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REVIEW ARTICLE

Diagnostic Role of the Stiff Rim Sign in Shear Wave Elastography For Guiding Biopsy Recommendation for BI-RADS 3 and 4 Breast Lesions

Peran Diagnostik *Stiff Rim Sign* pada *Shear Wave Elastography* untuk rekomendasi dalam menuntun biopsi pada lesi payudara BI-RADS 3 dan 4

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ABSTRACT

Breast cancer remains the most frequently diagnosed malignancy among women worldwide and continues to represent a major public health challenge. Accurate characterization of breast lesions is essential for early diagnosis and appropriate clinical management. Conventional ultrasound is widely used to evaluate breast lesions and classify them using the Breast Imaging Reporting and Data System (BI-RADS). However, differentiating benign from malignant lesions remains difficult, particularly in BI-RADS categories 3 and 4, which often lead to diagnostic uncertainty and unnecessary biopsies. Shear wave elastography (SWE) has emerged as an adjunct imaging technique that evaluates tissue stiffness and provides additional diagnostic information beyond conventional ultrasound. One characteristic elastography feature is the stiff rim sign, which appears as increased peri-lesional stiffness surrounding a breast mass and may reflect malignant tumor infiltration and stromal reaction. This systematic review aimed to evaluate the diagnostic role of the stiff rim sign detected by shear-wave elastography in differentiating benign from malignant breast lesions and its potential utility in guiding biopsy recommendations for BI-RADS category 3 and 4 lesions. A comprehensive literature search was conducted in PubMed, the Cochrane Library, and ScienceDirect to identify relevant studies assessing SWE and peri-lesional stiffness features in breast lesions. Studies that met predefined inclusion criteria were screened and evaluated, and relevant data on diagnostic performance were extracted for qualitative synthesis. The literature search identified 71 records, of which six studies met the eligibility criteria and were included in the final analysis. Across the included studies, the stiff rim sign demonstrated moderate to high diagnostic performance in differentiating malignant from benign breast lesions. Several studies reported high sensitivity, specificity, and area under the receiver operating characteristic curve when elastography findings were combined with conventional ultrasound parameters. Overall, the stiff rim sign detected by shear wave elastography appears to be a valuable imaging feature that may improve diagnostic accuracy and assist clinicians in guiding biopsy decisions for patients with BI-RADS 3 and 4 breast lesions.

Keywords: *BI-RADS; breast; biopsy,elastography; ultrasound*.

ABSTRAK

Kanker payudara merupakan keganasan yang paling sering didiagnosis pada wanita di seluruh dunia dan masih menjadi masalah kesehatan masyarakat yang signifikan. Karakterisasi lesi payudara secara akurat sangat penting untuk mendukung diagnosis dini dan menentukan penatalaksanaan yang tepat. Ultrasonografi konvensional banyak digunakan untuk mengevaluasi lesi payudara serta mengklasifikasikannya menggunakan sistem Breast Imaging Reporting and Data System (BI-RADS). Namun, pembedaan antara lesi jinak dan ganas masih menjadi tantangan, terutama pada lesi kategori BI-RADS 3 dan 4 yang sering menimbulkan ketidakpastian diagnostik serta berpotensi menyebabkan biopsi yang tidak diperlukan. Shear wave elastography (SWE) merupakan teknik pencitraan tambahan yang mampu menilai kekakuan jaringan dan memberikan informasi diagnostik tambahan di luar ultrasonografi konvensional. Salah satu temuan elastografi yang khas adalah stiff rim sign, yaitu peningkatan kekakuan jaringan di sekitar lesi yang dapat mencerminkan infiltrasi tumor dan reaksi stromal pada jaringan sekitarnya. Tinjauan sistematis ini bertujuan untuk mengevaluasi peran diagnostik stiff rim sign yang terdeteksi melalui shear wave elastography dalam membedakan lesi payudara jinak dan ganas serta menilai potensi penggunaannya dalam membantu rekomendasi biopsi pada lesi BI-RADS kategori 3 dan 4. Pencarian literatur dilakukan secara komprehensif melalui tiga basis data elektronik, yaitu PubMed, Cochrane Library, dan ScienceDirect. Studi yang memenuhi kriteria inklusi diseleksi dan dievaluasi, kemudian data terkait kinerja diagnostik diekstraksi untuk dilakukan sintesis kualitatif. Pencarian literatur mengidentifikasi 71 artikel, dan enam studi memenuhi kriteria kelayakan untuk dimasukkan dalam analisis akhir. Secara keseluruhan, stiff rim sign menunjukkan kinerja diagnostik sedang hingga tinggi dalam membedakan lesi payudara jinak dan ganas. Beberapa studi melaporkan nilai sensitivitas, spesifisitas, serta area under the receiver operating characteristic curve yang tinggi ketika temuan elastografi dikombinasikan dengan parameter ultrasonografi konvensional. Secara keseluruhan, stiff rim sign yang terdeteksi melalui shear wave elastography berpotensi menjadi fitur pencitraan yang bermanfaat untuk meningkatkan akurasi diagnosis serta membantu klinisi dalam menentukan keputusan biopsi pada pasien dengan lesi payudara kategori BI-RADS 3 dan 4.

Kata Kunci: *BI-RADS; elastografi; biopsi; payudara; ultrasonografi*.

INTRODUCTION

Breast cancer remains the most frequently diagnosed malignancy among women worldwide and continues to represent a major public health challenge. Global cancer statistics estimate that breast cancer accounts for more than 2.3 million new cases annually and remains one of the leading causes of cancer-related mortality among women.[1] The burden of disease continues to increase due to aging populations, lifestyle changes, and improved detection strategies. Early identification and accurate characterization of breast lesions are therefore essential to improve survival outcomes and reduce unnecessary invasive procedures.[1] Medical imaging plays a central role in the detection and evaluation of breast abnormalities. Although mammography remains the primary screening modality, its sensitivity may be limited in women with dense breast tissue, particularly among younger women and certain ethnic populations. Consequently, ultrasound has become an important complementary imaging modality for evaluating breast lesions. Conventional B-mode ultrasound provides morphological information, including lesion shape, margins, echogenicity, and posterior acoustic features, which are standardized using the Breast Imaging Reporting and Data System (BI-RADS) to estimate malignancy risk and guide clinical management.[2] Despite its widespread use, conventional ultrasound has limitations in distinguishing benign from malignant lesions, particularly in indeterminate categories such as BI-RADS 3 and BI-RADS 4. BI-RADS 3 lesions are generally considered probably benign but require short-term follow-up, whereas BI-RADS 4

lesions often lead to biopsy recommendations because of suspected malignancy. In clinical practice, many BI-RADS 4 lesions ultimately prove to be benign on histopathological examination, resulting in unnecessary biopsies, increased healthcare costs, and patient anxiety.[2]

