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ORIGINAL RESEARCH

Role of US elastography in the diagnosis of breast cancer

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Abstract

Introduction Elastography is a clinical imaging technique that assesses tissue stiffness by comparing the elasticity of a target region with that of surrounding tissue. In breast imaging, it is employed to evaluate the stiffness of breast lesions, aiding in their characterization. When integrated with B-mode ultrasound (US), elastography enhances the ability to distinguish between benign, malignant, and suspicious lesions. The aim of this study was to compare the histological findings of the breast tissue with their elastographic values and determine whether the latter, being a non-invasive technique, can help to avoid unnecessary biopsies. Furthermore, we aim to identify cutoff values that may indicate malignancy of the lesion.

Materials and methods A retrospective study was conducted involving 40 women who underwent both shear wave elastography (SWE) and breast tissue biopsy. During the conventional B-mode ultrasound examination, SWE was also performed to obtain quantitative elasticity measurements. The SWE parameters included the maximum stiffness value within the lesion (*E*), the stiffness of the perilesional adipose tissue, and the corresponding elasticity ratio (*E*-ratio). Histopathological analysis of biopsy samples was used to confirm the nature of the lesions and to serve as the reference standard for diagnostic accuracy. In addition, B-mode ultrasound findings were compared with those obtained from SWE to assess their diagnostic performance.

Results 40 breast lesions were analyzed. E-ratio values tended to be lower in B2 lesions, consistent with benign pathology, and higher in B4–B5 lesions, suggesting malignancy. Malignant lesions also demonstrated greater heterogeneity and significantly higher stiffness values compared to benign lesions.

Conclusions Qualitative assessment of lesion elasticity and perilesional tissue stiffness demonstrated good discriminatory performance in differentiating breast lesions identified on ultrasound. These findings support the use of shear wave elastography as a complementary tool to conventional B-mode ultrasound in the diagnostic evaluation of breast masses.

Keywords Breast cancer · Early diagnosis · Strain elastosonography · Share wave elastosonography · Biopsy

Introduction

Elastosonography is an advanced diagnostic technique that, when combined with conventional ultrasound, provides a more detailed assessment of breast nodule stiffness and their resistance to deformation. While traditional ultrasound evaluates the acoustic properties of tissues, elastosonography focuses on their mechanical characteristics. Malignant lesions typically exhibit greater stiffness than the surrounding tissues, appearing less deformable and therefore more rigid. In contrast, benign lesions, often hyperplastic in nature, tend to be softer and more elastic. However, it is important to note that these features may overlap in certain cases, potentially complicating the diagnostic process [1–3].

Elastosonography relies on the application of an external force that induces tissue deformation, known as shear stress, which generates transverse shear waves that travel

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longitudinally along the axis of the ultrasound beam. Since these waves are rapidly attenuated as they propagate through biological tissues, it is crucial to employ very low frequencies or, in some cases, static compression in order to minimize signal loss [3–5].

There are two main techniques used to assess tissue elasticity: strain elastography (SE) and shear wave elastography (SWE) [6, 7].

Both methods provide complementary diagnostic information to conventional ultrasound, enabling a multiparametric approach to lesion characterization. Due to its ability to deliver additional data in a non-invasive and risk-free manner, elastography is gaining increasing acceptance and clinical relevance in diagnostic imaging [4, 5].

Strain elastography is the most widely used technique. It is based on tissue deformation induced either by manual compression applied through the ultrasound probe or by acoustic pulses, which produce displacement along the longitudinal axis. The resulting deformation is displayed as a color-coded elastogram, representing the relative elasticity of different tissue regions. However, the quality of the elastographic image is highly operator-dependent and can be affected by factors such as breast thickness, which may limit the accuracy of elasticity assessment [5–7].

Shear wave elastography, by contrast, measures the propagation speed of shear waves generated within tissues by focused ultrasound pulses. This automated technique—also referred to as "dynamic elastography"—is employed not only in breast imaging but also in the evaluation of musculoskeletal structures and other clinical applications. SWE enables both qualitative and quantitative assessments of tissue elasticity. By calculating shear wave velocity (SWV), it estimates the tissue's elastic modulus, expressed in kilopascals (kPa), which serves as an indicator of tissue stiffness [8].

In both techniques, regions of interest (ROIs) as large as possible are selected to optimize measurement accuracy. These ROIs are placed both within the lesion—encompassing its margins—and in the surrounding adipose tissue at the same depth, in order to enable a more accurate comparison. SWE, being less operator-dependent than SE, allows for more precise and reproducible measurements of tissue stiffness [6, 8].

