ADDIS ABABA UNIVERSITY

SCHOOL OF MEDICINE

DEPARTMENT OF RADIOLOGY

EVALUATION OF FOCAL BREAST LESIONS USING ULTRASOUND ELASTOGRAPHY WITH FNAC AND/OR HISTOPATHOLOGY CORRELATION AMONG PATIENTS VISITING BREAST ULTRASOUND AND MAMMOGRAPHY UNIT RADIOLOGY DEPARTMENT OF TIKUR ANBESA SPECIALIZED HOSPITAL

By- Dr. BereketEngedasew(MD, Radiology Resident)

A RESEARCH THESIS SUBMITTED TO ADDIS ABABA UNIVERSITY, COLLEGE OF HEALTH SCIENCES, SCHOOL OF MEDICINE, DEPARTMENT OF RADIOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR SPECIALITY CERTIFICATE OF RADIOLOGY

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Full title of the research project	Evaluation of focal breast lesions using ultrasound elastography with FNAC and/or histopathology correlation among patients visiting breast ultrasound and mammography unit of radiology department of TikurAnbesa Specialized Hospital
Duration of project	January 1 to April 30, 2025 G.C
Study area	TikurAnbesa Specialized Hospital (TASH), Addis Ababa Ethiopia
Total cost of the project	69690.00 Ethiopian birr
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APPROVAL SHEET

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I, the undersigned Radiology Resident, declared that I have submitted my original work on a title: "*EVALUATION OF FOCAL BREAST LESIONS USING ULTRASOUND ELASTOGRAPHY WITH FNAC AND/OR HISTOPATHOLOGY CORRELATION AMONG PATIENTS VISITING BREAST ULTRASOUND AND MAMMOGRAPHY UNIT OF RADIOLOGY DEPARTMENT OF TIKUR ANBESA SPECIALIZED HOSPITAL, 2025*" for examination.

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APPROVAL BY BOARD OF EXAMINATION

This thesis by DR. BEREKET ENGEDASEW is accepted in its present form by the board of examiners as a requirement for the certificate of radiology.

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Statement of the author

By my signature below, I declare that this thesis is my own work. I followed the ethical guidelines while preparing the paper, collecting data and analyzing data. I declare that this thesis has not been submitted to any other institution for any academic degree, diploma, or certificate.

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Acronyms and Abbreviations

TASH-TikurAnbesa Specialized Hospital

ACR- American college of Radiology

AUC- Area Under curve

BIRADS-Breast Imaging Reporting and Data System

CNB- Core needle biopsy

DA-Diagnostic accuracy

ES- Elasticity score

FNAC- Fine needle aspiration cytology

NPV- Negative Predictive Value

PPV- Positive predictive value

ROI- Region of interest

ROC- Receiver operating characteristic

S- Sensitivity

SP- Specificity

SR- Strain ratio

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Abstract

Background*: Breast cancer is one of the most common causes of illness and death in Ethiopia and worldwide. In Ethiopia, diagnosis has usually relied on clinical palpation, mammography, and B-mode ultrasonography (US). Biopsy is still the best method for a definitive diagnosis. Recently, elastography has emerged as a useful tool alongside B-mode US. It improves specificity and helps in the early detection of breast cancer. By determining the need for biopsy procedures, elastography reduces both false-positive and unnecessary outcomes. However, it is still largely unexplored in Ethiopian clinical practice. This study aimed to examine the impact of ultrasound elastography on characterizing breast lesions and reducing unnecessary biopsies in our context.*

Methodology*: From January 1 to April 30, 2025, we conducted a prospective analytical cross-sectional study at TikurAnbessa Specialized Hospital (TASH) to evaluate focal breast and post-mastectomy chest wall lesions using ultrasound elastography. We correlated the results with fine needle aspiration cytology (FNAC) or core needle biopsy (CNB). We used structured checklists based on the ACR BI-RADS guidelines to collect data. A single radiologist trained in breast elastography acquired the images. The data was analyzed using IBM SPSS version 25.*

Result*: In this study100 patients were included and among this 72% had malignant lesions, 26% had benign lesions, and 2% showed atypical findings. The most common malignant lesion was invasive carcinoma and most common benign lesion was fibroadenoma. ROC analysis revealed that the BI-RADS classification alone had excellent sensitivity at 98.6% but poor specificity at 10.7%. Including elasticity scoring and strain ratio significantly improved diagnostic accuracy. Elasticity scoring had a sensitivity of 96% and a specificity of 68%. The strain ratio achieved 97.2% sensitivity and 57.2% specificity. When all three methods were used together, parallel testing resulted in perfect sensitivity and negative predictive value at 100%, but very low specificity at 4.3%. The serial testing method provided more balanced outcome, with 91.3% sensitivity, 87.7% specificity, and an overall accuracy of 91%. This suggests serial testing method has superior clinical value in reducing false positives.*

Conclusion*: These findings shows that the clinical importance of combining the BI-RADS category, elasticity score, and strain ratio during ultrasound diagnosis of breast lesions. The results support using multiparametric ultrasound techniques in routine practice to improve diagnostic accuracy, decrease unnecessary biopsies, and optimize patient management. Regular uses of elastography, especially in resource-limited areas help resolve diagnostic challenges.*

Keywords: *Breast cancer, Elastography, BI-RADS, Strain ratio, Elasticity score, Diagnostic performance*

CHAPTER ONE: INTRODUCTION

1.1. Background

In 2022, worldwide breast cancer were diagnosed in approximately 2.3 million women and had 670, 000 death globally (1). It is the leading cancer in Ethiopia and has 16,133 incidences in 2020. It also become most common cause of cancer morbidity among adult women, constituting 33% of all cancer cases in women and 20% of all cancers overall (2).

Historically, breast cancer diagnosis in Ethiopia relied on traditional methods such as palpation, mammography, and ultrasonography (US). While these methods provided valuable diagnostic insights, their accuracy and predictive value varied (3). For definitive diagnosis histopathology examination remained the gold.

Ultrasound (US) widely utilized as a screening tool for breast cancer because of its noninvasive nature, real time dynamic image and simplicity. But because it has to low specificity it has limitation in differentiating benign and malignant breast lesion. This leads to the need for frequent follow-up of BI-RADS 3 lesions and increased number of category 4 breast lesions being biopsied (4). BI-RADS 4 lesions are further subdivided into categories 4a, 4b, and 4c. BI-RADS category 4a lesion typically had malignancy rate of ranging from 2% to 10%, meaning that most biopsies in this category yield benign results (4, 5).

In 1991, Ophir et al. introduced ultrasound elastography, a non-invasive technique that assesses tissue stiffness under external compression, mimicking clinical palpation (6). Elastography provides valuable additional information about tissue properties thereby enhancing the ability to differentiate benign from malignant lesions and increasing diagnostic yield for breast cancer (7). Since its introduction, elastography was used for characterizing breast lesions and has been applied to other organs such as the thyroid, prostate, liver, and musculoskeletal system.

Currently there are two types of elastography techniques. This are strain elastography and shear wave elastography which are employed in clinical practice, each with its own set of advantages and limitations. Ultrasound elastography was incorporated into the 5th edition of the ACR BI-RADS lexicon, further standardizing its role in breast cancer diagnosis (8). Bojanic et al. demonstrated that BI-RADS classification of breast lesions can be modified using elastographyeither to upgrade or downgrade the lesion'swhich may help in reducing unnecessary biopsies and improving overall diagnostic accuracy.

1.2. Statement of the Problem

American College of Radiology (ACR) Breast Imaging-Reporting and Data System (BI-RADS) lexicon commonly used conventional B-mode ultrasonography modality for evaluating and categorization of breast lesions. While this system helps guide clinical decision-making, BI-RADS 3 or 4A breast lesions present diagnostic challenge for both clinicians and radiologists. BI-RADS 3 lesions have a low suspicion of malignancy, with malignancy rates reported to be less than 10%. Approximately 98% of BI-RADS category 3 lesions are histologically benign and recommended to have short-term follow-up. However, about 2% of the lesions diagnosed as malignant lesion on subsequent follow up. Poor adherence for follow up in BIRADS category 3 lesions due to lack of awareness and financial constraints, has led clinicians to opt for biopsy, which in most cases yields negative results (10).