Elastography has emerged as a promising imaging modality for evaluating tissue mechanical properties, particularly tissue stiffness. Malignant tumors generally demonstrate greater stiffness than surrounding normal tissue due to increased cellular density, tumor infiltration, stromal fibrosis, and desmoplastic reaction.[3] Among elastography techniques, shear wave elastography (SWE) enables quantitative measurement of tissue elasticity by analyzing the propagation of shear waves generated within tissue and displaying elasticity values as color-coded maps on ultrasound images.[3] Several studies have reported that SWE improves the diagnostic performance of ultrasound in differentiating benign and malignant breast lesions using quantitative parameters such as maximum elasticity, mean elasticity, and elasticity ratios.[4] In addition to quantitative measurements, qualitative elastography patterns have also been proposed as diagnostic indicators. One such feature is the stiff rim sign, which appears as a ring-like region of increased stiffness surrounding a breast lesion and is believed to reflect peritumoral stromal reactions and fibrosis.[5] Previous studies have reported that the stiff rim sign is more frequently observed in malignant lesions and may improve diagnostic accuracy when combined with conventional ultrasound and BI-RADS assessment.[6] However, reported diagnostic performance varies across studies due to differences in ultrasound equipment, acquisition techniques, and study populations.[7] Peri-lesional stiffness may also be influenced by lesion characteristics and surrounding tissue structure.[7] Recent investigations suggest that elastography may provide additional information regarding tumor invasion and staging.[8] Given the growing number of studies investigating the stiff rim sign, a comprehensive synthesis of available evidence is needed to evaluate its clinical relevance.[9] Therefore, this review aims to assess the diagnostic role of the stiff rim sign detected by shear wave elastography in guiding biopsy decisions for BI-RADS category 3 and 4 breast lesions.[10]

METHODS

Study Design and Reporting Standards

This review was conducted to evaluate the role of the stiff rim sign, detected by shear-wave elastography, in differentiating benign from malignant breast lesions and its potential value in guiding biopsy recommendations. The study methodology followed the principles of systematic evidence synthesis and was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review process involved systematic identification, screening, eligibility assessment, and qualitative synthesis of relevant studies examining the diagnostic value of peri-lesional stiffness and the stiff rim sign in breast elastography.

Data Sources and Literature Search Strategy

A comprehensive literature search was performed using three major electronic databases, including PubMed, the Cochrane Library, and ScienceDirect. The search aimed to identify studies that investigated the diagnostic performance of shear-wave elastography and the stiff rim sign in breast lesions. The search strategy combined keywords related to elastography techniques, breast lesions, and diagnostic assessment.

For the PubMed database, the following search strategy was used: ("stiff rim sign" OR "peritumoral stiffness" OR "perilesional stiffness") AND ("shear wave elastography" OR elastography OR SWE) AND ("breast lesion" OR "breast mass" OR "breast tumor" OR "breast cancer") AND (‘’Biopsy’’ OR ‘’biopsy decision’’ OR ‘’tissue sampling’’). For ScienceDirect, the search

query used was: ("stiff rim sign" OR "peritumoral stiffness" OR "perilesional stiffness") AND ("shear wave elastography") AND ("breast lesion" OR "breast mass") AND (''biopsy'' OR ''biopsy decision''). For the Cochrane Library, the search strategy included: (elastography OR "shear wave elastography" OR SWE) AND (breast OR "breast lesion" OR "breast mass" OR "breast tumor") AND (diagnosis OR diagnostic OR differentiation) AND (biopsy OR '' biopsy decision'' OR '' tissue sampling''). These search strategies were intentionally designed without restrictive field tags to ensure broader retrieval of potentially relevant studies.

The database search was conducted to capture all relevant studies published up to the time of the review. Additional manual screening of reference lists from eligible articles was also performed to identify potentially relevant studies that may not have been captured during the initial database search.

Eligibility Criteria

Studies were selected according to predefined inclusion and exclusion criteria. Eligible studies were original research articles evaluating female patients with breast lesions assessed with shear wave elastography. Studies were required to investigate the presence or diagnostic performance of the stiff rim sign or peri-lesional stiffness characteristics in breast lesions detected on ultrasound. The target population consisted of women with breast lesions classified as BI-RADS category 3 or 4, in whom elastography findings were used to assist diagnostic evaluation.

Studies were included if they evaluated the diagnostic performance of elastography features to differentiate benign and malignant breast lesions and reported sufficient clinical or imaging data. Acceptable study designs included prospective, retrospective, cross-sectional, or cohort diagnostic studies. Histopathological examination of biopsy or surgical specimens was considered the reference standard for confirming the final diagnosis.

Studies were excluded if they involved simple breast cysts or lesions with predominantly cystic characteristics. Studies involving breast masses larger than 5 cm, patients with a prior biopsy history affecting lesion characteristics, or cases with incomplete clinical or imaging data were also excluded. Articles focusing exclusively on pregnant or lactating women were excluded due to potential physiological alterations in breast tissue stiffness that could influence elastography findings.

Study Selection

All records retrieved from the database search were imported into a reference management system for screening and duplicate removal. The study selection process was conducted in several stages. First, duplicate records were identified and removed. The remaining records underwent title and abstract screening to evaluate their relevance to the research question.

Studies that appeared potentially eligible were then assessed through full-text review to determine whether they met the predefined inclusion criteria. During this stage, studies were excluded if they did not evaluate shear wave elastography, did not report findings on the stiff rim sign, or involved patient populations that did not meet the inclusion criteria. The final set of eligible studies was included in the qualitative synthesis of this review. The entire study selection process is summarized in the PRISMA flow diagram in Figure 1.

Data Extraction

Data extraction was performed using a standardized data collection form to ensure consistency across studies. Information extracted from each included study included the first author, year of publication, study design, country of study, sample size, patient demographics, imaging techniques used, and elastography parameters evaluated. Additional variables extracted included the presence or definition of the stiff rim sign, quantitative elastography measurements

such as maximum elasticity or mean elasticity, and reported diagnostic performance indicators, including sensitivity, specificity, and area under the receiver operating characteristic curve.

When available, information regarding BI-RADS classification, histopathological confirmation, and biopsy outcomes was also collected. Extracted data were organized into a structured table of characteristics and results to facilitate comparison between studies.

Risk of Bias Assessment

The methodological quality of the included studies was assessed using a structured risk-of-bias evaluation approach appropriate for diagnostic studies. The assessment focused on key methodological domains, including patient selection, index test evaluation, reference standard application, and participant flow through the study.

Each study was reviewed to determine whether the study population was appropriately defined, whether the elastography assessment was performed consistently, and whether the reference standard used for diagnosis was clearly described. Studies were categorized according to overall methodological quality, and potential sources of bias were documented. In accordance with the review framework applied in this study, studies were interpreted conservatively, and the overall risk of bias across studies was considered low to moderate.

Data Synthesis

Due to variations in study design, elastography parameters, and reported outcomes among the included studies, a qualitative synthesis approach was used. Diagnostic performance measures reported in each study were summarized descriptively, with particular focus on sensitivity, specificity, and overall diagnostic accuracy of the stiff rim sign and peri-lesional stiffness measurements.

Findings from the included studies were compared narratively to identify consistent trends in the diagnostic value of shear wave elastography and the stiff rim sign in breast lesion evaluation. The results were synthesized to provide an overall interpretation of the available evidence regarding the potential clinical utility of elastography features in guiding biopsy recommendations for suspicious breast lesions.