The aim of this study is to evaluate the diagnostic performance of shear wave elastography, in comparison with conventional B-mode ultrasound, for differentiating benign from malignant breast lesions based on elasticity parameters.

Materials and methods

40 patients were enrolled in the study between 2021 and 2023, all presenting with breast lesions identified on ultrasound. Lesions were classified according to the BI-RADS (Breast Imaging Reporting and Data System) criteria [9].

The study population was divided into two subgroups: women under 40 years of age, who underwent ultrasound as the sole imaging modality, and women over 40 years, for whom diagnostic work-up included both ultrasound and mammography. All lesions were subjected to histopathological analysis, and the histological findings were compared with the results obtained from both conventional ultrasound and elastosonography.

Lesions initially categorized as benign on ultrasound were monitored over time; in cases of significant growth, patients subsequently underwent biopsy and histological confirmation. Each lesion underwent elastosonographic evaluation in conjunction with conventional ultrasound [7]. For elastographic analysis, regions of interest (ROIs) measuring 2 mm in diameter were placed both at the center of the lesion and within the surrounding adipose tissue at the same depth. Stiffness values were recorded in kilopascals (kPa) for both the lesion and the adjacent adipose tissue, and the ratio between the two—referred to as the *E*-ratio—was calculated.

Results

40 breast lesions were evaluated. Among them, benign lesions displayed typical ultrasound characteristics including oval shape, regular margins, homogeneous echotexture, and predominantly horizontal orientation. Malignant lesions were generally associated with irregular shape, inhomogeneous echotexture, posterior acoustic attenuation, and vertical orientation. These features were more consistently observed in lesions larger than 7 mm.

The *E*-ratio values obtained with shear wave elastography (SWE) varied according to the BI-RADS classification assigned via B-mode ultrasound:

- Lesions classified as B2 had a mean *E*-ratio of 2.97.
- Lesions classified as B3 had a mean *E*-ratio of 6.33.
- Lesions classified as B5 showed a mean *E*-ratio of 8.57.

Lesions initially assessed as benign on B-mode ultrasound demonstrated a mean *E*-ratio of 2.03. After histopathological evaluation, the subgroup of lesions confirmed as benign (B2) exhibited a slightly higher mean *E*-ratio of 2.97.

Lesions classified as malignant on ultrasound showed a mean *E*-ratio of 7.83. After histological confirmation, the mean *E*-ratio for the corresponding malignant lesions (B5) increased to 8.57 (Figs. 1, 2, and 3).

Among the 9 lesions classified as B3 (suspicious), histopathological analysis confirmed 3 as benign (B2) and 6 as non-benign (5 B5, 1 B3). The mean *E*-ratio for the 6 non-benign lesions was 9.53 (Fig. 4).

The sensitivity and specificity of SWE in differentiating between benign and malignant lesions were 93.7 and 88, respectively. The rate of false positives and false negatives was 5% and 2.5% with an overall diagnostic accuracy of 90.5%. Quantitative *E*-ratio measurements demonstrated strong correlation with histopathological outcomes.

Discussion

Shear wave elastography (SWE) represents an innovative, non-invasive, and quantitative tool for the evaluation of breast lesions. In contrast to strain elastography, which relies on manual compression and is highly operator-dependent, SWE provides objective and reproducible measurements by evaluating the velocity of shear wave propagation through tissues. This technique has shown particular utility in improving diagnostic performance while reducing variability due to operator technique [2, 6, 10, 11].

