

A Review of Radiographic and MRI Diagnostic Performance at the Pre-Slip Stage of Slipped Capital Femoral Epiphysis

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Abstract: *Slipped capital femoral epiphysis (SCFE) is the most common adolescent hip disorder, and outcomes are strongly linked to how early the disease is recognized. The “preslip” (or “imminent”) stage-physal instability and early biomechanical failure before any measurable epiphyseal displacement-represents the earliest and most treatable point in the disease process, yet it is also the stage most likely to be missed on conventional imaging. This review summarizes the current evidence on the diagnostic accuracy of plain radiography and magnetic resonance imaging (MRI) for detecting preslip SCFE, with a focus on the peritubercle lucency sign, physal widening, bone marrow edema, and joint effusion, incorporates the most recent (2025–2026) literature, and discusses how the two modalities should be used together in clinical practice.*

Keywords: Slipped capital femoral epiphysis, Preslip SCFE, Magnetic resonance imaging, Plain radiography, Early diagnosis

1. Introduction

SCFE is a Salter-Harris type I injury through the proximal femoral physis, typically affecting adolescents during the growth spurt. Diagnosis is frequently delayed because early symptoms-vague hip, groin, thigh, or referred knee pain-are nonspecific, and standard anteroposterior (AP) hip radiographs can appear normal before frank epiphyseal displacement occurs. This pre-displacement window, the preslip stage, is defined radiographically and histologically by physal widening, irregularity, and mechanical failure at the growth plate without a measurable slip angle. Because roughly 20–40% of patients with unilateral SCFE go on to develop a contralateral slip, often within 12–18 months of the index diagnosis, accurate detection at the preslip stage-both at initial presentation and during surveillance of the “normal” contralateral hip-has become a central focus of pediatric hip imaging research.

2. Pathophysiology and Rationale for Early Detection

A rotational mechanism has been proposed in which the epiphyseal tubercle, a bony prominence on the posterior physal surface of the epiphysis, acts as a mechanical fulcrum. Under abnormal shear stress, this generates focal stress concentration and early structural change around the tubercle and metaphyseal fossa before gross epiphyseal displacement is visible. This mechanism underlies both a radiographic sign (the peritubercle lucency sign) and its MRI correlate (marrow signal change around the tubercle),

providing a shared anatomic basis for detection by either modality at the preslip stage.

3. Radiographic Findings and Diagnostic Performance

3.1 Conventional Signs

Standard evaluation uses AP and frog-leg (or true) lateral radiographs. Classic descriptors of early or preslip disease include widening and blurring of the physis relative to the contralateral side, relative loss of epiphyseal height on the AP view, loss of the normal anterior femoral neck concavity on the lateral view, and displacement of Klein's line such that it fails to intersect an adequate portion of the epiphysis. However, Klein's line has documented limitations: in one series it was normal in a majority of hips with SCFE that was already evident on the lateral projection by Southwick angle, and posterior slips-the earliest direction of displacement-are frequently missed on AP imaging alone, making a true lateral view essential.

3.2 The Peritubercle Lucency Sign

The peritubercle lucency sign, described by Maranhão and colleagues, is a radiolucent zone around the epiphyseal tubercle that can be visible on radiographs up to approximately 9 months before a measurable slip occurs. Reported diagnostic performance has varied across validation cohorts:

Study (design)	Sensitivity	Specificity	PPV	NPV	Notes
Maranhão et al., 2018 (contralateral-hip surveillance, n=250)	84%	99%	-	-	Sign preceded contralateral-slip diagnosis by median ~9 weeks; present in >1/3 while asymptomatic
Maranhão et al., 2020 (MRI as reference standard, n=71 hips)	97%	89%	93%	95%	Overall accuracy 94%; consistent across observer experience levels
Independent external validation (n=115)	70%	82%	-	-	Lower than original report; still clinically useful

Interobserver reliability of the sign has generally been reported as good regardless of reader experience, which

supports its potential use by general radiologists and orthopedic trainees, not only subspecialists. That said, an

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accompanying critique of the original validation study noted that its patient population had a high pretest probability of SCFE (60% prevalence in the MRI-referenced cohort), which inflates predictive values and means sensitivity/specificity figures should be interpreted with the caveat that they may not generalize directly to lower-prevalence screening populations.

3.3 Overall Radiographic Performance at the Preslip Stage

Outside of the peritubercle lucency sign, conventional radiographic measures (Klein's line, tilt/slip angle, Southwick angle) are considerably less sensitive for preslip disease, since by definition no measurable displacement is yet present. In practice, a substantial proportion of patients later confirmed to have preslip or early SCFE on MRI have normal or near-normal baseline radiographs, which is the principal argument for escalation to MRI when clinical suspicion remains high despite negative or equivocal films.

