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Review Article

Comparison of CT and MRI in diagnosing occult hip fracture: a systematic review and meta-analysis

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Abstract: Objective: To compare the diagnostic accuracy of computed tomography (CT) scans and magnetic resonance imaging (MRI) in detecting occult hip fractures. Methods: We conducted a systematic literature review and identified 12 articles involving 1,819 participants for inclusion. Data extraction and quality assessment were performed using the Quality Assessment of Diagnostic Accuracy Studies-2 tool. Publication bias was assessed with the Deek funnel plot asymmetry test. We conducted a meta-analysis using a random-effects model to derive pooled estimates of sensitivity, specificity, positive and negative likelihood ratios, and the diagnostic odds ratio, along with their 95% confidence intervals. A summary receiver operating characteristic curve was generated to illustrate the overall diagnostic accuracy. Results: The methodological quality of the included studies was high, with minimal concerns about the applicability of the tests in clinical settings. Both CT and MRI showed good diagnostic efficacy for occult hip fractures. However, MRI consistently outperformed CT, exhibiting significantly higher sensitivity, specificity, and likelihood ratios, thereby providing superior accuracy in confirming or excluding occult fractures. Meta-regression analysis revealed that sequence parameters and sample size significantly influenced the differences in sensitivity and specificity between CT and MRI. Conclusion: Both CT and MRI are effective modalities for detecting occult hip fractures, with MRI demonstrating greater diagnostic accuracy. This meta-analysis supports the use of MRI when higher sensitivity and specificity are required in clinical practice.

Keywords: Occult hip fracture, computed tomography, magnetic resonance imaging, diagnostic odds ratio, diagnostic accuracy

Introduction

The hip joint, a crucial weight-bearing structure in the human body, is prone to injuries, with hip fractures being a common occurrence in orthopedic practice [1]. These fractures often involve multiple fragments and are frequently comminuted, leading to displacement or intercalation of the broken ends, and occasionally, occult fractures are also present [2]. Hip fractures are typically complex and can severely impair mobility and function, causing substantial pain and leading to significant long-term disability [3]. Studies indicate that less than 50% of pre-injury hip joint function and mobility may be recovered within a year post-fracture [4]. Thus, prompt and accurate diagnosis is essential for optimizing patient outcomes and prognosis.

While X-rays are fast and simple, they provide only two-dimensional images and lack depth perception, which limits their ability to accurately depict the displacement of complex fracture fragments around the anatomically intricate hip joint [5, 6]. Patients with normal initial X-ray results but suspected occult hip fractures require further imaging evaluations. CT scans offer detailed images of anatomical structures and any associated injuries but have limited accuracy in identifying interruptions in bone trabeculae and cortical areas [7, 8]. Conversely, MRI provides multi-angle and multi-plane imaging capabilities, allowing for comprehensive visualization of bone trabeculae fractures [9]. It also delivers high-resolution images of bone trabeculae, articular cartilage, and tissue

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edema, making it potentially more effective for this purpose.

Given the importance of early detection of occult hip fractures, this meta-analysis aims to compare the diagnostic accuracy of CT and MRI in their detection, thereby identifying the more effective imaging modality.

Materials and methods

The analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines [10], and was registered on International Platform of Registered Systematic Review and Meta-analysis Protocols (ID: 202420093).

Literature search

We conducted a comprehensive search on PubMed, Web of Science, Cochrane Library, and EMBASE databases up to August 2022. Search terms included "Occult Hip Fractures", OR "Occult Femoral Neck Fractures", OR "Occult Fractures of the Proximal Femur", OR "Occult Intertrochanteric Fractures" OR "Occult Trochanteric Fractures" AND "Magnetic Resonance Imaging" OR "MRI" OR "MR Tomography" OR "NMR Imaging" AND "Computed Tomography" OR "CT" OR "CT Scan". The literature search was executed by two researchers independently, with a third person resolving any discrepancies.

Selection criteria

Inclusion criteria were: (1) Observational studies published in English; (2) Studies including patients with hip trauma and involving at least 30 cases; (3) Studies aimed at comparing the diagnostic value of CT or MRI for occult hip fractures; (4) Studies providing detailed diagnostic accuracy data (true positives/negatives, false positives/negatives) for MRI or CT.

Exclusions were review articles, duplicate publications, letters, case reports, and studies with incomplete data.

Data extraction and quality evaluation

Data extraction and quality assessment were independently performed by two researchers (HQ and LB), with any disagreements resolved by consensus. Extracted data included publication year, author(s), total number of patients, patient age, reference standard, study type, and objective. Quality was assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool [11].

Statistical analysis

Data analyses were conducted using RevMan 5.3 and Stata 15.1 software. Meta-analysis was performed with a random-effects model to calculate pooled sensitivity, specificity, positive and negative likelihood ratios, diagnostic odds ratio (DOR), and 95% confidence intervals (CIs). This approach accounts for study heterogeneity and provides robust diagnostic accuracy estimates. A Summary Receiver Operating Characteristic (SROC) curve, illustrating the overall diagnostic performance, was generated using R software. To assess study heterogeneity, we employed the Cochrane Q test and quantified it using the I^2 statistic. Meta-regression was performed using the Knapp-Hartung method under a random-effects model. Publication bias was evaluated using the Deeks funnel plot asymmetry test to investigate potential bias by examining the symmetry of the plot. Significant asymmetry would suggest the presence of publication bias.

