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REVIEW ARTICLE

# Accuracy of Lung Ultrasonography for Diagnosis of Heart Failure; a Systematic Review and Meta-analysis

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**Abstract:** **Introduction:** Despite the evident impact of ultrasonography on diagnosis in acute care settings, there is still a great deal of uncertainty regarding its accuracy. This study aimed to assess the diagnostic performance of lung ultrasonography (LUS) for the identification of acute heart failure in patients with suggestive manifestations. **Methods:** Medline, Scopus, and Web of Science were comprehensively searched from their inception to November 2024 to identify original studies investigating accuracy of LUS for diagnosis of heart failure. Data extraction and quality assessment were performed by two independent reviewers. The statistical analysis for pooling the results of diagnostic performance parameters was conducted using Stata and Meta-DiSc softwares. **Results:** Thirty-eight included studies in this meta-analysis were published between 2006 and 2024, encompassing a total of 6,783 patients. There was significant heterogeneity between included studies with respect to sensitivity (I2=92.51 and P<0.01) and specificity (I2=93.79 and P<0.01). The pooled sensitivity, specificity, and accuracy of LUS for detection of heart failure were 0.92 (95% CI, 0.87-0.95), 0.90 (95% CI, 0.86-0.93), and 0.96 (95% CI, 0.94-0.98), respectively. In addition, pooled positive likelihood ratio (PLR), negative likelihood ratio (NLR), and diagnostic odds ratio (DOR) were 7.87 (95% CI, 5.60-11.07), 0.14 (95% CI, 0.10-0.19), and 70.74 (95% CI, 41.98-119.21), respectively. **Conclusion:** Our meta-analysis demonstrates that LUS is a highly practical imaging for diagnosing acute heart failure, with excellent sensitivity, specificity, and accuracy. It is particularly valuable for excluding the heart failure when the result is negative. However, the influence of outlier and influential studies warrants caution, and future studies should aim to further validate these findings in diverse clinical contexts.

**Keywords:** Dyspnea; Heart Failure; Lung; Meta-analysis; Ultrasonography

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# 1. Introduction

One of the most prevalent complaints of patients referred to emergency departments is acute dyspnea, which is commonly related to pneumonia, acute heart failure, and chronic obstructive pulmonary disease (COPD) (1). In the United States, investigations have shown that acute heart failure is the cause of 40% of dyspnea cases (2, 3). Acute heart failure is associated with about 20% mortality during the first year of diagnosis. A critical challenge in diagnosing acute heart failure is differentiating between cardiac and non-cardiac causes. Common diagnostic measures for the identification of heart failure include determining the level of natriuretic peptides, clinical evaluations, and chest X-ray. It is estimated that approximately 20% of dyspnea cases are misdiagnosed through routine evaluations, leading to increased mortality (2, 4, 5). Although N-terminal pro-brain natriuretic peptide (NT-proBNP) can be used as a biomarker for the diagnosis of acute heart failure, its accuracy in previous studies is conflicting, and it is not easily and rapidly accessible in all settings (6). Echocardiography is considered a critical diagnostic evaluation for acute heart failure, but this imaging is not accessible in all settings and also requires a highly skilled specialist (7, 8).

Lung ultrasound (LUS), as an extension of the physical examination, is non-invasive, easy to use, and easy to teach and can be used for assessing patients with complaints of shortness of breath (9). Despite the evident impact of ultrasonography on diagnosis in acute care settings and previous investigations demonstrating its superiority to physical evaluation alone and chest X-ray, there is still a great deal of uncertainty regarding its accuracy and reproducibility for the diagnosis of acute heart failure in patients with dyspnea (10, 11). Some systematic reviews and meta-analyses have been conducted to investigate the accuracy of LUS for the diagnosis of acute heart failure, but each of them had a major limitation in that they included only a small portion of original studies (10, 12-16). Therefore, in this comprehensive meta-analysis, we aimed to assess the diagnostic performance of LUS for the identification of acute heart failure in patients with suggestive manifestations.

# 2. Methods

## 2.1. Search Strategy

Medline, Scopus, and Web of Science were comprehensively searched from their inception to November 2024 to identify original studies investigating accuracy of LUS for diagnosis of heart failure. The terms and keywords used for systematic search included ultrasonography* OR sonography* OR ultrasound* OR ultrasonic* OR “B-lines” OR “comet” OR “ultrasound lung comets” OR “ULCs” AND "heart failure" OR "Pulmonary Edema" OR "dyspnea*" OR "Ventricular Dysfunction" OR "cardiac failure" OR "cardiopulmonary failure" OR "pulmonary congestion" OR "Cardiac Decompensation" OR "Shortness of breath" OR “heart dysfunction” OR “cardiac dysfunction” OR “acute cardiogenic pulmonary edema” OR “AHF” OR “ACPE”. Moreover, the reference list of the included studies and google scholar were searched as the process of grey search. Similar articles suggested by PubMed for each included articles were also assessed for eligibility.

## 2.2. Eligibility Criteria

In this meta-analysis, we included diagnostic studies involving humans that investigated the value of LUS as a diagnostic imaging tool for identifying acute heart failure. Included studies had to report results of the diagnostic performance of LUS for identifying acute heart failure, including true positive (TP), true negative (TN), false positive (FP), false negative (FN), sensitivity, and specificity. Studies that did not report sufficient data to create a 2×2 table were excluded. Furthermore, case reports, case series with fewer than 10 cases, conference abstracts, commentary, and letters to editors (except those reporting results of original studies), preprints, non-peer-reviewed papers, and papers in languages other than English were excluded from our study.

## 2.3. Data Extraction and Quality Assessment

The data extracted from the included studies included the name of the first author, year of publication, country where the study was conducted, age and gender of the assessed patients, gold standard used for final diagnosis, TP, FP, FN, and TN. Risk of bias evaluation of the included studies was conducted using the Quality Assessment Tool for Diagnostic Accuracy Studies 2 (QUADAS-2), and the results were summarized in a table. Data extraction and quality assessment were performed by two independent reviewers, and inconsistencies were resolved by a third reviewer.

## 2.4. Statistical analysis

The statistical analysis for pooling the results of diagnostic parameters was conducted using Stata statistical software package (Stata Corp., College Station, TX, USA, version 17.0) and Meta-DiSc software. Metandi, Metadta, and Midas packages were used in Stata for meta-analysis.

Publication bias was assessed using Deeks’ Funnel plot and Deeks’ test. Heterogeneity was assessed using $I^2$ and the P-value of the Cochrane Q statistic. Sensitivity, specificity, positive likelihood ratio (PLR), negative likelihood ratio (NLR), diagnostic odds ratio (DOR), and area under the curve were estimated to evaluate the diagnostic performance of LUS. The results were presented as estimates of diagnostic parameters with 95% confidence intervals (CIs).

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# 3. Results

## 3.1. Study Selection and Characteristics

A total of 27,313 papers were initially retrieved through a systematic search of three electronic databases, of which 6,077 duplicate studies were removed using EndNote. Then, 21,236 papers underwent title and abstract screening. Finally, 645 papers were subjected to full-text review based on the eligibility criteria. Based on the eligibility criteria 38 studies were included in the study. The PRISMA flowchart of this systematic review is depicted in Figure 1. The included studies were published between 2006 and 2024, encompassing a total of 6,783 patients. Final diagnosis from comprehensive data review was the most commonly used gold standard for the diagnosis of heart failure. The majority of included studies were conducted in Italy, the USA, and France, respectively. Other characteristics of the included studies are summarized in Table 1.

## 3.2. Quality Assessment and Publication Bias

Quality assessment using QUADAS-2 revealed that the majority of included studies had a high risk of bias in the patient selection domain. Moreover, the reference standard and flow and timing domains had nine and eight studies with a high risk of bias, respectively. Evaluation of publication bias using Deeks' funnel plot showed no significant publication bias. as the distribution of studies around the line was symmetric, and the p-value was higher than 0.1 (P = 0.57; Figure 2).

## 3.3. Met-analysis

The pooled sensitivity and specificity of the included studies were 0.92 (95% CI, 0.87-0.95) and 0.90 (95% CI, 0.86-0.93), respectively (Figure 3). There was significant heterogeneity between included studies with respect to sensitivity (I2=92.51 and P<0.01) and specificity (I2=93.79 and P<0.01). Pooled PLR, NLR, and DOR were 7.87 (95% CI, 5.60-11.07), 0.14 (95% CI, 0.10-0.19), and 70.74 (95% CI, 41.98-119.21), respectively (Figures 4-6). There was also significant heterogeneity between included studies based on the results of PLR, NL, and DOR (I2>50% and P<0.01). The area under the summary receiver-operating characteristic (SROC) showed an accuracy of 0.96 (95% CI, 0.94-0.98) (Figure 7). Bivariate box plot with eight outliers suggest some degree of heterogeneity (Figure 8).