BI-RADS category 4 lesions, indicating a low to moderate risk of malignancy (ranging from 2% to 94%), are typically recommended for biopsy to further assess malignancy. Among these, BI-RADS category 4A lesions had 2% to 9% malignancy rate and more than 90% of benign breast lesions undergo unnecessary biopsy procedures which could potentially be avoided with more accurate non-invasive imaging techniques (10). In recent years B mode ultrasound aided by elastography enhanced the specificity of ultrasound thereby enhancing earlier detection of breast cancer. Specifically, quantitative elastography i.e. strain ratio shown to improve diagnostic accuracy for lesions with equivocal ultrasound features (e.g., BI-RADS 3 and 4) (11). By assisting clinicians in determining whether a biopsy is necessary, elastography helps reduce the rate of false positives and unnecessary procedures (12, 13).

Different studies have demonstrated the value of combining elastography and B-mode ultrasound in downgrading BI-RADS category 4A lesions, thereby reducing unnecessary biopsies. For instance, some studies have shown that BI-RADS category 4A a lesion that has low elastic score on elastography were not malignant, suggesting that these could be managed conservatively with follow-up rather than biopsy (13). Other research has similarly supported elastography's role in improving specificity for BI-RADS 4A lesions and avoiding benign biopsies through more accurate risk stratification (14, 15). Despite these findings, biopsies continue to be routinely taken for all BI-RADS category 4A lesions in clinical practice. The continued reliance on biopsies for benign lesions has introduced several challenges, including the risk of infection, patient anxiety, discomfort, dependence on operator experience, and increased healthcare costs.

While elastography's role in breast lesion detection and characterization has been explored in various studies from Western and Asian countries, it has not yet been widely integrated into clinical practice in our local setting. As a result the potential of elatography in breast lesion characterizationremains largely unexplored and underutilized.

1.3. Significance of study

- It provided information on the value of elastography in the characterization and detection different types of breast lesions.
- It also assessed the added value of elastography in differentiating between benign and malignant breast lesions, demonstrating its potential to enhance diagnostic accuracy.
- Based on the findings, further recommendations were made to support the incorporation of strain elastography into routine clinical practice.
- The study also emphasized the importance of promoting ongoing research to explore additional applications of elastography across various medical fields and to validate its effectiveness and reliability in diverse patient populations.

CHAPTER TWO: LITERATURE REVIEW

Numerous prospective studies conducted globally- including in countries such as India, Bangladesh, Pakistan, Japan, South Korea, Germany, Brazil, and Egypt- have investigated the utility of ultrasound elastography in evaluation of breast lesions. These studies consistently employed essential diagnostic parameters, including BI-RADS classification, elasticity scores, and strain ratio measurements. In most cases, imaging findings were correlated with histopathological outcomes results, reinforcing the reliability of elastography as a complementary diagnostic tool.

In India, a prospective study conducted at Katihar Medical College and Hospital assessed 120 patients with sonographically detected breast lesions using elastography, comparing results with histopathological and/or FNAC confirmation. Among these, 54 lesions (48.3%) were malignant and 58 (51.7%) benign. Malignant lesions demonstrated higher mean elasticity scores (3.42) and strain ratios (6.05) compared to benign lesions (1.88 and 2.63, respectively). Using an elasticity score cutoff of 3, the study reported excellent diagnostic performance with an AUC of 0.944, sensitivity of 97.0%, and specificity of 86.7%. Similarly, a strain ratio cutoff of 3.8 yielded an AUC of 0.952, sensitivity of 93.3%, and specificity of 95.5%, with a strong correlation (r = 0.7989) between elasticity scores and strain ratios (16).

A comparable study at a tertiary government teaching hospital examined 116 lesions (56 malignant, 60 benign), reporting an elasticity score cutoff of 3.5 with a sensitivity of 83.9%, specificity of 91.7%, and an AUC of 0.924. For strain ratios, a cutoff of 2.94 provided 91.1% sensitivity and 88.3% specificity (AUC = 0.969), with a very strong correlation (r = 0.936) between the elastography parameters (17). At Aster CMI Hospital, a study on 113 breast lesions showed that elastography significantly improved diagnostic accuracy over conventional ultrasound, with an AUC of 0.98 versus 0.90 (P = 0.02). The combined approach yielded 95% sensitivity, 94% specificity, and a negative predictive value of 97%, demonstrating its enhanced diagnostic performance (18).

Other Indian institutions also reported consistent findings. A cross-sectional study at JSS Hospital involving 90 patients noted that elastography had higher sensitivity (95.65%) but lower specificity (68.18%) than B-mode ultrasound, which showed 71.74% sensitivity and 90.91% specificity (19). Several smaller studies including those at Ramal Medical College and DrUlhasPatil Medical College confirmed the association between higher elasticity scores and malignancy. The latter study, with 90 women, reported diagnostic performance metrics of 93.6% sensitivity, 88.1% specificity, 92.86% PPV, 91.27% NPV, and 86.05% accuracy, further validating elastography's reliability (20, 21, and 22).

In Bangladesh, a cross-sectional study involving 104 women found a high diagnostic accuracy (91.3%) for strain elastography. Benign lesions had a mean strain ratio (SR) of 2.73, and malignant lesions had a mean SR of 8.1. Sensitivity, specificity, PPV, and NPV were 94.9%, 80%, 93.7%, and 83.3%, respectively. In Pakistan, a prospective observational study involving

200 women showed that shear wave elastography (mean score = 4.5) outperformed strain elastography (mean score = 3.2), with sensitivities and specificities around 85–90% for both benign and malignant lesions (23, 24).

A Japanese study assessing 170 ultrasonographically detected masses reported good performance of the E-index (sensitivity 85%, specificity 86%, AUC = 0.860) and slightly lower values for the E-ratio (sensitivity 78%, specificity 74%, AUC = 0.780). However, diagnostic challenges remained for certain lesions, such as DCIS and intraductalpapillomas, which showed overlapping elasticity values(25).

In South Korea, elastography was used to reclassify BI-RADS 4A lesions based on patient risk profiles. Among 255 lesions, those categorized as "soft" on elastography had significantly lower malignancy rates in average-risk women (1.5% vs. 14.2%, P = 0.004), suggesting a potential role in avoiding unnecessary biopsies. Another study in Seoul examined post-mastectomy chest wall lesions, demonstrating the value of BI-RADS in stratifying malignancy risk, with PPVs of 14.3% and 100% for BI-RADS 4A and 5 lesions respectively(26, 27).

A German hospital-based study on 108 patient compared B-mode ultrasound and elastography. B-mode showed higher sensitivity (91.8%) but lower specificity (78%), while elastography (observer 1 and 2) showed specificity of 91.5% and 84.7%, and sensitivities of 77.6% and 79.6%, respectively. Notably, deeper lesions (>1 cm from the skin surface) were more challenging to assess accurately with elastography (28).

In Brazil, a large scale study of 929 lesions showed improved diagnostic metrics when elastography was integrated with BI-RADS classification. Ultrasound alone yielded sensitivity, specificity, and accuracy of 93.85%, 72.07%, and 76.64%, respectively, while the addition of elastography increased these to 95.90%, 80.65%, and 91.39% (29).

Finally, a prospective comparative study at Suez Canal University in Egypt assessed 132 solid breast masses using elastography. The performance was comparable between strain ratio (AUC = 0.916), mean elasticity (AUC = 0.884), and stiff ratio (AUC = 0.872). When combined with B-mode ultrasound, diagnostic accuracy improved further (AUC = 0.920 for strain, 0.952 for shear wave; P < 0.001), with statistically significant enhancement over standalone techniques (P = 0.02) (30).

In summary, the global body of literature demonstrates that ultrasound elastography—especially when combined with traditional B-mode imaging—significantly enhances the diagnostic evaluation of breast lesions. It improves sensitivity, specificity, and overall accuracy, with strong agreement across diverse populations and healthcare settings.

CHAPTER THREE: OBJECTIVE

3.1. General Objective

The aim of this study was to evaluate focal breast and post-mastectomy chest wall lesions using ultrasound elastography and correlate the findings with FNAC/CNB among patients who visited the Breast and Mammography Unit, Radiology Department, TASH, between December 1, 2024, and April 30, 2025.

3.2. Specific Objectives

To determine the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of ultrasound elastography in diagnosing benign and malignant focal breast and post-mastectomy chest wall lesions among patients who visited the Breast and Mammography Unit, Radiology Department, TASH, during the study period.

CHAPTER 4: METHODOLOGY

4.1. Study Area and Period

The study was conducted at Tikur Anbessa Specialized Hospital (TASH) in Addis Ababa which is the main teaching hospital for various disciplines within the School of Medicine at Addis Ababa University. The hospital provides various clinical services. The study was carried out from December 1, 2024, to April 30, 2025.

