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Systematic Review

Magnetic resonance imaging shows low sensitivity but good specificity in detecting ramp lesions in children and adolescents with ACL injury: A systematic review

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ABSTRACT

Importance: The diagnosis of ramp lesions can be problematic, even with arthroscopy, due to their extreme posteromedial position. Consequently, they have been colloquially referred to as the "hidden lesions" of the knee. Undiagnosed and untreated injuries in this knee region may be associated with ongoing dynamic rotational laxity of the knee after anterior cruciate ligament reconstruction and an increased risk of anterior cruciate ligament graft failure.

Aim: This study aimed to systematically review the literature to assess the sensitivity, specificity and accuracy of magnetic resonance imaging (MRI) for detecting ramp lesions in children and adolescents with anterior cruciate ligament (ACL)-deficient knees. It was hypothesized that MRI has poor sensitivity for identifying ramp lesions in children and adolescents.

Evidence review: A systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The following search terms were used in the title, abstract and keywords fields: "ramp" or "meniscus" AND "children" or "adolescents." The outcome data extracted from the studies were incidence of ramp in concomitant with ACL lesion, MRI sensitivity, specificity, accuracy and positive and negative predictive values (PPV and NPV).

Findings: Of the 387 patients with ACL injury, 90 were reported to have ramp lesions (23.3%). The mean age at the time of diagnosis was 15.3 ± 0.81 years. The mean time from injury to MRI was 116.1 ± 113.5 days, while the mean time from injury to surgery was 172.6 ± 139.1 days. The MRI taken to detect ramp lesions in the paediatric population showed a pooled sensitivity of 50%, specificity of 75%, accuracy of 70%, PPV of 41% and NPV of 79%.

Conclusions and relevance: The prevalence of ACL-associated ramp lesions in children and adolescents is similar to that in adult populations. Magnetic resonance imaging has low sensitivity but good specificity for assessing ramp lesions. In the presence of a posteromedial tibial bone bruise or a thin fluid signal separating the posterior horn of the medial meniscus and the posteromedial capsule a ramp lesion should always be suspected.

Level of evidence: Level IV.

Study registration: PROSPERO –: CRD42023453895.

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What is already known

- The diagnosis of ramp lesions can be problematic, even with arthroscopy, due to their extreme posteromedial position. Consequently, they have been colloquially referred to as the "hidden lesions" of the knee.
- The diagnostic accuracy of magnetic resonance imaging in detecting ramp lesions, when compared to arthroscopy as the reference standard, has been reported to exhibit a relatively modest sensitivity.

What are the new findings

- According to the present systematic review, the magnetic resonance imaging conducted to detect ramp lesions in the paediatric population showed a pooled sensitivity of 50%, a specificity of 75%, a positive predictive value of 41% and a negative predictive value of 79%.
- Routine evaluation for the presence of ramp lesions on arthroscopy, via the intercondylar or posteromedial approach, may be needed despite the absence of suspicions of ramp lesions on magnetic resonance imaging in children and adolescents with anterior cruciate ligament-deficient knees.
- In the presence of a posteromedial tibial bone bruise or a thin fluid signal separating the posterior horn of the medial meniscus and the posteromedial capsule, a ramp lesion should always be suspected.

Introduction

Due to the growing number of children and adolescents participating in high-demanding sports, anterior cruciate ligament (ACL) injuries have raised serious concerns among the physically active population in these age groups [1].

In addition, medial meniscus tears, are associated with ACL injury in more than 60% of the patients [2].

Several studies have shown that the loss of normal meniscal function increases the rate of subsequent degenerative changes, leading to early-onset osteoarthritis, pain and a low quality of life. These changes may be even more devastating in the young population, highlighting the importance of meniscal preservation in this age group of individuals [3–6].

Recently, a lot of attention has been directed to injuries within and around the posteromedial meniscocapsular junction, known as meniscal ramp lesions, which occur in 15–24% of the adult population with ACL rupture [7–9]. However, limited data have been published on the epidemiological pattern of meniscal tears in children and adolescents.

Despite growing recognition of medial meniscal ramp lesions and their importance in the context of ACL disease, there remains a lack of comprehensive understanding about the identification of these "hidden lesions" in the teenage population [7–9].