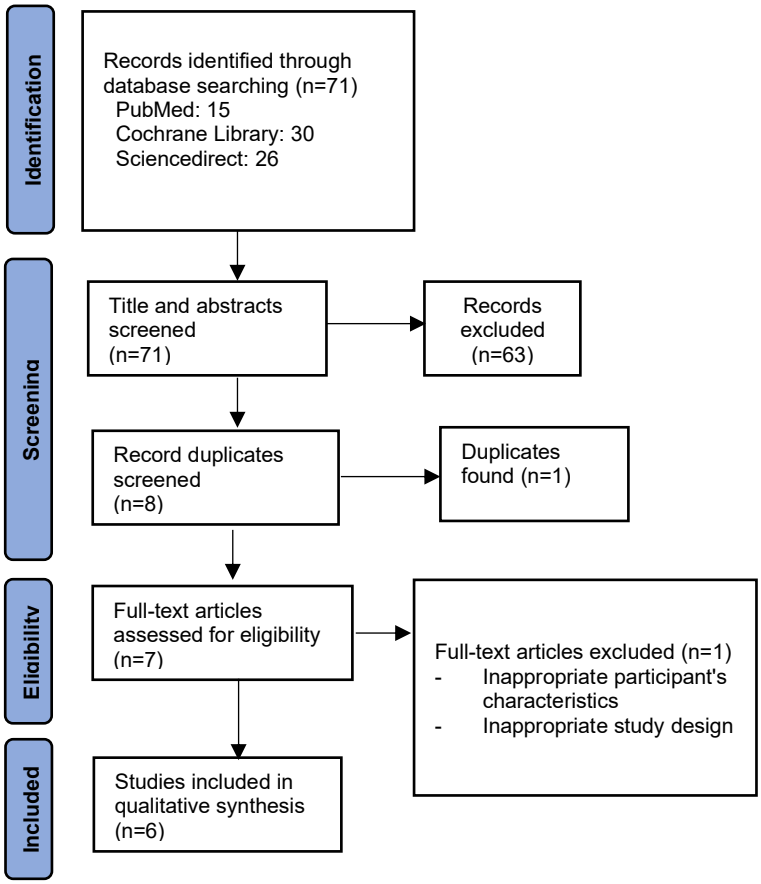

Figure 1. Diagram flow of literature search strategy for this review

RESULTS

Study Selection (PRISMA)

The systematic literature search identified 71 records across three electronic databases. Fifteen records were retrieved from PubMed, thirty from the Cochrane Library, and twenty-six from ScienceDirect. All records were imported into a reference management system to facilitate screening and duplicate detection. After removing duplicate entries, 126 unique studies remained for further evaluation.

Title and abstract screening were performed to assess the relevance of the identified studies according to the predefined inclusion criteria. During this stage, 63 studies were excluded for not meeting the eligibility criteria. The most common reasons for exclusion were studies that did not evaluate shear wave elastography, studies focusing on other organs or diseases, studies investigating different elastography techniques without assessing peri-lesional stiffness features, and review articles or methodological papers without original clinical data.

Eight potentially eligible articles remained after the initial screening stage. One duplicate record was identified and removed, leaving seven full-text articles for eligibility assessment. Following full-text evaluation, one study was excluded because its study population did not include BI-RADS category 3 or 4 breast lesions and therefore did not provide relevant data on biopsy guidance using the stiff rim sign. Ultimately, six studies fulfilled all eligibility criteria and were

included in the qualitative synthesis. The complete study selection process is summarized in the PRISMA flow diagram shown in Figure 1.

Characteristics of Included Studies

The six studies included in this review were published between 2014 and 2021 and were conducted primarily in Asian populations. Five studies were conducted in China, while one study was performed in Thailand. These studies evaluated the diagnostic value of shear wave elastography (SWE) and peri-lesional stiffness features, particularly the stiff rim sign, in differentiating benign from malignant breast lesions.

The included studies used observational diagnostic research designs, including both prospective and retrospective approaches. Two studies were prospective, enabling standardized data acquisition during ultrasound examinations, while the remaining studies employed retrospective designs using previously collected imaging and pathology data. Although retrospective studies may introduce certain limitations, such as selection bias, they remain commonly used in diagnostic imaging research.

Sample sizes varied considerably among the studies. The number of evaluated breast lesions ranged from approximately 193 lesions in the smallest cohort to more than 900 lesions in the largest study. In most cases, lesions were initially classified using conventional ultrasound according to the Breast Imaging Reporting and Data System (BI-RADS), particularly categories 3 and 4, which represent lesions with uncertain malignant potential and therefore require careful diagnostic evaluation.

All studies used shear wave elastography as the index imaging modality. SWE measures tissue stiffness by analyzing the propagation velocity of shear waves generated within the tissue. Malignant tumors typically demonstrate increased stiffness due to tumor infiltration, desmoplastic reaction, and alterations in the extracellular matrix. These pathological processes may produce characteristic imaging findings such as the stiff rim sign, which appears as a halo of increased stiffness surrounding a breast lesion.

Histopathological confirmation obtained via core-needle biopsy or surgical resection served as the reference standard across all included studies. These pathological findings were used to determine the final diagnosis of benign or malignant lesions and to evaluate the diagnostic performance of elastography findings.

Diagnostic Performance of the Stiff Rim Sign

Across the included studies, the stiff rim sign and peri-lesional stiffness measurements demonstrated meaningful diagnostic value in differentiating malignant from benign breast lesions. The presence of a peri-lesional stiffness halo was consistently associated with malignant pathology. [10-15]

In the prospective study conducted by Suvannarerg et al., qualitative elastography patterns, including the stiff rim sign, demonstrated favorable diagnostic performance. The reported sensitivity was approximately 73.96%, while specificity reached 93.24%.[11] The positive predictive value and negative predictive value were reported as 87.65% and 84.66%, respectively. The diagnostic performance improved when qualitative elastography patterns were combined with quantitative SWE parameters. The area under the receiver operating characteristic curve (AUC) was reported as 0.836 for qualitative elastography patterns alone and increased to approximately 0.905 when quantitative parameters were incorporated into the analysis.[11]

Similarly, Zhou et al. reported excellent diagnostic performance of the stiff rim sign, with a sensitivity of 98.2% and specificity of 92.0%. The AUC was 0.918, indicating strong discrimination between malignant and benign lesions.[12]

Other studies further demonstrated that peri-lesional stiffness measurements may provide stronger diagnostic indicators than intra-lesional stiffness parameters alone.[14] Kong et al. reported that the stiff rim sign and peri-lesional stiffness measurements improved diagnostic differentiation compared with several conventional quantitative elastography parameters.[13] Meanwhile, Xu et al. demonstrated that incorporating the stiff rim sign into BI-RADS classification could improve diagnostic stratification and potentially reduce unnecessary biopsies.[15]

Interpretation of Findings and Comparison with Previous Literature

The findings of this review indicate that the stiff rim sign is an important imaging feature of malignant breast lesions. Across the included studies, peri-lesional stiffness was observed predominantly in malignant tumors and was rarely present in benign lesions. This observation is consistent with previous literature demonstrating that elastography can improve the diagnostic specificity of breast ultrasound while maintaining high sensitivity for detecting malignancy.[3]

Previous studies have shown that malignant tumors typically exhibit greater stiffness than benign lesions due to increased cellular density, stromal fibrosis, and extracellular matrix remodeling.[4] In addition to intra-lesional stiffness, more recent research has emphasized the diagnostic importance of peri-lesional stiffness. Several studies have reported that stiffness changes surrounding the tumor may represent a stronger indicator of malignancy than stiffness measurements confined to the lesion itself.[16-18]