4.2. Study Design

Prospective analytical cross sectional study was conducted to evaluate focal breast and post-mastectomy chest wall lesions using ultrasound elastography, with correlation to FNAC/CNB findings at TASH.

4.3. Source Population

The source population included all patients visiting the Breast and Mammography Unit of the Radiology Department at TASH.

4.4. Study Population

The study population consisted of eligible patients who met the inclusion and exclusion criteria.

4.5. Inclusion and Exclusion Criteria

4.5.1. Inclusion Criteria

Females aged 16 to 80 years with B- mode ultrasound detectable solid breast lesions measuring less than 3 cm and classified as BI-RADS categories 3, 4, or 5.
BI-RADS 3 lesions that are included are lesions which underwent fine needle aspiration cytology (FNAC) or biopsy based on clinical or patient request.

4.5.2. Exclusion Criteria

Excluded lesions are BI-RADS category 2 lesions, lesions located near the skin surface or chest wall, lesions without cytological or histopathological diagnosis and breast lesions larger than 3 cm.

4.6. Variables

Dependent Variables- BI-RADS score, Elasticity score, Strain ratio

Independent Variable- Age, FNAC/CNB, morphologic characteristics of breast and post mastectomy chest wall lesion

4.7. Sample Size and Sampling Technique

Total sample size using P of 0.9 was 138 and estimating 5% non-response rate the total sample size was 145. A convenience sampling technique was used.

4.8. Data Collection Tools and Techniques

4.8.1. Data Collection Tool

A pre-prepared data collection checklist adapted from ACR BIRADS guideline was used as the primary tool for data collection.

4.8.2. Equipment

Mindray DC-60 Exp system, using the L14-6NE high-frequency linear array transducer was utilized for the examinations.

4.8.3. Conventional Sonography

Lesions were initially evaluated using ultrasonography. The precise location of each lesion was documented in the reports. Each lesion was classified into an appropriate BI-RADS category using ultrasound features such as shape, orientation, echotexture, margin and posterior acoustic characteristics.

4.8.4.Elastography Technique and Parameters

Elastographic data were acquired in the region from the subcutaneous fat layer to the pectoralis muscle, carefully avoiding the rib cage by setting the field-of-view box. The entire lesion should be captured within the field of view. Vertical compression was applied using light, controlled pressure with the transducer. Optimal compression was confirmed by observing two to three green blocks on the vertical bardisplay on the ultrasound monitor left side; inadequate compression appeared as one or no block, and excessive pressure was indicated by more than fourblocks.

Elasticity scores determined based on the 5-point Tsukuba classification proposed by Itoh et al (31):

Score 1: The lesion appeared uniformly green, indicating soft, homogeneous strain throughout.

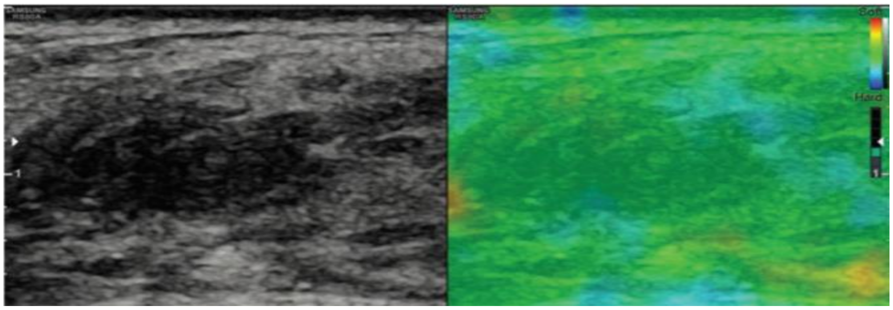

Fig 1- Breast lesion which has similar green shading on elastographyrepresenting fat necrosis suggesting score of 1.

Score 2: A mixture of green and blue indicated a mostly soft lesion with some stiff areas.

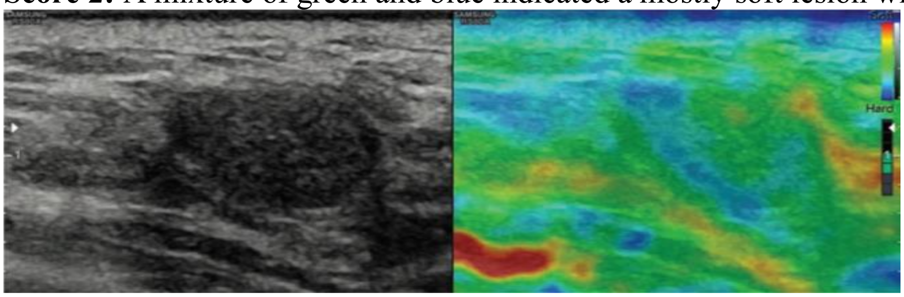

Fig 2-Breast lesion which shows both green and blue color shading representing fibro adenoma suggesting a score of 2.

Score 3: Peripheral green with a blue center reflected strain at the lesion's edges and stiffness centrally.

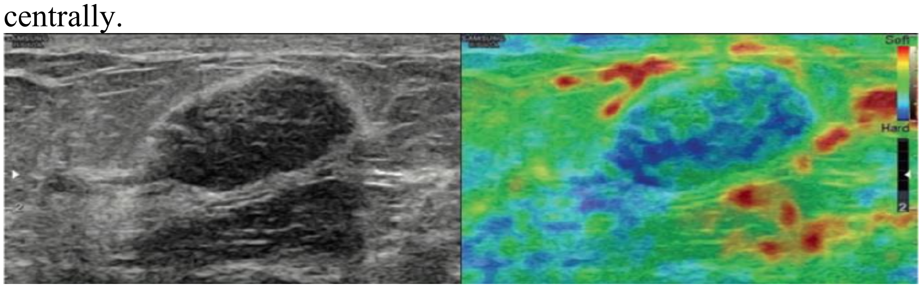

Fig 3-Breast lesion with mosaic pattern of color shading representing fibro adenomasuggesting a score of 3

Score 4: Homogeneous blue shading indicated the entire lesion was stiff.

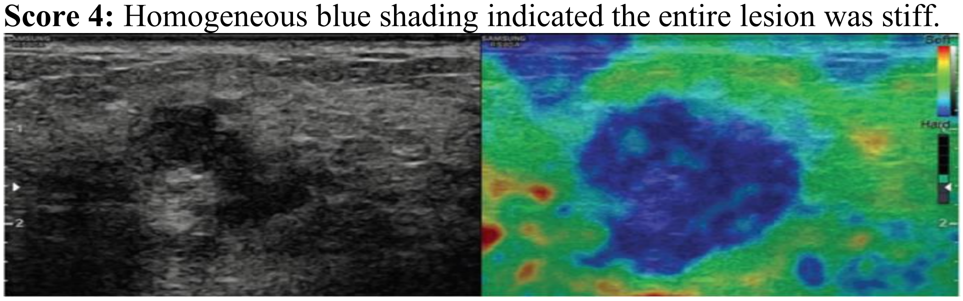

Fig 4-Breast lesion with even shading with blue color representing infiltrating carcinoma suggesting a score of 4.

Score 5: Blue shading over the lesion and surrounding tissue suggested marked stiffness in and around the lesion.

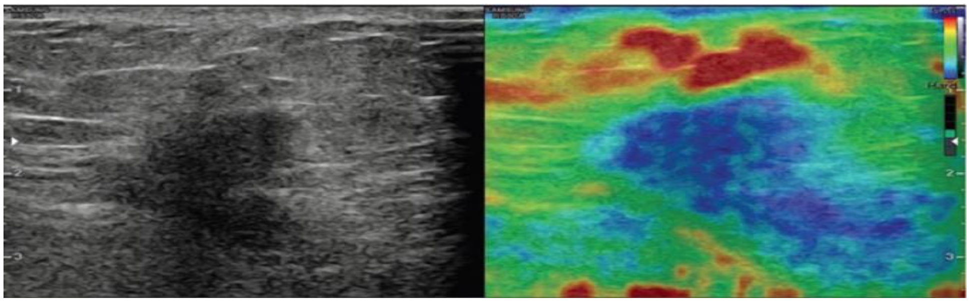

Fig 5-Breast lesion showing shading in the lesion and surrounding tissue representing invasive ductal carcinoma suggesting a score of 5.

Lesions scoring 1 to 3 were classified as benign, while scores of 4 or 5 were considered suspicious for malignancy.