Results

Literature selection

Figure 1 presents the flowchart for the literature selection process. An initial search yielded 750 papers, from which duplicates were removed, leaving 480 full-text articles that met the eligibility criteria. After reviewing titles and abstracts, 379 articles were excluded, leaving 101 potentially relevant full-text articles. Ultimately, 12 studies involving 1,819 participants were included in the final analysis. Of these, ten articles directly compared the diagnostic accuracy of CT scans and MRIs for occult hip fractures, and two articles examined the diagnostic sequence of CT followed by MRI.

Study characteristics

Table 1 details the characteristics of the included studies. Among the 12 articles, seven were retrospective and 2 were prospective. Sample

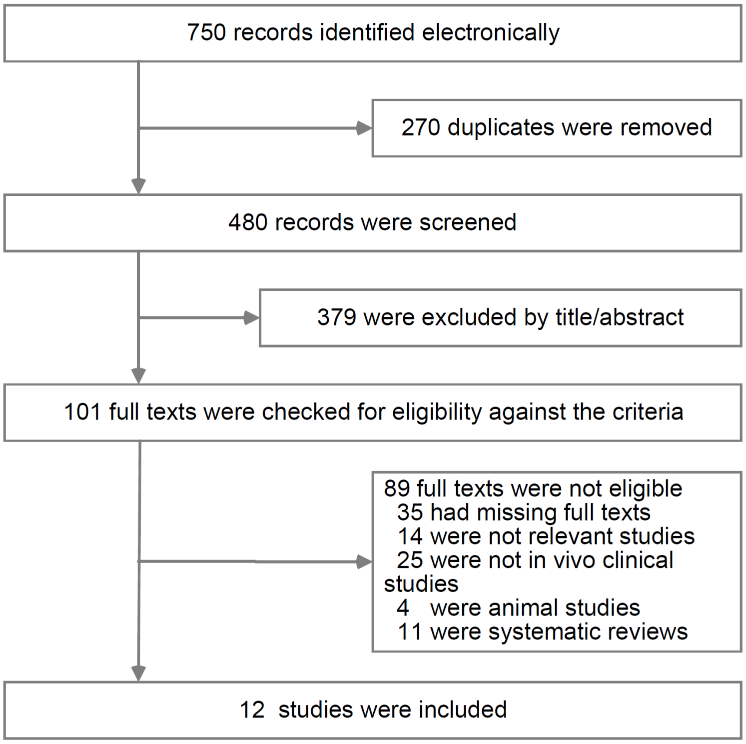

Figure 1. Study flowchart.

sizes ranged from 45 to 590 subjects. The extracted data for statistical analysis included true positives/negatives, and false positives/negatives, positive and negative likelihood ratios, sensitivity, and specificity.

Quality evaluation

Figure 2 illustrates the risk of bias assessment for the included studies, all of which exhibited high methodological quality, with minimal concerns about the clinical relevance of the tests.

Publication bias

Figure 3 demonstrates the absence of publication bias using Deeks's funnel plot method, with non-significant *p*-values of 0.14 and 0.87.

Diagnostic performance of MRI vs. CT

The diagnostic performance of MRI and CT in detecting occult hip fractures was analyzed. MRI showed a pooled sensitivity of 0.94 (95% CI: 0.80-0.99) and specificity of 0.98 (95% CI: 0.94-1.00), as depicted in **Figure 4**. For CT, the pooled sensitivity was 0.92 (95% CI: 0.81-0.96) and specificity was 0.94 (95% CI: 0.87-0.97), illustrated in **Figure 5**.

The pooled positive and negative likelihood ratios for CT were 7.60 (95% CI: 5.07-34.44) and 0.09 (95% CI: 0.04-0.21), respectively, shown in **Figure 6**. For MRI, these ratios were 8.14 (95% CI: 5.70-108.04) and 0.06 (95% CI: 0.01-0.22), respectively, presented in **Figure 7**.

The Summary Receiver Operating Characteristic (sROC) curves, shown in **Figure 8**, indicated the overall diagnostic performance of MRI and CT, with AUCs of 0.99 and 0.98, respectively, suggesting comparable accuracy between MRI and CT in the diagnosis of occult hip fractures.

Meta-regression

Meta-regression analysis (**Table 2**) indicated that sequence parameters and sample size significantly affected the variability in sensitivity and specificity for both CT (P=0.021 and 0.002, respectively) and MRI (P=0.035 and 0.009, respectively). However, variations due to study type and machine model were not statistically significant (all P>0.05).

Discussion

Occult hip fractures are common clinical challenges in orthopedics, where timely and accurate diagnosis is crucial for effective patient management [24]. While CT is effective for diagnosing visible fractures, it often fails to detect occult hip fractures, which hampers prompt and appropriate treatment [25]. In contrast, advancements in MRI technology have made it increasingly preferred for identifying these hidden fractures, often leading to better therapeutic outcomes [26].