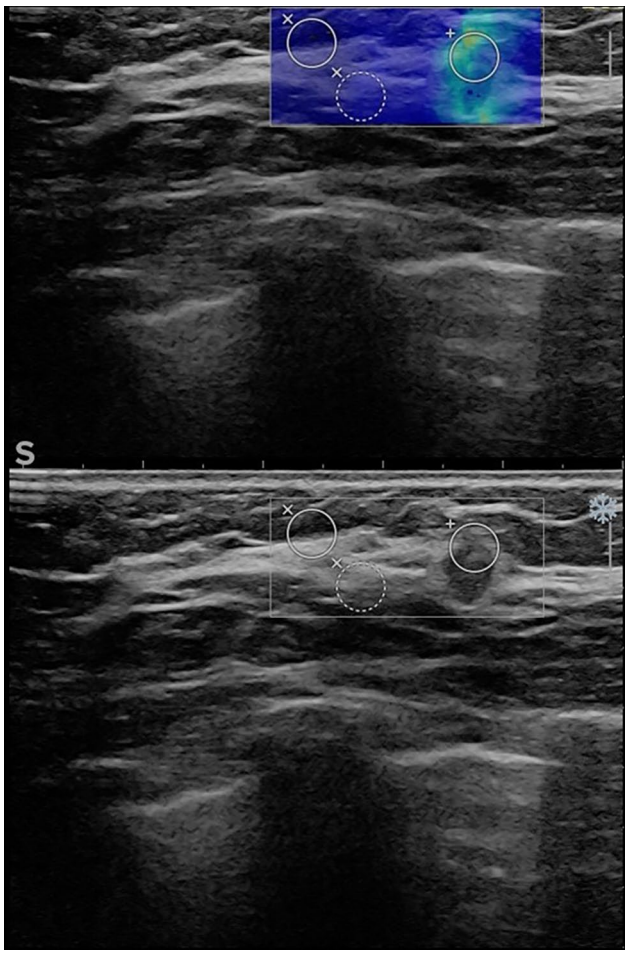

Fig. 1 B-mode ultrasound shows a small oval hypoechoic mass, with slightly irregular margins but without a posterior acoustic shadowing. The ultra-fast SWE shows in the colorimetric map a significant increase in the stiffness of the peripheral tissue, also supported by the numerical values of the ratio between kPa suspicious tissue/kPa healthy tissue (kPa ratio 15.69). The lesion resulted to be a non-special type invasive breast cancer (B5)

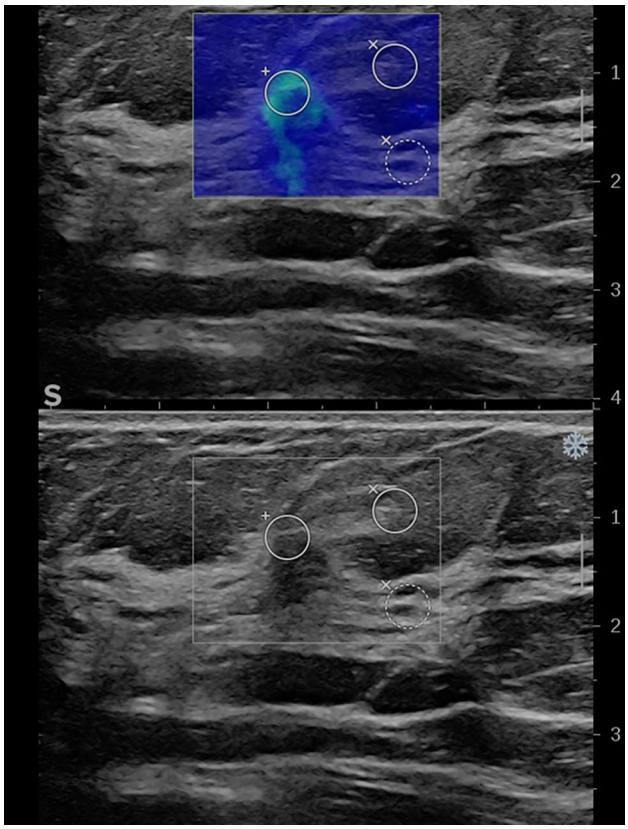

Fig. 2 B-mode ultrasound shows a small hypoechoic mass, with irregular margins and slight posterior acoustic shadowing. The ultra-fast SWE shows in the colorimetric map a significant increase in the stiffness of the peripheral tissue, also supported by the numerical values of the ratio between kPa suspicious tissue/kPa healthy tissue (kPa ratio 6.68). The lesion resulted to be a non-special type invasive breast cancer (B5)

The findings of the present study align with existing literature confirming the ability of SWE to discriminate between benign and malignant breast lesions based on tissue stiffness. In our cohort, malignant lesions consistently demonstrated higher *E*-ratio values than benign ones, with a mean *E*-ratio of 8.57 in B5 lesions compared to 2.97 in B2 lesions. Notably, suspicious lesions (BI-RADS 3) showed intermediate values (mean *E*-ratio 6.33), but histopathological examination revealed that most were malignant, highlighting the potential role of SWE in risk stratification of indeterminate findings.

