Pediatric Ramp Lesions

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Abstract: Meniscocapsular separations of the posterior horn of the medial meniscus, also known as ramp lesions, are common injuries associated with anterior cruciate ligament (ACL) tears. Though there is ample literature on ramp lesion diagnosis, treatment, and outcomes in adult populations, there is scarce work in pediatric populations where increasing ACL tear rates and different injury patterns make more studies and discussion on this topic paramount. We therefore review the available literature on ramp lesions as it relates to pediatric populations as well as anatomic and technical considerations that should be considered in this group of patients.

Key Points:

- Variably referred to as meniscocapsular separations of the PHMM, meniscosynovial tears, or ramp lesions, the definition of a ramp lesion is inconsistent across sources.
- The PHMM serves as a secondary restraint to anterior tibial translation, with forces on a reconstructed ACL graft increasing after medial meniscectomy.
- Imaging diagnosis of ramp lesions is based on the identification of irregularity of the peripheral meniscal margin or the presence of a vertically oriented cleft of fluid-like signal at and around the meniscocapsular junction.
- Detection of ramp lesions is highest with either placement of either a 30˚ or 70˚ scope through the standard anterolateral portal and obtaining the modified Gillquist view or through creation of an accessory posteromedial portal allowing for direct visualization.
- The repair technique should be chosen based on surgeon comfort and safety performing whatever technique is chosen, and the peripheral location of the ramp lesion should provide adequate blood supply for healing regardless of the technique used.

Introduction

Among U.S. children, the incidence of anterior cruciate ligament (ACL) tears has significantly increased since the early 1990s, with recent rates close to 400 tears per 100,000 patient-years in adolescent age groups.[1] This is likely in part a result of increased youth involvement in sport-related activities over this period, as well as increased year-round youth sports participation.[2] Pediatric ACL injuries are associated with concomitant meniscal tears in approximately 40-50% of cases.[3,4] One particular meniscus pathology that has gained recent interest is known as a "ramp" lesion, or a meniscocapsular separation of the posterior horn of the medial meniscus (PHMM).[5] Anatomic studies have demonstrated the importance of the PHMM as a

secondary restraint to anterior tibial translation, but ramp lesions have historically not been consistently identified or well understood.[6-9] While there has been increased interest in diagnosing, treating, and understanding the effects of ramp lesions in the adult orthopedic literature, little information about ramp lesions in pediatric patients currently exists. Therefore, this review will attempt to summarize the available information about ramp lesions in pediatric populations and will discuss some of the anatomic and treatment differences that should be considered for this age group.

Definition

Variably referred to as meniscocapsular separations of the PHMM, meniscosynovial tears, or ramp lesions, these terms generally describe tears of the meniscocapsular junction between the PHMM and the joint capsule.[10] The term "ramp lesion" was first coined by Strobel and originally referred to a meniscus injury of the peripheral attachment of the posteromedial meniscus seen in ACL deficient knees.[11] However, several authors more recently have considered vertical red-red zone tears of the posteromedial meniscus and meniscotibial tears (more commonly referred to as hidden lesions) to be ramp lesions as well.[12,13] There is, therefore, no true consensus on the definition of a ramp lesion, which makes the comparison of incidence, imaging findings, and outcomes difficult.[5] One study recently proposed a classification system for these lesions, although it has yet to gain traction in the literature.[14]

Anatomy

The medial meniscus has more peripheral attachments to the capsule and is significantly less mobile in the normal knee than the lateral meniscus. The PHMM serves as an important secondary restraint to anterior tibial translation, with forces on a reconstructed ACL graft increasing between 33-50% after medial meniscectomy in biomechanical studies.[15] Cadaveric ACL-deficient knees with ramp lesions also demonstrate increased tibial translation, pivot shift, and external rotation,[6-8] with restoration of knee stability only after simultaneous ACL reconstruction and ramp repair.[16] Anterior tibial translation and rotational laxity in normal knees are highest at younger ages and subsequently decrease with time.[17,18] This increased laxity in children may subject the meniscus and meniscocapsular junction to higher stresses at the time of ACL tear, and therefore may result in different meniscal tear patterns and a higher incidence of ramp lesions in children as compared to adults.

