

Comparing the accuracy of shear wave elastography and strain elastography in the diagnosis of breast tumors

A systematic review and meta-analysis

Huayu Wu, MM^a, Cong Wang, MM^b, Qi An, MM^b, Xiaomeng Qu, MM^a, Xiaohang Wu, MM^b, Yumei Yan, MM^{b,*}

Abstract

Background: Shear wave elastography (SWE) and strain elastography (SE) are 2 new ultrasonic technologies which have developed rapidly in recent years. Elastography transforms the elastic information of tissue into optical information for display, thus more intuitive display of tissue elasticity. Conflicting results have been obtained in different scholars' studies on the accuracy comparison of the 2 elastography technologies in the diagnosis of breast tumors. This meta-analysis aims to compare the accuracy of the 2 elastography technologies in the diagnosis of breast tumors, and provide a reference for clinical decision making.

Methods: We have searched Chinese and English literatures on the accuracy of SWE and SE in the diagnosis of breast tumors from PubMed, Web of Science, China national knowledge infrastructure and Wanfang databases, and the time was up to December 30, 2020. Two literature reviewers screened the literatures according to the screening criteria, and Quality Assessment of Diagnostic Accuracy Study tool was used to evaluate the quality of included literatures. Meta Disc 1.4 and Stata 14.0 softwares were used to perform heterogeneity test, sensitivity analysis and publication bias test.

Results: Ten literatures included 1599 patients and 1709 breast lesions. The final results in the SWE as follow: The pooled sensitivity was 0.852 (95% confidence interval [CI] [0.826–0.874]), the pooled specificity (Spe) was 0.799 (95% CI [0.776–0.820]), the pooled positive likelihood ratio was 4.758 (95% CI [3.443–6.576]), the pooled negative likelihood ratio was 0.192 (95% CI [0.147–0.250]), the pooled diagnostic odds ratio was 29.071 (95% CI [16.967–49.811]), and the area under the summary receiver operating characteristic curve was 0.9159. The final results in the SE as follow: The pooled sensitivity was 0.843 (95% CI [0.817–0.866]), the pooled Spe was 0.766 (95% CI [0.743–0.789]), the pooled positive likelihood ratio was 4.387 (95% CI [3.088–6.233]), the pooled negative likelihood ratio was 0.216 (95% CI [0.179–0.261]), the pooled diagnostic odds ratio was 22.610 (95% CI [15.622–32.724]), and the area under the summary receiver operating characteristic curve was 0.8987.

Conclusion: The sensitivity and Spe of SWE were higher than those of SE, suggesting that SWE may have a higher accuracy in the diagnosis of breast tumors.

Register name: PROSPERO. Registration number: CRD42021251110.

Abbreviations: AUC = area under curve, BI-RADS = Breast Imaging Reporting and Data System, CI = confidence interval, DOR = diagnostic odds ratio, FN = false negative number, FP = false positive number, NLR = negative likelihood ratio, PLR = positive likelihood ratio, SE = strain elastography, Sen = sensitivity, Spe = specificity, SROC = summary receiver operating characteristic, SWE = shear wave elastography, TN = true negative number, TP = true positive number.

1. Introduction

Breast cancer is the most common malignancy among women and the leading cause of most cancer-related deaths.^[1] Clinical manifestations of breast cancer are varied and can be characterized by painless lump, nipple discharge, nipple and areola color, abnormal shape, and axillary lymph node enlargement.

However, early breast cancer has no obvious clinical symptoms, which patients may ignore and miss the best treatment. Usually, breast cancer is hard, the surface is not smooth, and the activity is poor, but some special types of breast cancer are due to poor invasiveness, so the surface of the mass is smooth, good activity, not easy to distinguish from benign tumors.^[2-3] The main reason for breast cancer's high mortality

The authors have no funding and conflicts of interest to disclose.

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

This is a post that has been licensed on PROSPERO, allowing unrestricted use, distribution and reproduction in any medium, provided the original is quoted correctly.

The protocol of this meta-analysis has been accepted by journal Medicine.

^a The First Affiliated Hospital of Dalian Medical University, Dalian, China, ^b Ultrasound Department of the First Affiliated Hospital of Dalian Medical University, Dalian, China.

*Correspondence: Yumei Yan, Ultrasound department of the First Affiliated Hospital of Dalian Medical University, No. 222 Zhongshan Road, Xigang District, Dalian City, Liaoning Province 116011, China (e-mail: ymyan1980@163.com).

Copyright © 2022 the Author(s). Published by Wolters Kluwer Health, Inc. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial License 4.0 (CCBY-NC), where it is permissible to download, share, remix, transform, and buildup the work provided it is properly cited. The work cannot be used commercially without permission from the journal.

How to cite this article: Wu H, Wang C, An Q, Qu X, Wu X, Yan Y. Comparing the accuracy of shear wave elastography and strain elastography in the diagnosis of breast tumors: A systematic review and meta-analysis. *Medicine* 2022;101:44(e31526).

Received: 17 March 2022 / Received in final form: 3 October 2022 / Accepted: 4 October 2022

<http://dx.doi.org/10.1097/MD.0000000000031526>

rate is distant organ metastasis. Most patients have missed the best treatment time when diagnosed and cannot undergo radical surgery. Therefore, early screening is essential. Traditional screening methods for breast cancer include mammography and ultrasound examination, which are commonly used in clinical screening for breast cancer. Ultrasound is a common method for the diagnosis of breast tumors. Using ultrasound to detect breast tumors has the advantages of no radiation, simple operation, accurate positioning, and low price. Ultrasound accurately identifies cystic and solid masses, but its microcalcification detection is low. Mammograms mainly observed breast tumor margin, breast tumor morphology, microcalcification, and breast gland structure. The detection rate and sensitivity (Sen) of mammography for fine calcification are significantly higher than those of ultrasound. When mammography is used to detect dense breasts, the Sen is low, and the edge of the lesion cannot be displayed, resulting in missed diagnosis and misdiagnosis, resulting in decreased accuracy of breast cancer diagnosis.^[4,5] Elastography is a new technology that has developed rapidly in recent years and can accurately determine the hardness of tissues. Benign and malignant breast lesions have a different hardness on palpation for a long time, and lesions with low activity are more likely to be malignant.^[6] Therefore, this technology can be widely used in breast cancer screening. However, elastography differs greatly from the imaging method, including shear wave elastography (SWE) and strain elastography (SE). SWE is through the detection of acoustic radiation pulse, continuously focusing on the vibration of the lesions observed in the tissues, thus appearing as a transverse shear wave. Based on the shear wave velocity of accurate quantitative testing tissues, SWE can effectively distinguish benign and malignant mammary glands with good reproducibility and objectivity. However, artifacts caused by reflection and refraction may increase due to the large variation in shear wave velocities in normal and abnormal breast tissues. SE is to apply pressure to the tissue according to the different elastic coefficients between different groups to make the tissue's deformation degree under different stress levels under the action of stress and deformation of the operator tissue. The amplitude of the pressure echo signal changes into a real-time color image before and after the movement, and the image's color reflects the tissue's hardness. Finally, the determined tissue elasticity is color-coded and superimposed on a b-mode image on an ultrasound device monitor.^[7-9] However, measuring the magnitude of force or stress in the compression process is difficult, and it is impossible to calculate the absolute elasticity. The acquisition of data depends on the professional knowledge of the inspector, which leads to many variabilities between observers.^[10] When SWE and SE are applied to the same breast lesion, they will yield consistent or similar results if examined by an experienced operator. However, because each elastography has inherent defects, which can lead to false positive or negative results, the result may differ according to the application of the different technologies and their diagnostic criteria.^[11] The result of a study has shown that the thickness of the breast can lead to discrepancies in the diagnosis of 2 kinds of elastography methods. When the lesion location is deep, there will reduce the diagnostic accuracy of SE. However, SWE is not affected. That study also mentioned that SWE and SE have different Sen and Spe for different breast thicknesses, histopathology, and tumor grades.^[12] Barr and Zhang^[13] reported that SE has better diagnostic performance than SWE. However, Chang et al^[12] reported that SWE has higher Sen than SE, and SE has higher Spe than SWE, and Seo et al^[14] found no difference in the Sen and Spe of SE and SWE for lesions. The diagnostic results of the 2 elastography methods were indeed contradictory. We hope that the result of this meta-analyze will provide value for the accurate diagnosis of breast tumors to improve the Sen and Spe of evaluating breast lesions.

