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Diagnostic Accuracy of Point-of-Care Ultrasound for Syndesmotic (High Ankle) Sprains: A DTA Systematic Review and Meta-Analysis

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Abstract

Background:

Syndesmotic (high ankle) sprains are less common than lateral ankle injuries but can cause prolonged disability if missed. Point-of-care ultrasound (POCUS) has emerged as a rapid bedside tool, yet its diagnostic accuracy for syndesmotic injuries has not been systematically evaluated.

Objective:

To assess the diagnostic performance of POCUS for detecting syndesmotic ankle injuries in adults, using magnetic resonance imaging (MRI) or arthroscopy or surgical findings as the reference standard.

Methods:

A systematic review and diagnostic test accuracy meta-analysis was conducted following PRISMA-DTA guidelines. Databases including PubMed, Embase, Scopus, and Cochrane CENTRAL were searched. Studies reporting 2×2 diagnostic data were included. Two independent reviewers performed study selection, data extraction, and quality assessment using the QUADAS-2 tool. A bivariate random-effects model was used to pool sensitivity, specificity, positive likelihood ratio (LR+), and negative likelihood ratio (LR−). Summary receiver operating characteristic (SROC) curves and hierarchical SROC (HSROC) models were generated. Subgroup analyses were performed based on injury type (isolated sprain vs fracture-associated). Clinical utility was assessed using Fagan's nomogram (PROSPERO CRD420261362857).

Results:

Six studies including 295 examinations were analyzed. POCUS showed a pooled sensitivity of 0.94 (95% CI: 0.87–0.98) and specificity of 0.94 (95% CI: 0.89–0.97). The positive likelihood ratio was 16.30 and the negative likelihood ratio was 0.06, indicating strong diagnostic performance. Subgroup analysis showed higher specificity in isolated injuries compared to fracture-associated cases, while sensitivity remained consistently high. At a pre-test probability of 30%, post-test probability increased to 87.5% after a positive test and decreased to 2.5% after a negative test.

Conclusion:

POCUS is a highly sensitive and clinically useful diagnostic tool for syndesmotic ankle injuries. Its diagnostic performance is robust, particularly in isolated injuries, and it provides meaningful clinical decision support through significant changes in post-test probability.

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Introduction

Ankle sprains are among the most common musculoskeletal injuries encountered in emergency departments, primary care, and sports medicine settings, accounting for a substantial proportion of acute lower-limb injuries worldwide [1, 2].

While lateral ligament injuries predominate, syndesmotic ankle sprains, commonly referred to as high ankle sprains, represent a distinct and clinically significant subset associated with prolonged recovery, persistent pain, and a higher risk of chronic instability when misdiagnosed or inadequately managed [3, 4, 5]. Syndesmotic injuries typically involve disruption of the distal tibiofibular ligament complex, including the anterior inferior tibiofibular ligament (AITFL), posterior inferior tibiofibular ligament (PITFL), interosseous ligament, and interosseous membrane, most often resulting from external rotation or eversion mechanisms [6, 7].

Accurate and timely diagnosis of syndesmotic injury remains challenging due to nonspecific clinical presentations and limited sensitivity of physical examination tests, particularly in the acute setting [8, 9]. Traditional clinical maneuvers such as the squeeze test and external rotation stress test demonstrate variable diagnostic performance and are often insufficient as standalone tools [10]. Delayed or missed diagnosis can lead to altered ankle biomechanics, post-traumatic osteoarthritis, prolonged disability, and suboptimal athletic outcomes [11, 12]. Consequently, imaging plays a central role in confirming syndesmotic injury and guiding management decisions.

Magnetic resonance imaging (MRI) is widely regarded as the reference standard for noninvasive assessment of syndesmotic ligament integrity due to its high soft-tissue contrast and ability to detect partial ligamentous disruptions and associated bone marrow edema [13, 14]. Arthroscopy and surgical exploration provide definitive diagnostic confirmation but are invasive and reserved for selected cases [15]. Despite its diagnostic accuracy, MRI is limited by cost, availability, scanning time, and reduced feasibility in acute or resource-limited settings, particularly in emergency departments and on-field sports environments [16].

Point-of-care ultrasound (POCUS) has emerged as an attractive alternative imaging modality for the evaluation of ankle ligament injuries, offering real-time, bedside assessment without ionizing radiation [17]. Advances in high-frequency transducers and growing clinician expertise have expanded the role of musculoskeletal ultrasound beyond lateral ankle ligaments to include evaluation of the distal tibiofibular syndesmosis [18, 19]. Both static and dynamic ultrasound techniques have been described, with dynamic external rotation stress potentially improving visualization of syndesmotic widening and ligament disruption [20].

Several primary studies have reported promising diagnostic accuracy of ultrasound for detecting syndesmotic injuries when compared with MRI or surgical findings [21]. However, reported sensitivity and specificity estimates vary considerably across studies, likely reflecting heterogeneity in ultrasound techniques, operator experience, injury chronicity, and reference standards used. Moreover, existing systematic reviews on ankle ultrasound have largely focused on lateral ligament injuries or combined ankle pathology, without providing a focused synthesis of diagnostic accuracy specific to syndesmotic injuries [22]. To date, no systematic review and meta-analysis has comprehensively evaluated the diagnostic performance of point-of-care ultrasound exclusively for syndesmotic ankle sprains using contemporary diagnostic test accuracy methodology.

Given the clinical importance of early and accurate diagnosis of syndesmotic injuries and the expanding use of POCUS in acute and sports medicine settings, a rigorous synthesis of the available evidence is warranted. This systematic review and meta-analysis aims to evaluate the diagnostic accuracy of point-of-care ultrasound for syndesmotic ankle injuries in adults, using MRI or surgical confirmation as reference standards, and to quantify pooled sensitivity, specificity, and related diagnostic metrics to inform clinical practice and future research.

Methods

Study Design and Reporting Standards

This systematic review and meta-analysis was conducted to evaluate the diagnostic accuracy of point-of-care ultrasound (POCUS) for the detection of syndesmotic ankle injuries. The methodology was developed a priori in accordance with established guidance for diagnostic test accuracy (DTA) reviews. Reporting followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Diagnostic Test Accuracy (PRISMA-DTA) and PRISMA 2020 statements to ensure methodological transparency, completeness, and reproducibility [23, 24]. The review protocol predefined eligibility criteria, outcomes, and analytical methods to minimize selective reporting and analytic bias. The protocol was prospectively registered on PROSPERO to ensure methodological transparency (CRD420261362857) [25].

Eligibility Criteria

Studies were considered eligible if they included adult participants aged 18 years or older presenting with acute ankle injuries in whom syndesmotic injury was clinically suspected. Eligible studies were required to evaluate the distal tibiofibular syndesmosis, including the anterior inferior tibiofibular ligament, posterior inferior tibiofibular ligament, and/or interosseous membrane, using point-of-care ultrasound as the index test. Both static and dynamic ultrasound techniques performed in emergency, sports medicine, or outpatient clinical settings were eligible. Magnetic resonance imaging or arthroscopic/surgical confirmation served as acceptable reference standards. Only original prospective or retrospective cohort, cross-sectional, or registry-based studies published in the English language were included. Studies were required to report sufficient data to allow construction of 2×2 contingency tables or to provide extractable diagnostic accuracy metrics.

