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Imaging Characterization of Local Breast Lesions Using Shear Wave Sono elastography

Shadan Jasim Mohammed* Saeed Nadhim Younis Agha**

Abstract

Background & objective: Advancements in breast tumor screening and diagnosis are crucial for improving treatment outcomes and reducing mortality rates. This study evaluated the diagnostic accuracy of integrating quantitative shear wave elastography with B-mode ultrasonography to differentiate benign from malignant breast lesions, keeping histopathology as reference standard.

Methods: This cross-sectional observational study implemented in Breast center in Erbil, Kurdistan, from May to September 2022. The women with breast mass were examined clinically by breast surgeon at the center and then referred to Radiology department for imaging. Both B-mode Ultrasound and Shear Wave Elastography were performed on 45 US-detected breast masses prior to any biopsy procedures. For each detected lesion, two key parameters were assessed: The Breast Imaging Reporting and Data System category based on B-mode ultrasound images and the mean elasticity values obtained from Shear Wave Sono elastography images. This dual approach aimed to provide a comprehensive evaluation of each lesion. Following the imaging, histopathological diagnoses were obtained for all lesions, taken as the gold standard.

Results: Histopathological examination, carried out by a specialized radiologist using core biopsy and Fine Needle Aspiration Cytology and analyzed by a pathologist with a consistent assessment protocol, revealed 55.6%benign and 44.4% malignant. B-mode ultrasound using the BI-RADS system, categorized 71.1% as BI-RADS 4, 15.6% as BI-RADS 5, and 13.3% as BI-RADS 3. Shear Wave Sono elastography proved critical, revealing significantly higher mean elasticity malignant cases ($p<0.001$. A strong correlation was found between increased elasticity and malignancy, as well as between elasticity and BI-RADS categorization ($p=0.004$). Malignant tumors had a direct link to elasticity ($p=0.02$). The optimal cutoff mean shear wave elasticity was 80 kPa with 90%sensitivity, 80% specificity and 84.4%accuracy.

Conclusions: Quantitative shear wave Sono elastography, combined with B-mode ultrasonography effectively categorize breast lesions, correlating strongly with histopathological findings. It emerges as a vital, non-invasive diagnostic tool, enhancing the accuracy of breast lesions characterization.

Keywords: BI-RADS, Breast mass, Shear wave elastography, Ultrasonography

*M.B.Ch.B., Rizgary Teaching Hospital, Radiology Department, Erbil, Iraq Corresponding author: E-mail: Shadan.jassim@yahoo.com

**M.B.Ch.B, DMRD, Ph.D., Professor of Radiology, Kurdistan Board of Medical Specialties, Erbil, Iraq E-mail: drsaeedagha@yahoo.com

Introduction

Breast malignancy, primarily impacting women, ranks among the top five malignancies leading to high mortality rates globally.[1] In the past three decades, its incidence and mortality rates have risen significantly with new cases reaching 2.7 million and approximately 800,000 deaths globally.[2] This surge is attributed to lifestyle modernization, improved diagnostics, and better registration, especially in developing countries.[3] In Iraq, the situation reflects this trend, with breast cancer incidence climbing from 52.00 to 91.66 per 100,000 in the last two decades.[4]Histopathology is the gold standard for diagnosis and grading breast malignancy, but it's invasive, complex, and expensive.[5]In contrast, imaging techniques like ultrasonography and mammography are pivotal in screening and diagnosis, being safer and more cost-effective. Ultrasonography is more sensitive than mammography, particularly in younger women.[6] Advanced techniques such as Shear wave elastography (SWE) have become valuable for characterizing breast masses. Shear wave Sono elastography an imaging equivalent of clinical palpation, provides quantitative measures of lesion stiffness and is incorporated in fifth edition of BIRADS lexicon. By measuring the speed of shear waves, it calculates tissue stiffness, with wave velocity indicating the tissue hardness.[7]In Kurdistan, lung cancer predominates in men, while breast cancer is more common in women.[8]with higher incidence among younger women than in broader Middle East and Western countries.[9]Despite infrastructural and economic challenges, advancements in imaging technologies have notably improved breast tumor diagnosis and screening in the region.[10]

