



Medial meniscal posterior horn tears and ramp lesions in pediatric patients: lessons learned

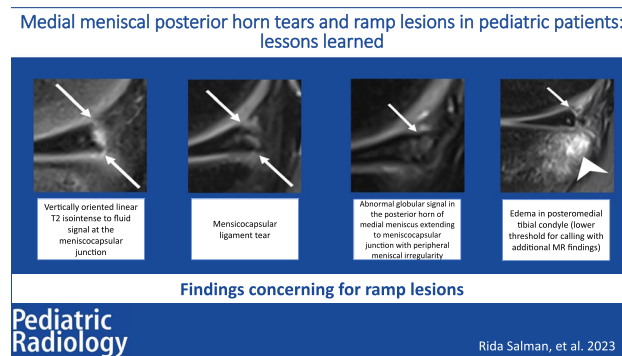
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Abstract

Meniscal injuries are increasingly reported in pediatric patients due to early sports participation and are commonly encountered during anterior cruciate ligament reconstruction. Preoperative identification of meniscal tears is crucial, particularly when involving the posteromedial meniscocapsular junction (ramp lesion). MRI plays an important role in detecting this particular type of meniscal injury. Consequently, pediatric radiologists should be aware of particular MRI findings related to ramp lesions including the presence of a medial meniscal tear, peripheral meniscal irregularity, meniscocapsular junctional fluid-like signal intensity, and capsular ligament tears. Thus, we illustrate the lessons we have learned from our institutional multidisciplinary arthroscopic-MR correlation conference for retrospectively identified posterior horn medial meniscal tears and ramp lesions.

Graphical Abstract



Keywords Arthroscopy · Medial meniscus · Meniscal tear · Meniscocapsular separation · MRI · Pediatric · Posterior horn · Ramp lesion

Key points

- MRI findings associated with posterior horn medial meniscus tears and ramp lesions include fluid signal intensity filling the meniscocapsular junction, capsular ligament tearing, and peripheral meniscal irregularity.
- The presence of marrow edema within the posterior-medial tibial plateau should lower the threshold to call a meniscal tear in the presence of additional posterior horn medial meniscal signal abnormalities.
- Keep in mind when you discuss discrepant results with surgical teams that false positive MRI results can sometimes be attributed to interval spontaneous healing.

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Introduction

Pediatric meniscal injuries, historically considered rare, are increasingly reported among skeletally immature patients, mainly due to early sports participation and intensive athletic activity [1–3]. Meniscal tears are frequently identified in pediatric patients undergoing anterior cruciate ligament (ACL) reconstruction with a reported prevalence up to 69% [4]. A particular type of meniscal injury in and around the

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posteromedial meniscocapsular junction, known as a meniscal ramp lesion, is the subject of renewed focus due to its biomechanical consequences and prognostic implications in ACL reconstructive interventions [5, 6]. Correction of anterior tibial translation and external rotational laxities can be achieved in patients undergoing ACL reconstruction when combined with posterior meniscocapsular repair [7]. In addition, specific arthroscopic attention and maneuvers are needed to identify and repair ramp lesions while exploring the posteromedial area of the knee [5]. Failure to identify and fix a co-existing ramp lesion might lead to early osteoarthritis, meniscal re-tear, and ACL graft failure [1, 6].

Diagnostic imaging plays a critical role with regards to obtaining this preoperative diagnosis, with MRI being the modality of choice to identify meniscal tears inclusive of ramp lesions [5, 6]. The reported diagnostic accuracy of MRI for pediatric meniscal tears varies between 78 and 93%, with a sensitivity of 59–87.5% and a specificity of 77–91% for medial meniscal tears [3, 8]. A few studies highlight the findings of ramp lesions on MRI in both pediatric and adult patients, including: the presence of a medial meniscal tear, peripheral meniscal irregularity, meniscocapsular junctional fluid-like signal intensity, and capsular ligament tears [5, 6, 9]. Pediatric radiologists need to be familiar with these findings to accurately make the diagnosis.

In this pictorial essay, we review the normal anatomy of the posterior medial meniscus and aim to illustrate the discrepancies between knee MRI reports and intraoperative arthroscopic findings of posterior horn medial meniscal and meniscocapsular junction tears (ramp lesions) in children and adolescents who had preoperative imaging at our institution. We aim to highlight the diagnostic challenges that radiologists may face while prospectively identifying ramp lesions and differentiating these injuries from normal variations of meniscocapsular attachments on MRI.

Institutional multidisciplinary arthroscopic-MRI correlation conference

At our quaternary children's hospital, we hold a monthly conference where pediatric musculoskeletal (MSK) radiologists and orthopedists present discrepant findings between MRI and arthroscopy. We discuss retrospective reviews of MRI examinations with arthroscopy as the reference standard. Discrepant findings are categorized into two groups: findings seen during arthroscopy but not described on MRI and findings described on MRI that were not seen during arthroscopy. We perform a second review of the MRI examinations to check if we agree or not with the arthroscopic findings. Figure 1 illustrates the flow chart showing the discrepant findings and retrospective MRI review results for 910 children and adolescents between January 2018 and

October 2022, with focus on posterior horn medial meniscal tears and ramp lesions.

Standard sports MRI protocol

At our institution, the standard knee sports MR imaging protocol includes the following sequences: axial and coronal proton density (PD) with fat-saturation (FS) and sagittal PD non-FS and sagittal T2-weighted FS images. An additional coronal T1-weighted non-FS sequence is obtained if the child is younger than 10 years old. Table 1 summarizes the scan parameters used at our institution.