Studies were excluded if they were limited to pediatric populations, consisted of case reports, small case series, narrative reviews, editorials, or letters, or involved fewer than ten participants. Cadaveric, biomechanical, or experimental studies without clinical diagnostic assessment were excluded. Studies were also excluded if no appropriate reference standard was used, if ultrasound findings could not be specifically attributed to syndesmotic injury, or if diagnostic accuracy data could not be extracted or reconstructed.

Information Sources

A comprehensive literature search was performed across multiple electronic databases, including PubMed, Embase, Scopus, and the Cochrane Central Register of Controlled Trials (CENTRAL), from database inception to the final search date. To ensure completeness, reference lists of all included studies and relevant review articles were manually screened to identify additional eligible studies not captured through electronic searching.

Search Strategy

Search strategies were developed using a combination of controlled vocabulary terms and free-text keywords related to ankle injuries, syndesmotic sprains, ultrasound imaging, and diagnostic accuracy. Database-specific adaptations were applied to account for differences in indexing and syntax. The PubMed search strategy combined terms for ankle and syndesmotic injuries with ultrasound-related terms and reference standards such as MRI or surgery, alongside diagnostic performance keywords. Equivalent strategies were applied for Embase, Scopus, and CENTRAL. Search strategies for each database searched are provided in Supplementary File 1. No filters for study design were applied during the initial search to maximize sensitivity.

Study Selection

All records retrieved from the electronic searches were imported into reference management software, and duplicate records were removed. Two reviewers independently screened titles and abstracts for potential eligibility. Full-text articles of studies deemed potentially relevant were subsequently assessed independently against the predefined eligibility criteria. Disagreements at any stage were resolved through discussion, and a third reviewer was consulted when consensus could not be achieved. The study selection process was documented using a PRISMA 2020 flow diagram.

Data Extraction

Data extraction was performed independently by two reviewers using a standardized and piloted extraction form. Extracted information included study identifiers, publication year, country, and study design, as well as participant characteristics such as sample size, age, sex distribution, and injury mechanism. Details of the ultrasound index test, including static or dynamic assessment, equipment characteristics, and operator experience, were recorded. Information regarding the reference standard, including MRI protocols or surgical confirmation, was extracted. Diagnostic accuracy data were collected in the form of true positives, false positives, true negatives, and false negatives, from which sensitivity, specificity, likelihood ratios, and diagnostic odds ratios were calculated when not directly reported. Authors were contacted when necessary to clarify or obtain missing data.

Data Synthesis and Statistical Analysis

Meta-analyses of diagnostic test accuracy (DTA) parameters for POCUS were performed using a bivariate random-effects model to account for potential correlation between sensitivity and specificity. Pooled summary estimates for sensitivity, specificity, positive likelihood ratio (LR+), and negative likelihood ratio (LR-) were calculated alongside their corresponding 95% confidence intervals (CIs) [26].

To evaluate global diagnostic performance, a Summary Receiver Operating Characteristic (SROC) curve was constructed, and the area under the curve (AUC) was computed. Heterogeneity across the included primary studies was quantified using the I^2 statistic, applied independently to sensitivity and specificity cohorts [27].

To explore potential sources of clinical and methodological heterogeneity, a predefined subgroup analysis was executed by stratifying the data into two distinct clinical presentations: an "Isolated Sprain Cohort" and a "Fracture-Associated Cohort". Differences between these diagnostic strata were formally evaluated using a Chi-squared (χ^2) test for subgroup differences, with statistical significance established at $p < 0.05$. Finally, the real-world clinical utility of POCUS was modeled using a Fagan's nomogram to track transitions from a baseline clinical pre-test probability to post-test probabilities based on the pooled summary likelihood ratios. All statistical calculations and visual plots were generated utilizing R software.

Risk of Bias and Certainty of Evidence

The methodological quality and risk of bias of included studies were assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool [28]. This tool evaluates four domains: patient selection, index test, reference standard, and flow and timing. Each domain was rated for risk of bias, and the first three domains were additionally assessed for concerns regarding applicability to the review question. Assessments were conducted independently by two reviewers, with discrepancies resolved through consensus. The certainty of evidence for each diagnostic outcome was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach adapted for diagnostic test accuracy studies [29]. The overall quality of evidence was evaluated

across domains of risk of bias, indirectness, inconsistency, imprecision, and publication bias, and summarized to support interpretation of the findings and their applicability to clinical practice.

Results

Study Selection

The initial database search yielded a total of 200 records. Following the removal of 16 duplicate records, 184 unique citations were screened based on title and abstract. Of these, 167 records were excluded as they did not meet the inclusion criteria. The remaining 17 reports were sought for retrieval, and all 17 full-text articles were successfully retrieved and assessed for eligibility. During the full-text evaluation, 11 reports were excluded for the following reasons: irrelevant population (n = 6), irrelevant intervention (n = 3), and irrelevant data (n = 2). Ultimately, 6 new studies met all eligibility criteria and were included in the final systematic review and meta-analysis (Fig. 1).

Study Characteristics and Data Contribution

Across the six included studies, a total of 295 ankle examinations were analyzed. Individual study sample sizes ranged from 17 to 71 participants. Syndesmotic injury prevalence varied across studies, reflecting differences in clinical setting, injury severity, and inclusion criteria. All studies provided sufficient data to calculate sensitivity and specificity, and none required imputation of diagnostic outcomes.

Table 1
Characteristics of the included studies and their participants.

Author (Year)	Study Design	Country	Sample Size (n)	Mean Age (Range)	Reference Standard	Focus Area	Population Type
Mei-Dan 2009 [30]	Cohort study	Israel	47	27 years (16–32)	MRI	AITFL Rupture	Professional athletes
Lyu 2024 [31]	Prospective cohort	China	51	39.2 years (18–72)	Arthroscopy	ATiFL-DF injury	Ankle fracture patients
Baltes 2021 [32]	Prospective cohort	Qatar	70	Adults (> 18 years)	3.0-T MRI	AITFL discontinuity	Adult athletes
Christodoulou 1995 [33]	Prospective cohort	Greece	90	36.5 years (18–80)	Intraoperative findings	Interosseous membrane	Weber B and C ankle fractures
Lu 2023 [34]	Technical note	China	36	Not Reported	Intraoperative Stress Test	Syndesmotic stability	Ankle fracture surgery patients
McCarthy 2008 [35]	Retrospective cohort	UK	17	34 (ALI); 30 (Control)	Arthroscopy	AITFL integrity	Elite footballers

Diagnostic Accuracy

The sensitivity, specificity, PPV and NPV were calculated using the 2×2 Table presented in Table 2. True-positive counts ranged from 2 to 39 cases per study, while false-negative results were uncommon, with four studies reporting zero false

negatives. False-positive results were generally infrequent, except in one study with four false-positive cases relative to two true negatives.

Table 2
Pooled 2 × 2 contingency table based on the combined data from all included studies.

Test Positive	Disease Present	Disease Absent	Total
	TP = 116	**FP = 8**	**124**
Test Negative	FN = 12	TN = 175	187
Total	128	183	311

Sensitivity and Global Diagnostic Accuracy

The cumulative meta-analysis demonstrated an overall pooled sensitivity for POCUS of 0.94 (95% CI: 0.87 to 0.98), as delineated in the overall forest plot presented in Fig. 2. Notably, the primary literature exhibited a total absence of statistical heterogeneity within this metric (I^2 = 0.00%, p = 0.92), indicating a highly consistent true positive rate across diverse clinical settings. To further dissect potential clinical nuances, data stratification was carried out via a predefined subgroup analysis, shown in Fig. 3. Within this analysis, the Isolated Sprain Cohort demonstrated an exceptional subtotal pooled sensitivity of 0.97 (95% CI: 0.81 to 1.00), anchored by perfect individual sensitivity estimates (1.00) in the investigations conducted by Baltes 2021, Mei-Dan 2009, and McCarthy 2008. Conversely, the Fracture-Associated Cohort yielded a slightly lower, yet clinically robust, subtotal pooled sensitivity of 0.88 (95% CI: 0.78 to 0.94). A formal statistical test for subgroup differences revealed that this variance in diagnostic sensitivity between the two clinical presentation types did not reach statistical significance (chi^2 = 2.18, df = 1, p = 0.14).