Our meta-analysis, which included 12 studies comparing MRI with CT in diagnosing occult hip fractures, revealed that MRI generally provides diagnostic accuracy comparable to CT. Despite

Table 1. The characteristics of included publications

Study	Diagnostic method	Machine model	Sequence parameters	Subjects	Age*	Reference standard	Study design	Study purpose
Gill et al., 2013 [12]	CT vs. MRI	CT: Siemens scanners MRI: Philips	CT: a×4 quad slice and ×1 62 slice T1 MRI: weighted spine echo + STIR axial and coronal scan	92	82 (22)	Operation and follow-up	Retrospective study	Comparison of sensitivity of CT and MRI in occult fracture
Collin et al., 2016 [13]	CT vs. MRI	CT: Siemens SOMATOM MRI: Siemnes	CT: a 16-detector row scanner MRI: 1.5-Tesla (T) Symphony whole-body scanner	45	79 (60-96)	Imaging and clinical follow-up	Retrospective study	Evaluation of CT and MRI in the diagnosis of occult hip fractures
Haubro et al., 2015 [14]	CT vs. MRI	CT: GE MRI: Philips	CT: 4-slice VCT scanner MRI: 3T Acieva	67	80	Follow-up	Prospective cohort study	Comparison of sensitivity and specificity of CT and MRI in fracture of proximal femur
Deleanu et al., 2015 [15]	CT vs. MRI	CT: GE MRI: Philips Brilliance	CT: MX 16 slice MRI: LX 1 Tesla	82	N/A	Follow-up	Retrospective study	Evaluation of CT and MRI in the diagnosis of occult fractures of the proximal femur
Kutaiba et al., 2020 [16]	CT	CT: GE MRI: Siemens	CT: 64-slice scanner MRI: 1.5T Avanto or 3T Skyra	181	82 (20)	Imaging and clinical follow-up	Retrospective study	CT and further MRI in the diagnosis of occult fracture of the femoral neck
Eggenberger et al., 2019 [17]	CT vs. MRI	CT: GE MRI: Siemens	CT: XTlight Speed VCT 64 slice MRI: 1.5T Acieva	218	77 (12)	Imaging follow-up and clinical history	Retrospective study	Evaluation of CT and MRI in the diagnosis of hip or pelvic fractures
Lubovsky et al., 2005 [18]	CT vs. MRI	CT: GE MRI: Philips	CT: 1 slice scanner MRI: 1T Panorama (open)	590	73	Clinical follow-up	Retrospective study	Comparison of the accuracy of CT scan and MRI in diagnosing occult hip fractures
Cabarrus et al., 2008 [19]	CT vs. MRI	CT: GE MRI: Philips	MRI: 1.5T Acieva	145	65.9±17.7	Clinical follow-up	Retrospective study	Comparison of sensitivity of CT and MRI in occult fracture
Williams et al., 2019 [20]	CT	Toshiba Medical Systems	Toshiba Aquilion 64 scanner	206	82	Imaging and clinical follow-up	Retrospective study	CT and further MRI in the diagnosis of occult geriatric hip fractures
Lanotte et al., 2020 [21]	CT vs. MRI	CT: Philips Medical Systems MRI: Siemens Healthcare	CT: Brilliance 40 slice MRI: 3T Verio	102	83±8.8 76.8±10.1	Clinical follow-up	Two-center prospective study	Evaluation of CT and MRI in the diagnosis of occult fracture of femur
Rehman et al., 2016 [22]	CT vs. MRI	CT: GE MRI: Philips	CT: MX 16 slice MRI: LX 1 Tesla	71	82±13	Imaging and clinical follow-up	Retrospective study	Evaluation of occult fracture by CT and MRI
Davidson et al., 2021 [23]	CT vs. MRI	CT: Siemens SOMATOM MRI: Siemens MAGNET	CT: multislice helical scanners MRI: T1 weighted spin echo + STIR axial and coronal scans	103	78.4 (22-103)	Imaging and clinical follow-up	Retrospective study	Evaluation of occult hip fracture by CT and CT+MRI

*: Data were represented as mean ± SD years. CT: Computed Tomography; MRI: Magnetic Resonance Imaging; N/A: Not Available; SD: Standard Deviation.