2. Methods

The study was followed by PROSPERO. Registration number: CRD42021251110, the preferred reporting item of the Systematic Review and Meta-Analysis was the guideline for the design of this study.

The study does not require the approval of the Ethics Committee and the Institutional Review Committee.

2.1. Search methods

Studies From the establishment of PubMed, Web of Science, Wanfang, and China national knowledge infrastructure databases until December 30, 2020, including published, unpublished, in the press, and progress, were included in this meta-analysis. Relevant literature was retrieved, and research data was obtained without language restrictions. Keywords and free words were used for retrieval. We used professional retrieval in Wanfang Database, and the search strategy is as follows: "The theme: (Breast Tumor or Breast Cancer) and the theme: (Shear wave elastography and Strain elastography) and the theme: (Diagnosis)." PubMed's search strategy is shown in Table 1. Other databases were used for the same strategy (The related free words for Breast tumor are Breast Cancer or Breast Neoplasm or Neoplasm, Breast or Breast Tumors or Breast Tumor or Tumor, Breast or Tumors, Breast or Neoplasms, Breast or Breast Cancer or Cancer, Breast or Mammary Cancer or Cancer, Mammary or Cancers, Mammary or Mammary Cancers or Malignant Neoplasm of Breast or Breast Malignant Neoplasm or Breast Malignant Neoplasms or Malignant Tumor of Breast or Breast Malignant Tumor or Breast Malignant Tumors or Cancer of Breast or Cancer of the Breast or Mammary Carcinoma, Human or Carcinoma, Human Mammary or Carcinomas, Human Mammary or Human Mammary Carcinomas or Mammary Carcinomas, Human or Human Mammary Carcinoma or Mammary Neoplasms, Human or Human Mammary Neoplasm or Human Mammary Neoplasms or Neoplasm, Human Mammary or Neoplasms, Human Mammary or Mammary Neoplasm, Human or Breast Carcinoma or Breast Carcinomas or Carcinoma, Breast or Carcinomas, Breast). We retrieved references twice to avoid missing literature.

2.2. Inclusion criteria

Chinese and English literature on the comparison of SWE and SE in the diagnosis of breast tumors; the final pathological result by open surgical biopsy or frozen Section as the gold standard; the true positive number (TP), false positive number (FP), false negative number (FN) and true negative number (TN) can be obtained directly or indirectly; >40 cases per literature sample. Exclusion criteria: the TP, FP, FN, and TN can't be obtained directly or indirectly in the literature; case reports, animal studies, expert experience, conference articles, and duplicate publications; no pathological results as the gold standard.

Table 1

The search strategy sample of PubMed.

Search terms

Breast cancer or breast neoplasm or neoplasm, breast or breast tumors
Shear wave elastography and strain elastography
Sensitive or sensitivity and specificity or predictive or predictive value of test or accuracy
and 1-3

2.3. Literature screening and quality assessment

Literature screening was conducted independently by 2 persons according to the inclusion and exclusion criteria, and imported the literature into NoteExpress software. Quality assessment is critical in the systematic review of diagnostic accuracy research. Quality Assessment of Diagnostic Accuracy Studies tool developed by Whiting et al^[15] was used to evaluate the Quality of included literature. The tool is an evidence-based quality assessment tool for a systematic review of diagnostic accuracy literature, it can assess the Quality of literature on diagnostic accuracy, and it can distinguish between high-quality and low-quality literature. The tool includes 14 items and provides guidelines for scoring each item included in the tool, and the Quality of literature was assessed by these

items from the tool. Each question should be answered “yes” (2), “no” (1), or “unclear” (0). Answer “yes” if there was sufficient information from the literature fits one of the items, and “no” if not. If insufficient information was available to make a judgment, it should be answered as “unclear.” Finally, we decided to choose 14 Diagnostic tests and Quality evaluation criteria. Quality Assessment of Diagnostic Accuracy Studies scores range from 0 to 28, with a score of 22 indicating good Quality. Any differences between the 2 investigators were resolved by a third investigator through discussing and negotiating, and the author selected trials and removed duplicate or incompatible studies based on inclusion criteria. The following important information was extracted from screened literature: name of the first author, year of publication, literature design, the country of the author, the average age of