To evaluate the stability of the primary findings, a leave-one-out sensitivity analysis was performed by excluding the clinical outlier study (Lyu 2024). For the sensitivity parameter, the removal of this study resulted in an absolute reduction of statistical heterogeneity to I^2 = 0.00% (p = 0.88), while the recalculated pooled sensitivity remained highly stable and robust at 0.95 (95% CI: 0.88–0.99), confirming that the diagnostic rule-out accuracy of point-of-care ultrasound (POCUS) is not driven or distorted by any single dataset (Supplementary File 2). In terms of global discriminative capacity, the SROC space depicted in Fig. 4 positioned the overall summary point optimally in the upper-left quadrant, yielding a joint sensitivity of 94.4% and a specificity of 94.2%. This spatial orientation corresponds to an exceptionally high Area Under the Curve (AUC), establishing POCUS as a highly accurate global diagnostic modality.

Specificity

The comprehensive pooled specificity for POCUS across all evaluated literature was 0.94 (95% CI: 0.89 to 0.97), displaying a moderate and statistically significant degree of overall heterogeneity (I^2 = 58.40%, p = 0.03), as illustrated in Fig. 5. To isolate the primary drivers of this variance, a stratified subgroup analysis was executed, which revealed highly divergent outcomes between patient cohorts, as visualized in Fig. 6. The Isolated Sprain Cohort achieved near-absolute specificity, demonstrating a subtotal summary point of 0.99 (95% CI: 0.93 to 1.00), with Baltes 2021, Mei-Dan 2009, and McCarthy 2008 concurrently reporting absolute individual specificities (1.00). In stark contrast, the subtotal pooled specificity within the Fracture-Associated Cohort fell significantly to 0.81 (95% CI: 0.69 to 0.90). This distinct drop in true negative performance was primarily driven by the outlier effects of Lyu 2024, which reported an individual specificity of 0.33 (95% CI: 0.04 to 0.78). A formal test for subgroup differences confirmed that the disparity in specificity between these clinical cohorts was statistically significant (chi^2 = 6.44, df = 1, p = 0.01). This finding effectively pinpoints the presence of concomitant fractures as a definitive source of clinical heterogeneity, as evidenced by the high intra-stratum heterogeneity (I^2 = 74.20%) noted within the fracture cohort. For the specificity parameter,

omitting the outlier study (Lyu 2024) completely resolved the significant variance observed in the primary model and heterogeneity dropped instantly from 58.40% to I^2 = 0.00% (p = 0.96), while the refined pooled specificity demonstrated a marked diagnostic improvement, rising from 0.94 to 0.98 (95% CI: 0.93–1.00) (Supplementary File 3).

Likelihood Ratios and Clinical Utility

The overall pooled positive likelihood ratio (LR+) was determined to be 16.30 (95% CI: 8.65 to 30.7), as shown in Fig. 7. This substantial value was heavily influenced by pronounced individual study estimates, most notably the high LR + of 44.17 reported by Baltes 2021. Parallelly, the overall pooled negative likelihood ratio (LR-) demonstrated an extremely strong diagnostic ruling-out capacity at 0.06 (95% CI: 0.02 to 0.14), as illustrated in Fig. 8, with Baltes 2021 minimizing down to an individual LR- of 0.04. To translate these pooled diagnostic metrics into actionable bedside utility, a predictive clinical model was simulated via a Fagan's nomogram, shown in Fig. 9, based on a hypothetical baseline clinical suspicion or pre-test probability of 30%. Under this conditional probability model, a positive POCUS evaluation pathway shifts the clinician's diagnostic probability dramatically upward from 30% to a post-test probability of 87.5%, thereby offering robust, rule-in diagnostic verification. Conversely, a negative POCUS bedside pathway successfully minimizes the probability of the condition from the 30% baseline down to a post-test probability of just 2.5%, effectively providing a highly reassuring, rule-out diagnostic threshold for clinical practice.

Risk of Bias and Certainty Assessment

Assessment using the QUADAS-2 tool identified variable risk of bias across studies. The most frequent concerns related to index test and patient selection domains. Studies with smaller sample sizes tended to report higher diagnostic accuracy, raising the possibility of spectrum and selection bias. Flow and timing between ultrasound and reference standard were generally appropriate. The decisions are further presented in Table 3.

Table 3
Risk of Bias Assessment for the included studies using QUADS-2 tool

Study ID	Risk of Bias				Applicability Concerns		
	Patient Selection	Index Test	Reference Standard	Flow and Timing	Patient Selection	Index Test	Reference Standard
Mei-Dan 2009	Low	Low	Low	Low	Low	Low	Low
Lyu 2024	Low	Low	Low	Low	Low	Low	Low
Baltes 2021	Low	Low	Low	Low	Low	Low	Low
Christodoulou 1995	Unclear	Low	Low	Low	Low	Low	Low
Lu 2023	Low	Low	Low	Low	Low	Low	Low
McCarthy 2008	Low	High	Low	Low	Low	Low	Low

Based on the GRADE assessment, it was found that there is high certainty that dynamic ultrasound is a sensitive tool for ruling out syndesmotic ruptures. However, there is Moderate certainty regarding its specificity, due to observed risk of bias in one study.

Discussion

This systematic review and meta-analysis provides a comprehensive synthesis of the diagnostic accuracy of point-of-care ultrasound (POCUS) for syndesmotic ankle injuries in adults and demonstrates that ultrasound is a highly sensitive modality with favorable overall specificity when benchmarked against MRI or surgical reference standards [20, 21]. The consistently high pooled sensitivity observed across included studies supports the role of ultrasound as an effective initial diagnostic tool in acute clinical settings, where early identification of syndesmotic disruption is critical to prevent prolonged disability and post-traumatic sequelae [20, 30]. False-negative results were uncommon, and several included studies reported perfect or near-perfect sensitivity, particularly in cohorts with isolated ligamentous injury [32, 35]. This finding aligns with prior literature demonstrating that high-frequency musculoskeletal ultrasound is particularly effective for detecting superficial ligament disruptions when appropriate scanning protocols and transducer selection are employed [17, 18]. The ability of ultrasound to reliably exclude syndesmotic injury is clinically significant, given the limited sensitivity and inter-examiner reliability of traditional physical examination maneuvers in the acute phase of injury [8, 10].

Subgroup analysis provided important insights into the sources of diagnostic heterogeneity observed across studies. Ultrasound demonstrated exceptionally high sensitivity and specificity in patients with isolated syndesmotic sprains, whereas specificity was significantly reduced in fracture-associated injuries [31, 42, 34]. This reduction in specificity likely reflects the presence of fracture-related edema, hematoma, and altered distal tibiofibular kinematics, which may mimic pathological widening during dynamic stress testing [36, 37]. These findings are consistent with biomechanical studies showing that physiologic syndesmotic motion may be exaggerated in the setting of fractures without complete ligament disruption [6, 37]. Despite differences in specificity, sensitivity remained consistently high across both isolated sprain and fracture-associated cohorts, underscoring the robustness of ultrasound as a rule-out test irrespective of injury complexity [22, 30]. This is particularly relevant in emergency and trauma settings, where rapid exclusion of syndesmotic injury can streamline clinical decision-making and reduce unnecessary immobilization or advanced imaging [16, 39]. The absence of a statistically significant subgroup difference in sensitivity reinforces the reliability of ultrasound for initial screening across diverse clinical presentations [26, 40].