The exams were performed on either 1.5-Tesla (T) or 3-T magnets within Philips Ingenia (Philips Healthcare, Best, the Netherlands) and Siemens Skyra, Aera, Vida, and Sola platforms (Siemens Healthineers, Erlangen, Germany) using a 15-channel, 16-channel, or 18-channel knee coil, depending on the magnet used for scanning.

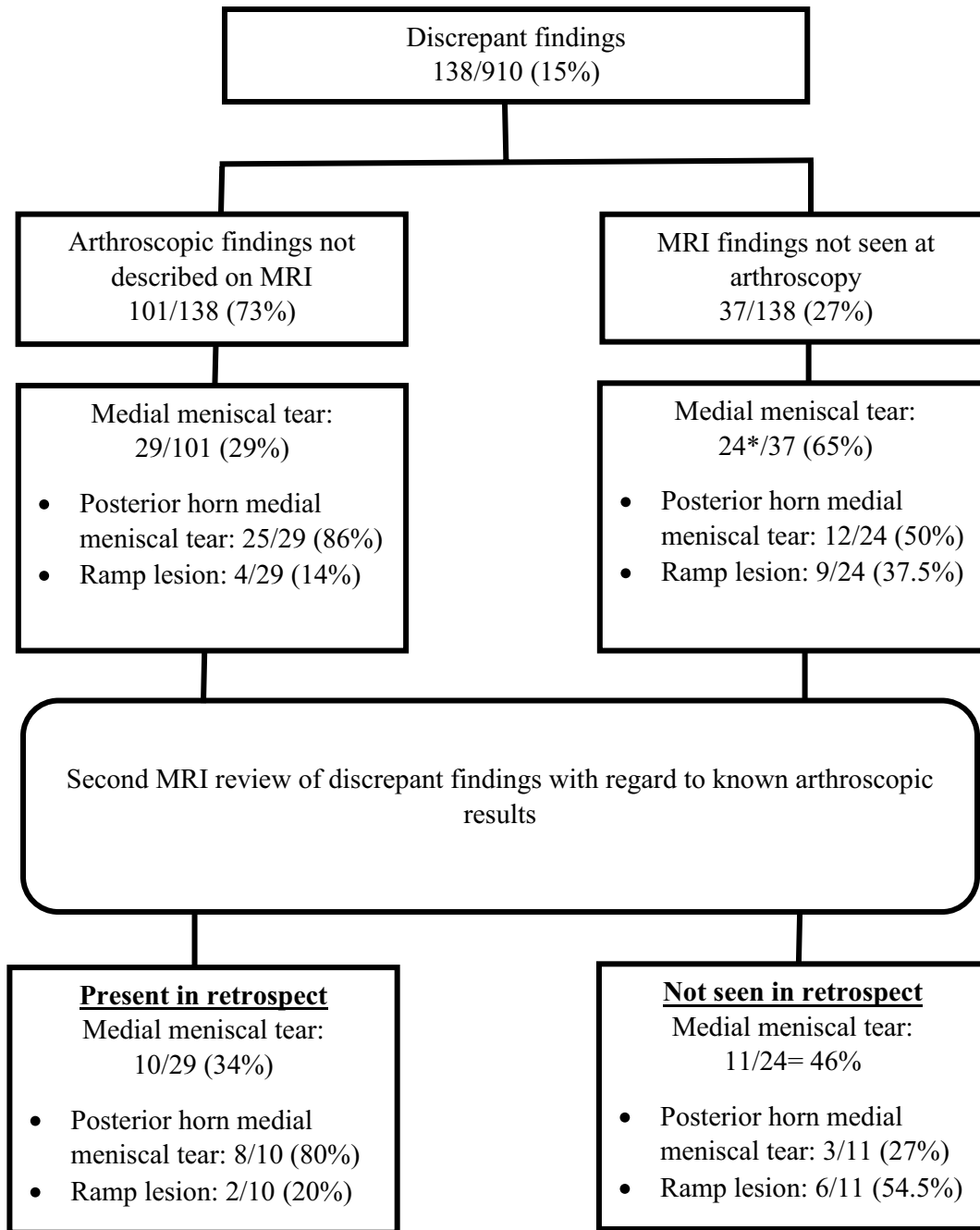
Normal posterior medial meniscus anatomy

The medial meniscus is a semicircular fibrocartilage structure with variable insertion of its anterior horn and firm attachment of its posterior horn to the posterior intercondylar area of the tibia directly anterior to the insertion of the posterior cruciate ligament [10]. Several anatomic structures contribute to the posterior medial meniscal attachments including the posterior meniscocapsular and meniscotibial ligaments which form the superior and inferior aspects of the posterior capsular junction, respectively (Fig. 2) [11, 12]. The posterior meniscocapsular and meniscotibial ligaments contribute together with the posterior horn of the medial meniscus to the knee stability against anterior tibial translation and posteromedial rotation [12]. A normal meniscocapsular junction near the medial meniscus posterior root seen on arthroscopy is also displayed in Fig. 2.

The meniscus is predominantly supplied by the geniculate arteries via the perimeniscal capillary plexus [10, 11]. Following birth, the central two-thirds to three quarters of the meniscus become progressively avascular with residual peripheral perfusion, leading to the described arrangement of red-red, red-white, and white-white zones [10, 11]. The red-red zone corresponds to the vascular peripheral part of the meniscus and includes the ligamentous attachments to the joint capsule [11].

What is a ramp lesion?