Calculating strain ratio (SR) was by placing the first region of interest within the lesion and the second region of interest in adjacent normal tissue at similar size and depth, allowing for quantitative comparison of tissue stiffness.

4.8.5. Histopathology

Finally, the lesions undergo fine-needle aspiration cytology (FNAC) or guided core needle biopsy or surgical excision. The biopsy result used as reference for comparing the findings with elastography and ultrasound findings.

4.9. Data Collection Procedure

Radiological evaluation, including B-mode ultrasonography and ultrasound elastography, was performed after obtaining informed consent from all patients. Image acquisition was carried out by a single radiologist trained in breast elastography.

4.10. Data Quality Control

The primary investigator check completeness of the data by verifying that it was accurate, comprehensive, clear, and consistent. All complete responses were entered into SPSS version 25.0 for analysis.

4.11. Data Processing, Analysis, and Interpretation

IBM Statistical Package for Social Sciences (SPSS) version 25 used for processing and analyzing the data. Frequencies and percentages were used to describe nominal variables, while means and standard deviations were calculated for continuous or discrete variables. For BIRADS, elastic score and strain ratio sensitivity, specificity, PPV, NPV and diagnostic accuracy was calculated. A statistically significant association was considered with p-value of less than 0.05. Receiver operating characteristic (ROC) curves were generated for BIRADS score, elastic score and strain ratio and the area under the curve (AUC) was compared. Correlationcoefficient between BIRADS score, elastic score and strain ratio was also assessed. Results were presented in table's charts, and graphs.

4.12. Ethical Consideration

Ethical clearance was obtained from the Radiology Department. All patient information was kept confidential and anonymous and patient participation in the study was strictly voluntary.

4.13. Dissemination of Findings

The findings of this research will be submitted to the Department of Radiology at the College of Health Sciences, Addis Ababa University, through formal reporting and presentations as per departmental guidelines. In addition, the results will be shared with key institutions, including the Federal Ministry of Health (FMOH) and other relevant stakeholders engaged in breast cancer screening and treatment. Efforts will be made to publish the study in the Ethiopian Journal of Health Developmentor other peer-reviewed scientific journals. Furthermore, key stakeholders will be invited to participate in dissemination workshops or presentations to facilitate the translation of findings into policy and practice.

4.14. Operational Definitions

Elasticity Score

Benign lesions: ES 1 to 3
Malignant lesions: ES 4 and 5

Strain Ratio (SR)

Benign lesions: SR < 3.1
Malignant lesions: SR ≥ 3.1

CHAPTER FIVE: RESULT

A total of 112 cases with breast and post-mastectomy chest wall lesions were initially selected. However, 12 cases were excluded due to loss to follow-up, resulting in 100 participants being included in the subsequent follow-up phase.Majority (36, 36%) were in the age group 31-40 years, followed by 41-50 years age group (33,33%) and 14(14%) patients in the 21-30 age group and 6(6%) in the 60-70 age group. 42.6years was mean age with standard deviation of 11yrs.

Table 1: Age Distribution of Patients with Breast and Post-Mastectomy Chest Wall Lesions Visiting the Breast and Mammography Unit, Radiology Department, TASH (December 1, 2025-April 30, 2025)

Age Category	Frequency	Percent
21-30	14	14.0
31-40	36	36.0
41-50	33	33.0
51-60	10	10.0
61-70	6	6.0
71-80	1	1.0
Total	100	100.0

Most participants 63(63%) underwent examination for breast lump followed by routine screening 19(19%).13(13%) patients underwent examination to rule out post mastectomy chest wall recurrence.

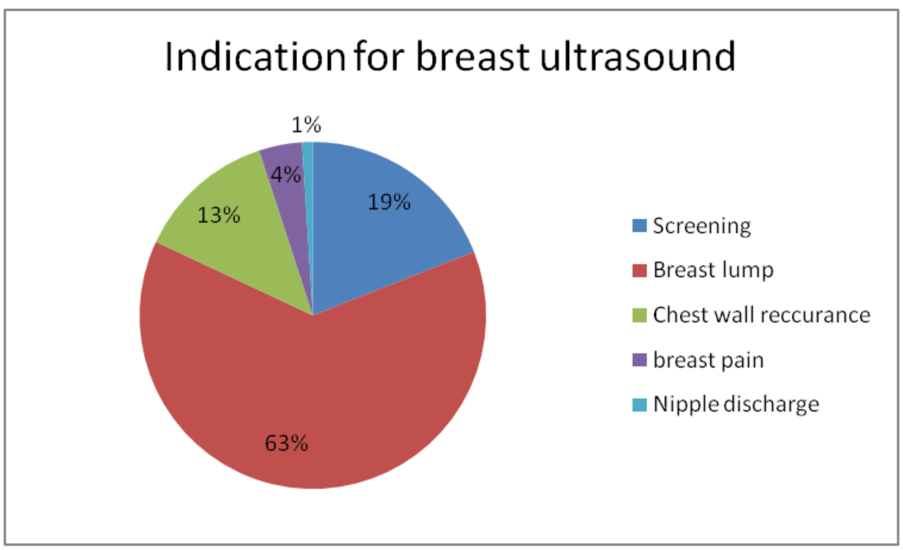

Figure 1: Pie Chart Illustrating Indications for Breast Ultrasound among Patients Visiting the Breast and Mammography Unit, Radiology Department, TASH (December 1, 2025 – April 30, 2025)

The analysis of FNAC and CNB specimen examination of 100 patients 72(72%) patients had malignant lesions, 26(26%) had benign lesions and 2(2%) had atypical lesions. The commonest malignant lesions were invasive carcinoma 67(93.1%) and whereas commonest benign lesions were fibroadenoma.

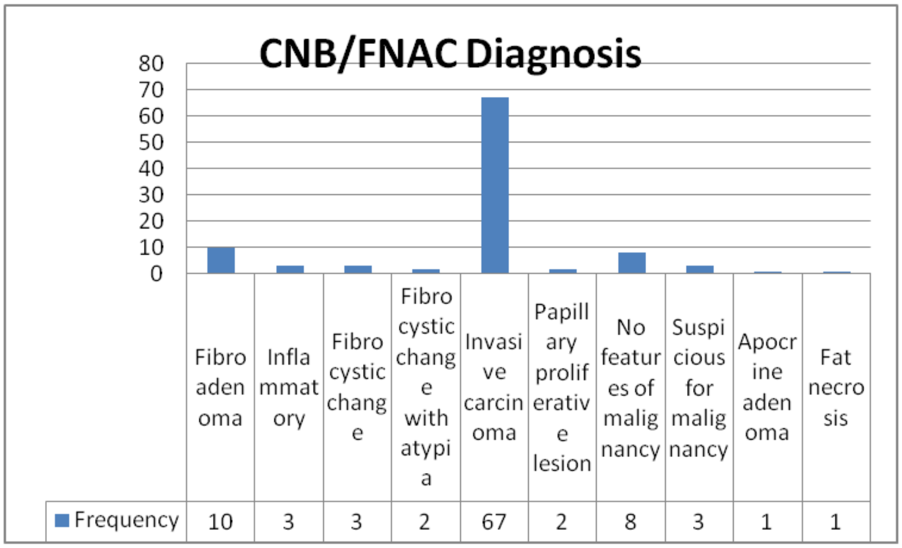

Figure 2: Bar Chart Showing CNB/FNAC Diagnosis of Breast and Post-Mastectomy Lesions among Patients Attending the Breast and Mammography Unit, Radiology Department, TASH (December 1, 2025 – April 30, 2025)

The majority of the examined breast tissues, 46 cases (52.9%), exhibited a homogeneous distribution of fibro glandular elements, followed by a heterogeneous echotexture in 28 cases (32.2%) and a homogeneous distribution of fatty elements in 13 cases (14.9%). Most breast lesions were located in the right breast (50 cases, 57.5%), while the remaining 37 lesions (42.5%) were in the left breast.

Anatomically, the most common site of breast lesionswas the upper outer quadrant accounting for 53 cases (60.9%), followed by both the lower outer and upper inner quadrants, each with 13 cases (14.9%). The lower inner quadrant and retro areolar regions were the least common locations, with 4 cases (4.6%) each.