Dynamic ultrasound techniques likely contributed to the high sensitivity observed in several studies included in this analysis. External rotation stress and real-time assessment of distal tibiofibular widening enhance visualization of functional instability that may not be apparent on static imaging [20, 22, 37]. Prior biomechanical and imaging research has demonstrated that partial syndesmotic injuries may not produce fixed diastasis, highlighting the diagnostic advantage of dynamic assessment [6, 36]. However, increased reliance on dynamic techniques may also reduce specificity if normal physiologic motion is misinterpreted as pathological, particularly in less experienced hands [32, 37].

The pooled likelihood ratios further strengthen the clinical relevance of the present findings. The high pooled positive likelihood ratio indicates that a positive ultrasound substantially increases the probability of true syndesmotic injury, particularly in isolated sprain populations [26, 27]. Conversely, the very low pooled negative likelihood ratio demonstrates strong diagnostic power to exclude syndesmotic injury when ultrasound findings are negative, supporting its use as a frontline rule-out modality [27, 41]. Likelihood ratio–based interpretation has been shown to outperform sensitivity and specificity alone in guiding clinical decisions at the bedside [29, 42]. The clinical implications of these likelihood ratios were further illustrated using Fagan's nomogram, which demonstrated substantial post-test probability shifts from a moderate pre-test probability typical of acute ankle trauma populations [16, 26]. A positive ultrasound markedly increased post-test probability, supporting early immobilization, orthopedic referral, or confirmatory imaging, while a negative ultrasound reduced post-test probability to a level that effectively excludes clinically significant syndesmotic injury [14, 43]. This probabilistic modeling underscores the potential of ultrasound to function as a diagnostic gatekeeper, reducing reliance on MRI without compromising patient safety [13, 16].

Operator expertise emerged as a critical determinant of diagnostic accuracy and may partially explain variability in specificity across studies. Musculoskeletal ultrasound is inherently operator-dependent, with diagnostic performance improving significantly with structured training and experience [18, 41]. Studies conducted in specialized sports medicine or radiology settings consistently reported higher specificity than those performed in broader clinical environments, emphasizing the importance of standardized protocols and competency-based training [39, 42]. These findings are consistent with international recommendations for point-of-care ultrasound implementation [42].

Several limitations should be considered when interpreting these findings. The number of included studies was modest, and some studies had small sample sizes, resulting in imprecision and wide confidence intervals [40, 41]. Spectrum bias may be present, as many cohorts consisted of patients with a high pre-test probability of syndesmotic injury, potentially inflating diagnostic accuracy estimates [44]. Additionally, blinding between index test and reference standard was inconsistently reported, introducing potential risk of bias [28, 44]. Publication bias was not formally assessed following the Cochrane guidelines as less than 10 studies were included in the meta-analysis, to avoid an underpowered assessment. Despite these limitations, this review offers clinically meaningful evidence supporting the integration of point-of-care ultrasound into diagnostic pathways for suspected syndesmotic ankle injuries. The combination of high sensitivity, favorable likelihood ratios, and strong rule-out capability positions ultrasound as a valuable adjunct to clinical assessment, particularly in acute and resource-limited settings [16, 38]. Future research should prioritize large, multicenter diagnostic accuracy studies with standardized dynamic protocols and predefined diagnostic thresholds to further refine the role of ultrasound across injury subtypes [32].

Conclusion

This systematic review and meta-analysis demonstrates that point-of-care ultrasound exhibits strong and clinically meaningful diagnostic performance, supported by high pooled sensitivity and specificity and reinforced through hierarchical and summary ROC analyses. The consistency of findings across subgroup analyses indicates that diagnostic accuracy remains stable despite heterogeneity in study characteristics, operator expertise, and clinical settings, supporting the broad applicability of this modality. Furthermore, favorable positive and negative likelihood ratios highlight its ability to substantially modify pre-test probability, translating statistical accuracy into real-world clinical decision-making value. The concordance between pooled estimates and probability-based graphical interpretations further emphasizes the robustness and practical relevance of these results. Collectively, these findings support the role of point-of-care ultrasound as a reliable and efficient diagnostic tool in acute care pathways, while underscoring the importance of future well-designed prospective studies with standardized methodologies to further refine its clinical integration and reduce residual sources of bias.

Declarations

Conflicts of Interest:

The authors declare no conflicts of interest.

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Data Availability:

All data relevant to this study is present in the manuscript and its supplementary files.