Patients and methods

This prospective clinical follow-up study was conducted at a Breast Center in Erbil, Kurdistan, from May to September 2022, focusing on women with BI-RADS 3, 4, or 5 breast lesions identified via sonography. Excluding those with prior breast surgeries, cancer treatments, or lost to follow-up, forty-five women with breast masses were carefully selected based on the defined criteria. Ethical compliance was ensured in line with the Helsinki Declaration. The study was approved from the scientific committee of Kurdistan higher Council of Medical Specialties. Participants underwent clinical examinations and subsequent imaging at the Radiology department. Two specialized radiologists with long experience in Shear Wave Elastography (SWE) performed the ultrasound imaging using a high-frequency linear 8MHz Siemens machine including both B-mode and color Doppler. Lesions were categorized per the ACR BI-RADS lexicon, and SWE was conducted for targeted lesions. Selecting the appropriate elastography views is vital. The chosen views should most clearly display areas of abnormal stiffness, free from movement or pressure artifacts. Within these views, a specific region of interest (ROI) is selected for calculating the tissue's elasticity value. The mean elasticity value within this ROI is then considered the final measurement for analysis. "The color mapping in Shear Wave Elastography (SWE) provides an intuitive representation of tissue stiffness, overlaying a spectrum of colors onto grayscale ultrasound images for a detailed view of structure and elasticity. The color variation corresponds to tissue stiffness, with cooler tones indicating softer tissues and warmer tones indicating harder tissues. This aids clinician in quickly identifying areas of concern. Accurate application and interpretation of SWE's color map are essential for precise tissue stiffness assessment."

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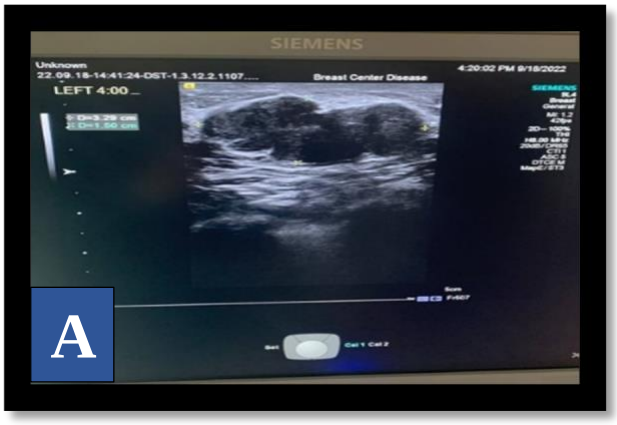


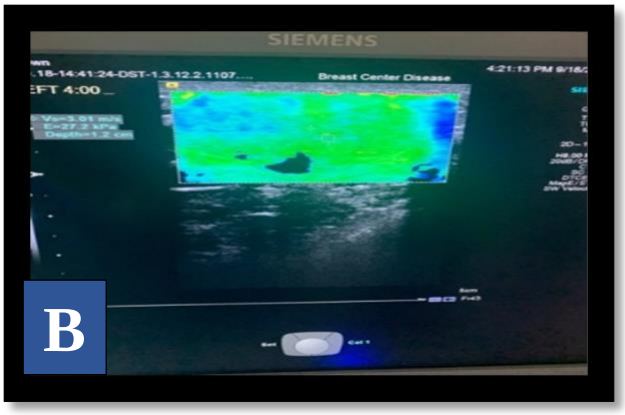
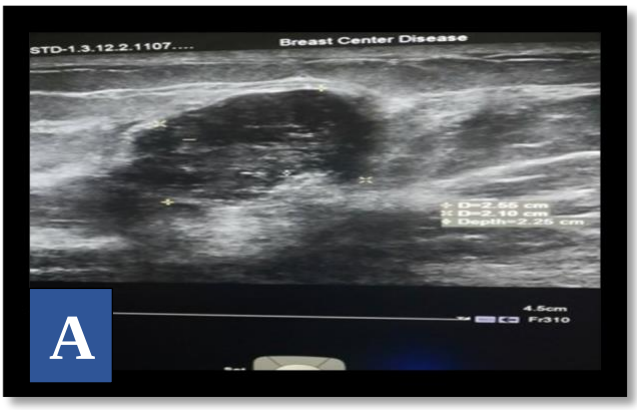


