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Systematic review and meta-analysis of magnetic resonance imaging in the diagnosis of pulmonary embolism

Chuan-Hua Yang[1], Miao Yu[2] and Deng-Chao Wang[3*]

Abstract

Background Pulmonary embolism is a significant clinical challenge with high mortality risk. Computed Tomography Pulmonary Angiography (CTPA) is the gold standard for diagnosis but involves radiation risks. Magnetic Resonance Imaging (MRI) offers a radiation-free alternative, yet its adoption is hindered by inconsistent validation of its diagnostic accuracy. This study systematically assesses MRI's efficacy in diagnosing pulmonary embolism, incorporating a broad range of literature to ensure comprehensive analysis.

Methods Relevant studies on the diagnostic use of MRI for pulmonary embolism were collected through computer searches of PubMed, Embase, Cochrane Library, Web of Science, China National Knowledge Infrastructure (CNKI), Wanfang Database, VIP Database, and China Biology Medicine disc (CBM) databases up to May 12, 2024. Literature was screened based on inclusion and exclusion criteria, data extracted, and study quality assessed according to Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) standards. Data analysis was performed using Stata (versions 17.0 and 14.0) and Meta-Disc 1.4 software. Stata software was used to calculate pooled sensitivity, pooled specificity, positive likelihood ratio, negative likelihood ratio, and diagnostic odds ratio, and to plot forest plots, hierarchical summary receiver operating characteristic (HSROC) curves, and summary receiver operating characteristic (SROC) curves. The area under the SROC curve (AUC) was calculated, and publication bias was assessed through Deek's funnel plot, Egger's test, and Begg's test.

Results Eighteen articles involving 1,264 participants were included. The meta-analysis showed that MRI for the diagnosis of pulmonary embolism had a pooled sensitivity of 0.89 (95% CI: 0.79–0.94) and a specificity of 0.94 (95% CI: 0.89–0.97). The pooled positive likelihood ratio was 14.6 (95% CI: 8.0-26.7) and the negative likelihood ratio was 0.12 (95% CI: 0.06–0.23). The diagnostic odds ratio was 121 (95% CI: 49–299). The AUC of the SROC was 0.97. Deek's funnel plot suggested potential publication bias in the studies included.

Conclusion MRI exhibits high sensitivity and specificity in the diagnosis of pulmonary embolism, demonstrating excellent diagnostic efficacy. Despite potential publication bias, MRI continues to show strong potential for clinical application.

Keywords Magnetic resonance, Pulmonary embolism, Meta-analysis

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Introduction

Pulmonary embolism is an urgent circulatory system disorder with a high mortality and morbidity rate, making rapid and accurate diagnosis crucial for ensuring patient safety. The clinical symptoms of pulmonary embolism are varied and nonspecific, presenting a significant diagnostic challenge in clinical settings [1, 2]. Computed tomography pulmonary angiography (CTPA) is currently the gold standard for diagnosing pulmonary embolism, but it poses significant radiation risks and potential side effects from contrast agents to patients [3, 4]. Therefore, exploring safer and equally effective alternative diagnostic tools is an important direction in medical research.

Magnetic resonance imaging (MRI) has demonstrated unique advantages in multiple fields due to its radiation-free nature and high contrast [5]. For the diagnosis of pulmonary embolism, MRI offers a potential radiation-free alternative, particularly suitable for radiation-sensitive populations [6, 7]. However, despite theoretical advantages, the clinical efficacy and safety of MRI in diagnosing pulmonary embolism have not been widely accepted due to insufficient and inconsistent data on its diagnostic performance. Existing research results are inconsistent and controversial, with some studies having small sample sizes and insufficient evidence [8–25]. Therefore, a comprehensive and objective assessment of the accuracy and clinical prospects of MRI in the diagnosis of pulmonary embolism is of great importance. In 2017, Squizzato and colleagues published a meta-analysis [26] showing that MRI has high specificity but limited sensitivity in diagnosing pulmonary embolism, attributed to the inclusion of only English-language literature. This study aims to conduct a comprehensive search of both Chinese and English studies and evaluate the diagnostic value of MRI in pulmonary embolism through meta-analysis. We hope to provide a comprehensive assessment of the sensitivity, specificity, and other diagnostic metrics of MRI in diagnosing pulmonary embolism, to assist clinicians in making more informed decisions when selecting diagnostic tools. This approach not only aids in improving diagnostic strategies for pulmonary embolism but could also significantly reduce radiation exposure for patients.

Materials and methods

Our systematic review follows the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA-P) [27] and has been registered with the identifier INPLASY202470060.