A ramp lesion was first described by Strobel in 1988 as a longitudinal tear of the peripheral attachment of the posterior medial meniscal horn at the meniscocapsular junction of less than 2.5 cm in length [13, 14]. However, this definition has since been expanded to include tears involving the meniscotibial ligament attachment which were identified



*Three patients had tears involving the anterior horn and/or the body of the medial meniscus, contributing to the 24 discrepancies mentioned in the flowchart which is focusing on the posterior medial meniscal tears.

Fig. 1 Flow chart shows the discrepant findings and results of the second review of MRIs

through a specific posteromedial probing [15]. In addition, a recent cadaveric study provided further evidence that meniscocapsular and meniscotibial ligaments merge at a common attachment point on the posterior horn of the

medial meniscus [16]. These histologic findings were integrated into a new classification suggested by Grief et al. [17] which is considered an extended version of the prior Thunat classification [18].

Table 1 MRI knee protocol scan parameters

Plane	Sequence	FOV (mm)	Phase encode direction	Slice thickness (mm)	Inter-slice gap (mm)	TR (msec)	TE (msec)
Pre-school							
Coronal	PD FS	90×100	R-L	3	0	2400–4000	20–40
Axial	PD FS	90×100	R-L	3	0	2400–4000	20–40
Sagittal	PD	60×100	F–H	3	0	2400–4000	20–40
Sagittal	T2 FS	90×100	F–H	3	0	3000–6000	50–60
Coronal	T1	90×100	R-L	3	0	600–850	ALARA
Pre-teen							
Coronal	PD FS	120×90	R-L	3	10	2400–4000	20–40
Axial	PD FS	120×90	R-L	4	0	2400–4000	20–40
Sagittal	PD	100×100	F–H	3	10	2400–4000	20–40
Sagittal	T2 FS	110×110	F–H	3	10	3000–6000	50–60
Coronal	T1	120×90	R-L	3	10	600–850	ALARA
Teen							
Coronal	PD FS	150×90	R-L	3	10	2400–4000	20–40
Axial	PD FS	150×90	R-L	4	10	2400–4000	20–40
Sagittal	PD	110×100	F–H	3	10	2400–4000	20–40
Sagittal	T2 FS	140×110	F–H	3	10	3000–6000	50–60

FOV, field of view; TR, repetition time; TE, echo time; PD, proton density; FS, fat saturated; R, right; L, left; F, foot; H, head

Lessons learned

Findings not to be missed

Given the lack of consensus on the definition of meniscal ramp lesions and the presence of different surgical

classifications, several proposed MRI criteria are associated with this diagnosis [5, 6, 9, 12]. Similarly, we found that the presence of abnormal T2-weighted hyperintense globular signal within the posterior horn of the medial meniscus extending into the meniscocapsular attachment with concomitant peripheral meniscal irregularity and

Fig. 2 Normal anatomy of posterior horn of the medial meniscus (red zone) and meniscocapsular attachment in a 17-year-old male. **a** Sagittal T2-weighted (T2W) fat saturated (FS) image, **(b)** corresponding illustrated view of the posterior meniscal anatomy, and **(c)** arthroscopic image. Normal meniscocapsular junction (white arrow) near the medial meniscus posterior root (white dashed arrow) viewed with the 30-degree arthroscope positioned just medial and posterior to the posterior cruciate ligament. The posterior capsule (black arrow) and the femur (black dashed arrow) are also visualized

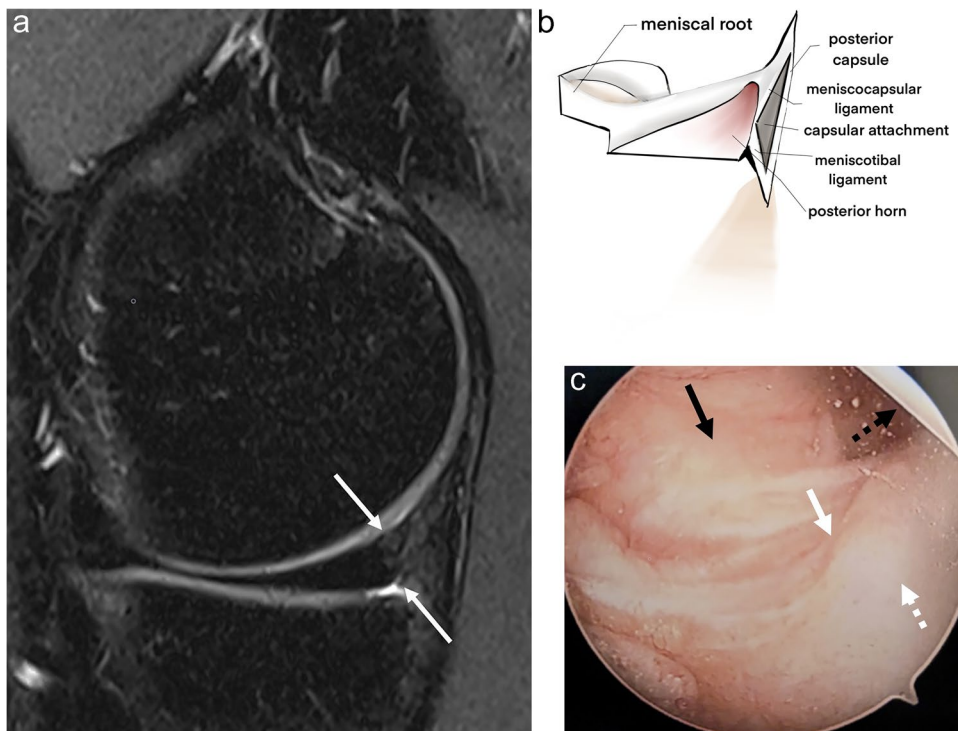
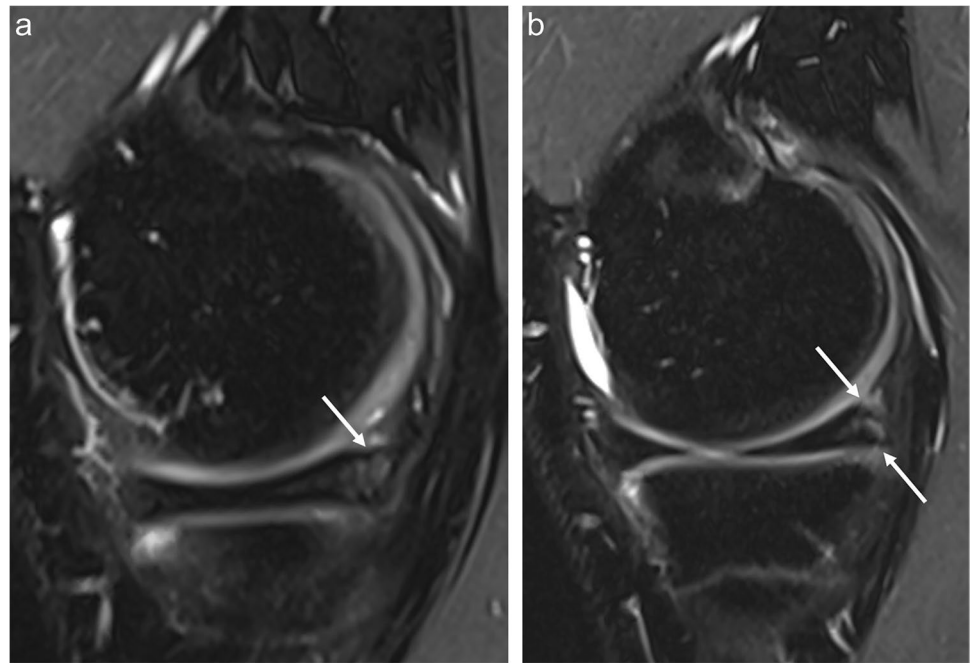