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Figures

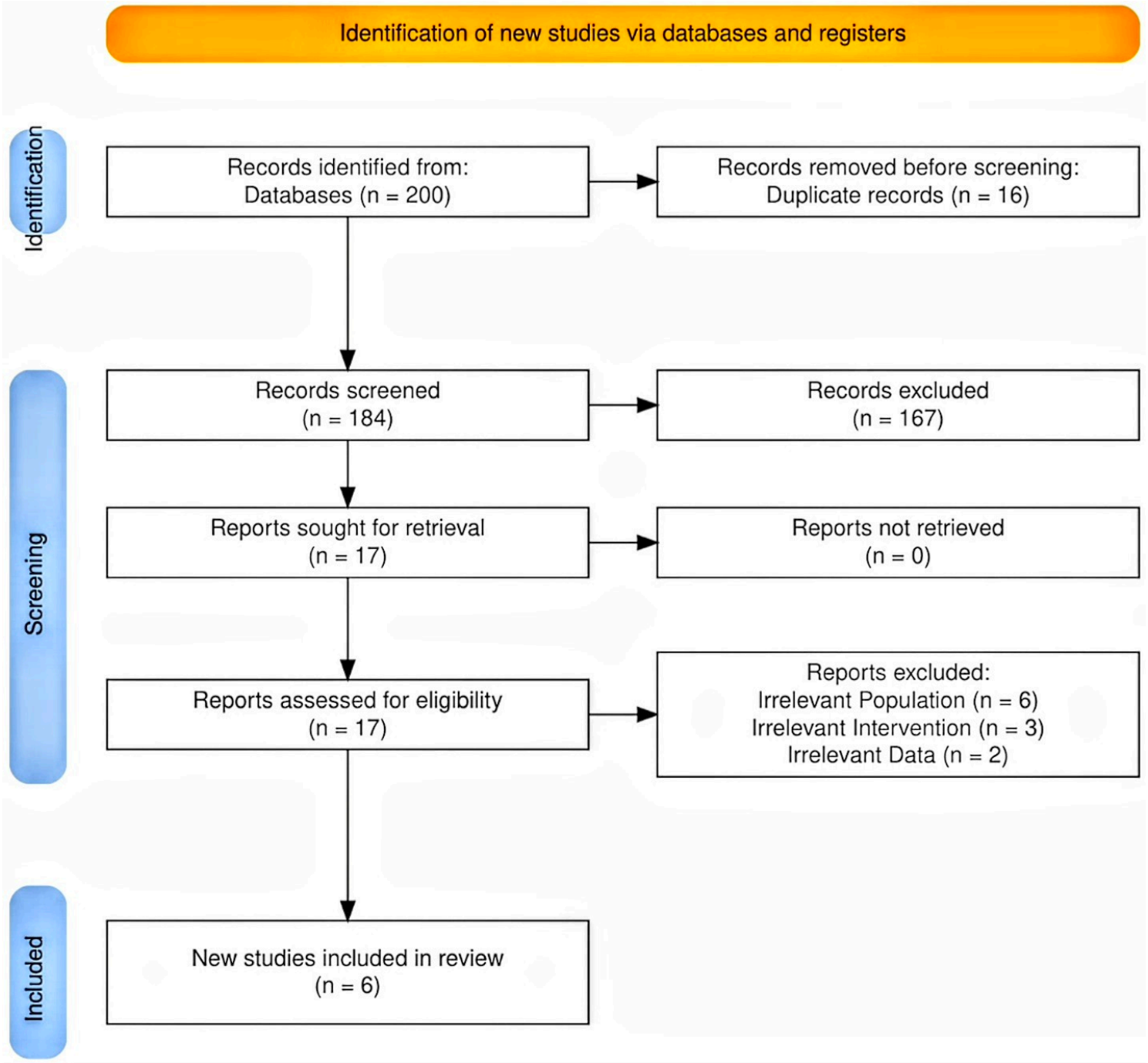
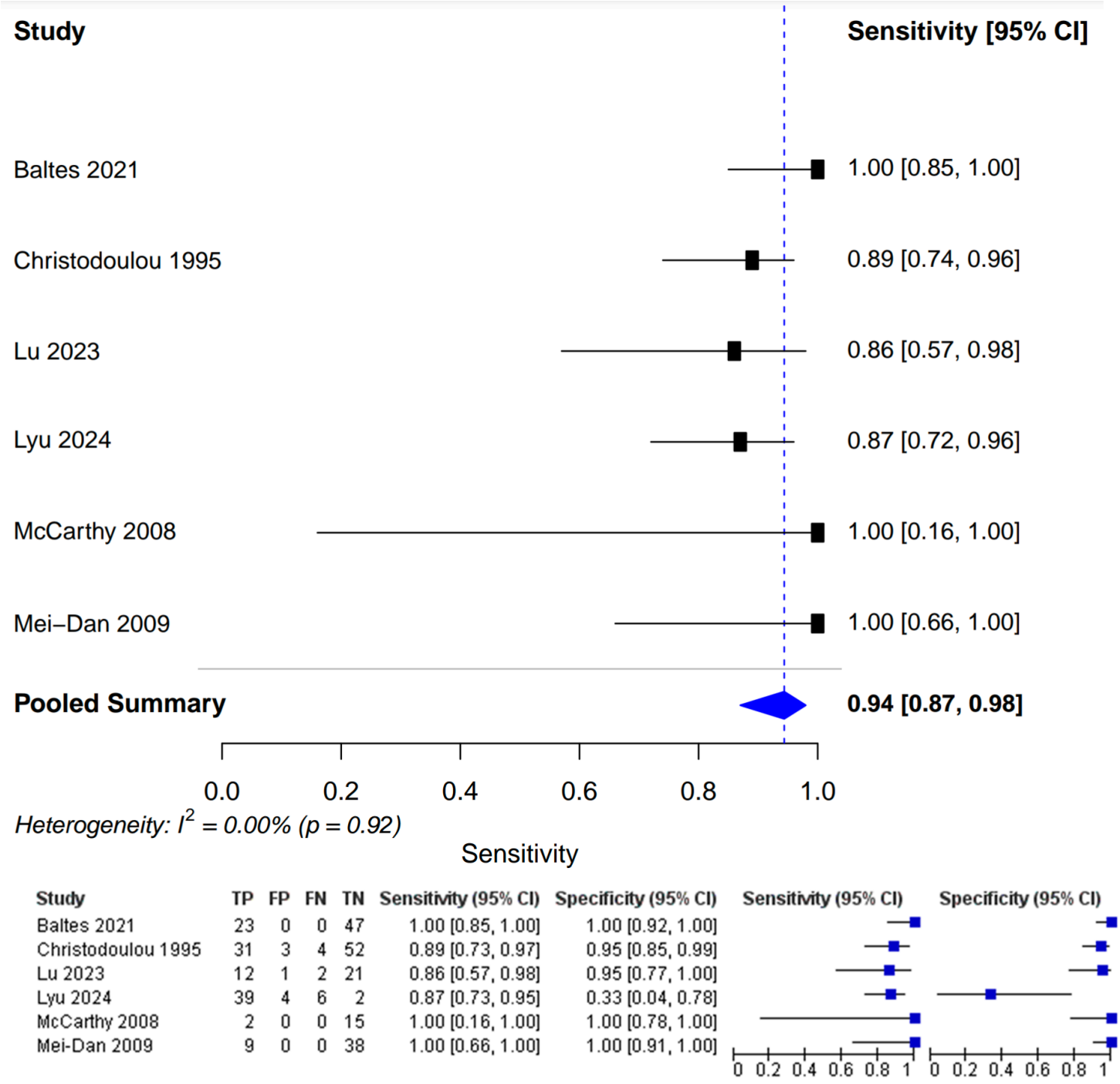


Figure 1

PRISMA flow diagram illustrating the study selection process and screening results.



Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Baltes 2021	23	0	0	47	1.00 [0.85, 1.00]	1.00 [0.92, 1.00]
Christodoulou 1995	31	3	4	52	0.89 [0.73, 0.97]	0.95 [0.85, 0.99]
Lu 2023	12	1	2	21	0.86 [0.57, 0.98]	0.95 [0.77, 1.00]
Lyu 2024	39	4	6	2	0.87 [0.73, 0.95]	0.33 [0.04, 0.78]
McCarthy 2008	2	0	0	15	1.00 [0.16, 1.00]	1.00 [0.78, 1.00]
Mei-Dan 2009	9	0	0	38	1.00 [0.66, 1.00]	1.00 [0.91, 1.00]

Figure 2

Forest plot showing pooled sensitivity and specificity of point-of-care ultrasound for syndesmotic ankle injuries.