Inclusion and exclusion criteria

Inclusion Criteria: (1) Study subjects are adults who have been diagnosed with or are suspected to have pulmonary embolism. (2) MRI is utilized as the diagnostic tool for pulmonary embolism. (3) MRI results must be compared with the gold standards, which include CTPA, Digital Subtraction Angiography (DSA), and radionuclide lung ventilation/perfusion scanning. (4) Studies must provide sufficient data to calculate the true positive (TP), true negative (TN), false positive (FP), and false negative (FN) values for MRI in the diagnosis of pulmonary embolism. (5) Studies should provide full-text articles in either English or Chinese.

Exclusion Criteria: (1) Case reports and studies with small sample sizes (e.g., fewer than 10 participants). (2) Review articles, commentaries, and conference abstracts. (3) Studies that include duplicate datasets, for instance, datasets reported in multiple publications. (4) Research involving children or minors. (5) Animal studies.

Search strategy

Searches were conducted on PubMed, Embase, the Cochrane Library, Web of Science, China National Knowledge Infrastructure (CNKI), Wanfang Database, VIP Database, and the China Biology Medicine disc (CBM) for Chinese and English literature published on MRI for the diagnosis of pulmonary embolism up to May 12, 2024. A combination of MeSH terms and free-text terms was used. The search terms included NMR Imaging, MR Tomography, NMR Tomography, Zeugmatography, Magnetic Resonance Image, MRI Scan, Pulmonary Embolism, Lung Embolism, and Pulmonary Thromboembolism. For example, the search strategy for PubMed was: ((“Magnetic Resonance Imaging“[Mesh]) OR ((((((NMR Imaging[Title/Abstract]) OR (MR Tomography[Title/Abstract])) OR (NMR Tomography[Title/Abstract])) OR (Zeugmatography[Title/Abstract])) OR (Magnetic Resonance Image[Title/Abstract])) OR (MRI Scan[Title/Abstract]))) AND ((“Pulmonary Embolism“[Mesh]) OR ((Lung Embolism[Title/Abstract]) OR (pulmonary thromboembolism[Title/Abstract]))). Additionally, to further the research, references from the included studies were reviewed to assess their eligibility according to the inclusion criteria.

Literature screening and data extraction

Two researchers independently screened the literature based on predetermined inclusion and exclusion criteria and cross-checked the extracted information. Any disagreements were resolved through discussion or consultation with a third researcher. The extracted information included: (1) General data: first author, publication year, country, sample size, age of participants, gold standard for the diagnosis of pulmonary embolism, magnetic field strength of MRI, and MRI brand used; (2) Outcome indicators: TP, FP, FN, and TN.

Quality assessment

The quality of the studies included in the meta-analysis was evaluated using the QUADAS-2 tool, which is specifically designed for diagnostic accuracy studies. QUADAS-2 focuses on four main areas: patient selection, the index test, the reference standard, and the flow and timing of the study. We examined all domains for potential risk of bias (ROB) and evaluated the first three for applicability concerns. The risk of bias was categorized as 'low', 'high', or 'unclear' [28]. Two independent researchers conducted the QUADAS-2 assessment, and any discrepancies were resolved through consensus among the researchers.

Statistical analysis

Data analysis was performed using Stata (versions 17.0 and 14.0) and Meta-Disc 1.4 software. Heterogeneity among studies was assessed using the Cochran-Q test and I^2 statistic; significant heterogeneity was indicated by $P<0.05$ and $I^2>50\%$, in which case a random-effects model was employed. If heterogeneity was not significant, a fixed-effect model was used. Calculations included pooled sensitivity, specificity, positive and negative likelihood ratios, and the 95% confidence intervals for the diagnostic odds ratio. Forest plots, hierarchical summary receiver operating characteristic (HSROC) curves, and summary receiver operating characteristic (SROC) curves were also constructed, and the area under the curve (AUC) was estimated. If heterogeneity was detected, Meta-Disc 1.4 was used to explore the presence of a threshold effect (determined by Spearman correlation coefficient), and meta-regression was conducted to identify potential sources of heterogeneity. Additionally, subgroup analyses were performed to compare sensitivity and specificity across different subgroups. Potential publication bias was assessed using Deek's funnel plot, Egger's test, and Begg's test, with a P-value of less than 0.10 indicating the presence of publication bias.

Results

Literature search results

A total of 10,023 articles were initially retrieved from various databases. After screening titles and abstracts, 894 duplicate articles were excluded, along with 8,853 articles irrelevant to the research objectives. Furthermore, 223 experience summaries, conference abstracts, 13 animal studies, 13 articles involving patients already diagnosed with pulmonary embolism, 5 articles where it was not possible to calculate all TP, TN, FP, FN values, and 4 articles lacking a reference or gold standard were also excluded. After a detailed screening process, 18 articles [8–25] involving 1,264 participants were finally included. The detailed screening process is shown in Fig. 1, and the basic information of the articles is presented in Table 1.