These findings support the concept that elastography provides additional diagnostic information beyond conventional grayscale ultrasound. By integrating elastography features with BI-RADS classification, clinicians may achieve more accurate risk stratification of breast lesions and improve overall diagnostic performance.[17]

Biological Mechanisms

The stiff rim sign likely reflects biological processes within the tumor microenvironment. Malignant tumors often trigger a desmoplastic response in surrounding stromal tissue, marked by fibroblast activation, collagen deposition, and extracellular matrix remodeling. These processes increase the stiffness of tissues surrounding the tumor and produce the characteristic peri-lesional stiffness halo observed on elastography imaging.[5]

Tumor invasion into adjacent tissue may also contribute to the development of peri-lesional stiffness. As malignant cells infiltrate surrounding structures, they disrupt normal tissue architecture and trigger inflammatory responses. These changes alter tissue mechanical properties, resulting in increased stiffness detectable on elastography.[18]

Additional mechanisms may involve tumor-induced alterations in vascular structure and interstitial pressure. Abnormal angiogenesis and increased interstitial fluid pressure within the tumor microenvironment may further influence tissue elasticity and contribute to the appearance of peri-lesional stiffness patterns.[19,20]

Clinical Implications

The clinical implications of these findings are particularly relevant for the diagnostic evaluation of breast lesions detected on ultrasound. BI-RADS category 3 and 4 lesions often pose a diagnostic challenge because their malignancy risk is uncertain. In many cases, BI-RADS category 4 lesions undergo biopsy, despite a substantial proportion ultimately proving benign.[11]

Incorporating elastography findings into ultrasound assessment may help refine biopsy decisions. Lesions demonstrating benign morphological features and lacking peri-lesional stiffness may potentially be downgraded and managed with imaging follow-up rather than immediate biopsy. Conversely, lesions exhibiting a pronounced stiff rim sign may be considered highly suspicious for malignancy and therefore require biopsy or further diagnostic evaluation.[6]

Reducing unnecessary biopsies represents an important clinical benefit because biopsy procedures are invasive, costly, and associated with patient anxiety. Studies have suggested that elastography-based adjustments to BI-RADS classification may reduce the number of benign biopsies while maintaining high sensitivity for detecting malignancy.[17]

Risk of Bias and Limitations

The methodological quality of the included studies was generally acceptable, although several potential sources of bias should be considered. Some studies used retrospective designs, which may introduce selection bias and limit generalizability. In addition, variations in elastography acquisition protocols, stiffness thresholds, and imaging equipment may contribute to heterogeneity in reported diagnostic performance.

Differences in operator experience and ultrasound equipment settings may also influence elastography measurements. Because elastography is partially operator-dependent, standardized imaging protocols are necessary to ensure reproducibility across clinical settings.

Future Research Directions

Future research should focus on large multicenter prospective studies to validate the diagnostic value of the stiff rim sign across diverse populations and imaging systems. Standardization of elastography acquisition protocols and stiffness measurement thresholds would improve the comparability of findings between studies.

Another promising direction involves integrating elastography features with advanced imaging analysis techniques such as radiomics and machine learning. Combining quantitative elastography parameters with computational image analysis may further improve diagnostic accuracy and assist clinicians in differentiating benign from malignant breast lesions.

Longitudinal studies exploring the relationship between peri-lesional stiffness patterns and tumor biology may also provide valuable insights into the role of elastography in breast cancer diagnosis and prognosis.

Table 1. Characteristics and results of the included studies

No	Authors' name, Year	Research title	Population	Data	Findings
1	Suvannarerg et al., 2019[11]	Diagnostic performance of shear wave elastography for breast masses	228 women with 244 breast masses (148 benign, 96 malignant) undergoing US-guided biopsy	Sensitivity 73.96%, specificity 93.24%, PPV 87.65%, NPV 84.66%, AUC 0.836–0.905	SWE showed good diagnostic performance in differentiating benign and malignant breast masses. Combining SWE parameters improved diagnostic accuracy and allowed some BI-RADS 4A lesions to be downgraded, potentially reducing unnecessary biopsies.
2	Zhou et al., 2014[12]	Diagnostic value of stiff rim sign in shear wave elastography	156 women with 193 breast lesions (56 malignant, 137 benign)	Sensitivity 98.2%, specificity 92.0%, PPV 85.9%, NPV 99.2%, AUC 0.918	The stiff rim sign showed high diagnostic accuracy and improved differentiation between malignant and benign lesions when combined with conventional ultrasound.
3	Xiang et al., 2019[14]	Factors associated with stiff rim sign in breast lesions	907 breast lesions evaluated with ultrasound and SWE	Multivariate analysis evaluating factors associated with stiff rim sign appearance	Older age, larger lesion size, deeper lesions, poorly defined margins, heterogeneous internal components, and positive CDFI were significantly associated with the stiff rim sign in benign breast lesions.

No	Authors' name, Year	Research title	Population	Data	Findings
4	Kong et al., 2019[13]	Diagnostic value of peri-lesional stiffness using SWE	192 patients with 199 breast lesions (75 malignant, 124 benign)	Sensitivity 88.0%, specificity 89.5% for stiff rim sign	Combining stiff rim sign with BI-RADS increased sensitivity from 88.0% to 92.0% and improved diagnostic accuracy in differentiating benign and malignant lesions.
5	Xu et al., 2021[15]	Role of stiff rim sign in BI-RADS stratification and tumor staging	210 breast lesions evaluated using ultrasound and SWE	Increased PPV for tumor staging (≈30% vs B-mode ultrasound)	Stiff rim sign improved BI-RADS diagnostic stratification and helped identify lesions requiring biopsy while reducing unnecessary procedures.
6	Yu et al., 2022[10]	SWE prediction model for BI-RADS 3 and 4a lesions	468 patients with 488 breast lesions undergoing SWE and ultrasound	Sensitivity 93.6%, specificity 85.3%, AUC 0.850	SWE prediction model combining qualitative and quantitative parameters improved differentiation between benign and malignant lesions and assisted biopsy decision-making.

CONCLUSION

This review evaluated the role of the stiff rim sign, detected by shear-wave elastography, in assessing breast lesions, particularly in the context of BI-RADS category 3 and 4 masses. The findings suggest that the stiff rim sign represents a valuable qualitative elastography feature associated with malignant breast lesions. Across the included studies, peri-lesional stiffness patterns demonstrated moderate-to-high diagnostic performance and were consistently associated with malignant pathology. The presence of a stiff rim surrounding breast lesions likely reflects biological processes such as desmoplastic reaction, tumor infiltration into surrounding tissue, and stromal remodeling. These pathological changes contribute to increased stiffness in the peritumoral region, which can be visualized using shear-wave elastography. When incorporated into conventional ultrasound evaluation, the stiff rim sign may improve diagnostic confidence and assist clinicians in differentiating benign from malignant lesions.

Importantly, integrating elastography findings with BI-RADS classification may help refine biopsy decision-making for indeterminate breast lesions. The stiff rim sign may serve as an adjunct imaging indicator that helps identify lesions requiring biopsy while potentially reducing unnecessary invasive procedures in benign cases. Although the available evidence supports the diagnostic value of the stiff rim sign, further prospective multicenter studies with standardized elastography protocols are needed to confirm its clinical utility. Future research should also explore integrating elastography findings with advanced imaging analysis techniques to further enhance diagnostic accuracy. Overall, the stiff rim sign detected by shear-wave elastography represents a promising imaging biomarker that may improve risk stratification and the precision of management of breast lesions.