Fig. 3 17-year-old male with a ramp lesion on MRI which was only seen during retrospective review after arthroscopy which was performed 19 days after the MRI. **a, b** Sagittal T2W FS images show abnormal increased T2W signal intensity within the posterior horn medial meniscus extending into the meniscocapsular attachment with associated peripheral meniscal irregularity (*arrow* in **a**) and tearing of the meniscocapsular ligament (*arrow* in **b**)



meniscocapsular ligament tearing (Fig. 3) is associated with an arthroscopic diagnosis of a ramp lesion. Nguyen et al. [6] described in their cohort of 35 patients younger than 20 years old a strong positive association between the presence of a ramp lesion and a posterior horn medial meniscal tear or peripheral meniscal irregularity. This observation is concordant with Greif's and Thauat's classifications for meniscal ramp lesions, which are not only defined by the presence of meniscocapsular ligament tearing (type 1), but also by other tears involving the peripheral posterior meniscal horn (types 2–5) [17, 18]. Peripheral meniscal globular signal and irregularity is also attributed to presumed scarring/granulation tissue secondary to meniscocapsular separation [9].

Furthermore, the presence of junctional vertically oriented linear T2-weighted hyperintense signal at the level of the meniscocapsular attachment of the posterior horn medial meniscus suggests the presence of meniscocapsular separation, consistent with a ramp lesion (Fig. 4, Supplementary material 1). This vertically oriented linear T2 hyperintensity should be isointense to intra-articular joint fluid signal between the capsule and the posterior wall of the medial meniscus. This finding is in contrast to capsular edema where the signal abnormality is not as hyperintense as intra-articular joint fluid signal and does not have linearity [5]. Capsular edema is typically not considered sufficient to make a diagnosis of a meniscal ramp lesion (Fig. 5) [9]. However, the MR finding of junctional fluid-like signal intensity was found to be highly specific with variable sensitivity for ramp lesions

in different studies including adolescents and adults [5, 6, 9]. Vertically oriented junctional fluid-like signal should be within 2–3 mm of the capsule when the term ramp lesion should be employed. False negative results can be explained by the artificial reduction of meniscocapsular separation with the knee being in near full extension during standard image acquisition, thus decreasing the chance to visualize the fluid-like signal intensity between the capsule and the posterior wall [5, 6].

In addition, the presence of marrow edema-like signal within the posterior medial tibial plateau adjacent to signal abnormalities involving the periphery of the posterior horn medial meniscus should lower the threshold to call a meniscal tear (Figs. 6 and 7). A posterior-medial tibial plateau bone contusion results from a pivot shift, contre-coup type injury and anterior translation of the medial tibial plateau with respect to the medial femoral condyle [10]. Several studies describe this potentially combined injury pattern of posterior medial tibial plateau contusion and ramp lesion [19–21], but others have not found a statistically significant association between these two findings [5, 6, 22].