Goodness-of-Fit Q-Q plot (Figure 9.a) shows that points fall approximately along the 45-degree line and bivariate normality assumption was also met as points fall along this line (Figure 9.b). Influential analysis identified seven studies that have strong impact on meta-analysis results (Figure 9.c). Outlier analysis showed one study (Figure 9.d).

The Fagan plot demonstrates that with a prior probability of disease at 0.49, the probability of the disease increases to 0.90 when ultrasonography suggests the presence of the disease (Figure 10). Conversely, if ultrasonography suggests no disease, the probability of disease decreases to 0.08. This illustrates the clinical utility of ultrasonography, showing how it can significantly impact the likelihood of disease based on the test results. The likelihood ratio scattergram shows that ultrasonography is located in left lower quadrant of plot suggesting test is appropriate for exclusion of the heart failure (when negative) and not for confirmation of the disease (when positive) (figure 11). Paired forest plot of empirical Bayes versus observed sensitivity and specificity are shown figure 12. This plot shows adjusted values of sensitivity and specificity using Bayes framework to reduce effects of outliers and extreme values.

## 3.4. Meta-regression

Investigating the source of heterogeneity using meta-regression revealed that year, sample size, gold standard of the included studies did not significantly affect the diagnostic parameters (P=0.41, P=0.86, and P=0.85, respectively) (Figure 13).

# 4. Discussion

Our meta-analysis revealed that LUS is a promising imaging technique for diagnosing acute heart failure, with sensitivity, specificity, and accuracy of 0.92, 0.90, and 0.96, respectively. The pooled PLR and NLR were 7.87 and 0.14, respectively. Evaluation of clinical applicability showed that lung ultrasonography is more useful for excluding heart failure when the result is negative. Given a prior probability of disease of 0.49, this probability increases to 0.90 when ultrasonography suggests the presence of the disease, while it decreases to 0.08 when ultrasonography suggests no disease. However, we identified one outlier study and seven influential studies that could have a significant effect on the pooled estimates.

A similar systematic review and meta-analysis was conducted by McGivery et al. (14) to assess the accuracy of lung ultrasonography for diagnosing acute heart failure. The authors performed a systematic search in Embase, the Cochrane Library, and Medline to identify relevant studies. They included seven studies with a total of 1,861 patients in their meta-analysis and reported sensitivity and specificity values of 82.5% and 83.6%, respectively, for lung ultrasonography. These values are lower than those found in our meta-analysis. The differences may be partly due to the variation in the number of included studies. Our meta-analysis included 38 studies with a total of 6,783 patients, resulting from a comprehensive systematic search in Medline, Scopus, and Web of Science.

Interestingly, lung ultrasonography has also been shown to serve as a prognostic imaging tool in patients with symptoms of heart failure (17).

In this context, a pooled analysis of eight cohort studies, including patients at admission, discharge, and in outpatient clinics, was conducted to investigate the association between the number of B-lines observed in lung ultrasonography and outcomes such as rehospitalization for heart failure and all-cause mortality. The analysis found that a higher number

of B-lines in patients with heart failure was correlated with an increased risk of morbidity and mortality. These findings, along with the results of our study, suggest that lung ultrasonography can be used as both a diagnostic and prognostic imaging tool in patients with heart failure.

Another systematic review and meta-analysis was conducted by Rui et al. (13) on the accuracy of lung ultrasonography for diagnosing acute heart failure. In this study, the authors searched EBSCO, ClinicalTrials.gov, PubMed, ProQuest, CNKI, WanFang Data, OvidSP (EMBASE), the Cochrane Library, and Web of Science, which resulted in the identification of 15 studies involving 3,309 patients. They found that the sensitivity and specificity of lung ultrasonography for diagnosing heart failure were 85% and 91%, respectively. Although their specificity was similar to ours, their sensitivity was lower than what we found in our study. This difference in sensitivity could be explained, in part, by variations in the number of included studies and patients. However, meta-regression using sample size showed that this factor did not significantly affect the sensitivity and specificity of ultrasonography.

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## 5. Limitations

Our study had several limitations. First, we did not search for or include studies published in languages other than English or consider unpublished studies, which may have introduced publication bias and limited the generalizability of our findings. Second, the quality of the sonography performed and the type of reference standard used can significantly impact the results of individual studies, and there were notable differences in these aspects among the studies we included. Third, variations in the settings where sonography was performed and the types of patients assessed may influence the outcomes of our meta-analysis and limit the applicability of our findings to other populations or clinical contexts. Fourth, a significant proportion of the included studies exhibited a high risk of patient selection bias, highlighting the need for future research using consecutive or random sampling methods and avoiding case-control study designs to enhance validity. Finally, we were unable to conduct meta-regression analyses based on additional factors that may contribute to heterogeneity, limiting our ability to explore the influence of other potential confounding variables. Future studies should address these limitations to provide more robust and generalizable evidence.

## 6. Conclusions

Our meta-analysis demonstrates that LUS is a highly practical imaging for diagnosing acute heart failure, with excellent sensitivity, specificity, and accuracy. It is particularly valuable for excluding the heart failure when the result is negative. However, the influence of outlier and influential studies warrants caution, and future studies should aim to further validate these findings in diverse clinical contexts.

## 7. Declarations

### *7.1. Acknowledgments*

The authors thank all those who contributed to this study.

### *7.2. Author Contribution*

All authors contributed to study design, data collection, and writing the draft of the study. All authors read and approved the final version of manuscript.

### *7.3. Funding/Support*

None.

### *7.4. Conflict of interest*

None.

### *7.5. Data Availability*

Not applicable.

### *7.6. Using Artificial Intelligence Chatbots*

None.

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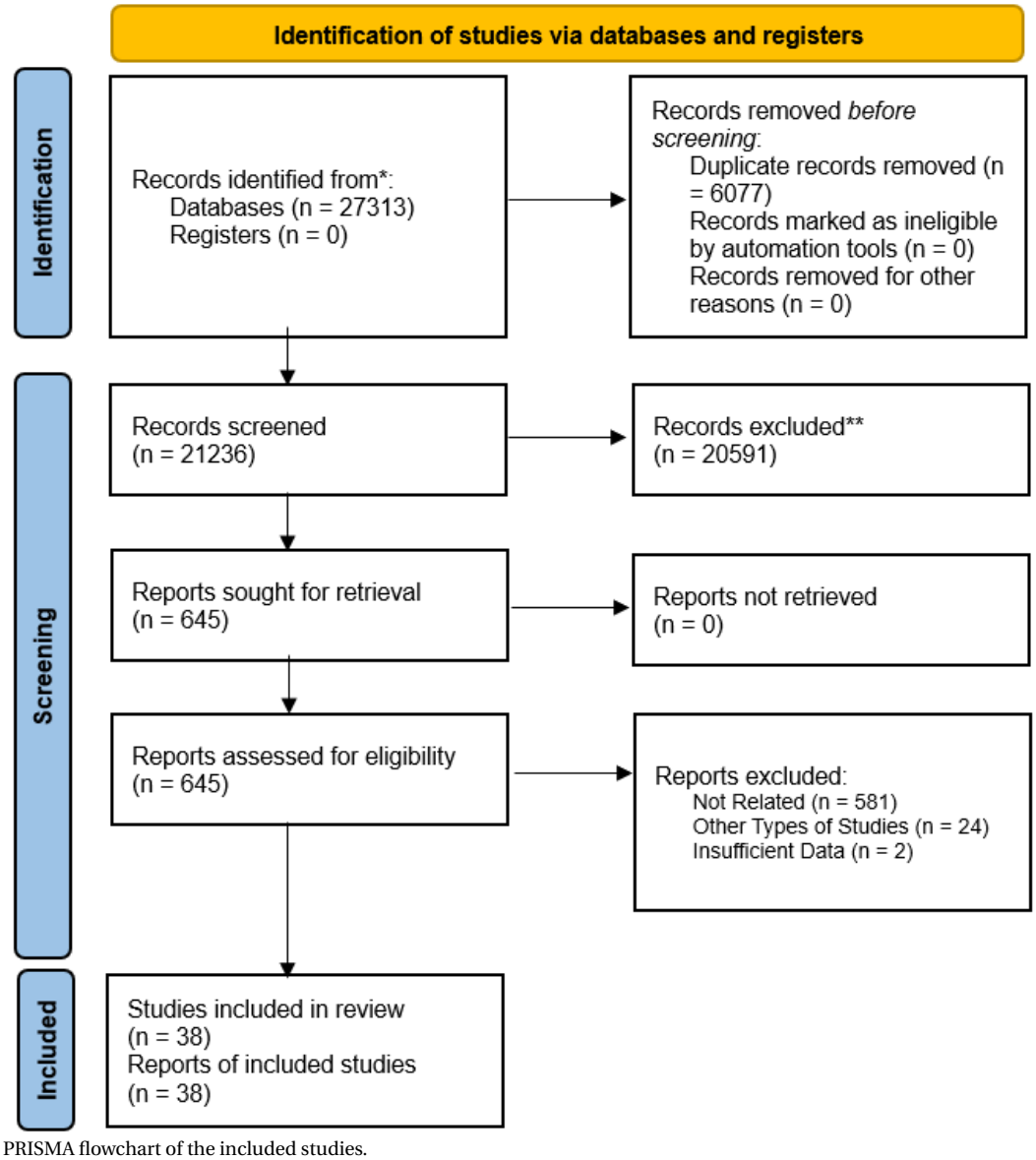