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AUTHORS CONTRIBUTION

All authors contributed substantially to the conception and design of the study. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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REVIEW ARTICLE

Diagnostic Role of the Stiff Rim Sign in Shear Wave Elastography For Guiding Biopsy Recommendation for BI-RADS 3 and 4 Breast Lesions

Peran Diagnostik *Stiff Rim Sign* pada *Shear Wave Elastography* untuk rekomendasi dalam menuntun biopsi pada lesi payudara BI-RADS 3 dan 4

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ABSTRACT

Breast cancer remains the most frequently diagnosed malignancy among women worldwide and continues to represent a major public health challenge. Accurate characterization of breast lesions is essential for early diagnosis and appropriate clinical management. Conventional ultrasound is widely used to evaluate breast lesions and classify them using the Breast Imaging Reporting and Data System (BI-RADS). However, differentiating benign from malignant lesions remains difficult, particularly in BI-RADS categories 3 and 4, which often lead to diagnostic uncertainty and unnecessary biopsies. Shear wave elastography (SWE) has emerged as an adjunct imaging technique that evaluates tissue stiffness and provides additional diagnostic information beyond conventional ultrasound. One characteristic elastography feature is the stiff rim sign, which appears as increased peri-lesional stiffness surrounding a breast mass and may reflect malignant tumor infiltration and stromal reaction. This systematic review aimed to evaluate the diagnostic role of the stiff rim sign detected by shear-wave elastography in differentiating benign from malignant breast lesions and its potential utility in guiding biopsy recommendations for BI-RADS category 3 and 4 lesions. A comprehensive literature search was conducted in PubMed, the Cochrane Library, and ScienceDirect to identify relevant studies assessing SWE and peri-lesional stiffness features in breast lesions. Studies that met predefined inclusion criteria were screened and evaluated, and relevant data on diagnostic performance were extracted for qualitative synthesis. The literature search identified 71 records, of which six studies met the eligibility criteria and were included in the final analysis. Across the included studies, the stiff rim sign demonstrated moderate to high diagnostic performance in differentiating malignant from benign breast lesions. Several studies reported high sensitivity, specificity, and area under the receiver operating characteristic curve when elastography findings were combined with conventional ultrasound parameters. Overall, the stiff rim sign detected by shear wave elastography appears to be a valuable imaging feature that may improve diagnostic accuracy and assist clinicians in guiding biopsy decisions for patients with BI-RADS 3 and 4 breast lesions.

Keywords: *BI-RADS; breast; biopsy,elastography; ultrasound.*

ABSTRAK

Kanker payudara merupakan keganasan yang paling sering didiagnosis pada wanita di seluruh dunia dan masih menjadi masalah kesehatan masyarakat yang signifikan. Karakterisasi lesi payudara secara akurat sangat penting untuk mendukung diagnosis dini dan menentukan penatalaksanaan yang tepat. Ultrasonografi konvensional banyak digunakan untuk mengevaluasi lesi payudara serta mengklasifikasikannya menggunakan sistem Breast Imaging Reporting and Data System (BI-RADS). Namun, pembedaan antara lesi jinak dan ganas masih menjadi tantangan, terutama pada lesi kategori BI-RADS 3 dan 4 yang sering menimbulkan ketidakpastian diagnostik serta berpotensi menyebabkan biopsi yang tidak diperlukan. Shear wave elastography (SWE) merupakan teknik pencitraan tambahan yang mampu menilai kekakuan jaringan dan memberikan informasi diagnostik tambahan di luar ultrasonografi konvensional. Salah satu temuan elastografi yang khas adalah stiff rim sign, yaitu peningkatan kekakuan jaringan di sekitar lesi yang dapat mencerminkan infiltrasi tumor dan reaksi stromal pada jaringan sekitarnya. Tinjauan sistematis ini bertujuan untuk mengevaluasi peran diagnostik stiff rim sign yang terdeteksi melalui shear wave elastography dalam membedakan lesi payudara jinak dan ganas serta menilai potensi penggunaannya dalam membantu rekomendasi biopsi pada lesi BI-RADS kategori 3 dan 4. Pencarian literatur dilakukan secara komprehensif melalui tiga basis data elektronik, yaitu PubMed, Cochrane Library, dan ScienceDirect. Studi yang memenuhi kriteria inklusi diseleksi dan dievaluasi, kemudian data terkait kinerja diagnostik diekstraksi untuk dilakukan sintesis kualitatif. Pencarian literatur mengidentifikasi 71 artikel, dan enam studi memenuhi kriteria kelayakan untuk dimasukkan dalam analisis akhir. Secara keseluruhan, stiff rim sign menunjukkan kinerja diagnostik sedang hingga tinggi dalam membedakan lesi payudara jinak dan ganas. Beberapa studi melaporkan nilai sensitivitas, spesifisitas, serta area under the receiver operating characteristic curve yang tinggi ketika temuan elastografi dikombinasikan dengan parameter ultrasonografi konvensional. Secara keseluruhan, stiff rim sign yang terdeteksi melalui shear wave elastography berpotensi menjadi fitur pencitraan yang bermanfaat untuk meningkatkan akurasi diagnosis serta membantu klinisi dalam menentukan keputusan biopsi pada pasien dengan lesi payudara kategori BI-RADS 3 dan 4.

Kata Kunci: *BI-RADS; elastografi; biopsi; payudara; ultrasonografi.*

INTRODUCTION

Breast cancer remains the most frequently diagnosed malignancy among women worldwide and continues to represent a major public health challenge. Global cancer statistics estimate that breast cancer accounts for more than 2.3 million new cases annually and remains one of the leading causes of cancer-related mortality among women.[1] The burden of disease continues to increase due to aging populations, lifestyle changes, and improved detection strategies. Early identification and accurate characterization of breast lesions are therefore essential to improve survival outcomes and reduce unnecessary invasive procedures.[1] Medical imaging plays a central role in the detection and evaluation of breast abnormalities. Although mammography remains the primary screening modality, its sensitivity may be limited in women with dense breast tissue, particularly among younger women and certain ethnic populations. Consequently, ultrasound has become an important complementary imaging modality for evaluating breast lesions. Conventional B-mode ultrasound provides morphological information, including lesion shape, margins, echogenicity, and posterior acoustic features, which are standardized using the Breast Imaging Reporting and Data System (BI-RADS) to estimate malignancy risk and guide clinical management.[2] Despite its widespread use, conventional ultrasound has limitations in distinguishing benign from malignant lesions, particularly in indeterminate categories such as BI-RADS 3 and BI-RADS 4. BI-RADS 3 lesions are generally considered probably benign but require short-term follow-up, whereas BI-RADS 4

lesions often lead to biopsy recommendations because of suspected malignancy. In clinical practice, many BI-RADS 4 lesions ultimately prove to be benign on histopathological examination, resulting in unnecessary biopsies, increased healthcare costs, and patient anxiety.[2]