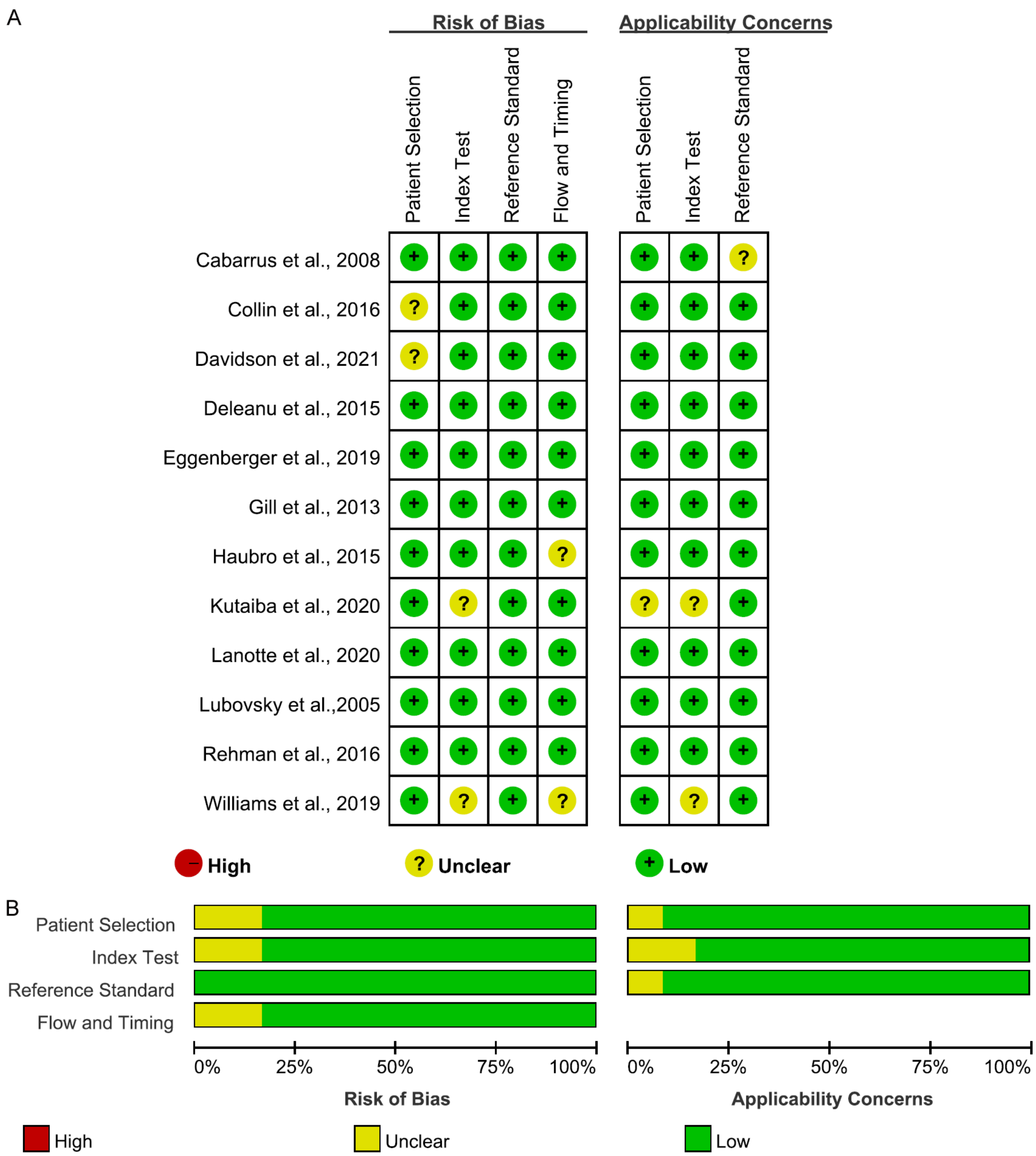

Figure 2. Methodological quality evaluation by QUADAS-2. A. Methodological quality summary. B. Methodological quality graph. QUADAS-2: Quality Assessment of Diagnostic Accuracy Studies-2.

the broad application of CT in fracture diagnosis - owing to its ability to perform multislice scanning and reconstruct images in various planes such as coronal, sagittal, and cross-sectional - there are significant limitations. These include difficulties and missed diagnoses associated with the complex structure of the intertrochanteric region, interference from nutrient vessels, and the potential for missed scans [27]. In fact, studies suggest that CT misses 30% to 60% of fractures, especially those in the femoral head [28].

However, spiral CT continues to offer advantages such as rapid scanning, affordability, suitability for elderly patients, and advanced image processing capabilities in later stages [29]. Rogers et al. reported that CT's diagnostic value is comparable to MRI's [30], while Rehman et al. argued that the advantages of MRI

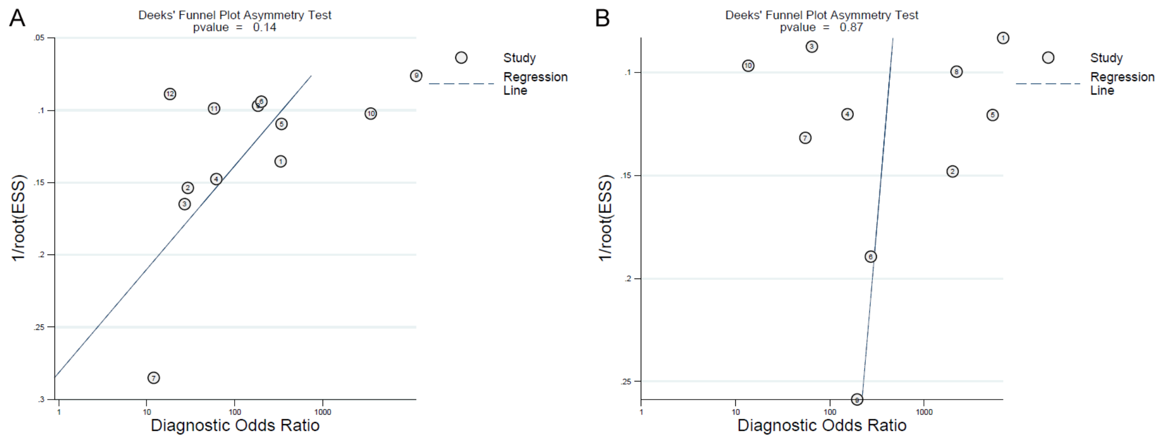

Figure 3. Funnel plot for publication bias. A. CT. B. MRI. CT: Computed Tomography; MRI: Magnetic Resonance Imaging.