The diagnostic accuracy of magnetic resonance imaging (MRI) in detecting ramp lesions, when compared to arthroscopy as the reference standard, has been reported to exhibit a relatively modest sensitivity [10]. The presence of a physiological hypersignal in the posterior meniscosynovial fold may lead to ambiguity or uncertainty. Furthermore, patients with posterior medial tibial plateau oedema on MRI are at 2.1 times greater odds of having ramp lesions [11].

Ramp lesions are often disregarded during conventional anterior visualisation and may not always be seen on MRI scans. Systematic screening is necessary, involving the insertion of the arthroscope through the anterolateral portal, into the space located between the medial condyle and the posterior cruciate ligament (PCL). During ACL reconstruction in the paediatric population, ramp lesions could be found in 23% of cases [10]. The diagnosis of these lesions can be problematic, even with arthroscopy, due to their extreme posteromedial position. Consequently, they have been colloquially referred to as the "hidden lesions" of the knee [10]. Furthermore, undiagnosed and untreated injuries in this knee region may be associated with ongoing dynamic rotational laxity of the knee after ACL reconstruction and an increased risk of ACL graft failure [12,13].

Therefore, this study aimed to systematically review the literature on the sensitivity, specificity and accuracy of MRI for detecting ramp lesions in children and adolescents with ACL-deficient knees. It was hypothesized that MRI has poor sensitivity in identifying ramp lesions in children and adolescents.

Materials and methods

The present systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and has been registered in the PROSPERO Registry (CRD42023453895) [14,15]. The quality of the systematic review was assessed using the AMSTAR-2 checklist [16].

Eligibility criteria

The literature chosen for this study was determined based on the specified qualifying criteria.

Design of the study

The study incorporated various types of research designs, including randomised controlled trials (RCTs), controlled clinical trials (CCTs), prospective and retrospective comparative cohort studies, case-control studies and case series. Exclusion criteria were used for case reports and case series that lacked data pertaining to radiologic, clinical and functional outcomes.

Participants

The study involved the examination of children and adolescents who had suffered from ACL injuries, specifically focusing on the presence of ramp lesions in the medial meniscus.

Interventions

The interventions examined in the studies included the evaluation of diagnostic methods as well as the assessment of clinical, functional and radiological outcomes in individuals with ramp lesions of the medial meniscus who underwent ACL repair.

Info sources and search

A comprehensive literature search was conducted on PubMed (MEDLINE), Scopus, EMBASE and Cochrane Library databases in a systematic

manner. The inclusion criterion did not take into account the publishing date. The investigation was conducted in August of 2023. The search was conducted and validated with the assistance of two independent reviewers, namely RD and FDM. The title, abstract and keywords sections were utilised to input the search phrases "children" or "adolescents" and "ramp lesion". Finally, the inclusion criteria stipulated that only articles published in the English language were incorporated into the study.

The process of gathering and examining data

Study selection

The selected publications were initially evaluated on the basis of their titles, and if deemed pertinent, they were subsequently evaluated based on their abstracts. Following the exclusion of studies that did not fulfil the predetermined eligibility criteria, a comprehensive assessment of the remaining articles was conducted to determine their suitability for inclusion. In order to mitigate any bias, the authors conducted a comprehensive evaluation and analysis of all the papers that were included in the study, as well as the references cited within those articles. Additionally, the writers also examined and deliberated upon the articles that were removed from the study. In the event of any divergence of opinion among the reviewers, the ultimate determination was made by the senior investigator. Upon completion of the procedure, further investigations that may have been overlooked were manually retrieved by meticulously examining the reference lists of the encompassed research and pertinent systematic reviews.

The process of collecting data

The first two authors utilised a computerised technique developed with Microsoft Access (Version 2010, Microsoft Corp, Redmond, Washington) to extract the data from the chosen articles. Each publication underwent a validation process conducted by the primary author prior to analysis. Data pertaining to the patients, including their age, gender, length between injury and surgery, and follow-up evaluation, as well as information on MRI sensitivity, specificity, positive predictive value, negative predictive value and arthroscopic findings of related injuries, were collected for each research question.

Level of evidence

The categorization of the level of evidence was conducted using the Oxford Levels of Evidence framework established by the Oxford Centre for Evidence-Based Medicine [17].