**Figure 1:** PRISMA flowchart of the included studies.

**Table 1:** Characteristics of the included studies

| Author | Year | Country | Age | M/F Ratio | Gold Standard | Sample Size |
|---|---|---|---|---|---|---|
| Russell et al. (b) (19) | 2024 | USA | 64 M | 1 | Final Diagnosis* | 40 |
| Lajili et al. (20) | 2024 | Tunisia | 68 ±11 | 1.96 | Final Diagnosis | 380 |
| Núñez Ramos et al. (21) | 2024 | Colombia | 64 ±17 | 1.29 | Final Diagnosis | 119 |
| Gundersen et al. (22) | 2023 | Denmark | 76 M | 1.14 | Final Diagnosis | 194 |
| Schoeneck et al. (23) | 2021 | USA | 64 ±17 | 1.32 | Final Diagnosis | 65 |
| Msolli et al. (24) | 2021 | Tunisia | 68 ±20 | 1.43 | Final Diagnosis | 700 |
| Nakao et al. (25) | 2021 | Canada | 79 M | 0.97 | Final Diagnosis | 81 |
| Vauthier et al. (26) | 2021 | France | 73 ± 17 | 1 | Final Diagnosis | 103 |
| Balen et al. (27) | 2020 | France | 84 ± 9 | 0.61 | Final Diagnosis | 116 |
| Glöckner et al. (b) (28) | 2020 | Germany | 73 M | 1.4 | Final Diagnosis | 89 |
| Baker et al. (29) | 2019 | Australia | 76 M | 1.37 | Final Diagnosis | 218 |
| Pivetta et al. (b) | 2019 | Italy | 79 M | 1.13 | Final Diagnosis | 258 |
| Farahmand et al. (3) | 2019 | Iran | 60 ± 16 | 1.14 | BNP Levels | 120 |
| Scharonow et al. (30) | 2018 | Germany | 57.8 ± 25.6 | 1.34 | Final Diagnosis | 72 |
| Zanatta et al. (31) | 2018 | Italy | 80 ±12 | NR | Final Diagnosis | 30 |
| Ohmand et al. (32) | 2017 | Finland | 71.4 ± 14.8 | NR | Final Diagnosis | 100 |
| Perrone et al. (33) | 2017 | Italy | 81± 9 | 0.85 | Final Diagnosis | 130 |
| Aggarwal et al. (34) | 2016 | India | 64.4 | 1.62 | Final Diagnosis | 42 |
| Glo¨ckner et al. (a) (35) | 2016 | Germany | 72 M | 2.12 | Final Diagnosis | 25 |
| Mumoli et al. (36) | 2016 | Italy | 78.7±12.7 | 0.71 | Final Diagnosis | 226 |
| Sartini et al. (37) | 2016 | Italy | 79.98 ±12.13 | 0.98 | Final Diagnosis | 236 |
| Shah et al. (38) | 2016 | USA | 36 M | 0.78 | Final Diagnosis | 117 |
| Laursen et al. (39) | 2016 | Denmark | 74 M | 0.53 | Final Diagnosis | 40 |
| Dexheimer et al. (40) | 2015 | Brazil | 73 ± 15 | 0.75 | Final Diagnosis | 36 |
| Gallard et al. (7) | 2015 | France | 81.9 ± 10.2 | 1.18 | Final Diagnosis | 130 |
| Chiem et al. (41) | 2015 | USA | 55 ± 12 | 1.22 | Final Diagnosis | 380 |
| Pivetta et al. (a) (42) | 2015 | Italy | 77 M | 1.16 | Final Diagnosis | 1005 |
| Russell et al. (a) (43) | 2015 | USA | 56 ± 13 | 1.25 | Final Diagnosis | 99 |
| Unluer et al. a (44) | 2014 | Turkey | 70.59 | 1.64 | Final Diagnosis | 96 |
| Unluer et al. b (44) | 2014 | Turkey | 70.59 | 1.64 | Final Diagnosis | 96 |
| Pirozzi et al. (45) | 2014 | Italy | 74 | NR | Final Diagnosis | 168 |
| Anderson et al. (46) | 2013 | USA | 62 | 1.04 | Final Diagnosis | 101 |
| Cibinel et al. (47) | 2012 | Italy | 82.1 M | 1.66 | Final Diagnosis | 56 |
| Kajimoto et al. (48) | 2012 | Japan | 78.1±9.9 | 1 | Final Diagnosis | 90 |
| Prosen et al. (49) | 2011 | Slovenia | 70.9 ± 11.7 | 0.67 | Final Diagnosis | 218 |
| Vitturi et al. (50) | 2011 | Italy | NR | NR | Final Diagnosis | 152 |
| Liteplo et al. (51) | 2009 | USA | 74±14 | 1.43 | Final Diagnosis | 100 |
| Lichtenstein et al. (52) | 2008 | France | 68±16 | 1.16 | Final Diagnosis | 260 |
| Volpicelli et al. (53) | 2006 | Italy | 68.4±15.2 | 1.63 | Final Diagnosis | 295 |

*: Final diagnosis at the time of discharge based on the comprehensive clinical, imaging and laboratory findings.
NR: not reported.

**Table 2:** Quality assessment of the include studies using QUADAS-2 tool

| Study | Risk of bias | | | | Applicability concerns | | |
|---|---|---|---|---|---|---|---|
| | Patient selection | Index test | Reference standard | Flow and timing | Patient selection | Index test | Reference standard |
| Russell et al. (b) | ☺ | ☹ | ? | ☹ | ☹ | ☹ | ☹ |
| Lajili et al. | ? | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Núñez Ramos et al. | ? | ? | ? | ☹ | ☹ | ☹ | ☹ |
| Gundersen et al. | ☺ | ☹ | ☹ | ? | ☹ | ☹ | ☹ |
| Schoeneck et al. | ☺ | ☹ | ☹ | ? | ☹ | ☹ | ☹ |
| Msolli et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Nakao et al. | ☹ | ☹ | ☺ | ☹ | ☹ | ☹ | ☹ |
| Vauthier et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Balen et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Glöckner et al. (b) | ? | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Baker et al. | ☺ | ☹ | ☺ | ☹ | ☹ | ☹ | ☹ |
| Pivetta et al. (b) | ☺ | ☹ | ☺ | ☹ | ☹ | ☹ | ☹ |
| Farahmand et al. | ☹ | ☹ | ☺ | ☹ | ☹ | ☹ | ☹ |
| Scharonow et al. | ? | ☹ | ? | ☹ | ☹ | ☹ | ☹ |
| Zanatta et al. | ☺ | ☹ | ? | ☹ | ☹ | ☹ | ☹ |
| Ohmand et al. | ☹ | ☹ | ☺ | ☹ | ☹ | ☹ | ☹ |
| Perrone et al. | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ | ☹ |
| Aggarwal et al. | ☺ | ☺ | ☹ | ? | ☺ | ☺ | ☹ |
| Glo¨ckner et al. (a) | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Mumoli et al. | ☹ | ☹ | ☹ | ☺ | ☹ | ☹ | ☹ |
| Sartini et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Shah et al. | ☺ | ☹ | ☺ | ☹ | ☹ | ☹ | ? |
| Laursen et al. | ? | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Dexheimer et al. | ☺ | ☹ | ☹ | ☺ | ☹ | ☹ | ☹ |
| Gallard et al. | ☺ | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ |
| Chiem et al. | ☺ | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ |
| Pivetta et al. (a) | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Russell et al. (a) | ? | ☹ | ☺ | ☹ | ☹ | ☹ | ☹ |
| Unluer et al. a | ? | ? | ☹ | ☹ | ☹ | ? | ☹ |
| Unluer et al. b | ? | ? | ☹ | ☹ | ☹ | ? | ☹ |
| Pirozzi et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Anderson et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Cibinel et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Kajimoto et al. | ☺ | ? | ☹ | ☹ | ☺ | ? | ☹ |
| Prosen et al. | ☺ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Vitturi et al. | ☹ | ☹ | ☺ | ☺ | ☹ | ☹ | ☹ |
| Liteplo et al. | ☺ | ☹ | ☹ | ☺ | ☹ | ☹ | ☹ |
| Lichtenstein et al. | ☺ | ☺ | ☹ | ☺ | ☹ | ☹ | ☹ |
| Volpicelli et al. | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |

☹: High risk; ☺: Low risk; ?: unclear.

