJ. The cannula is then advanced through the MCJ and stabilized over the posteromedial tibial cortex to prepare for anchor fixation. After predrilling, the anchor is inserted. We prefer to use a double-loaded anchor to multiply fixation points. One double-loaded anchor is often sufficient to fix the MTL and reduce tibial forward translation. In this case, we used a 4.5-mm Twinfix Ultra suture anchor (Smith & Nephew). Once the anchor is deployed, the sutures are shuttled through the notch and the anterolateral portal, for easier suture manipulation. A suture hook device (Linvatec Spectrum II Suture Hook; CONMED) with a 90° curve is then used to shuttle sutures through tissue;

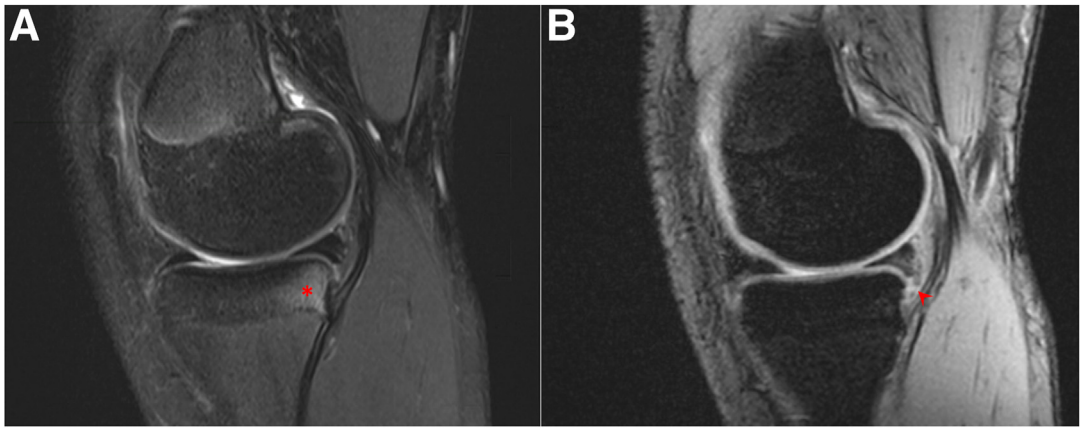

Fig 4. Magnetic resonance imaging views of the medial femorotibial compartment in a left knee compatible with a reverse ramp lesion. (A) Sagittal T2 fat-saturation view demonstrating bone bruising of the posteromedial tibial plateau (red asterisk) at the insertion of the meniscotibial ligament. (B) Sagittal T2 gradient recalled echo view demonstrating meniscotibial ligament avulsion tear from its tibial insertion (red arrowhead). It is important to note the forward translation of the tibial plateau relative to the femoral condyle, compatible with the anteromedial rotatory instability pattern.

left and right curved hooks are used for left and right knees, respectively. Both mattress or simple sutures can be used for fixation. To pass the sutures through both the MCJ and the MTL, a suture hook is first passed through the superior and normal MCJ perpendicular to the tibial cortex, 4 mm below the joint line or the PHMM. The hook is then passed through the MTL, which creates a different biofeedback, and sliding off the posterior tibial cortex to make sure all tissue thickness is captured. The first suture tail is therefore introduced through the soft tissue as previously mentioned, starting from the central area, medial to the meniscal root. We advise handling and fixation of the more central suture first, as tying the side knot first may make tissue penetration centrally harder to achieve. A suture manipulator is then used to retrieve both the suture tail and the wire of the suture hook through the anterolateral portal, and the suture relay is carried outside the joint, in order to retrieve the suture tail back from the posteromedial portal (Fig 6C). Of note, suture manipulation through the notch is performed easier with the knee in a semiextended position. With the knee back to 90° of flexion, a self-locking sliding knot is finally tied using a knot-pusher. The second knot is set more lateral to gather a wider area of soft tissue repair and tied in a similar fashion. At this point, external rotation laxity of the tibia should be reduced with repeat arthroscopic examination. After all meniscal work is done, we can proceed with ligament reconstructions.