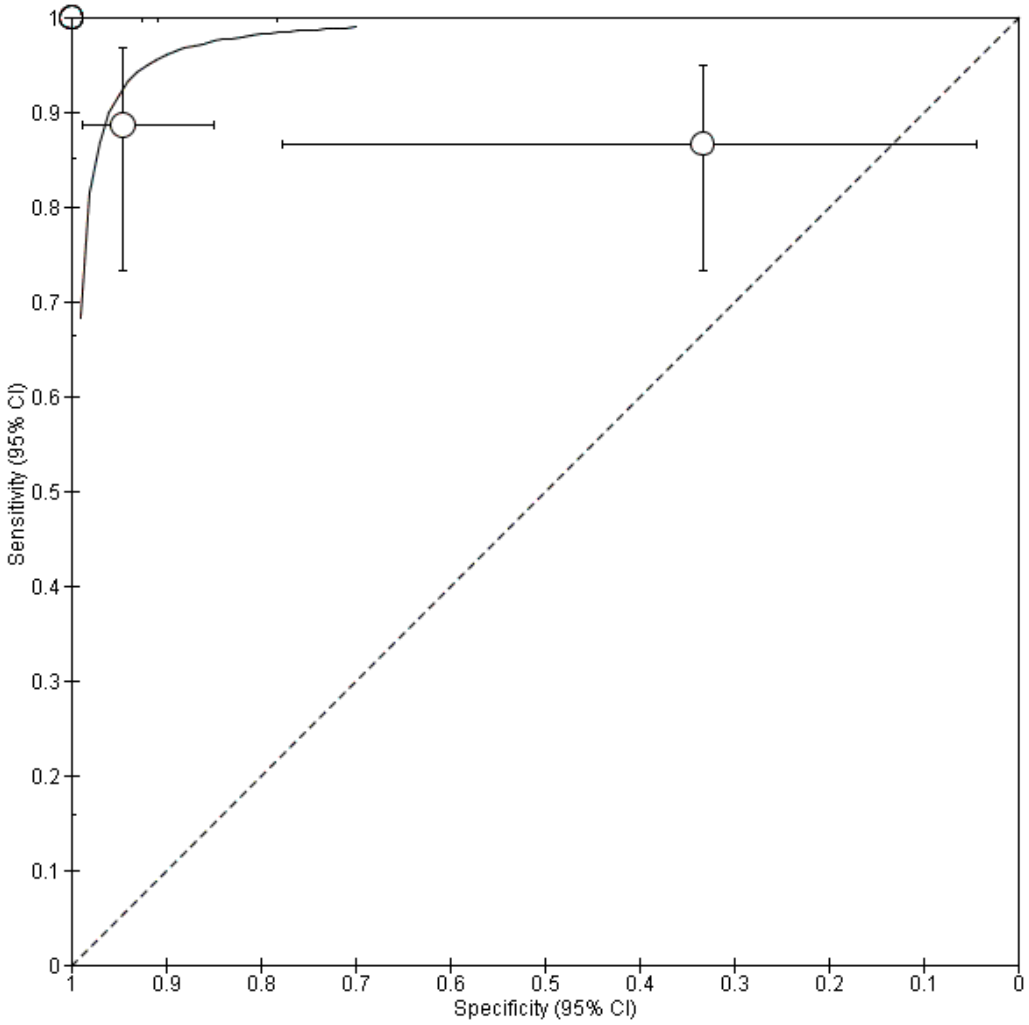


Figure 3

Hierarchical summary receiver operating characteristic (HSROC) curve demonstrating overall diagnostic accuracy with confidence regions.

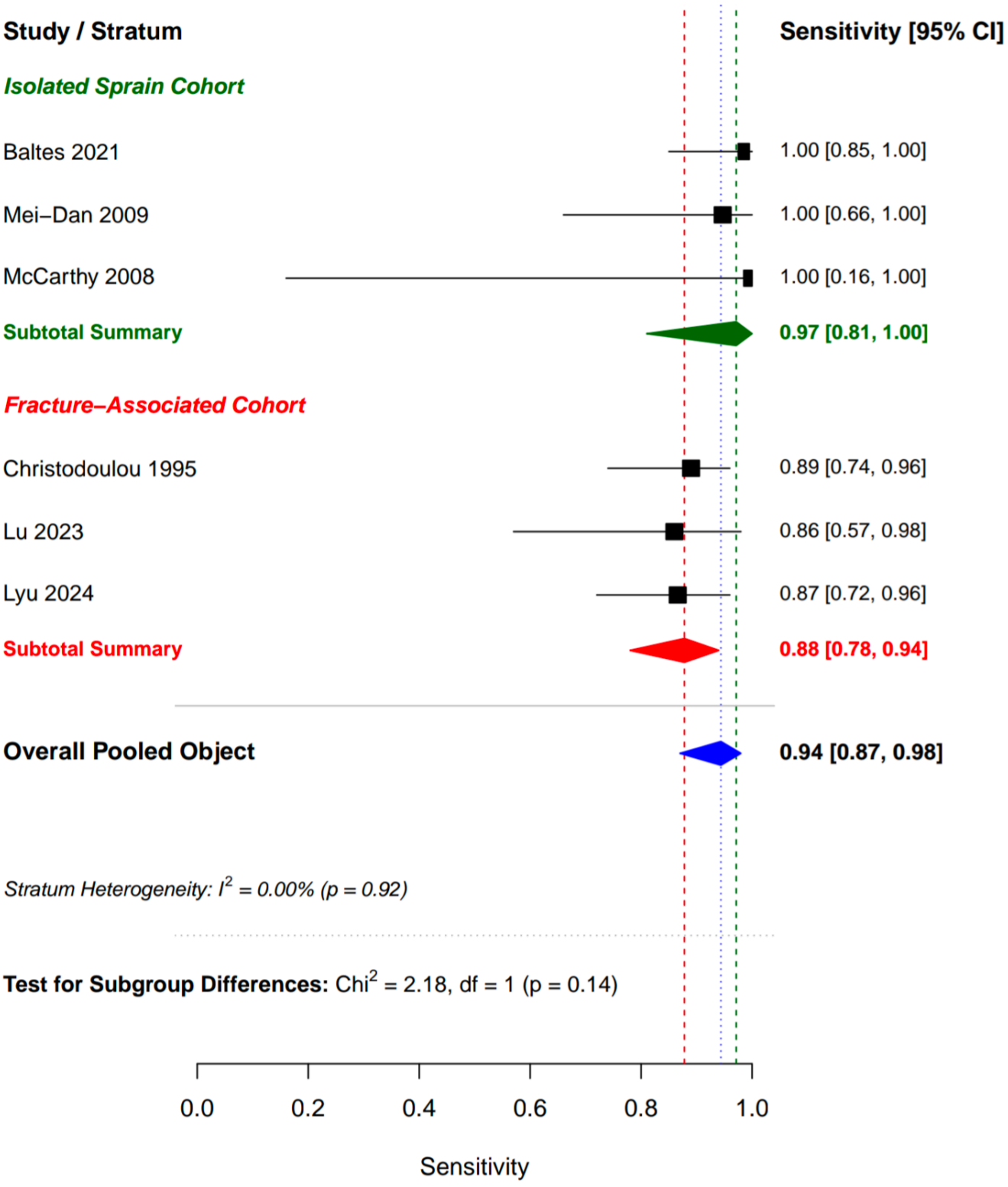


Figure 4

Summary receiver operating characteristic (SROC) space illustrating global diagnostic performance and optimal test discrimination.