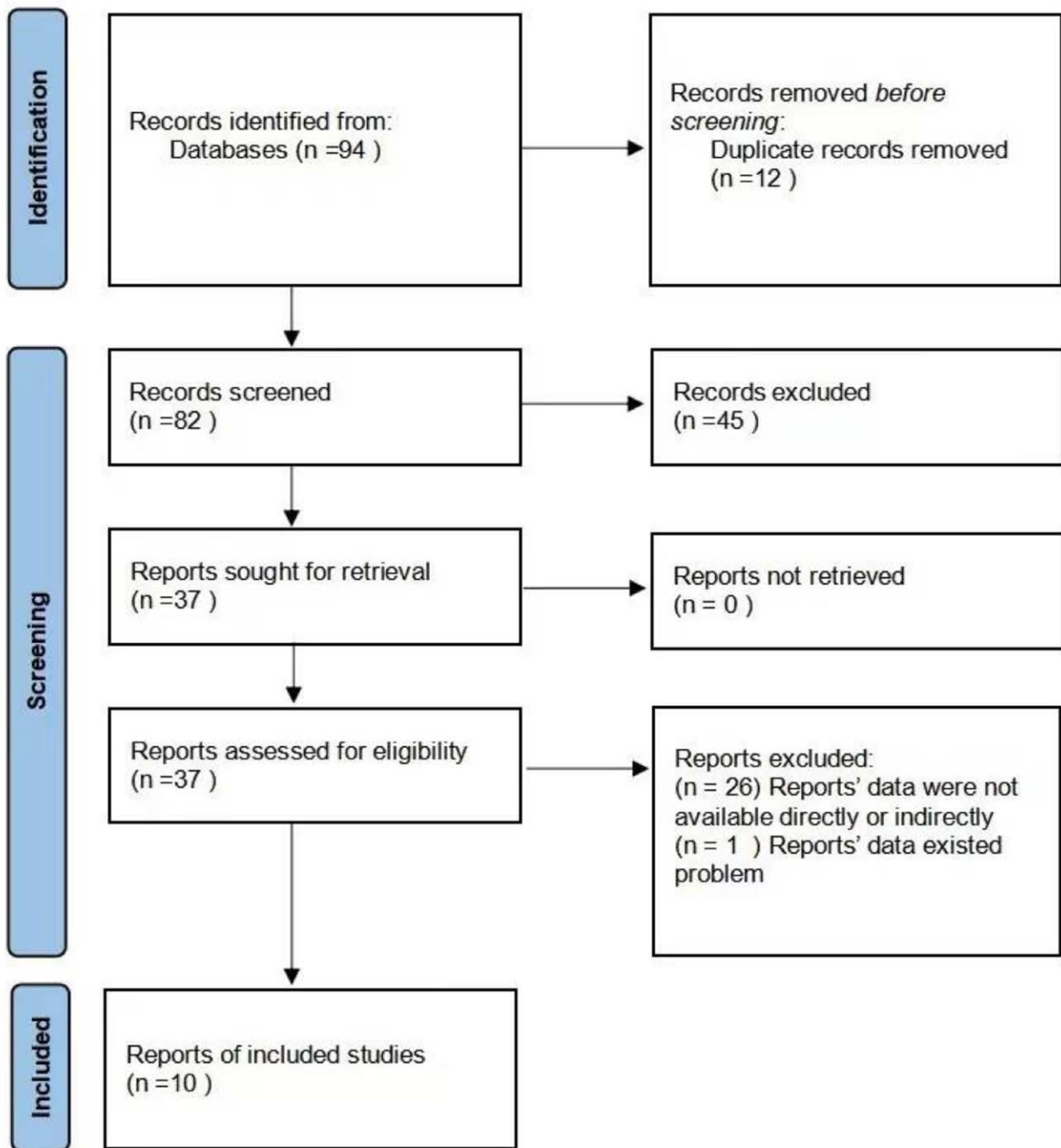


Figure 1. Flow chart of literature search and study selection. Ten literatures were included in this meta-analysis.

patients, sample size (The total of malignant and benign), the language of literature, measurement index (SWE and SE), cut-off value (SWE and SE), and TP, FP, FN, and TN are obtained from the literature.

2.4. Statistical analysis

The pooled Sen, Spe, positive likelihood ratio (PLR), negative likelihood ratio (NLR), diagnostic odds ratio (DOR), and area under the SROC curve (AUC) were calculated by Meta Disc 1.4 software. The test DOR is the ratio of positive for disease to positive for non-disease, which can be interpreted as the ratio of the chance of testing positive to the possibility of testing negative. The value of DOR ranges from 0 to infinity. The larger the value, the better the identification test's performance. The threshold effect is determined by observing whether the image was distributed in the shoulder or arm shape or whether the *P* value was more significant than 0.05. If *P* > .05 exists threshold effect, the SROC curve can only be fitted, and the area under the SROC curve can be calculated. If *P* < .05, *I*² < 50%, there was no heterogeneity caused by the non-threshold effect, and the fixed effect model was used to merge the effect size. If *P* < .05, *I*² ≥ 50%, indicating heterogeneity caused by non-threshold effect. A random effect model was used to combine effect size. Stata14.0 software should be used for Sen analysis and publication bias tests. If

heterogeneity was caused by a non-threshold effect, further meta-regression analysis should be conducted on the included studies to explore the source of heterogeneity between studies. The Beggs funnel plot should be used to investigate publication bias.

3. The results

3.1. Literature screening

Ninety-four pieces of literature in Chinese and English were initially screened through the database search, in which 12 pieces of repetitive literature were excluded. By reading the Title and abstract, 45 non-conforming literature were excluded. We carefully examined the full text of the remaining 37 articles. The TP, FP, FN, and TN could not be obtained directly or indirectly in 27 articles. Ten pieces of literature were finally included, including 6 pieces of English literature and 4 pieces of Chinese literature, and 1599 patients were involved in the study. Among the ten pieces of literature, 3 works of literature used SWE and SE with multiple parameters for diagnosis comparison, so the TP, FP, FN, and TN of multiple groups were obtained, and all the data were included and analyzed. Figure 1 shows the selection process of eligible literature. Basic information and related parameters of included literature are shown in Table 2, and quality evaluation of included literature is shown in Table 3.

Table 2

Basic information and related parameters of included literatures.

Author	Year	Design	Cases	Country	Language	Age	Measurement (SWE)	Cutoff point (SWE)	Measurement (SE)	Cutoff point (SE)	SWE				SE			
											TP	FP	FN	TN	TN	TN	TN	TN
1 Chang JM ^[13]	2013	Prospective	150	Korea	English	47.8	E _{ela}	80.00 kPa	ES	4	68	12	3	67	58	5	13	74
2 Peng XJ ^[15]	2016	Retrospective	155	China	Chinese	43.8	E _{max}	34.30 kPa	ES	4	47	17	11	80	46	16	12	81
3 Peng XJ ^[15]	2016	Retrospective	155	China	Chinese	43.8	E _{sd}	7.25 kPa	SR	1.91	45	8	13	89	42	11	16	86
4 Seo M ^[12]	2017	Prospective	45	Korea	English	47.4	E _{mean}	13.50 kPa	SR	2.63	17	1	3	24	19	4	1	21
5 Zheng XY ^[25]	2018	Prospective	504	China	English	DK	SWV	3.30 M/S	ES	3	32	109	17	336	41	134	8	311
6 Han LS ^[14]	2019	Retrospective	92	China	Chinese	42.1	E _{max}	61.45 kPa	ES	4	28	3	5	56	29	8	4	51
7 Xia XN ^[26]	2019	Retrospective	190	China	Chinese	44.0	E _{max}	106.60 kPa	SR	3.60	81	19	23	67	80	19	24	67
8 Fujioka T ^{[27]1}	2019	Retrospective	148	Japan	English	DK	Score2		Tsu	2	83	27	5	33	85	36	3	24
9 Fujioka T ^{[27]2}	2019	Retrospective	148	Japan	English	DK	E _{col}	50.00 kPa	FLR	1.50	80	20	8	40	80	28	8	32
10 Singla V ^{[28]1}	2019	Prospective	199	India	English	DK	E _{mean}	113.00 kPa	ES	4	104	17	15	63	100	17	19	63
11 Singla V ^{[28]2}	2019	Prospective	199	India	English	DK	E _{ratio}	7.32	SR	3.91	99	22	20	58	96	16	23	64
12 Gürüf A ^[29]	2019	Prospective	87	Turkey	English	49.5	SWV	3.14M/S	SR	3.22	37	6	5	39	37	7	5	38
13 Ma X ^[30]	2020	Retrospective	139	China	Chinese	40.8	E _{max}	43.35 kPa	SR	3.42	31	4	3	101	31	7	3	98

DK = don't know, ES = elasticity scores, SEFLR = fat lesion ratio, SETsu = Tsukuba score, SR = strain ratio, SWEcol = elasticity color assessment, SWE_{ela} = elasticity value, SWE_{max} = elasticity maximum, SWE_{mean} = elasticity mean, SWE_{ratio} = elasticity ratio, SWE_{sd} = elasticity standard deviation, SWV = shear wave velocities

Table 3

Quality evaluation of included literatures.