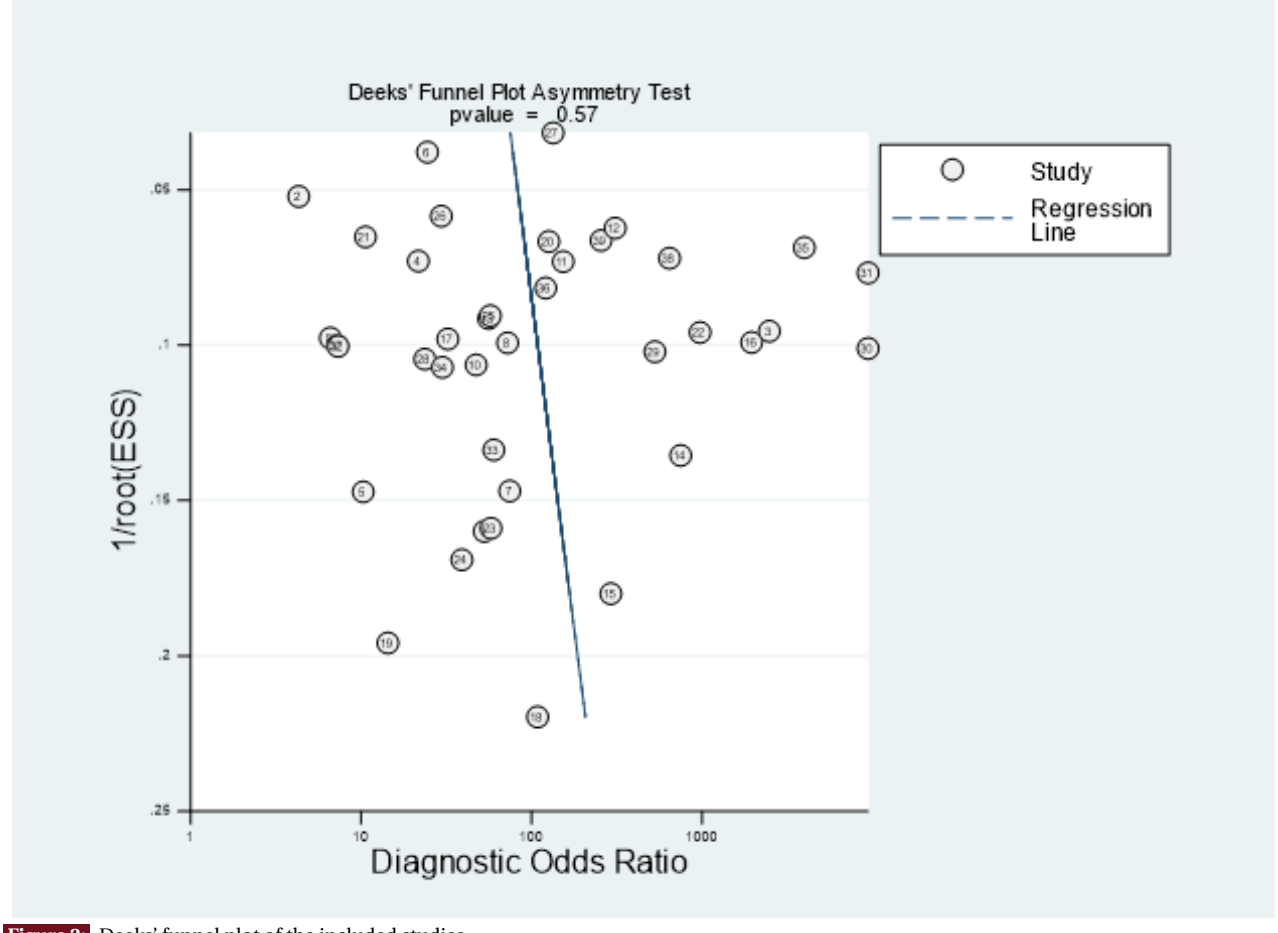


**Figure 2:** Deeks' funnel plot of the included studies.

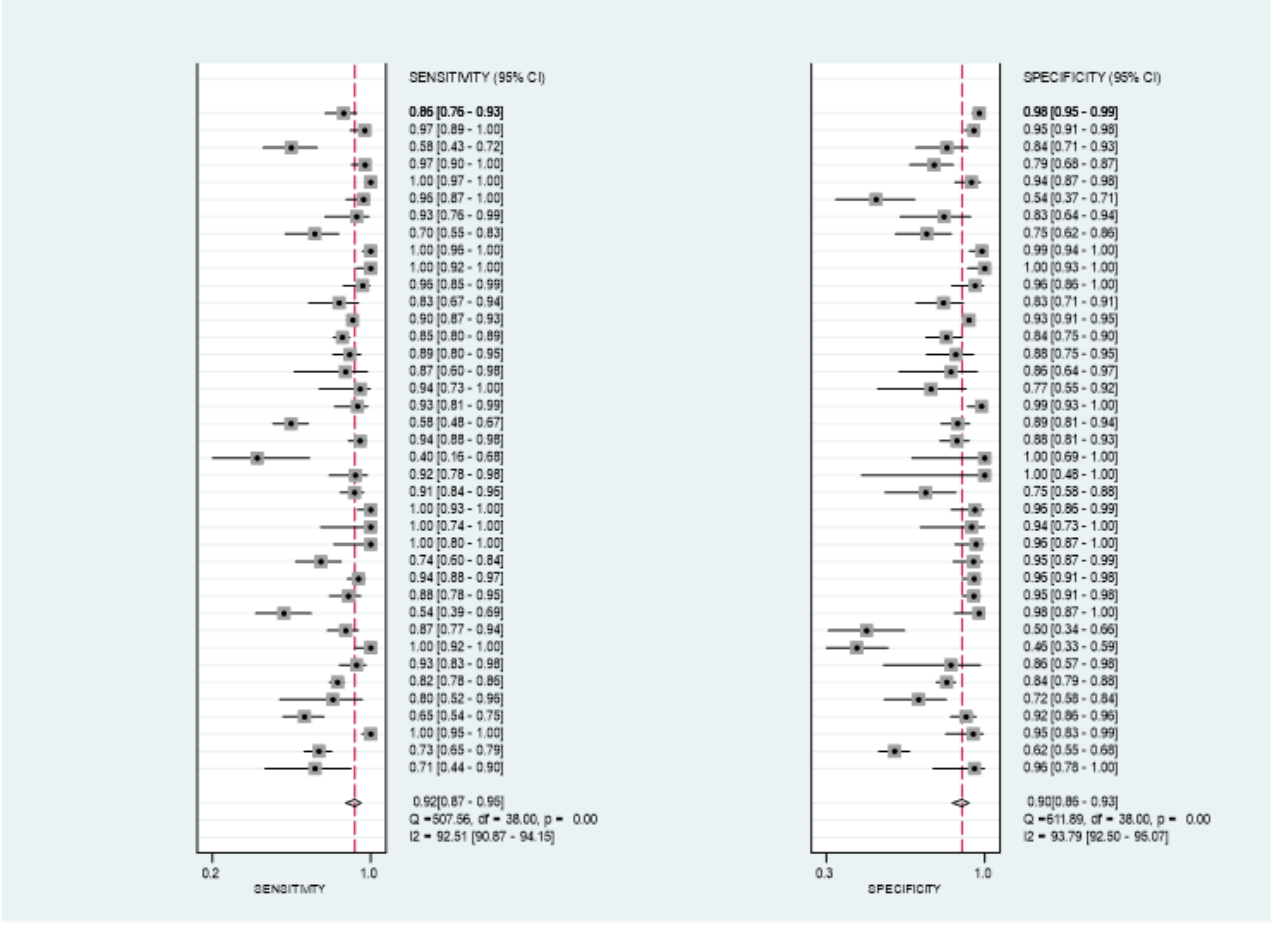


**Figure 3:** Pooled sensitivity and specificity of the included studies.

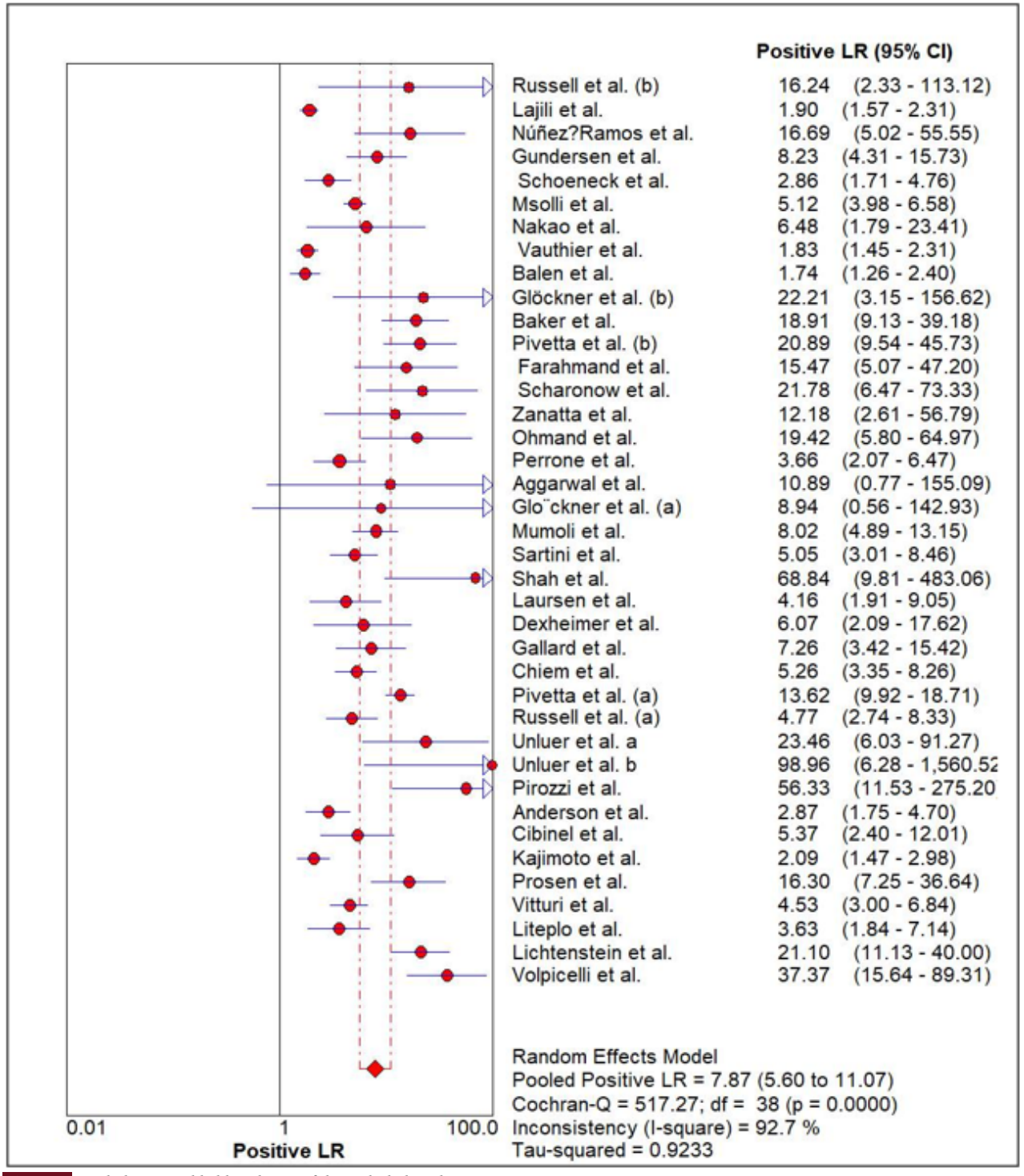


