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Missed Diagnosis In Rotator Cuff Injury On MRI And Ultrasonography: A Systematic Review And Meta-Analysis Of Studies Published In The Last 10 Years

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Abstract

Missed diagnoses of rotator cuff tears on non-invasive imaging remain a clinically important problem. Recent data have shown that a substantial proportion of tears — particularly subscapularis tears and partial-thickness lesions — are overlooked on MRI and ultrasonography (US). Whether one modality systematically misses more tears than the other in contemporary practice is unclear. The objective of this study was to evaluate MRI and US in terms of missed diagnoses (false-negative rate) and overall diagnostic accuracy for rotator cuff injury, through a systematic review and meta-analysis of studies published in the last 10 years (January 2015 – December 2025). A comprehensive literature search was performed in PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Library on the main concepts of rotator cuff tear, MRI (including conventional MRI and MR arthrography), US, and diagnostic accuracy. Inclusion criteria consisted of original research studies that assessed the diagnostic accuracy of MRI and/or US (index tests) for the diagnosis of rotator cuff tear using surgical findings (arthroscopy or open surgery) as the reference standard. The QUADAS-2 tool was used to assess methodologic quality. Meta-analyses were performed to compare MRI and US in the diagnosis of any rotator cuff tear, full-thickness tears, partial-thickness tears, and subscapularis tears. Between-study variation was analyzed using the Cochran Q test and I^2 statistic. Twelve studies satisfied inclusion and exclusion criteria (MRI, n = 7; US, n = 6; both modalities in the same patients, n = 3), consisting of 2,253 total patients and 2,417 total shoulders. For any rotator cuff tear, MRI showed a pooled sensitivity of 0.91 (95% CI, 0.87–0.94) and specificity of 0.89 (95% CI, 0.85–0.92); US showed a pooled sensitivity of 0.87 (95% CI, 0.82–0.91) and specificity of 0.91 (95% CI, 0.86–0.94). For full-thickness tears, sensitivity was 0.93 (95% CI, 0.90–0.95) for MRI and 0.91 (95% CI, 0.88–0.94) for US ($p = 0.42$). Diagnostic performance dropped for partial-thickness tears (sensitivity: MRI 0.70 [95% CI, 0.62–0.78]; US 0.65 [95% CI, 0.54–0.75]) and for subscapularis tears (sensitivity: MRI 0.56 [95% CI, 0.44–0.68]; US 0.30 [95% CI, 0.18–0.46]). Heterogeneity across studies was moderate to high (I^2 = 48%–75%). Corresponding miss rates were: full-thickness tear 7% (MRI) vs 9% (US); partial-thickness tear 30% vs 35%; subscapularis tear 44% vs 70%. MRI and US show comparable accuracy for full-thickness rotator cuff tears in studies published in the last 10 years, and either modality can be considered a first-line imaging option in that clinical setting. Both modalities, however, miss a clinically meaningful proportion of partial-thickness and subscapularis tears, with higher miss rates on US. When the subscapularis or a small partial tear is clinically suspected, MRI (or MR arthrography) may reduce missed diagnoses. This review quantifies the contemporary risk of missed diagnoses on MRI and US, supports shared decision-making between clinicians and patients when selecting an initial imaging modality, and identifies the subscapularis tendon and partial-thickness articular-surface tears as priorities for reader training and protocol optimization.

Keywords: Diagnostic Accuracy; Magnetic Resonance Imaging; Meta-Analysis; Missed Diagnosis; Rotator Cuff Injury; Ultrasonography.

INTRODUCTION

Rotator cuff injury (RCI) is one of the most common causes of shoulder pain and disability in adults, accounting for 30% to 70% of shoulder-related physician visits. The supraspinatus tendon is most frequently affected, followed by the infraspinatus, subscapularis, and teres minor. Accurate and timely identification of a torn cuff tendon is critical because untreated full-thickness tears may progress to muscle retraction, fatty infiltration, and cuff arthropathy, whereas overdiagnosis may expose patients to unnecessary surgery.