Author	QUADAS item													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Jung Min Chang	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2 Richard G. Barr	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
3 Xiaojing Peng	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
4 Mirinae Seo	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
5 Xueyi Zheng	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
6 Lishu Han	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
7 Xiaona Xia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
8 Tomoyuki Fujioka	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
9 Singla Veenu	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
10 Aykut GÜRÜF	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
11 Xiaoxi Ma	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No

3.2. Quantitative data synthesis

Firstly, we used Meta-Disc 1.4 software to analyze the threshold effect, and the spearman correlation coefficient between Sen logarithms and $(1 - \text{Spe})$ logarithms of SWE and SE were 0.016 ($P = .957 > .05$) and 0.181 ($P = .553 > .05$), which means there was no threshold effect. Stata14.0 software was used to perform the publication bias test, and we found that $P < .05$ in both SWE and SE (Figs. 2 and 3), indicating the existence of publication bias. The Cochran - Q test of the

DOR in the SWE (Fig. 4) showed that Cochran - $Q = 50.09$, $P < .001$, and the Cochran - Q test of the DOR in the SE (Fig. 5) showed that Cochran - $Q = 24.01$, $P < .05$, indicating that there was heterogeneity caused by non-threshold effect. The meta-regression analysis was performed using the Meta Disc 1.4 software on the included literature to explore the source of heterogeneity. Combined with the clinical data of the included literature, the region (China/Other), year of publication (2013–2016/2017–2020), study method (prospective/

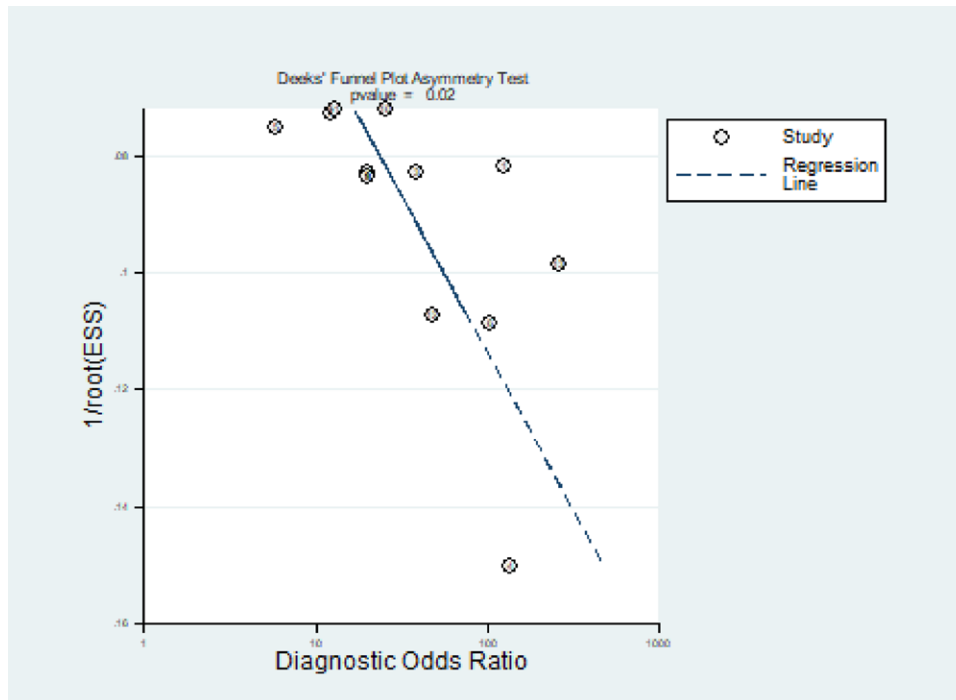


Figure 2. Publication bias in the shear wave elastography.

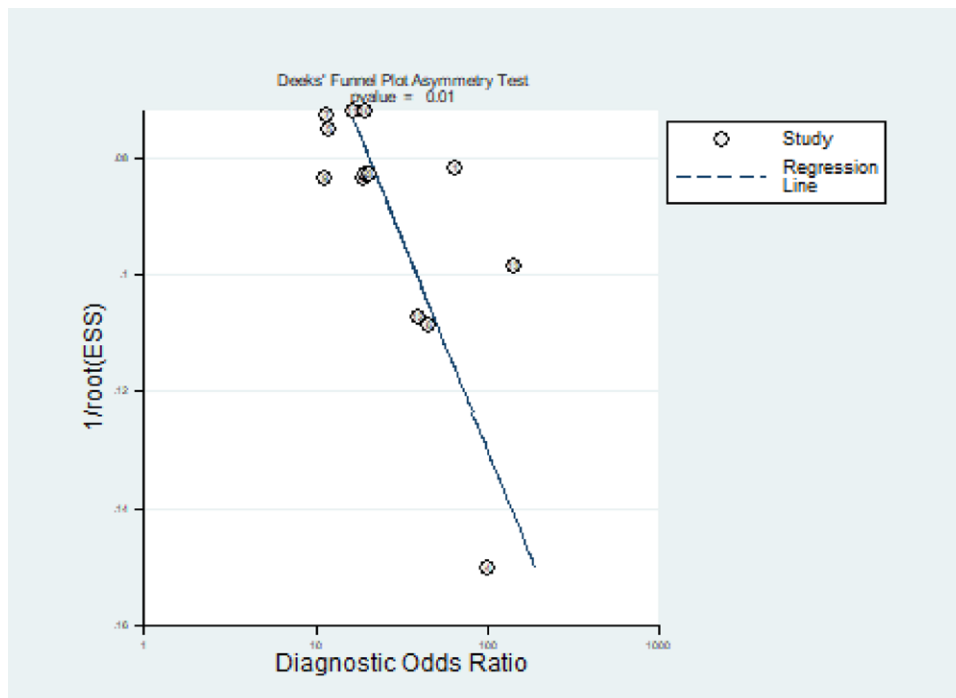


Figure 3. Publication bias in the strain elastography.

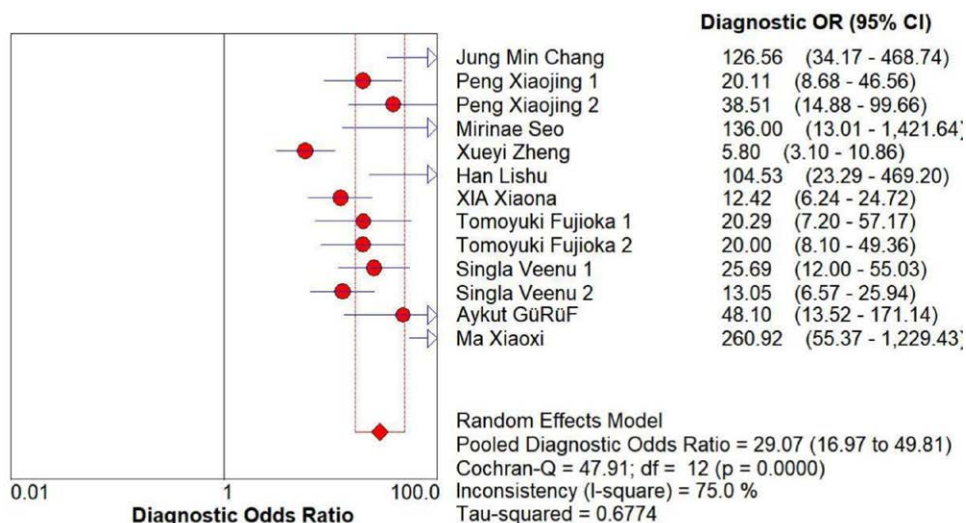


Figure 4. Forest plot of diagnostic OR of shear wave elastography for the diagnosis of breast tumors. CI = confidence interval, OR = odds ratio.