**Figure 4:** Pooled positive likelihood ratio of the included studies.

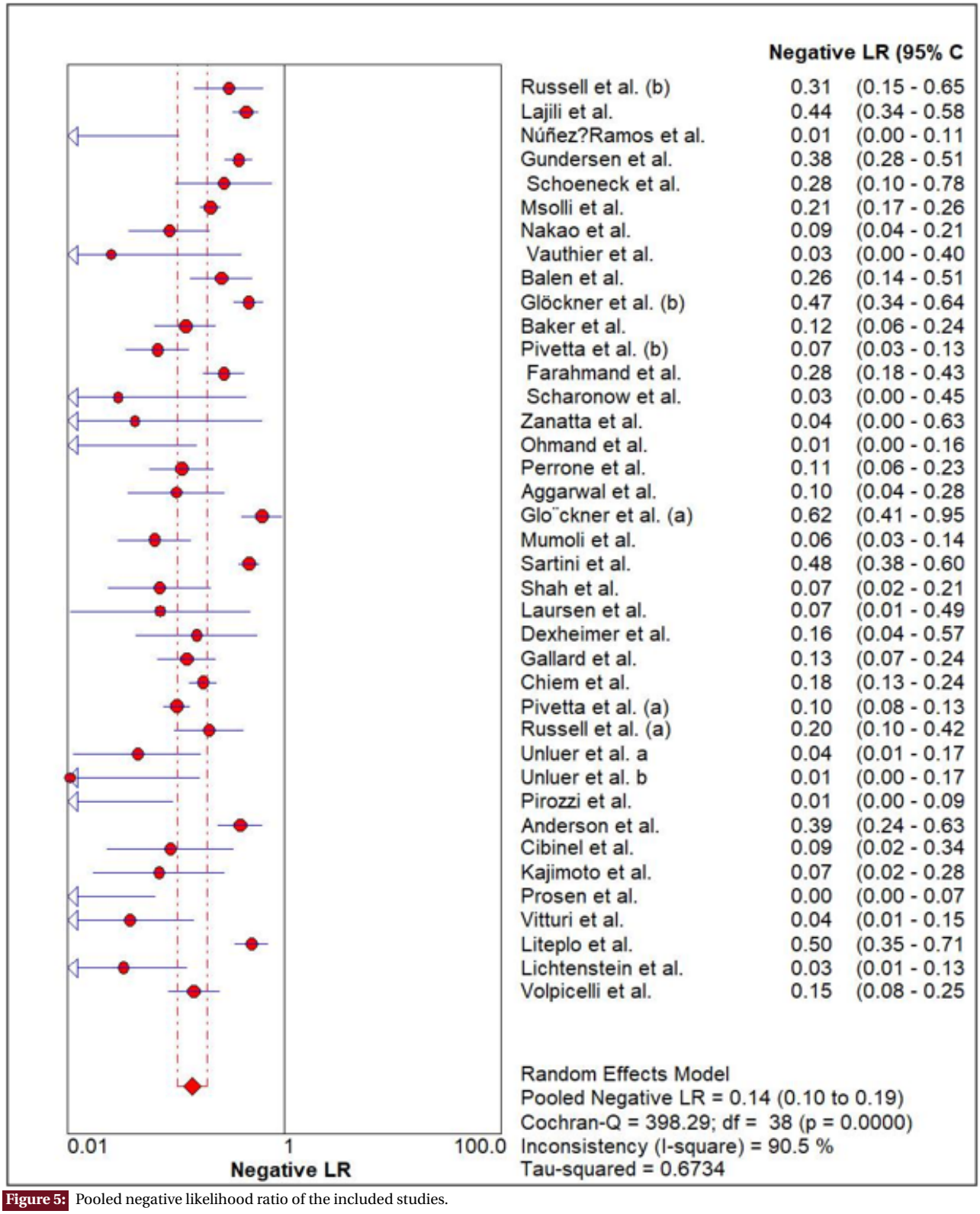


**Figure 5:** Pooled negative likelihood ratio of the included studies.

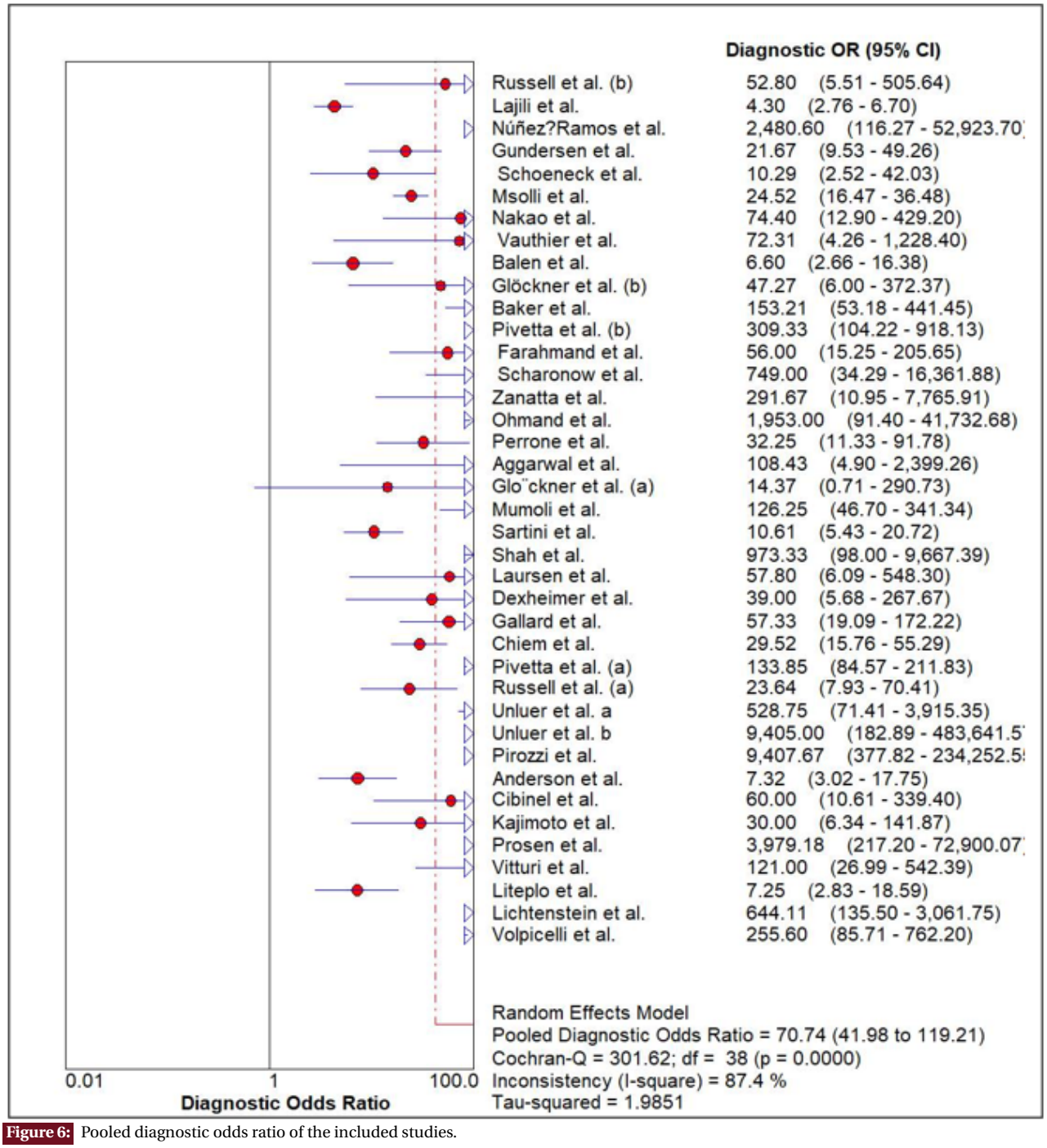


**Figure 6:** Pooled diagnostic odds ratio of the included studies.

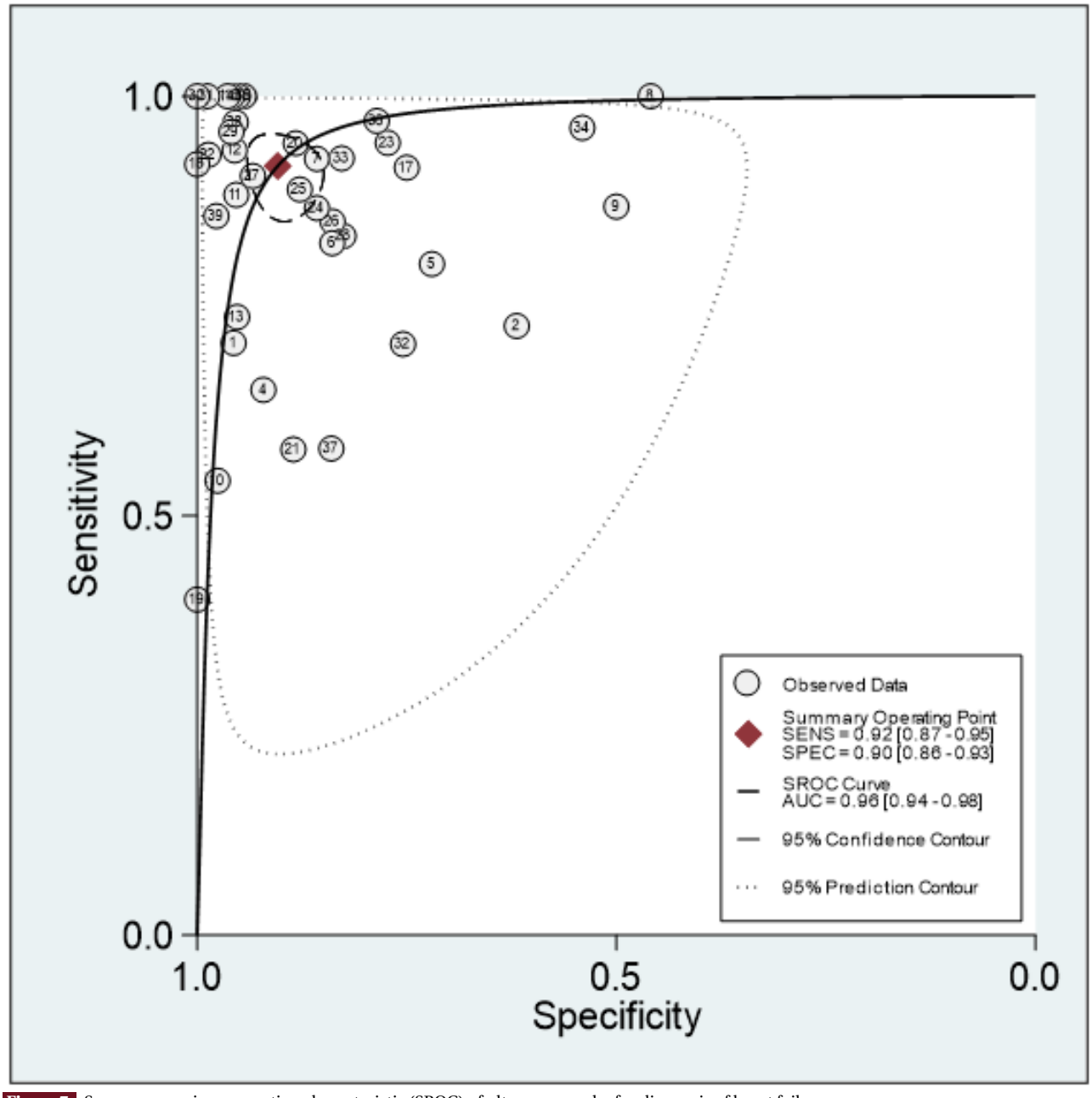