Figure (1): A 27-years-old women with palpable breast mass, (A) B mode ultrasound shows well circumscribed oval hypoechoic mass with angular margin inferiorly, (B) SWE shows the soft nature of mass (E mean=27 KPa). The final diagnosis was fibroadenoma by histopathology



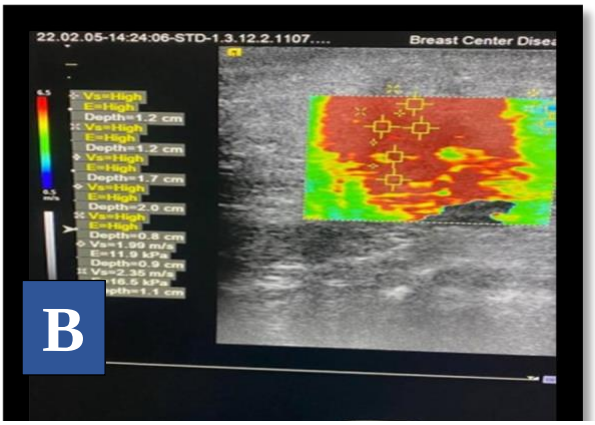


Figure (2): A 46 -years-old women with a family history of breast cancer. (A) B mode ultrasound (B) SWE. US shows suspicious lesion which appear hard on SWE (E mean> 120 KPa). The final diagnosis was Grade II invasive ductal carcinoma by histopathology

An 80 Kpa cutoff in SWE was used to distinguish benign from malignant lesions, balancing sensitivity and specificity for enhanced diagnostic accuracy. The choice of subsequent US-guided needle biopsies, be it FNAC or core biopsy were performed accordingly. Histopathological analyses were conducted by an expert pathologist in the center's laboratory unit. Follow-up continued until histopathology examination completion, through direct interviews or phone calls. Data was analyzed using SPSS (version 26), presented in descriptive tables. Statistical methods included Chi-square, Fisher's exact test, and t-test for variables. The ROC curve determined mean elasticity cutoffs for malignancy prediction, with significance set at a P-value of 0.05 or lower.

Results

The demographic analysis of 45 women with breast masses shows that the most prevalent age group was 40-49 years, accounting for 40% of the participants. This was followed by those under 40 years, constituting 33.3%, and the least common group was women aged 50

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years and older, at 26.7%. The mean age of participants was 44.3 years ± [standard deviation]. Additionally, 33.3% had a family history of breast tumors, indicating a potential genetic link. The majority of participants, about two-thirds, were premenopausal, while 31.1% were postmenopausal, providing insights into the incidence of breast masses across different stages of life. Moreover, a significant 82.2% of these women were married. This detailed demographic data, including age distribution, menopausal status, and marital status, is essential for interpreting the study's results and understanding the incidence of breast masses in various demographic groups. The results from this study highlight a significant correlation between age and the likelihood of breast malignancy, with a notable increase in breast cancer risk associated with higher age (p=0.05). However, the study also found that family history, menstrual status, and marital status did not exhibit significant differences in the incidence of malignant versus benign breast tumors. Specifically, family history showed a p-value of 0.67, menstrual status a p-value of 0.61, and marital status a p-value of 0.25, Table (1).

Table (1): Distribution of women's general characteristics according to breast tumor histopathology.

Variable	Breast tumor				p-value
	Totals	Benign	Malignant		
Age (mean±SD)					0.05 S
<40 years	33.3%	48.0%	15.0%		
40-49 years	40.0%	28.0%	55.0%		
≥50 years	26.7%	24.0%	30.0%		
Family history of breast tumor					0.67 NS
Yes	33.3%	36.0%	30.0%		
No	66.7%	64.0%	70.0%		
Menstrual status					0.61 NS
Premenopausal	68.9%	72.0%	65.0%		
Postmenopausal	31.1%	28.0%	35.0%		
Marital status					0.25 NS
Married	82.2%	88.0%	75.0%		
Unmarried	17.8%	12.0%	25.0%		

S=Significant, NS=Not significant.