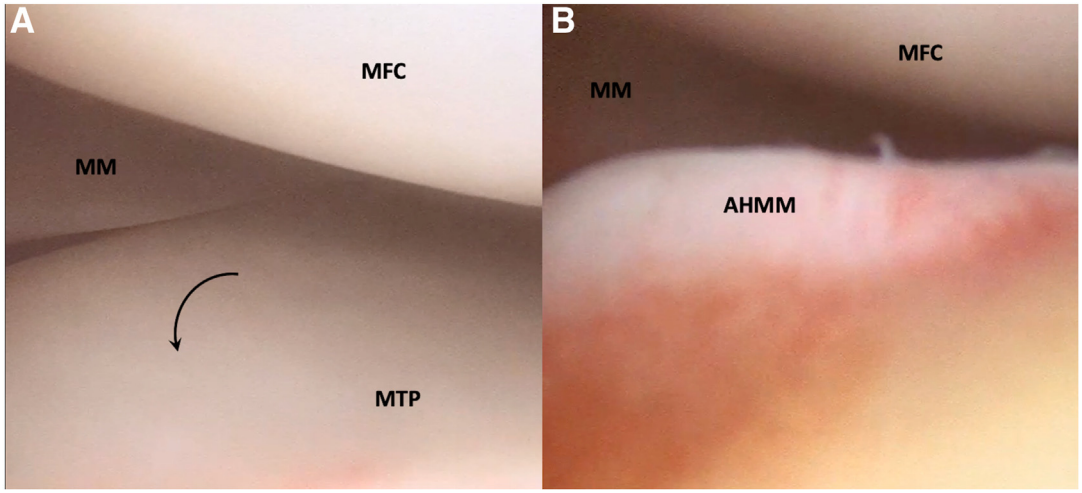

Fig 5. Arthroscopic views of the medial femorotibial compartment through the anterolateral portal in a left knee at 20° to 30° of flexion. (A) External rotation of the tibia reveals significant forward translation (black arrow) of the medial tibial plateau, suggestive of an underlying anteromedial rotatory instability (AMRI). (B) With the scope fixed in the same position as in position (A), internal rotation of the tibia shows reduction of the AMRI, with the anterior horn of the medial meniscus (AHMM) now visible. (MFC, medial femoral condyle; MM, medial meniscus; MTP, medial tibial plateau.)

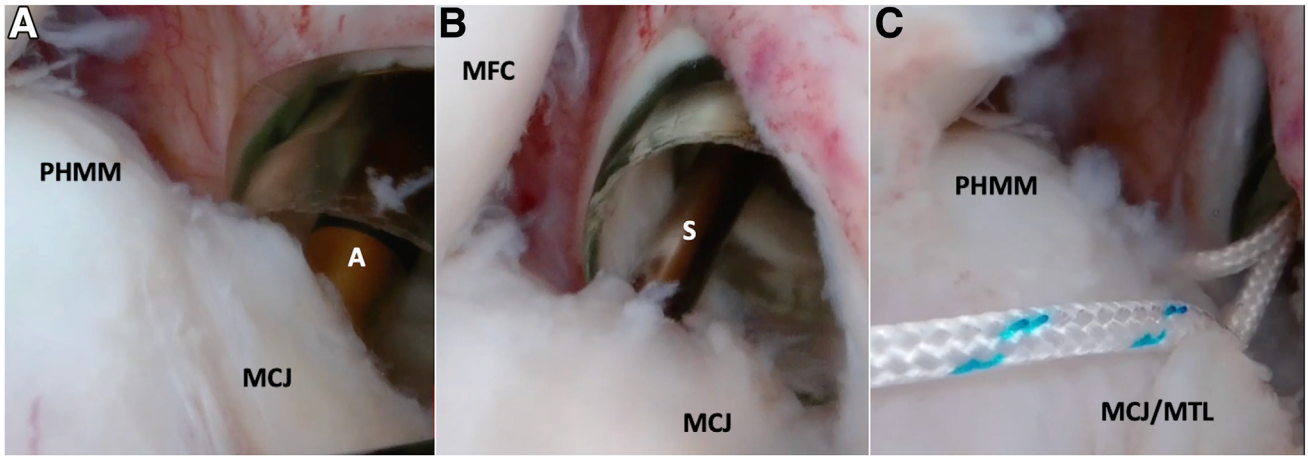

Fig 6. Arthroscopic views of the posteromedial compartment through the posterolateral portal in a left knee at 90° of flexion showing a reverse ramp lesion repair. (A) Anchor (A, in white) insertion into the posterior tibial cortex 4 to 6 mm below the joint line, after blunt dissection was done through the inferior part of the MCJ. (B) Suture hook repair of the MTL using a 90° left curved spectrum (S, in white). Passing through the MTL often creates a different biofeedback. (C) A double-loaded anchor with simple or mattress sliding knots is often sufficient for repair. (MCJ, meniscocapsular junction; MFC, medial femoral condyle; MTL, meniscotibial ligament; PHMM, posterior horn of the medial meniscus.)