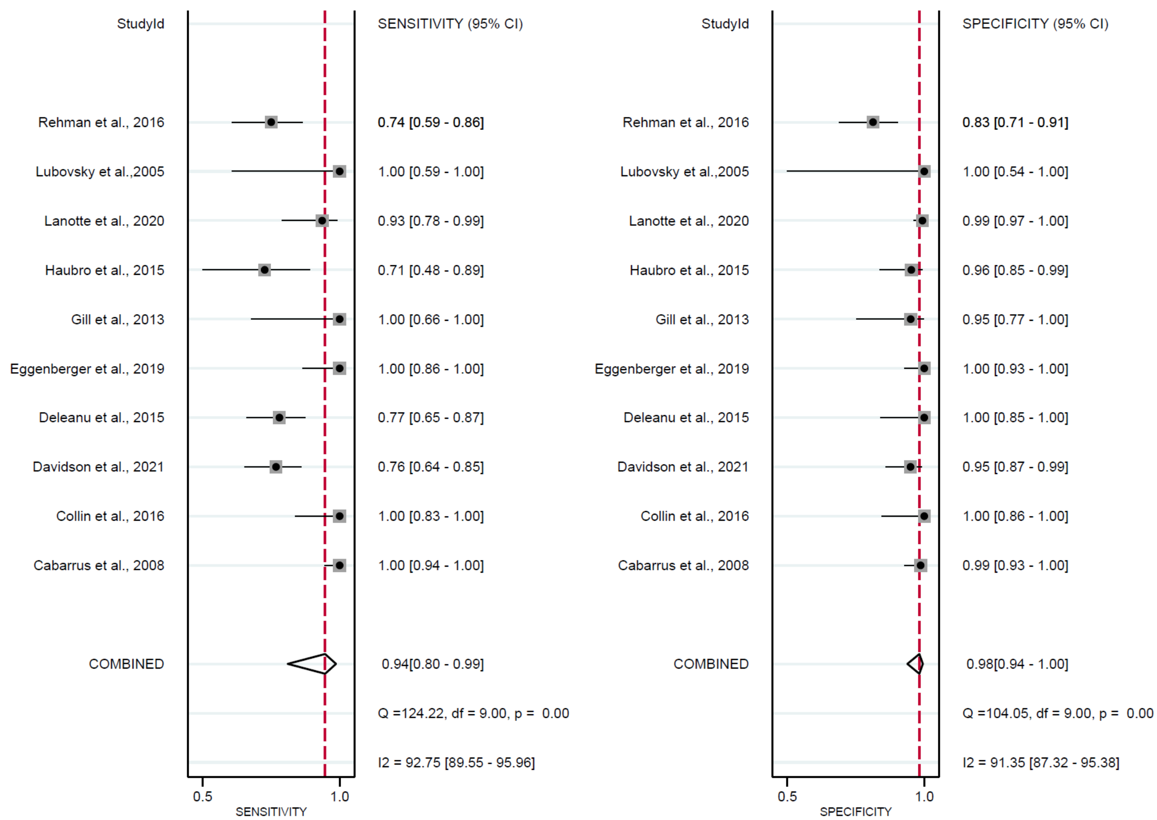

Figure 4. Forest plots exhibited diagnostic accuracy of MRI in occult hip fracture. MRI: Magnetic Resonance Imaging.

for evaluating occult hip fractures might be overstated [30]. Moreover, recent comparisons between multilayer detector CT and MRI for detecting occult fractures suggest that CT might be superior in distinguishing between simple trabecular and cortical fractures [31]. Despite this, MRI demonstrates higher sensitivity in detecting fractures [32], suggesting that its utility might be underappreciated.

Ample high-quality evidence suggests that MRI surpasses CT in clinical accuracy. Collin et al. [13] noted that MRI is more reliable than CT for diagnosing hip fractures. Additionally, a study