Quality assessment results of included studies

The results of the quality assessment of the included studies are presented in Table 2.

Heterogeneity and threshold effect analysis

The combined sensitivity and specificity of MRI for diagnosing pulmonary embolism had I^2 values of 73.11% and 79.45%, respectively. The P values for Cochran's Q test for combined sensitivity and specificity were both 0.00, indicating significant heterogeneity among the included studies. Therefore, a threshold effect analysis was necessary. Using Meta Disc 1.4, a Spearman correlation coefficient of -0.235 with a P value of 0.440 was calculated, indicating the presence of non-threshold effect heterogeneity. Consequently, a random effects model was used to estimate the combined effect sizes.

Meta-analysis results

Forest plots and SROC curves were generated to calculate the combined sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, and diagnostic odds ratio, along with the AUC of the SROC curve. The combined sensitivity and specificity were 0.89 (95% CI: 0.79–0.94) and 0.94 (95% CI: 0.89–0.97), respectively. The combined positive likelihood ratio and negative likelihood ratio were 14.6 (95% CI: 8.0-26.7) and 0.12 (95% CI: 0.06–0.23), respectively. The diagnostic odds ratio was 121 (95% CI: 49–299), with an AUC of 0.97 for the SROC curve. The forest plots and SROC curves for the MRI diagnosis of pulmonary embolism are shown in Figs. 2 and 3. Additionally, the HSROC curve provides further insight by accounting for the variability between studies, with its 95% CI and prediction region displayed, as shown in Fig. 4.

Publication bias

Publication bias for MRI diagnosis of pulmonary embolism was assessed using Deek's funnel plot, which showed asymmetry, as shown in Fig. 5. Although the P values for Egger's test and Begg's test were 0.929 and 0.436, respectively, the P value for the linear regression test was 0.01, suggesting the potential presence of publication bias.

Meta-regression and subgroup analysis

Heterogeneity due to threshold effects has been excluded. Therefore, univariate meta-regression analysis was conducted using publication year, country, sample size, gold standard for the diagnosis of pulmonary embolism, and MRI field strength as variables. The results indicated that the country was the primary cause of heterogeneity in sensitivity, while the gold standard for the diagnosis of pulmonary embolism was the primary cause of heterogeneity in specificity. The results of the subgroup analysis are detailed in Table 3.