**Figure 7:** Summary receiver-operating characteristic (SROC) of ultrasonography for diagnosis of heart failure.

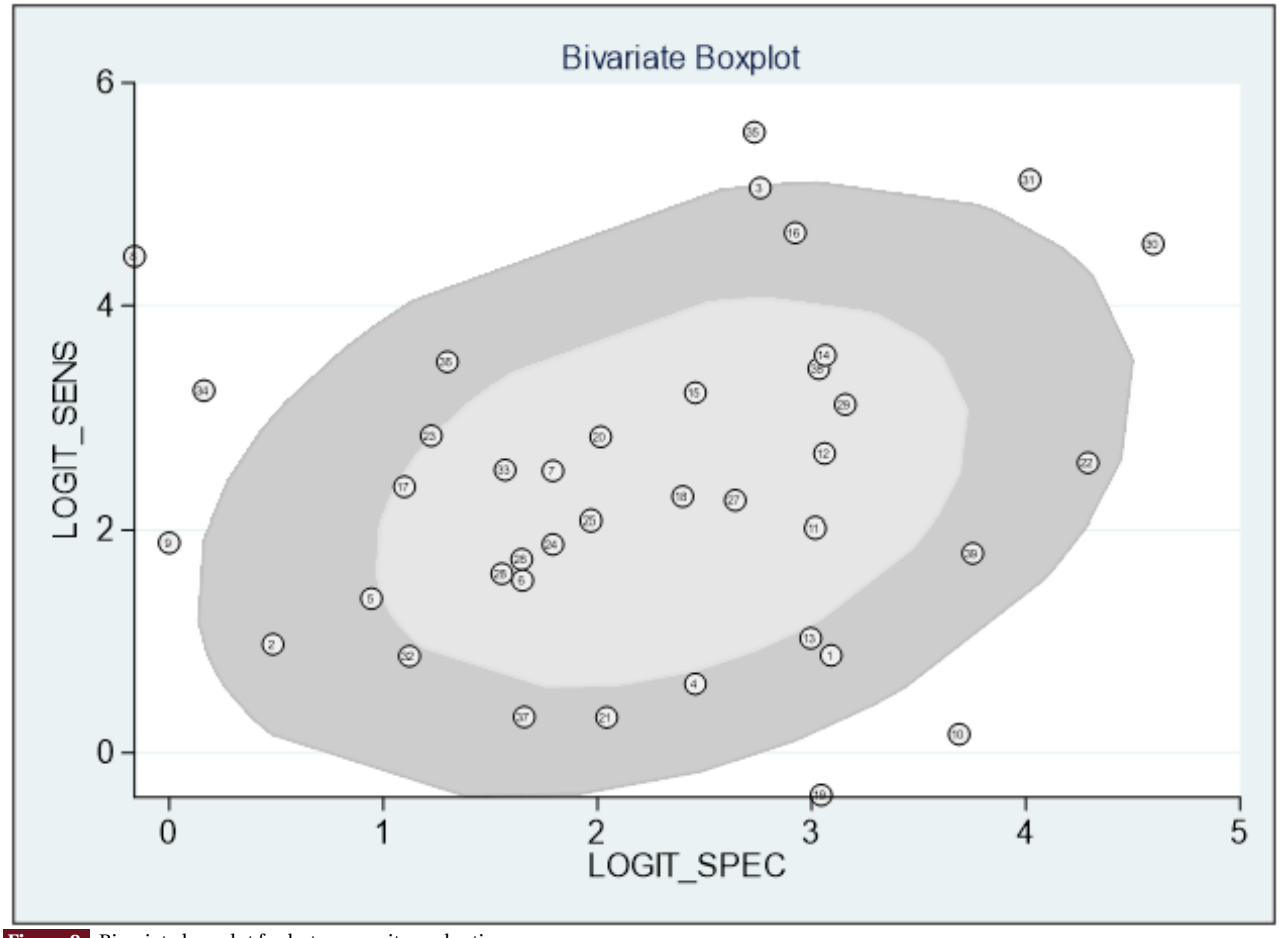


**Figure 8:** Bivariate box plot for heterogeneity evaluation.

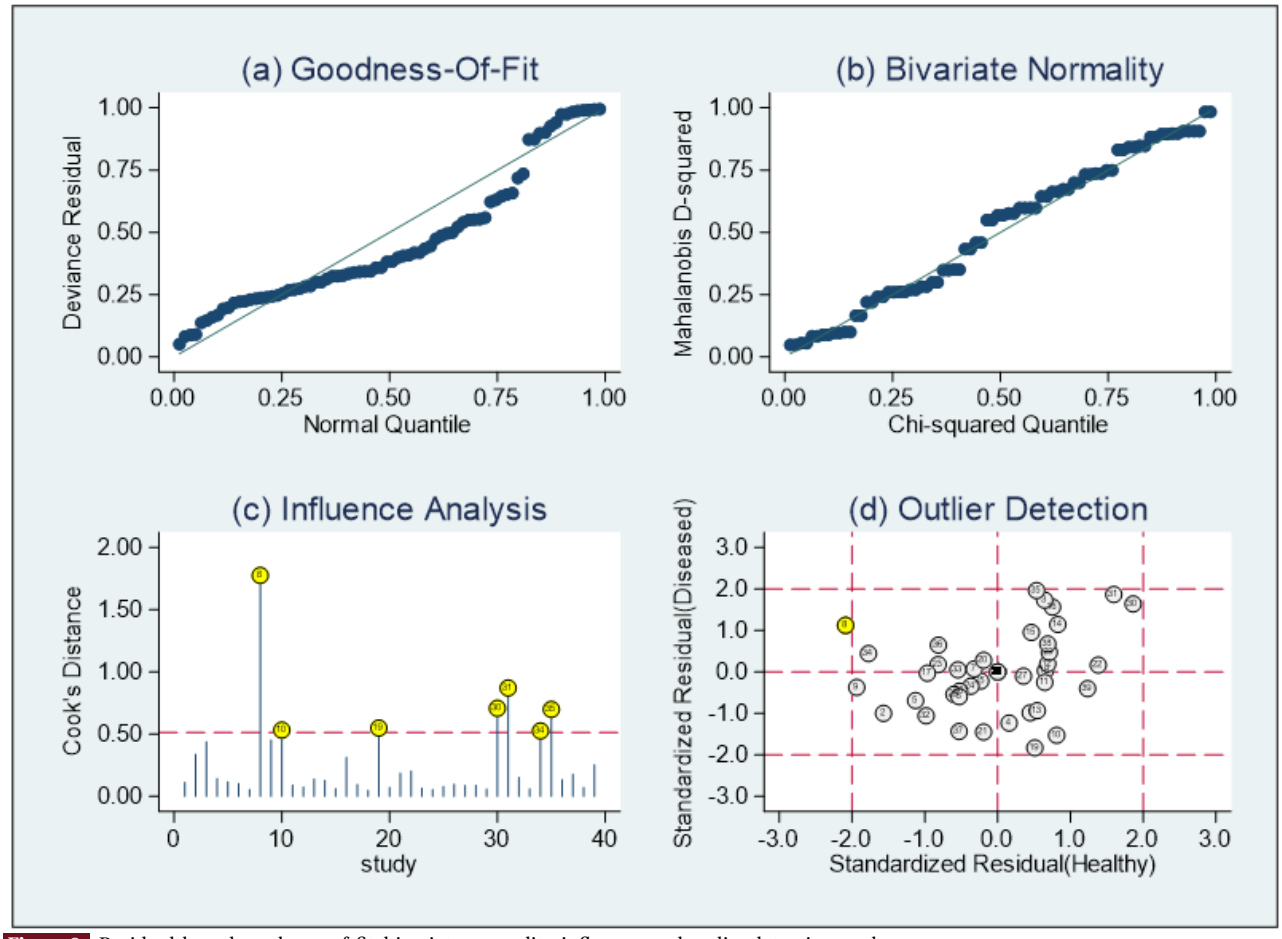