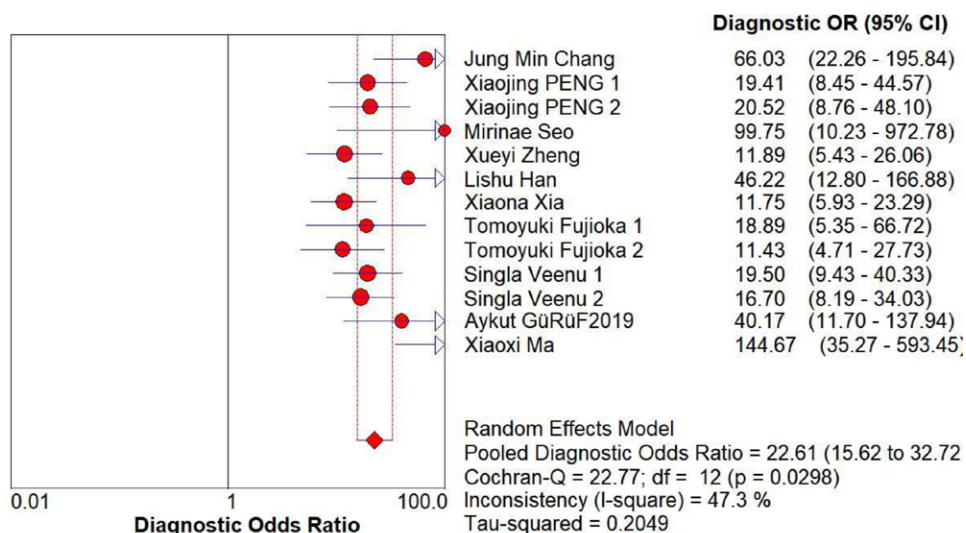


Figure 5. Forest plot of diagnostic OR of strain elastography for the diagnosis of breast tumors. CI = confidence interval, OR = odds ratio.

retrospective), and sample size (<100, 100–200, >200) were considered as possible factors for the source of heterogeneity. The results showed that the sample size ($P = .018$) might be the source of heterogeneity in the SWE. However, all factors ($P > .05$) were not the source of heterogeneity in the SE. Because of the significant heterogeneity, the data of the 2 groups were pooled by the random effects model.

Our meta-analysis revealed that the pooled Sen of the SWE was 0.852 (95% confidence interval [CI] [0.826–0.874]), the pooled Spe was 0.799 (95% CI [0.776–0.820]), the pooled PLR was 4.758 (95% CI [3.443–6.576]), the pooled NLR was 0.192 (95% CI [0.147–0.250]), the pooled DOR was 29.071 (95% CI [16.967–49.811]) (Figs. 4 and 6), the result was plotted as a symmetrical SROC curve, and the corresponding AUC was 0.9159 (Fig. 7). The pooled Sen of the SE was 0.843 (95% CI [0.817–0.866]), the pooled Spe was 0.766 (95% CI [0.743–0.789]), the pooled PLR was 4.387 (95% CI [3.088–6.233]), the pooled NLR was 0.216 (95% CI [0.179–0.261]), the pooled DOR was 22.610 (95% CI [15.622–32.724]), and the corresponding AUC was 0.8987 (Figs. 5, 8, and 9).

3.3. Sensitivity analysis

Stata14.0 software was used for the Sen analysis of this meta-analysis, and it was found that 2 groups of original data in the SWE had strong Sen, including the fifth and eighth groups. Other original data did not cause Sen to the calculation results. Two groups of original data in the SE had strong Sen, including the eighth and thirteen groups. After excluding the fifth and eighth original data, the pooled Sen of the SWE was 0.854 (95% CI [0.826–0.878]), the pooled Spe was 0.841 (95% CI [0.814–0.866]), and the corresponding AUC was 0.9247. When the original data of the eighth and thirteen groups were removed in the SE, the pooled Sen was found to be 0.825 (95% CI [0.796–0.852]), and the pooled Spe was found to be 0.770 (95% CI [0.7450.794]), and the corresponding AUC was found to be 0.8858.

4. Discussion

Despite significant advances in cancer research in recent years, breast cancer remains a major health problem and the most common cancer affecting women worldwide, with a substantial