The histopathology examination revealed 55.6% of breast masses were benign, with fibroadenoma being the most common at 36%, followed by Phyllodes tumor and fat necrosis at 12% each, and other benign conditions like breast abscess and fibroadenotic change each at 8%. Meanwhile, 44.4% were malignant, predominantly invasive ductal carcinoma Grade II (GII) at 70%, and other malignancies including invasive ductal carcinoma Grade I (GI) and Ductal Carcinoma in Situ (DCIS) at 10%

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each. Ultrasonography BI-RADS categorization showed 71.1% of masses as BI-RADS 4, 15.6% as BI-RADS 5, and 13.3% as BI-RADS 3, with a mean Shear Wave Elastography (SWE) value of 78.6 kPa,Table (2).

Table (2): Ultrasonic characteristics.

Variable	No.	%
Breast tumor type		
Malignant	20	44.4
Benign	25	55.6
BI-RADS		
BI-RAD 3	6	13.3
BI-RAD 4	32	71.1
BI-RAD 5	7	15.6
Mean Elasticity mean±SD (78.6±39.8 kPa)		
Total	45	100.0

The analysis of breast tumor characteristics in relation to Ultrasonography BI-RADS findings showed significant association was found between women categorized as BI-RADS 5 and the presence of breast malignancy, with a p-value of 0.01. This indicates a strong likelihood of malignancy in breast masses classified as BI-RADS 5. Furthermore, the mean elasticity, as measured by Shear Wave Elastography (SWE), was significantly higher in women with breast malignancy (p<0.001). This suggests that higher elasticity values are a strong indicator of malignancy in breast masses, Table (3).

Table (3): Distribution of breast tumor characteristics according to US BIRAD findings.

Variable	Breast tumor				P
	Benign		Malignant		
	No.	%	No.	%	
BI-RADS					0.01 S
BI-RAD 3	2	8.0	4	20.0	
BI-RAD 4	22	88.0	10	50.0	
BI-RAD 5	1	4.0	6	30.0	
Mean Elasticity					<0.001 S
Mean±SD (kPa)	41.9±9.5		114.6±19		

S=Significant.

As shown in Figure (3), the mean elasticity was significantly related to BI-RADS classification of women (p=0.004). Specifically, higher mean elasticity values were observed in women categorized as BI-RADS 5, indicating that increased elasticity is associated with this higher-risk category.

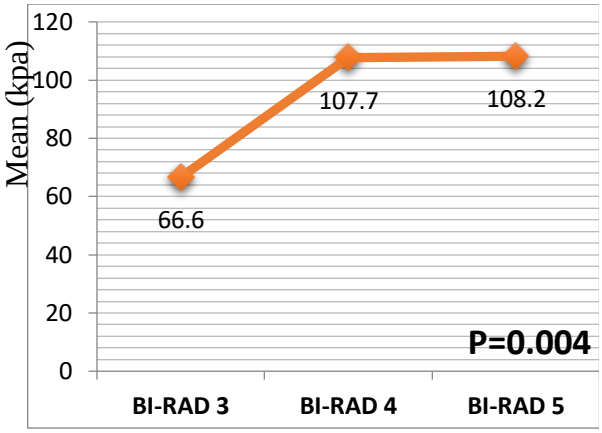

Figure (3): Elasticity mean distribution according to BI-RADS of breast tumor.

As shown in Figure (4), the mean elasticity was significantly related to malignant breasttumors(p=0.02), Women with invasive ductal carcinomas Grades II and III displayed higher elasticity values, suggesting that greater tissue stiffness correlates with these more severe forms of breast malignancy.