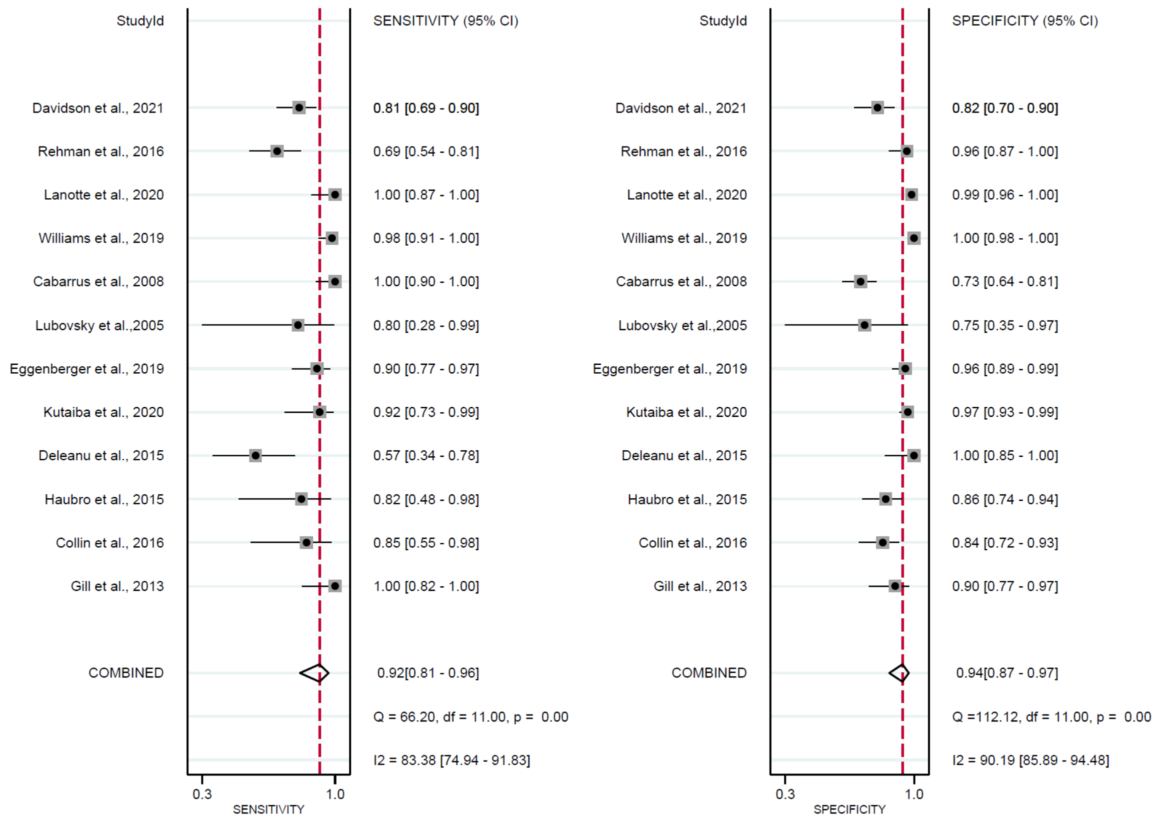

Figure 5. Forest plots exhibited diagnostic accuracy of CT in occult hip fracture. CT: Computed Tomography.