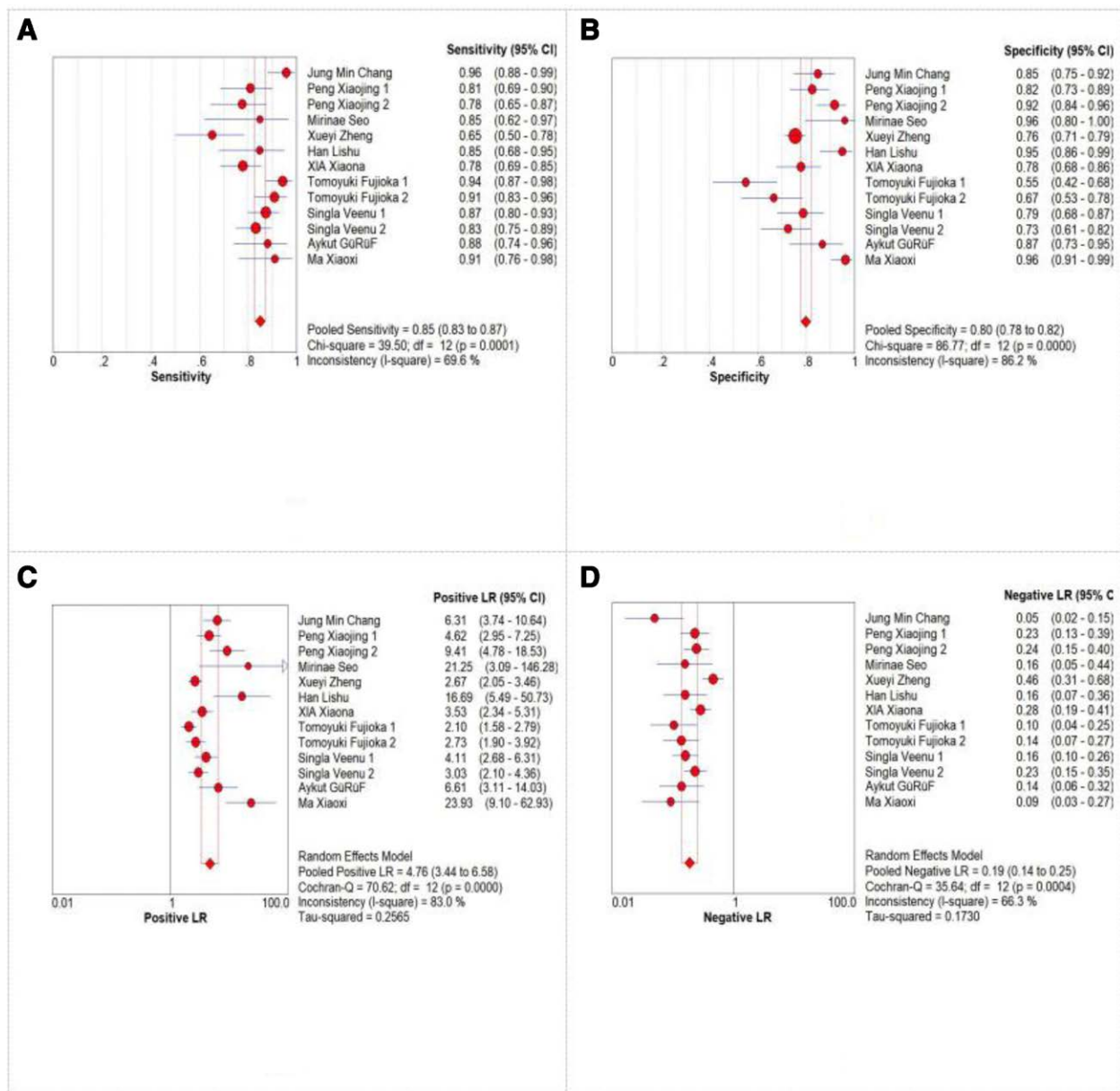


Figure 6. Forest plots for the accuracy of shear wave elastography for the diagnosis of breast tumors. (A) Sensitivity. (B) Specificity. (C) Positive LR. (D) Negative LR. CI = confidence interval, LR = likelihood ratio.

increase in morbidity and mortality expected in the coming years.^[18] Breast lesions found by conventional US examination can be classified according to the possibility of malignancy in the Breast Imaging Reporting and Data System (BI-RADS). Terms and criteria for describing and classifying breast lesions are standardized, which have good diagnostic performance. BI-RADS type 3 breast lesions may be benign, and observation is recommended. Many Bi-RADS type 4 lesions were benign, but biopsies are performed unnecessarily due to the false positive rate of conventional US. The existence of elastography combined with the use of US can reduce BI-RADS type 4A lesions, an unnecessary biopsy of benign breast lesions, and patients' anxiety and medical costs. Some literature focused on BI-RADS type 3 and 4 lesions and integrated SE strain ratio (SR) into the BI-RADS classification system. They used the best cutoff point of 2.98, successfully distinguished benign and malignant breast masses, improved the overall Sen of BI-RADS type 3 lesions without reducing Spe, and improved global Spe of BI-RADS type 4A lesions without reducing Sen.^[19-22] At the same time,

some literature has found that SWE combined with the conventional US can also improve the diagnostic performance of breast lesions and help BI-RADS to reclassify type 3 or 4A lesions according to traditional US morphological criteria, downgrading BI-RADS type 4A lesions to follow-up or upgraded BI-RADS type 3 lesions to biopsy. The Spe of BI-RADS type 3 lesions was improved. Without changing the Sen, the Spe was increased from 61.1% to 78.5% by visual color stiffness and 77.4% by the maximum elastic modulus (E_{max}).^[10] These results indicate that ultrasound elastography is promising in diagnosing breast lesions, especially BI-RADS type 4 lesions, but elastography cannot replace the conventional US.^[23,24] Combining the conventional US with elastography can improve the performance of the diagnosis of breast lesions. Therefore, it is necessary to find a more effective elastography method in the 2 kinds of elastography to identify the characteristics of tumor lesions and the differentiation of benign and malignant lesions.

This meta-analysis aims at the accuracy of 2 kinds of elastography in diagnosing breast tumors to provide a comprehensive

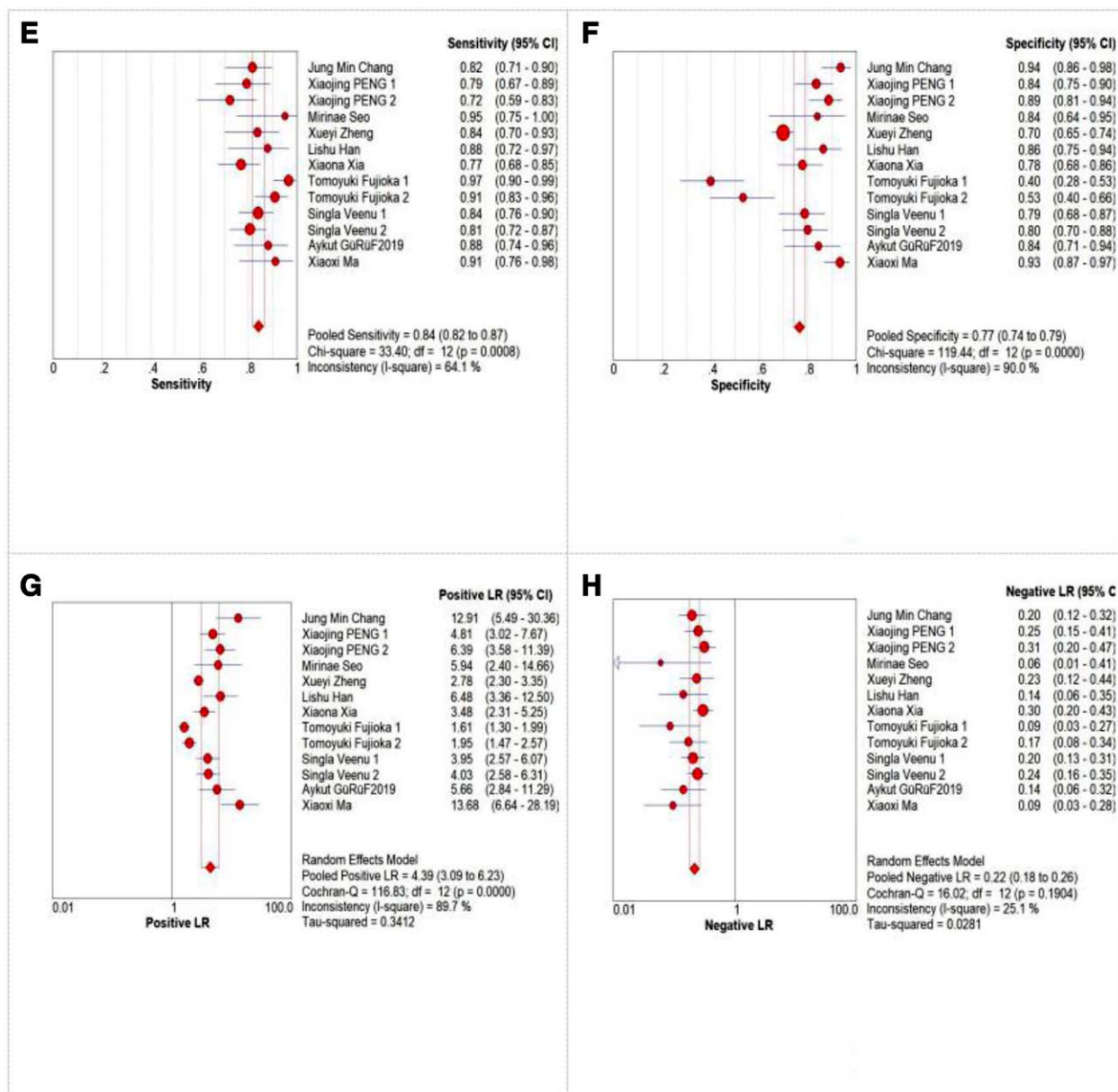


Figure 7. SROC curve for the accuracy of shear wave elastography in the diagnosis of breast tumors. AUC = area under curve, SE = strain elastography, SROC = summary receiver operating characteristic.