False-positive findings

The fuzzy appearance at the periphery of the posterior horn medial meniscus should not be considered suggestive of tear, particularly in the absence of increased T2-weighted signal which can be normally seen beyond the periphery of the posterior horn (Fig. 8, Supplementary material 2). A vertical

Fig. 4 12-year-old male with a ramp lesion on MRI which was only seen in retrospect after arthroscopy which was performed 38 days after the MRI. **a, b** Sagittal T2W FS images show junctional fluid-like signal intensity at the level of the meniscocapsular attachment of the posterior horn medial meniscus (*arrows*) suggesting meniscocapsular separation. **c** Arthroscopic correlate of the ramp lesion (*white arrows*) described on MRI. This tear was nondisplaced, so a posteromedial portal was not required for repair. Repair was performed for this nondisplaced tear in an attempt to address all potential re-tear risk factors in this young and therefore high-risk patient. **d** Arthroscopic image demonstrates the meniscocapsular junction post repair (*star*). The posterior capsule (*black arrow*), medial meniscus (*white dashed arrow*) and femur (*black dashed arrow*) are also visualized. This is the arthroscopic correlate of the tear described on MRI

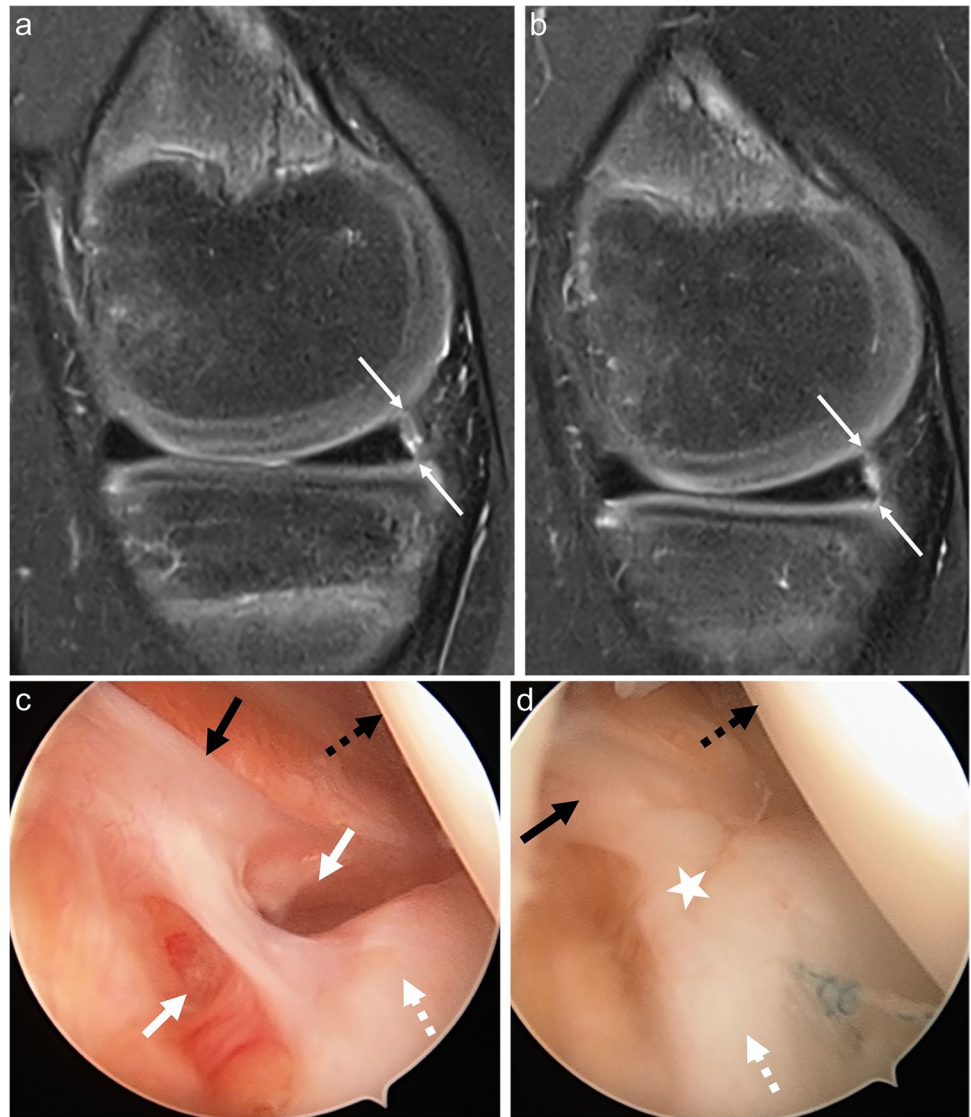


Fig. 5 16-year-old male with a ramp lesion described on MRI which was not seen during arthroscopy which was performed 69 days after the MRI nor on retrospective review. **a, b** Sagittal T2W FS images show a normal meniscocapsular attachment with normal central increased T2W signal intensity between intact anterior and posterior meniscocapsular attachments (*arrows*)