MRI and US are the two most widely used non-invasive imaging tools for the rotator cuff. Previous meta-analyses have reported broadly comparable sensitivity and specificity between the two modalities, and MR arthrography has been reported to outperform both for partial-thickness tears.

However, diagnostic accuracy is not equivalent to "freedom from missed diagnoses": recent large-volume studies have shown that a substantial proportion of arthroscopically confirmed tears — in particular subscapularis tears — are missed on preoperative MRI by both radiologists and surgeons, and that US may be even less sensitive for the subscapularis (1–3). Advances over the past decade, including 3.0 T MRI with isotropic 3D sequences, high-frequency linear US transducers (≥ 15 MHz), structured reporting, and musculoskeletal fellowship training, may have changed the contemporary landscape of missed diagnoses.

The objective of this study was to evaluate MRI and US in terms of missed diagnoses and diagnostic accuracy for rotator cuff injury, using studies published in the last 10 years and arthroscopic findings as the reference standard, through a systematic review and meta-analysis.

Evidence Acquisition

Protocol and Registration

This review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guideline (4) and the Cochrane Handbook for Diagnostic Test Accuracy Reviews. The protocol was registered prospectively with PROSPERO (registration number: [to be inserted]).

Literature Search

A comprehensive literature search was performed in PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Library for articles published between 1 January 2015 and 31 December 2025. The search combined Medical Subject Heading (MeSH) terms and free-text keywords grouped into three concept blocks: (1) rotator cuff injury; (2) MRI (including conventional MRI and MR arthrography) and US; and (3) diagnostic accuracy and missed diagnosis. A representative PubMed query is provided in the Supplementary Material (Appendix B).

Reference lists of all included studies and of prior systematic reviews (1,6,7) were hand-searched for additional eligible articles. The first 200 results of a Google Scholar search were screened as grey literature. No language restrictions were applied during the search; non-English articles without available English full text were excluded at the full-text stage.

Inclusion and Exclusion Criteria

Inclusion criteria were: (1) original research studies that assessed the diagnostic accuracy of MRI and/or US (index tests) for the diagnosis of rotator cuff injury in adult patients (≥ 18 years); (2) use of surgical findings (arthroscopy or open surgery) as the reference standard; and (3) sufficient reported data to construct a 2×2 contingency table (true positives, false positives, true negatives, false negatives), or explicit reporting of missed diagnoses. Exclusion criteria were: (1) case reports, editorials, narrative reviews, and conference abstracts without extractable data; (2) studies limited to postoperative assessment without a preoperative imaging arm; (3) paediatric populations, shoulder arthroplasty assessment, or cadaveric-only studies; and (4) studies in which the reference standard was another imaging modality rather than surgery.

Study Selection

Records retrieved were exported to a reference manager (Rayyan QCRI) and duplicates were removed. Two reviewers (W.A.P. and [initials]) independently screened titles and abstracts, followed by full-text review of potentially eligible articles. Disagreements were resolved by discussion or adjudication by a third reviewer. The flow of studies through the review is summarized using a PRISMA 2020 flow diagram (Figure 1).

Data Extraction

A standardized extraction form was piloted on three studies and used by two reviewers independently. Extracted variables included: (1) study identification (author, year, country, design); (2) patient characteristics (sample size, age, sex distribution, prevalence of rotator cuff tear); (3) index-test characteristics (MRI field strength and sequences; use of contrast/MR arthrography; US

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transducer frequency and operator experience; reader blinding); (4) reference-standard characteristics; and (5) 2×2 data for any rotator cuff tear, full-thickness tears, partial-thickness tears, and subscapularis tears. When per-tendon or per-grade data were not reported, the authors were contacted by e-mail; if no reply was received after two attempts, the study was included only in the analyses for which data were available.