This trend is supported by the meta-analysis conducted by Liu et al., which included over 5800 lesions and demonstrated a pooled sensitivity and specificity of approximately 88.6% and 86.6%, respectively, with an area under the curve (AUC) of 0.94. When SWE was combined with conventional B-mode ultrasound, diagnostic sensitivity increased further,

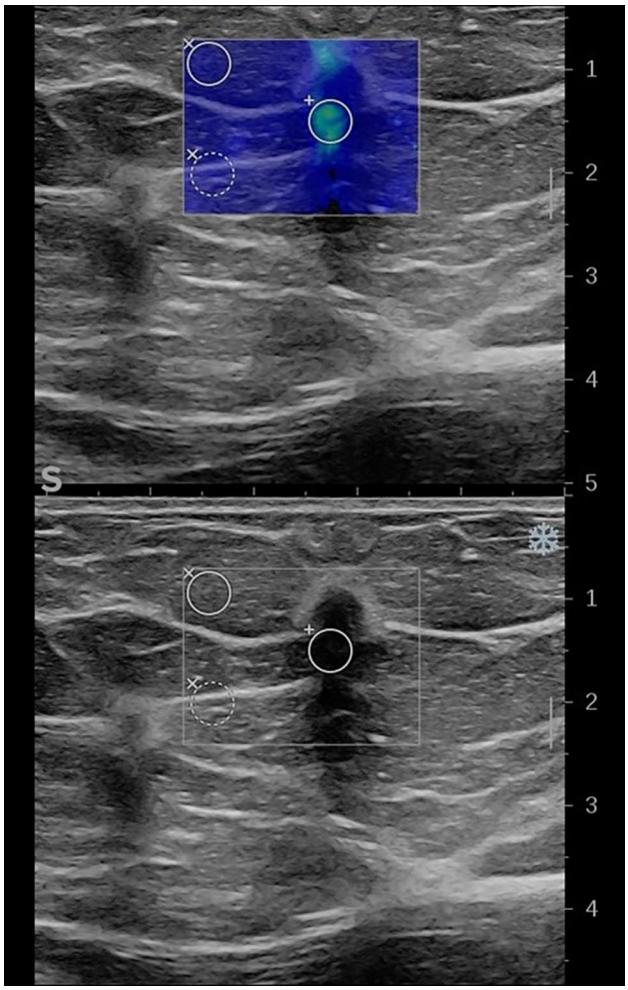

Fig. 3 B-mode ultrasound shows a small hypoechoic mass with irregular margins and posterior acoustic shadowing. Ultra-fast SWE shows in the colorimetric map a significant increase in the stiffness of the peripheral tissue, also supported by the numerical values of the ratio between kPa suspicious tissue/kPa healthy tissue (kPa ratio 7.31). The lesion resulted to be a non-special type invasive breast cancer (B5)

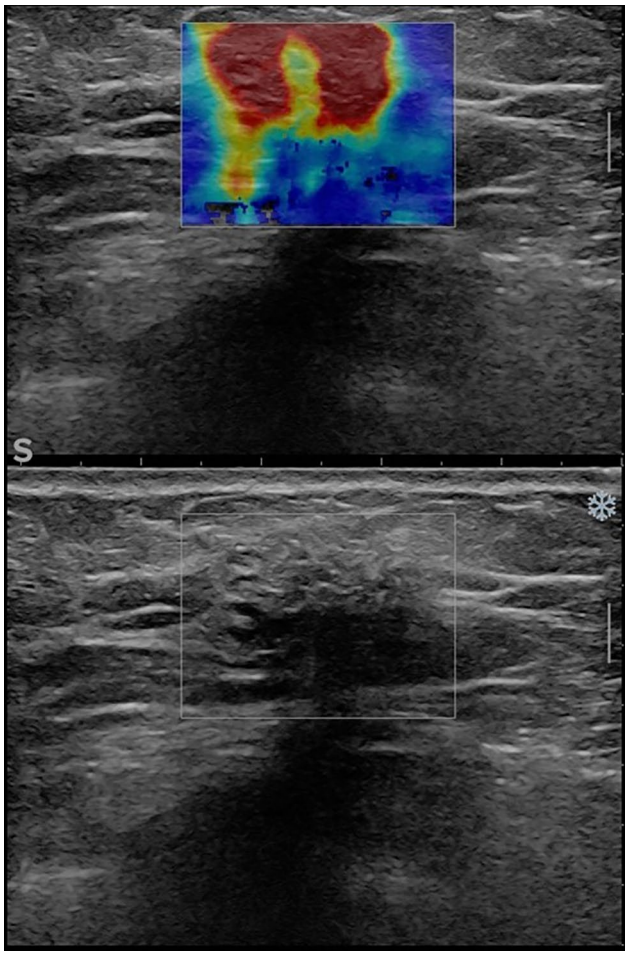

Fig. 4 B-mode ultrasound shows a non-mass lesion with posterior acoustic shadowing. Ultra-fast SWE shows in the colorimetric map a significant increase in stiffness both contextual to the lesion and in the peripheral tissue, also supported by the numerical values of the ratio between kPa suspicious tissue/kPa healthy tissue (kPa ratio 14.96). The lesion resulted to be a non-special type invasive breast cancer