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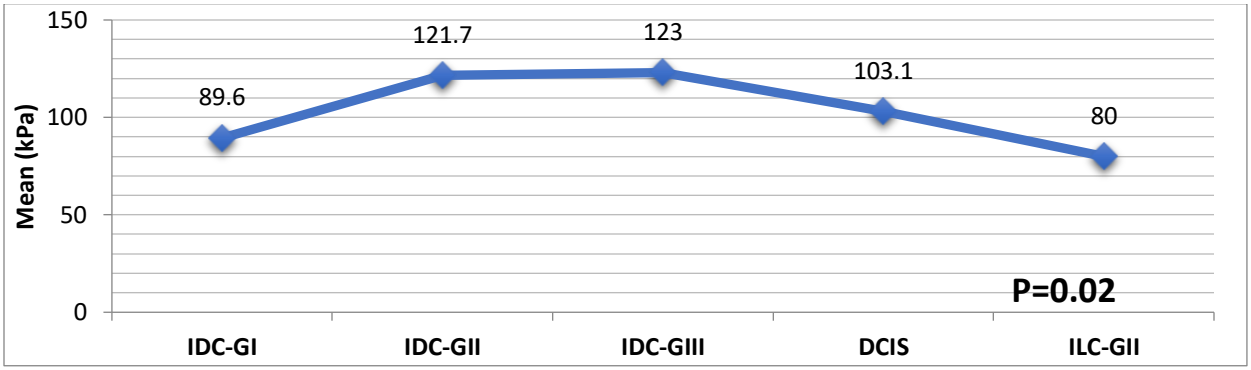

Figure (4): Elasticity mean distribution according to malignant breast tumors.
An optimal cutoff value of mean shear wave elasticity for diagnosing malignant breast tumors was determined to be 80 kPawith a sensitivity 90%, specificity of 80% and an accuracy of (84.4%), Table (5) and Figure (5).

Table (5): ROC validity findings of mean elasticity in relation to malignancy.

Mean Elasticity (kPa)	Sensitivity	Specificity	PPV	NPV	Accuracy
68.7	100%	76%	76.9%	100.0%	86.8%
74.5	95%	76%	76%	95%	84.4%
80	90%	80%	78.2%	90.9%	84.4%
81	85%	84%	80.9%	87.5%	84.4%
86	85%	88%	85%	88%	86.6%

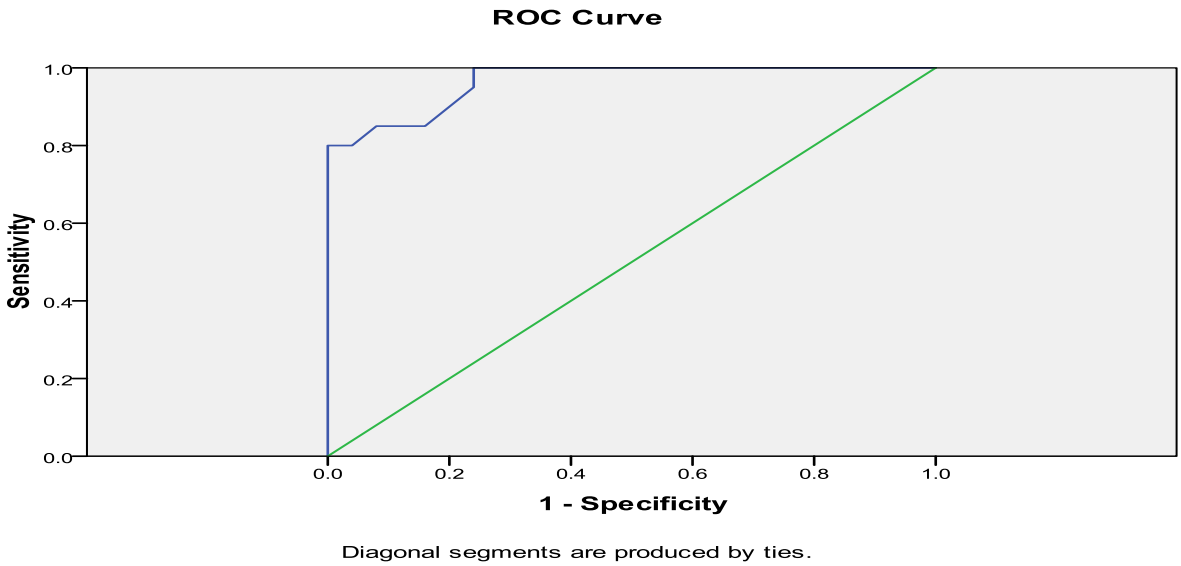

Figure (5): ROC curve of Elasticity mean in prediction of malignant breast tumors (AUC=0.96).