4. MRI Findings and Diagnostic Performance

4.1 Characteristic MRI Findings

MRI is consistently described as the most sensitive imaging modality for the preslip stage, detecting marrow and physal

change before radiographs or CT become abnormal. Key findings include:

- Diffuse or globular widening of the physis
- Bone marrow edema / hyperintense T2 signal along the metaphyseal side of the physis, reflecting mechanical stress
- Peritubercular marrow signal change-the MRI correlate of the radiographic peritubercle lucency sign
- Joint effusion and synovitis
- Physal irregularity / "winding" on axial and sagittal sequences, useful for detecting posterior retroversion at the epiphyseal-metaphyseal junction

4.2 Diagnostic Accuracy for Predicting Contralateral (Sequential) Slip

Because most preslip diagnostic-accuracy data derive from surveillance of the asymptomatic contralateral hip in patients with known unilateral SCFE, MRI performance is best summarized in that context:

Study / Parameter	Sensitivity	Specificity	PPV	NPV
MRI marrow-edema sign (33 patients, prospective follow-up)	80%	92.90%	66.70%	96.30%
Modified Oxford Bone Score (radiographic, same cohort)	45.50%	93%	62.50%	87%
Posterior slope angle (radiographic, same cohort)	9.10%	81.40%	11.10%	77.80%
Open triradiate cartilage (risk marker)	72.70%	81.40%	50%	92.10%

MRI-positive preslip findings were present in roughly two-thirds of patients who ultimately developed a sequential contralateral slip, meaningfully outperforming radiographic risk scores such as the posterior slope angle and modified Oxford Bone Score in the same cohort. The very high negative predictive value (96%) is arguably the most clinically useful feature: a negative MRI makes an impending contralateral slip unlikely, which can help avoid unnecessary prophylactic pinning of an asymptomatic hip.

4.3 Limitations of MRI Performance Data

Reported sensitivity is not uniformly high across studies; a positive MRI does not guarantee that a contralateral slip will

occur (in one cohort, two of six MRI-positive hips did not progress to radiographic slip), raising the possibility that mild marrow signal change can represent subclinical or self-limited stress without evolving into mechanical failure. PPV values across studies (in the 60–70% range) are also more modest than sensitivity/specificity/NPV, reflecting both the relatively low prevalence of true sequential slip in surveillance cohorts and genuine biological variability in disease progression.

5. Comparative Summary: Radiograph vs. MRI at the Preslip Stage

Feature	Radiograph (Peritubercle Lucency Sign)	MRI
Sensitivity for preslip/early change	~70–97% (sign- and validation-dependent)	Most sensitive single modality; ~80% for predicting sequential slip
Specificity	~82–99%	~93% for predicting sequential slip
Cost, availability, radiation	Low cost, widely available, minimal radiation	Higher cost, less immediate availability, no ionizing radiation, may need sedation in younger children
Best use case	First-line screening and contralateral-hip surveillance	Second-line workup for normal/equivocal radiographs with high suspicion; diagnostic problem-solving
Key limitation	Depends on reader awareness of a subtle sign; variable across cohorts/prevalence	Marrow edema not perfectly specific; not all MRI-positive hips progress to slip

Both modalities converge anatomically on the same target-stress-related change around the epiphyseal tubercle and physis-which is why the radiographic and MRI signs are often

described as correlates of one another rather than independent findings.

6. Suggested Clinical Approach

- Obtain AP and true lateral (or frog-leg lateral) radiographs of both hips in any adolescent with atypical hip, groin, thigh, or knee pain, since posterior displacement is missed by AP-only imaging.
- Specifically evaluate for the peritubercle lucency sign, particularly on follow-up radiographs of the contralateral hip in patients with known unilateral SCFE.
- If radiographs are normal or equivocal but clinical suspicion persists (persistent pain, antalgic gait, risk factors such as obesity or endocrinopathy), proceed to MRI of both hips.
- Interpret a positive MRI (marrow edema, physeal widening, effusion) as high risk for evolving or imminent SCFE and treat accordingly; interpret a negative MRI as reassuring given its high negative predictive value, while continuing clinical follow-up.
- Recognize that no single sign, radiographic or MRI-based, has perfect accuracy; in ambiguous cases, correlate findings across both modalities and with clinical risk factors rather than relying on either test in isolation.