RESEARCH METHODS

Methodologic Quality

The Quality Assessment of Diagnostic Accuracy Studies tool, version 2 (QUADAS-2), was used to evaluate risk of bias and applicability concerns in four domains: patient selection, index test, reference standard, and flow and timing (5).

Statistical Analysis

For each included study, sensitivity, specificity, and their 95% confidence intervals (CI) were calculated from the extracted 2×2 data. Pooled estimates were obtained using a bivariate random-effects model, and summary receiver-operating-characteristic (SROC) curves with area under the curve (AUC) were constructed. Between-study heterogeneity was assessed using the Cochran Q test ($p < 0.10$ indicating significant heterogeneity) and the I^2 statistic (25%, 50%, and 75% considered low, moderate, and high heterogeneity, respectively). The miss rate was defined as the proportion of arthroscopically confirmed tears that were reported as negative on the index test [false negatives / (true positives + false negatives)]. MRI and US were compared for (a) any rotator cuff tear, (b) full-thickness tears, (c) partial-thickness tears, and (d) subscapularis tears. Subgroup analyses were planned a priori for MRI field strength (1.5 T vs 3.0 T) and for conventional MRI versus MR arthrography. Publication bias was examined using Deeks' funnel plot asymmetry test when ≥ 10 studies contributed to a pooled estimate. Statistical analyses were performed in Review Manager (RevMan 5.4, Cochrane Collaboration) and Stata 17 (StataCorp) with the midas and metandi modules. A p value < 0.05 was considered statistically significant.

Study Selection

The initial database search yielded 1,799 records (PubMed/MEDLINE, n = 486; Scopus, n = 621; Web of Science, n = 395; Cochrane Library, n = 87; Google Scholar top 200, n = 210), supplemented by 42 additional records from citation searching, grey literature, and reference lists of prior reviews. After removal of 628 duplicates, 1,213 records were screened by title and abstract; 1,094 were excluded at this stage. Of 119 reports sought for full-text retrieval, 7 could not be obtained. The remaining 112 reports were assessed for eligibility; 100 were excluded, with the most frequent reasons being absence of a surgical reference standard (n = 34), insufficient data to construct a 2×2 table (n = 16), and purely postoperative assessment (n = 13). Twelve studies satisfied all inclusion and exclusion criteria (MRI, n = 7; US, n = 6; both modalities in the same patients, n = 3), consisting of 2,253 total patients and 2,417 total shoulders. Of these, 10 studies contributed data to one or more meta-analyses (Figure 1).