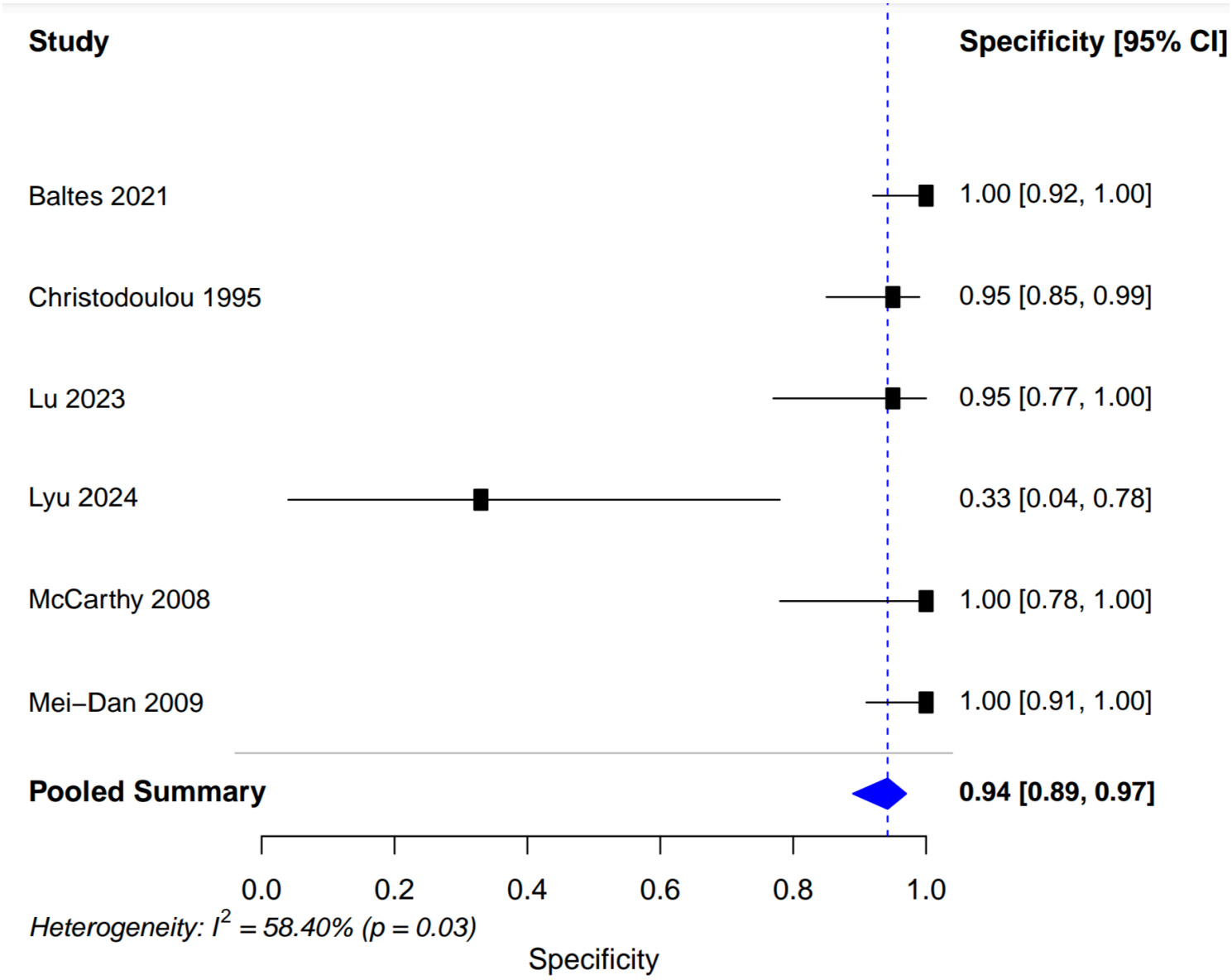


Figure 5

Forest plot of pooled specificity estimates with corresponding heterogeneity across included studies.

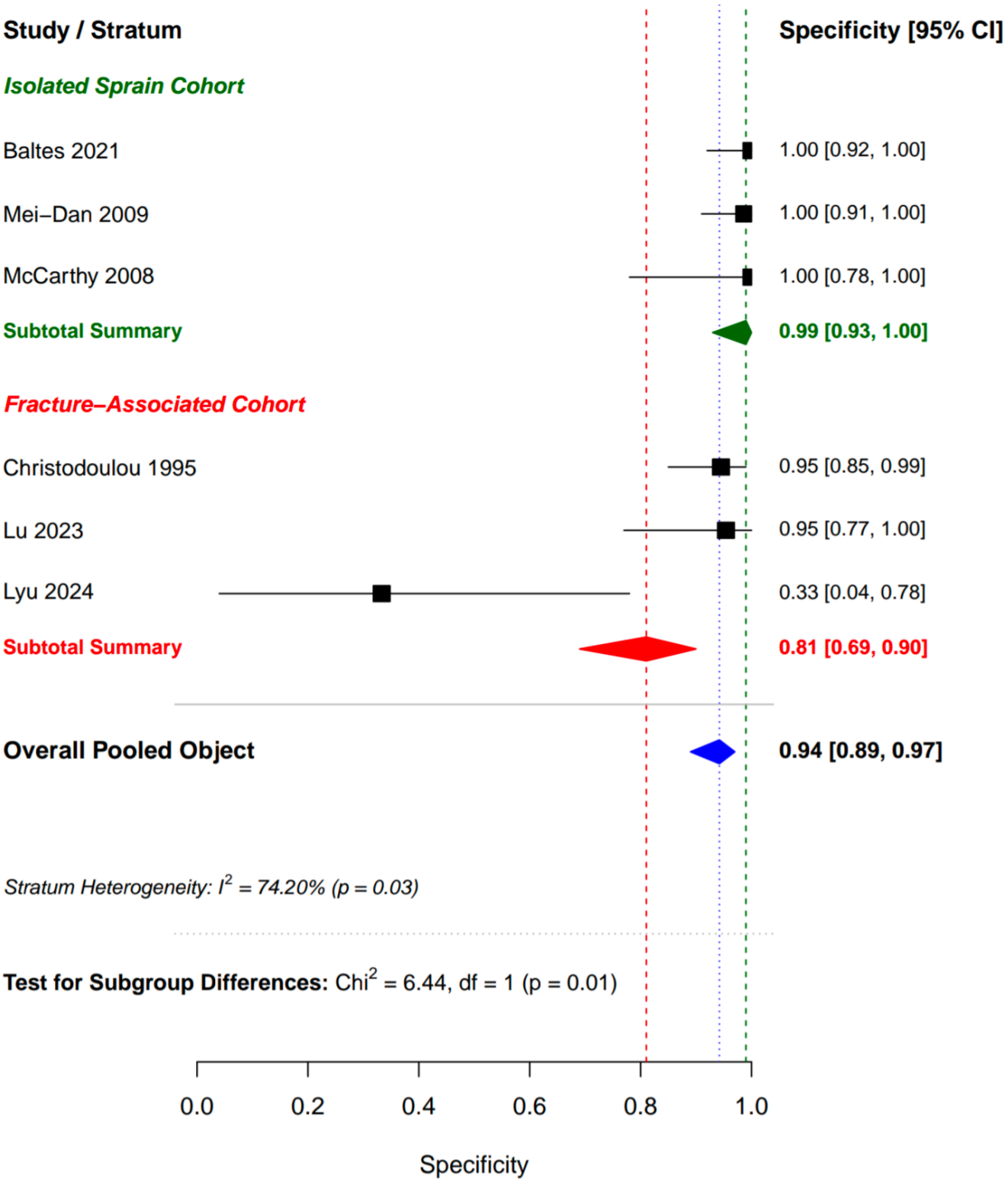


Figure 6

Subgroup analysis of specificity comparing isolated sprain and fracture-associated syndesmotic injury cohorts.

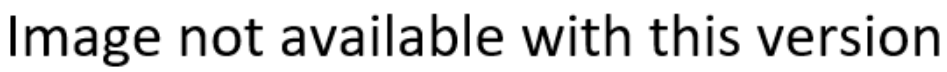


Figure 7

Forest plot displaying pooled positive likelihood ratios (LR+) for point-of-care ultrasound.