Authors	Year	N	Age Group	Ramp Lesion Definition	Population (and exclusions)	Prevalence
Liu [12]	2011	221	10-20 years	Peripheral attachment of the PHMM at the synovial-meniscus junction or in the red-red zone	ACL reconstruction (no notable exclusions)	20.8%
0.4	2018	56	12-17 years	Longitudinal tears of the peripheral attachment of the PHMM at the meniscocapsular junction	ACL reconstruction (excluded multi-ligamentous injuries)	23.2%
Sonnery-Cottet [30]	2018	938	<20 years	Medial meniscocapsular tear of the PHMM	ACL reconstruction (excluded multi-ligamentous injuries and other medial meniscus pathology)	27.2%

Table 1. *Ramp Lesion Prevalence in Pediatric Populations*

However, no studies have specifically examined this association yet.

Pediatric patients have several other key anatomic differences from their adult counterparts to consider when treating ACL injuries, including open physes, more cartilaginous joints, and decreased motor control and coordination as they adjust to their growing bodies. Menisci in children >10 years old are mostly composed of type I collagen fibers, with only the peripheral 10-30% of the meniscus still vascularized by the age of 10 years, similar to what is observed in adults.[19,20] Therefore, it is unlikely that intrinsic meniscal anatomy is significantly different between adolescents and younger adults. One setting in which the intrinsic anatomy of the meniscus does differ from normal meniscal tissue is in the discoid meniscus, which is present in up to 0.1-17% of children.[21] Discoid menisci are more common in the lateral meniscus, but histologic studies have shown that both the medial and lateral meniscus in these patients is composed of less organized, more immature appearing tissue than in normal patients, and is therefore at greater risk of tearing.[21] However, the ramifications of this abnormal tissue on the incidence of ramp tear and ACL injury is unknown.

Prevalence and Risk Factors

The rate of concomitant ramp lesions in the setting of ACL injury have been reported to be between 9-30% in adult populations.[22,23] Among adolescents, one study noted a 20.8% incidence (46/221) for patients aged 10-20 years, while another showed slightly higher rates among patients aged <20 years old (255/938 = 27.2%) (Table 1). In both studies, the prevalence of ramp lesions in patients <30 years old was significantly greater than that for patients aged >30. Another group found that patients with ramp lesions were an average of 7.5 years younger than patients without such lesions, though not specifically in a pediatric population.[24] In the only true pediatric study of ramp lesions, Malatray et al. demonstrated a 23.2% (13/56) prevalence of ramp lesions associated with ACL tears in a small cohort.[25] Other studies have included pediatric patients but did not separate them for analysis.[9,13,23,26-29]

Several risk factors for ramp lesions have been reported. Revision ACL procedure has been shown to be an independent risk factor for ramp lesions, although it is unknown if the ramp lesions were missed at the time of initial injury and were a risk factor for the recurrent injury, or if they were sustained at the time of the recurrent injury.[30] In pediatric patients who may be more likely to return to sports after operative treatment than adults, the associated high rate of ACL graft tear requiring revision surgery may in part, account for the observed increased incidence of ramp lesions in younger populations. In addition, increased time from injury to surgery is associated with a higher incidence of medial meniscal lesions in adolescent patients with chronically ACL-deficient knees.[3,31,32] Though not separately analyzed, two studies including adolescent patients demonstrated that progressively increased time from injury to surgery was also associated with a higher incidence of arthroscopically detected ramp lesions.[12,30]