The sonographic evaluation of breast lesions revealed that most were irregular in shape (64.4%) and exhibited a non-parallel orientation (70.1%). Significant portions had non-circumscribed margins (65.5%) and were primarily hypoechoic (80.5%). Other echogenic patterns included heterogeneous (9.2%), complex cystic and solid (6.9%), and isoechoic (3.4%) appearances. Posterior acoustic features were absent in 44.8% of cases, while 42.5% showed posterior shadowing. Roughly half of the lesions contained calcifications. Most lacked associated features (64.4%), although architectural distortion and skin thickening were observed in 21.8% and 8% of cases, respectively. Internal vascularity was detected in 73.6% of lesions on Doppler ultrasound.

Post-mastectomy chest wall lesions were more frequently located on the left side (61.5%). Both round and irregular shapes were common, each present in 38.5% of cases. A non-parallel orientation was found in 76.9% of these lesions, and 61.5% had circumscribed margins. Hypoechoic echogenicity was the dominant pattern (84.6%). Posterior acoustic features and associated findings were absent in the vast majority (92.3%), and calcifications were rare. Nevertheless, Doppler imaging revealed internal vascularity in 69.2% of cases.

When evaluating all lesions, nearly half (48%) were classified as BI-RADS category 5, followed by 38% in category 4A. Categories 4B and 3 accounted for 10% and 4% of cases, respectively. Only a small number of lesions (4%) were categorized BI-RADS 3(benign) lesion, while the majorities (96%) were considered BI-RADS 4 or 5(malignant). Benign lesions typically featured oval shapes, parallel orientation, circumscribed margins, and hypoechoic echogenicity without posterior features, calcifications, or associated findings. In contrast, malignant lesions were usually irregular (63.5%), non-parallel (72.5%), and non-circumscribed (64.5%), with hypoechoicechotexture (80.2%) and internal vascularity (74%). The absence of posterior acoustic features, calcifications, and associated abnormalities further reinforced their malignant characterization.

An ordinal logistic regression analysis of breast lesion sonographic features demonstrated a well-fitting model ($P < 0.001$; goodness-of-fit = 1; test of parallel lines = 1), confirming the reliability of associations with BI-RADS classification. Features such as oval and round shape, circumscribed margins, isoechoic pattern, posterior enhancement, and absence of vascularity or calcifications were linked to lower BI-RADS scores, suggesting benignity. In contrast, irregular shape, non-circumscribed margins, heterogeneous echotexture, posterior shadowing, vascularity, and calcifications were associated with higher BI-RADS scores, indicating suspicion of malignancy. Unexpected negative associations were observed for architectural distortion and ductal changes, possibly due to data or coding limitations. Conversely, the model for post-mastectomy chest wall lesions did not meet criteria for good fit ($P = 0.075$; goodness-of-fit = 0.63; test of parallel lines = 0.218), limiting confidence in its findings. Nonetheless, positive associations were observed between higher BI-RADS scores and features such as hyperechoic and isoechoicecho patterns, vascularity, and calcification, while oval and round shapes were linked to lower scores. Other sonographic features showed no significant effect. These results highlight meaningful predictors in breast imaging while underscoring the need for further validation in post-mastectomy cases.

Table 2: Sonographic Classification and logistic Regression Analysis of Breast and Chest Wall Lesions among Patients at the Breast and Mammography Unit, Radiology Department, TASH (December 1, 2025 – April 30, 2026)

Sonographic morphology of Breast and post mastectomy chest wall lesion		BIRADS 3 lesion		BIRADS 4 and 5 lesion		Estimates for breast lesions	Estimates for postmastectomy chest wall
		Frequency	Percent	Frequency	percentag		
Shape	Oval	3	75.0%	18	18.7%	-34.488	-3.712
	Round	1	25.0%	17	17.7%	-1.182	-.610
	Irregular	0	0.0%	61	63.5%	0	0
Orientation	Parallel	3	75.0%	26	27.0%	-.442	0
	Not parallel	1	25.0%	70	72.9%	0	0
Margin	Circumscribed	4	100.0%	34	35.4%	-1.863	0
	Not	0	0.0%	62	64.5%	0	0
Echo pattern	Hyperechoic	0	0.0%	1	1.0%		17.993
	Hypoechoic	4	100.0%	77	80.2%	.153	0
	Complex cystic and solid	0	0.0%	7	7.3%	.289	3.325
	Isoechoic	0	0.0%	3	3.1%	-2.608	
	Hetrogenous	4	100.0%	8	8.3%	0	
Posterior feature	No posterior features	0	0.0%	47	48.9%	-.275	0
	Enhancement	0	0.0%	12	12.5%	-2.338	0
	Shadowing	0	0.0%	37	38.5%	0	
Calcification	Present	1	25.0%	42	43.8%	.760	17.9
	Absent	3	75.0%	54	56.2%	0	0
Associated feature	Normal	4	100.0%	64	66.7%	-19.334	0
	Architectural distortion	0	0.0%	20	20.8%	-16.575	0
	Ductal change	0	0.0%	5	5.2%	-35.907	
	Skin change(skin thickening, skin	0	0.0%	7	7.3%	0	
Vascularity	Present	2	50.0%	71	74.0%	1.447	2.8
	Absent	2	50.0%	25	26.0%	0	0

An analysis of BI-RADS scores indicated that most benign lesions were classified in categories 3 and 4a, with none assigned to category 5. These lesions had a mean BI-RADS score of 3.9 ± 0.34. In contrast, the majority of malignant lesions were found in categories 5 and 4a, with only one malignant case falling under category 3. The mean BI-RADS score for malignant lesions was 6.1 ± 1.3. The two atypical lesions were categorized as BI-RADS 3 and 4a, with a mean score of 3.5 ± 0.7. A statistically significant association was observed between BI-RADS scores and FNAC/CNB results, with a p-value of <0.001.

Table 3: Association between BI-RADS Scores and FNAC/CNB Results among Patients at the Breast and Mammography Unit, Radiology Department, TASH (December 1, 2025 – April 30, 2025)

BIRADS score * FNAC/CNB		FNAC/CNB			Total
		Benign	Malignant	Atypical	
BIRADS score	Category 3: Probably Benign	2	1	1	4
	Category 4A: Low suspicion for malignancy	23	14	1	38
	Category 4B: Moderate suspicion for malignancy	1	9	0	10
	Category 5: Highly Suggestive of Malignancy	0	48	0	48
Total		26	72	2	100

Receiver operating characteristic (ROC) analysis of the BI-RADS scoring system demonstrated a sensitivity of 98.6% and a specificity of 10.7% at a cutoff value of 3.5. The area under the curve (AUC) was 0.89, with a positive predictive value (PPV) of 74.7%, a negative predictive value (NPV) of 66.7%, and an overall diagnostic accuracy of 74.5%.Based on these findings, the BI-RADS scoring system led to 23 unnecessary biopsies due to false-positive results, which could have been avoided.

Among the 13 post-mastectomy chest wall lesions, 2 (15.4%) were benign, and 11 (84.6%) were malignant. The BI-RADS distribution for these lesions was: 2 (15.4%) in category 3, 4 (30.7%) in 4A, 1 (7.7%) in 4B and 6 (46.1%) in category 5. The evaluation of the BI-RADS scoring system for post-mastectomy chest wall lesions revealed a sensitivity of 91%, specificity of 50%, positive predictive value (PPV) of 91%, negative predictive value (NPV) of 50%, and an overall accuracy of 84.6%.

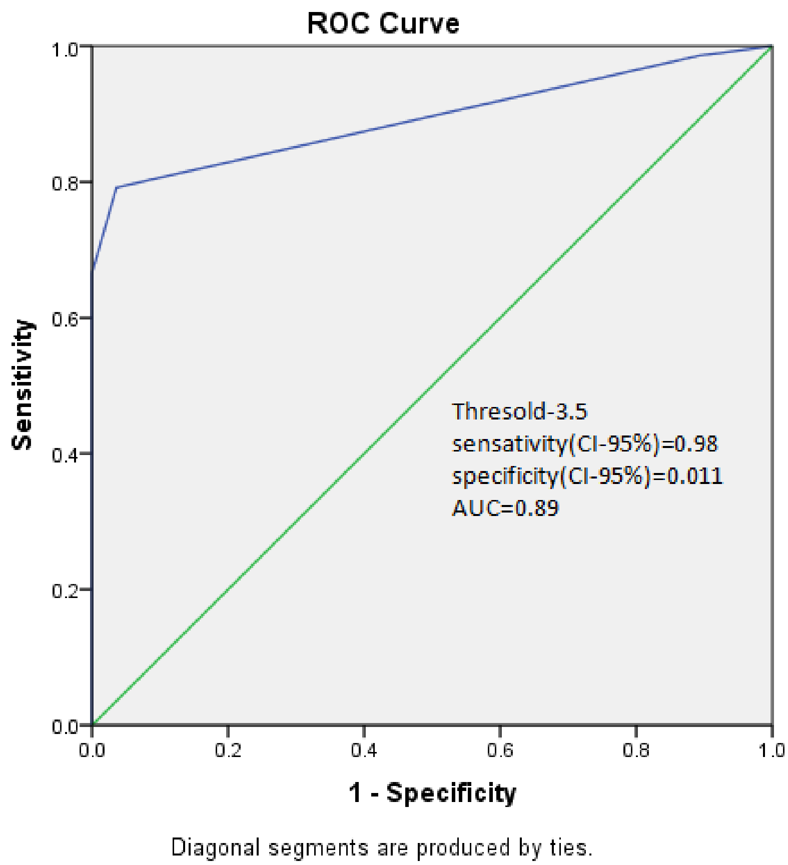

Figure 3: ROC curve for conventional ultrasound demonstrating a sensitivity of 98% and a specificity of 11% at a BIRADS cutoff value of 3.5, based on data from breast and post-mastectomy lesions in patients seen at the Breast and Mammography Unit, Radiology Department, TASH, between December 1, 2025, and April 30, 2025.