7. Recent Updates (2025–2026)

Several developments since the initial wave of peritubercle lucency and MRI-surveillance studies refine-and in some cases complicate-the diagnostic picture:

- **Pathomechanics-focused synthesis (Rosenbaum and Cooper, *Skeletal Radiology*, 2025).** This 2025 review reinforces that diagnostic delay remains common despite imaging advances, and centers the epiphyseal tubercle as the anatomic site of rotational microinstability that drives early physeal change. It emphasizes that careful side-to-side comparison of physeal morphology, at every stage of disease, is essential, and that technique errors (poor positioning, omission of a true lateral view) are a recurrent, correctable cause of missed early disease. It positions cross-sectional imaging (MRI, selectively CT) as a problem-solving tool for equivocal early/preslip cases and for surgical planning in more advanced disease, rather than as a first-line screening test.
- **Primary care evidence review (*American Family Physician*, October 2025).** This rapid evidence review reiterates that SCFE incidence is rising in parallel with pediatric obesity, and highlights emerging systemic risk-factor data, including 2025 studies linking vitamin D deficiency to SCFE risk. These findings do not change imaging accuracy directly but strengthen the case for a lower threshold to image at-risk adolescents with atypical hip, groin, or knee pain.
- **Conflicting evidence on MRI's predictive value.** Not all data support MRI as a reliable predictor of future contralateral slip. At least one study found that MRI parameters obtained at the time of primary diagnosis did not significantly differ between patients who later developed a sequential contralateral slip and those who remained unilateral-MRI at that single time point failed to predict subsequent slip in that cohort. A 2025 review (Khalifa, *European Journal of Orthopaedic Surgery & Traumatology*) similarly frames prophylactic contralateral fixation, and the imaging criteria used to justify it, as still controversial and without a single validated predictive

method. This tempers the more optimistic sensitivity/specificity figures reported by smaller single-center MRI surveillance cohorts and argues for cautious, individualized interpretation rather than treating a positive or negative MRI as definitive.

- **Continued refinement of radiographic–MRI correlation (2024–2026 narrative reviews).** Subsequent narrative reviews-including an updated 2026 publication in the *Journal of Orthopaedic Reports* by the same author group behind the 2024 Heliyon review-continue to affirm MRI as the most sensitive modality for preslip change, while reiterating that the peritubercle lucency sign gives radiographs a meaningful, low-cost, low-radiation first-line role, and that the two findings are anatomically linked correlates of the same rotational-instability mechanism rather than competing, independent tests.

Practical implication of the 2025–2026 literature: the core sensitivity/specificity estimates for the peritubercle lucency sign and MRI marrow-edema findings summarized in Sections 3–5 remain the best available quantitative estimates, but the newest literature cautions against over-reliance on a single positive or negative MRI to make binary treatment decisions (e.g., prophylactic contralateral pinning), favors comparison-based physeal assessment and correct radiographic technique as underappreciated sources of diagnostic delay, and supports a lower threshold for imaging adolescents with systemic risk factors such as obesity or vitamin D deficiency.

8. Limitations of the Current Evidence Base

Most available diagnostic-accuracy studies are retrospective, single-center, and drawn from relatively small, high-prevalence surveillance cohorts (patients already known to have unilateral SCFE), which likely inflates predictive values relative to a general pediatric population presenting with hip pain. External validation of the peritubercle lucency sign has shown lower, though still clinically meaningful, sensitivity and specificity compared with the original description. Prospective, multicenter studies using consistent MRI protocols and blinded, standardized radiographic scoring are needed to better define real-world diagnostic accuracy at the preslip stage.

9. Conclusion

At the preslip stage of SCFE, plain radiographs-particularly when specifically assessed for the peritubercle lucency sign-can achieve sensitivity and specificity in the 70–97% and 82–99% ranges, respectively, and remain the appropriate first-line study. MRI, however, remains the most sensitive single modality for detecting the earliest physeal and marrow changes of SCFE, particularly when radiographs are normal, and offers a very high negative predictive value that is valuable for excluding impending contralateral slip. Because the two modalities detect related but not identical facets of the same pathophysiologic process, they are best used complementarily: radiographs for first-line screening and longitudinal surveillance, and MRI reserved for cases with high clinical suspicion and negative or equivocal radiographic findings. The 2025–2026 literature adds an important caveat: neither modality should be used in isolation to make binary

treatment decisions, and correct technique plus side-to-side comparison remain as important as the choice of modality itself.

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This review synthesizes previously published diagnostic-accuracy data and is intended for educational purposes. It does not replace formal systematic review methodology (e.g., PRISMA-DTA) and should not be used alone to guide individual patient management.