Elastography has emerged as a promising imaging modality for evaluating tissue mechanical properties, particularly tissue stiffness. Malignant tumors generally demonstrate greater stiffness than surrounding normal tissue due to increased cellular density, tumor infiltration, stromal fibrosis, and desmoplastic reaction.[3] Among elastography techniques, shear wave elastography (SWE) enables quantitative measurement of tissue elasticity by analyzing the propagation of shear waves generated within tissue and displaying elasticity values as color-coded maps on ultrasound images.[3] Several studies have reported that SWE improves the diagnostic performance of ultrasound in differentiating benign and malignant breast lesions using quantitative parameters such as maximum elasticity, mean elasticity, and elasticity ratios.[4] In addition to quantitative measurements, qualitative elastography patterns have also been proposed as diagnostic indicators. One such feature is the stiff rim sign, which appears as a ring-like region of increased stiffness surrounding a breast lesion and is believed to reflect peritumoral stromal reactions and fibrosis.[5] Previous studies have reported that the stiff rim sign is more frequently observed in malignant lesions and may improve diagnostic accuracy when combined with conventional ultrasound and BI-RADS assessment.[6] However, reported diagnostic performance varies across studies due to differences in ultrasound equipment, acquisition techniques, and study populations.[7] Peri-lesional stiffness may also be influenced by lesion characteristics and surrounding tissue structure.[7] Recent investigations suggest that elastography may provide additional information regarding tumor invasion and staging.[8] Given the growing number of studies investigating the stiff rim sign, a comprehensive synthesis of available evidence is needed to evaluate its clinical relevance.[9] Therefore, this review aims to assess the diagnostic role of the stiff rim sign detected by shear wave elastography in guiding biopsy decisions for BI-RADS category 3 and 4 breast lesions.[10]

METHODS

Study Design and Reporting Standards

This review was conducted to evaluate the role of the stiff rim sign, detected by shear-wave elastography, in differentiating benign from malignant breast lesions and its potential value in guiding biopsy recommendations. The study methodology followed the principles of systematic evidence synthesis and was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review process involved systematic identification, screening, eligibility assessment, and qualitative synthesis of relevant studies examining the diagnostic value of peri-lesional stiffness and the stiff rim sign in breast elastography.

Data Sources and Literature Search Strategy

A comprehensive literature search was performed using three major electronic databases, including PubMed, the Cochrane Library, and ScienceDirect. The search aimed to identify studies that investigated the diagnostic performance of shear-wave elastography and the stiff rim sign in breast lesions. The search strategy combined keywords related to elastography techniques, breast lesions, and diagnostic assessment.

For the PubMed database, the following search strategy was used: ("stiff rim sign" OR "peritumoral stiffness" OR "perilesional stiffness") AND ("shear wave elastography" OR elastography OR SWE) AND ("breast lesion" OR "breast mass" OR "breast tumor" OR "breast cancer") AND (''Biopsy'' OR ''biopsy decision'' OR ''tissue sampling''). For ScienceDirect, the search

query used was: ("stiff rim sign" OR "peritumoral stiffness" OR "perilesional stiffness") AND ("shear wave elastography") AND ("breast lesion" OR "breast mass") AND (''biopsy'' OR ''biopsy decision''). For the Cochrane Library, the search strategy included: (elastography OR "shear wave elastography" OR SWE) AND (breast OR "breast lesion" OR "breast mass" OR "breast tumor") AND (diagnosis OR diagnostic OR differentiation) AND (biopsy OR '' biopsy decision'' OR '' tissue sampling''). These search strategies were intentionally designed without restrictive field tags to ensure broader retrieval of potentially relevant studies.

The database search was conducted to capture all relevant studies published up to the time of the review. Additional manual screening of reference lists from eligible articles was also performed to identify potentially relevant studies that may not have been captured during the initial database search.

Eligibility Criteria

Studies were selected according to predefined inclusion and exclusion criteria. Eligible studies were original research articles evaluating female patients with breast lesions assessed with shear wave elastography. Studies were required to investigate the presence or diagnostic performance of the stiff rim sign or peri-lesional stiffness characteristics in breast lesions detected on ultrasound. The target population consisted of women with breast lesions classified as BI-RADS category 3 or 4, in whom elastography findings were used to assist diagnostic evaluation.

Studies were included if they evaluated the diagnostic performance of elastography features to differentiate benign and malignant breast lesions and reported sufficient clinical or imaging data. Acceptable study designs included prospective, retrospective, cross-sectional, or cohort diagnostic studies. Histopathological examination of biopsy or surgical specimens was considered the reference standard for confirming the final diagnosis.

Studies were excluded if they involved simple breast cysts or lesions with predominantly cystic characteristics. Studies involving breast masses larger than 5 cm, patients with a prior biopsy history affecting lesion characteristics, or cases with incomplete clinical or imaging data were also excluded. Articles focusing exclusively on pregnant or lactating women were excluded due to potential physiological alterations in breast tissue stiffness that could influence elastography findings.

Study Selection

All records retrieved from the database search were imported into a reference management system for screening and duplicate removal. The study selection process was conducted in several stages. First, duplicate records were identified and removed. The remaining records underwent title and abstract screening to evaluate their relevance to the research question.

Studies that appeared potentially eligible were then assessed through full-text review to determine whether they met the predefined inclusion criteria. During this stage, studies were excluded if they did not evaluate shear wave elastography, did not report findings on the stiff rim sign, or involved patient populations that did not meet the inclusion criteria. The final set of eligible studies was included in the qualitative synthesis of this review. The entire study selection process is summarized in the PRISMA flow diagram in Figure 1.

Data Extraction

Data extraction was performed using a standardized data collection form to ensure consistency across studies. Information extracted from each included study included the first author, year of publication, study design, country of study, sample size, patient demographics, imaging techniques used, and elastography parameters evaluated. Additional variables extracted included the presence or definition of the stiff rim sign, quantitative elastography measurements

such as maximum elasticity or mean elasticity, and reported diagnostic performance indicators, including sensitivity, specificity, and area under the receiver operating characteristic curve.

When available, information regarding BI-RADS classification, histopathological confirmation, and biopsy outcomes was also collected. Extracted data were organized into a structured table of characteristics and results to facilitate comparison between studies.

Risk of Bias Assessment

The methodological quality of the included studies was assessed using a structured risk-of-bias evaluation approach appropriate for diagnostic studies. The assessment focused on key methodological domains, including patient selection, index test evaluation, reference standard application, and participant flow through the study.

Each study was reviewed to determine whether the study population was appropriately defined, whether the elastography assessment was performed consistently, and whether the reference standard used for diagnosis was clearly described. Studies were categorized according to overall methodological quality, and potential sources of bias were documented. In accordance with the review framework applied in this study, studies were interpreted conservatively, and the overall risk of bias across studies was considered low to moderate.

Data Synthesis

Due to variations in study design, elastography parameters, and reported outcomes among the included studies, a qualitative synthesis approach was used. Diagnostic performance measures reported in each study were summarized descriptively, with particular focus on sensitivity, specificity, and overall diagnostic accuracy of the stiff rim sign and peri-lesional stiffness measurements.

Findings from the included studies were compared narratively to identify consistent trends in the diagnostic value of shear wave elastography and the stiff rim sign in breast lesion evaluation. The results were synthesized to provide an overall interpretation of the available evidence regarding the potential clinical utility of elastography features in guiding biopsy recommendations for suspicious breast lesions.