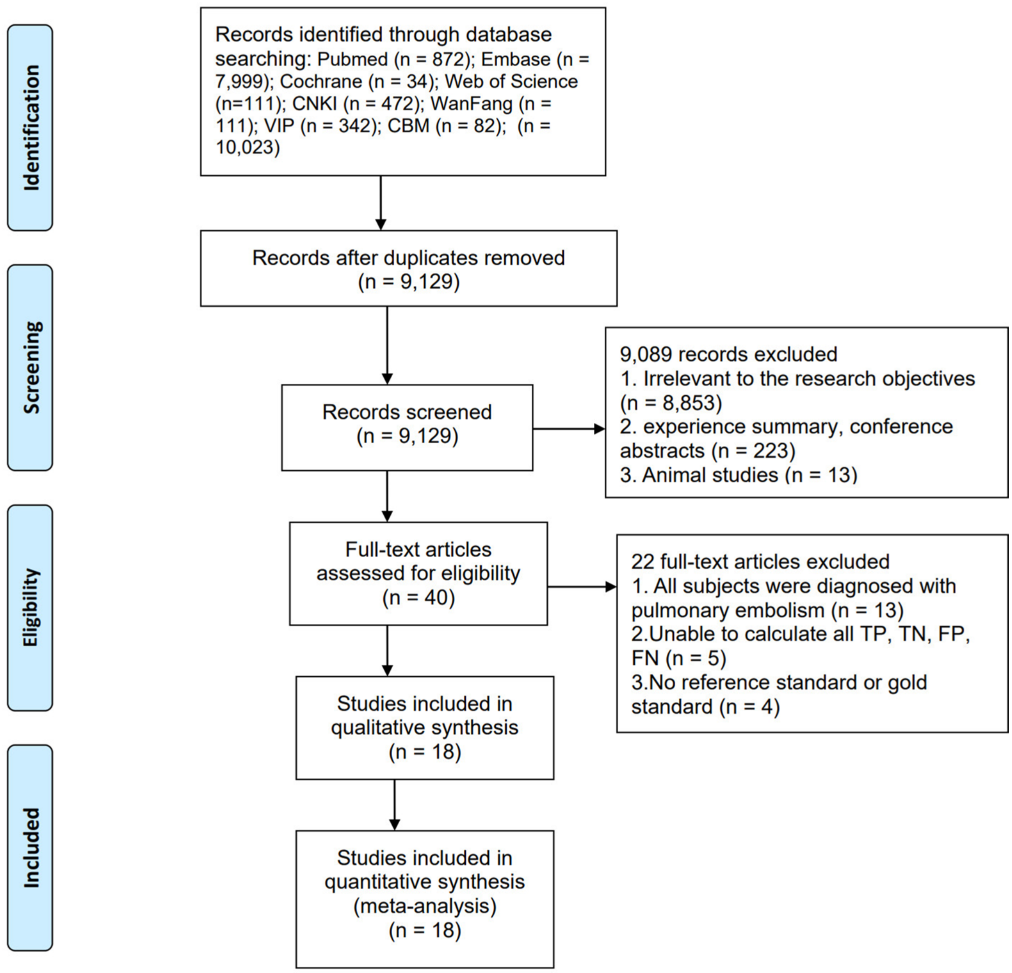

Fig. 1 Study screening process

Discussion

Pulmonary embolism is a serious cardiovascular disease that, without timely diagnosis and treatment, can lead to high mortality [29]. Traditional diagnostic methods such as CTPA and DSA, although highly sensitive, pose potential risks to certain patients (e.g., those with renal insufficiency, pregnant women) due to radiation exposure and the use of contrast agents [30, 31]. Therefore, exploring a safe and effective alternative diagnostic tool is particularly important. MRI, as a radiation-free imaging technique, has shown great potential in the diagnosis of pulmonary embolism in recent years [32]. MRI utilizes a strong magnetic field and radio waves to detect changes in water molecules within the body, thereby producing high-resolution images [33]. In the diagnosis of pulmonary embolism, MRI not only can reveal structural abnormalities in the blood vessels but also assists in the diagnosis through hemodynamic changes and perfusion status of lung tissue [34, 35]. For example, Magnetic Resonance Pulmonary Angiography (MRPA) with MRI can visually display the condition of vascular blockage, while magnetic resonance perfusion imaging helps assess areas of blood flow deficit [36, 37]

The results of this systematic review and meta-analysis demonstrate that MRI exhibits high sensitivity and specificity in diagnosing pulmonary embolism. With a pooled sensitivity of 0.89 and a specificity of 0.94, MRI effectively distinguishes between patients with and without pulmonary embolism. Additionally, the high values of the positive and negative likelihood ratios further reinforce the diagnostic value of MRI, indicating its significant clinical relevance in confirming or excluding pulmonary embolism. A positive likelihood ratio of 14.6 suggests that the odds of having pulmonary embolism are about 15 times higher if the MRI result is positive. Conversely, a negative likelihood ratio of 0.12 implies that the odds of not having pulmonary embolism increase about 8 times if the MRI result is negative. Such remarkable diagnostic performance is invaluable in clinical settings, especially in emergency environments where rapid and accurate diagnosis is crucial.

Table 1 Basic characteristics of included studies

Study	Country	Sample size (M/F)	Age (years)	Gold standard for the diagnosis of PE	Magnetic field strength of MRI)	MRI brand	TP	FP	FN	TN
Blum 2005 [8]	France	89 (45/44)	64 ± 16*	CTPA	1.5T	GE	47	5	16	21
Ersoy 2007 [9]	USA	24 (Na/Na)	62 (35–92)#	CTPA	1.5-T	GE	2	2	7	13
Grist 1993 [10]	USA	14 (7/7)	35–82**	CTPA	1.5 T	GE	6	3	0	5
Gupta 1999 [11]	Australia	36 (17/19)	28–84**	DSA	1.5-T	Siemens	11	1	2	22
Kluge 2006 [12]	Germany	62 (Na/Na)	60.9 ± 15.7*	CTPA	1.5-T	Siemens	19	3	0	40
Loubeyre 1994 [13]	France	23 (12/11)	20–66**	DSA	1.5-T	Na	10	0	2	11
Meaney 1997 [14]	USA	30 (15/15)	52(22–83)#	DSA	1.5-T	GE	8	1	0	21
Meng 2005 [15]	China	56 (35/21)	32–63**	Ventilation/Perfusion	1.5-T	Na	36	2	3	15
Ohno 2004 [16]	Japan	48 (26/22)	22–73**	DSA	1.5-T	Philips	11	2	1	34
Osman 2016 [17]	Egypt	50 (15/35)	45–70**	CTPA	1.5-T	Na	31	2	4	13
Oudkerk 2002 [18]	Netherlands	118 (Na/Na)	53(16–87)#	DSA	1.5T	Siemens	27	2	8	81
Pleszewski 2006 [19]	Switzerland	48 (20/28)	55(22–84) #	CTPA /DSA	1.5-T	GE	9	0	2	37
Revel 2012 [20]	France	274 (137/147)	59.8 ± 19.0*	CTPA	1.5-T	GE	87	2	16	169
Sostman 1996 [21]	USA	25 (Na/Na)	26–80**	DSA	1.5-T	GE	3	2	4	16
Stein 2010 [22]	USA	279 (Na/Na)	49 ± 15*	CTPA	1.5-T	Na	59	2	17	201
Yu 2005 [23]	China	38 (19/19)	37–76**	DSA	1.5-T	Na	30	2	0	6
Zhang 2013 [24]	China	27 (18/9)	38.9 ± 14.4*	CTPA	3-T	Siemens	24	0	0	3
Zhao 2016 [25]	China	23 (19/4)	37.8 ± 14.6*	CTPA	3.0-T	Na	13	3	1	6