It has also been reported that males have a higher incidence of ramp lesions,[12,30] which is in contrast to the overall significantly higher rates of ACL tears observed among female youth athletes.[33] Though there has been no study examining why males are more likely to sustain ramp lesions, there may be some association with the higher hamstrings to quadriceps strength ratio that has been observed in male athletes compared to female athletes.[34] There are two proposed theories to explain the mechanism of ramp lesions, one being that they arise due to contraction of the semimembranosus at its insertion along the posteromedial capsule, which may stress the peripheral meniscus and lead to meniscocapsular tearing at the time of injury or during subsequent instability episodes.[16] If this is the case, males with stronger hamstrings may actually have higher stresses on the attachments of the PHMM to the capsule and be more likely to sustain a ramp lesion. Other studies have shown that contact mechanism of injury is a risk factor for ramp lesions.[26,28] In younger patients

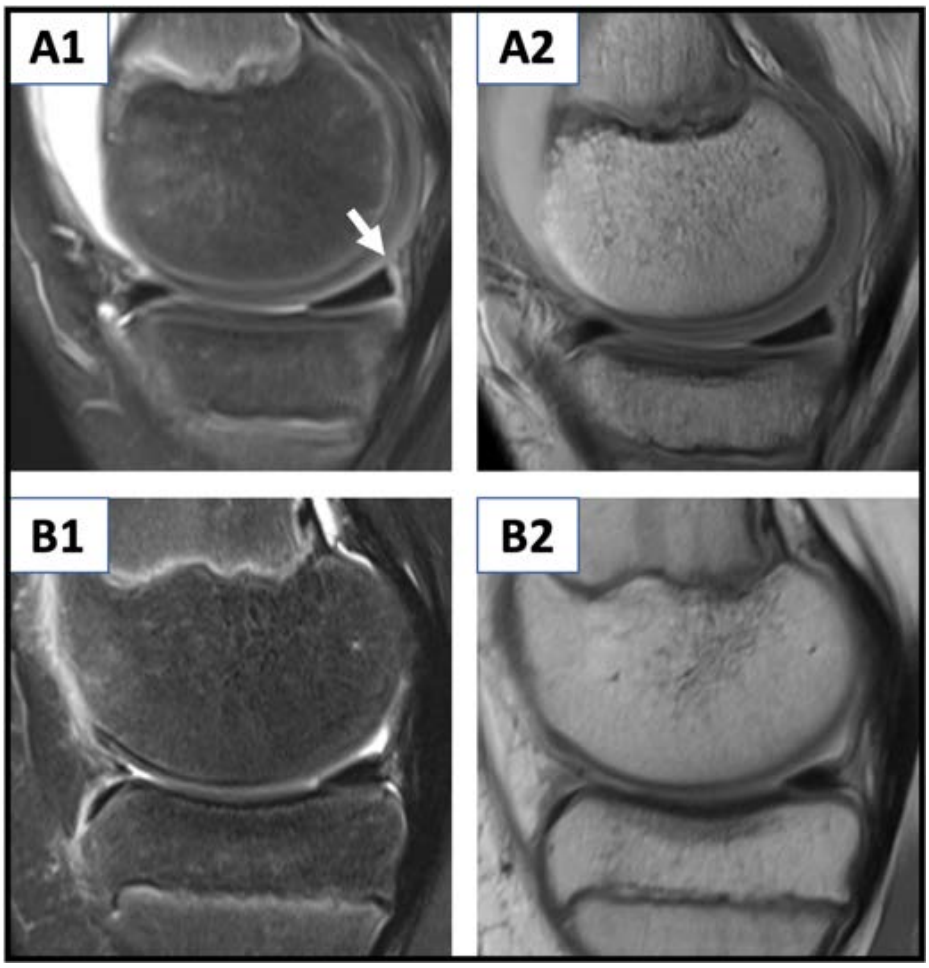

Figure 1. *Sagittal MRI images from a 13-year-old male with a ramp (A1, A2) and 13-year-old female with a normal meniscocapsular junction (B1, B2). The cleft of fluid-like signal intensity at the meniscocapsular junction (arrow) is more conspicuous on T2-weighted (T2W) fat-suppressed images (A1, B1) than on intermediate-weighted (A2, B2) images.*

actively involved in high-demand activities and sports that require sharp cuts and high agility, it is likely that increased shear forces and torsion on the knee may lead to higher rates of damage to the capsule and menisci, which further serves to increase ramp lesion incidence.[35] Because male youth athletes suffer a higher proportion of contact-related ACL tears compared to females, it may be that the tear mechanism in males further predisposes them to a higher incidence of ramp lesions.[36]