and reliable conclusion. In this meta-analysis, we systematically evaluated the technical performance and accuracy of SWE and SE in the differential diagnosis of breast tumors in 10 pieces of literature, including 1599 patients and 1709 breast lesions. In the SWE, the pooled Sen and Spe were 0.852 (95% CI [0.826–0.874]) and 0.799 (95% CI [0.776–0.820]), the corresponding AUC was 0.9159. In the SE, the pooled Sen and Spe were 0.843 (95% CI [0.817–0.866]) and 0.766 (95% CI [0.743–0.789]), the corresponding AUC was 0.8987. After removing the Sen data of the 2 groups, the pooled Sen and Spe of SWE were 0.854 (95% CI [0.826–0.878]) and 0.841 (95% CI [0.814–0.866]), and the corresponding AUC was 0.9247, AUC > 0.9, indicating that the SWE has high accuracy in the diagnosis of breast tumors. The pooled Sen and Spe of SE were 0.825 (95% CI [0.796–0.852]) and 0.770 (95% CI [0.745–0.794]), and the corresponding AUC was 0.8858, AUC < 0.9, but AUC > 0.7, indicating that SE has a moderate efficiency in the diagnosis of breast tumors.

The pooled Sen, Spe, and the corresponding SWE AUC are higher than SE. It is suggested that SWE is a good tool for differentiating benign and malignant breast tumors, which is inconsistent with the results of previous studies by some scholars. SE is an operator-dependent technique, so there must be measurement bias among different Sonologist in clinical practice. Compared with SE, SWE is a more independent quantitative analysis method, avoiding some limitations of SE. However, there are some limitations to this paper. Firstly, because the related research is less, the sample size differences of included literature cause heterogeneity, and the part of Quality of literature were low, so we lacked sufficient statistical support to evaluate the results of the accuracy of the 2 types of elasticity imaging diagnosis of breast tumor. Secondly, meta-analysis is a retrospective study that may lead to subject selection bias. Retrieving Chinese-English literature will lead to bias in research selection. Notably, most of the included literature was from Asia, which could adversely affect the reliability and validity of our results.

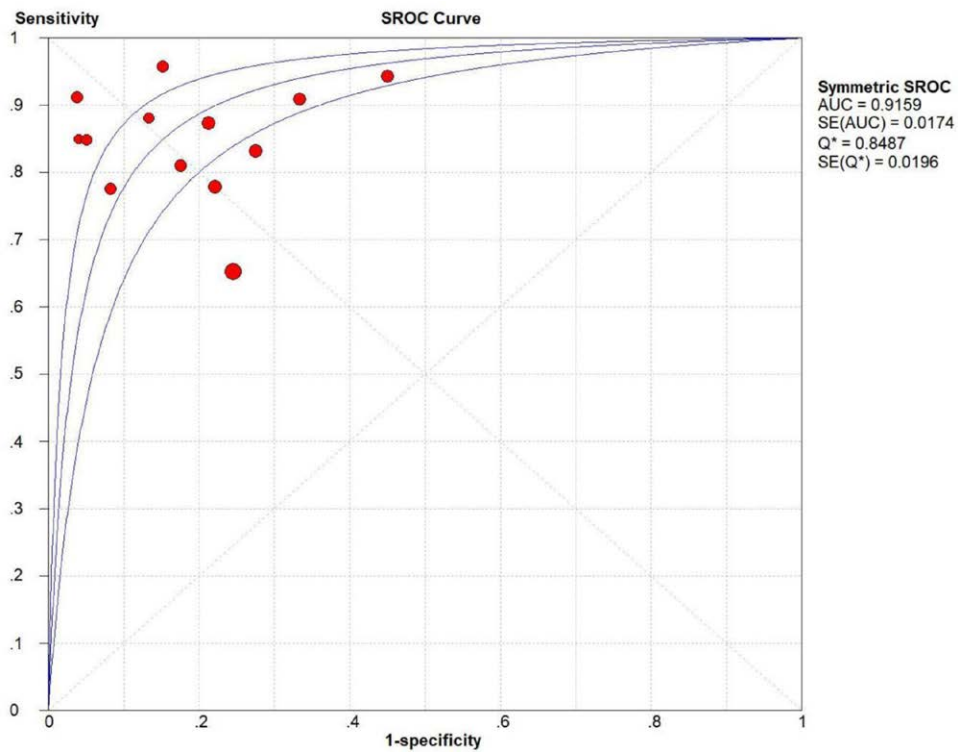


Figure 8. Forest plots for the accuracy of SE for the diagnosis of breast tumors. (E) Sensitivity. (F) Specificity. (G) Positive LR. (H) Negative LR. CI = confidence interval, LR = likelihood ratio.

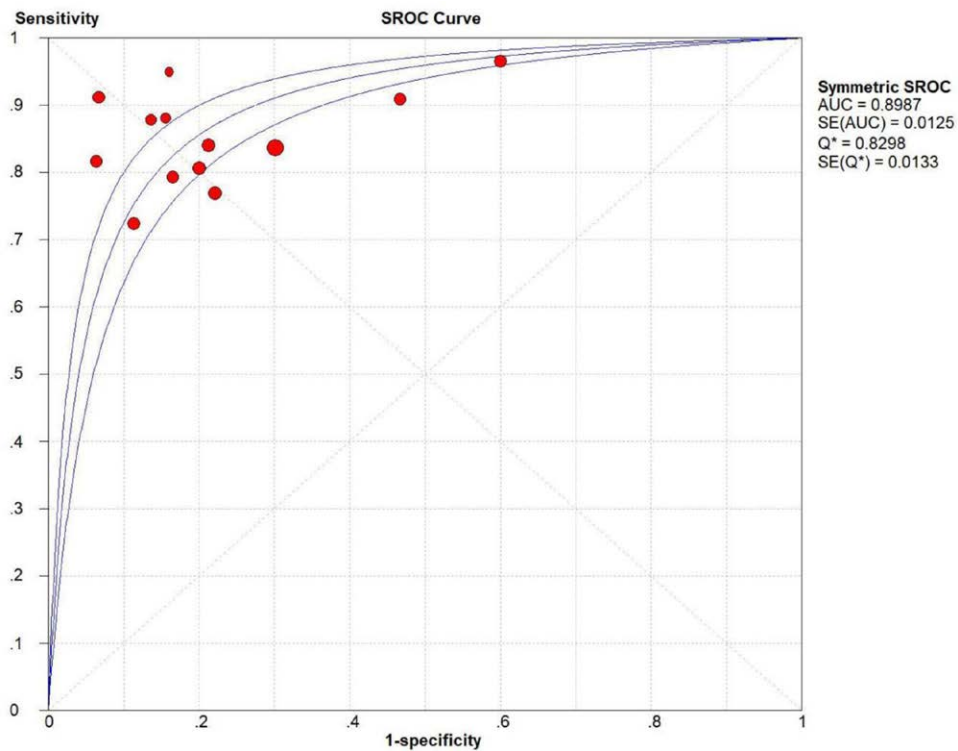


Figure 9. SROC curve for the accuracy of SE in the diagnosis of breast tumors. AUC = area under curve, SE = strain elastography, SROC = summary receiver operating characteristic.