Elastography-based assessment of elasticity scores showed that most benign lesions were scored as 2 or 3, with eight cases receiving a score of 4 and none assigned a score of 5. The mean elasticity score for benign lesions was 3.1 ± 0.67. In contrast, the majority of malignant lesions had scores of 5 and 4, accounting for 49 and 20 cases, respectively. Additionally, two malignant lesions were scored as 3 and one as 2. The mean elasticity score among malignant lesions was 4.6 ± 0.61. The two atypical lesions received scores of 3 and 4, with a mean elasticity score of 3.5 ± 0.7. A statistically significant correlation was found between elasticity scores and FNAC/CNB results, with a p-value of <0.001.

Table 4: Association betweenElastography Elasticity Scores and FNAC/CNB Findings among Patients at the Breast and Mammography Unit, Radiology Department, TASH (December 1, 2025 – April 30, 2025)

Elasticity score * FNAC/CNB Crosstabulation		FNAC/CNB			Total
		Benign	Malignant	Atypical	
Elasticity score	score 2	4	1	0	5
	score 3	14	2	1	17
	score 4	8	20	1	29
	score 5	0	49	0	49
Total		26	72	2	100

Receiver operating characteristic (ROC) analysis of the elasticity scoring system demonstrated a sensitivity of 96% and a specificity of 68% at a cutoff value of 3.5. The area under the curve (AUC) was 0.92. The system yielded a positive predictive value (PPV) of 90%, a negative predictive value (NPV) of 85%, and an overall diagnostic accuracy of 89%.Despite its strong performance, the elasticity scoring system misclassified 8 patients with benign lesions as false positives, leading to unnecessary biopsies.

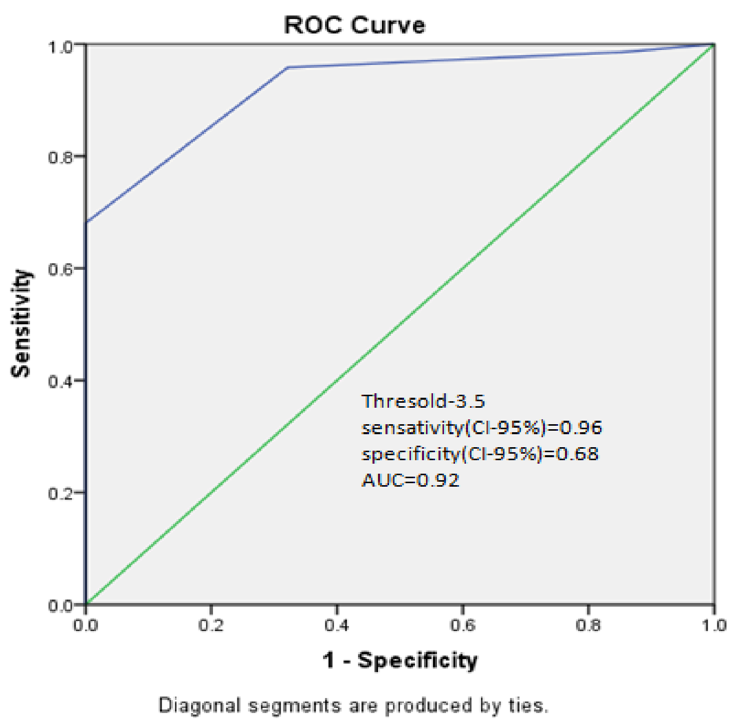

Figure 4: ROC curve for the elasticity (Tsukuba) score, indicating a sensitivity of 96% and a specificity of 68% at a cutoff value of 3.5, based on data from breast and post-mastectomy lesions in patients assessed at the Breast and Mammography Unit, Radiology Department, TASH, between December 1, 2025, and April 30, 2025.

Strain ratio analysis revealed that 14 benign lesions had values below the cutoff of 3.1, while 12 benign lesions had strain ratios equal to or above this threshold. The mean strain ratio for benign lesions was 3.4 ± 2.1. In contrast, the majority of malignant lesions (71 cases) had strain ratios of 3.1 or higher, with only one case falling below the cutoff. The mean strain ratio for malignant lesions was 5.2 ± 1.1. Both atypical lesions showed strain ratios below 3.1. A statistically significant association was observed between strain ratio and FNAC/CNB results, with a p-value of <0.001.

Table 5: Associationbetween Strain Ratio and FNAC/CNB Results among Patients at the Breast and Mammography Unit, Radiology Department, TASH (December 1, 2025 – April 30, 2025)

Categorized strain ratio * FNAC/CNB Crosstabulation		FNAC/CNB			Total
		Benign	Malignant	Atypical	
Categorized strain ratio	<3.1	14	1	1	16
	>=3.1	12	71	1	84
Total		26	72	2	100

Receiver operating characteristic (ROC) analysis of the strain ratio demonstrated a sensitivity of 97.2% and a specificity of 57.2% at the cutoff value of 3.1. The area under the curve (AUC) was 0.85. The diagnostic performance included a positive predictive value (PPV) of 92.8%, a negative predictive value (NPV) of 78.2%, and an overall accuracy of 91.2%.Despite its effectiveness, the strain ratio system misclassified 11 patients with benign lesions as false positives.

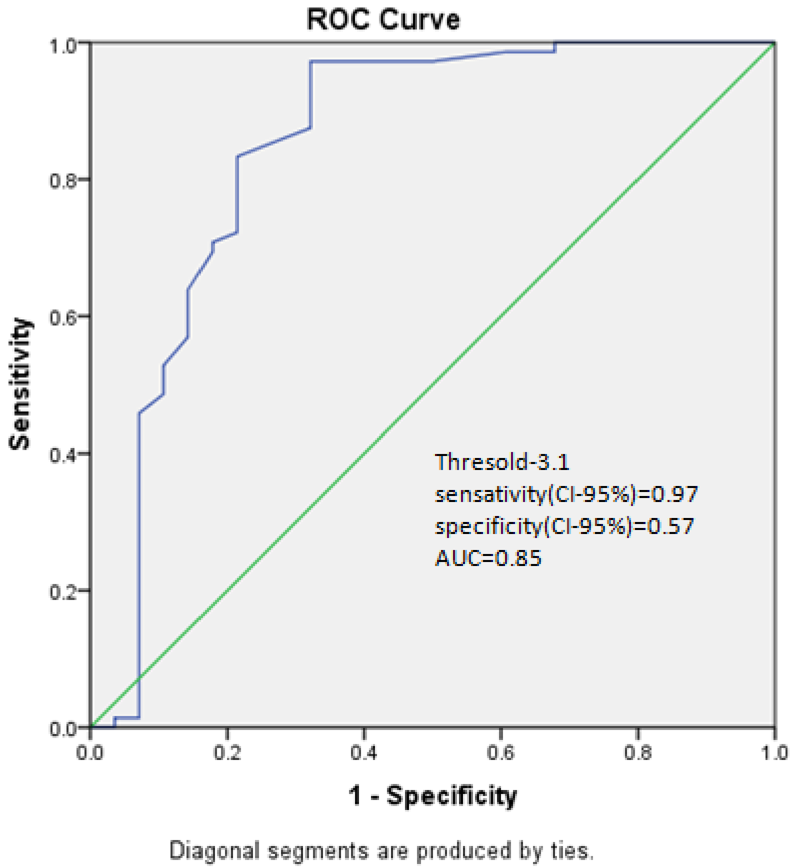

Figure 5: ROC curve for the strain ratio, demonstrating a sensitivity of 97% and a specificity of 57% at a cutoff value of 3.1, derived from data on breast and post-mastectomy lesions in patients evaluated at the Breast and Mammography Unit, Radiology Department, TASH, between December 1, 2025, and April 30, 2025.