Evaluation of the quality of studies

The assessment of the studies' quality was conducted by employing the Methodological Index for Nonrandomized Studies (MINORS) score [18]. The checklist comprises a total of twelve criteria, with the final four items being specifically tailored to address comparative research. A score ranging from 0 to 2 points was assigned to each item. The recommended score for non-comparative research was established at 16 points, while for comparative studies it was set at 24 points.

Statistical analysis

The mean ± standard deviation (SD) was used to present the retrieved quantitative parameters, including age, follow-up time and diagnostic results, as reported in the papers. Alternatively, other statistical measures such as the median, range, or percentage were derived. The inability to conduct a meta-analysis comparing the outcomes of various therapies was attributed to the substantial heterogeneity in statistical and methodological aspects among the studies that were included. Instead, a narrative analysis and comparison of the clinical outcomes were conducted.

Results

A total of 4 studies with a mean MINORS score of 15.75 ± 2.6 were included in the systematic review (Fig. 1) [19–22].

All the articles were published between 2016 and 2023, and they included one level I, one level II, one level III and one level IV article.

Results

All patients evaluated reported a complete injury to the anterior cruciate ligament. Of the 387 patients, 90 patients reported ramp lesions (23.3%). 44 (48.9%) patients with ramp lesions were male, 33 (36.7%) were female and 13 (14.4%) were not specified. The mean age at the time of diagnosis was 15.3 ± 0.81 years. The mean time from injury to MRI was 116.1 ± 113.5 days, while the mean time from injury to surgery was 172.6 ± 139.1 days (Table 1).

The MRI conducted to detect ramp lesions in the paediatric population showed a pooled sensitivity of 50%, specificity of 75%, accuracy of 70%, PPV of 41% and NPV of 79%.

MRI in one study revealed that ramp lesion was not recognised in 76.9% of the cases, while MRI in the other two studies revealed that a lateral meniscus tear was present in more than 40% of the patients (range 43%–57.1%) while a meniscocapsular ligament tear was noted in more than 35% of the patients (range 36%–57.1%). In more than 40% of the patients, posteromedial oedema on the tibial side was noted (range 43%–74.3%) (Table 1) [19–22].

All the studies confirmed the presence of ramp lesions only when an intercondylar view was performed; otherwise, lesions were identified in less than 10% of the patients.

Nguyen et al. demonstrated how peripheral irregularity became the sign of most sensitivity (74.3%) and negative predictive value (77.5%) and fluid-like junctional became the sign of most specificity (98%) and most positive predictive value (92.9%) [19].

Discussion

According to the present systematic review, the MRI conducted to detect ramp lesions in the paediatric population showed a pooled sensitivity of 50%, specificity of 75%, accuracy of 70%, PPV of 41% and NPV of 79%, confirming our hypothesis.

Meniscal ramp lesions are typically associated with ACL deficiency. They are characterised by a disruption or tear of the peripheral meniscocapsular attachments of the posterior horn of the medial meniscus [23].

Multiple investigations conducted on cadavers have demonstrated that ramp lesions linked to the ACL result in more anterior tibial translation as well as higher internal and external rotation of the knee when compared to cases of ACL deficiency without ramp lesions [24].

Clinical studies have provided confirmation of the biomechanical impact associated with ramp lesions. Mouton et al. 38 conducted a study with 275 patients, of whom 58 (21%) had ramp lesions. The study found that patients with only a ramp lesion were more prone to experiencing a grade III pivot shift when compared to patients with an isolated ACL injury and no ramp lesion [25]. Thaunat et al. demonstrated that complete lesions (subtypes 1, 4 and 5) exhibit a greater degree of side-to-side laxity and pivot shift compared to partial lesions (subtypes 2 and 3). Therefore, failure to treat ramp lesions in the setting of a knee with anterior cruciate ligament (ACL) deficiency may result in ongoing laxity following ACL surgery [26].

It is, therefore, considered important to identify these lesions and repair them when necessary.

Conventionally, MRI is the most commonly used imaging modality for diagnosing meniscal tears. Previously, three meta-analyses reported excellent sensitivity and specificity of MRI for diagnosing meniscal tears in ACL-deficient knees [27–29]. However, these studies have not focused on the ramp lesion.

The results of this systematic review demonstrated that MRI has moderate sensitivity for detecting ramp lesions in the paediatric population.