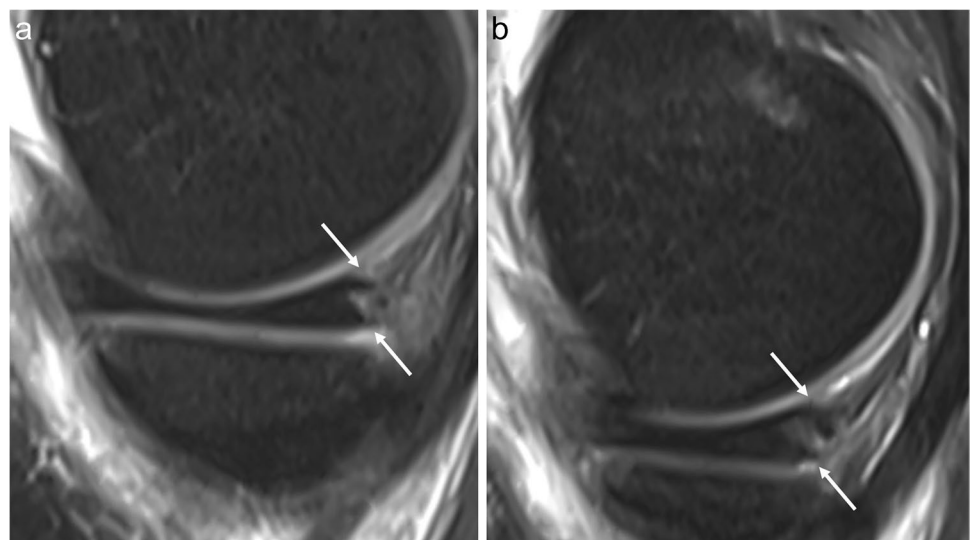
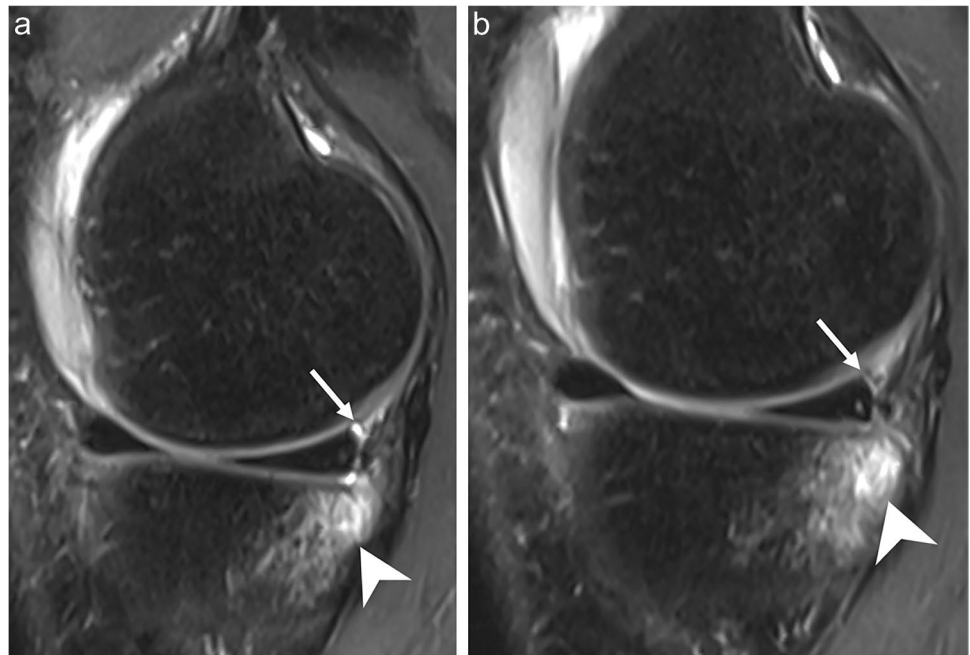


Fig. 6 17-year-old male with a posteromedial ramp lesion of the medial meniscus on MRI which was only seen in retrospect after arthroscopy which was performed 18 days after the MRI. **a, b** Sagittal T2W FS images show a far peripheral longitudinal tear of the posterior horn medial meniscus (*arrow*) with associated edema-like signal within the posterior aspect of the medial tibial plateau (*arrowhead*)



linear signal along the periphery of the meniscus can be seen along the central component of the posterior medial meniscus near the meniscal root (Fig. 8, Supplementary material 2) and should not be mistaken for a ramp lesion. In addition, not all increased T2-weighted signal intensity at the periphery of the posterior horn is a tear. We can normally see such signal intensity centrally between intact anterior and posterior meniscocapsular attachments (Fig. 5). So, when peripheral meniscal irregularities are visualized, radiologists need to look for additional findings to suggest a ramp lesion such

as focal discontinuity, a step-like deformity, or irregularity involving the capsular attachments [12].

Similar to any meniscal tear, when intrameniscal T2-weighted signal does not reach an adjacent articular surface, in addition to having intact anterior and posterior meniscocapsular attachments, a ramp lesion should not be considered (Fig. 9). The increased peripheral intrameniscal signal intensity is not necessarily related to a meniscal injury and may be attributed to profuse physiologic vascularity at the meniscal periphery in

Fig. 7 17-year-old male with a tear of the posterior horn medial meniscus on MRI which was only seen in retrospect after arthroscopy which was performed 13 days after the MRI. **a, b** Sagittal T2W FS images show the vertical tear involving the red zone (*arrow*) with associated edema-like signal within the posterior aspect of the medial tibial plateau (*arrowhead*)