In conclusion, SWE has better diagnostic performance than SE in diagnosing breast tumors, and using SWE combined with the conventional US can further improve the accuracy in diagnosing breast tumors.

Author contributions

Data curation: Huayu Wu, Qi An, Xiaomeng Qu.
Formal analysis: Huayu Wu.

Funding acquisition: Yumei Yan.

Investigation: Huayu Wu.

Methodology: Huayu Wu, Yumei Yan, Cong Wang, Xiaohang Wu.

Project administration: Huayu Wu.

Software: Huayu Wu, Xiaomeng Qu.

Supervision: Huayu Wu, Yumei Yan, Cong Wang.

Validation: Yumei Yan.

Visualization: Yumei Yan.

Writing – original draft: Huayu Wu.

Writing – review & editing: Huayu Wu.

References

- [1] Liang Y, Zhang H, Song X, Yang Q. Metastatic heterogeneity of breast cancer: molecular mechanism and potential therapeutic targets. *Semin Cancer Biol.* 2020;60:14–27.
- [2] Xue S, Zhao Q, Tai M, Li N, Liu Y. Correlation between breast ultrasound microcalcification and the prognosis of breast cancer. *J Health Eng.* 2021;2021:6835963.
- [3] Jia MM, Zheng R, Zhang S. Female breast cancer incidence and mortality in 2011, China. *Thorax Dis.* 2015;7:1221–6.
- [4] Haicang Y, Xin H, Pengfei G. Clinical value of molybdenum photography X-ray in breast cancer screening for perimenopausal women. *Oncol Progress.* 2021;19.
- [5] Ianculescu V, Ciolovan LM, Dunant A, et al. Added value of Virtual Touch IQ shear wave elastography in the ultrasound assessment of breast lesions. *Eur J Radiol.* 2014;83:773–7.
- [6] Zhang L, Dong YJ, Zhou JQ, Jia XH, Li S, Zhan WW. Similar reproducibility for strain and shear wave elastography in breast mass evaluation: a prospective study using the same ultrasound system. *Ultrasound Med Biol.* 2020;46:981–91.
- [7] Stachs A, Hartmann S, Stubert J, et al. Differentiating between malignant and benign breast masses: factors limiting sonoelastographic strain ratio. *Ultraschall Med.* 2013;34:131–6.
- [8] Deffieux T, Gennisson JL, Bercoff J, Tanter M. On the effects of reflected waves in transient shear wave elastography. *IEEE Trans Ultrason Ferroelectr Freq Control.* 2011;58:2032–5.
- [9] Dietrich CF, Barr RG, Farrokh A, et al. Strain elastography – how to do it? *Ultrasound Int Open.* 2017;3:E137–49.
- [10] Youk JH, Gweon HM, Son EJ. Shear-wave elastography in breast ultrasonography: the state of the art. *Ultrasonography.* 2017;36:300–9.
- [11] Chang JM, Moon WK, Cho N, Kim SJ. Breast mass evaluation: factors influencing the quality of US elastography. *Radiology.* 2011;259:59–64.
- [12] Chang JM, Won JK, Lee KB, Park IA, Yi A, Moon WK. Comparison of shear-wave and strain ultrasound elastography in the differentiation of benign and malignant breast lesions. *AJR Am J Roentgenol.* 2013;201:W347–56.
- [13] Barr RG, Zhang Z. Shear-wave elastography of the breast: value of a quality measure and comparison with strain elastography. *Radiology.* 2015;275:45–53.
- [14] Seo M, Ahn HS, Park SH, et al. Comparison and combination of strain and shear wave elastography of breast masses for differentiation of benign and malignant lesions by quantitative assessment: preliminary study. *J Ultrasound Med.* 2018;37:99–109.
- [15] Whiting P, Rutjes AW, Reitsma JB, Bossuyt PM, Kleijnen J. The development of QUADAS: a tool for the quality assessment of studies of diagnostic accuracy included in systematic reviews. *BMC Med Res Methodol.* 2003;3:25.
- [16] Gürüf A, Öztürk M, Bayrak IK, Polat AV. Shear wave versus strain elastography in the differentiation of benign and malignant breast lesions. *Turk J Med Sci.* 2019;49:1509–17.
- [17] Ma X, Xia BL. Differential diagnosis of benign and malignant breast nodules by strain elastography and shear wave elastography. *Med Inf.* 2020;33.
- [18] Kim YS, Park JG, Kim BS, Lee CH, Ryu DW. Diagnostic value of elastography using acoustic radiation force impulse imaging and strain ratio for breast tumors. *J Breast Cancer.* 2014;17:76–82.
- [19] Han J, Li F, Peng C, et al. Reducing unnecessary biopsy of breast lesions: preliminary results with combination of strain and shear-wave elastography. *Ultrasound Med Biol.* 2019;45:2317–27.
- [20] Balleyguier C, Canale S, Ben Hassen W, et al. Breast elasticity: principles, technique, results: an update and overview of commercially available software. *Eur J Radiol.* 2013;82:427–34.
- [21] Zhao XB, Yao JY, Zhou XC, et al. Strain elastography: a valuable additional method to BI-RADS? *Ultraschall Med.* 2018;39:526–34.
- [22] Cantisani V, David E, Barr RG, et al. US-elastography for breast lesion characterization: prospective comparison of US BIRADS, strain elastography and shear wave elastography. *Ultraschall Med.* 2021;42:533–40.
- [23] Peker A, Balci P, Basara Akin I, Özgül HA, Aksoy SO, Gürel D. Shear-wave elastography-guided core needle biopsy for the determination of breast cancer molecular subtype. *J Ultrasound Med.* 2021;40:1183–92.
- [24] Carlsen JF, Hansen KL, Ewertsen C, Nielsen MB. Elastography in breast imaging. *Ultraschall Med.* 2019;40:688–91.
- [25] Peng XJ, Li A, Ye XH, Yuan T. Comparison of the diagnostic performances between strain elastography and shear-wave elastography in differentiation of benign and malignant solid breast lesions. *China. Med Ultrasound (Electronic Edition).* 2016;13.
- [26] Zheng XY, Huang Y, Wang Y, et al. Combination of different types of elastography in downgrading ultrasound breast imaging-reporting and data system category 4a breast lesions. *Breast Cancer Res Treat.* 2019;174:423–32.
- [27] Han LS, Cui GH, Li XQ, Yu P. Comparative study of shear wave elastography and strain elastography in differential diagnosis of benign and malignant breast masses. *J Mod Med Health.* 2019;35.
- [28] Xia XN, Ma BB, Zhang Y, Wu CR, Zhao QL, Ruan LT. Evaluation of breast masses by strain elasticity and shear wave elastography. *J Xi'an Jiaotong Univ (Medical Sciences).* 2019;40.
- [29] Fujioka T, Mori M, Kubota K, et al. Simultaneous comparison between strain and shear wave elastography of breast masses for the differentiation of benign and malignant lesions by qualitative and quantitative assessments. *Breast Cancer.* 2019;26:792–8.
- [30] Singla V, Prakash A, Prabhakar N, et al. Does shear wave elastography score over strain elastography in breast masses or vice versa? *Curr Probl Diagn Radiol.* 2020;49:96–101.