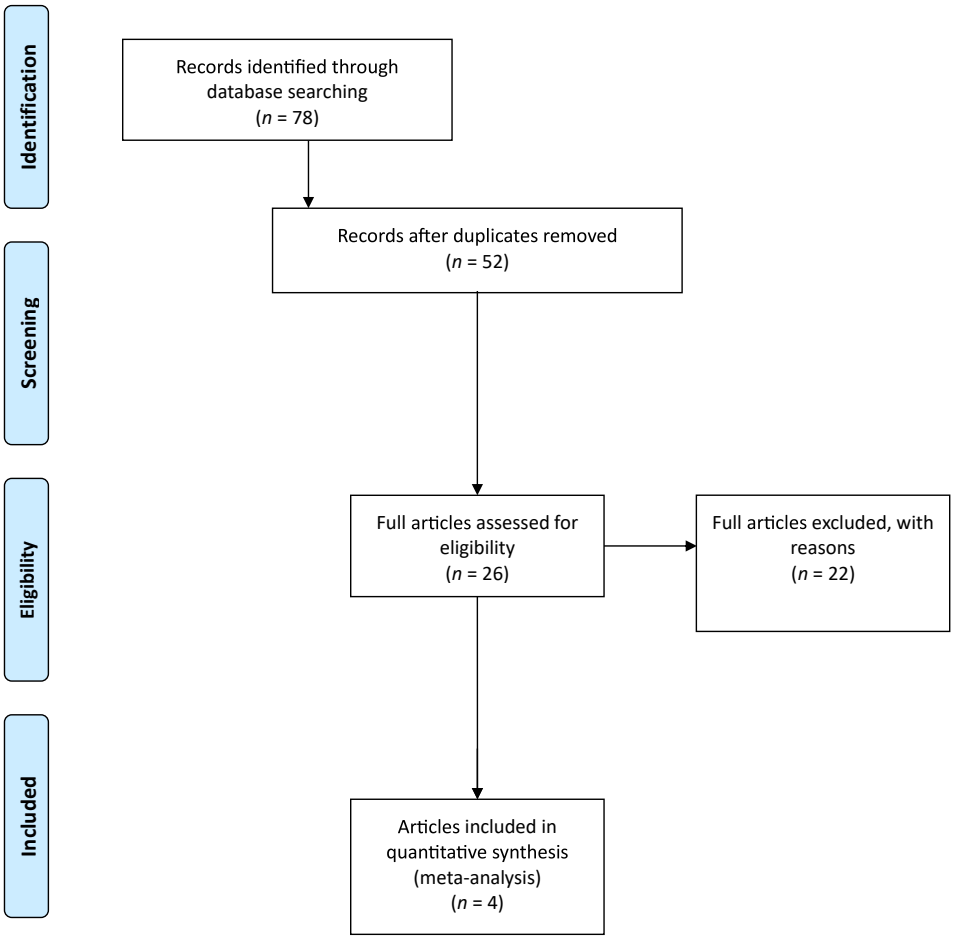

Fig. 1. A flowchart (PRISMA Chart) of the literature screening performed in this study.

A recent meta-analysis and systematic review on the diagnostic accuracy of MRI for ramp lesions, conducted by Koo et al., showed better overall sensitivity and specificity, at 71% and 94%, respectively. However, only four out of eight studies included children and adolescents in their samples [30].

This difference in MRI accuracy could be explained by multiple factors, including the small sample size in our review, which focused only on the paediatric population. Takeda et al. showed that high-intensity signals in the menisci, probably due to the increased vascularization, could generate false positive cases of tears in asymptomatic children and adolescents [31]. Furthermore, the mean time from injury to MRI and from injury to surgery was relatively long in our review, with an average of 4 months, which has been reported as a risk factor for ramp lesions if it exceeds 3 months. In this time frame, some ramp lesions could have occurred while others could have healed, and some indirect signs on MRI for detecting ramp lesions may be missing, generating false negatives [32]. This concept is even more important in the paediatric population, due to the better healing of meniscal tears demonstrated in several studies [33–35].

Looking specifically at our studies, Malatray et al. revealed a mean time from injury to surgery of 20 months and the worst sensitivity and specificity on MRI [22].

Previous studies demonstrated the effectiveness of MRI findings for diagnosing ramp lesions [36,37,23,38].