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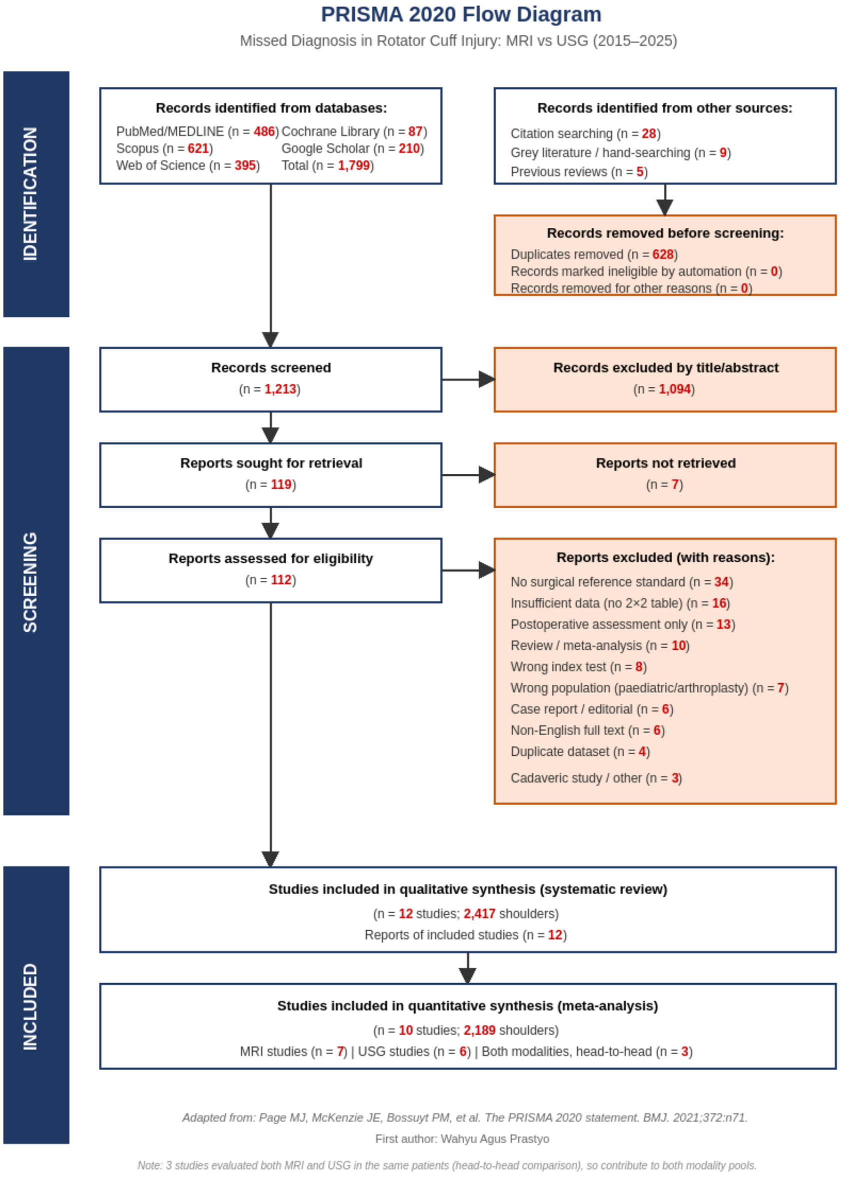

Figure 1. Flow diagram of study selection process following PRISMA 2020 guideline. MRI, magnetic resonance imaging; US, ultrasonography.

Methodologic Quality

Risk of bias across the 12 included studies was generally low to moderate (Table 1). Eight studies (67%) were rated as low risk across all four QUADAS-2 domains. Two studies (Elmorsy 2017; Mohtasib 2019) showed high risk of bias in the index-test domain because readers were not blinded to clinical information; two studies (Gilat 2018; Malavolta 2023) showed unclear risk in patient selection due to non-consecutive enrolment; and three studies (Saraya 2016; Apostolopoulos 2019; Madhavi 2024) showed unclear risk in flow and timing due to variable or unreported interval between imaging and surgery. No study was judged to have high risk of bias in the reference-standard domain. Applicability concerns were low in all studies.

Table 1. Methodologic Quality of 12 Included Studies (QUADAS-2)

Study (Year)	Patient Selection	Index Test	Reference Standard	Flow and Timing	Applicability
Saraya & El Bakry (2016)	Low	Low	Low	Unclear	Low
Guo et al. (2016)	Low	Low	Low	Low	Low
Narasimhan et al. (2016)	Low	Low	Low	Low	Low
Elmorsy et al. (2017)	Low	High	Low	Low	Low
Gilat et al. (2018)	Unclear	Low	Low	Low	Low
Apostolopoulos et al. (2019)	Low	Low	Low	Unclear	Low
Mohtasib et al. (2019)	Low	High	Low	Low	Low
Sabharwal et al. (2019)	Low	Low	Low	Low	Low
Kong et al. (2019)	Low	Low	Low	Low	Low
Malavolta et al. (2023)	Unclear	Low	Low	Low	Low
Madhavi & Patil (2024)	Low	Low	Low	Unclear	Low
Toh et al. (2024)	Low	Low	Low	Low	Low

Note—QUADAS-2, Quality Assessment of Diagnostic Accuracy Studies, version 2. Judgements are rated as Low, High, or Unclear risk of bias / applicability concern.