Physical Exam and Imaging Findings

Although no preoperative physical exam findings have been identified that are specific for ramp lesions, the decreased reliability of the history and physical exam in younger children may warrant a m ore thorough evaluation for the presence of meniscal pathology using magnetic resonance imaging (MRI) and arthroscopic exam.[37] One study of arthroscopic cases demonstrated that the diagnosis of knee pathology based on clinical exam alone was only accurate in 18% of cases in patients under 14 years old, versus 44% in patients >14 years of age.[38] However, pain at the posteromedial joint line or other physical exam findings consistent with a potential medial meniscus tear should still alert the surgeon to look more closely at preoperative imaging or the arthroscopic exam for the presence of a ramp lesion if there is no other obvious medial meniscus pathology.

On MRI, the diagnosis of a ramp lesion typically relies on the identification of irregularity of the peripheral meniscal margin or the presence of a vertically oriented cleft of fluid-like signal at and around the meniscocapsular junction of the PHMM on sagittal fluid-sensitive images (Figure 1).[23,39] Overall, the sensitivity of MRI ranges from 48-86%,[27,40] while the specificity is 79-99%.[40,41] In a pediatric population, no definitive diagnostic criteria have been established. Malatray reported a MRI sensitivity of 23% and specificity of 98% for the detection of ramp lesions.[25] This sensitivity is much lower than that observed in adult populations and may be a result of imaging characteristics particular to children, as other studies have also demonstrated lower sensitivity and specificity for the detection of meniscal lesions in pediatric patients on MRI.[42,43] An increased prevalence of high-signal

intensity within the periphery of the menisci has been reported in children (66% vs. 29%) when compared to adults.[44] This finding has previously been attributed to normal vascularity that progressively decreases with age,[44] but can overlap with grade 3 signals and be mistaken for a meniscal tear. These physiologic changes were most commonly observed in the PHMM, which may further explain the limitations in accurately identifying ramp lesions in children on MRI.

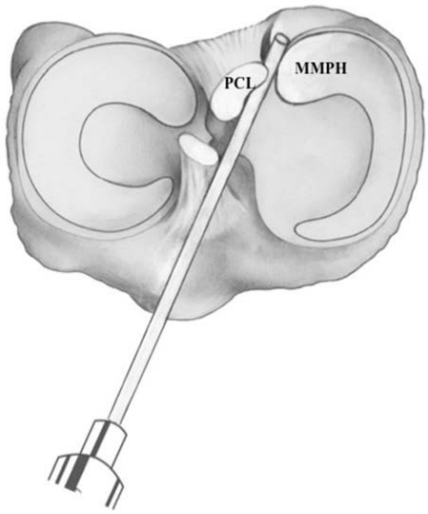

Figure 2. *Schematic demonstrating the modified Gillquist view. PCL stands for Posterior Cruciate Ligament, and MMPH stands for Medial Meniscus Posterior Horn. Reprinted by permission from Springer Nature Customer Service Centre GmbH: Springer Nature. Knee Surgery, Sports Traumatology, Arthroscopy. Arthroscopic posteromedial drive-through test in posterior cruciate ligament insufficiency: a new diagnostic test, Kyung-Wook Nha et al. (2014).*