5.1. Diagnostic Performance of Combined Methods

When BI-RADS and elasticity scores were combined using the parallel testing approach, the results showed a sensitivity of 99.9%, specificity of 7.3%, positive predictive value (PPV) of 90.6%, negative predictive value (NPV) of 93.1%, and an overall diagnostic accuracy of 90.6%. Under the serial testing approach, sensitivity was 94.7%, specificity 71.4%, PPV 96.8%, NPV 59.8%, and overall accuracy 92.3%. A Spearman correlation coefficient of 0.873 indicated a strong correlation between BI-RADS and elasticity scores.Using the serial testing approach, this combined method led to 7 unnecessary biopsies because of false-positive results.

Combining BI-RADS with strain ratio, parallel testing yielded a sensitivity of 99.9%, specificity of 5.7%, PPV of 90.5%, NPV of 97%, and accuracy of 90.5%. Under serial testing, sensitivity was 97.2%, specificity 58.6%, PPV 95.5%, NPV 70.3%, and accuracy 93.4%. The Spearman correlation coefficient for this combination was 0.594, suggesting a moderate correlation.Using the serial testing approach, the combined strategy resulted in 11 unnecessary biopsies due to false-positive findings.

For the combination of elasticity score and strain ratio, parallel testing achieved a sensitivity of 99.9%, specificity of 36.4%, PPV of 93.4%, NPV of 98.6%, and diagnostic accuracy of 93.6%. Serial testing resulted in a sensitivity of 94.7%, specificity of 84.7%, PPV of 93.4%, NPV of 63.8%, and accuracy of 93.7%. The Spearman correlation coefficient between these two methods was 0.703, indicating a strong correlation.When applied with the serial testing approach, this combined method resulted in only 4 unnecessary biopsies due to false-positive results.

When all three methods,BI-RADS, elasticity score, and strain ratio were combined, the parallel testing strategy produced a sensitivity of 100%, specificity of 4.3%, PPV of 90.4%, NPV of 100%, and accuracy of 91%. In contrast, the serial testing approach gave a sensitivity of 91.3%, specificity of 87.7%, PPV of 98.5%, NPV of 52.3%, and accuracy of 91%.Using the serial testing approach, the combined method resulted in only 3 unnecessary biopsies due to false-positive findings.

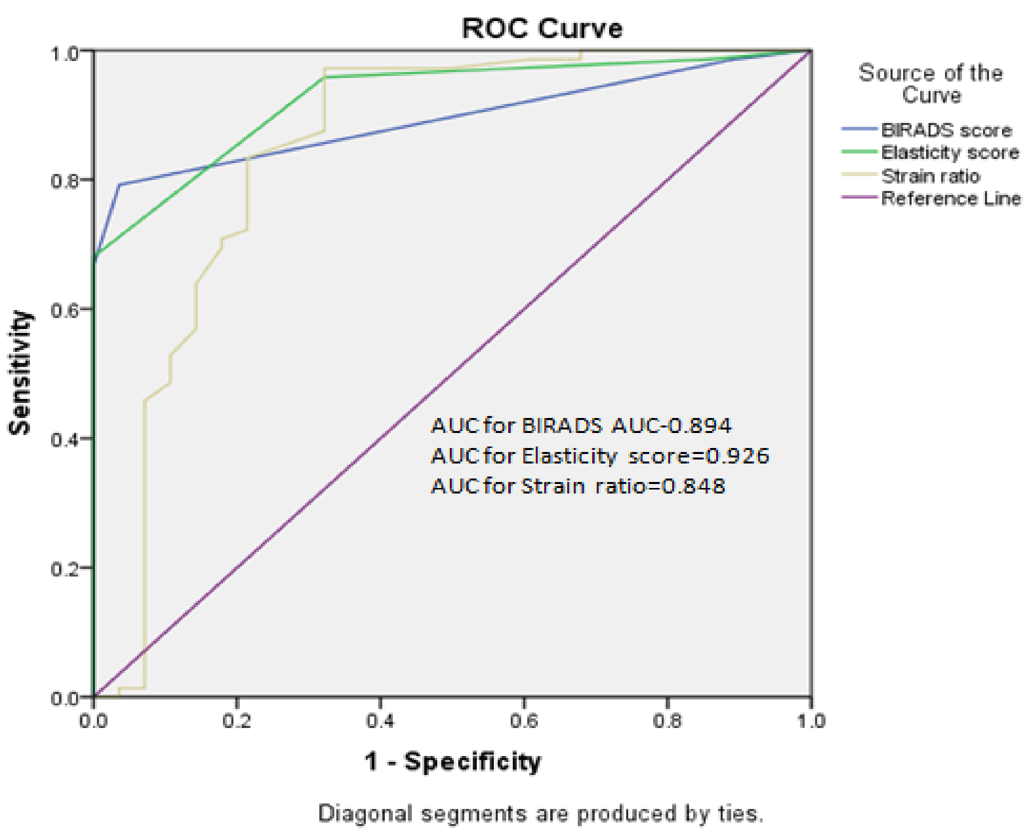

Figure 6: Combined ROC curve for the BI-RADS score, elasticity score, and strain ratio, illustrating the area under the curve (AUC) based on data from breast and post-mastectomy lesions in patients assessed at the Breast and Mammography Unit, Radiology Department, TASH, between December 1, 2025, and April 30, 2025.

CHAPTER SIX: DISCUSSION

In this study, the majority of participants presented with a breast lump (63%), followed by those undergoing routine screening (19%). These findings align with a study conducted in Bangladesh, where breast lumps and pain were identified as common reasons for seeking breast examination (23, 24). The analysis of 100 patients using FNAC and CNB revealed that 72% had malignant lesions, with invasive carcinoma being the most common malignant type (93.1%), while 26% were benign, and fibroadenoma was the most frequent benign lesion. These results are consistent with studies conducted in India, where a higher incidence of benign lesions was reported, such as in a study at a tertiary hospital, where benign lesions accounted for 74% of cases. However, across all studies, the most common bening lesion was fibroadenomawhile invasive ductal carcinoma was the commonest malignant lesion (16, 17, and 18).

Regarding lesion location, right breast account 57.5%,and the upper outer quadrant most commonly affected site (60.9%). This distribution mirrors findings from a tertiary hospital in India, where 52% of lesions were located in the right breast and 42% in the upper outer quadrant (17). These anatomical patterns highlight the importance of understanding lesion distribution for targeted diagnostic and treatment approaches.

In terms of ultrasound features, benign lesions in this study predominantly exhibited oval shape and parallel orientation (75%), circumscribed margins (100%), and a hypoechoicecho pattern (100%), without associated calcification or posterior acoustic features. In contrast, malignant lesions were characterized by irregular shape, non-parallel orientation,non-circumscribed margins, hypoechoicecho pattern and increased vascularity (63.5%), (72.5%), (64.5%),(80.2%), and (74%) respectively. These observations are consistent with previous studies, such as those conducted at Enam Medical College and Hospital in India, which found similar patterns of shape, margin, and echo pattern differentiation between benign and malignant lesions (23).

Additionally, 13 post-mastectomy chest wall lesions were evaluated, of which 11 (84.6%) were malignant, and 2 (15.4%) were benign. BI-RADS classification was applied, revealing that 2 lesions were classified as BI-RADS 3, 4 lesions as BI-RADS 4A, and 6 lesions as BI-RADS 5. The BI-RADS system demonstrated a high sensitivity (91%) and positive predictive value (91%), but lower specificity and negative predictive value (50% each), resulting in an overall diagnostic accuracy of 84.6%. These findings underscore the utility of BI-RADS in assessing post-mastectomy lesions, but they also highlight the moderate specificity and NPV, indicating a potential for false-positive results. The moderate specificity emphasizes the need for careful clinical and histopathological correlation in such cases. Our results are consistent with those of a study in Seoul, South Korea, where BI-RADS categories 4 and 5 were effective in detecting malignancy and recurrence at mastectomy sites (27).