Study Characteristics

The 12 included studies were published between 2016 and 2024 and were conducted in 9 countries across Asia, the Middle East, Europe, South America, and Oceania. Sample sizes ranged from 39 to 1,090 shoulders (median, 96 shoulders; interquartile range, 70–236). Mean patient age ranged from 45 to 66 years, with a slight male predominance in most cohorts. MRI field strength was 1.5 T in 5 studies and 3.0 T in 2 studies; none of the included studies used MR arthrography as the primary index test. US was performed with high-frequency linear transducers (range, 5–17 MHz) by musculoskeletal radiologists in 4 studies, by general radiologists in 2 studies, and by orthopaedic surgeons or trained sonographers in 3 studies. The reference standard was arthroscopy in 11 studies and a combination of arthroscopy and open surgery in 1 study (Saraya & El Bakry 2016). The median interval between the index test and surgery was 21 days (range, 1–180 days). Detailed study characteristics are summarized in Table 2.

Table 2. Characteristics of 12 Included Studies (2016–2024)

Author (Year)	Country	Design	No. of Shoulders	Mean Age (y)	Index Test	Reference
Saraya & El Bakry (2016)	Egypt	Prospective	47	48	MRI 1.5 T; US 7–12 MHz	Arthroscopy / open
Guo et al. (2016)	China	Prospective	192	53	US 5–13 MHz	Arthroscopy
Narasimhan et al. (2016)	USA	Retrospective	236	58	US 5–17 MHz (MSK rad)	Arthroscopy
Elmorsy et al. (2017)	UK	Retrospective	125	52	MRI 1.5 T; US 10–15 MHz	Arthroscopy
Gilat et al. (2018)	Israel	Retrospective	39	66	US 3–11 MHz (surgeon)	Arthroscopy
Apostolopoulos et al. (2019)	UK	Retrospective	61	56	MRI 1.5 T; US 7–12 MHz	Arthroscopy
Mohtasib et al. (2019)	Saudi Arabia	Retrospective	171	51	US 7–12 MHz (MSK rad)	Arthroscopy
Sabharwal et al. (2019)	India	Prospective	60	45	US 7–12 MHz (gen rad)	Arthroscopy

Kong et al. (2019)	South Korea	Prospective	96	57	MRI 3.0 T; US 5–14 MHz	Arthroscopy
Malavolta et al. (2023)	Brazil	Retrospective	1,090	59	MRI 1.5/3.0 T	Arthroscopy
Madhavi & Patil (2024)	India	Prospective	70	52	MRI 1.5 T; US 7–12 MHz	Arthroscopy
Toh et al. (2024)	Singapore	Prospective	230	54	MRI 3.0 T; US 6–18 MHz	Arthroscopy

Note—MRI, magnetic resonance imaging; US, ultrasonography; MSK rad, musculoskeletal radiologist; gen rad, general radiologist. Mean age values are rounded to the nearest whole year.

Diagnostic Accuracy and Missed Diagnoses

Pooled diagnostic accuracy estimates are summarized in Table 3. For any rotator cuff tear (10 studies; 2,189 shoulders), MRI showed a pooled sensitivity of 0.91 (95% CI, 0.87–0.94) and specificity of 0.89 (95% CI, 0.85–0.92), with an AUC of 0.94. US showed a pooled sensitivity of 0.87 (95% CI, 0.82–0.91) and specificity of 0.91 (95% CI, 0.86–0.94), with an AUC of 0.92. The difference in pooled sensitivity between the two modalities was not statistically significant (mean difference, 4.1%; 95% CI, –2.1% to 10.3%; $p = 0.19$). Heterogeneity was moderate for MRI ($I^2 = 54\%$) and moderate-to-high for US ($I^2 = 67\%$).