Visualization

Arthroscopic identification of ramp lesions often requires the use of additional visualization tools or accessory portals, as the posteromedial meniscocapsular junction is not easily seen in a standard diagnostic knee arthroscopy. When viewing the medial compartment, a probe can be used to feel for a separation of the meniscus and capsule posteriorly, as well as for any extrusion of the medial meniscus into the joint. Because this technique has low sensitivity, two consistent techniques have also been used to examine the knee for ramp lesions: (1) placement of either a 30˚ or 70˚ scope through the standard anterolateral portal, and obtaining the modified Gillquist view by driving through the intercondylar notch medial to the PCL (Figure 2), or (2) creation of an accessory posteromedial portal through which the lesion can be directly viewed (or probed if the scope remains in the anterolateral portal (Figure 3).[10] When utilizing a posteromedial portal as the gold standard for detecting ramp lesions, the sensitivity of the anterolateral portal and modified Gillquist view is widely variable in adults and is likely technique dependent.[13,45,46] However, the sensitivity can be improved if a 70˚ scope is used versus a 30˚ scope, improving from 48% to 100% in one study.[45] In a pediatric population, the reported sensitivity using a 30˚ scope through the intercondylar notch was 100%, while traditional anterolateral portal sensitivity was low at 8%.[25]

In cases where a posteromedial portal is required, a less invasive alternative prior to creating the portal is to insert a spinal needle into the posteromedial compartment while viewing through the notch for probing of a suspected ramp lesion.[8] The biggest concern with posteromedial portal creation in all populations is the potential damage to the saphenous neurovascular bundle.[47] In children and adolescents, this risk is theoretically increased due to smaller anatomic size and closer proximity of these structures to the site of portal placement. Therefore, in a pediatric population, thorough evaluation for a ramp lesion using other techniques should be conducted prior to the creation of a posteromedial portal.

Indications for Fixation

Because both adults and children have good blood supply to the periphery of the meniscus (within 3mm of the capsule), both groups should be able to heal ramp lesions appropriately, regardless of the fixation technique used. As a result, indications for fixation do not necessarily differ between adults and children at this

point. In adult populations, it has been reported that ramp lesions up to 1.5cm can heal without surgical fixation, provided that the lesion is initially stable and that the knee is stabilized adequately through a successful ACL reconstruction.[48] While others have reported similar findings,[49,50] one article concluded that peripheral PHMM tears >1 cm should be repaired during concurrent ACL reconstructions.[51] DePhillipo et al. reported that the majority (89%) of U.S. sports surgeons use the extent of the tear (i.e., partial vs. full thickness) and the stability of tear upon probing (81%) as the main criteria for intraoperative decision making.[52] Additionally, 58% of surgeons indicated the size of the tear (i.e., >2.5 or <2.5 cm in length) was a decision-making criterion, with 25% also citing involvement of the meniscotibial ligament as a criterion for meniscal repair. A more recent study found that ramp lesions of 2.5cm did not affect the biomechanics of the ACL-intact knee unless the meniscus subluxated into the joint, suggesting that the indications for fixation may be relatively limited.[53] Overall, more research is required to identify appropriate candidates for repair, both in the adult and pediatric population.

At the senior author's institution, ramp lesions are surgically repaired if the tibial plateau can be observed through the lesion intraoperatively with probing, signifying a larger full-thickness tear. Additionally, intraoperative assessment of lesion stability helps to determine whether the meniscus is providing adequate secondary stabilization to the ACL, so an unstable or subluxating lesion is an important factor in the decision-making algorithm and is typically repaired.

Techniques for Fixation

Many surgeons have reported using a standard all-inside technique for ramp lesion repair with success.[30,54-60] Some report utilizing the all-inside approach with an additional posterolateral trans-septal portal, noting better protection of neurovascular structures with this technique.[61,62] Only two studies have evaluated inside-out repair of ramp lesions, reporting that even though the inside-out technique is more technically demanding, it