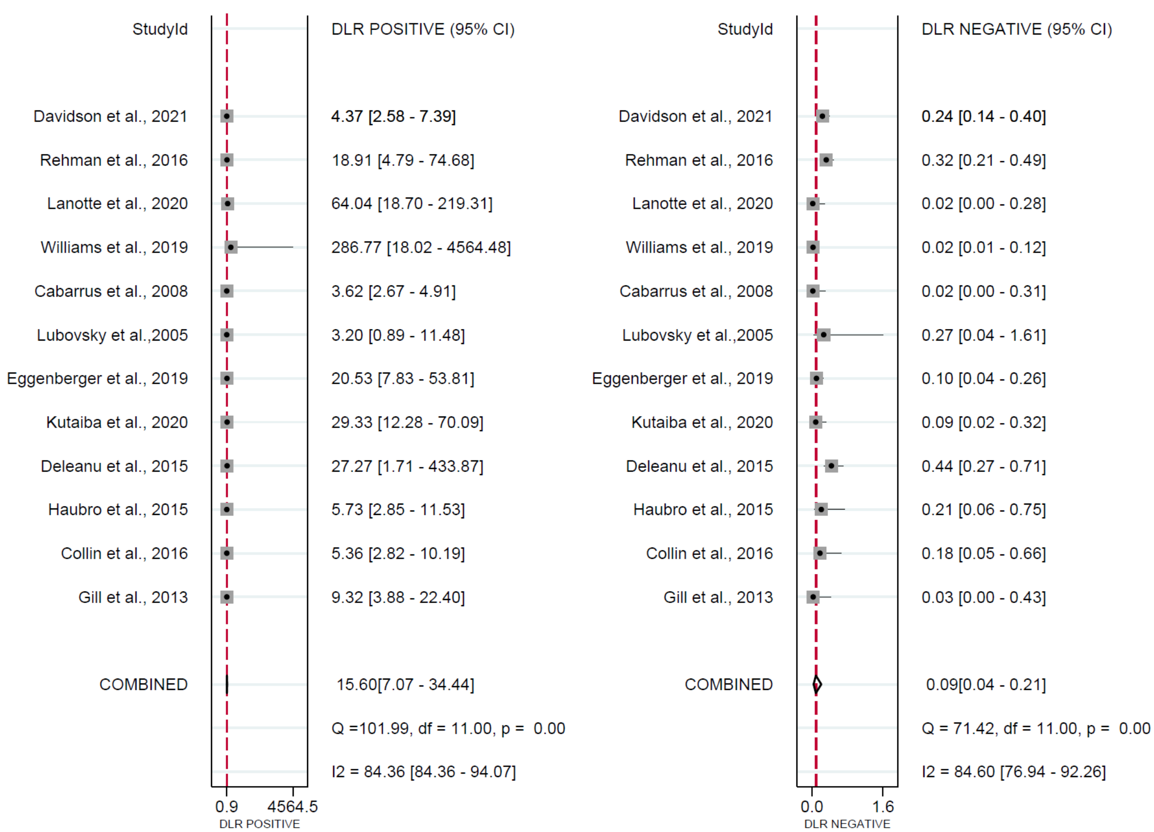

Figure 6. Forest plots exhibited the positive likelihood ratio and negative likelihood ratio of CT in diagnosing occult hip fracture. CT: Computed Tomography.

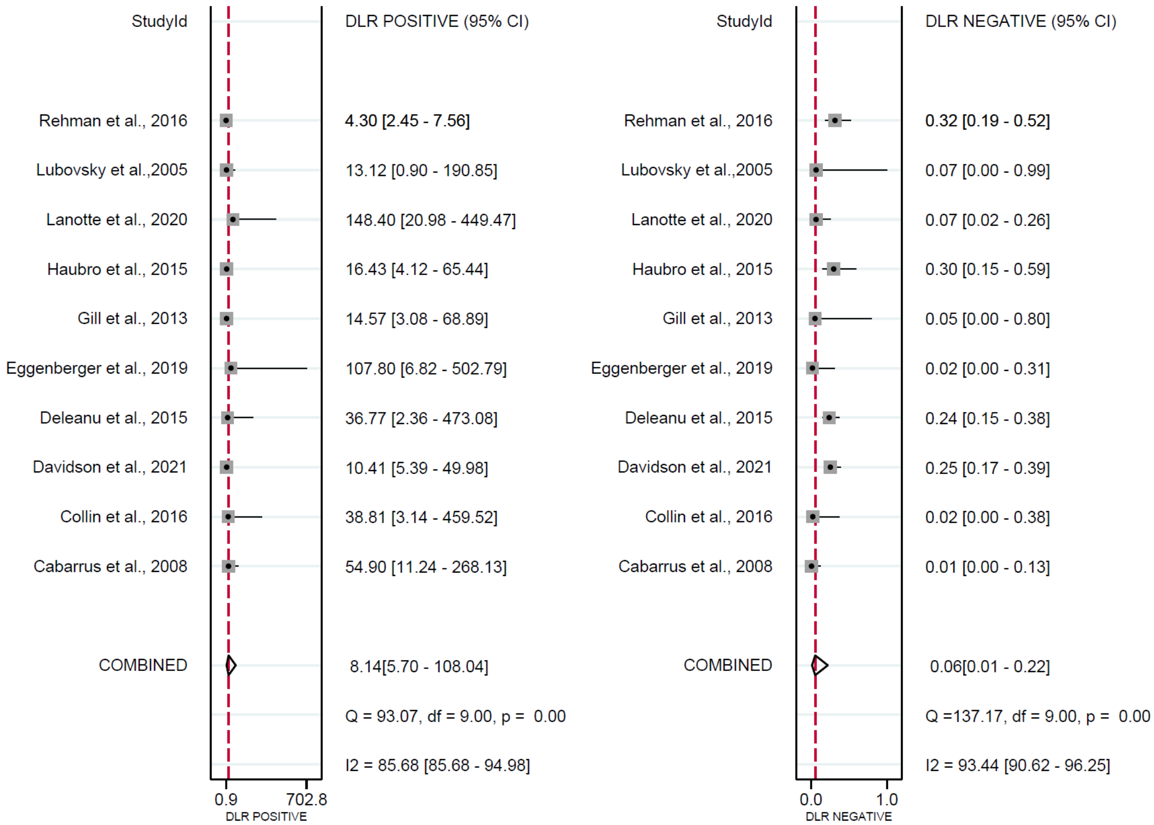

Figure 7. Forest plots exhibited the positive likelihood ratio and negative likelihood ratio of MRI in diagnosing occult hip fracture. MRI: Magnetic Resonance Imaging.