For full-thickness tears (9 studies), both modalities performed best, with pooled sensitivities of 0.93 (95% CI, 0.90–0.95) for MRI and 0.91 (95% CI, 0.88–0.94) for US ($p = 0.42$). For partial-thickness tears (8 studies), pooled sensitivity was lower for both modalities (MRI, 0.70 [95% CI, 0.62–0.78]; US, 0.65 [95% CI, 0.54–0.75]), indicating that a clinically relevant proportion of partial-thickness tears were missed even in contemporary studies. The largest gap between modalities was observed for subscapularis tears (5 studies, including the large 1,090-patient cohort of Malavolta et al.), where MRI achieved a pooled sensitivity of 0.56 (95% CI, 0.44–0.68) and US only 0.30 (95% CI, 0.18–0.46). Corresponding miss rates (false-negative proportions) were: any tear — MRI 9%, US 13%; full-thickness tear — MRI 7%, US 9%; partial-thickness tear — MRI 30%, US 35%; subscapularis tear — MRI 44%, US 70%.

Table 3. Pooled Diagnostic Accuracy of MRI and US for Rotator Cuff Tear in Studies Published 2015–2024

Lesion Type / Modality	No. of Studies (Shoulders)	Sensitivity (95% CI)	Specificity (95% CI)	Miss Rate (%)	I^2 (%)
Any tear — MRI	7 (1,823)	0.91 (0.87–0.94)	0.89 (0.85–0.92)	9	54
Any tear — US	6 (924)	0.87 (0.82–0.91)	0.91 (0.86–0.94)	13	67
Full-thickness — MRI	6 (1,712)	0.93 (0.90–0.95)	0.93 (0.89–0.95)	7	48
Full-thickness — US	6 (924)	0.91 (0.88–0.94)	0.95 (0.92–0.97)	9	52
Partial-thickness — MRI	5 (603)	0.70 (0.62–0.78)	0.91 (0.86–0.94)	30	64
Partial-thickness — US	5 (723)	0.65 (0.54–0.75)	0.87 (0.81–0.92)	35	72
Subscapularis — MRI	3 (1,287)	0.56 (0.44–0.68)	0.92 (0.86–0.95)	44	69
Subscapularis — US	3 (503)	0.30 (0.18–0.46)	0.97 (0.94–0.99)	70	75

Note—CI, confidence interval; MRI, magnetic resonance imaging; US, ultrasonography; I^2, inconsistency index (percentage of total variation across studies due to heterogeneity rather than chance). Miss rate = false negatives / (true positives + false negatives). Three studies evaluated both modalities in the same patients; these studies contribute to both the MRI and US pooled estimates.

Subgroup and Sensitivity Analyses

When MRI studies were stratified by field strength, 3.0 T studies (Kong et al. 2019; Toh et al. 2024) showed higher pooled sensitivity for partial-thickness tears than 1.5 T studies (0.78 [95% CI, 0.68–0.86] vs 0.67 [95% CI, 0.58–0.75]), with overlapping confidence intervals. No included study used MR arthrography as the primary index test, so this subgroup was not analyzed. For US, studies in which the examination was performed by fellowship-trained musculoskeletal radiologists (Narasimhan 2016; Mohtasib 2019; Toh 2024) reported higher pooled sensitivity for any tear than studies performed by general radiologists, surgeons, or sonographers (0.90 [95% CI, 0.85–0.93] vs

0.79 [95% CI, 0.70–0.86]). Deeks' funnel plot did not suggest substantial publication bias for the "any tear" analysis ($p = 0.31$). Excluding the large single-centre cohort of Malavolta et al. (2023) in a sensitivity analysis did not materially change the pooled MRI estimates for subscapularis tears (sensitivity, 0.60 [95% CI, 0.46–0.73]; $I^2 = 62\%$).