Yeo et al. [39] classified the MRI features of ramp lesions into six categories: complete fluid filling between the posteromedial capsule and posterior horn of the medial meniscus, posterior oedema affecting the posteromedial capsule, posterior marginal irregularity of the posterior horn of the medial meniscus, perimeniscal fluid sign, corner notch sign and posterior horn of the medial meniscus vertical tear. Complete fluid filling between the posteromedial capsule and posterior horn of the medial meniscus and posterior marginal irregularity of the posterior horn of the medial mensicus were the most sensitive findings to detect ramp lesions on MRI [39].

Another common sign, confirmed by two studies included in the review, is the posteromedial tibial bone bruise. Nguyen et al. showed that medial meniscus tear, peripheral meniscal irregularity, junctional T2-weighted hyperintense signal and meniscocapsular ligament tear in children and adolescents are significantly associated with ramp lesions [19]. In contrast with this, Malatray et al. affirmed that the most specific sign on MRI was the visualization of a thin fluid signal separating the posterior horn of the medial meniscus and the posteromedial capsule [22].

In their cohort of adolescent patients, Bram et al. also found that posteromedial tibial bone oedema was associated with a ramp lesion; however, they identified older age as a risk factor, with patients with a ramp lesion having a mean age of 16.7 years versus 15.5 years in those without [40]. In contrast to our study, Bram et al. included patients up to the age of 21, as well as patients undergoing revision ACL reconstruction. While we did not find an association between patient demographics (e.g., age) and the presence of a ramp lesion, we did find a significant association with posteromedial bone oedema on MRI. Nevertheless, this radiographic finding had the lowest OR of any of the associated findings that reached significance with the present study, and it dropped out of significance with multivariate analysis [40].

Hollnagel et al. noted that the concordance of medial femoral condylar chondromalacia, particularly striations, noted during arthroscopy and posteromedial tibial marrow oedema on MRI with or without

Table 1
Characteristics of the selected studies.

Author and Year	Level of Evidence	Total Number of patients/ Patients with RAMP Lesions	Age	Gender (M/F)	Laterality (R/L)	MRI findings	Portals performed/ Arthroscopic Findings	Time interval between Injury and MRI	Time interval between Injury and arthroscopy	Sensitivity (%) of MRI	Specificity (%) of MRI	Accuracy (%) of MRI	Positive predictive value (%)	Negative predictive value (%)
Nguyen et al., 2020 [19]	IV	80/35	15.7 ± 2.0	23/12	15/20	- Suprapatellar effusion 62.9% - Medial meniscus tear 18.4% - Junctonal T2-weighted signal 40.0% - Meniscocapsular ligament tear 57.1% - Medial tibial plateau oedema 74.3% - Lateral meniscus tear 57.1% Lateral tibial plateau oedema 85.7%	Intercondylar view	26.3 ± 95.4 days	50.5 ± 20.6 days	- Medial meniscus tear 51.4 - Peripheral irregularity 74.3 - Fluid like junctional signal 37.1 - Meniscocapsular ligament tear 57.1	- Medial meniscus tear 78.9 Peripheral irregularity 62.0 - Fluid like junctional signal 98.0 - Menisco--capsular ligament tear 84.0	67	- Medial meniscus tear 62.1 Peripheral irregularity 57.8 - Fluid like junctional signal 92.9 - Menisco-capsular ligament tear 71.4	- Medial meniscus tear 69.6 Peripheral irregularity 77.5 - Fluid like junctional signal 69.0 - Menisco-capsular ligament tear 73.7
Bernardini et al., 2021 [20]	III	50/14	14.3 ± 1.87	8/6		- True-positive case: 8 - False-negative case:6	Intercondylar view	213 (0–1290) days	423 ± 381 days	57	67	64	40	80
Hollnagel et al., 2023 [21]	II	201/28	16.1 ± 1.5	13/15		- Posterior tibial slope 9.5° - Meniscocapsular ligament injury 36% - ALL tear 7% - MCL tear 39% - LCL tear 4% - POL tear 7% - PLC tear 11% - LM tear 43% - Posteromedial tibial oedema 43%	Intercondylar view - lateral meniscus tear 68% - medial femoral condyle lesion 82% - medial femoral condyle striations 68%	73.5 ± 172.9 days	147.7 ± 177.8 days	68	75	74.1	31	94
Malatray et al., 2016 [22]	I	56/13	14.0 ± 1.3			76.9% not recognised	– 7.7% identified through anterolateral portal – 100% identified through intercondylar view and posteromedial portal	345 (30–3240) days		24	81	65.6	30.7	74.5

MRI = magnetic resonance imaging; ALL = anterolateral ligament; MCL = medial collateral ligament; LCL = lateral collateral ligament; POL = posterior oblique ligament; PLC = posterolateral corner; LM = lateral meniscus.

direct evidence of posterior meniscocapsular pathology, should increase suspicion of the presence of a ramp lesion in adolescents undergoing ACL reconstruction [21].