*: Mean age and standard deviation; **: Range of ages; #: Median age and range of age data

CTPA: Computed Tomography Pulmonary Angiography; DSA: Digital Subtraction Angiography; F: Female; FN: False Negative; FP: False Positive; GE: General Electric; M: Male; Na: Not Available; TN: True Negative; TP: True Positive

Table 2 Quality assessment results of included studies

Study	Risk of bias				Applicability concerns		
	①	②	③	④	①	②	③
Blum 2005 [8]	Low Risk	High Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Ersoy 2007 [9]	Low Risk	Unclear Risk	Unclear Risk	Unclear Risk	Low Risk	Low Risk	Low Risk
Grist 1993 [10]	Unclear Risk	Unclear Risk	Unclear Risk	Unclear Risk	Unclear Risk	Unclear Risk	Low Risk
Gupta 1999 [11]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Kluge 2006 [12]	Unclear Risk	Unclear Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Loubeyre 1994 [13]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Meaney 1997 [14]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Meng 2005 [15]	Unclear Risk	Unclear Risk	Unclear Risk	Unclear Risk	Low Risk	Low Risk	Unclear Risk
Ohno 2004 [16]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Osman 2016 [17]	Unclear Risk	Unclear Risk	Low Risk	Unclear Risk	Low Risk	Low Risk	Low Risk
Oudkerk 2002 [18]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Pleszewski 2006 [19]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Revel 2012 [20]	Unclear Risk	Low Risk	Unclear Risk	Low Risk	Unclear Risk	Low Risk	Low Risk
Sostman 1996 [21]	Unclear Risk	Unclear Risk	Low Risk	Low Risk	Unclear Risk	Low Risk	Low Risk
Stein 2010 [22]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Yu 2005 [23]	Unclear Risk	Unclear Risk	Unclear Risk	Unclear Risk	Low Risk	Low Risk	Unclear Risk
Zhang 2013 [24]	Unclear Risk	Low Risk	Low Risk	Low Risk	Unclear Risk	Low Risk	Low Risk
Zhao 2016 [25]	Unclear Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk

①: Patient Selection; ②: Index Test; ③: Reference Standard; ④: Flow and Timing

The AUC of SROC curve reached 0.97, indicating that MRI's diagnostic capability for pulmonary embolism is nearly perfect. This high value underscores the potential of MRI as a diagnostic tool for pulmonary embolism. High AUC values typically indicate high accuracy of a diagnostic test, and the results of this analysis support the use of MRI as a reliable tool for diagnosing pulmonary embolism. The clinical implications of these results are particularly significant, as misdiagnosis or missed diagnosis of pulmonary embolism can lead to severe or even fatal consequences. Furthermore, the forest plots and SROC curves visually display the heterogeneity