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Discussion

The significance of the study lies in its detailed examination of Shear Wave Elastography's (SWE) application in breast tumor diagnosis, emphasizing its critical role in distinguishing between benign and malignant lesions. By analyzing the association between BI-RADS categorization, mean elasticity values, and histopathological results, SWE offers a non-invasive, reliable method to assess tissue stiffness, which is essential for accurate diagnosis. In our study, approximately 29% of BI-RADS 4 lesions were malignant, paralleling findings by Liu et al.[11] where 37.3% of lesions classified as BI-RADS 4 were malignant. This highlights the ambiguous nature of BI-RADS 4 lesions, underscoring the necessity of supplementary diagnostic measures. Comparatively, Chang et al.[12] reported higher mean elasticity values in malignant cases (153.3 kPa ± 58.1) compared to benign ones (46.1 kPa ± 42.9), with a significant difference ($P < 0.0001$) aligning with our results where malignant lesions showed a mean elasticity of 114.6±19 kPa, and benign ones at 41.9±9.5 kPa with a significant difference ($P < 0.001$).Notably, Gu et al's[13] study showed significant correlations between mean elasticity in SWE and BI-RADS, with E mean (kPa) for benign lesions at 24.0 ± 19.3 versus 81.8 ± 38.3 for malignant lesions. In our study, E mean (kPa) for benign lesions was 41.9±9.5 versus 114.6±19 for malignant ones. We established an optimal SWE cutoff at 80 kPa, balancing sensitivity (90%) and specificity (80%) with an accuracy of 84.4%, superior to Yang et al.[14] and Chamming's et al.'s[15]studies, which documented sensitivity and specificity of 86% and 83.3%, respectively, with a 64 kPa cutoff. Our results are closer to Kadhim and Abed's[16] findings, suggesting an 83 kPa cutoff with 89.5% sensitivity, 60.9% specificity, and 73.8% accuracy. Park et al[17] and Choi et al[18] used an 85.1 KPa cutoff, yielding different diagnostic parameters compared to ours: the former reported 68.4% sensitivity, 93.2% specificity, and 80% accuracy, while the latter reported 78.4% sensitivity, 95.2% specificity, and 84.5% accuracy. Variations in the outcomes of SWE-related studies can be attributed to several factors. Firstly, the sample size can significantly impact the study's conclusions. Additionally, disease-related aspects such as duration, grading, and particularly lesion size play a crucial role. For instance, very large lesions might extend beyond the maximum 5-cm SWE overlay or even the ultrasound's field of view. In such cases, there's a risk that the examiner might not capture the stiffest part of the mass, potentially leading to inaccurate assessments of tissue stiffness via shear wave elastography. Furthermore, factors related to the ultrasound device itself are influential. These include the operator's experience and proficiency with the equipment, the degree of probe compression during the examination, and the placement of the region of interest (ROI). If the ROI is positioned away from the stiffest portion of the lesion or adjacent tissue, it could result in a less accurate evaluation of the lesion's elasticity. Therefore, the methodology and precision in conducting SWE are as crucial as the technology itself for reliable diagnostic outcomes.

Conclusion

This study effectively demonstrates the utility of combining quantitative shear wave elastography with B-mode ultrasonography in the characterization of breast lesions. By correlating these imaging findings with histopathology examinations, our results indicate a significant potential for accurately differentiating between benign and malignant breast lesions. This approach not only enhances the diagnostic accuracy but also offers a non-invasive, cost-effective alternative to traditional methods, providing

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a valuable tool for clinicians in the effective management of breast cancer.

Conflicts of interest

None.

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