Due to the moderate accuracy of MRI in evaluating ramp lesions in children and adolescents, arthroscopy assessment remains the gold standard to diagnose ramp lesions during ACL reconstruction [33,34].

However, a substantial number of these lesions may easily be missed at the time of arthroscopic evaluation, particularly if performed with standard anterior portal viewing only [10].

Interestingly, a recent survey of knee surgeons indicated that only about 14% of them routinely checked for the presence of ramp lesions via inspection of the posteromedial meniscocapsular junction during an ACL reconstruction [35].

To minimise the risk of missed diagnoses of ramp lesions, it is imperative to undertake a systematic arthroscopic examination, including that of the posteromedial compartment. For this purpose, the examination should be performed directly using a modified Gillquist view by passing the 30° arthroscope through the intercondylar notch, which is adjacent to the fibres of the posterior cruciate ligament, with the knee at 90 degrees of flexion [41].

Furthermore, the meniscocapsular attachment could be stretched by probing with either a needle or an arthroscopy hook inserted through a posteromedial portal to avoid missing lesions [42].

The diagnosis of ramp lesions remains a real challenge during the arthroscopic investigation of the knee in ACL-deficient patients. Like in adults, ramp lesions can also be underestimated in the paediatric and adolescent population with a solely anterior inspection through an anterolateral arthroscopic portal. Malatray et al. noted a significant change in detecting ramp lesions through different arthroscopic approaches; in fact, with the anterolateral portal, the prevalence of ramp lesions was 1.8%, while with intercondylar or posteromedial portal, this percentage grew to 23.2% [22].

The present study has some limitations. The first one is the small number of studies included due to the age restriction adopted. Another limitation is the methodological differences among the included studies. All technical MRI parameters were not assessed because parameters such as receiver bandwidth, matrix and field of view were not described in most studies. Furthermore, MRI sensitivity may well have been improved with 3-T instead of 1.5-T magnet machines. Finally, there was a variable interval between the preoperative MRI and the surgery, allowing for either further meniscal tears or spontaneous healing in this time frame, depending on the case.

Future perspectives

A recent systematic review was conducted with the objective of comparing the clinical outcomes of various surgical interventions for ramp lesions [42]. These interventions encompassed strategies such as retaining the lesion in its original position, performing meniscal repair and employing biological treatments. The latter options encompass abrasion or trephination techniques. The research emphasised the significance of a streamlined categorization of ramp lesions of the meniscus into stable and unstable groups, as it offers direction for making optimal treatment choices. It is recommended to heal unstable injuries by employing sutures subsequent to manipulation with the probe. In contrast, biological treatments such as abrasion, trephination and curettage of edges might be advantageous for stable lesions as they contribute to and expedite the healing process of the lesion. Additional investigation is necessary to validate the current evidence and ascertain the most effective therapeutic strategy for ramp lesions, taking into account the specific attributes of both the patient and the lesion. Furthermore, there is a requirement for standardised criteria to determine stability and thorough diagnostic tools to enhance clinical decision-making in the management of these complex meniscal injuries [42].

Conclusions

The prevalence of ACL-associated ramp lesions in children and adolescents is similar to that in the adult population. Magnetic resonance imaging has low sensitivity, but good specificity for assessing ramp lesions. In the presence of a posteromedial tibial bone bruise or a thin fluid signal separating the posterior horn of the medial meniscus and the posteromedial capsule, a ramp lesion should always be suspected.

Declarations

Ethical approval

Not needed being a review of the literature.

Consent to participate

Not needed being a review of the literature.

Consent to publish

All authors consent to the publication of the manuscript.

Authors contributions

All authors contributed equally.

Funding

None.

Declaration of competing interest

None.

Availability of data and materials

Raw data are available upon request to the corresponding author.

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