**Figure 9:** Residual-based goodness-of-fit, bivariate normality, influence and outlier detection analyses.

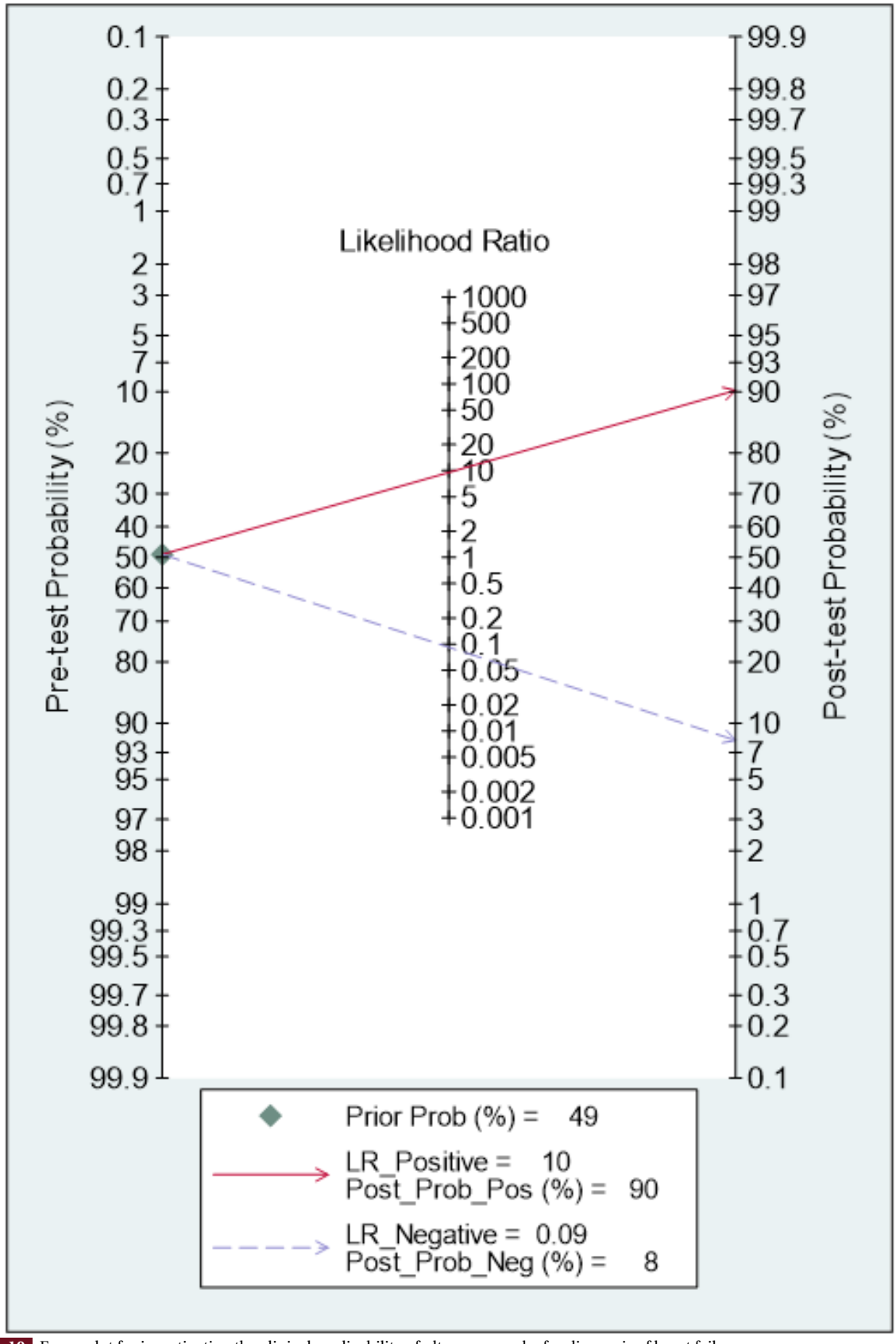


**Figure 10:** Fagan plot for investigating the clinical applicability of ultrasonography for diagnosis of heart failure.