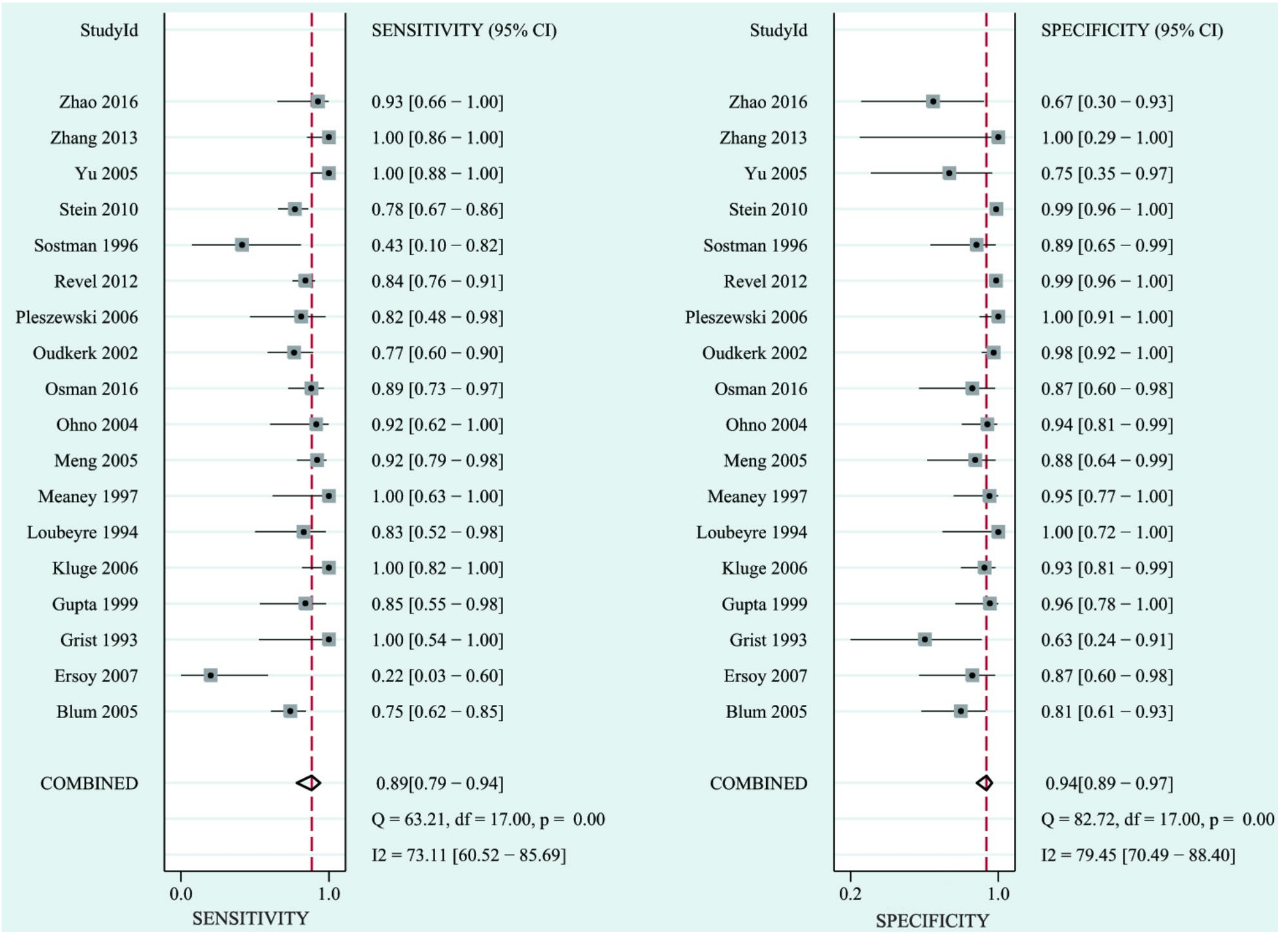

Fig. 2 Forest plot of sensitivity and specificity for MRI diagnosis of pulmonary embolism