Rehabilitation

The postoperative protocol is dictated by the overall injury and reconstruction procedures performed, but similar to any unstable meniscal repair, protected weightbearing is advised for 4 to 6 weeks. Flexion is limited to 90° for the first 6 weeks. Early rehabilitation is focused on maintaining full extension and quadriceps vastus medialis oblique activation. Return to non-pivoting sports activities can be started at 4 months postoperatively, with full activities at 8 to 9 months.

Discussion

The presented technique involves the arthroscopic exploration and repair of MTL avulsion injury, or reverse ramp lesion. The term "reverse ramp" was introduced due to major differences between MTL avulsion injury and previously described ramp lesions,[7] including mechanism of injury, tear location, MRI findings, arthroscopic examination, and repair techniques. The most important factor is the injury pattern associated with each of the 2 injuries. Ramp lesions are typically described and evaluated in the setting of ACL tears.[13,14] The exact mechanism of injury is not fully understood. It is hypothesized that a reflex contraction of the semimembranosus tendon secondary to anterior tibial translation during ACL injury may explain a MCJ disruption.[10,15] On the contrary, a reverse ramp was found only in the setting of multiligament injury combining ACL and PLC injury. We hypothesize that a concomitant PLC injury would support the extensive AMRI pattern and would lead to MTL avulsion from its tibial attachment.

Ramp lesion is initially described with PMRI,[10] but recently it was found associated with both internal rotation (IR) and external rotation (ER) instability.[12] Biomechanical studies in ACL-deficient knees confirmed both increased anterior translation and rotatory instability with ramp lesions and better rotational stability after ACLR + ramp repair.[2,5,16] However, the rotational part is still not fully understood. Some studies showed correlation only with ER laxity,[5,16] and some showed correlation with both IR and ER laxity.[2] Smith et al.[5] evaluated the effect of both MTL disruption versus peripheral or meniscocapsular tear and found similar findings with regards to anterior and rotational laxity. However, their MTL disruption was close to the joint line, which could explain the similarities in both groups. We feel differences in rotational instability are in part due to the location of ramp injury; a more proximal MTL tear or a MCJ disruption could induce both IR and ER instability, as reported in most cadaveric studies. On the contrary, if it is inferior and close to the tibial attachment, as is the case with MTL avulsion, it would more often lead to ER laxity only, compatible with both the AMRI pattern found in such injuries and the stable PMRI on examination.

MRI evaluation is crucial as a preoperative arsenal in multiligament knee injuries,[17] especially in the acute phase where clinical examination is not reliable to detect rotational laxity. Interestingly, a tear in the MTL on MRI was found in 50% among traumatic knee dislocations and in 100% of the cases when an injury to the PHMM was associated.[18] This supports our observation where MTL avulsion injuries are often observed in the setting of a multiligament knee injury, particularly a combined ACL-PLC injury. Thus, we urge the surgeons to suspect a reverse ramp lesion whenever the MRI reveals the signs described above (i.e., the

combination of bone bruising and/or disruption of the MTL at its tibial attachment 6 mm below the joint line, as well as forward medial tibial plateau translation in the absence of injury to the MCL or other components of the posteromedial corner).

Arthroscopic examination is the gold standard to diagnosing meniscal ramp lesions.[19] Similarly, in a reverse ramp injury, examination under direct visualization as described in this technique is important to detect MTL avulsion. We emphasize the importance of meniscotibial mismatch with forward tibial translation, as opposed to the meniscal hypermobility on anterior probing, often found in a classic ramp lesion. Thus, an isolated AMRI pattern with a stable PHMM is consistent with a reverse ramp lesion.