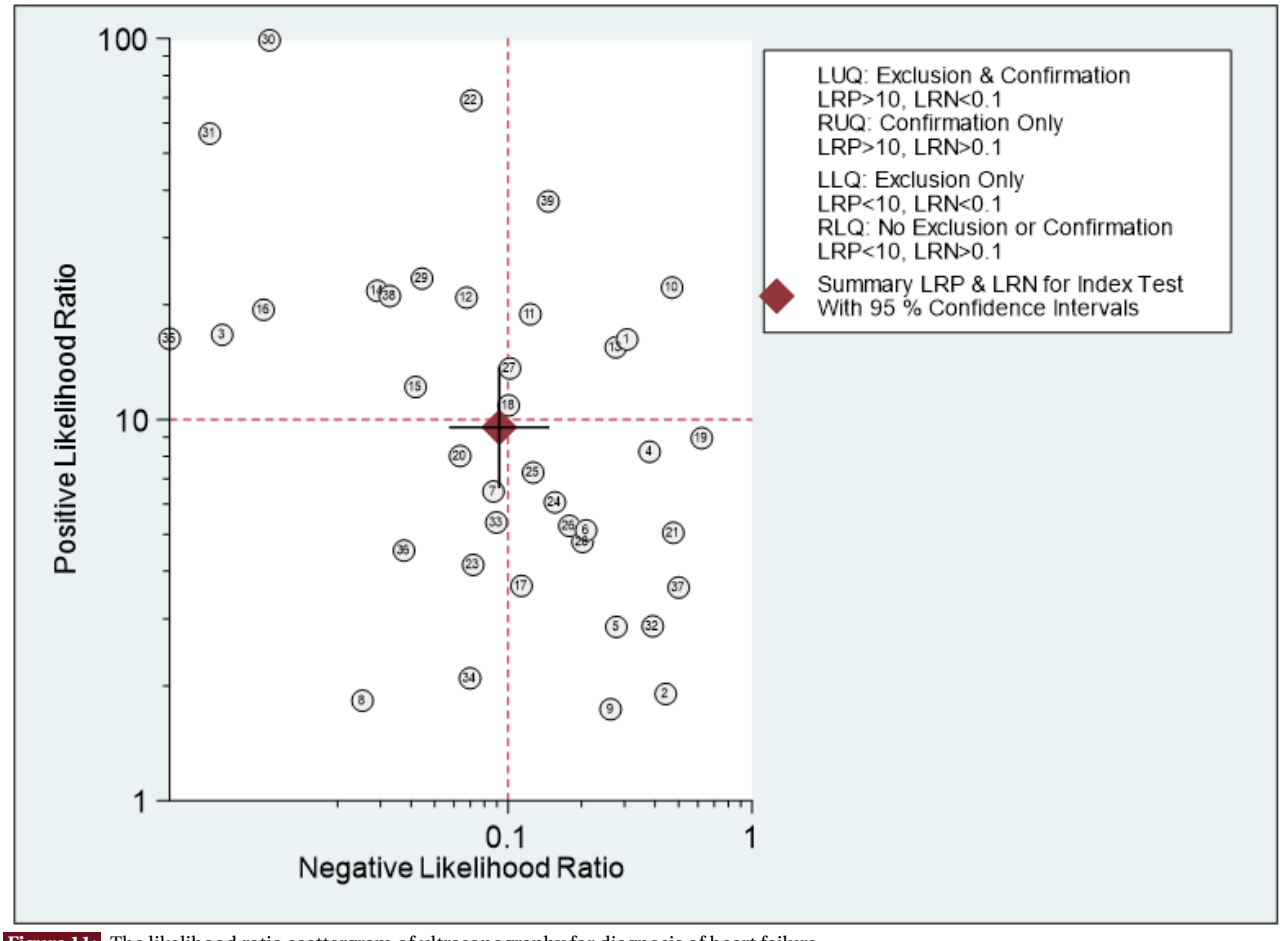


**Figure 11:** The likelihood ratio scattergram of ultrasonography for diagnosis of heart failure.


**Figure 12:** Paired forest plot depiction of empirical Bayes predicted versus observed sensitivity and specificity.

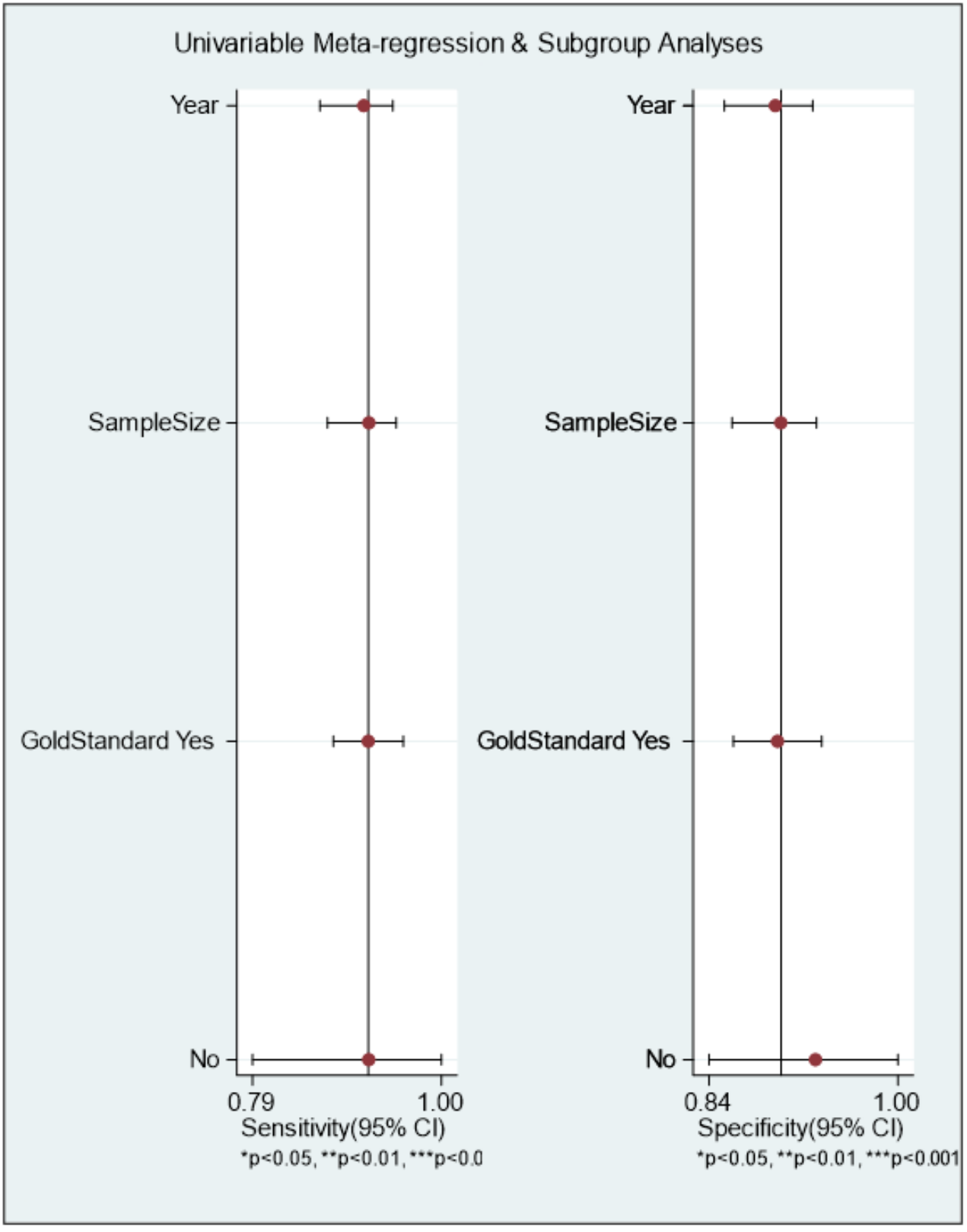


**Figure 13:** Forest plot of multiple univariable meta-regression and subgroup analyses. Gold standard-Yes includes studies that used final diagnosis based on comprehensive data review.