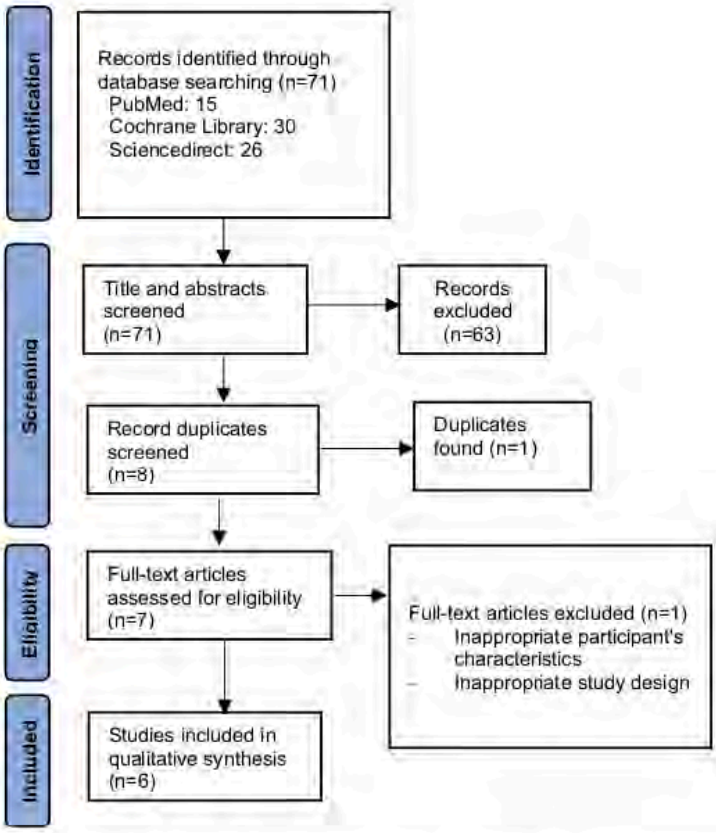

Figure 1. Diagram flow of literature search strategy for this review

RESULTS

Study Selection (PRISMA)

The systematic literature search identified 71 records across three electronic databases. Fifteen records were retrieved from PubMed, thirty from the Cochrane Library, and twenty-six from ScienceDirect. All records were imported into a reference management system to facilitate screening and duplicate detection. After removing duplicate entries, 126 unique studies remained for further evaluation.

Title and abstract screening were performed to assess the relevance of the identified studies according to the predefined inclusion criteria. During this stage, 63 studies were excluded for not meeting the eligibility criteria. The most common reasons for exclusion were studies that did not evaluate shear wave elastography, studies focusing on other organs or diseases, studies investigating different elastography techniques without assessing peri-lesional stiffness features, and review articles or methodological papers without original clinical data.

Eight potentially eligible articles remained after the initial screening stage. One duplicate record was identified and removed, leaving seven full-text articles for eligibility assessment. Following full-text evaluation, one study was excluded because its study population did not include BI-RADS category 3 or 4 breast lesions and therefore did not provide relevant data on biopsy guidance using the stiff rim sign. Ultimately, six studies fulfilled all eligibility criteria and were

included in the qualitative synthesis. The complete study selection process is summarized in the PRISMA flow diagram shown in Figure 1.

Characteristics of Included Studies

The six studies included in this review were published between 2014 and 2021 and were conducted primarily in Asian populations. Five studies were conducted in China, while one study was performed in Thailand. These studies evaluated the diagnostic value of shear wave elastography (SWE) and peri-lesional stiffness features, particularly the stiff rim sign, in differentiating benign from malignant breast lesions.

The included studies used observational diagnostic research designs, including both prospective and retrospective approaches. Two studies were prospective, enabling standardized data acquisition during ultrasound examinations, while the remaining studies employed retrospective designs using previously collected imaging and pathology data. Although retrospective studies may introduce certain limitations, such as selection bias, they remain commonly used in diagnostic imaging research.

Sample sizes varied considerably among the studies. The number of evaluated breast lesions ranged from approximately 193 lesions in the smallest cohort to more than 900 lesions in the largest study. In most cases, lesions were initially classified using conventional ultrasound according to the Breast Imaging Reporting and Data System (BI-RADS), particularly categories 3 and 4, which represent lesions with uncertain malignant potential and therefore require careful diagnostic evaluation.

All studies used shear wave elastography as the index imaging modality. SWE measures tissue stiffness by analyzing the propagation velocity of shear waves generated within the tissue. Malignant tumors typically demonstrate increased stiffness due to tumor infiltration, desmoplastic reaction, and alterations in the extracellular matrix. These pathological processes may produce characteristic imaging findings such as the stiff rim sign, which appears as a halo of increased stiffness surrounding a breast lesion.

Histopathological confirmation obtained via core-needle biopsy or surgical resection served as the reference standard across all included studies. These pathological findings were used to determine the final diagnosis of benign or malignant lesions and to evaluate the diagnostic performance of elastography findings.

Diagnostic Performance of the Stiff Rim Sign

Across the included studies, the stiff rim sign and peri-lesional stiffness measurements demonstrated meaningful diagnostic value in differentiating malignant from benign breast lesions. The presence of a peri-lesional stiffness halo was consistently associated with malignant pathology. [10-15]

In the prospective study conducted by Suvannarerg et al., qualitative elastography patterns, including the stiff rim sign, demonstrated favorable diagnostic performance. The reported sensitivity was approximately 73.96%, while specificity reached 93.24%.[11] The positive predictive value and negative predictive value were reported as 87.65% and 84.66%, respectively. The diagnostic performance improved when qualitative elastography patterns were combined with quantitative SWE parameters. The area under the receiver operating characteristic curve (AUC) was reported as 0.836 for qualitative elastography patterns alone and increased to approximately 0.905 when quantitative parameters were incorporated into the analysis.[11]

Similarly, Zhou et al. reported excellent diagnostic performance of the stiff rim sign, with a sensitivity of 98.2% and specificity of 92.0%. The AUC was 0.918, indicating strong discrimination between malignant and benign lesions.[12]

Other studies further demonstrated that peri-lesional stiffness measurements may provide stronger diagnostic indicators than intra-lesional stiffness parameters alone.[14] Kong et al. reported that the stiff rim sign and peri-lesional stiffness measurements improved diagnostic differentiation compared with several conventional quantitative elastography parameters.[13] Meanwhile, Xu et al. demonstrated that incorporating the stiff rim sign into BI-RADS classification could improve diagnostic stratification and potentially reduce unnecessary biopsies.[15]

Interpretation of Findings and Comparison with Previous Literature

The findings of this review indicate that the stiff rim sign is an important imaging feature of malignant breast lesions. Across the included studies, peri-lesional stiffness was observed predominantly in malignant tumors and was rarely present in benign lesions. This observation is consistent with previous literature demonstrating that elastography can improve the diagnostic specificity of breast ultrasound while maintaining high sensitivity for detecting malignancy.[3]

Previous studies have shown that malignant tumors typically exhibit greater stiffness than benign lesions due to increased cellular density, stromal fibrosis, and extracellular matrix remodeling.[4] In addition to intra-lesional stiffness, more recent research has emphasized the diagnostic importance of peri-lesional stiffness. Several studies have reported that stiffness changes surrounding the tumor may represent a stronger indicator of malignancy than stiffness measurements confined to the lesion itself.[16-18]

These findings support the concept that elastography provides additional diagnostic information beyond conventional grayscale ultrasound. By integrating elastography features with BI-RADS classification, clinicians may achieve more accurate risk stratification of breast lesions and improve overall diagnostic performance.[17]