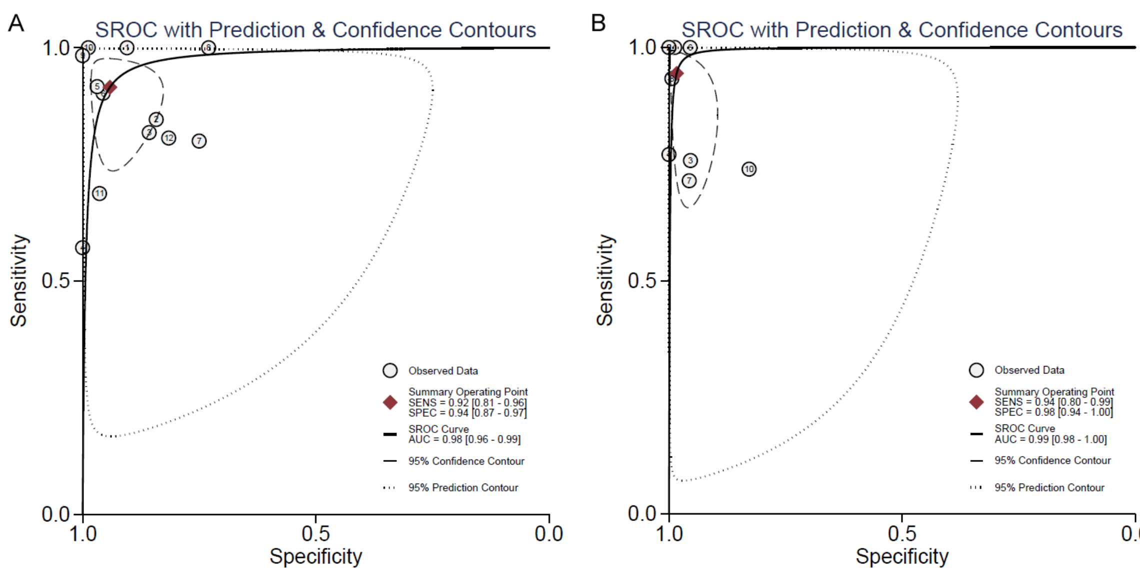

Figure 8. SROC curve exhibited diagnostic accuracy of MRI (A) and CT (B) in occult hip fracture. CT: Computed Tomography; MRI: Magnetic Resonance Imaging; SROC: Summary Receiver Operating Characteristic.

Table 2. Meta-regression on the significance of differences in sensitivity and specificity of CT and MRI in the diagnosis of occult hip fracture

Factors	CT		MRI	
	Coeff	P	Coeff	P
Machine model	0.896	0.801	0.651	0.090
Sequence parameters	2.147	0.021	1.902	0.035
Sample size	1.170	0.002	2.337	0.009
Study type	0.786	0.280	0.556	0.462

Coeff: coefficient; CT: Computed Tomography; MRI: Magnetic Resonance Imaging.

has demonstrated CT's limited ability to detect disruptions in bone trabeculae and cortex [33], which can lead to damage to small blood vessels in the medullary cavity, resulting in intramedullary hemorrhage and edema. MRI effectively identifies these critical signal changes. Thus, MRI is the preferred modality for diagnosing occult fractures [34].

Our meta-analysis found MRI to exhibit higher sensitivity and specificity than CT in diagnosing occult hip fractures. The area under the ROC curve was also greater for MRI, underscoring its superior diagnostic precision and effectiveness in clinical settings. These findings advocate for MRI as the preferred modality for detecting occult fractures, aligning with its enhanced capability to provide a more accurate and detailed evaluation of complex bone injuries.

Heterogeneity is an inherent aspect of meta-analysis, which may not be completely avoidable [35]. Identifying sources of heterogeneity is critical for assessing the precision of estimates and for deciding whether the statistical pooling of results is appropriate [36]. It is essential to explore the underlying causes of this heterogeneity. In our study, heterogeneity in sensitivity and specificity might be attributed to factors like the model of CT or MRI machines, scanning sequence parameters, and the diagnostic proficiency of clinicians. Our meta-regression analysis indicated significant impacts from sequence parameters (P=0.021 for CT and P=0.035 for MRI) and sample size (P=0.002 for CT and P=0.009 for MRI) on these variances. However, the type of study and machine model showed negligible effects.

To further understand the differences in diagnostic accuracy between CT and MRI for occult hip fractures, it is beneficial to compare our findings with existing literature. Tringale et al. [37] reported higher sensitivity with MRI, aligning with our results, whereas Boehm and colleagues [38] found CT to be more sensitive in detecting small, minimally displaced fractures, contradicting our findings. These discrepancies may stem from differences in patient populations, fracture types, and severities. Technical variations such as slice thickness and imaging protocols, along with the radiologists' experience and interpretation criteria, could also contribute to these differences.

Moreover, recent studies highlight the importance of considering the anatomical location of the fracture when selecting an imaging modality. Agarwal et al. [39] emphasized this point, and Smyth et al. [40] suggested that MRI is superior for detecting fractures in the femoral neck and acetabulum, while CT performs better for proximal femur fractures. This anatomical specificity could partly explain the variability in performance between the modalities across studies.

There are several limitations to consider in this meta-analysis. First, the number of included studies is relatively small. However, all studies were assessed for quality and representativeness using the QUADAS-2 tool, and heterogeneity was evaluated prior to analysis to ensure comparability. Second, the sample sizes in some studies were small, potentially reducing the statistical power and possibly overstating diagnostic accuracy. Additionally, there may be bias due to the use of imaging follow-up as the reference standard. Future research with well-designed, larger-scale studies is necessary to confirm these findings and to refine the imaging strategy for occult hip fractures.

In conclusion, despite these limitations, our analysis demonstrates that both CT and MRI are effective in detecting occult fractures, with MRI showing significantly higher sensitivity and specificity. We recommend the use of MRI over CT when feasible and when there are no contraindications.

Disclosure of conflict of interest

None.

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