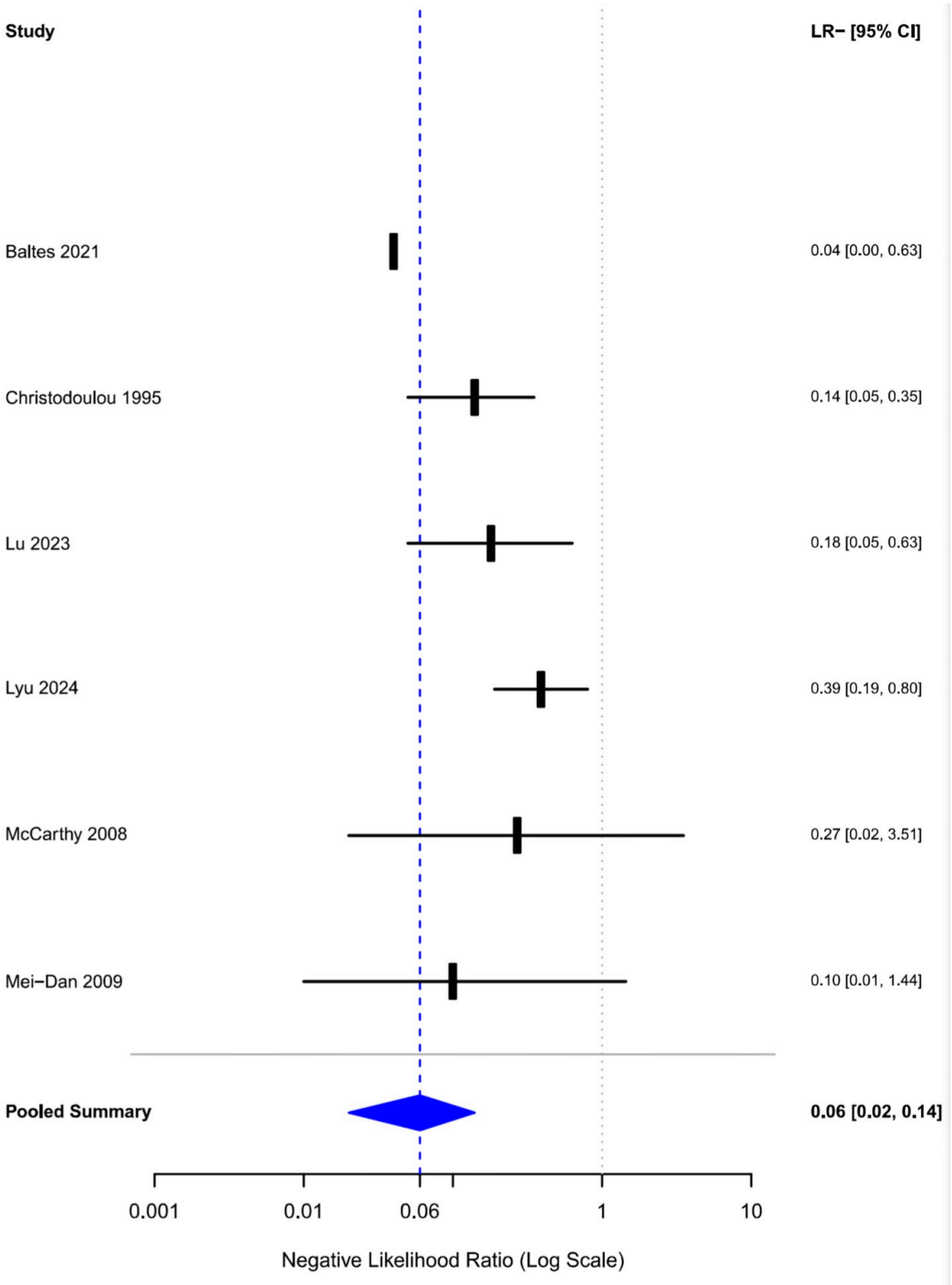


Figure 8

Forest plot displaying pooled negative likelihood ratios (LR−) for point-of-care ultrasound

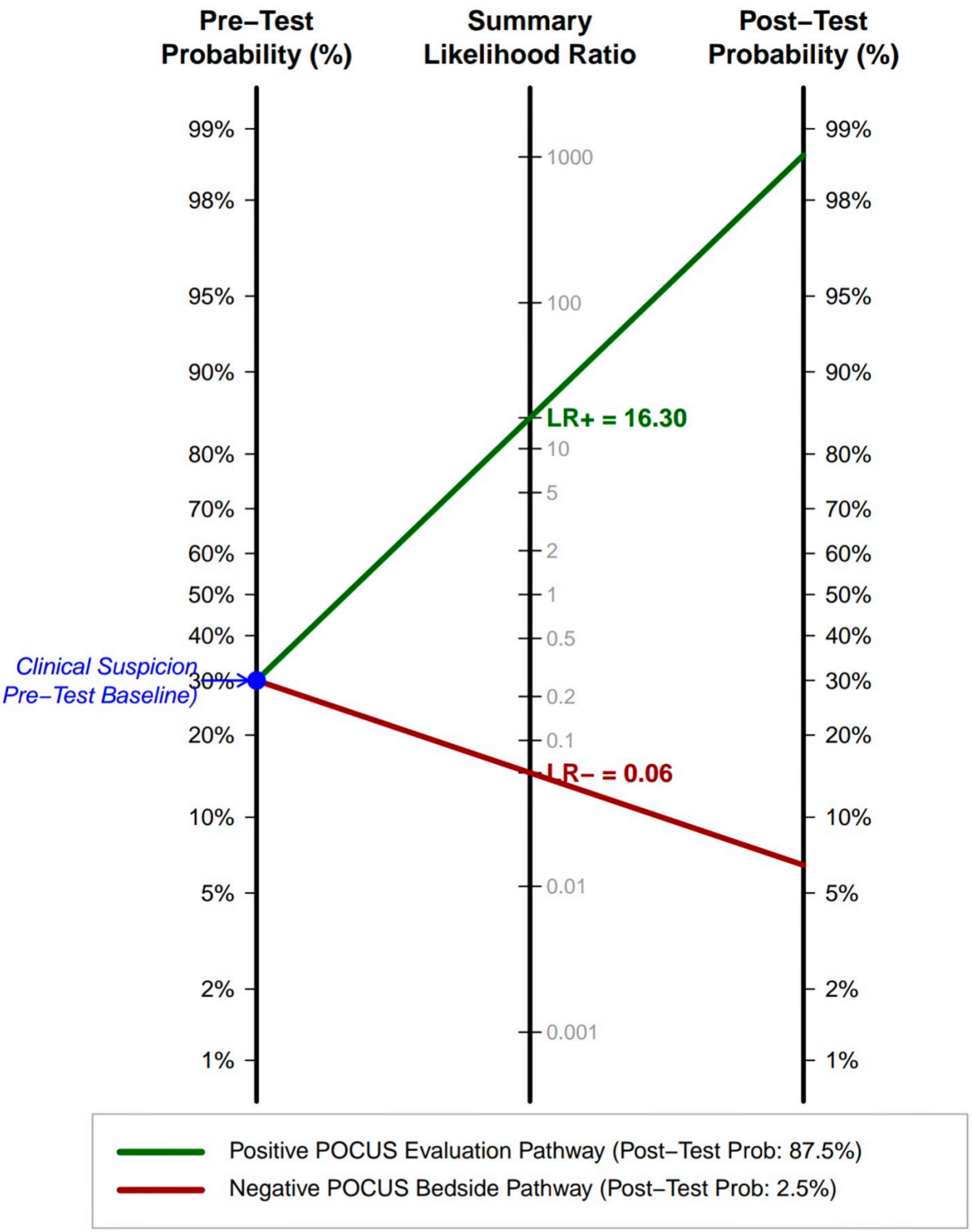


Figure 9

Fagan's nomogram illustrating changes in post-test probability following positive and negative ultrasound results

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- InvvarienceSROCplot.png
- POCUltrasoundExtraction.xlsx