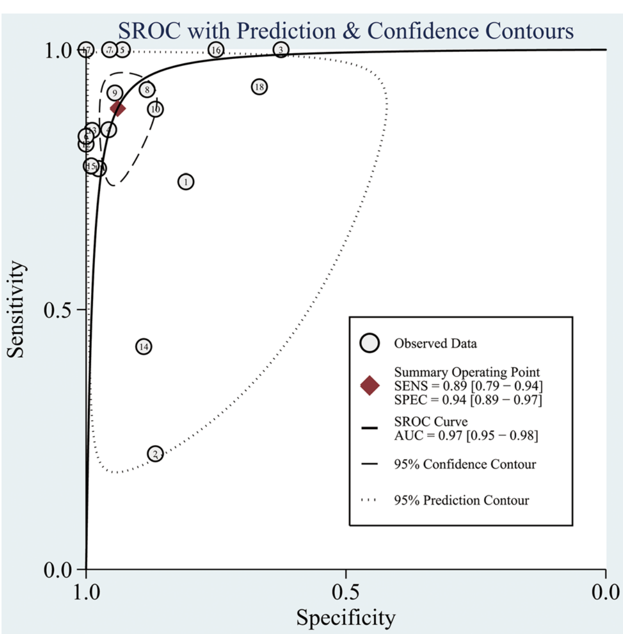

Fig. 3 ROC curve for MRI diagnosis of pulmonary embolism

between different studies and the overall efficacy trend. Although the results of individual studies show some variability, the overall trend confirms the strong diagnostic potential of MRI in this field. This meta-analysis reveals high diagnostic performance of MRI, but Deek's funnel plot suggests potential publication bias. This bias may arise from a tendency to publish only those studies that show favorable MRI performance. This calls for caution in interpreting these results and indicates the need for more representative multicenter studies to validate these findings and promote measures such as registered study protocols. The presence of publication bias may affect our comprehensive understanding of MRI's diagnostic efficiency for pulmonary embolism; thus, broader and more in-depth research is essential before MRI can be considered a standard diagnostic tool.

MRI provides a safe and effective diagnostic option for the diagnosis of pulmonary embolism. However, practical application must consider the complexity of operation and the skill requirements for operators, as well as limitations related to cost, equipment availability, and longer scanning times in clinical practice [38, 39]. Future

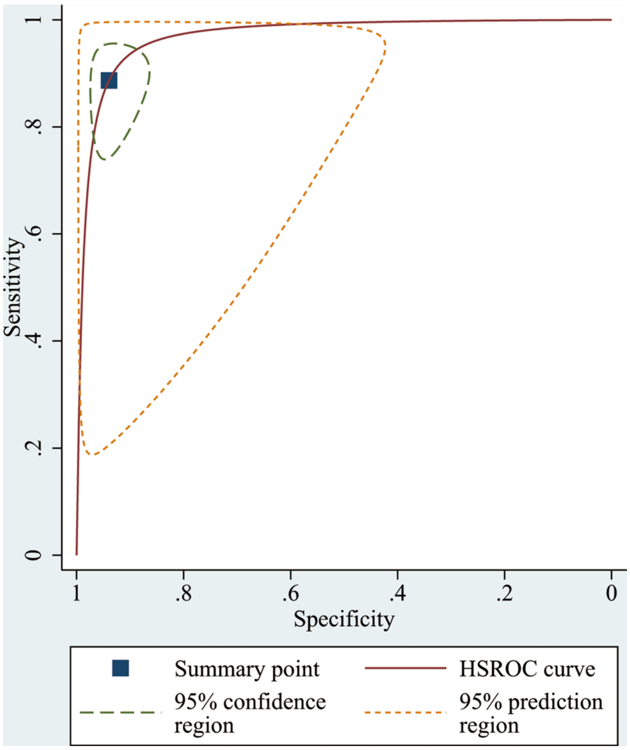

Fig. 4 HSROC curve for MRI diagnosis of pulmonary embolism. The curve shows the summary point (blue square) along with the 95% confidence region (green dashed line) and 95% prediction region (orange dashed line). The HSROC curve (red solid line) accounts for variability between studies in the meta-analysis

research should explore the relative efficacy and cost-effectiveness of MRI compared to CTPA and other diagnostic methods, such as ultrasound and D-dimer tests, and aim to reduce costs through technological innovation. Globally, especially in resource-limited settings, cost and accessibility are key determinants in the adoption of medical technology. Although MRI provides excellent diagnostic data, its high costs and operational complexity limit its prevalence in low-income countries [40]. Therefore, researchers and policymakers need to evaluate not only the diagnostic benefits of MRI but also its economic burden and feasibility of implementation.

This study also has certain limitations: (1) The relatively small sample size may limit the generalizability and extrapolation of our analysis results. Moreover, the quality and design heterogeneity of the included studies may affect the interpretation of the results, despite the assessment of study quality according to QUADAS standards. (2) Funnel plot analysis suggests the presence of potential publication bias, which may indicate a tendency to publish studies that demonstrate high sensitivity and specificity of MRI. This bias could lead to an overly optimistic assessment of MRI's diagnostic efficacy. (3) All studies were conducted up to May 12, 2024, and the continual emergence of new technologies and methods may limit the timeliness of our conclusions. Future research might reveal new evidence that could support or contradict our findings.