Biological Mechanisms

The stiff rim sign likely reflects biological processes within the tumor microenvironment. Malignant tumors often trigger a desmoplastic response in surrounding stromal tissue, marked by fibroblast activation, collagen deposition, and extracellular matrix remodeling. These processes increase the stiffness of tissues surrounding the tumor and produce the characteristic peri-lesional stiffness halo observed on elastography imaging.[5]

Tumor invasion into adjacent tissue may also contribute to the development of peri-lesional stiffness. As malignant cells infiltrate surrounding structures, they disrupt normal tissue architecture and trigger inflammatory responses. These changes alter tissue mechanical properties, resulting in increased stiffness detectable on elastography.[18]

Additional mechanisms may involve tumor-induced alterations in vascular structure and interstitial pressure. Abnormal angiogenesis and increased interstitial fluid pressure within the tumor microenvironment may further influence tissue elasticity and contribute to the appearance of peri-lesional stiffness patterns.[19,20]

Clinical Implications

The clinical implications of these findings are particularly relevant for the diagnostic evaluation of breast lesions detected on ultrasound. BI-RADS category 3 and 4 lesions often pose a diagnostic challenge because their malignancy risk is uncertain. In many cases, BI-RADS category 4 lesions undergo biopsy, despite a substantial proportion ultimately proving benign.[11]

Incorporating elastography findings into ultrasound assessment may help refine biopsy decisions. Lesions demonstrating benign morphological features and lacking peri-lesional stiffness may potentially be downgraded and managed with imaging follow-up rather than immediate biopsy. Conversely, lesions exhibiting a pronounced stiff rim sign may be considered highly suspicious for malignancy and therefore require biopsy or further diagnostic evaluation.[6]

Reducing unnecessary biopsies represents an important clinical benefit because biopsy procedures are invasive, costly, and associated with patient anxiety. Studies have suggested that elastography-based adjustments to BI-RADS classification may reduce the number of benign biopsies while maintaining high sensitivity for detecting malignancy.[17]

Risk of Bias and Limitations

The methodological quality of the included studies was generally acceptable, although several potential sources of bias should be considered. Some studies used retrospective designs, which may introduce selection bias and limit generalizability. In addition, variations in elastography acquisition protocols, stiffness thresholds, and imaging equipment may contribute to heterogeneity in reported diagnostic performance.

Differences in operator experience and ultrasound equipment settings may also influence elastography measurements. Because elastography is partially operator-dependent, standardized imaging protocols are necessary to ensure reproducibility across clinical settings.

Future Research Directions

Future research should focus on large multicenter prospective studies to validate the diagnostic value of the stiff rim sign across diverse populations and imaging systems. Standardization of elastography acquisition protocols and stiffness measurement thresholds would improve the comparability of findings between studies.

Another promising direction involves integrating elastography features with advanced imaging analysis techniques such as radiomics and machine learning. Combining quantitative elastography parameters with computational image analysis may further improve diagnostic accuracy and assist clinicians in differentiating benign from malignant breast lesions.

Longitudinal studies exploring the relationship between peri-lesional stiffness patterns and tumor biology may also provide valuable insights into the role of elastography in breast cancer diagnosis and prognosis.

Table 1. Characteristics and results of the included studies

No	Authors' name, Year	Research title	Population	Data	Findings
1	Suvannarerg et al., 2019[11]	Diagnostic performance of shear wave elastography for breast masses	228 women with 244 breast masses (148 benign, 96 malignant) undergoing US-guided biopsy	Sensitivity 73.96%, specificity 93.24%, PPV 87.65%, NPV 84.66%, AUC 0.836–0.905	SWE showed good diagnostic performance in differentiating benign and malignant breast masses. Combining SWE parameters improved diagnostic accuracy and allowed some BI-RADS 4A lesions to be downgraded, potentially reducing unnecessary biopsies.
2	Zhou et al., 2014[12]	Diagnostic value of stiff rim sign in shear wave elastography	156 women with 193 breast lesions (56 malignant, 137 benign)	Sensitivity 98.2%, specificity 92.0%, PPV 85.9%, NPV 99.2%, AUC 0.918	The stiff rim sign showed high diagnostic accuracy and improved differentiation between malignant and benign lesions when combined with conventional ultrasound.
3	Xiang et al., 2019[14]	Factors associated with stiff rim sign in breast lesions	907 breast lesions evaluated with ultrasound and SWE	Multivariate analysis evaluating factors associated with stiff rim sign appearance	Older age, larger lesion size, deeper lesions, poorly defined margins, heterogeneous internal components, and positive CDFI were significantly associated with the stiff rim sign in benign breast lesions.

No	Authors' name, Year	Research title	Population	Data	Findings
4	Kong et al., 2019[13]	Diagnostic value of peri-lesional stiffness using SWE	192 patients with 199 breast lesions (75 malignant, 124 benign)	Sensitivity 88.0%, specificity 89.5% for stiff rim sign	Combining stiff rim sign with BI-RADS increased sensitivity from 88.0% to 92.0% and improved diagnostic accuracy in differentiating benign and malignant lesions.
5	Xu et al., 2021[15]	Role of stiff rim sign in BI-RADS stratification and tumor staging	210 breast lesions evaluated using ultrasound and SWE	Increased PPV for tumor staging (≈30% vs B-mode ultrasound)	Stiff rim sign improved BI-RADS diagnostic stratification and helped identify lesions requiring biopsy while reducing unnecessary procedures.
6	Yu et al., 2022[10]	SWE prediction model for BI-RADS 3 and 4a lesions	468 patients with 488 breast lesions undergoing SWE and ultrasound	Sensitivity 93.6%, specificity 85.3%, AUC 0.850	SWE prediction model combining qualitative and quantitative parameters improved differentiation between benign and malignant lesions and assisted biopsy decision-making.

CONCLUSION

This review evaluated the role of the stiff rim sign, detected by shear-wave elastography, in assessing breast lesions, particularly in the context of BI-RADS category 3 and 4 masses. The findings suggest that the stiff rim sign represents a valuable qualitative elastography feature associated with malignant breast lesions. Across the included studies, peri-lesional stiffness patterns demonstrated moderate-to-high diagnostic performance and were consistently associated with malignant pathology. The presence of a stiff rim surrounding breast lesions likely reflects biological processes such as desmoplastic reaction, tumor infiltration into surrounding tissue, and stromal remodeling. These pathological changes contribute to increased stiffness in the peritumoral region, which can be visualized using shear-wave elastography. When incorporated into conventional ultrasound evaluation, the stiff rim sign may improve diagnostic confidence and assist clinicians in differentiating benign from malignant lesions.

Importantly, integrating elastography findings with BI-RADS classification may help refine biopsy decision-making for indeterminate breast lesions. The stiff rim sign may serve as an adjunct imaging indicator that helps identify lesions requiring biopsy while potentially reducing unnecessary invasive procedures in benign cases. Although the available evidence supports the diagnostic value of the stiff rim sign, further prospective multicenter studies with standardized elastography protocols are needed to confirm its clinical utility. Future research should also explore integrating elastography findings with advanced imaging analysis techniques to further enhance diagnostic accuracy. Overall, the stiff rim sign detected by shear-wave elastography represents a promising imaging biomarker that may improve risk stratification and the precision of management of breast lesions.

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AUTHORS CONTRIBUTION

All authors contributed substantially to the conception and design of the study. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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