ROC analysis of the BI-RADS scoring system in our study demonstrated a high sensitivity of 98.6% but a low specificity of 10.7% at a cutoff value of 3.5. The AUC was 0.89, suggesting strong diagnostic performance. While the system is highly sensitive in detecting malignancy, its low specificity may lead to false-positive results, necessitating careful follow-up and histopathological confirmation, particularly in cases with ambiguous imaging features. These results are consistent with a study from Aster CMI Hospital in India, where conventional ultrasound exhibited a sensitivity of 90% and specificity of 63.8%, with an AUC of 0.90 (18). This comparison underscores the importance of BI-RADS as a reliable screening tool with high sensitivity, but it also highlights the need for complementary diagnostic techniques to enhance specificity and minimize unnecessary interventions.

Similarly, ROC analysis of the elasticity scoring (ES) system in our study showed a sensitivity of 96% and specificity of 68% at a cutoff value of 3.5, with an AUC of 0.92. The ES system achieved a PPV of 90%, NPV of 85%, and overall diagnostic accuracy of 89%. These findings align with those from Aster CMI Hospital, where ROC analysis revealed a sensitivity of 92.3% and specificity of 94.59%, with an AUC of 0.98 (18). The higher specificity and overall performance in the Aster CMI study suggest that while both studies demonstrate high sensitivity and diagnostic reliability, there may be slight differences in population and study parameters that impact performance. Nevertheless, the consistency in PPV and high sensitivity between the studies reinforces the value of elasticity scoring as a non-invasive method.

Further, ROC analysis of the strain ratio in our study revealed a sensitivity of 97.2% and specificity of 57.2% at a cutoff value of 3.1, with an AUC of 0.85. The strain ratio demonstrated a PPV of 92.8%, NPV of 78.2%, and diagnostic accuracy of 91.2%. These results are comparable to a study at Aster CMI Hospital, where the optimal strain ratio cutoff of 3.0 yielded a sensitivity of 89.7%, specificity of 93.2%, and AUC of 0.96 (18). Despite the lower specificity in our study, the high sensitivity and similar diagnostic accuracy suggest that strain ratio can be a valuable adjunct in the evaluation of suspicious breast lesions, particularly for high-sensitivity screening.

In our study, the combination of BI-RADS and elasticity scores under the parallel testing approach demonstrated a high sensitivity of 99.9%, with a specificity of 7.3%, a PPV of 90.6%, an NPV of 93.1%, and an overall diagnostic accuracy of 90.6%. In contrast, the serial testing method yielded a sensitivity of 94.7%, a specificity of 71.4%, a PPV of 96.8%, an NPV of 59.8%, and an accuracy of 92.3%. The strong correlation between BI-RADS and elasticity scores was further supported by a Spearman correlation coefficient of 0.873, suggesting a high level of agreement between the two modalities. These findings are consistent with prior research conducted in Brazil, where the integration of elastography with ultrasound improved diagnostic performance, increasing sensitivity, specificity, and accuracy from 93.85%, 72.07%, and 76.64% to 95.90%, 80.65%, and 91.39%, respectively (29). This supports the added value of elastography when used alongside conventional imaging in breast lesion evaluation.

6.1. Strengths and Limitations of the Study

Our study has several notable strengths. It provides a thorough assessment of multiple diagnostic tools BI-RADS, elasticity scoring, and strain ratio both independently and in combination, using rigorous statistical analyses including ROC curves and diagnostic accuracy measures. By employing both parallel and serial testing strategies, the study offers valuable insights into how different testing combinations impact diagnostic parameters such as sensitivity and specificity. The consistently high sensitivity achieved, particularly when modalities were combined, highlights the promise of these non-invasive approaches for the early and reliable detection of breast cancer. Moreover, the alignment of this study's findings with both national and international research enhances the external validity and clinical relevance of the results.

Despite these strengths, there are certain limitations to consider. The low specificity observed in some parallel testing scenarios raises concerns about the risk increased false positives, which could result in unnecessary biopsies and increased patient anxiety. Additionally, the study's high malignancy prevalence (72%) may not reflect that of the general population, thereby limiting the applicability of the results to broader screening contexts. Although a strong correlation between diagnostic methods was demonstrated, the study did not evaluate interobserver variability or the potential impact of operator dependency- key considerations in ultrasound-based imaging. Lastly, as a single-center study, the findings may be influenced by local demographic or institutional factors, underscoring the need for larger, multicenter investigations to validate and generalize the results and refine diagnostic thresholds.

CHAPTER SEVEN: CONCLUSION

This study underscores the clinical utility of combining BI-RADS, elasticity scoring, and strain ratio in the evaluation of breast lesions. Breast lumps emerged as the most frequent presenting symptom, with fibro adenoma being the most common being lesion and invasive ductal carcinoma being the predominant malignant lesionthat align with both regional and international data. The observed lesion locations and ultrasound characteristics were consistent with established patterns used to distinguish benign from malignant findings.

Although BI-RADS demonstrated excellent sensitivity, its low specificity highlighted the risk of false-positive results. However, the incorporation of elasticity scoring and strain ratio notably improved overall diagnostic accuracy. In particular, combining BI-RADS with elasticity scoring under a serial testing strategy offered a more balanced diagnostic profile, maintaining high sensitivity while enhancing specificity, supported by a strong correlation between modalities.

ROC analysis confirmed the strong performance of all three tools individually, with elasticity scoring and strain ratio yielding high sensitivity and reliable accuracy. While certain limitations were noted such as low specificity in some combinations and the high prevalence of malignancy in the study sample the findings clearly support the effectiveness of these techniques when applied together. Overall, the study advocates for the routine use of multiparametric ultrasound in breast lesion evaluation, emphasizing the value of integrating imaging results with histopathological confirmation to ensure accurate diagnosis and reduce unnecessary interventions.

CHAPETER EIGHT: RECOMMENDATION

The following recommendations are proposed based on the findings to enhance the diagnostic accuracy of breast lesion evaluation using ultrasound:

1. **Integration of Elastography with BI-RADS:**
   It is recommended that the BI-RADS classification system be routinely complemented with elasticity scoring and strain ratio measurements during ultrasound assessments. While BI-RADS demonstrate high sensitivity, its relatively low specificity may lead to unnecessary biopsies and increased patient anxiety. The addition of elasticity-based techniques can significantly improve specificity and reduce false-positive results.
2. **Implementation of Serial Testing Strategies:**
   In clinical practice, a serial testing approach particularly combining BI-RADS assessment with elasticity scoring should be considered. This combined method offers a more balanced diagnostic strategy, maintaining high sensitivity while improving specificity.
3. **Use of Quantitative Strain Ratio Analysis:**
   Quantitative strain ratio analysis is especially recommended in cases where diagnostic certainty is critical, such as in post-mastectomy evaluations or when imaging findings are indeterminate. This approach provides objective data to support clinical decision-making.
4. **Need for Multicenter and Larger-Scale Studies:**
   Future multicenter studies involving larger, more diverse populations are encouraged to refine optimal cutoff values and further validate the diagnostic performance of elastography techniques across different clinical settings.
5. **Standardized Training and Protocols:**
   To reduce operator dependency and ensure consistent results, standardized training programs in ultrasound elastography should be developed and implemented across healthcare institutions. This will help improve inter-operator reliability and diagnostic consistency.
6. **Promotion of Multiparametric Ultrasound Approaches:**
   A multiparametric ultrasound approach that integrates conventional B-mode imaging, elastography, and clinical context should be adopted.

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Annex-1 Data collection checklist

Age		
Indication for breast ultrasound		
Breast Tissue	**Terms**	
Tissue composition	Homogeneous background echotexture – fat	
	Homogeneous background echotexture- fibroglandular	
	Heterogeneous background echotexture	
Characterization of breast mass		
Shape	Oval	
	Round	
	Irregular	
Orientation	Parallel	
	Not parallel	
Margins	Circumscribed	
	Not circumscribed	
Echo pattern	Anechoic	
	Hyperechoic	
	Complex cystic and solid	
	Hypoechoic	
	Isoechoic	
	Heterogeneous	
Posterior features	No posterior features	
	Enhancement	

	Shadowing	
	Combined pattern	
Calcifications	Present	
	Absent	
Associated features	Normal	
	Architectural distortion	
	Duct changes	
	Skin changes (Skin thickening, Skin retraction)	
	Edema	
Vascularity	Present	
	Absent	
Quadrant	Multiple	
	Upper outer	
	Upper inner	
	Lower outer	
	Lower inner	
BIRADS score		
Elasticity score		
Strain ratio		
FNAC/Histopathology diagnosis		