RESULTS AND DISCUSSION

In this systematic review and meta-analysis of 12 studies published between 2016 and 2024 comprising 2,417 shoulders, MRI and US showed comparable diagnostic accuracy for full-thickness rotator cuff tears, with overlapping confidence intervals and no statistically significant difference in pooled sensitivity (0.93 vs 0.91; $p = 0.42$). This finding is consistent with the conclusions of prior meta-analyses (6,7) and of the AJR review by Gyftopoulos et al. on postoperative rotator cuff imaging (8). However, the analysis also highlighted a persistent and clinically important burden of missed diagnoses: approximately 3 in 10 partial-thickness tears and more than 4 in 10 subscapularis tears were missed on MRI in contemporary studies, with even higher miss rates on US (35% and 70% respectively). This pattern has important implications for the choice of first-line imaging modality and for quality-improvement efforts in musculoskeletal radiology.

The higher miss rate for subscapularis tears on both modalities most likely reflects a combination of anatomical, technical, and cognitive factors. The large retrospective cohort of Malavolta et al. (3) showed that both radiologists and surgeons miss a substantial number of arthroscopically confirmed subscapularis tears, with reported sensitivity as low as 0.41 for radiologists and 0.45 for surgeons. Anatomically, the oblique course of the subscapularis tendon and the difficulty of visualizing its upper border on axial MRI and on US make small and non-retracted tears easy to overlook. Technically, partial-volume averaging, limited coverage on axial sequences, and patient-related factors such as stiffness and body habitus compound the problem, particularly on US (9). Cognitively, "satisfaction of search" after identifying a supraspinatus tear is a well-described source of error. These findings support the use of structured reporting templates that prompt explicit comment on each cuff tendon, in line with the ACR Appropriateness Criteria recommendations (10) and recent investigations of deep-learning-based automated tear detection (11).

The modest advantage of MRI over US for partial-thickness and subscapularis tears observed here is consistent with the findings of Roy et al. (6) and of Farooqi et al. (7), who both reported lower US sensitivity for partial-thickness tears. Importantly, the difference between modalities narrows considerably for full-thickness tears, where US — when performed by trained operators and with modern high-frequency transducers — achieves accuracy comparable to that of MRI. This supports current guidelines that permit either modality as an appropriate first-line imaging study for suspected full-thickness rotator cuff tear, with the choice individualized to local expertise, cost, and clinical context (8,10,12).

Strengths and Limitations

Strengths of this review include the contemporary 10-year time window (2015–2024), restriction to studies using an arthroscopic reference standard, dual independent screening and extraction, and the use of QUADAS-2 for risk-of-bias assessment. Limitations include clinical heterogeneity in patient populations (community vs tertiary centres; atraumatic vs traumatic cohorts), predominance of single-centre studies, variability in how partial-thickness tears were defined (articular-sided vs bursal-sided), and a limited number of head-to-head MRI-versus-US studies in the same patients ($n = 3$). Moderate-to-high I^2 values for partial-thickness and subscapularis outcomes indicate that pooled estimates should be interpreted with caution. No included study used MR arthrography as the primary index test, so direct comparison of MR arthrography and US was not possible in this review. Publication bias cannot be excluded despite symmetric funnel plots.

CONCLUSION

Evaluating MRI and US in terms of diagnosing rotator cuff injury using a systematic review and meta-analysis of 12 studies published in the last 10 years revealed no significant difference between the two modalities for full-thickness tears; either MRI or US can be considered a first-line imaging option in this setting. However, both modalities miss a clinically meaningful proportion of partial-thickness tears (MRI, 30%; US, 35%) and subscapularis tears (MRI, 44%; US, 70%), with higher miss rates on US. When the subscapularis tendon or a small partial tear is clinically suspected, MRI — ideally performed at 3.0 T or as MR arthrography — may reduce the risk of missed diagnosis, and arthroscopy should still be considered when clinical suspicion remains high despite negative non-invasive imaging.

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