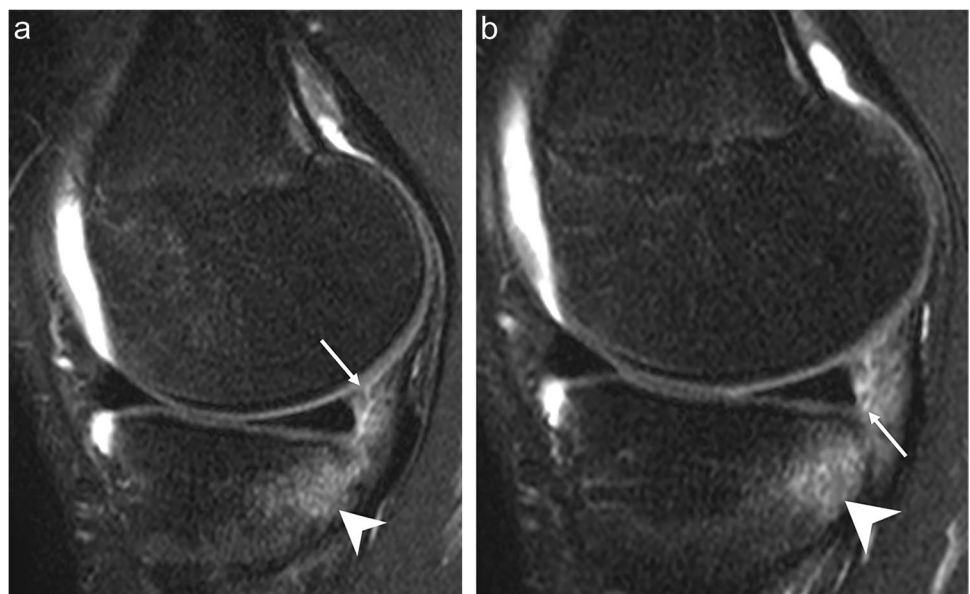
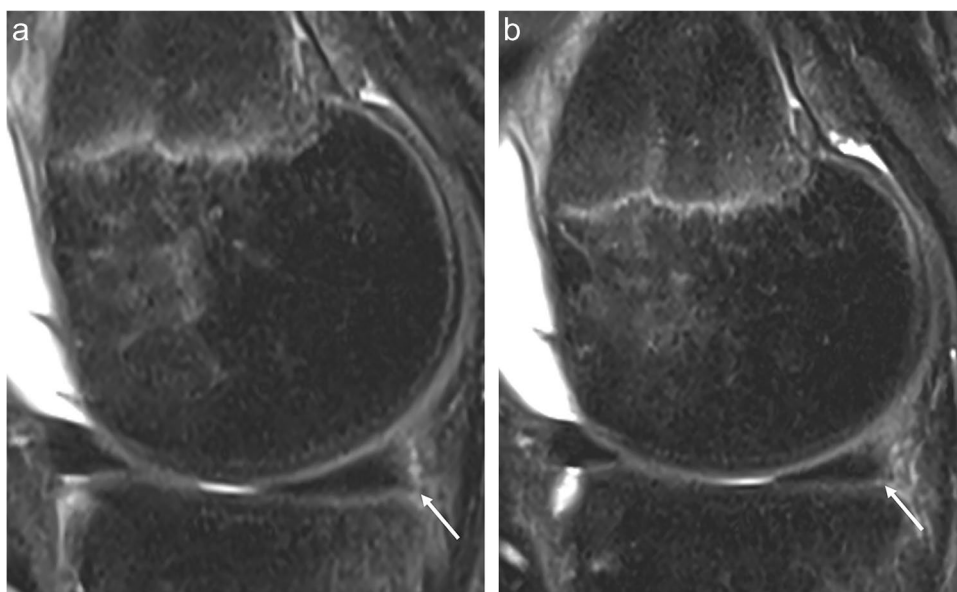


Fig. 8 17-year-old male with a tear of the posterior horn medial meniscus described on MRI but not seen during arthroscopy which was performed 43 days after the MRI nor on retrospective review. **a, b** Sagittal T2W FS images show a normal appearing posterior horn with normal increased T2-weighted signal intensity beyond its periphery (*arrows*) which can be a normal finding more centrally near the meniscal root



children. The perimeniscal capillary plexus vascularizes the peripheral approximately 50% of the meniscus (the red zone) in newborns and only 10–30% in adults [23]. For this reason, tears involving the peripheral zone have a greater potential to spontaneously heal [23, 24].

We should be aware that spontaneous meniscal healing can occur even within a short period of time (Fig. 10). De Smet et al. [25] suggested that a 6-week interval was probably sufficient for healing to occur and to account for some of the false-positive results in their study.

Fig. 9 15-year-old male with a ramp lesion described on MRI which was not seen during arthroscopy which was performed 44 days after the MRI nor on retrospective review. **a, b** Sagittal T2W FS images show a normal meniscocapsular attachment (*arrows*). The increased peripheral intrameniscal T2-weighted signal intensity is likely related to normal abundant vascularity within the meniscal periphery or red zone

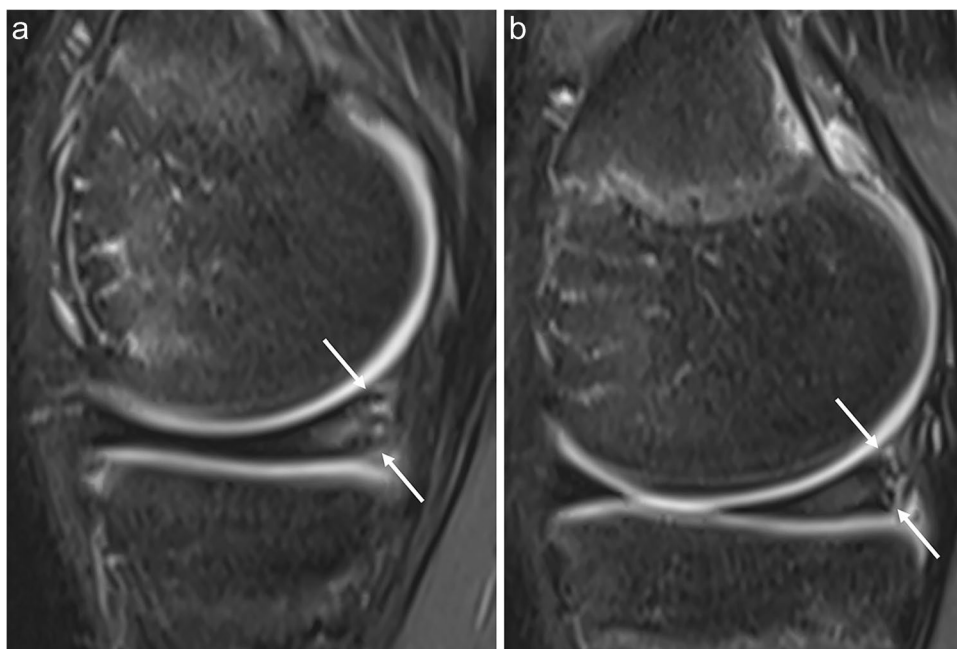


Table 2 summarizes the MRI findings concerning for ramp lesions and the findings that are more likely to be false positive.