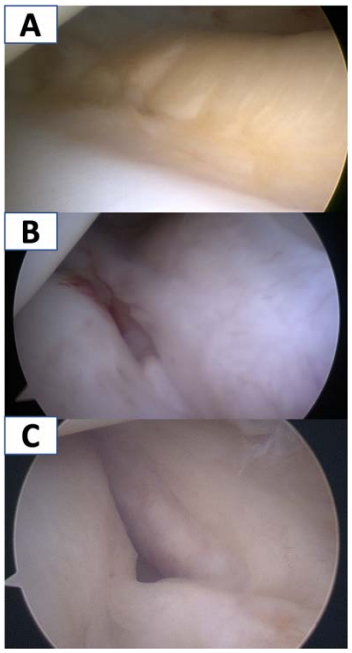

Figure 3. *Arthroscopic images from a patient with a normal meniscocapsular junction (A), and two patients (B, C) with intraoperatively identified ramp lesions.*

provides greater versatility in suture placement and allows the surgeon to pass a greater number of sutures, thereby creating a stronger repair.[63,64] As previously discussed, the peripheral location of the ramp lesion should provide adequate blood supply for healing regardless of the technique used, and the repair technique should be chosen based on surgeon comfort and safety performing whatever technique is chosen. This is particularly important in pediatric patients, as the overall distance of neurovascular structures from the joint capsule is even smaller than in adults. For example, the average distance from the posteromedial meniscus to the popliteal artery is 20.3mm in children 9-11 years old and decreases with age and child size.[65] This should be considered with any ramp or posteromedial meniscus repair technique chosen in children.

Our institution uses multiple techniques for fixation including all-inside, inside-out, and outside-in repairs depending on the severity of the tear and concomitant injuries. In an all-inside technique for ramp lesion repair, a curved suture passer is inserted posteromedially and passed through the posterior capsule and then the meniscus, with suture passage and sequential tying executed from medial to lateral. Tears that occur in the peripheral aspect of the meniscus are often treated with a

more standard all-inside suture device. Larger tears that extend into the body of the meniscus peripherally can be managed with a combination of all-inside and inside-out techniques.

Outcomes

The literature regarding ramp lesion outcomes after repair is scarce. No comparative studies of ramp lesion repair have demonstrated a significant difference in outcome based on operative technique, including all-inside repair versus simple abrasion/trephination, but ramp lesion repair is likely to lead to healing regardless of the technique used.[48,66] Ramp lesion repair failure rate has been reported to be of 6.8% (9/132), which was based on the need for a subsequent reoperation on the meniscus for pain or symptoms, though the average age of the study population was 26.4 years.[56]

While the data regarding ramp lesions in children is lacking, there are multiple studies of outcomes after medial meniscus repair in the pediatric population. Some authors have found that the risk of meniscal failure after medial meniscus repair is significantly higher than for lateral tears [67-70], though this has not been consistently demonstrated.[71,72] Nevertheless, in general, repairing meniscus tears seems to significantly improve clinical outcomes in the pediatric population,[68,72,73] and repair of a concomitant ACL tear further improves results.[71] Significant increases in Lysholm scores at one year specifically after medial meniscus repair have been demonstrated, with an average return to sport of 5.5 months.[74] While these studies are not specific to pediatric meniscal ramp lesions, children do benefit from stabilization of meniscal injuries and will likely show clinical improvement after repair of more unstable ramp lesions compared to those that are not identified and repaired. However, future studies are required to better understand the ramifications of repair and observation of smaller, more stable pediatric ramp lesions.

Summary

Meniscal ramp lesions are an increasingly recognized injury in the setting of ACL tear. The biomechanical and clinical ramifications of these lesions are being studied in the adult population, but minimal research has been done to understand these lesions, specifically in the pediatric population. Because ACL injuries are occurring at higher rates in the pediatric population than in the past, and because ACL re-injury is a significant challenge in pediatric ACL care, ongoing work is needed to improve our understanding, identification, and treatment of ramp lesions in the pediatric population.

Additional Links

Ramp Lesion Repair (Mathieu Thaunat):
https://www.youtube.com/watch?v=Z9TPKHZgmTY

Ramp Lesion Repair (Thomas DeBerardino):
https://www.arthrex.com/resources/video/SmWc76SYn0CEGAFd0fgkzw/meniscus-ramp-lesion-repair

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