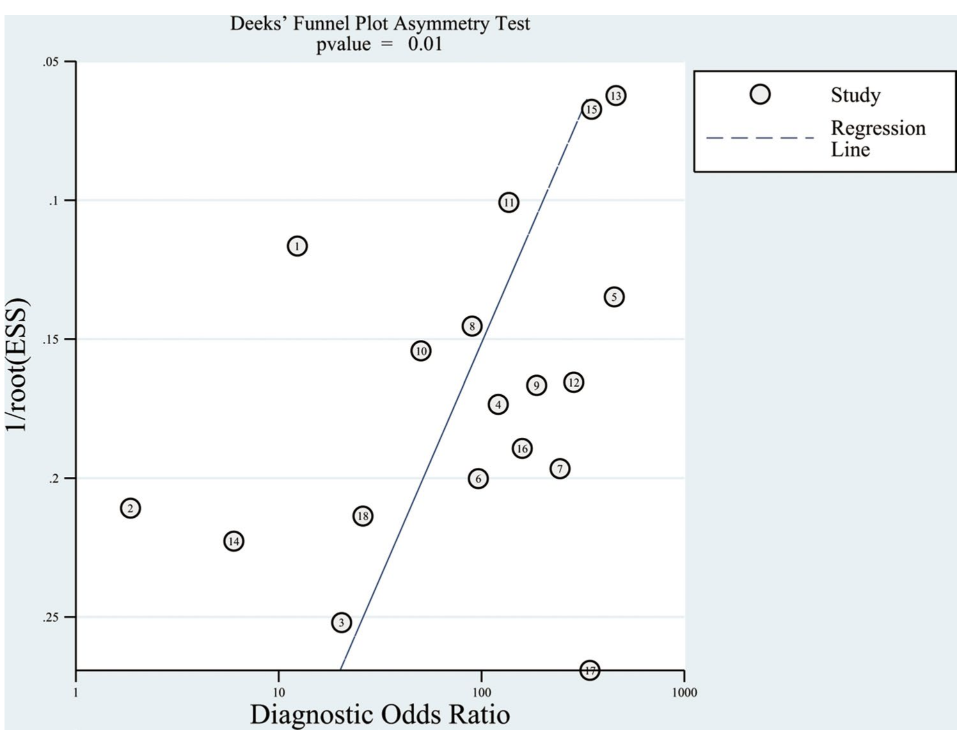

Fig. 5 Deek's funnel plot

Table 3 Subgroup analysis results of included studies

Factor	Subgroup	Number of studies	Sensitivity (95%CI)	*P*-value	Specificity (95%CI)	*P*-value
Publication year	Before 2000	5	0.87 (0.71 ~ 1.00)	0.62	0.93 (0.84 ~ 1.00)	0.22
	After 2000	13	0.89 (0.81 ~ 0.97)		0.94 (0.90 ~ 0.98)	
Country	High-income	13	0.81 (0.72 ~ 0.91)	0	0.96 (0.93 ~ 0.98)	0.59
	Middle-income	5	0.96 (0.91 ~ 1.00)		0.84 (0.70 ~ 0.99)	
Sample size	≥ 50	7	0.87 (0.76 ~ 0.98)	0.28	0.96 (0.92 ~ 0.99)	0.42
	< 50	11	0.90 (0.81 ~ 0.99)		0.92 (0.86 ~ 0.98)	
Gold standard for the diagnosis of pulmonary embolism	CTPA	9	0.88 (0.78 ~ 0.99)	0.39	0.92 (0.86 ~ 0.98)	0.03
	Non-CTPA	9	0.89 (0.79 ~ 0.99)		0.96 (0.92 ~ 1.00)	
MRI field strength	1.5-T	16	0.86 (0.78 ~ 0.94)	0.31	0.95 (0.91 ~ 0.98)	0.12
	3.0-T	2	0.98 (0.93 ~ 1.00)		0.81 (0.49 ~ 1.00)	

CI: Confidence Interval; CTPA: Computed Tomography Pulmonary Angiography

Conclusion

This meta-analysis confirms the high sensitivity and specificity of MRI in the diagnosis of pulmonary embolism, its clinical application remains limited by equipment costs and operational requirements. Additionally, the publication bias identified in the study underscores the need for more high-quality, multicenter research to further validate the broad applicability of these results. With improvements in MRI technology and increased accessibility, MRI has the potential to become an important tool for diagnosing pulmonary embolism and other complex diseases in the future.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12880-025-01629-w.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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None.

Author contributions
Chuan-Hua Yang (CY): Involved in the study design, methodology development, drafted the initial manuscript, and provided critical revisions of the manuscript. Miao Yu (MY): Contributed to the literature review, data extraction, statistical analysis, and drafted the initial manuscript. Deng-Chao Wang (DW): Supervised the entire project, contributed to study conception and interpretation of data, and critically revised the manuscript for important intellectual content.

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Data availability
Data can be obtained from the original articles included in this meta-analysis.

Declarations

Ethics approval and consent to participate
An ethics statement is not applicable because this study is based exclusively on published literature.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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