Orthopedic surgeon perspective

Ramp lesion is a diagnostic challenge and MRI plays a crucial role in dictating the surgical management by suggesting the presence of a ramp lesion, since specific non-standard arthroscopic techniques are performed to evaluate

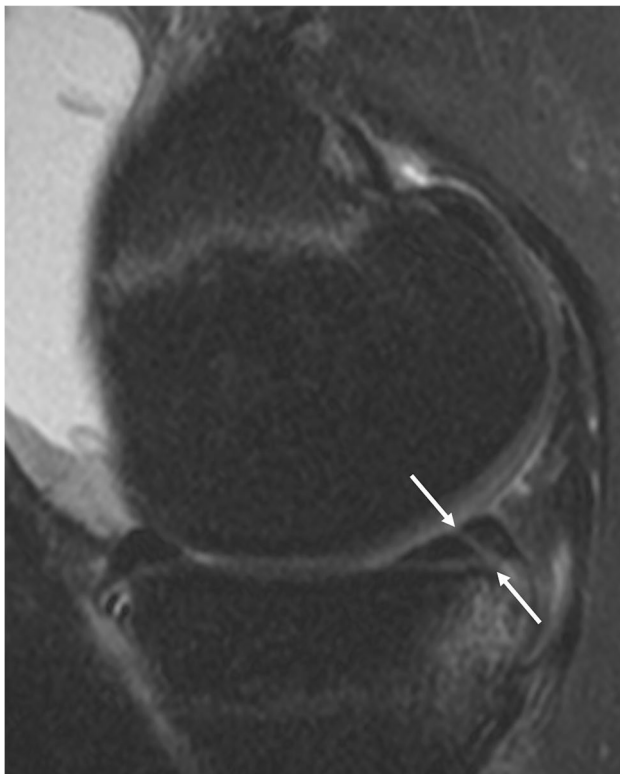


Fig. 10 16-year-old female with a described ramp lesion on MRI. Sagittal T2W FS image shows an oblique longitudinal tear of the posterior horn medial meniscus extending to the superior and inferior articular surfaces (*arrows*) with adjacent edema-like signal within the posterior medial tibial plateau. Evidence of healing was found during arthroscopy performed 4 weeks from the day of injury and 20 days after the MRI. No repair was needed

the posteromedial area of the knee with potential need for ramp lesion repair if identified arthroscopically. Therefore, it is important to include in our MRI reports any imaging findings suggestive of a ramp lesion including a questionable meniscal or meniscocapsular irregularity and meniscocapsular edema, given the potential reduction of

meniscocapsular separation that can occur with the patient extended in the knee coil during image acquisition as we described above, leading to false negative results. By providing these details, surgeons can properly prepare for their arthroscopic approach.

At arthroscopy, the standard notch view of the posterior horn medial meniscus is used to visualize the posterior meniscocapsular junction adjacent to the posterior root. This is done while using the anterolateral portal for visualization. The camera is advanced over the medial tibial spine, and between the medial femoral condyle and PCL. This camera position allows visualization of the posterior root of the medial meniscus root, and the adjacent meniscocapsular junction [26].

The repair can be performed with all-inside, capsular based repair devices (Fig. 4).

Several arthroscopic techniques are described for diagnosing and treating more displaced ramp lesions including the use of additional posteromedial portal sites [26, 27]. Though specific techniques of repair are outside the scope of this paper, additional equipment and setup is sometimes required for treatment of ramp lesions. The MRI report of a ramp lesion is quite helpful for the surgeon to plan the operation, especially in the setting of concurrent ACL reconstruction.

Conclusion

We share the lessons we have learned from our institutional multidisciplinary arthroscopic-MRI correlation conference regarding retrospectively identified posterior horn medial meniscal tears and ramp lesions. Recognition of MRI findings associated with these tears is crucial knowledge enabling pediatric radiologists who interpret MSK imaging to provide orthopedists with relevant information to enable appropriate surgical planning and to avoid potential complications if these tears were failed to be recognized before or during surgical procedure including early osteoarthritis, meniscal re-tear, and increased risk of ACL graft failure [1, 6].

Table 2 MRI findings concerning for ramp lesions versus findings more likely to be false positive

Findings concerning for ramp lesions	Findings more likely to be false positives
Vertically oriented linear T2 isointense to fluid signal at the meniscocapsular junction	Meniscocapsular edema without other findings
Meniscocapsular ligament tear	Irregular (fuzzy) periphery of posterior horn medial meniscus without abnormal T2 signal
Peripheral meniscal abnormal globular signal in posterior horn of medial meniscus extending to meniscocapsular junction with peripheral meniscal irregularity	Vertical linear signal along the periphery of the central component of the medial meniscus near the root without other findings
Edema in posteromedial tibial condyle (lower threshold for calling with additional above findings)	Increased T2 signal between intact meniscocapsular attachments
	Abnormal intra-meniscal signal that does not extend to an articular surface (such as posterior horn vascularity)

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Data availability Available upon request

Code availability Not applicable

Declarations

Ethics approval Not applicable

Conflicts of interest None

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