With recent arthroscopic advances, numerous techniques are described to repair meniscocapsular injuries using inside-out, all-inside devices or, more commonly, using a suture hook repair.[6,12] More recently, there have been attempts to repair using 2 PM portals,[20] a transseptal approach,[21] and even using a scorpion suture passer.[22] The use of suture anchors has shown reliable fixation for MTL repair in cadaveric studies with open posterior dissection.[2,5] In fact, anchors are the optimal fixation to reattaching the MTL and its MCJ to its tibial insertion, as it is required in cases with avulsed MTL. Ramos et al.[23] used suture anchors to repair MTL injuries among patients with injury to the posteromedial corner, using an open approach as well. Recently, suture anchor fixation was arthroscopically demonstrated for an unstable ramp lesion repair concomitant to ACLR, with stable attachment on second-look arthroscopy at 12 to 24 months after surgery.[9] The current article offers an alternative approach to fixing MTL avulsion or reverse ramp injuries and a salvage plan whenever primary repair of a ramp lesion is not feasible.

The classification of ramp lesions by Thaunat et al.[7] sheds light on the importance of the MTL. Ramp lesion types 1 and 2, sparing the MTL, are not associated with significant instability or notable meniscal mobility on probing, as opposed to the remaining 3 categories that include a MTL disruption, and therefore are often unstable requiring repair. In particular, type 3 ramp lesions include partial inferior tears or hidden lesions. A modified classification recently identified type 3B as an isolated MTL tear.[24] In both classifications, the tear location described was mid-substance or at the PHMM attachment. Thus, MTL avulsion from its tibial insertion has not been described to date. Although a reverse ramp injury has its differences compared to a ramp lesion, it could still be considered a hidden lesion. We propose an algorithm for identification and treatment of reverse ramp injuries, as proper management is associated with better rotational stability in ligamentous knee injuries (Fig 7).

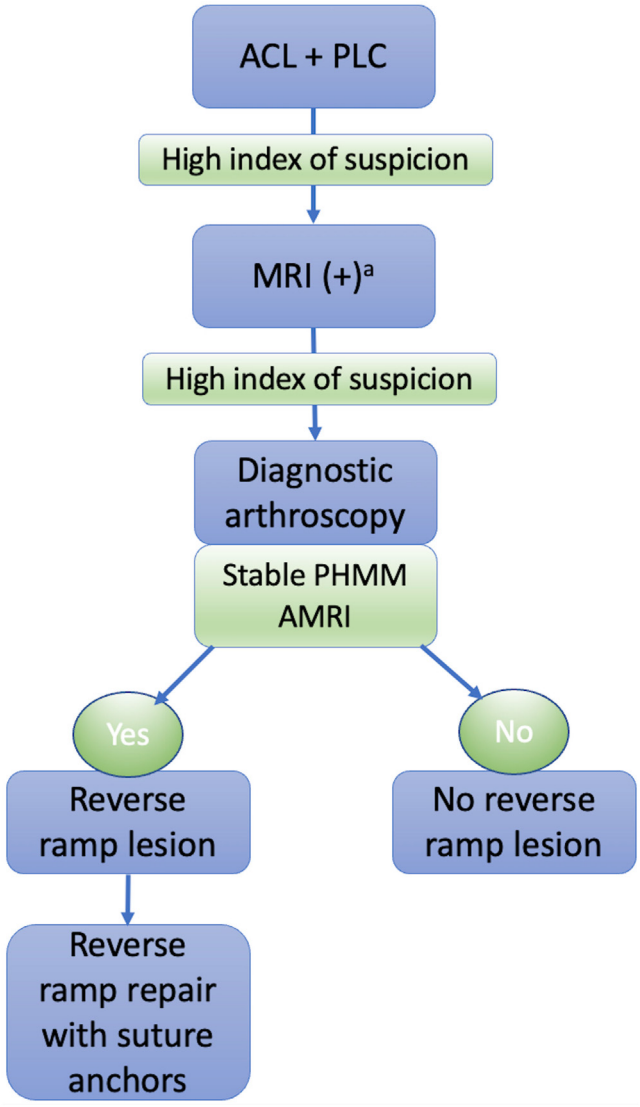

Fig 7. Proposed algorithm for diagnosis and management of a reverse ramp lesion in the setting of a combined ACL-PLC knee injury. [a]Combination of bone bruising, disruption of the meniscotibial ligament at its tibial attachment, and forward medial tibial plateau translation. (ACL, anterior cruciate ligament; AMRI, anteromedial rotatory instability; MRI, magnetic resonance imaging; PHMM, posterior horn of the medial meniscus; PLC, posterolateral corner.)

Disclosures

The authors report the following potential conflicts of interest or sources of funding: C.R.M. is a consultant and co-founder of Tactile Orthopaedics, received grants from Smith & Nephew, and is a consultant for Arthrex, outside the submitted work. All other authors (J.R., P.D.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

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