reaching 97%, underscoring the complementary role of SWE in multiparametric imaging [12].

Similarly, Xue et al. confirmed SWE's high diagnostic accuracy in a separate meta-analysis including 4,546 breast lesions, reporting AUC values between 0.92 and 0.95. The authors emphasized the relevance of SWE in early cancer detection, particularly when used routinely alongside traditional imaging [13].

A more recent meta-analysis by Park and Kang (2021) specifically investigated the impact of adding SWE to B-mode ultrasound. Their results demonstrated a marked improvement in specificity (from ~ 61% to ~ 85%) while maintaining high sensitivity (~ 94%). Importantly, the combined approach enabled the downgrading of BI-RADS 4 lesions and a potential reduction of unnecessary biopsies by approximately 41% [14].

These findings mirror the results observed in our study, where E-ratio values in benign lesions remained low and stable, suggesting that SWE could support conservative management when imaging and clinical context are concordant.

Beyond overall stiffness values, recent studies have explored the role of elasticity heterogeneity. Huang et al. demonstrated that assessing intra-lesional stiffness variation significantly increased diagnostic sensitivity (up to 93.8%) without compromising specificity. Their results suggest that elasticity heterogeneity may be particularly useful in evaluating BI-RADS 4A lesions, which are often the most challenging from a diagnostic standpoint [15].

Regarding quantitative thresholds, Marukatat et al. proposed a lesion-to-fat E-ratio cutoff of approximately 5.89 and a mean elasticity value threshold of 90.35 kPa for malignancy prediction. In their study, SWE achieved sensitivity and specificity values around 87–89%, confirming the

technique's reliability when objective criteria are applied [16].

Taken together, these findings support the integration of SWE into standard breast imaging workflows. In particular, SWE appears especially valuable in the assessment of BI-RADS 3 and 4 lesions, where quantitative stiffness data can complement morphological criteria and guide more informed biopsy decisions. In addition, the reproducibility of SWE and its low inter-operator variability make it well suited for routine use and for monitoring lesion evolution over time.

Nevertheless, this study has some limitations. The sample size was relatively small potentially limiting external validity. Moreover, while ROI positioning was standardized, variability in lesion depth, size, and echotexture may still influence stiffness measurements. Future multicenter studies with larger and more heterogeneous populations are warranted to validate optimal E-ratio thresholds and standardize SWE protocols.

Conclusions

Shear wave elastography (SWE) represents a significant advancement in the diagnostic evaluation of breast lesions. Its ability to quantitatively assess tissue stiffness enables more accurate differentiation between benign and malignant lesions, contributing to timely diagnoses and potentially reducing the number of unnecessary biopsies. When integrated with conventional B-mode ultrasound, SWE enhances diagnostic confidence and supports more precise management, particularly in lesions with indeterminate characteristics.

The incorporation of SWE into routine clinical practice may lead to improved stratification of breast lesions, optimization of follow-up protocols, and a reduction in invasive procedures. Future research should aim to define standardized *E*-ratio cutoff values across diverse populations and validate the clinical utility of SWE in larger, multicenter settings.

Author contributions V.D.R., M.M. and C.C contributed to study conception, data collection, and participated in drafting the figures. C.C. designed the study, performed data collection and analysis, and wrote the first draft of the manuscript. V.V. participated in patient recruitment, ultrasound imaging, and data interpretation. C.P. was involved in data organization and bibliographic research. N.L. assisted in the data analysis and critically revised the manuscript. M.M. supervised the project, validated the final data, and provided substantial revisions to the manuscript. All the authors read and approved the final version of the manuscript.

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Data availability The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflicts of interest The authors have no conflicts of interest or competing interests to disclose.

Ethics approval This study was approved by the Ethics Committee of the University of Bari Aldo Moro, Italy (protocol number 6944).

Consent to participate Informed consent was obtained from all individual participants included in the study.

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